WORLD DX GUIDE

FIRST STEPS IN DX-ING
SHORT WAVE PROPAGATION
ORGANIZING A DX CLUB
IONOSPHERIC VARIATIONS
SHORT WAVE RECEIVING ANTENNAS
MEDIUM WAVE PROPAGATION
DX VOCABULARY, RECEPTION CODES, WIRE TABLE

875

World DX Guide

1st edition

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FOREWORD

I am delighted to have been invited to write the foreword to the "World DX-Guide". DX-ing has been a part of me for almost as long as I can remember, and I am indebted to it in many ways. I credit it with introducing me to the wonders of radio communications and for kindling my enthusiasm to pursue professionally the technical field of radio broadcasting. I would like to share a few personal experiences with you.

I can still recall my introduction to DX-ing. It was in New York City on a cold winter night in 1929, when I was just over five years old. My father had recently completed the construction of a newly designed radio receiver. He clamped a pair of oversized earphones on my small head and excitedly exclaimed: "Listen son, we caught Canada, do you hear it? That's Toronto there!" I was bitten by the DX bug, and that was the spark that eventually set a flame afire.

I followed the world's drama as it unfolded during the 1930's, first over multi-band radios built by my father, and later, over radios I had assembled myself. There was the screeching voice of Adolf Hitler and the roars of the crowds that worshipped him; the fog-horned rants of Benito Mussolini; the emotionally filled voice of Edward VIII as he announced the abdication of his throne "for the woman I love"; the annual Christmas messages of George VI, all booming into the private sanctuary of my bedroom listening post. The leaders of the world all talking directly to me, or so it seemed!

How many hours I would spend in those early days of my youth daydreaming of some of the romantic, mysterious and charismatic places I would hear on my radio; India, Egypt, Australia, Japan, Antarctica, and a host of others. A wall in my parent's house is still decorated with QSL cards received during that era.

I can recall today, as clearly as I heard it then, the strong, confident voice of Winston Churchill, telling me and the world that Britain was alive and fighting during those dark and gloomy early days of World War II. Later in that War, while I was serving in Europe with the American 8th Air Force, I carried my small ECHOPHONE shortwave receiver with me as a link with home. What a wonderful feeling it was to listen to a familiar programme on the Voice of America and know that my family at home in the States might be listening to the same programme at the same time.

This is the real thrill and fascination associated with DX-ing. DX radio signals cross frontiers, span oceans and bridge continents to provide direct, universal, personal and immediate communications.

I thank my early interest in DX radio for getting me started in the wonderful world of amateur radio, where it is not only possible to listen to the world, but to talk back as well! Through the years amateur radio has made for me invisible friends throughout the world, friendships that vault political, social and economic barriers, and are as fraternal, warm and sincere as any I have made in my lifetime.

But enough about my experiences, and now for a few words about this important guide, which can enhance your experiences as a DX-er. The "World DX-Guide" is a fresh, new approach to the world of DX-ing, viewed strictly from the practical point of view and based on the actual experiences of the world's experts. To my knowledge, nothing like it has been published previously for the DX-er. All aspects of DX-ing are covered; the how's, the what's and the where's, and between its covers there is much to say to the newcomer and the old-timer alike. It is, in my opinion, a most important and valuable publication. It should be a constant and constantly helpful companion to all those who want to look through that wonderful window on the world called DX RADIO, and enjoy the exciting and fascinating view.

73, and good listening.

George Jacobs, P.E.

Director, Research & Engineering,
Board for International Broadcasting,
Washington, D.C., U.S.A.

INTRODUCTION

Probably very few people read forewords or introductions in books, as they are much too eager to start out on the "real thing".

As I, until recently, also belonged to this group of readers, your are forgiven beforehand if you do not read these lines, though I do indeed have something sensible to say before "starting out".

The idea for this book came from Jens Frost, my friend and well-known editor of the "World Radio TV Handbook". He wanted to re-use the best articles from previous editions of "How to Listen to the World", and to update them where necessary, to supplement them with some chapters by myself, and to publish them in book form. How this was to be done, and which articles were to be chosen, was left to me, and the result of this free cooperation between us now lies before you.

We have tried to give the book popular appeal with as wide a possible scope and to include valuable information for everyone who takes his radio or TV receiving hobby seriously. As you will see, the work is divided into four sections. The first section will be found useful by those readers who are still trying to find their way around the radio waves.

The second part is a collection of chapters which will interest the more experienced hobbyist, and the third section spotlights various aspects in more detail.

The reference section – though never complete – was selected with care to provide data which are sometimes difficult to find, but which have a definite connection with the hobby. We have tried to cover the most interesting fields of DX-ing, as you will find when browsing through the book.

It is perhaps inevitable that one or two subjects have not been covered, and your remarks and suggestions will be appreciated with an eye to making a possible next edition even more complete.

We hope that the book as it stands will help you in getting more pleasure out of your hobby.

May, 1978 — Jim Vastenhoud

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SECTION I

"Getting on your way"

Chapter 1

FIRST STEPS IN DX-ING

by Jim Vastenhoud

Our opening chapter is intended to serve as an introduction to DX-ing, a hobby pursued by many thousands of enthusiasts all over the globe. In later chapters, contributed by authors specialized in various fields, you will find more detailed information on some subjects only touched upon here, but which are in fact "meat and drink" to the experienced DX-er.

In this introductory chapter we cover general subjects giving you the information you need to start your DX-ing, such as the division of the radio spectrum and relevant nomenclature; the various services and their frequency allocation; something about the Radio Regulations and the Body controlling them – the ITU (International Telecommunication Union); – the two types of modulation, AM and FM; the receiver and the antenna, and, last but not least, DX-ing itself.

The radio spectrum, which is used for the propagation of intelligent information, is wide, and new frequency ranges are still being added as technology improves and the need for more communication space remains pressing. In order to create some order in the chaos of frequency denomination, a standardized nomenclature of frequency bands has been adopted world wide. The following table covers that part of the spectrum, which is important to DX-ers.

Frequency range	Corresponding waverange	Designation
30-300 kilohertz	10,000-1000 metres	LF, Low Frequency band
300-3000 kilohertz (=0.3-3 megahertz)	1,000-100 metres	MF, Medium Frequency band
3-30 megahertz	100-10 metres	HF, High Frequency band
30-300 megahertz	10-1 metres	VHF, Very High Frequency band
300-3000 megahertz	1-0.1 metres	UHF, Ultra High Frequency band

The table gives the frequencies in kilohertz or megahertz. The unit of "frequency" is the hertz. One hertz is equal to one cycle per second. The prefix "kilo" indicates a factor 1,000, and the prefix "mega" a factor 1,000,000. For still higher frequencies, like those which are mainly used for satellite transmissions, still another prefix is used: gigahertz. One gigahertz is equal to 1,000 megahertz or 1,000,000,000 hertz.

Likewise, prefixes can be used to indicate decimal parts of units. For a standard unit like the metre, or meter, which is the keystone of the metric system, smaller parts are indicated by abbreviations like "cm", for centimetre, or 1/100th metre; or "mm" for millimetre, which indicates 1/1000th of a metre. Smaller still is the micron, symbol μ, indicating one millionth of a metre.

The prefixes are also used to indicate parts of electrical units like the farad (F), which is the unit of capacitance. Practical values of capacitors in radio and television receivers have capacitances which are expressed in microfarads (μF), nanofarads or picofarads. One nanofarad (nF) is one thousandth of a microfarad, and one picofarad (pF or $\mu\mu$F), or one micro-microfarad, is one millionth of a microfarad. Getting familiar with these prefixes is one step on the road to become a good DX-er.

As we can read from the table, there seems to be a connection between the frequency and the wavelength. 3 MegaHertz (MHz) seems to be equal to 100 metres (m), and 30 MHz to 10 metres. It must thus be possible to convert frequencies into wavelengths, and vice versa. Let us take a closer look at this.

As already said, the frequency indicates the number of rhythmic variations per second. The wavelength will indicate the physical length of one wave, in our case measured in metres.

The conversion from one unit to another can be made if we know the propagation speed of the wave. This can be explained with the help of *figure 1.*

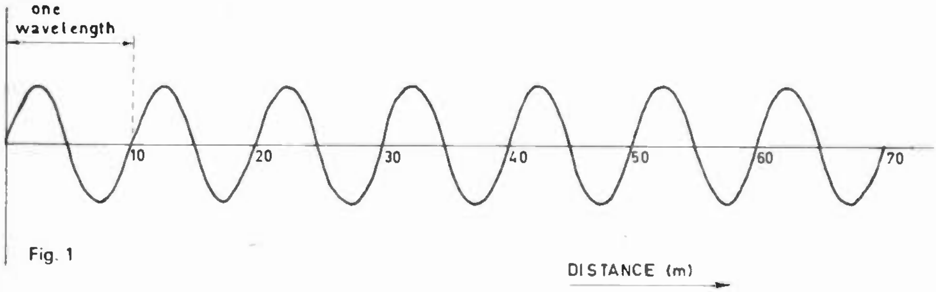


Fig. 1

Let us suppose that the wave travels with a speed of 70 metres per second. If seven waves are radiated during this time lapse, we have a wavelength of 10 metres per wave. The frequency of the signal is 7 Hz, the corresponding wavelength 10 metres.

Radio waves travel at the speed of light. This statement is an approximation, as the speed of light is only reached in a vacuum. In air, the travelling speed of a radio wave is slightly less. It is however assumed that the speed of light is 300,000 kilometres per second (km/s).

If the frequency of our signal is, say 200 kilohertz (kHz), the corresponding wavelength can be found by dividing the distance covered in one second, by the number of wavelengths radiated in one second. Thus, the corresponding wavelength will become $\frac{300,000}{200} = 1500$ metres.

It should be noted that both the speed of light and the frequency had the prefix "kilo". This enabled us to make the division right away, without having to convert all units to the basic "metres" and "hertz". Under normal conditions, however, it is safer to include this extra step, to prevent decimal mistakes.

Some simple formulas, in which these decimal factors have already been solved, are available. It will be useful to memorize that:

$$\text{wavelength (in metres)} = \frac{300}{\text{frequency in megahertz (MHz)}}$$

In our example, the frequency of the 200 kHz station is 0.2 MHz. The wavelength computated with the formula, thus becomes:

$$\text{wavelength (m)} = \frac{300}{0.2} = 1500.$$

It is equally simple to convert wavelengths into frequencies by using a similar formula:

$$\text{frequency (MHz)} = \frac{300}{\text{wavelength (m)}}$$

The frequency ranges mentioned in the table, together cover a continuous part of the radio spectrum from 30 kHz up to 3 GHz. Within this frequency space, a number of frequency users have their own, allocated bands. Most of the allocations are made on a world-wide basis, but not all. It has been necessary to introduce a number of radio zones, or "regions".

As can be seen in the reference part of this book, the world is divided into three regions. Region 1 comprises mainly Europe, the Soviet part of Asia, and Africa. Region 2 encompasses all of the Americas, and region 3 the major part of Asia and the Pacific area.

It was also necessary to create a so-called tropical zone, to cope with typical problems which pertain in this part of the world, due to the high electric "noise" levels.

A number of frequency allocations, which were developed and agreed among nations in the past century, have historical backgrounds and had thus to be restricted to a "regional" basis. Also, some frequency arrangements had to be restricted to the tropical belt, which roughly extends between the tropics at $23\frac{1}{2}$ degrees northern and southern latitude.

Some of the major frequency users of the spectrum are: the maritime mobile service, the aeronautical mobile service, the fixed service, the broadcasters and the amateurs.

The *maritime mobile* service provides radio communication between coastal stations and ships, or mutual contact between ships. Maritime radio navigation is intended for the benefit of ships and may consist of coastal radio beacons, direction-finding stations and shipboard radar.

The *aeronautical mobile* service provides radio communication between a land station and an aircraft, or between aircraft. The aeronautical bands distinguish between bands for use within one region only, and those for communication between regions.

Land mobile services can be used for communication between a base station and mobile stations, or solely between mobile stations. Applications are found in military communications, but also in e.g. taxis.

The service with the largest share in the spectrum is the *fixed service*, used for communication between fixed points on earth. Sometimes, people speak about "point-to-point" rather than "fixed" traffic. Most fixed services are operated by national telecommunication services and provide telephone, telex and other communications between nations. An increasing part of the fixed traffic is now gradually being shifted to satellite communications, which provide a much more reliable, and more continuous, communications link.

Broadcasting is a radio communication intended for direct reception by the general public. This service is of prime interest to the readers of this book. Well-known broadcasting bands are:

Band	Frequency range	Wave band	Remarks
Long wave	150- 285 kHz	2000-1053 m	Not allocated in regions 2 and 3
Medium wave (Standard Broadcast Band)	525- 1605 kHz	571- 187 m	
Tropical wave	2300- 2498 kHz 3200- 3400 kHz 4750- 4995 kHz 5005- 5060 kHz	120 m 90 m 60 m	
Short wave	3950- 4000 kHz	75 m	Not allocated in region 2. 3900-4000 kHz allocated in region 3.
	5950- 6200 kHz	49 m	
	7100- 7300 kHz	41 m	Not allocated in region 2.
	9500- 9775 kHz	31 m	
	11700-11975 kHz	25 m	
	15100-15450 kHz	19 m	
	17700-17900 kHz	16 m	
	21450-21750 kHz	13 m	
	25600-26100 kHz	11 m	
VHF-FM	76- 87 MHz 87.5- 108 MHz		In Japan only 87.5-100 MHz in region 1.

A survey of television bands and television systems can be found in the reference section of this book.

As the interest in amateur band listening is continuous and substantial, a listing of major amateur bands is given below:

Frequency Range	Wave band	Remarks
1800- 2000 kHz	160 m	Not allocated in region 1.
3500- 3800 kHz	80 m	3500-4000 kHz in region 2. 3500-3900 kHz in region 3.
7000- 7300 kHz	40 m	7000-7100 kHz in regions 1 and 3.
14000-14350 kHz	20 m	
21000-21450 kHz	15 m	
28000-29700 kHz	10 m	
50- 54 MHz	6 m	Not allocated in region 1.
144- 148 MHz	2 m	144-146 MHz in region 1.
220- 225 MHz	—	In region 2 only.
420- 450 MHz	—	430-440 MHz in region 1.
1215-1300 MHz	—	

The data, gathered in these tables, were selected from article V of the *Radio Regulations*, a work that contains all the rules which have been agreed upon by those users of the radio spectrum, which are also members of the United Nations. The Radio Regulations are the result of many international conferences, held over the past century, and new chapters are still being added as discussions about additional frequency allocations, or re-allocation of parts of the spectrum, continue.

The international body which is responsible for the proper use and allocation of the spectrum, and for a fair distribution of the available space among frequency users, is the I.T.U. or International Telecommunication Union. Its seat is Geneva in Switzerland.

The I.T.U. can be regarded as a union of the national telecommunications services of most nations. Its advisory body is the CCIR, or International Consultative Committee, which operates with working parties and study groups, in which experts from many nations collaborate in drafting proposals for I.T.U. meetings and conferences.

One of the subjects which was covered by the I.T.U. in the past, is the spacing of channels in the various bands. The channel spacing determines the number of stations which can operate interference-free in the bands, and has to be adapted to the state of technology in receiver design, as their ability to separate the various channels has a direct connection with the channel spacing that can be allowed. For broadcasting in region 2, comprising north, central and south America, the spacing is still 10 kHz, but for regions 1 and 3 it has been reduced to 9 kHz a few years ago.

For shortwave, the frequency "grid" is 5 kHz. The intention of its creators was to observe a 10 kHz channel separation at any receiving site on earth, but a 5 kHz separation to carrier frequencies of broadcasts aimed at different areas. This process is called "interleaving". Most modern receivers have the ability to separate stations which are 9 kHz apart in the band. Older receiver types, especially pre-war sets, do not have this ability, and are therefore not suitable for present-day reception.

One of the terms which often confuses radio listeners, is "modulation". *Modulation* is the process by which the audio information, which we want to be propagated, is mated with a much higher frequency, which is able to propagate over large distances. The carrier frequency is only necessary for the transportation of the signal. In the receiver, the *demodulator* or detector, separates the audio from the carrier, thus reversing the process that has taken place in the transmitter.

There are two types of modulation of interest to the radio listener: AM and FM. AM, or amplitude modulation, is a process in which the amplitude of the carrier is varied with the rhythm of the audio signal. It is the most common type of modulation, and applied in long, medium and shortwave broadcasting as well as in most amateur traffic, and by maritime mobile and aeronautical mobile services.

FM, or frequency modulation, is a process in which the frequency of the carrier is varied in accordance with the audio signal. The frequency "deviation" thus obtained, can be 150 kHz for a stereophonic signal. In FM, there is no longer a carrier with a fixed frequency, but rather a centre frequency, which is generated in the absence of an audio signal. Frequency modulation is mainly used for the modulation of the audio signal in VHF broadcasts on frequencies between 88 and 108 MHz, and in television broadcasting. Also, small-deviation FM is sometimes used by amateurs in the amateur shortwave bands.

Since FM and AM are completely different modulation methods, they require different demodulators. In many receivers, the AM and FM circuits are completely separated, up to the audio amplification stage, which is used for both of them.

Receivers

A radio or television receiver is a black box, which is able to convert wireless signals into audible signals.

Let's concentrate on radio receivers, and try to give you some useful data, which will help in selecting a receiver. A receiver will only give you the full enjoyment of DX-ing, if it is of a sufficiently high quality. Of course, it is hard to judge the quality of a receiver by its appearance, but a first impression can be obtained if you handle the knobs. Do they "feel" good? Are they in the right place? Do they turn smoothly, yet without obvious play? The most important factor is undoubtedly the tuning control. Try to get an impression of the reduction that is applied and try it especially on shortwave, where tuning is so much more critical than on medium wave. Does the set perhaps have a two-position vernier, so that you can adjust the reduction of the tuning knob to the type of band you're tuning into?

Then, take a close look at the dial. How long is the dial? Does it give you a sufficient bandspread on shortwave?

Does it have a trim look, neatly divided into frequencies or wavelengths, or is it one of those haphazard things, which has no tuning accuracy, or where the pointer is so far away from the dial that you never known for sure which frequency you're reading?

These first impressions are important. They give you an idea of the effort that has gone into making the receiver – at least judging from outside appearance – suitable for its job.

If you have little or no knowledge of electronic circuits, our first advice must undoubtedly be to buy a medium or high priced receiver of a well-known brand. You then know that you've got value for money, because well-known manufacturers will always maintain a fair relation between the price of the set and the quality.

Also, take your time before you buy. Never buy on an impulse, and never go for that bargain of an unknown or little known brand, which happens to look so flashy. Many radio listeners and DX-ers have paid the toll, and it's a setback to the hobby, because unwanted whistles or stations found far away from their listed frequency, become an annoyance in the long run.

So, try to make a list of the properties which you want your radio to have, apart from an attractive appearance. Do you want the shortwave range spread over two or more dial ranges? They call it "bandspread" and it really helps in making tuning into shortwave easier. Of course, bandspread will increase the price of the set, because you need extra components in your electronic circuits, and the waverange-switch is one of them. Waverange switches are sometimes in odd places, because they operate in the high frequency (RF) section of the set, where it is important to have the wiring as short as possible. Some receivers have two waverange switches, one for the various bands and one especially for the different shortwave bands. This is a sign of a good receiver design and should be regarded as a "plus" for the receiver. If a receiver is said to have "dual conversion" for shortwave, that is an extra recommendation, because it will do away with the strange habit of receivers to produce the same shortwave station in two spots on the dial instead of one. The second appearance is called the "image frequency" of the station. This happens frequently on single-conversion receivers, especially on frequencies of over 12 MHz (25 m). The phenomenon will be explained at another place in this book. Many people have learned to judge the performance of a set by checking the three "S-es", these being: sensitivity, selectivity and stability.

Nowadays, sensitivity is not the great problem it used to be, and it is moreover hard to judge in a shop. Selectivity, the receiver's ability to separate stations, is indeed important. Selectivity will increase with the price, and can be checked most easily on shortwave, where interference is most likely to occur. By comparing two sets, tuned to the same part of the same band, it is easy to tell the difference in separation ability between adjacent channels. The better this "selectivity", the better the set.

Stability is a very important factor indeed. By "stability" we do not mean the mechanical sturdiness of a receiver, but the electrical stability of its electronic circuits. Check the stability by tuning to the highest shortwave frequency that you can find. Tune properly and leave the set alone for a minute or so. Then, check if you have to change the position of the tuning knob in order to remain properly tuned. If the tuning knob does not have to be adjusted, the stability of the set is OK.

For the reception of amateur signals, working on single sideband (SSB), a receiver with an extremely stable electronic circuit is a must. Such a receiver will show its quality also outwardly, because you will find at least two knobs which are not present on other sets: a "BFO"-control and an "RF gain" control. The BFO or beat frequency oscillator, is an extra unit, necessary for the demodulation of single sideband (SSB) signals. Also, the ratio between the received signal and the locally made BFO-signal, must be carefully balanced in order to obtain the proper performance. Thus, we need an extra manual control of the front-end amplification circuit of the receiver. The RF gain control knob takes care of this.

An accurate frequency reading on the shortwave bands is very important for shortwave listening.

Since fairly recently, manufacturers have been tackling this problem. One handy, but engineering wise conventional solution, is to equip the set with a "crystal callibrator" or "marker". Press the knob of the "marker" generator and you'll identify a weak carrier every 250 or 500 kHz, enough to give you a fair idea about the dial deviation at that point.

Some receivers have a dial adjustment, to put the marker at the right frequency on the dial, thus calibrating the dial for frequencies in the vicinity of the marker or calibration frequency.

More and more receivers designed for proper shortwave reception, are nowadays equipped with a digital readout of the frequencies on shortwave.

The readout logic is comparable to that of pocket calculators, and can be considered quite reliable, giving you an absolute accurate readout of shortwave frequencies, thus putting an end to the frustrating "frequency guessing" that DX-ers have been subject to for many years. As the readout logic can cause interference to the receiving circuitry of the receiver, and also requires substantial battery power, a special switch may be present on the set to activate it.

The tuning meter, or S-meter, is a handy gadget which adds to the professional look of the receiver, but it is not a necessity for the DX-er.

A tuning meter indicates the momentary signal strength of the received station, thus giving you a visual display of the relative level of the signal, and a way to check whether you are correctly tuned to the station or not.

An S-meter is a level meter, which is calibrated in so-called S-units. In the reference section of this book, you will find a table which gives the relation between S-units and other indicators of signal strength. The S-unit stems from the so-called RST-code, which is used by the radio amateurs or "hams".

Last but not least, check the external connections which can be made to the radio. If you want to record received information on tape, look out for a tape recorder connection. An earphone jack comes in very handy for quiet DX-ing at night, and enables you to enjoy the hobby without disturbing others.

An external antenna connection is almost a "must" if you want to take your shortwave listening seriously. So let us look at that subject a little more in detail.

Antennas

Almost all modern receivers – mostly portables – are equipped with two antennas: a ferrite antenna and a telescopic rod antenna. The ferrite antenna is sensitive to the magnetic component of the radio wave and is suitable for long wave and medium wave reception. A ferrite antenna is directional, so it is possible to arrive at maximum signal strength for each station, by turning the antenna or, if it is at a fixed place inside the receiver, to turn the receiver.

The telescopic antenna reacts strongly to the electric component of the passing wavefield, thus making it more effective on the higher frequencies: shortwave and VHF-FM.

Both the ferrite and the built-in telescopic antenna give limited reception possibilities, depending on the location of the receiver. If the radio is situated within a reinforced concrete or steel-framed building, reception could be very poor indeed. If, on the other hand, you are in a wooden shed in the open field, you will probably not feel the need for an additional antenna, because the set performs just as well without it.

Many listeners wonder why a small, telescopic antenna on top of a portable, can give such good results when operating under the proper conditions. The answer is that radio manufacturers can make the full use of the built-in telescopic antenna, because they know all its characteristics, and so can thus adapt the front-end circuitry of the receiver to provide an optimal matching to the antenna. Thus, the efficiency of the small antenna can be increased.

On the other hand, a manufacturer does not know what kind of an antenna will be connected to the external antenna jack of the receiver. Thus, he will provide for a rather loose coupling between this unknown antenna and the antenna input circuit of the receiver. This means that the transfer of signal is not optimal; the external antenna is not used to its full possibilities. Yet, a good outdoor antenna gives much better results than a badly positioned telescopic rod, because its ability to pick up the signal is much better.

Communications receivers require the connection of antennas and transmission lines of certain prescribed properties. Once you know what the meaning of all this technical jargon is, you will be able to make the most suitable antenna for any kind of receiver.

Our advice is therefore to use the external antenna jack of your portable for shortwave reception, especially if the signal is screened from reaching the telescopic antenna of your receiver by built-up areas, large metal surfaces or metal cages, e.g. formed by the steel reinforcing rods in concrete.

For a normal portable or domestic set, the shape and length of the outdoor antenna are not of paramount importance. For best results, make your outdoor antenna free-standing, well-insulated from surfaces which become conductive in wet weather, and as high up as possible. Also, see to it that it does not pick up local interference sources, which stem from passing vehicles, sparking electric motors or fluorescent tubes.

Preferably use copper wire for your antenna, because it is corrosion resistant and has an excellent electrical conductivity.

The wire diameter (gauge number) is not very important. If local regulations do not permit the use of outdoor antennas, an "invisible" antenna, made of 0.3 or 0.4 mm (AWG 26 or 28) magnet wire (enamelled copper wire) may provide an acceptable solution for all parties. In normal cases, however, a wire diameter of about 1 mm (AWG 18) is recommended.

In a later chapter, the subject of antennas will be covered more in detail, and attention will be given to suitable antenna systems for various applications.

Correspondence with radio stations

You now know something of the basics of DX-ing. The question is, what use are you going to make of it, and what side of the hobby attracts you most?

Some BC (broadcast) DX-ers are content to achieve the best possible reception conditions for listening. They tune in to shortwave, medium wave or FM, enjoy the handling of their radio and the programmes they hear, and they never think about corresponding with radio stations, because they do not know what they have to tell.

Although these "armchair travellers" are happy listeners, they belong to a group which is unknown to the shortwave broadcasters, because their names will not be present on any (free of charge) mailing list.

Others, who also make good use of their receivers, collect QSL-cards. These are cards, sent out by amateurs and also by many shortwave broadcasters, to verify a correct reception report. QSL-hunting is a hobby that is usually performed for a couple of years by young DX-ers, who in this period form quite a collection of attractive cards and characteristic verification confirmations, and in the process learn a lot about the nature of shortwave propagation and the conditions in the band.

Yet another group of listeners selects one or two favourite stations and become loyal "monitors" of those stations, informing them regularly about the reception in their areas. To a shortwave station, these monitors are undoubtedly of great importance, as they form a reliable and continuous source of reception data, which a shortwave broadcasting station cannot/might not be able to obtain otherwise. Nowadays, most world broadcasting stations have a network of "monitors", selected from those listeners who have distinguished themselves by regular correspondence and a positive attitude towards the station.

Generally speaking, listener-response is important to a SW radio station, and for different reasons. First of all, letters establish contact between a radio station and its audience, and show that the station's aims are being fulfilled, and that its message is coming over. Besides, letters from listeners often contain worthwhile information: remarks, criticism or other reactions to the programmes, data regarding reception, etc.

Many shortwave stations stimulate the flow of letters by offering small tokens or information in return: programme schedules, stamps, picture postcards, and sometimes even attractive souvenirs. Some stations with a strong political background offer printed and illustrated material, with which to acquaint the listeners with their ideologies. The result of all this is that a major shortwave station receives great quantities of mail each year, and has quite a job in dealing with it. This may explain why it sometimes takes a couple of months and more before letters are answered, particularly if there is a peak in the incoming mail. It keeps a small army of secretaries and correspondents busy in the various language sections.

However, part of the mail can be answered more quickly, if it is a matter of supplying the demand for, say, printed information that is available for the listeners, and offered in the broadcasts. A large part of the mail, too, may be made up of so-called reception reports, which provide the stations with useful indications as to how the broadcasts are reaching the ears of the listeners in the reception areas.

Let us see, what a report should contain, in order to be of vaue to a station. It will be clear that the date and time of reception, and the frequency or wavelength, must be given accurately to enable the station to identify its transmission. Another important detail is the quality of reception, because from this information a station can decide whether or not to shift to another frequency, for example in the case of reported strong interference from another station. A few programme details are also needed, certainly for stations that run a number of transmissions simultaneously.

To sum up: a reception report is of value to a radio station if it contains the date, time and frequency or wavelength; an assessment of the quality of reception, and some programme details. And, if you want a QSL-card, do not forget to ask for it!

Two things mentioned above may cause some eyebrow-raising.

For instance: what time indication should be given? Also, what is a proper way to indicate the quality of reception?

Let us deal with these subjects one by one.

The time indication, given in a report or letter, can be either local time, or GMT. GMT, which stands for "Greenwich Mean Time", also known as UT, Universal Time, is a standard reference time which is used world wide. Most programme schedules of world broadcasting systems are given in GMT, and indicating the reception time in GMT will be appreciated by many a secretary who has to check the details of your report, and already has a head full of regional times, summer times, half-hour time deviations and all those confusing data which hamper that quick check which she needs in order to cope with the day's mail. So, stick to GMT, please and use the world time chart given in the *reference section* of this book, if you want to convert your local time into GMT.

Rating reception quality is a problem at first. Of course "fair" or "good" will give the station some indication, but such general terms are not enough for the station officials who have to check the reports for accuracy, and for irregularities in reception conditions. Many things can go wrong in shortwave transmissions, such as disturbances in the ionosphere, interference from other stations, or caused by a vacuum cleaner or other household appliances in your own or your neighbour's home, to say nothing of fluorescent lighting. This means that, though reception in your home may be bad, a neighbour two or three doors away might be having excellent reception!

It follows, then, that the station checker will only be able to get a clear picture of conditions if your report on reception quality is more detailed. In order to facilitate this, an international code was drawn up, which became known as the SINPO code. It is quite simple to use.

Each of the five letters in SINPO represents one of the five sub-divisions of a report.

The "S" stands for Signal Strength, which is simply the degree of audibility of a station's signal, as reproduced in the radio set. Many receivers have signal strength indicators: a meter or a magic eye, and sometimes a so-called S-meter, on which you can find an indication of the relative signal strength.

The "I" in SINPO stands for Interference. Under this heading you give the degree of interference from other stations.

If you can trace the identity of the interfering station, mention it in your report. You will be supplying very useful additional information !

The "N" stands for Noise, which you can interpret as meaning noise from local or household sources. Under this heading you give a rating for the degree of interference resulting from street traffic, fluorescent tubes, drills, electric motors, etc.

The "P" is rather more difficult. It indicates Propagation disturbances, and it can only be rated properly if you know something about the behaviour of the ionosphere, and its effect on propagation. Usually, reporters use this to indicate the degree of fading in a transmission (that is why many people substitute an "F" for the "P", and refer to the SINFO code). However, there are many other kinds of propagation disturbance, besides signal fadeouts. For example, magnetic and ionospheric storms, and so on.

However, for the time being you need not worry too much about this. Finally, the "O", under which heading you assess the Overall Merit. If you listen to a transmission for ten to fifteen minutes, you will be best able to form an idea of what rating you should give here.

Now about the rating itself, for each of these code-letters. You express the rating in a number, running from 1 to 5. A high mark always indicates a *favourable* situation. So a 4 or 5 for Signal Strength means a strong signal, but for interference it means little or no interference.

Let's take a closer look at the "S" and the "O". Here, 5 means excellent, 4 good, 3 fair, 2 insufficient and 1 bad.

Now the "I", the "N" and the "P". In these cases 5 means little or no interference, or noise or, let's say, fading; 4 indicates slight, 3 noticeable, 2 strong or severe and 1 very severe. If all this is above your head for the time being, you can reduce the code to SIO, which involves only the easily measurable and rateable sub-divisions of the code. Give it a try, and you will see that, with a little practice, using the SINPO code will become second nature.

Signal Strength	Interference	Noise	Propagation Disturbance	Overall Merit	
5 excellent	nil	nil	nil	excellent	5
4 good	slight	slight	slight	good	4
3 fair	rather strong	rather strong	rather strong	fair	3
2 insufficient	severe	severe	severe	insufficient	2
1 bad	very severe	very severe	very severe	bad	1
0				not intelligible	0

We hope that, by this introduction into the world of DX-ing, we have roused enough interest to make you want to go on with the following chapters.

The first section of this book recounts experiences and gives good advice which you will need in the hobby.

Part two approaches various problems and phenomena from a more scientific angle.

Section three contains editorial articles, intended to give you some background knowledge, thus paving the way to reading professional literature on specialized subjects in the future.

Section four is the reference section, in which we have collected useful, handy and sometimes indispensable information for the broadcast listener or DX-er. It gives tables, maps and charts which we think you will need regularly in the pursuit of your hobby.

Chapter 2

OPERATING YOUR LISTENING POST

by Pip Duke

Your receiver is installed, antenna erected, lightening arrestor in feeder-line from antenna to the receiver, world time-chart pinned handily on the wall, transmission schedules and/or programme booklets of foreign shortwave broadcasting stations by your operating position – you are ready to go! Or are you? How about that lighting? Is your chair comfortable? Are you located in a reasonably quiet part of the house – or apartment? Have you a log book? How about some form of frequency listing such as "The World Radio TV Handbook"? Will your QSL cards go up on the wall of your shack or into a card-index system? Have you a set of "cans" (head phones) for late night listening? Much of the most elusive DX, shortwave and standard-band, is obtainable only very late at night or very early in the morning – before dawn. Since you expect to be putting in quite a few of those precious leisure hours at your listening position – make sure you are quite comfortable, with adequate light and a reliable clock! One of those "world-time" clocks is very useful as they show local times in various parts of the world – plus your own local time automatically. OK then, you have considered all these factors and now you are all set to go. But wait, one more thing. How are you going to request your QSL card? By letter, reception report form or by pre-printed postcard? Many SWL clubs have their own printed reception forms which include space for QSL requests. By joining one of these clubs you can regularly obtain these forms and also become part of the SWL DX-ing fraternity. The enjoyment of your chosen hobby can be increased in direct proportion to your knowledge and understanding of what you are trying to do – receive distant radio stations – sometimes under adverse conditions. Every SWL shack should have a small but vital library on the subject. Many inexpensive books and magazines are available especially written for the not too technically-minded DX-er. A SWL club will recommend a list of them.

Now before switching on the receiver – make sure you have a pad and pencils handy. You will be surprised how often you'll need them.

Definitions of terms

In your DX-ing, some terms and abbreviations will first puzzle – and even confuse you. But they will soon become quite familiar and before long, you will even be using them yourself – quite automatically. Here are a few of the most used of them!

SWL	A shortwave listener.
DX	Abbreviation for "distant" or "far away". Also used to mean a rare radio station – thus the term, "a choice piece of DX."
SWL-er or DXer	Someone who chases DX or monitors the shortwave spectrum.
QSL	From the international "Q" code. Means a written acknowledgement of reception or contact.
QSL card	A pre-printed card sent out by many radio stations as their acknowledgement (and confirmation) or your reception of their transmission. To be valid a QSL should indicate date, time and frequency of reception.
BC	Broadcast.
BCB	Broadcast band (standard band or medium wave).
BCL	Broadcast listener.
LW	Long wave.
QRM	Interference from man-made sources.
QRN	Interference from natural sources – such as atmospherics or static.
Rig	Equipment.
QSY	To change frequency.

AGC	Automatic Gain Control.
AVC	Automatic Volume Control.
AF	Audio Frequency.
IF	Intermediate Frequency.
RF	Radio Frequency.
Tube	Called a Valve in many English speaking countries.
Valve	Tube.
RT	Radio-Telephone.
CW	Continuous Wave.
RTTY	Radio-teletype.
FM	Frequency Modulation.
AM	Amplitude Modulation.
SSB	Single side band.
QSB	Fading, i.e. fast QSB means "fast fading", and slow QSB means "slow fading", and so on.
ID	Identification by station.
kHz	Kilohertz.
MHz	Megahertz.
IRC	International Reply Coupon.
kW	Kilowatt (1000 watts).

This list should start you off and you can add to it as you come across more abbreviations which may be useful.

Operating

Shortwave DX-ing is fun. But at times, it also is exasperating. Other writers in this handbook have explained about the vagaries of shortwave reception and radio propagation via the ionosphere. If you haven't done so already, study what they have to say. It will be of great help – and save you many hours of fruitless effort. You won't tune the 16 metre band for European stations at 2300 GMT in December during sunspot minimum conditions if you live in North America, for example. You'll know enough to search in the 41 and 49 metre bands for them. You will learn that a weak signal, barely audible due to QRM and fading, is not necessarily a piece of choice DX. Oh no! It could be only a "back wave" of a radio station's skip zone signal only a couple of hundred miles away. Get to know the basic principles of radio propagation so you will easily recognize the difference between good and poor reception conditions of certain "key" transmission paths or circuits. For example, the North Atlantic path (Europe to North America – and vice versa), the Pacific path, the Asian path, and so on. Check powerful "key" shortwave broadcasting stations in a few "key" areas of the world. Learn to recognize their signal strength under normal conditions to use as a guide to propagation conditions. Before you start your day's or night's DX-ing, just check that your "guide" stations are coming in OK. If they are, then conditions are normal – so good DX-ing ahead! However, if they have a weak or fluttery signal, then beware of conditions over that particular transmission path. You will save yourself much wasted efford if you learn which areas of the world are receivable on particular frequencies at different times of the day – or night, at your location.

Some of the most difficult stations to find are certain of the Latin Americans, due to their low power, low frequencies and use of non-directional antennas for local or regional broadcasting. By low power, I mean about 1 kW or less. Most of them can be found in the broadcast bands between 3 MHz, and 10 MHz, i.e. 90, 60, 49, 41 and 31 metre bands. Darkness tuning will provide your best chance. Once you have found your DX station, be sure to enter it in your log book immediately – especially the log reading on the receiver tuning dial, if you have one.

So you can find it again easily. Be careful to recognize and differentiate between the source of your programme. Is it a primary transmission – or a re-broadcast? Voice of America, BBC and others operate many re-broadcast transmitting bases around the world. Don't confuse Voice of America transmitting facility in Greenville, North Carolina with their base in Monrovia, Liberia. Have a good world map on the wall of your post and mark them with coloured pins or labels. If you monitor carefully, especially on the full hour, or half-hour, most of these stations will identify the location of their particular transmitter to which you are tuned. It takes a great deal of patience and the success of your efforts will be measured by the number of QSL's you have in your index or displayed on the walls of your shack. In this connection, learn how to make out a reception report correctly. It will certainly increase your chances of obtaining a QSL card from that DX radio station. Be sure to indicate, date, time (GMT or local) and the frequency, or wavelength and some brief programme details which you heard. And of course, the reception report itself. You may use the RST system although many shortwave stations now prefer the SINPO method. SINPO are the initial letters or parameters for Signal Strength, Interference, Noise, Propagation (fading) and Overall Merit or readability of the transmission. More details can be obtained from technical handbooks or from the radio station concerned. Most SWL clubs also have explanations of the SINPO code.

One of the problems you will encounter very early in your DX-ing career is time. Local time is not the same for different locations around the earth. Midnight in London, England (GMT) is 7 pm in Montreal (EST) but 1 o'clock in the morning in Berlin (CET). However, with some practice, and the use of a time conversion chart or clock, you will be able to identify the time of transmission correctly on your reception report. If you are not too certain, I suggest you show your own local time (that's the time in your home town), and let the radio station work it out. But be sure to identify the time used – whatever it is, GMT, CET, EST, LMT (local mean time), and so on. By the way, the "World Radio and TV Handbook" lists world time differences alphabetically by countries.

Interval Signals and Idents

If your mother tongue is English and your are not a linguist, you may experience difficulty in recognizing and identifying foreign-language stations. But there are tricks of the trade which can help you, and one of these is the interval or identity signal used by each radio station. For example, you may not speak the language of the Ivory Coast, in West Africa, but you will easily recognize the "talking drums" used by Radio Abidjan. Similarly, if you cannot speak Italian, Radio Rome is still easily identified by their "nightingale" signal. It is possible to buy a tape or disc identifying many of these identities or interval signals. Again, your nearest SWL club should be able to help.

Maintenance

If you are to get the most consistent, efficient use out of your receiving equipment, which represents a sizeable financial investment for many SWL's, regular, preventative maintenance of the antenna and receiver is very important. The antenna should not need much attention once it is erected, but it should be inspected at least monthly. Look for any signs of rust, especially around joints or soldered connections. Watch out for frayed halyards, guy wires, loose strainers, frayed ropes, stuck pulleys, worn insulation and so on. Tighten any sags in the antenna and watch for bulges which could develop in most piping. Check your lightning arrestor at the start of each thunderstorm season if you live in an area where storms occur. Make a special insulation check on the feed-line where it passes through the window or wall into your listening post. Inspect all connections at the back of the receiver. Ensure the ground is connected – and working properly. This may present a problem for some apartment dwellers. Remember, time spent on regular preventative maintenance is seldom wasted. Now to the receiver. Check antenna and earth connections. Check for noisy controls, especially volume or AF gain potentiometers. If noisy, clean with carbon tetrachloride but be extremely cautious and do NOT inhale. Keep your head as far to one side as possible if using this cleaning agent. It is safer to ask your radio dealer for a can of safe switch-cleaner fluid. Disconnect receiver from electricity supply. Check for loose tubes.

Note:– Before carrying out any maintenance checks or repairs in the receiver, DISCONNECT POWER SUPPLY. Tighten control knobs which may have worked loose. Do not touch the IF stage (or stages) of your receiver unless you are skilled in this type of work. To check receiver sensitivity, first note set "noise" with antenna connected. Then disconnect antenna from receiver. If necessary re-peak antenna trimmer. If your receiver can still pick up atmospheric noise, the noise level of the receiver is low enough to permit efficient reception of weak signals (sensitivity) with antenna connected. Do not become despondent if your receiver does not perform as well as your friend's. Remember, no two receiving locations are exactly the same, and a sensitive receiver may operate quite poorly at one location but outperform all others in another location a short distance away. As most shortwave radio engineers will tell you, DX reception on shortwave is full of surprises and no piece of equipment should be condemned without first subjecting it to comparative tests over a reasonable length of time.

Test Equipment

It is not necessary to purchase a list of expensive test equipment to keep your listening post maintained properly. If you have the necessary skill, plus a little spare cash, the following items will prove very useful. They are not expensive:

Soldering iron or gun – 60 watt. – Two or three assorted screwdrivers insulated. – Pair of side-cutters. – Flat nose pincers. – Pliers. – Simple volt-ohmeter.

Visit your local wholesale radio or "ham" equipment dealer and browse around. You may spot one or two more inexpensive items which will facilitate maintenance of your station.

Note that WWV, the US National Bureau of Standards time and frequency standard radio station operates on 2.5, 5, 10 and 15 MHz twenty-four hours a day. You can recognize it easily by the "clock ticks" and voice announcement at each five minute mark. Use it as a frequency calibration check to prove correct readings on your receiver tuning dial.

Finally, do not expect more from your equipment than it is designed to give. The more YOU understand the technicalities of your chosen hobby, the more efficient use you will make of the receiving equipment. If you are a beginner, start off in a small way with an inexpensive receiver. But novice or old hand, always use the best outdoor antenna possible, even if it is only a whip mounted on a window-sill. The secret of successful DX-ing is in the antenna – and lots and lots of patient monitoring of the right hands at the right time. Good DX-ing.

Chapter 3

TAPE-RECORDING OF REPORTS

by Jim Vastenhoud

One of the drawbacks of a written reception report is the personal interpretation by the reporter, of the reception quality, signal strength and different disturbance factors, but up to, say, ten years ago there was no alternative, and a conscientious study of the reception quality always implied comparison of many reports recorded of the same transmission at approximately the same time in the same area.

In this respect, the growing use of tape recorders can be a substantial asset to the SW station in checking reception, because it does away with subjective interpretation: the station officials who listen to taped reports can judge reception quality for themselves.

On the other hand, the taped report also has its disadvantages, chief among them being the time factor. It takes much longer to listen to a tape than it does to study reception data on paper, and it also requires the equipment to listen to tapes recorded at different speeds and with different machines. Moreover, a tape has to be returned to the sender, because it is rather expensive material, and this can lead to budgetary problems when tapes are received in great numbers, as they are at some shortwave stations.

It is a good thing to bear this in mind, and to start reporting on tape only after the station has confirmed its agreement, and notified its speed preference, the frequencies to be monitored, the programmes which are of special importance to it, etc. Sometimes, the station will not only be interested in taped reports, but will want to check, the voice quality of their announcers and reporters on shortwave, to ensure that even under less favourable propagation conditions and/or interference they still remain intelligible.

For the DX-er, the tape recorder opens up another interesting field. He can combine his DX activities with the tape recorder hobby with useful results. He can help a station to keep informed about reception and help in tracing interfering transmitters by recording them, thus giving his hobby real justification. At the same time, we must realize that a taped report is only of value if its technical quality is equal to that of loudspeaker or headphones reproduction. This means in fact that the tape recorder must be in good order, that the correct type of tape is used and that no loss in quality results from improper matching between the receiver and the tape recorder.

When reporting to a station on tape, the first choice we have to consider is the reel diameter. The disadvantage of a small reel is that the duration of the report is relatively short, but in most cases the station will be more inclined to regard this as a point in favour, because "time is money". Moreover, modern long-playing tapes can store quite some information, especially when the recorder is of the two or four-track type. A small, three inch reel can nowadays contain up to 40 minutes of playing time on one track, so a tape recorded on a 4-track machine affords the station an opportunity to listen to the reception quality for more than 2½ hours.

A small reel of tape weighs little and so costs less in the mail. This is another advantage, especially if you want to airmail your report, which is recommended because the value of a report depends upon its freshness.

Start a taped report by stating your name, your address and a request to return the tape after use: this will prevent it from going astray once the sleeve is removed.

In order to store as much valuable information on the tape as possible, actual reception recordings should be short, about one minute or so. This duration is long enough for the radio station to judge the reception quality in normal cases. Should interference be experienced, it might be worthwhile to record a little longer. Actual pick-ups should be preceded by a brief announcement stating the date, time and frequency. Comment on the reception will be appreciated afterwards if it is meaningful. Data regarding the aerial and receiver used should be given once, and be short and concise.

If a station is interested in a different procedure, they will undoubtedly tell you so. If you are interested in some kind of follow-up, like a QSL-card on one of the recorded transmissions, make your request on tape. Remember that if you record long stretches of programme, interest will flag and there will be an inclination to play your tape at double speed, so that your request may go unnoticed. The taped report can be a very valuable help to the station, providing the monitor bears in mind what the station wants. Sometimes this will be a series of recordings made at the same time and on the same frequencies on several days or weeks, but the station may also ask for incidental recordings, especially to check the result of some action from their side like a frequency change, the news bulletin by the new announcer, or to check special propagation phenomena.

When the recording is ready, check it immediately to ensure that it is flawless, and after all recordings have taken place send it to the station by the quickest possible means. Find out which way of postal handling is the cheapest. Some countries will accept a package marked "Phonopost", and others will require the word "Petit Paquet" (small package) on it. Still other countries reject all tape recorded messages unless they are sent as letters. Even in this case, the use of special flexible reels as applied for 8 mm films and a minimum amount of packaging will keep postage within limits.

Some measures are necessary to ensure the highest possible technical quality. One of the first precautions to take is the cleaning of the recording head, using a stiff brush or a non-fluffed rag wound around a match or another piece of soft, non-ferrous material. Special fluids are available to facilitate this job, but take care not to use a liquid that might dissolve the enamelled insulation of the wire in the recording head.

Make sure that your tape is of good quality. The tape noise can be checked by recording "silence" and playing back the tape at a high position of the volume control. If you are not completely sure that the capstan of the recorder runs at a constant speed, the best check is to record a piece of piano music. If there is no wow when you play it back, all is well.

The most preferable speed for this kind of work is $3\frac{3}{4}$ ips (inches per second) or $9\frac{1}{2}$ cm/second for a reel-to-reel recorder. At this speed, even an old recorder can reproduce frequencies up to about 8000 HZ, and this is sufficient for the registration of AM radio signals.

On the other hand, this tape speed is low enough to enable you to record much information on a small reel of tape. Most radio stations will be able to play back both two track and four track recordings, but if you are not sure of this, it is advised to record only the tracks 1 and 4 on a four-track machine.

The most popular vehicle for recorded programmes between listeners and radio stations is undoubtedly the compact cassette. It is a flat, 6×10 cm plastic box containing two reels of $\frac{1}{4}$ inch wide tape. It runs at a speed of $1\frac{7}{8}$ inches per second. The most popular type of cassette tape has a duration of 30 minutes on each side, so that up to 60 minutes of monaural recording time is available.

The compact cassette is played on a cassette player or a cassette recorder, usually a small unit in either a portable or desk-type execution. The most simple type of cassette recorder is monaural, and it is well suited for our purpose.

It is important to make the right connection between the receiver and the recorder. A recording which is made by positioning the microphone before the loudspeaker of the receiver, is of no use to the station, as the distortion which this recording method introduces, renders the recording unfit for proper analysis.

A better, and in fact the only acceptable condition for a good recording of a radio programme is a direct, metallic connection between the tape recorder output (sometimes called "diode output") of the receiver and the "phono", "radio" or "auxiliary" input of the recorder.

The diode output is connected to the circuitry of the receiver at a point between the detector stage and the audio amplifier stage. If it is not available on your set, it can be added easily, e.g. by connecting the outer tags of the volume control to a screened "microphone" cable. The screening braid of the cable is connected to the "cold" or chassis side of the volume control, and the centre conductor to its "hot" side. A small capacitor of about $0.5\mu F$ (e.g. 470,000 pF) can be soldered between the hot tag and the centre conductor of the cable, to prevent any spurious DC from the receiver reaching the recorder. This is illustrated in *figure 1*. The use of this connection has the advantage that the recording level is independent of the volume control setting of the receiver.

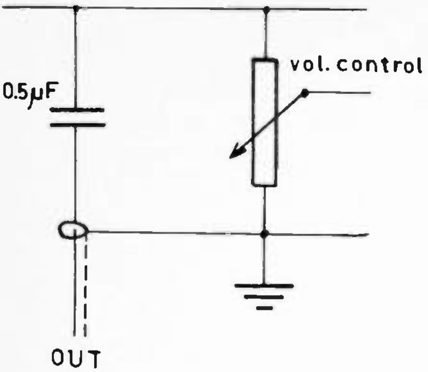


Fig. 1

As long as the receiver and the recorder are of the same make and approximately the same year of manufacture, it can be assumed that the tape recorder output of the radio and the radio (phono) input of the recorder will approximately match, so that no audible distortion will be noted on the recording. If, however, you happen to own a receiver and a recorder which have been manufactured in different parts of the world, you will probably need a suitable matching network (matching circuit) between the output of the receiver and the input of the recorder.

If you are handy and can read the symbols of electronic parts and make soldering joints, the following will come in useful.

If you want to use the external speaker connection of the receiver, and the microphone input of the recorder, use a short (about 4 feet or 1.2 metres) piece of shielded microphone cable (or shielded audio cable). Near the loudspeaker jack, insert a 0.5 μF capacitor, a 220 k Ω resistor and a 200 ohms resistor as shown in *figure 2*. The value of the large resistor may still need adjustment, this determines the loudness of your volume control.

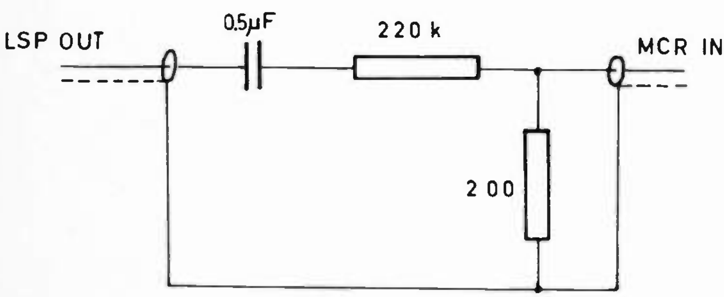


Fig. 2

If you want to tap the signal from across the volume control of the (transistor) receiver, the matching network looks a little bit different. The series resistor should be at least 47 kΩ, and again you can use the microphone input of the recorder. See *figure 3*.

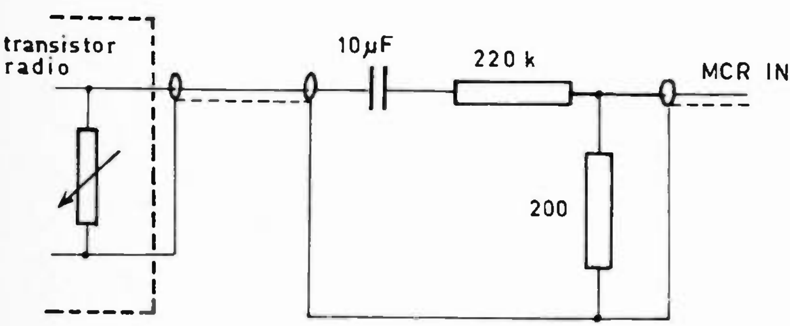


Fig. 3

If the receiver is fitted with a cinch output plug for the tape recorder connection, while the recorder has a DIN input, the network is again slightly different, as shown in *figure 4*.

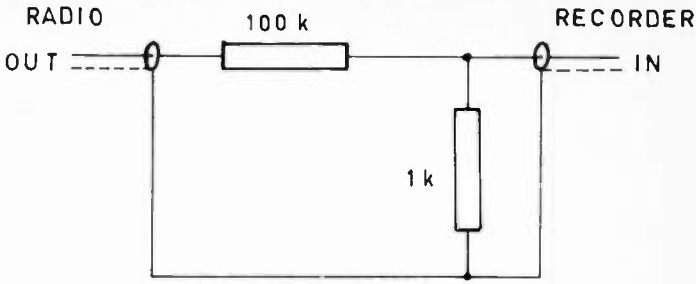


Fig. 4

Funny things can happen sometimes when an arbitrary receiver is hooked up to a recorder of a different brand, especially if the receiver has a "positive" ground, and the recorder a negative ground, or vice versa. In such a case, it is again recommended to introduce a 0.5 μF capacitor in the centre conductor of the connecting cord, to prevent damage of recorder or receiver by an unwanted DC current. The capacitor will effectively block any DC, but it will pass (although somewhat weakened) the audio frequencies.

When all technical difficulties are solved, and test recordings show that all is well and no audible distortion occurs, you are ready to serve your favourite station(s) with valuable reports on tape. Please remember:

- At the beginning of each tape or cassette, record your name and address, and ask for the return of the tape after use.
- Before every recording of a piece of programme, state briefly: date, time (GMT), frequency and reception quality.
- Record not longer than one minute of a programme item, except when you want to demonstrate a particular facet.
- Record the same broadcast at the same time and on the same frequency on at least three consecutive days, to level out differences in propagation conditions.
- Record over a period of not longer than 14 days, to avoid your data from becoming stale.
- Send tape by airmail.
- Do not expect to find a station recording on the returned tape: station officials simply do not have the time to render such a service . . . but
- at the end of your own recordings, you can ask for a short comment from the station (either on the tape or in written form) to help you to improve your service.

Chapter 4

INTERFERENCE AND YOU

by S. B. Duke

So far as the short wave listener is concerned, interference consists basically of two types: Man-made (QRM); Natural (QRN).

We will consider the man-made type first. However, before we do so, perhaps we should first define what interference is. Well, by interference we usually mean noise, man-made or of natural geophysical origin which degrades or completely spoils the signal you wish to receive.

Probably, the most often encountered type of QRM on the shortwave broadcast bands is man-made and one or more of the following:

Heterodynes which may be of the low frequency type (LF hets) or high frequency (HF hets) depending upon the frequency of the audio beat note, or "whistle" produced by the carrier waves of the desired and interfering stations beating together. These types of "whistles" or more professionally, heterodynes (LF or HF) are usually of constant pitch.

Modulation spread (or splash) causes adjacent channel interference when it is heard over the modulation, or programme of the desired station. Due to the seriously overcrowded conditions of the shortwave broadcasting bands, more than one station is more than likely operating on the same frequency though on different beam directions. Insufficient geographical separation of the transmitters, ionospheric propagation conditions and off-beam radiation from the transmitting antennas are some of the contributing factors to co-channel and adjacent channel interference. Co-channel inteference may be recognized by the presence of two intelligible programmes on the same frequency with both programmes about the same signal strength. Adjacent channel interference may be recognized as unintelligible modulation or programmes heard mixed with the desired programme with the intefering signal originating from a station about 5 kHz on either side of the frequency on which the desired station is operating. Since the Administrative Radio Conference in Geneva which ended in December, 1959, the international shortwave broadcasting bands have been sub-divided into channels with only 5 kHz separation between them. This is technically insufficient owing to the poor discrimination of most of the shortwave radio receivers in use today. This means that the majority of the cheaper transistor or tube-type receivers are unable to discriminate between the wanted and unwanted station if their operating frequencies are too close, in this case with only 5 kHz separation between, or selectivity is necessary if the multitude of shortwave signals are to be received without mutual interference. This means increased costs to you, the listener. This is one reason why some shortwave receivers are more expensive than others. Because they incorporate more sophisticated circuits and important factors like selectivity, sensitivity and discrimination are enhanced. These, together with noise limiters and band-spreading do much to reduce the annoyance of degradation of reception caused by the various forms of interference we are discussing. Here I should add that the Geneva decision to adopt the 5 kHz channel separation principle was due to the acute overcrowding in the shortwave broadcasting bands 13 through 49 metres.

Thus, we can say that *co-channel* interference is due to two or more stations operating on the same channel or frequency, whereas *adjacent-channel* interference is caused by the modulation, or programme of a station spilling onto or mixing with that of a station operating next to it, perhaps 5 kHz or less apart in frequency.

Code signals on or near the operating frequency of a shortwave station will often cause QRM which an experienced SWL will be able to recognize as morse code (CW), facsimile signals, radio teletype etc. But do not forget that this type of man made interference in your receiver could be due to a harmonic radiation of the interfering station's fundamental frequency.

Jamming (jammer splash) is a broadcast or a transmission of man-made noise which is intended to blanket another programme and so make it unintelligible. The noise used as jamming is usually on tape and may be a recording of a diesel motor or "white noise". Much of the jamming has disappeared from the shortwave broadcast bands compared with conditions five or six years ago. Again, like other forms of interference (QRM), jamming can be either co-channel or adjacent-channel. However, if it is of the adjacent-channel variety, then we call it jammer "splash" since it "splashes over" onto the frequencies on either side of the jammed frequency and, inadvertently, spoils the broadcasts which happen to be on them at the time. Sometimes jamming transmissions are sufficiently broad to cover more than one channel – perhaps up to three or four channels at a time. Nowadays, it is possible to hear "narrow band" jamming, or "MAYAK" jamming. This is usually confined to the frequency to be jammed and the jamming modulation is usually one of the Moscow home programmes – the MAYAK programme – hence the term "MAYAK-type" jamming.

Before proceeding on to the NATURAL type of interference (QRN), a short explanation of "birdies" or "chirping" may be useful. Most superheterodyne receivers can respond to frequencies other than that to which they are actually tuned. Here is what happens. When a strong signal is picked up by the receiver, the harmonics generated by rectification may get into the radio frequency or mixer stages and so be converted to the intermediate frequency (IF) of the receiver and passed on through succeeding stages like a bona fide signal. The "birdie" appears as a chirping sound or heterodyne on the desired signal. One cure may be a reduction in the length of the receiving antenna.

Now to noise. There are basically two types of natural noise present at the antenna.

They are: Atmospherics; Galactic or Extra-terrestrial.

We will first consider atmospheric noise: *Atmospherics* sometimes called static noise is the most erratic type. It varies with the time of day, season of the year and it increases the nearer the receiver is to the equator. The crashing noise resulting from a flash of lightning is a good example of this type of interference. So far as the SWL is concerned, the type of noise most experienced is that resulting from a lightning flash. Don't forget a flash of lightning is an electro-magnetic wave just like a radio wave and it too will travel over great distances. Thus, a powerful lightning flash in say, Nigeria may well interfere with reception in the United Kingdom or Sweden owing to the crashing noise it causes in the shortwave receiver, via the receiver antenna system. – *Extra-terrestrial* noise, sometimes called cosmic noise includes solar and galactic noice. Galactic noise sounds similar to thermal noise in amplifiers and it can be an interference factor towards the upper end of the shortwave spectrum – say around 25 MHz. It is unlikely to be heard in your receiver below about 20 MHz. It sounds like a steady hiss and it will increase rapidly during some types of solar disturbance. During others, the SIO or "Dellinger" for example, it may disappear suddenly and completely. So to summarize what we know about interference. It is to two main types: *Man-made* (QRM) – perhaps produced by sparking high-tension lines during damp weather, worn carbon brushes on an electric motor commutator, a loose electrical connection, fluorescent lighting, car ignition and so on. – *Natural noise* (QRN) – static, galactic, sometimes called cosmic noise which originates in from the sun or even from outside our solar system. Especially high during periods of sunspot or flare activity on our sun. May disappear completely along with shortwave reception generally during certain types of geophysical disturbance.

Finally, when providing reception information to radio stations operating in the international shortwave broadcasting bands it is very helpful to the station engineers if you provide information about any interference to their transmission. You should include the following data in your reception report: Identify the type of interference (CW), jamming, ignition etc. Try to determine where it is originated.

If the QRM is broadcast type try to get the call sign, interval signal or identity of the interfering station.

Try to determine as accurately as possible the operating frequency of the interfering station. Try to estimate the degree of interference in terms of the degradation it causes to the desired signal.

Chapter 5

A PRACTICAL INTRODUCTION TO SHORTWAVE ANTENNAS

by Jim Vastenhoud

If you had a perfectly shielded radio receiver, you could not receive any station with it, until you connected it to a device which delivers the signal to it. Such a device is called an antenna, and it can be regarded as the sensor of your radio. The importance of the antenna has recently been boosted by space communications, where antennas with a sharp directivity and the ability to concentrate the received energy from space to the area where the antenna is situated, render it possible to make the faint signals from outer space intelligible.

Such methods cannot be attained for short waves, because the physical dimensions of such an antenna would become simply too large. Nevertheless, it shows us that the antenna is of great importance to enable the receiver to work properly. A *good* antenna, moreover, is the cheapest and simplest means to boost signals enough to be well received. It is, in fact, the combination of a good antenna and a good receiver that makes a fine rig, something that will give you a lot of pleasure in DX-ing or shortwave listening.

Antennas are usually very cheap devices, because they can be home-made. A number of shortwave antennas, especially the multi-band types, are also made commercially. The antenna usually consists of several parts, which have different functions. The antenna proper or *"radiator"* is the element which is capable of radiating, or receiving, signals. It is usually a piece of wire, sometimes of a special configuration, mounted as high as possible in the air. From this radiator, the signals must be transferred to the receiver. For this, we need a so called feedline, or *feeder*. Several kinds are available. They all have in common that they are non-radiating elements. This means that, in theory, no signal is lost in bringing it upward from a transmitter to the radiator, or alternatively no signal is lost in bringing it down from the antenna to the receiver. Neither will the feeder pick up additional signal.

Next, we may need a device to transform the energy captured from the air into a form which is more suitable for the radio receiver. Some receivers like to be fed low-ohmic signals on their antenna terminals, while others were designed to operate best on high-ohmic signals. A receiver with a low input "impedance" e.g. a type with 50 or 75 ohms, while the high-ohmic types will be about 600 ohms or more. It is advantageous to match the signal to the *antenna input "impedance"* of the receiver in cases where a substantial loss of signal, due to mismatch, would otherwise result. In these cases, we need a so called matching device, or "antenna tuner", to perform a loss-free transfer of energy from the antenna to the receiver.

It will be clear that for long-distance reception, as is generally the case with shortwave listening, all three elements of which our antenna consists: the radiator, the feeder and the matching unit, have to be carefully considered in order to make the desired antenna.

Let's take a look at either of the parts.

The Radiator

The radiating element, or radiator, has to be situated as free standing as possible, so that the signals can reach it freely without being obscured by tall buildings, trees or other nearby obstacles. Usually, this means that it has to be erected as high as possible. Also the radiator must pick up as few interfering signals, like street noise or power line interference, as possible. This condition will usually make it advisable to erect the antenna as far from the street as possible, and preferably not running parallel to overhead power lines. In this respect, it may be useful to know that street noise is effectively shielded by the house itself, and is virtually non-existent if you situate the antenna more than 1.5 metres (5 feet) above the house.

Sometimes, and this is especially important to listeners living in rural areas, there is no need to bother about all the noise problems which hamper good shortwave reception of the city-dwellers. In this case, remember that it is still good to have your antenna at a height of at least 7 metres (20 feet) above the ground to improve its effectiveness.

To prevent the loss of signal, insulate this radiator very carefully. Use glazed porcelain, pyrex glass, or polypropylene insulators at the ends to prevent signal from leaking away. For these high frequency signals, loss easily occurs in rainy weather, especially because dust and other debris settle on the insulators and, after a while, make its surface slightly conducting. Increasing the leakage path by using more than one insulator, and the application of insulators with a ribbed construction will help you maintain a good antenna even in bad weather.

Some people make a point of erecting their antennas perfectly horizontal, or perfectly vertical. In reality, however, this is of little importance for long-distance shortwave reception. The only disadvantage of a vertical antenna is that it is more susceptible to static discharges.

The passing wavefields introduce very weak signals in the antenna, usually in the order of microvolts or millivolts. A good conductor is needed to conduct them, with as few losses as possible, to the antenna terminal of the receiver. That is why antennas are usually made of copper wire of a sufficiently large diameter. One millimeter (AWG 18) will usually suffice, and will have enough strength to withstand high wind speeds and icing, if its length does not exceed 30 metres (100 feet). With the good old silicon-bronze wire out of production in many countries, people have turned to enamelled copper wire, the type used for winding transformers. It is also called "magnet wire". The enamel is an insulator, which prevents corrosion of the copper for a while. For high-frequency antennas, the use of plastic-insulated wire, or stranded copper wire, is also perfectly acceptable.

The erection of this part of the antenna may pose some problems. Many will consider the chimney of the house fit to act as support for one end of the antenna, but another chimney, or other rigid point at approximately the same height may not be at hand so easily. Consider your possibilities within a range of, say, 10 to 30 metres (30 to 100 feet). If a suitable support is available, but at a greater distance away, the use of some insulators will have the desired effect of limiting the length of the antenna to 30 metres, but you may need a stronger wire to span this distance. If several supports are available within your 10 metre range, it may be useful to run the antenna from one chimney to another, until a length of at least 10 metres is obtained.

The presence of television antennas may also present a problem. Pass them by at a distance of at least 3 metres (10 feet) to avoid pickup of radiation from a television receiver connected to one of these antennas!

Sometimes, a tree will seem an ideal support, and it can indeed be utilized as such, if you keep in mind that it moves in the wind. It may be necessary to introduce a flexible construction to keep your antenna wire tight while the tree sways. This can be done by ending the antenna at a point well out of the foliage, using the terminal insulator to hook up a perlon line, which runs across a pulley attached to the stem of the tree, as sketched in *figure 1*. A stone or brick of sufficient weight is employed to keep the radiator at the right tension. The counterweight is attached to a safety line to prevent it from falling in case the antenna breaks.

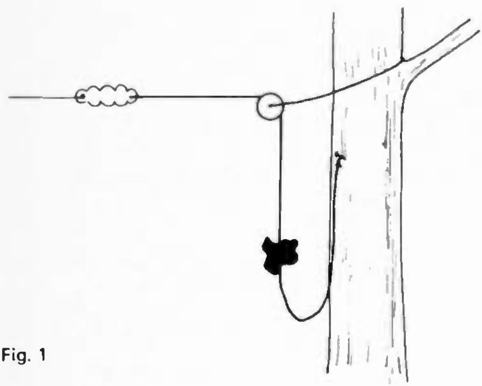


Fig. 1

Fig. 2

Now that we have the radiator properly placed, the next problem is to get the energy to the receiver.

The Feeder

In its simplest form the feedline is just a piece of single wire, connected between one end of the antenna and the receiver. The combination of this feeder and the radiator is called an L-antenna, or single wire antenna. (*See fig. 2*). It is one of the most applied general-purpose shortwave antennas and it will give acceptable performance on all shortwave bands.

To avoid making joints between the radiator and the feeder, they might as well be made out of one piece of wire. In that case, start constructing the antenna by preparing the terminal which is furthest from the receiver, and work towards it. From the insulator closest to the house, run the feeder to the receiver, using stand-off insulators if necessary. Keep clear of metal gutters or other large metal surfaces, like corrugated iron roofs. Keep in mind that this part of the antenna is most susceptible to picking up ignition noise from passing vehicles. Bring the antenna inside the house via a piece of insulated tubing, e.g. an old ballpen-sleeve inserted in a hole through the window pane. Inside the house, your antenna can again pick up electric noise, especially from fluorescent tubes, vacuum-cleaners etc. Therefore, keep its length as short as possible. Connect the antenna to the receiver by a suitable banana-plug, so that good electrical contact is established. In this way, you have built a simple but effective antenna.

Many readers may now feel disappointed, because they are not able to erect an outdoor antenna. For them, the following part of this chapter may be useful.

Limited Scale Antennas

Suppose that you have regarded the possibility of putting up an outdoor antenna made of thin wire, invisible from the street and to your landlord who did not agree to your request to put it up. Even in such a case, some people are resourceful enough to put up temporarily so-called dark-hour antennas, easily mounted and dismounted by means of rubber strings. For you, however, all these dodges to avoid being forced to rely on an indoor antenna, have failed. In that case, here is your last resort to make something worthwhile in shortwave reception antennas. It involves the construction of indoor and window sill antennas. If done with skill and imagination, such an antenna can give quite satisfactory results, but you may have a hard job finding the best position for your antenna, because there are a lot of things to be reckoned with when putting it up.

In the first place, there is the point of free admission of signal to it. To meet this important requirement as well as circumstances permit, you should be aware of the shielding of signals which is caused by the nearness of large *metal* objects. A corrugated iron or zinc roof will make the attic of your home quite unsuitable for erecting an antenna there. If you are an apartment dweller, living in a building made of reinforced concrete, the inter-connected reinforcement rods will form an effective Faraday cage, shielding all radio signals from outside.

The nearness of water pipes, gutters, electric wiring, telephone lines, television antenna feeders or fluorescent tubes has to be avoided as much as possible. In some severe cases, it leaves just the window itself to fix an antenna to, and in that case a strip of aluminium foil applied to it can still do a good job.

The absence of moisture inside the house will do away with most of the insulation problem. Here, relatively simple insulators can be used to prevent signals from leaking away to ground. The dimensions of the antenna, however, are usually rather restricted, even if the whole of the attic is at your disposal. It means that, in almost all cases, a truly effective antenna can only be obtained if careful matching takes place, and if we make the most of the antenna construction proper. A few generally known types are at our disposal. One of the best is the windowsill antenna, consisting of a metal rod extending from an insulator fixed to the windowsill. It is available in a number of versions, which will be dealt with in this chapter.

Another type is the indoor L-antenna; a single wire running up to the attic, or the ceiling; and the provisions of top capacity by stringing some 20 metres (60 ft) of wire to it. Different configurations are possible for the provision of such a top capacity but their shape is not very important for the antenna's performance. Neither are the 20 metres a must; just use your imagination to add some capacity to the antenna at the top, to improve its effectiveness.

Another possibility inside the room, or inside the house, is the use of spiralized wire, strung in front of the window or, in the case of a wooden or brick house, simply as high as possible. Sometimes, steel wire is used for this. It should be kept in mind that the conductivity of iron or steel is inferior to that of copper, so that a thicker wire is recommended. Sometimes, the steel is copper or silver plated for the sake of improving conductivity, and such antennas are usually of good quality.

It can be advantageous to calculate the total length of wire of a spiralized antenna, because it can act as a quarter-wave resonant antenna if the total wire length comes near to half the wavelength of a desired band.

The use of a matching unit, as mentioned before, is strongly recommended in order to get the best possible signal transfer from antenna to receiver. A simple unit for matching short wire antennas or rod antennas will be described below.

Sometimes, shortwave listeners can benefit from curtain rods, steel doors, window-screens, etc. which can act as antennas if they happen to be insulated from earth. Furthermore, some manufacturers market antennas for those who have limited space. Examples are the Mosley (Bridgeton, Mo, USA) vertical trap antenna (SWV-7) and the "Joystick" (Partridge Electronics, Broadstairs, England), which is an indoor, centre loaded, rod antenna. On the whole, the performance of indoor antennas will strongly depend on the amount of signal admitted to them, the length of wire that can be admitted inside the house, and the performance of the matching unit coupled between the antenna and the receiver. The windowsill rod antenna is usually just a little bit better, especially if a length of about 4 or 5 metres (12-15 ft) can be tolerated.

The windowsill antenna can be put close to the receiver, preferably at that side of the house which is relatively open to the reception of shortwave signals. The rod, or whip, should not run upwards parallel to the wall, but should emerge from the house like a kind of fishing rod, making an angle of between 45 and 60 degrees with the horizontal. Thus positioned, it will be able to capture as much signal as possible.

If you want your whip antenna resonant for any of the shortwave broadcasting ranges, proceed as follows: use a piece of plastic conduit of about 15 cm (6 inches) long, space your turns at a mutual distance which is at least equal to the wire diameter, and use a stiff $1\frac{1}{2}$ or 2 mm

(AWG 14) enamelled or bare copper wire to construct the coil. The diameter of the conduit must be about 1½ to 2 inches (3.75-5 cm). The coil can be tapped at various turns, and the taps can be connected to the different tags of a 7-position waverage-switch, so that a selectable number of turns can be short-circuited. An additional 150 pF maximum capacity variable capacitor will complete the matching network, as indicated in *figure 3.* A short coaxial cable connects the matching unit, which can be housed in a small box close to the base of the antenna, to the receiver. The shielding of this cable is connected to the ground terminal of the receiver, and to the set of rotator plates of the variable capacitor. It is advantageous to use a good earth connection as well. For this, a short connection to the water supply pipe, or a rod driven deep into the ground, can be another asset in improving the efficiency of your antenna.

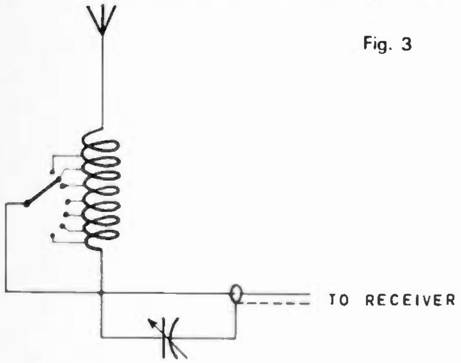


Fig. 3

In reality, however, a good earth system is rather difficult to obtain, because the metal surface of the earth lead which is in contact with the subsoil water will determine the earth resistance. With a good earth, however, it is possible to make a good antenna system also!

In summing up, the city-dweller has the choice of a number of short antennas, if he cannot erect an "invisible" antenna. Most of these short antennas will give their best performance if they can be made "resonant" for the waveband selected by the listener. For this, an adequate antenna tuning network is a necessity.

In windowsill antennas, the matching unit should be situated near the base of the antenna, and the same goes for the grounded antenna types.

For a good indoor antenna, some insight in selecting the best position for the wire is highly desirable. A top capacity, formed by a length of wire or some bulk of metal, will improve the efficiency of the antenna. An antenna tuner will furthermore enable us to make it resonant on the different shortwave bands.

And now, back to the outdoor antennas.

The Dipole Antenna

More elaborate antenna systems than the L-type antenna can give you better results, but have their own limitations. Some have definite directional characteristics, others give substantially better results for one waveband, but lack sensitivity at others. One of them will be discussed here: the dipole.

The dipole antenna is regarded as the basic resonant antenna.

It consists of two equal parts, placed symetrically with respect to the centre insulator. Two versions of the dipole will be dealt with, the so-called single dipole, illustrated in *figure 4a,* and the folded dipole, represented by *figure 4b.* The last type is perfectly equal to the single dipole in dimensions, but a second wire of the same size and diameter as the radiator runs parallel to it at a distance of about 4-5 cm (2 inches). This distances is not critical, as long as it is more than ten times the wire diameter. The folded dipole is a kind of closed loop, while the single dipole consists merely of two balanced parts of equal length.

The total length of the dipole antenna, between its terminal insulators, is subject to specific rules. The dipole is a so-called half-wave antenna, its physical length being slightly less than half the wavelength of the band to which it is designed. Each limb is thus equal to about one quarter wavelength. The centre insulator must be positioned exactly in the middle between the terminal

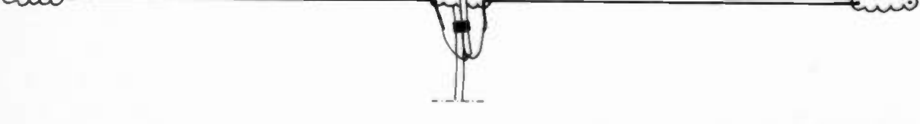


Fig. 4a

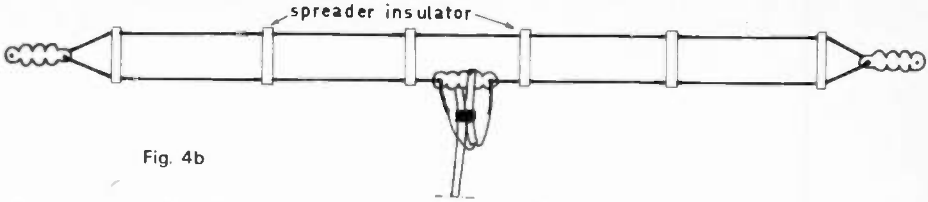


Fig. 4b

insulators, and is the point where the feeder is connected to the antenna. A dipole is cut for one waveband only, and it will give optimum results for this band. On other ranges, it will not outperform a good L-antenna, except on wavelengths which are one half, or one quarter of the wavelength for which the antenna was cut. The actual length of a dipole can be determined by a simple formula:

$$\text{length in metres} = \frac{142.5}{\text{frequency (MHz)}} \text{ or}$$

$$\text{length in feet} = \frac{468}{\text{frequency (MHz)}}$$

and it includes both limbs plus the centre insulator. The two terminal insulators are not included in this formula. The length of the folded dipole, cut for the same waveband is exactly the same. Usually, the dipole is cut for the midband-frequency, and it will then give the desired gain over the L-antenna for the whole band.

A dipole antenna also shows some directional characteristics. It will be most sensitive to signals beaming in at right angles, but its sensitivity will not substantially decrease for signals arriving at other angles. The only important property of the dipole to keep in mind, is that it will not receive any signals which arrive from the directions in which the antenna is pointing. So, if you suspend it in a North-South direction, it will not receive signals coming precisely from the north or from the south. No other limitations need to be taken into account. Bear in mind, however, that a globe is needed to determine the regions of the world for which the antenna is insensitive. Maps unduly distort the picture over these great distances, due to their projection method.

The dipole is a balanced antenna, and must preferably be fed from a two-wire feedline. For the folded dipole, this is 240 ohm or 300 ohm twin line, the same type as used for television antennas. The combination of this ribbon and the antenna is very suitable for most receivers except for types having 50 or 75 ohms input impedance. For these, the single dipole is better suited. As 75 ohms twin line is not so easy to obtain, it is quite possible to use 75 or 73 ohm coaxial cable for a feedline with a single dipole.

In all cases, the feedline is slung across the centre insulator and fastened with a plastic clamp underneath. Thus, it will be able to support its own weight. The two wires of the feeder will now be bared at their ends, and each of them has to be connected to one limb, extending from this centre insulator. To secure good electrical contact, make them soldered joints. At the receiver side, the two wires are connected to the antenna terminals, or to the antenna and ground terminals. If your receiver has no ground terminal, it is no use making a dipole antenna.

Running the twin lead from the antenna to the receiver may present some difficulties, especially as the centre insulator is usually located well off the house. If you want to keep a perfect balance, run the feeder away at right angles with the antenna, and keep it that way until you are at least a quarter wavelength away from the antenna. Usually, you will need a support here, fitted with an insulator to keep the feeder tight. Apply stand-off insulators every 2 metres (6 feet) and avoid both large metal surfaces and electric interference zones. If, in the case of a single dipole, 75 ohm coaxial cable is used, things are somewhat different. At the antenna feed point, i.e. the centre insulator, connect the shielding to one antenna limb, and the core to the other limb. At the receiver, the shielding is usually connected to the ground terminal, leaving the core to be connected to the antenna terminal. Here also the rule applies that the feeder must be run off perpendicular to the antenna, maintaining this for a quarter wavelength. But otherwise, none of the normal precautions, necessary with twin line, need be taken into account. Coaxial line can be guided along gutters, can be stapled to the wall if necessary. The coupling of a balanced antenna and an unbalanced feedline will cause some signal loss, but this is very small for frequencies below 20 MHz.

In using coaxial cable in combination with a single dipole, two additional remarks are necessary. In the first place, prevent rain from entering the cable, by taking adequate measures at the feedpoint connection, and secondly, use high quality low-loss coaxial cable for your purpose. The use of coaxial cable with the folded dipole is also possible, but would require a matching device.

This brings us back to the beginning of the chapter, where we mentioned the matching unit as a handy gadget to use in combination with a non-resonant antenna.

A Simple Antenna Matching Unit

This device, which can be easily home made, is primarily used in combination with a single sire antenna of arbitrary length. ***Figure 5*** shows both the circuit diagram and the lay-out of the parts. Have a good look at it!

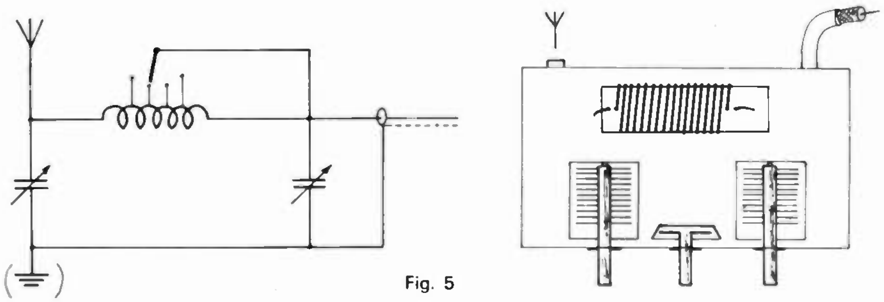


Fig. 5

The device will not be necessary for receivers equipped with a knob called "antenna trimmer" or "antenna tuner". In all other cases, the use of a matching device is recommended to get optimum results from your antenna at all wavebands. Although matching units are commercially available ("Joymatch", Partridge Electronics, England), it is very easy to make one yourself. It consists of one home-made coil, two variable capacitors with approximately 470 pF ($\mu\mu$F) maximum capacity, and a switch with one deck and 6 positions. The unit can be housed in a small plastic box, to be placed alongside the receiver.

The coil is made from enamelled copper wire ("magnet wire") with a diameter of between 0.8 and 1 mm (AWG 18 or 19). You need less than 1.5 metres of it. It is wound on a form, for which a piece of 1" plastic tubing (conduit) can be used. A length of 5 cm (2") will suffice. After small holes are drilled at one cm from each end of the coil to hold the wire, make 15 turns in all. Space them slightly, until you cover a length of some 3 to 3¼ cm (1¼"). Make tappings at the 3rd, 4th, 5th, 7th, 9th and 12th winding, by removing the enamel at these places with a pen-knife and applying some solder. Then thin, flexible wires will be applied at these places for the connections with the 6-position switch, as outlined in the diagram, *figure 5*. Your coil is now ready.

The two capacitors are positioned at the right and left sides of the plastic box, their shafts protruding on the front side. Keep sufficient space to fix the switch in centrally between them, and connect all components as indicated in *figure 5*. The movable plates are connected to the ground connection of the receiver, the fixed plates of them to either side of the coil.

The connections from the antenna tuner to the receiver can be made through a short piece of screened cable (so-called coaxial cable), the shielding of which is used for the interconnection of the grounds of both sets, while the core feeds the antenna signal to the receiver. The best position of the switch and the two capacitors for each waveband is found by trial and error. The antenna tuner, the construction of which is also outlined in detail in a Radio Nederland data sheet on the subject (free of charge on request in Hilversum) will enable you to match the antenna to your receiver for any of the wavebands selected. Maximum signal strength can be checked with the help of the signal-indicator on your receiver, or audibly.

Chapter 6

MW DX-ing IN THE WESTERN HEMISPHERE

by Thomas Sundstrom

PREFACE

Medium wave (MW) DX-ing in the 535-1605 kHz band is an interesting and fascinating hobby. In many ways it can be more exciting than DX-ing the international shortwave broadcast bands, whereas the latter frequencies are frequently subject to "power plays" SW broadcasters nowadays seem to play the power game called "up the kilowatts" or "who's got the megawatt?" The MW band in the Western Hemisphere is less subject to this sort of aggravation and, in fact, a knowledge of the MW band can provide benefits other than just hearing DX.

For example, this writer is a hockey fan attending games of one of the teams in the National Hockey League, Western Division. The NHL covers the entire USA and Canada, and it is easily possible to listen to virtually any game played on any given night. Of the 18 teams in the NHL in 1974-75, this writer can hear the home-town broadcaster for 13 of them . . . and odds are that those five teams I cannot hear will play a team who I can listen to. In recent years, the division races in the NHL have been closely contested, and my wife and I can pick and choose the crucial games, as we please, to listen to. Similarly, DX-ers who follow other professional sports listen to games of their choice.

The MW band is taken for granted by many people. If the listener will look closely, however, there is a whole new and fascinating world of DX-ing. In one year's time, it is relatively easy to hear 400 or 500 stations in 40 or so states and provinces. and up to 30 different countries. Some older MW DX-ers have worked their way up to 2000 or 3000 verifications from more than 100 countries, but even some newcomers in the past three years have logged and verified over 1000 stations.

Time, patience, and knowledge are essential ingredients to being a successful MW DX-er. The balance of this article will address itself to the last element specified.

RECEIVERS

What kind of receiver is necessary for MW DX-ing? Well, the small 8-transistor portables will inhale a lot of signals, and many younger MW DX-ers begin by using such receivers but, generally speaking, they cannot "cut the mustard".

It should be pointed out, emphatically, that some new DX-ers are easily discouraged at this point in time because they read, in club bulletins and magazines, of unusual and rare catches that they have no hope of hearing on their $20 "zip" special. Dear readers, everyone has to begin at some point and the hobbyist getting into MW DX-ing for the first time should not be downcast at the seemingly inability to log "Nibi-Nibi" that experienced DX-ers are logging with apparent ease. Much of your good catches will be "luck" – until you gain the expertise to recognise DX conditions and the best times for DX-ing.

For best results, a communications receiver is a necessity. Unfortunately there are not too many manufacturers marketing new equipment, and the number seems to be decreasing. Perhaps the best place to start inquiring about receivers is at a local amateur radio supply house or with advertisers in some of the general electronics magazines. The price range of new equipment nowadays is about $150 to $1000, with one at the astronomical level of $2500. There are several good receivers to choose from under $500, and two popular models under $160.

The alternative choice to new equipment is that which is used, and it is possible to locate good, clean, receivers from either commercial outlets that accept trades or from private citizens. This type of shopping, however, has to be highlighted as "buyer beware". A rapport with a local service technician is worthwhile; he can look over the receiver and determine what steps must be taken, if any, to put the equipment in tip-top shape. Obvious visual checks can be quickly made.

Has the cabinet been knocked around? A fresh paint job will hide hard useage. How about the knobs? Are they worn, or newly replaced? Pull the chassis and look underneath. Any charred wiring indicating shorts or other component replacement? I should emphasize simple things such as a realignment job or a new set of tubes should not deter you from an otherwise "clean" receiver. Modifications and changes in original wiring should normally be avoided, if such are extensive, unless appropriate notes are made on the accompanying service manual and schematic (which should be obtained on any purchase of used gear). It is impossible to give a "rule of thumb" on prices to be paid, but your desires to own the receiver should be guided by how much needs to be done to the unit to make it functional.

In choosing a receiver, whether new or used, the DX-er should look for the three "S-s": sensitivity, selectivity, and stability.

Sensitivity is the measure of the receiver's ability to hear weak signals. It is usually quantified in terms of a number expressing dB in signal-to-noise ratio – the lower the number of microvolts, the better. A receiver sporting a sensitivity of 2 uV for a 10 dB s/n ratio is better than one offering 50 uV for the same 10 dB s/n ratio.

Good sensitivity in a receiver mandates the use of an r.f. (radio frequency) amplifying stage. This is the first section of the receiver the incoming signal encounters. The weak signal is amplified, i.e. made stronger, for further processing in the mixer and i.f. (intermediate frequency) stages.

A mixer circuit converts the incoming frequency, whether it be 610 kHz or 1540 kHz or whatever, after amplification, to one common frequency, called the intermediate frequency (i.f.).

The i.f. stages are all finely tuned to one common frequency, 455 kHz. It is impossible to have a receiver's circuits designed to process *all* frequencies incoming, hence the conversion to one. The more i.f. stages a receiver has, the more selective the receiver is. Two or three i.f. stages is a good measure of a selective receiver. Some of the more expensive receivers have two or three i.f. strips of different frequencies and are called dual and triple conversion, respectively. Typical i.f.'s used are 6000 kHz, 1650 kHz, 455 kHz and 262 kHz; a dual or triple conversion receiver may have any combinations of these, each strip having two or three stages.

As dual or triple conversions help to improve selectivity, so do crystal or mechanical filters and Q-multipliers. The idea is that the broadness of the receiver bandpass skirts is lessened. (*See Fig. 1.)*

The mechanical filter is better than the crystal filter in that, at the peak of the i.f. curve, the top of the bandpass is squared off to pass more audio in the sidebands (wherein lies all the "intelligence") than with the "sharpness" of the crystal filter or Q-multiplier.

The crystal filter and the mechanical filter are fix-tuned to a particular i.f., whereas the Q-multiplier can be varied by a few kHz up and down to "fine-tune" closely spaced stations. An advantage of the Q-multiplier is that it can not only be used to "peak" a desired station but it can also "null" an annoying heterodyne (whistle) caused by the interaction of the carriers of two closely-spaced stations.

The Q-multiplier's "peak" control is variable and sharpens the i.f. bandpass, whereas the "null" function inserts a "notch" into the receiver bandpass and which is tunable across its full range. As such, the annoying heterodyne can be wiped out by tuning the "notch" (depth of the notch is variable) to stop the interfering frequency in the i.f. bandpass.

Unfortunately, if a Q-multiplier is not included within the receiver, a circuit has to be built from scratch as there are not units commercially available in assembled or kit form. Amateur radio journals are probably the best source of such schematics: in the United States, look to the section entitled "Improving Receiver Selectivity" in the *ARRL The Radio Amateur's Handbook.*

How does one judge the adequacy of receiver selectivity? One needs two measurements of the i.f. bandpass to get a decent idea. Typically, 6 dB at 6 kHz and 60 dB at 10 kHz would be excellent. The first measurement is at the peak of the curve, and the second is at the bottom of the curve; the plotting of a curve is indicative of the i.f. response and the frequencies adjacent to it. The "peakedness" of the curve is a graphical illustration of the receiver's selectivity. (*See Fig. 1.)*

For example, receiver A has a curve of 6 dB at 6 kHz and 30 dB at 18 kHz. Receiver B has a curve of 6 dB at 6 kHz and 40 dB at 10 kHz. Which one has the better selectivity? Receiver B . . . despite both having identical responses of 6 dB at 6 kHz at the peak of the i.f. curve, as B has a smaller bandpass further "down" from the peak of the i.f. curve.

Dual or triple conversion i.f. receivers can also eliminate spurs and images. True images, if present, can be heard at a frequency twice the i.f. below the transmitting frequency of a station. For example, I have a local station on 1460 kHz and a single conversion receiver with a 455 kHz i.f. strip. If I could hear the station on 550 (1460–2x455=550) kHz, my receiver would have image rejection problems. A measurement of image rejection is expressed in dB – the higher the dB figure, the better.

Typically, image rejection on a multi-band receiver is better on the lower frequency bands than on the higher ones. This is inherent in the design of superheterodyne receivers, and is to be expected.

With multiple i.f. conversions, you can see what would happen with image responses. It is virtually removed, as the second i.f. times 2 falls well outside the range of image frequency created by the first i.f. strip.

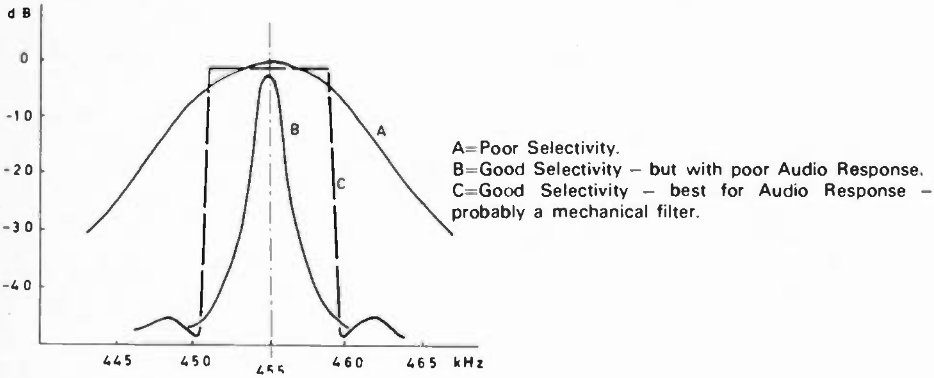


Fig. 1

Spurs, most often caused by two or more strong signals mixing their frequencies in various combination either externally or internally of the receiver, will cause signals of the two stations to appear in strange places on the dial. Often it sounds like you're listening to two stations at once. Fortunately, an r.f. stage and multiple i.f. stages eliminate the problem for all but those who are unfortunate enough to live near concentration of high-powered transmitters, such as in the meadowlands of New Jersey just west of New York City.

An example of external mixing spurs, as experienced by the writer in southern New Jersey, is the sum and the difference generated by two Philadephia stations, WCAU on 1210 kHz, and WFIL on 560 kHz. These generate an external mixing spur on 1770 kHz and on 650 kHz . . . which covers up KORL on 650 kHz in Honolulu, Hawaii. External mixing spurs will act as if they are an actual transmitter, and can be tuned as any other signal in that area of the band. While nothing can be done about external mixing spurs, usually an alignment job or better shielding will remove internal mixing spurs. Integral spurs will also appear in the receiver when the receiver is tuned to one frequency and an antenna preamplifier or antenna tuner is set to another frequency.

There isn't much point in having selectivity unless the receiver has accurate dial calibration. The small radios tend to compact the dial and one virtually has to "fish" for the desired station. Receivers with dial cords also cause problems with "dial backlash". Direct drive dials are best, and are to be found in communications receivers that cover SW bands too. Popular receivers are being, or have been, marketed by Hammarlund, Hallicrafters, Drake, National, and Galaxy. Others, because of price, are not true communications receivers but enjoy a wide following by the beginner DX-er as they are less than $160: the Realistic DX-160 series and the Lafayette HA-600 series.

Good dial calibration is important to the DX-er who winds up being interested in foreign BCB DX-ing. As you'll see later, not all stations operation on the even 10 kHz assignments used by North American stations. A minimum readout accuracy should be 10 kHz, but it might be preferable to be able to spot a frequency to the nearest 5 kHz. The newer transistorized receivers, such as the Drake SW-4 and SPR-4 and Galaxy R-530, that use a crystal controlled oscillator to tune 500 kHz segments have a readout to 1 kHz with interpolation to 200 Hz (1/5 of 1 kHz)!

To enjoy good dial calibration, you must have the third "S": stability. If a tube-type receiver, it helps to have a VR (voltage regulator) tube in the power supply. Once the set warms up (heat causes a receiver to drift as components change, minimally, values), the VR will help to minimize further drifting, i.e. changing frequency without tuning, of the receiver. Transistorized receivers don't have a heat problem, but drift does occasionally occur with changes in a.c. line voltage. A variac transformer and a.c. line meter can be inserted into the line to stabilize line voltage changes effects upon the receiver. With power shortages and "brownouts" such equipment is likely to be very popular in the future.

All of the above sounds very complicated, and I don't want to scare the reader. What you have here is some verbage to assist you in understanding the terminology of the literature put forth – don't forget the true test of the receiver is trying it yourself, and see how it "fits", Do some comparison shopping and you'll quickly see what we've been talking about here. A good receiver, whether new or used, will be readily apparent to you after a foray or two into the marketplace before the initial purchase is made.

ANTENNAS

The communications receiver that you use is only as good as the antenna inhaling the signals. There are, basically, two types of antennas used by DX-ers: the long-wire (LW) and the loop.

The LW is simply a length of wire put up as high and long as possible, between two insulators with a down-lead to the receiver. Typically, it would be best installed broadside to the area of the world from which reception is desired. I found a N-S orientation on the East coast to be a good compromise for Europe/Africa and Asia which also minimizes the pickup of the normally dominant Latin Americans. A minimum run of 50 feet is desirable. Several mail order electronics houses sell ready-made LW antenna kits with all parts included, if the junkbox in your cellar is lacking.

An interesting variation of the LW is the "beverage" antenna, currently used by some BCB DX-ers who are fortunate to have the room required for a *long* length of copper wire run out in a straight line and hung on supports a few feet above the ground. The "beverage" is best at a wavelength or two. A wavelength in feet can be determined by the formula: length (ft)=984/MHz. Thus a wavelength at 540 kHz would be 984/.54 or 1825 feet, and at 1600 kHz about 615 feet. A 1000 foot beverage antenna would drop you right in the middle of the band (near 1000 kHz), giving you a half-wave at the bottom end and about 1½ wavelengths on the top. The longer the antenna is in wavelengths, the more directional it becomes. *(See Figs. 2a and 2b.)* Thus a 1000 foot "beverage" will exhibit more of a directional effect as you tune toward 1600 kHz, and less of a directional effect as you approach 540 kHz. In any case, the "beverage" antenna must be installed in a straight line for the entire distance; the co-ax feedline to the receiver may be bent to enter the house. The antenna is receptive to stations off either end of the wire, not to stations broadside to it, at these lengths. Thus, the wire should be erected in such a manner that it "points" (on the "great circle" path) to the area of the world you want to receive. In Florida a few DX seasons ago, a DX-er ran a "beverage" due west from his receiver for about 1200 feet or so – he enjoyed nightly reception of low-powered daytime stations in California prior to sunset in California. Medium-powered stations in Hawaii were common place, and an

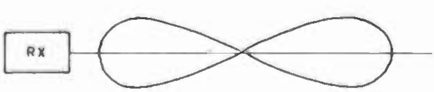


Fig. 2a

A beverage ungrounded at the far end is bi-modal.

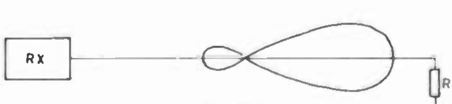


Fig. 2b

Grounding the far end makes the beverage sensitive to signals from only one direction.
As the wavelength increases, the lobes decrease in width. A true beverage must be at least one wavelength long.

amazing tape was made of 50 kW 4QD on 1550 kHz in Emerald, Australia, while 50 kW CBE Windsor, Ontario was on the air.

The "beverage" is bi-modal, i.e. will receive signals off both ends of the antenna but, very simply, can be made uni-directional by grounding the far end of the antenna. The antenna is grounded to a copper grounding rod through a 300 to 1000 ohm (experiment to determine best value) resistor. It involves considerable antenna theory, but briefly the grounding of the far end eliminates signal pickup of stations from the back side. For example, that DX-er in Florida had his receiver on the East end of that wire, ran the wire West, and grounded the West end. In doing so, he eliminated Cuban stations that otherwise tend to dominate the dial in southern Florida, along with any other signals coming from the East.

Incidentally, if you are fortunate enough to be able to erect a "beverage" and perhaps install multiple "beverage" antennas or a single "beverage" and some other kind of antenna, you should take care to ground *any* antenna not in use. An adjacent antenna left underground will influence the directional aspects of the "beverage", and vice versa. Use one antenna at a time, and ground the ones not in use through the use of "shorting" switches. Needless to say, the appropriate precautions against lightning damage should also be taken.

Unfortunately, those living in urban or suburban communities don't have the acreage required to install a "beverage". An excellent antenna that takes up little space and which requires no outdoor installation is the loop antenna.

There are several variations in design, but the standard design is the box loop: 11 turns spaced $\frac{1}{2}$ inch apart on four spacers on the ends of the cross-arms, giving 4 feet on a side, are tuned by variable capacitors. A 365 $\mu\mu$f variable will cover almost the whole band, but it may be necessary to switch in additional fixed or variable capacitors in parallel to extend coverage to the bottom of the band. A single turn placed between the fifth and sixth turns feeds the receiver. (*See Fig. 3.)*

This is the easiest loop to build and use; it is unamplified, but still can inhale the weak signals. The sophisticated version of this box loop is an amplified version having a small tuneable preamp and the ability to tilt the loop in two planes.

Fig. 3

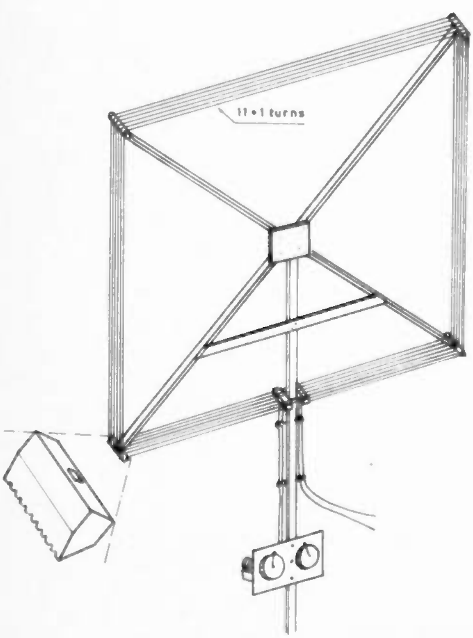
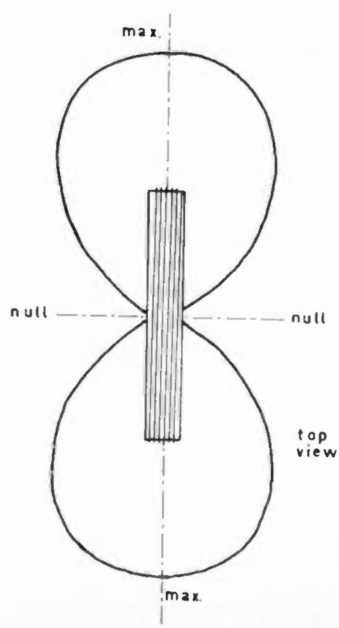


Fig. 4



In either version, loops are directional and exhibit sharp nulls perpendicular to the plane of the loop. As such it is possible to peak either the desired signal or null an offending one. One the crowded frequencies it is often possible to dig out two or three stations that are normally under the dominant local. Loops are also good for direction finding, and it is possible to determine the approximate area of the world the signal is coming from.

Figure 5 shows the schematic diagram of the loop antenna. The 11-turn winding is tuned to resonance with the parallel capacitor(s). The single turn is connected to the antenna and ground terminals of the receiver. If the receiver has two antenna inputs, use these instead.

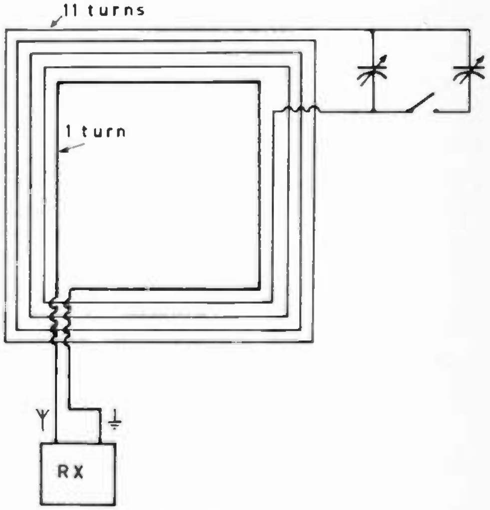


Fig. 5

Plans for various loops are available through the National Radio Club, Box 127, Boonton, NJ 07005, USA, or the International Radio Club of America, 12536 Arabian Way, Poway, CA 92064, USA. Costs are nominal; write to check on availability first.

A relatively new antenna has come upon the MW DX-ing market. Developed by Joseph Worcester, he calls it the "Space Magnet". Several variations are available. Basically, it consists of a 12 inch ferrite rod wrapped with litz wire and with a tuneable pre-amplififer, all of which can be rotated in one or two planes (depending upon the model selected). It's popularity stems from the fact that it equals or surpasses a bulky non-amplified air-core loop (as described above) in much less space, and it is an assembled product. Being compact, it is also a wife-pleaser. Write: Joseph A. Worcester Electronics Laboratory, RD illustration 1, Frankfort, NY 13340, USA, for a fact sheet and price list.

ACCESSORIES

There are all kinds of interesting gadgets which can be added to your listening post. Probably the most fundamental piece is a crystal calibrator of something better than the standard 100 kHz unit. One that emits markers every 10 kHz, or even every 5 kHz, would be ideal and, fortunately, with the advances in transistor and IC technology today several compact units are available in North America for less than $40.

If your receiver does not have any selectivity controls built in, a Q-multiplier circuit ought to be put together and wired into your receiver, as we discussed earlier. An alternative choice is to acquire mechanical filters and install one or two within the IF strip of your set. The latter option is more expensive, however, and one has to weight the expense of mechanical filters versus upgrading the communications receiver.

If you operate with a random length wire as an antenna, an antenna tuner is a must. It matches the impedance of the antenna to the input of your receiver, and a good match can easily add two or three (or more) s-units in signal strength. There are numerous circuits around, including ones published within the '73 edition of HOW TO LISTEN TO THE WORLD. A good antenna tuner can help in reducing images and internal mixing spurs too.

Another useful addition is a piece of surplus equipment called a "Q-5er". It is a US Signal Corps BC-453 which tunes, within its range, 455 kHz. 455 kHz is a popular i.f. for many receivers and the BC-453 "inhales" (through inductive coupling – no direct connection – to the last i.f. stage) the 455 kHz signal and continues processing the signal through its own 85 kHz i.e., which, in effect, gives another conversion stage. As I indicated before, dual conversion is better than single, and triple better than dual, but I know of no generally available communications receiver having triple conversion on the MW band, and only a few have dual conversion. The Q-5er is an inexpensive way to help a less-expensive receiver perform a bit better.

Relatively new to the SWL market is the spectrum analyzer. Surplus dealers occasionally come up with a bulky vintage panadaptor, but operative ones are few and far between.

Heath Company of Benton Harbour, MI 49022, USA, now markets its SB-620 "Spectrum Analyzer" as part of its amateur radio line, and the SB-620 can be wired into almost any receiver i.f. found in today's receivers. It's fascination lies in the fact that it displays as little as a 10 kHz spread or as much as a 500 kHz spread centred on the receiver's i.f. One can resolve stations as little as one-half kHz apart if the signals are of more-or-less equal strength, or one-to-three kHz if one is much stronger than the other. Openings can be "seen" with signals displayed on the CRT before they are normally audible with the receiver bandpass being wide open.

The super-sophisticated listening post, with unlimited budgets, may also contain a frequency counter, a signal generator, and an oscilloscope. It is most useful for Latin American DX-ing wherein many LA stations have transmitters that drift in frequency, but this gear allows measurement of any frequency desired . . . to the nearest Hz. In simplest terms, a warmed-up, thus stabilized, signal generator is inductively coupled into the front end, or antenna circuit, of the receiver. The signal generator output is set to zero-beat (i.e. minimize the oscillations on the s-meter or with an oscilloscope's vertical input tied into the receiver AVC line with the horizontal sweep adjusted to 4 Hz) with the incoming signal. Once zero-beat, the frequency of the signal generator is read on the frequency counter to an unbelievable accuracy of 1 or 2 Hz.

And finally, another useful acquisition is the tape recorder. Many DX-ers consider a tape recorder to be an absolute must . . . but this is a whole separate story; please refer to the companion article elsewhere in this edition.

LOGS

Most DX-ers like to keep track of what stations have been heard, and this activity is called "keeping a log". Depending upon your particular desires to pursue DX awards and keep track a variable number of "DX statistics", your answers to these questions will dictate the kind of log and the number of cross-references you'll want to generate.

Most MW DX-ers in NA will keep a tally on the following: stations, states, Canadian provinces, and countries, each category in number "heard" and number "verified".

For award purposes, a basic log might include the following data elements:

1) date.
2) time (either Eastern local time or GMT; see the following discussion).
3) call (or slogan, or both).
4) frequency.
5) power.
6) location.
7) programme notes.
8) date reception report sent and date verification received.

Let me insert my own bias at this time and suggest one method of log keeping which can satisfy the above demands and yet does not entail much drudgery . . . I'd rather DX than make laborious log notes.

A basic log is maintained on 3×5 index cards, one per frequency (540, 550 . . . 1590, 1600). The 3×5 card lists the data elements 1, 3, 5, and 6 above. A "V" is also added to each single-line entry if the station is later verified. As a particular frequency card is filled, a new card is added to the file. For example, 3 index cards summarize a total of 30 stations logged over a 13-year period on 1580 kHz. The card file log, arranged by frequency, is in the format most useful in answering the question "have I heard this station before on this frequency?"

The cards are easy to manipulate and one can quickly tabulate the heard and verified counts referred to earlier. The detail to support the card-file log is found within two other documents: a steno pad and a spiral bound notebook.

The steno pad is used for rough note taking when DX-ing. It is the *only* writing pad used, and it contains the data for reception reports, tape recorder index readings (so I can re-check the tape in case of an unidentified station) marking the point in time of an ID to be checked, and other notes and comments. This is, by design, in chronological order and, as a steno pad fills up and is completed, it goes into my files and a new one is started. The purpose of this method? I don't have miscellaneous notes on scraps of paper scattered around the "shack" which can be lost or otherwise disposed of.

A spiral bound notebook is kept, also in chronological order, wherein resides my "finished" reports in the format used to report loggings to SWL club bulletins. The "edited" reports in the spiral bound notebook are usually sufficient for any necessary research – such as time of day – and the steno pad's notes serve as back-up. The "finished" reports are entered in the spiral bound notebook during free time; completed notebooks are also filed as they are filled.

Whatever system you develop to keep track of the stations you hear, the "measuring stick" of a "good" system is how well it works for you. If somone asks you a question about a logging that you've reported, can you satisfactorily find the answer in a time frame suitable to you? If you are a "bug" on statistics, is the information easily compilable? I can't answer those questions but, with experience, you can. The methodology suggested above is just one way of "doing it" . . . but may not be the best way for you.

Let's go back and talk about the time logging for a moment. Convention has it that domestic logs, i.e. US and Canadian stations, are kept in Eastern local time. Two of the largest clubs use ELT to commonly define schedules for sign-on and sign-off times and for frequency checks (which we'll discuss later). Operating schedules and frequency check schedules do not normally change in clock terms from "Standard" to "Daylight" and back. A station that operates from 6 a.m. to 12 midnight daily will continue to do so whether it be on EST or EDT. To define schedules in EST or, possibly in Greenwich Mean Time (GMT), only would cause a horrendous conversion problem twice a year.

Foreign loggings are noted in GMT. All the warnings and procedures for the SW DX-er are equally applicable to the MW DX-er when reporting foreign stations in GMT. The switch from "Standard" to "Daylight" is not particularly bothersome here, and the MW DX-er has the advantage of having operating schedules in the *World Radio/TV Handbook* expressed in GMT. Accordingly, errors in time conversion are minimized. Research in DX literature is also simplified, with only the end product needing adjustment to one's local time.

Of course, readers outside the North American continent are going to have a different problem on their hands. Never having had the opportunity to DX from outside this area of the world, I would suspect that maintenance of logs in GMT for *all* catches would be the simplest way to go. A conversion chart for the several US time zones would probably be quite useful for those unfortunate enough to be able to DX the NA continent.

PUBLICATIONS

Essential ingredients to the "complete" listening post are certain commercial and DX-club publications that provide up-to-date information on stations. Quite often only a partial identification is heard, or the pronunciation of the town's name is difficult to understand. A replay of the tape may not clear it up. How does one complete the missing information?

The *World Radio-TV Handbook* does not have to have too much said about its format or contents, but I can only emphasize this one is a "must" for the foreign DX-er.

The WRTH foreign listings are excellent, but have some shortcomings on domestic stations in that it doesn't list the lower-powered stations. North America-based DX-ers need something with more detail. There are several sources available.

"White's Radio Log" is now owned by Davis Publications, Inc. 229 Park Avenue South, New York, NY 10008, USA. The "Log" appears in Davis' *Communications World*, a magazine published twice a year. It is a 3-way listing (frequency, call and location) of moderate accuracy. News-stand price in 1975 was $1.35 US, but the magazine can also be brought through the mail.

Howard W. Sams Publications of Indianapolis, Indiana, publishes the "Vane A. Jones Log" on an irregular basis. This too is a 3-way listing, and sells for about $5. Virtually any electronics supplies house who sells Sams publications can get this one for you.

Perhaps the best MW log around is the *National Radio Club Domestic Log*. By frequency, it includes addresses, operating schedules, network affiliations, and other data not found in those items mentioned above. Publication frequency and availability is not predictable (all volunteer work); write to the National Radio Club, Box 127, Boonton, NJ 07005, USA, to check on price and availability. The last edition was issued in 1975 for a price of $8 US.

For the foreign DX-er, the International Radio Club of America publishes its "Foreign Log", a compilation of all DX reported in the prior DX season to the IRCA bulletin. It is arranged by frequency and sorted out into Europe-Africa, Latin America, and Asia-Oceania groupings. Again, write for price and available, to IRCA, 12536 Arabian Way, Poway, CA 92064, USA. The WRTH is a necessary companion piece to this effort which gives the reader an excellent idea of what has been heard where at what times with certain kinds of programming.

THE ART OF DX-ING

What to listen to? To DX the BCB it is best to know something of its organization.

Domestic stations are divided into four major classes. Class I stations operate on "clear" channels with 10 to 50 kW, with only one (I-A) or two (I-B) stations on the frequency at night in North America (a treaty makes this possible). This permits sky-wave service without interference into remote areas at night.

Class II are secondary stations on clear channels with powers of 0.25 kW to 50 kW, serving a population centre and an adjacent suburban area. Schedules and antenna patterns are arranged so as not to interfere with Class I stations – which usually means daytime operations.

Class III stations are similar to Class II stations in service, but utilize "regional" frequencies and powers of 0.5 to 5 kW, both daytime and unlimited operations. There are 41 regional channels and more than 2000 Class III stations.

Class IV stations operate on "local" channels with maximum powers of 1 kW day and 0.25 kW night. There are more than 150 station on each of the six local channels.

The domestic channels are on 10 kHz spacing, from 540 to 1600 kHz inclusive. European, Near Eastern Asia and Africa stations utilize 9 kHz spacing once they hit 539 kHz . . . 520, 529, 539, 548, 557, 566 kHz, etc. As you can see, many of these assignments fall in between the 10 kHz spacing of the domestics, and it is possible to tune the trans-Atlantic (TA) signals nightly. Monday mornings, US time, is a good time to DX foreign stations if one has only a moderately selective receiver. For instance, Droitwich, England, on 1088 kHz is easy after WBAL-1090 Baltimore goes off the air at 1 a.m. on Mondays. Otherwise, DX the TA stations beginning at sunset here through dawn in Europe. During the winter months, the best time for TA DX-ing, stations in eastern Europe will begin disappearing around Midnight EST and the western European stations will go out by 2 a.m. or so. Excepting the 24-hour TAs, you'll hear sign-offs at sunset here, and sign-ons in the wee hours of the morning. (See Table II.)

The only other group of stations you'll find that are not on even 10 kHz assignments are a few Latin Americans and a small handful of trans-Pacific (TP) stations. In the case of the LA stations, some purposely place their carrier frequency in between the 10 kHz assignments, and others appear by accident or lack of knowledge pertaining to transmitter maintenance. In any case, these are called "splits" because they "split" the even-10 kHz assignments in the Western hemisphere. (See Tables III and IV.)

Perhaps the most widely-heard "split" is 4VEF, 10 kW on 1035 kHz, in Cap Haitien, Haiti, with English and French religious programmes. 4VEF is part of a 2 medium-wave, 5 shortwave transmitter array for Radio 4VEH. (See Table IV).

The Cuban stations are notorious for drifting off frequency by 100 or 200 kHz. The Czech-built transmitters are apparently difficult to maintain, and you can hear such examples of drift by heterodynes on 720, 1020, 1060, 1210 and 1270 kHz. A loop is ideal for nulling the Cuban interference.

The beginner DX-er is liable to say, "Who, me? Hear those TA and TP stations? Never!" Let's look at some domestic DX tips:

1) Monday mornings will find many of the high-powered clear channel stations off the air for varying lengths of time, usually servicing equipment. For example, WSM-650 Nashville is off, leaving the frequency open for KORL-650 in Honolulu. Many Class II and II stations do their equipment testing on Monday mornings and provide good DX-ing opportunities. A Class II station on a clear channel might make it from coast to coast while testing, if the Class I is off. Tones and continuous lengths of music without announcements typify a station testing; identifications are usually infrequent, so be patient. You may turn up a rare catch.

2) The fall, winter, and early spring months are usually the best times for listening. Atmospheric static is a limiting factor in the summer, though it is possible to find a handful of days when conditions are quiet and some excellent domestic and foreign DX can be heard. Also, propagation conditions are better during the winter months – with the longer nights – and a useful clue to solar conditions is broadcast by WWV at 18 minutes past the hour and WWVH at 45 minutes past. These standard time-frequency stations transmit on 2.5, 5.0, 10.0, 15.0, 20.0, and 25.0 MHz; at the time specified a propagation report and forecast is given. The auroral index (A-index) is the second item announced; the count can range from zero to forty or more. Typically, the count ranges from six to fifteen but several days of low (0 to 4) A-indices were a clue to excellent TP conditions in the fall of 1971 (10 kW VSZ-1 Tarawa in Gilbert & Ellice Islands made it into New Jersey and New York during that time), as well as good conditions into Europe and Africa. It appears that the Latin American signals get stronger whereas they are actually just less subject to skywave signals that normally arrive from the East and West. The combination of low atmospheric noise and low A-indices for a period of several days to a week or two should mean good DX-ing conditions to points that are trans-continental or trans-oceanic.

3) A good time to DX the domestics is at sunrise and sunset. On the regional and local channels there are many stations, operating on daytime only, signing on at local sunrise and signing off at local sunset. Stations to the east of the listener can most easily be heard at sunrise, and stations to the west are best heard at sunset.

On the East coast, for example, most stations are to the West. Following 1580 here, for example, local stations in Pennsylvania and Maryland first go off the air, and then every 15 minutes more sign-offs are heard from stations in Ohio, Kentucky, Tennessee until an hour or so later when the last are heard from Illinois and Iowa – by this time the Canadian usually dominates the frequency.

Sunrise DX-ing even for East coast listeners can be profitable too, if the right frequency is chosen. For example, WQXR-1560 New York does not sign on until 7 a.m. local time on Sunday mornings. In the space of one hour, from 6 a.m. to 7 a.m., one morning in April 1972, the writer taped sign-ons from no less than seven stations in six states, one each from Kentucky, North Carolina, Ohio, Tennessee, and West Virginia and two from Indiana.

West coast DX-ers can use sign-ons to best advantage. In the wee hours of the morning West coast time, the channels are open to the East. As the sun rises on the East coast stations will begin to sign on. Every fifteen minutes a new group can be heard, and then will fade out as sunlight hits the transmitter sites . . . continuing to open the frequency as dawn moves across the country. On certain clear channels having Class I stations located in the East, the Class I stations will fade with sunrise at their locations, opening the clear for easy pickings of any Class II stations that are located to the West of the Class I and signing on when dawn comes to their location. Clear channel 1050 kHz, with WHN in New York and CHUM Toronto would be a good example; there are over 50 day-time stations to pick over on this frequency.

Incidentally, it is extremely helpful to have a tape recorder running while DX-ing either sunrise or sunset skip. Quite frequently you will have as many as six signing on or off at the same time; a replay of the tape and careful examination of what might normally be written off as an impossible jumble of interference may yield several good identifications. Replaying of the tape through audio filters, cutting highs and lows to pass a narrow band of audio frequencies, often does wonders in improving intelligibility. Don't have an audio filter? Play it back through your hi-fi or stereo system, adjusting controls accordingly, and use earphones to listen to the tape to cut extraneous noise.

4) Frequency checks are an excellent way to add many low-powered, rare, stations to the log. A frequency check is a regularly scheduled test broadcast during the experimental period of Midnight to 6 a.m. local time. Most tests are run for 15 minutes and consist of test tone, usually 1000 Hz, with one or two IDs. Recent changes in the FCC rules and regulations will mandate monthly checks on the accuracy of the transmitter frequency. Various companies have the appropriate measuring equipment to spot the transmitter frequency to the nearest Hertz. The International Radio Club of America and the National Radio Club publish, annually, a list of the frequency checks run during the experimental period; several monitoring companies cooperate with the clubs, and IRCA and NRC members also report frequency checks heard. Most checks are run on a particular day of the month. Examples of some regular frequency checks which

enable the MW DX-er to hear some rare states are, on the first Monday of each month, ones from KUPK-1050 (5 kW) Garden City, Kansas, at 0215-0230 ELT and, a few minutes later, KGHL-790 (5 kW) Billings, Montana, at 0245-0300 ELT. Both run test tone (TT). Frequency checks on "graveyard" frequencies can also enjoy wide coverage. One such regular is WFOY-1240 (1 kW) St. Augustine, Florida, on the third Friday of each month at 0010-0025 ELT, also with TT.

Frequency checks are different from equipment tests, as the former are usually on a regular, repeating schedule from month to month. Although some run music, most frequency checks run a constant tone. Equipment tests (ETs) are usually longer than 15 minutes, run a variety of tones (from 20 Hz to 10,000 Hz) and music. Announcements can be very frequent, and sometimes an ET can almost sound like "regular schedule" less commercials.

CLUBS

Half the fun of DX-ing is sharing your catches and information with other DX-ers. To that end, there are several large listeners' clubs in North America that deal with MW DX-ing. The medium of information exchange is a bulletin distributed among the membership, and each club below also has an annual picnic or convention.

The *International Radio Club of America,* 12536 Arabian Way, Poway, CA 92064, USA publishes an offset bulletin of 8½×11 inches some 34 times a year, and weekly during the DX season. There are columns on domestic DX catches, members' comments, and international DX loggings, as well as a few technical articles.

The *National Radio Club,* Box 127, Boonton, NJ 07005, USA, publishes a bulletin 34 times a year and also weekly during the DX season excepting skips around Thanks giving and Christmas. This bulletin is also offset which accommodates a multitude of technical articles. The domestic DX column, a members' "muslings" column, and an international DX column are also present. The oldest MW-only club going, it was founded in 1933 and now has some 600 members.

Some DX-ers believe IRCA and NRC coverage are duplicatory, but this is not so. It is confirmed to by some 400 individuals who belong to both clubs.

A third club is the all-band-coverage *Newark News Radio Club,* Box 539, Newark, NJ 07001, USA. This is the oldest club in existence, having started as a MW club in 1927, but now it is an all-band effort of monthly bulletins of some 60 pages each. Additional coverage is provided for SW broadcast, utility, amateur, FM, TV, card and tape swapping.

Postage costs and publishing materials and supplies dictate membership fees, as all clubs are strictly volunteer efforts. Write for information on membership rates.

All clubs enjoy a membership of over 500 apiece, and all three have Courtesy Programme Committees (CPCs). These CPCs arrange "DX tests" from hard-to-log stations all over NA. In the case of daytimers, the cooperating station usually modifies his equipment test or extends his frequency check to include additional identifications as the day-timer is not allowed to operate at night for purposes of a dedicated programme to a club or other audience. The stations allowed to operate "unlimited" hours will occasionally go all-out in putting on a special programme with fancy identifications, special music, and on-the-air phone calls. Both will, occasionally, include code identifications which penetrate interference very well . . . and is the only item heard. In many tests now, a phone number is made known (either on the air or through the bulletins) and the DX-ers are invited to call the station (not collect!) and the station gets an instant feedback of its coverage. The CPCs usually arrange such programmes or tests during the winter months, when conditions are quiet, and for Monday mornings if at all possible. They are usually scheduled well in advance of the broadcast date so that the clubs can notify their respective memberships that such a test or programme is forthcoming. The CPCs have arranged between 50 and 100 tests for each of the past three DX seasons.

GENERAL

There are a few items that have not been discussed heretofore, and let's talk about them briefly.

One of the most useful pieces of equipment in a MW DX-er's shack is a tape recorder. Missed IDs can be replayed, and "de-bugging" of multiple signals containing sign-on or sign-off announcements can be repeated as many times as is necessary to decipher the contents thereof.

Furthermore, it is often enjoyable to build up a tape file containing all or part of your DX catches. The writer just keeps a tape of the better loggings, and to me I enjoy those tapes just as much as a written verification.

Speaking of written verifications all the rules that SW DX-ers follow in assembling a complete report still hold true for MW DX reports. Two points, however: first, attempt to put the report's time into that of the station's local time zone if reporting to a domestic station (otherwise use GMT), and second, be sure to enclose return postage. The stations don't have the large budgets of the international shortwave broadcasters. Request, don't demand, the verification; after all, it is a courtesy on the part of the chief engineer, the usual respondent, in taking his time and a secretary's time to write or otherwise prepare a verification in reply.

MW DX-ing is, indeed, a fascinating hobby. In many ways it can be more interesting than DX-ing the SW bands and I have noticed, in the years I've been listening, that quite a few of the newer SW DX-ers convert to the lower MW band. Unfortunately, the congestion on the MW band often discourages beginners who attempt to use less-than-quality equipment. This article has attempted to discuss some of the problems in MW DX-ing, and hopefully the reader will be able to bypass the usual pitfalls. Now, it's your turn . . .

Table I
Frequency Allocations in North America
"Clear" channels: 540, 640-780, 800-900, 940, 990-1140, 1160-1220, and 1500-1580 kHz.

"Regional" channels: 550-630, 790, 910-930, 950-980, 1150, 1250-1330— 1350-1390, 1410-1440, 1460-1480, 1590, and 1600 kHz.

"Local" channels: 1230, 1240, 1340, 1400, 1450, and 1490 kHz.

An examination of the WRTH or any other BCB listing for the USA, Canada, and Mexico will disclose the dominant station on each "clear" allocation.

Table I-A
Best Bets for the Fifty States
Note: Use a WRTH or an NRC log for specific station information. In the list below, the abbreviations used are:

FC=frequency check.
MM=Monday morning.
Times are in Eastern local time.

Alabama:	WAAY-1550
Alaska:	KFQD-750/KFAR-660
Arizona:	KTUF-1580
Arkansas:	KAAY-1050
California:	KFI-640
Colorado:	KOA-850
Connecticut:	WTIC-1080
Delaware:	WDOV-1410/WDEL-1150
Georgia:	WSB-750
Hawaii:	KORL-650
Idaho:	KGEM-1140/KBOI-670
Illinois:	WLS-890
Indiana:	WOWO-1190
Iowa:	WHO-1040
Kansas:	KUPK-1050 (FC 1st MM 0215-0230)
Kentucky:	WHAS-840
Louisiana:	WWL-870
Maine:	WABI-910/WCSH-970
Maryland:	WBAL-1090
Massachusetts:	WBZ-1030
Michigan:	WJR-760
Minnesota:	WCCO-830
Mississippi:	WOKJ-1550
Missouri:	KMOX-1120
Montana:	KGHL-790 (FC 1st MM 0245-0300)
Nebraska:	KFAB-1110/KRVN-880
Nevada:	KLUC-1140 (FC 3rd MM 0315-0330)/KCRL-780
New Hampshire:	WFEA-1370
New Jersey:	WPTA-930
New Mexico:	KOB-770
New York:	WABC-770
North Carolina:	WBT-1110
North Dakota:	KFYR-550
Ohio:	WLW-700
Oklahoma:	KOMA-1520
Oregon:	KEX-1190/KPNW-1120
Pennsylvania:	KDKA-1020
Rhode Island:	WPRO-630
South Carolina:	WBSC-1550
South Dakota:	WNAX-570
Tennessee:	WSM-650
Texas:	WOAI-1200
Utah:	KSL-1160
Vermont:	WHWB-1000
Virginia:	WRVA-1140
Washington:	KGA-1510/KING-1090
West Virginia:	WWVA-1170
Wisconsin:	WKOW-1070
Wyoming:	KNIE-1530
District of Columbia:	WTPO-1500

Table II

Trans-Atlantic Stations Easily Heard

This represents some of the more common TAs heard in North America. It is *not* an all-inclusive list.

Freq.	*Call*	*kW*	*Location*
•665		135	Lisbon, Portugal
683	RNE	250	Seville, Spain
737	RNE	125/250	Barcelona, Spain
		1200	Tel Aviv, Israel
755		135	Lisbon, Portugal
•746		200	Dakar, Senegal
782	CSB9	100	Miramar, Portugal
818		900	La Vieja, Andorra
		450	Batra, Egypt
836	ORTF	150	Nancy, France
•845	RAI	540	Rome, Italy
863	ORTF	300	Paris, France
•1034	CSB2	120	Lisbon, Portugal
1088	BBC	500	Crowborough, England
1196	VOA	300	Munich, West Germany
•1205	ORTF	300	Bordeaux, France
•1214	BBC	60	Washford, England
1295	BBC	600	Crowborough, England
1385	ECS11	20	Madrid, Spain
1394		500	Shkodra, Albania
1457		500	Durres, Albania (R. Peking relay)
1466	3AM2	400	Monte Carlo, Monaco
1538	DLF	700	Mainflingen, West Germany
1554	ORTF	300	Nice, France
1578	CSB5	10	Porto, Portugal
1586	WDR	800	Langenberg, West Germany
1602	BR	370	Munich, West Germany

•best bets for reception on the West coast of North America.

Table III

Trans-Pacific Stations Easily Heard

The great circle path through the auroral zone from Asia to most of North America, especially the Eastern half, and the fact that most assignments are on the even 10-kHz spots, limits the possibilities of TP reception. The following is *not* an all-inclusive list.

Freq.	*Call*	*kW*	*Location*
•650	KORL	10	Honolulu, Hawaii
655			Pyongyang, North Korea
725			Kimchaek, North Korea
770	JOUB		Akita, Japan
830	JOBB	300	Osaka, Japan
835			Nanchang, China
•844	VSZI	10	Tarawa, Gilbert & Ellice Islands
877			Wonsan, North Korea
1040		1500	Shanghai, China
1178	VOA	1000	Okinawa
1529			Asiatic RSFSR (location unknown)

•best bets for reception on the East coast of North America.

Chapter 7

DX-ing 60 METRES

by Anker Petersen, Denmark

The 60 meterband is that Tropical Broadcasting Band which offers the most audible stations to the DX-er. During 12 months of regular listening I was able to hear 245 broadcasting stations in 71 countries, out of which just two countries were European (Albania and the USSR), and consequently most stations can be considered as true DX-stations.

I systematically listened on 60 meters in 1969 to find out which stations could be heard at what times. The observations were made by careful tuning through the band each hour of the day noting the signal strength of each audible broadcasting station on the S-meter. This was done again each calendar month throughout 1969. At my listening post outside Copenhagen I used a DRAKE R-4B receiver with a 29 metres long, 4 metres high WINDOM-antenna directed SE-NW. Since these receiving factors were not changed during the year, all signal strengths noted can be compared mutually.

All stations logged were plotted on square diagrams – one for each area of the world. Three examples are shown in this article. Each square indicates a full-hour period (in GMT) at a particular month. The number of stations heard from that area at that hour and month is shown by the number of crosses. Their height above the bottom line of the month is indicating the signal strength in S-meter values. The curves of the sunset and sunrise at the reflection points will be discussed later.

I hope that DX-ers, by using this survey, will be able to concentrate their listening to the hours and months when the chances for logging a certain station are best, and thus make the DX-ing more effective. There is not much difference in the propagation of radiowaves in 60 mb and radiowaves in the 49, 75 and 90 meterbands, because the frequencies used only cover a relatively narrow span of 3 MHz. This survey therefore also indicates how tropical stations in these bands can be heard, but it must be born in mind that each of these 3 bands are allocated and used by the countries differently from the 60 mb.

This survey shows how reception is in Denmark, but there is not much difference in the reception throughout Europe for stations situated in South Asia, Africa and Latin America. DX-ers in the British Isles, France and Iberia should, however, add one hour to the theoretical hours of reception mentioned here, because of their westerly longitude compared to Denmark. Radio signals from stations in the Pacific, the Far East and Southeast Asia are received in Europe from an east-northeasterly direction, meaning that during wintertime they will pass the polar zone of darkness on their way to North European listeners, whereas they will pass the USSR south of the darkness zone on their way to listeners in Central Europe. Because of this, there is a marked difference in reception of these stations, being regularly good in Finland, North Sweden and in Norway, but only occasionally good in the rest of Europe.

WHICH STATIONS BROADCAST ON 60 METERS

The frequency range of 4750-5060 kHz is assigned by the International Telecommunication Union for domestic broadcasting in tropical areas, where a high static noise level originating from the daily thunderstorms limits the service area of mediumwave stations. Most countries situated on and between the Tropic of Cancer and the Tropic of Capricorn use this band for their home services. Some countries outside the Tropical Zone also use it, namely North Korea, Mongolia, Kashmir, West Pakistan, Afghanistan, Albania and the Azores; and for both Home and Foreign Services: the USSR and China.

HOW ARE BROADCAST CONDITIONS ON 60 METERS

During the night hours, radiowaves in this frequency spectrum are usually refracted earthwards in the ionized F-layer about 250-300 kilometres above the ground, this giving good reception 1000-2000 kilometres or more from the transmitter, all depending on its effective radiated power.

As soon as the sun rises over the horizon, its ultra-violet and X-rays will also ionize the D-layer at an altitude of 70 kilometres, and the E-layer at 110 kilometres. Many molecules of gas are present, particularly in the low D-layer and these molecules will be hit by the electrons of a radiowave trying to pass this layer. By these collisions the electrons lose their energy, and thus the radio signal becomes attenuated before it reaches the reflecting F-layer. This absorption varies greatly with time of day and season of the year, being proportional to the sun's altitude. The greatest absorption is found at noon in the tropics, where the sun is directly overhead.

For this reason broadcasting during the daylight hours is not possible, except via the ground wave which can cover a local area of about 50 kilometres radius all day. Consequently, tropical stations broadcasting domestic services to a larger area only use the 60 mb in the early morning from station sign-on until sunrise, and again from sunset to close-down at night. During the daylight hours they change to frequencies mostly in the 49, 41 or 31 meterbands, although some stations keep the 60-meter frequency on the air for local broadcasting. By the way, most Latin American stations are only intended for local broadcasting, and so they stay on 60 meters all the day.

DX-PROPAGATION OF 60 METERS

As opposed to the ordinary listener, who requires a strong and steady signal without much noise, the DX-er is happy as soon as he can pick up a weak signal from a far-away station. Therefore propagation of the stations in the 60 mb can be regarded as worldwide according to DX principles.

If these radiowaves are not absorbed in the D-layer they will be subject of multiple-hop propagation following the same rules as for other shortwave transmissions on other frequencies or wavelengths.

The radiowaves of 60 meters move along the great circle path from transmitter to receiver, and so it is possible to study this route on a globe by stretching a string between these two points. It will be understood from above that it is of utmost importance for the propagation whether or not the ionispheric wave reflection points are in sunshine. The reflection points can be pinpointed along the great circle path in this way: If the transmission path is less than 4000 kilometres, only one reflection is needed, and the reflection point is midway between transmitter and receiver. Multi-hop propagation occurs for distances of more than 4000 km, and for practical purposes it is sufficient to have a look at the conditions at a reflection point located 2000 km away from the transmitter, and at another located 2000 km from the receiver.

The general rule is that *a transmission path is open for DX-reception when the sun is under the horizon both at the transmitter reflection point and at the receiver reflection point.* Weak signals may get through, however, also during twilight when the sun is slightly over the horizon at one reflection point, but still under at the other. It is my observation from several thousand loggings that 91% of all 60 mb reception occurred with night conditions at both reflection points, while 8% of the loggings were made in twilight as described above. The remaining 1% were heard with sunshine at both reflection points, but all close to the twilight period.

The signal strength increases steadily from the stations fade-in at the beginning of darkness on the path since absorption becomes lesser. In many cases, but not all, a peak occurs about two hours after fade-in, followed by 3-4 hours with weaker signal strength. Then the strength increases again and stays on a good level until the station fades out when sunrise reaches the first reflection point. Of course most stations are closed down during the latter part of this period since this covers the hours from local midnight until sunrise. The path is open, however, so watch for prolonged broadcasting hours on national holidays, elections, revolutions, earthquake catastrophes etc., since the stations may be heard well then.

The regularity with which the 60 mb stations are heard depends to a great extent on the characteristics of the transmitter and antenna, and in particular their power output. Generally, stations in Asia and Africa using 50 kW or more and Latin American stations of 10 kW or more are heard regularly, while hearing stations with lower power depend much more on the varying ionospheric conditions. The reason for the better reception of Latin America seems to be the fact that all earth reflections of the multi-hop transmissions from Latin America to Europe occur on water (the North Atlantic) where reflection is better than for ground reflections as found on routes from Africa, Asia and the Pacific.

DAILY VARIATIONS IN 60 METER RECEPTION

When DX-ing 60 meters one soon finds that the amount of audible stations does vary much from day to day. Just the 5-10 most regular Latin Americans may be audible one night, whereas there might be a Latin American station present at each 5 kHz throughout the band the following night. Often a rare station is just audible for a period of some days, and then disappears again for a long time, maybe for several years. This makes DX-ing in the tropical bands a great challenge.

The nature of this daily variation is not fully explored, but the following phenomena seem to be of importance:

The Maximum usable frequency, *(MUF)* for a given transmission path is in nearly all cases higher than 5 MHz, meaning that the radiowaves of 60 metres will – if not absorbed in the lower layers – be reflected to earth when they reach the F-layer, and not continue out in space as for frequencies higher than the MUF. Radio transmissions using the MUF will provide the highest signal strength, while this will decrease due to ionospheric absorption as the frequency is changed to lower values. If the MUF for the route West-Africa-Denmar, one evening is 7 MHz, reception will be strong in the 41 mb, and good in the 60 mb of African stations, while they have faded out totally in the 19 and 25 meterbands. On the other hand, if one can hear Africans with good reception in the 19 mb, the MUF is higher than 15 MHz, and on 60 meters just the most powerful Africans may be audible.

Solar activity has great influence on all long distance reception on the earth. At the eruption of flares and occurrence of visible spots on the solar surface, a wave of electrically charged particles is ejected from the sun. It has been noted that radio signals often are stronger than normal at the time around the eruption. Some 20-40 hours later this "Solar Wind" reaches the ionosphere causing great disturbances in the earth's magnetic field. Particularly in the auroral zones around the Magnetic Poles (Northern Canada and Southern Indian Ocean) these ionospheric storms are effectively attenuate the radio signals and make fading faster and deeper. During years with minimum solar activity the normal MUF is low, and so ionospheric storms will then have higher effect in the 60 mb.

The duration of such storms varies a great deal, and it may take several days before normal reception conditions are re-established. For 60 mb-listeners in Northern Europe, transmission paths from the Pacific, the Far East and Central America will be affected first during periods of rather high geomagnetic activity, while other paths remain stable. When, on rare occasions, high activity occurs, stations in all directions will be weakened here, if not disappear completely. Since similar solar activity and the consequent reception conditions often recur at 27 day intervals following the rotation of the sun, the DX-er may be guided thus.

Static Noise will always be present at a certain level, and it is produced mainly in the earth's atmosphere in connection with thunderstorms. The lighting pulses propagate by groundwave as well as by skywave. The groundwave carries a typical crashing noise – easily identified on 60 mb and mediumwave during thunderstorms – as far as a few hundred kilometres from the source. The E- and F-layers sometimes reflect the noise from tropical thunderstorms, and this just increases our general noise level.

Interference is another annoying problem, because outside the tropical zone the 60 mb is allocated to utility stations using telegraphy, teletype and teleprinter, and as DX-ers know, they use it extensively. However, their activity is reduced about 30% during weekends, and this part of the week thus offers the best listening conditions because of less interference.

SEASONAL VARIATIONS IN 60 METERS RECEPTION

All areas broadcasting on 60 meters, except the Pacific, can be heard in Europe in all 12 months of the year, but for all areas there is a marked variation in reception quality and reception periods with some months being better than others – which months depend on the Continent listened to. In the following survey I'll describe the reception in Denmark of each area, but first some general observations:

Absorption seems to be stronger during the winter than during summer because a higher transmitter power is needed to penetrate the ionospheric absorbing layers, even though the MUF at night is lower than at summer.

Static Noise, mainly from tropical thunderstorms, may have an influence in the propagation of 60 mb signals. The geographical distribution of these tropical noise centres is changing throughout the year following the movement of the sun. Thus the centres are located during: June, July and August: Vietnam-India, Sudan-Nigeria, Caribbean Sea; September-November, March-May: Indonesia, Kenya-Congo, Amazon-area; December, January and February: New Guinea, Tanzania-Angola, Brazil-Bolivia. Observations made here confirm to some extent that reception of a particular area is poor when a noise centre is located there.

Most local thunderstorms are noted in Denmark in June-August.

Interference in the 60 mb from non-tropical stations is also varying throughout the year. It is highest during the fall-winter-spring months (September-April) when the utility stations occupy many frequencies in this band. During summer several change to higher frequencies. The number of regular strong broadcast stations in the USSR and China is also much higher in winter.

SURVEY OF 60 METERBAND RECEPTION IN DENMARK

I have divided the world into 14 broadcasting areas; within each there is very small variation in the reception here. The countries logged during 1969 are listed first in the survey below. Then follows a description of the theoretical reception of stations in the area in Denmark, constituting the hours of complete darkness on the path between transmitter and receiver reflection points. If an area can be heard only during some months of the year, the longest period of audibility is always around winter solstice.

The actual reception as I heard it in 1969 is then given in full hour periods, divided up into four seasons. Mentioned first are the hours when the path was found to be open; this means that stations were heard with any signal strength between S1 and S9+ in the S-meter "%" means that the 60 mb was not open these months at that period. To emphasize the best reception hours I end the table by listing the better periods, i.e. those when stations were heard with S6 or more. DX-ers using receivers with just fair sensitivity may only be able to hear stations in these good periods. "–" means that signal strength was below S6 for all stations during that period.

ALL TIMES ARE IN G.M.T.

PACIFIC

Australia and Papua.

Located on the opposite side of the globe of Europe, these stations can be heard via two routes, one passing East China, Mongolia and the Northern USSR, and another passing Antarctica, Chile, Argentina, Paraguay and Brazil.

Theoretical reception:

Early afternoon: October-February, fading in 1215 to sign off 1400.

Evening: All months, from sign on 2000 to fade out 2030-2200.

Morning: October-March around 0700-0930, when sunset at the transmitter reflection point in the South Pacific appears about ½ hour before sunrise at the receiver reflection point southwest of the British Isles.

Actual reception:

		NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
East Asian Route:	Open	1200-1400	/	/	/
	Open	2000-2100	/	2000-2100	/
	Good	–	–	–	–
S. American Route	Open	0800-0900	/	/	/
	Good	–	–	–	–

Best time of the year for all 3 periods is around winter solstice in December.

NORTHEAST ASIA

USSR (East Siberia), Mongolia and China.

Theoretical reception:

All months from sunset at receiver reflection point over Northern Europe USSR until sunrise at the transmitter reflection point over Northern Siberia. This open period varies from 1130-0130 in December to 1830-2115 in June. The Home Service Stations sign off between 1520 and 1730 and sign on again around 2200. Radio Peking broadcasts Foreign Service on several frequencies throughout the evening.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	1200-1900	1500-1800	1700-2400	1400-2400
Open	2000-0200	1900-0200	/	/
Good	1500-1800	2200-2300	–	–
Good	0000-0200	–	–	–

Reception of the local stations is influenced much by the auroral ionospheric conditions en route. Most were heard in November, December and March. Even if signal strength is very low shortly after noon, some Far Eastern stations can be heard best at this time, before the utility transmitters come on the air in the mid-afternoon.

SOUTHEAST ASIA

Indonesia, Eastern and Western Malaysia, Singapore, North Vietnam, Cambodia and Burma.

Theoretical reception:

Mid afternoon: August-May from fade in between 1245 in December and 1600 in August and May to sign off between 1430 and 1630.

Late evening: All months from sign on between 2100 and 2300 until fade out around 2400.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	1200-1700	1500-1700	1500-1700	1300-1600
Open	2100-0100	2200-2400	2200-0100	2200-2400
Good	–	–	–	–

The best months are October-February, but the reception of the very low-powered stations is very sporadic.

SOUTH ASIA

Sri Lanka, The Maldive Republic, India, Kashmir and Pakistan.

Theoretical reception:

Afternoon: All months from fade in between 1300 in November-January and 1700 in June to sign off 1700-1730 (except "Azad Kashmir" around 1845).

Midnight: August-May sign on between 0030 and 0130 to fade out between 0400 in December and 0100 in August and May.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	1300-1800	1500-1900	1500-1900	1400-1900
Open	0100-0500	0100-0200	0100-0300	0100-0200
Good	1700-1800	1600-1900	1700-1900	1600-1900
Good	0200-0300	0100-0200	0100-0200	–

The best reception is during October-November.

CENTRAL ASIA

Afghanistan and USSR (Central Asia, West Siberia).

Theoretical reception:

All months from fade in during the afternoon until fade out after midnight, i.e. 1230-0500 in December-January to 1730-2400 in June-July. All stations usually close down between 1730 and 2100 and open again between 2300 and 0200.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	1200-2300	1400-2100	1500-2100	1200-2200
Open	2300-0600	2300-0500	2300-0300	2300-0400
Good	1400-2200	1600-2100	1700-2100	1500-2100
Good	0000-0500	2300-0300	2300-0100	2300-0300

The best months are September-March when several stations can be heard with signal strength S9+.

EAST EUROPE

USSR (European part) and Albania.

Theoretical reception:

Strong reception all months from fade in during the afternoon until fade out in the morning, except for non-broadcasting hours around midnight. The Home Service stations usually sign off between 2100 and 2200 and sign on between 0100 and 0300. Radio Moscow uses several frequencies for Foreign Service throughout the evening and night. The hours of darkness at the reflection point midway are varying from 1345-0645 in December to 1900-0130 in June.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	1200-0900	1200-2200	1200-2300	1200-2200
Open	1200-0900	0100-0900	0100-0900	2300-0900
Good	1300-0800	1400-2200	1500-2300	1300-2200
Good	1300-0800	0100-0600	0100-0500	2300-0600

The best months are September-March. The stations, particularly the most westerly, can also be heard outside the hours of darkness at the reflection point, because absorption only occurs at one point.

NEAR EAST AND EAST AFRICA

Kuwait, Yemen, Saudi Arabia ("Yemeni Royalist Radio"), Southern Yemen, Afars & Issas, Sudan, Uganda, Kenya, Tanzania, Mauritius, Reunion, Malagasy, Mozambique, Zambia and Rhodesia.

Theoretical reception:

Evening: All months from fade in between 1745 in June and 1530 in December-January to sign off between 1815 and 2200.

Morning: During September-April from sign on between 0225 and 0400 to fade out between 0445 in December-January and 0300 in September and April (except for Malagasy, Reunion and Mauritius which are in sunshine all months).

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	1500-2300	1600-2200	1600-2200	1600-2200
Open	0300-0600	0300-0500	/	/
Good	1700-2100	1700-2100	1700-2200	1600-1900
Good	0500-0600	–	–	–

Regular strong reception in the early evening is noted during April-August, while some stations can also be heard occasionally in the early mornings in November-February.

SOUTH AFRICA

Botswana and Republic of South Africa.

Theoretical reception:

All months from fade in between 1630 in September and March and 1800 in June to fade out between 0400 in October and April and 0300 in June-July. The Republic of South Africa uses the 60 mb only during September-February, including one all-night frequency.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	1600-0200	1700-2000	1700-2100	1600-2400
Open	0300-0500	/	/	/
Good	0300-0500	–	–	–

Best months are December-January both evening and morning reception.

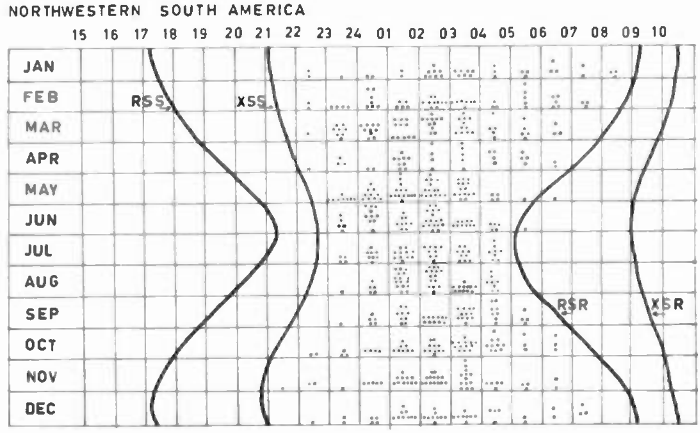
CENTRAL AFRICA

Angola, Zaire, Congo-Brazzaville, Gabon, Cabinda, Sao Tome e Princ., Equatorial Guinea, Cameroon, Central African Empire and Chad.

Theoretical reception:

Evening: All months from fade in shortly after 1600 (1730 in June-July) to sign off between 2000 and 2300. (Radio Comercial de Angola closes at 0100 and Kinshasa at 0300).

Morning: During October-March from sign on between 0400 and 0700 to fade out around 0530.


NORTHWESTERN SOUTH AMERICA
15 16 17 18 19 20 21 22 23 24 01 02 03 04 05 06 07 08 09 10
JAN
FEB
MAR
APR
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JUL
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SEP
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NOV
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RSS
XSS
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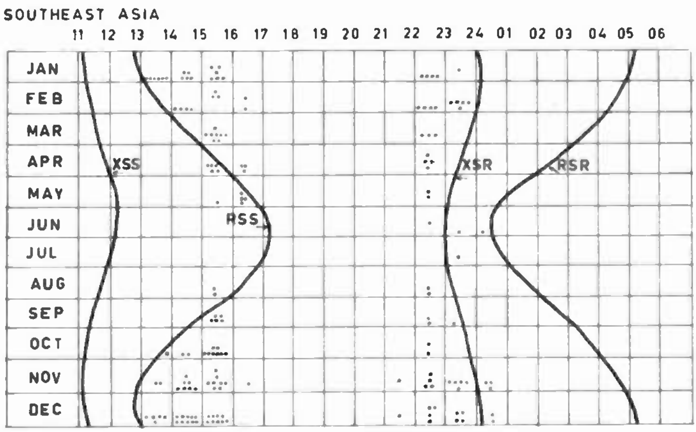
SOUTHEAST ASIA
11 12 13 14 15 16 17 18 19 20 21 22 23 24 01 02 03 04 05 06
JAN
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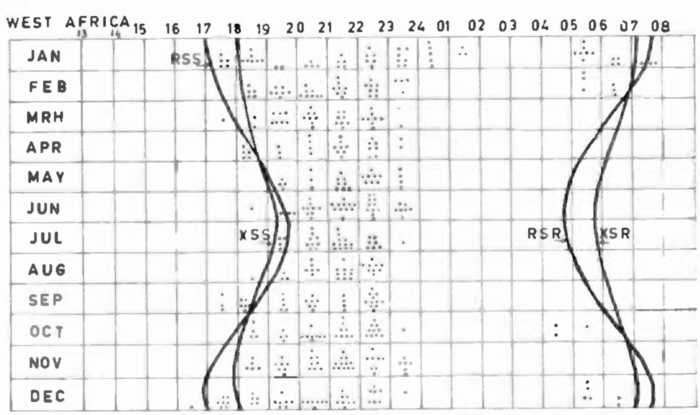

WEST AFRICA
15 16 17 18 19 20 21 22 23 24 01 02 03 04 05 06 07 08
JAN
FEB
MRH
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
RSS
XSS
RSR
XSR

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	1600-0100	1700-2400	1700-2400	1600-2300
Open	0400-0600	/	/	/
Good	2100-2200	1800-2100	1800-2400	2100-2200

Best months are April-September in the evenings.

WEST AFRICA

Nigeria, Benin, Togo, Ghana, Upper Volta, Ivory Coast, Mali, Liberia, Guinea, Guinea-Bissau, Gambia, Senegal, Mauritius, Cape Verde and the Azores.

Theoretical reception:

Evening: All months fade-in between 1745 in November-December and 1930 in June-July to sign-off between 2100 and 2400.

Morning: During August-April from sign-on between 0430 and 0700 to fade-out between 0700 in November-February and 0500 in April and August.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	1600-0200	1700-2400	1700-2400	1700-2400
Open	0400-0800	0400-0500	/	0400-0600
Good	2000-0100	2000-2300	1800-2300	1700-2300
Good	0500-0600	–	–	–

The best months are May-August in the evenings.

NORTHEASTERN SOUTH AMERICA

Brazil.

Theoretical reception:

Night: All months from fade in around 2030 at sunset of transmitter reflection point until sign off between 0100 and 0400 (Radio Jornal do Brazil at 0500 and Radio Relogio all night).

Morning: During December-January from sign on varying between 0730 and 1200 until fade out at 0800.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	2100-0500	2200-0400	2100-0400	2100-0400
Open	0700-0800	/	/	/
Good	–	–	2300-0100	–

The best months are May-July. Very few stations are coming through in December-January.

CENTRAL SOUTH AMERICA

Bolivia, Peru and Ecuador.

Theoretical reception:

All months from fade-in at sunset of transmitter reflection point around 2230 until fade out at sunrise of receiver reflection point varying from 0830 in December-January to 0500 in June-July. Most stations, however, close down between 0300 and 0500.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	0100-0800	0000-0700	2300-0500	2300-0600
Good	–	–	–	–

The best months are July-September. Very few stations are coming through during November-January.

NORTHWESTERN SOUTH AMERICA

Columbia and Venezuela.

Theoretical reception:

All months from fade in between 2100 in November-December and 2230 in June-July to fade out between 0900 in December-January and 0515 in June-July. Most stations close down between 0300 and 0500.

中國廣播公司

Voice of Free China

Languages	Time (GMT)	Target area	Frequency (kHz)
Mandarin	0000-0100	North America	15345 15425 17890
	1000-1100		11745
	2040-2140		9685 17890
Cantonese	0200-0300		15345 17890
	1200-1300		11745
English	0100-0200		15345 15425 17890
	0300-0350		
	2140-2240		9685 17890
Arabic	1830-1930	Africa Middle East West Europe	9510 11860 15225
French	1930-2030		17720
	2030-2130		9510 9600 11860
English	2130-2230		15225 17720
Spanish	2300-2350	Latin America	17800

53 Jen Ai Road, Section 3
Taipei, Taiwan.
Republic of China

RADIO EXTERIOR DE ESPAÑA

Apartado 150.039
Prado del Rey, Madrid.

DX-Programmes

I **Europe in Spanish**
Sun. at 2020 GMT on 6140, 7105, 9570 and 11920 kHz.

II **Europe in English**
Sat. at 2118 GMT. Repetition at 2218 GMT on 9505, 9580 and 11840 kHz.

III **North America in English**
Sun. at 0045 GMT.
1st repetition at 0145 GMT, 2nd repetition at 0600 GMT on 9630 and 11880 kHz.

IV **America in Spanish**
Sun. at 0145 GMT.
Repetition at 0345 GMT.

1. **South America**: On 9360, 9530, 11775 and 11945 kHz.
2. **Central America and Caribbean**: On 9360 and 11775 kHz.
3. **Central and North America**: On 9360, 9630, 11775 and 11815 kHz.
4. **Canarian Regional for America**: Sat. at 2200 GMT on 11880 kHz.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	2100-0900	2200-0700	2300-0700	2200-0700
Good	0300-0700	0100-0600	0000-0500	0000-0500

The best months are May-June and September-November. Only high-powered stations are heard in December-February when morning reception of the all-night stations often is good, though.

CENTRAL AMERICA

Dominican Republic, Haiti and Honduras.

Theoretical reception:

All months from fade in between 2030 in November-December and 2300 in June-July to sign off between 0400 and 0600.

Actual reception:

	NOV-FEB	MAR-APR	MAY-AUG	SEP-OCT
Open	0200-0600	0000-0500	2200-0500	0100-0600

The best months are April-June and in September. Very few stations come through in December-February.

Chapter 8

UTILITY DX-ing

by the Radio Communications DX-Club, Holland

A. INTRODUCTION ON UTILITY DX-ING

1. Why DX-ers listen to utility stations

Many DX-ers find that, after scanning the broadcasting bands for a number of years, it becomes very difficult to add more new countries to their totals.

Apart from the fact that due to various reasons BC (broadcasting) reception will be impossible from certain countries for a longer or shorter period (we need only think of propagation), several radio countries will never be heard at all in certain parts of the world, because their broadcasting services are transmitting on medium wave or FM.

If you haven't heard New Caledonia, Gambia, the Seychelles, the Mariana Islands, Upper Volta, Jan Mayen or even Antarctica, utility DX will enable you to do so.

2. What are utility stations and where to find them

The question "Where are utility stations?" is very easily answered. Utility stations are all radio stations except broadcasting and radio amateur stations. Broadcasting stations transmit for diversion (entertainment and educational information) of a large audience. Radio amateur stations are also operated by radio amateurs to enjoy themselves.

Utility stations are operated for other reasons. They transmit useful information for a very small audience, who needs this information for professional purposes; for scientific studies; for navigation on land, air or water; for communication with each other, etc.

You may look for utility stations everywhere outside the broadcasting and radio amateur bands. And we really mean everywhere. In the entire radio frequency spectrum from 10 kHz up to 30 GHz (=30 gigahertz=30,000,000 kilohertz) all other bands outside the broadcasting and radio amateur bands are assigned to utility stations.

There are many types of utilities, namely standard frequency stations; time signal stations; meteorological stations; radio beacons; aeronautical navigation stations; aeronautical mobile stations; aeronautical fixed stations; aircraft stations; satellite communications stations; satellite tracking stations; maritime mobile stations; coastal stations; ship stations; maritime navigation stations; fixed public stations for radio telephone, radio telegraph, radio teletype and radio facsmile services; fixed and mobile stations for the police, the fire-brigades, the industries; scientific expeditions stations; fixed and mobile military stations; epidemic warning stations; etc, etc.

3. Favourite types of utility DX-ing

An abundance of radio beacons used for navigational purposes by aircraft and ships is to be found in the low and medium frequency bands 70-150 kHz, 285-410 kHz and 510-525 kHz. These stations constantly transmit their 1 to 3-letter identifications in CW (morse) and trying to identify them is known as the best method for learning the morse-code well.

However, the short wave bands from 2-30 MHz offer you a much wider variety of utility stations. Favourite types of utilities on short wave are:

(i) Time signal and Standard frequency stations.
(ii) Maritime communications stations.
(iii) Aeronautical communications stations.
(iv) Fixed communications stations (=PTP-stations).

These four types of utility stations use one or more modulation methods. The modulation methods are:

(i) Continuous wave (CW) radio telegraphy (A1 modulation).
(ii) Tone modulated radio telegraphy (A2 modulation).
(iii) Radio telephony or voice modulation (A3 modulation).

(iv) Radio facsimile (A4 modulation) to transmit a.o. press-photos by radio.
(v) Frequency shift keying (FSK) (F1 modulation) used by radio teletype stations Maritime, aeronautical and fixed communications stations, which use radio telegraphy (A1 or A2 modulation) aren't often listened to, because most DX-ers don't have the gift of being able to write down the used high speed morse. DX-ers normally listen to these stations, when they are using voice (A3 modulation).

Time signal and Standard frequency stations also often use morse, but they can be identified more easily. These stations always use slow speed morse, so that you can put down the points and dashes in a note-book and after that you can translate the signs into ordinary letters and figures.

Only a few DX-ers are so lucky to have a telex machine connected to their receiver to intercept radio teletype transmissions (F1 modulation). As far as we know, there are no DX-ers who have the equipment to receive radio-facsimile transmissions (A4 modulation).

B. TIME SIGNAL AND STANDARD FREQUENCY STATIONS

1. "Beep-beep" DX

Listening to Time signal stations and Standard frequency stations is a special and interesting aspect of the DX-hobby. Those who don't realize the need of these stations, should try to imagine a world without a proper time standard.

Besides all sorts of every-day difficulties that would occur, space programmes and other scientific research would be impossible.

Apart from the fact that those services supply us DX-ers with a constant and accurate time, the Standard frequency stations are of great help in determining given frequencies you may want while scanning the bands. In other words, you can calibrate your set and/or figure out its pointer deviation by tuning in to one of the well-known Standard frequency stations.

To many it is an unknown fact that these services have been run from the very early days of radio way back in the twenties. A transmitter was installed on top of the Eiffel Tower in Paris and the United States Navy (at present still operating such stations on Guam, Hawaii and in the Canal Zone as well as on the North American continent) also transmitted time signals, mainly for the purpose of adjusting ships' navigational equipment.

Many stations around the world are still transmitting time signal services for the same purpose in the coastal bands. Other stations offer their services for the benefit of numerous branches of science, such as seismology, meteorology, astronomy, geodesy, etc.

Among the stations a constant effort is being made to co-ordinate their time internationally so that in the future they will all be able to maintain and supply a worldwide time standard without the slightest deviation.

2. High precision of time signals

An important frequency range for scientific research is the very low frequency (VLF) band which runs from 10 to 150 kHz. The intensive use of this band has a number of obvious advantages over the high frequency (HF) radio spectrum. The VLF-band guarantees continuous and reliable reception over very long distances all year round and this is a necessity for stability and extremely high precision, whereas the HF-bands are affected all the time by various propagational phenomena. Unfortunately, very few DX-ers have this band on their receiver.

However, those of you who would like to have a go at these interesting stations, should try the standard frequencies in the HF-range, viz. 2.5, 5, 10, 15, 20 and 25 MHz. As most of the stations operating on these channels use atomic frequency control, you couldn't wish for a better means to check your receiver's calibration. Caesium beam standards which seem to be the last word in highly precise frequency standards.

Some of these stations may easily be identified since they use voice announcements for their time checks. Among them are:

FFH Paris, the two Italian stations IAM and IBF, JJY Japan, LOL Argentina and WWV Fort Collins, Colorado (USA) and WWVH in Hawaii, both operated by the National Bureau of Standards. This institute is known to have the most advanced services and probably also the highest precision (people speak about deviations of a thousandth of a second!).

The time given over WWV and WWVH is in Greenwich Mean Time (or UT2, as the world time standard of the Bureau International de l'Heure in Paris is scientifically known) every five minutes both in voice and morse and in addition time information giving the second, minute, hour and day of the year is emitted in a special code ten times per hour.

Musicians may even tune their instruments to the tones given and also accurate and valuable propagation information is furnished in the transmissions. These tones may also be useful to determine whether your crystals still have the exact value. A number of stations work in the bands allocated for the use of stations operating fixed circuits (the PTP bands) and for a start you may try to log the only two of this category using voice announcement, i.e. VNG of the Australian Post Office (4500, 7500 and 12000 kHz) giving an hourly 1-minute identification and CHU of the Dominion Observatory in Canada (3330, 7335 and 14670 kHz) which has a time check in English and French every minute.

All stations have second pulses which are a certain number of cycles (mostly 5) out of 200 Hertz. New minutes may be indicated by skipping a pulse or by prolonging one.

3. Long-term reports

If you have trouble hearing a given station, it will help if you ask for the station's transmission schedule, because it may have changed or the station may have moved to another frequency as propagation conditions require. Having their detailed schedule at hand may also facilitate identification.

Most stations will appreciate your letters, but you should pay special attention to your report as it will generally reach scientists. Therefore include as many details about your reception as possible: the way the minutes are marked, whether modulated or unmodulated pulses are used, the exact wording of the announcements, etc.

You should also be aware of the fact that a report about one single reception is of little or no interest to the station: better make a comparative report featuring a longer period. You will be rewarded and enjoy this "beep-beep" DX.

C. MARITIME COMMUNICATIONS STATIONS

1. The Maritime short wave bands

Maritime stations can be divided into three types: the stations operating ship-to-shore (ship stations working to coastal stations), the stations operating shore-to-ship and the stations operating ship-to-ship.

The bands on which these stations can be heard are:

2625-2650 kHz	12330-13200 kHz
4063-4438 kHz	16460-17360 kHz
6200-6525 kHz	22000-22720 kHz
8195-8815 kHz	25070-25110 kHz

The most popular bands for listening are the 2, 4, 8, 12 and 16 MHz bands, for those bands are nearly always used for communications. Each band is divided into two halves. The lower half is assigned to ship transmitters and the upper half to coastal stations (short transmitters).

2. Maritime stations heard in practice

In practice, you mostly hear the shore-to-ship and not the ship-to-shore traffic. The reason for this is the fact that the coastal stations are more powerful than the ship stations. A second fact is, that the ship transmitters always sign-off immediately after the traffic is over. The coastal station however, remains on the air with a modulation signal like an interrupted whistle (e.g. the Dutch coastal station Scheveningen-Radio) or a continuous standard test speech used a.o. by Roma Radio (Italy), Helsinki Radio (Finland), Athinai Radio (Greece) or Saint Lys Radio (France).

All these coastal stations and many others use standard test tapes to keep their frequencies free from interference by other stations. Also, with the help of these continuous identifications, it is possible for the ship station to tune accurately to the coastal station, so that it becomes much easier to contact the coastal station. For the DX-er it is quite simple to identify the station too.

D. AERONAUTICAL COMMUNICATIONS STATIONS

1. The aero bands

Aeronautical communications are the communications between aircraft and ground stations, the ground stations and the aircraft and last but not least the communications from aircraft to aircraft.

The short wave bands which are assigned to these stations are:

2850-3155 kHz	5430-5730 kHz	10005-10100 kHz	17900-18030 kHz
3400-3500 kHz	6525-6765 kHz	11175-11400 kHz	21850-22000 kHz
3800-3950 kHz	8815-9040 kHz	13200-13360 kHz	23200-23350 kHz
4650-4750 kHz		15010-15100 kHz	

The most attractive bands for hunting aero stations are the 5, 8 and 13 MHz bands. The aeronautical ground stations also identify themselves with a short standard test speech on tape or by mentioning their name when calling the aircraft. The name of the station is often the same as the city or island on which the airport is located. The airfield's name can also be used for identification.

Listening to aeronautical ground stations and aircraft stations is rather easy, for many stations use one and the same frequency after each other. The only thing you have to do, is to look for an active channel (frequency) and wait. In this way it is possible to log three or four stations without leaving a certain spot on your dial.

The most important ground stations on the North Atlantic Air Routes are Shannon (Ireland), Prestwick (UK), Gander (Canada) and New York (USA).

2. VOLMET weather reports

Very interesting to listen for, are the so-called VOLMET weather reports, broadcast by the stations of Shannon, Gander and New York. These VOLMET reports are continuously broadcast according to the following schedule:

(a) on 5559, 8828.5 and 13264.5 kHz
at 1000-2200 GMT (period: April 1-October 31)
at 1200-1800 GMT (period: November 1-March 31)

(b) on 3001, 5559 and 8828.5 kHz
at 2200-1000 GMT (period: April 1-October 31)
at 1800-1200 GMT (period: November 1-March 31)

Shannon aeradio is in charge for each first and third quarter of every hour and gives weather forecasts and metreports of Amsterdam, Brussels, Frankfurt, Cologne, Zurich, Geneva, Shannon, Dublin, Prestwick, London, Gatwick, Copenhagen, Orly, Le Bourget, Rome, Madrid, Lisbon and Santa Maria. (Always in this order!) Gander and New York share the second and fourth quarters of the hour and they give the weather conditions on the North American continent, viz. Baltimore, Washington, Philadelphia, New York, Newark, Boston, Gander, Goose Bay, Montreal, Stephenville, Halifax, Toronto, Ottawa, Chicago, Detroit, Sydney, Sonderstrom, Frobisher and Idelwild (Kennedy Airport).

When you listen to these weather reports, you will have the weather information much quicker than in the ordinary way via your local radio or TV station.

3. Reporting Aeronautical or Maritime stations

For reporting aeronautical or maritime communications stations you need some special hints as there are differences compared to BC-DX. First and foremost you must realize that these stations are not interested in reception reports, simply because they don't need them like broadcasting stations do. They get information on the readability of their signals from their corresponding stations and from other official monitoring sources. So, if they verify your report (many do and some have even issued magnificent cards), it is merely out of courtesy. Now you will understand that you should compile a first-class report, as detailed as possible.

To prove that you heard the station, you should copy the details of the weather reports you received, the flight information you intercepted, the wording of the standard test recording transmitted either in morse or voice, etc.

Make your reports as personal as possible (never use a report form!), be friendly and always enclose an international reply coupon. To increase your chance for a verification, write your report in the language spoken in the country concerned, or any foreign language they are likely to understand best. Aeronautical and Maritime DX is a hobby for those who like pioneering: you have to experiment a lot for there are no books covering this subject. This also applies to addresses of these stations, but your report will reach the right destination if you carefully note the station's name and location, mentioned in the identifications. Finally, about the frequency you heard the station. If you use an ordinary receiver, you will find it difficult to determine the exact channel on which you're listening. This problem can be overcome by buying a surplus frequency meter, an inexpensive crystal calibrator, or just indicating verified frequencies on your dial, thus making your own calibration. Frequency calibration may also be facilitated by comparing your frequency to that of a near standard frequency or time signal station.

E. FIXED COMMUNICATIONS STATIONS

1. The magic words "Point-to-Point"

Fixed communications stations maintain radio telephone, radio telegraph, telex and facsimile services from one fixed point to another fixed point. That's why the term "Point-to-Point" (PTP) is used for this type of telecommunications.

The stations are owned by the many PTT-organizations around the world or by commercial companies like American Telephone and Telegraph Company, Cable & Wireless Limited, ITT World Communications, France Cables et Radio, Tropical Telegraph Company, etc.

However, it's a pity that the term "Point-to-Point" is misused by many DX clubs. They think all stations, which aren't broadcasting or radio amateur stations, are Point-to-Point stations. Well, this is completely untrue. Those clubs think they are right, but in fact they don't know the rights of it. PTP-stations are a part of the wide variety of utility stations. Each PTP-station is a utility station, but NOT each utility station needs to be a PTP-station. You can compare this wishful thinking of these clubs with the ridiculous statement "Each animal is a kangaroo".

2. The identification of PTP-stations

The PTP-stations or fixed communications stations mostly use a recorded identification which may be a morse identification, a voice identification or a musical item.

When the stations use A1 or A2 modulation the identification is in morse. It is called a "V-marker", because the call-sign is preceded by a series of V, e.g. "VVV VVV VVV WEK67 ATTC NY K" (VVV means something like "attention". WEK 67 is the call-sign of the transmitter frequency used by the American Telephone and Telegraph Company (ATTC) in New York City (NY). K means "over" or "Please contact us"). When the stations use A3 modulation (full amplitude modulation, single side band, double side band or independent side band transmissions), the identification is a so-called "voice mirror" or "melody mirror".

A "voice mirror" or vm is a recorded standard test speech. It is often multi-lingual and sometimes a short musical item – characteristic for the country – is added.

Some stations have a "melody mirror" as identification. The "melody mirror" or mm consists of a few notes recorded on tape. These stations can only be identified by "hanging-on" till they stop the tape and call their corresponding stations.

The vm and mm standard test recordings are generally in the single side band (SSB) mode, but you shouldn't have any trouble receiving them at normal speech level with a BFO (Beat Frequency Oscillator) on your set. However, as soon as the exchange of traffic starts, the modulation is scrambled for the protection of privacy.

3. Fixed communications bands

On short wave between 2 and 30 MHz there are 32 bands allocated to Point-to-Point stations. They are:

2000-2170 kHz	4750-4995 kHz	9775- 9995 kHz	17160-17700 kHz
2194-2498 kHz	5005-5480 kHz	10100-11175 kHz	18030-19990 kHz
2502-2625 kHz	5730-5950 kHz	11400-11700 kHz	20010-21000 kHz
2650-2850 kHz	6200-6525 kHz	11975-12330 kHz	21750-22000 kHz
3155-3400 kHz	6765-7000 kHz	12925-13200 kHz	22720-24900 kHz
3500-3900 kHz	7300-8195 kHz	13360-14000 kHz	25010-25070 kHz
3950-4063 kHz	8615-8815 kHz	14250-14990 kHz	25110-25600 kHz
4438-4650 kHz	9040-9500 kHz	15450-16460 kHz	26100-27500 kHz

There are some bands which are (partly) shared with other utility services like mobile stations and with broadcasting and amateur stations. Fixed communications stations mostly try to use a frequency as high as possible (think of propagation). Between 15 MHz and 24 MHz you will have the best success to hear them.

4. Reporting PTP-stations

Before sending a report, you must be 100 per cent sure about the station's identity. This is vital. Much harm has been done through careless reporting.

As in BC-DX, it is not necessary to listen to a PTP-station for e.g. at least 15 minutes at a stretch. Only mention the time it took you to copy the vm, mm or V-marker and judge the quality of reception. However, be sure to have a watch at hand with the accurate time when listening.

Mostly the V-marker or the voice mirror is the "programme detail" which proves your reception. It is not absolutely necessary to get the whole wording, but you should do your utmost to copy as much as possible. Other useful details are the times of breaks for communication with the other end of the circuit, and if possible mention which station they were calling. If you can hear the traffic (conversation or morse) that follows, do not mention this in your report.

Since your report generally reaches an engineer, you can in most cases use the Q-code, but it is advisable to describe the reception in words, too. The SINPO-code should be avoided, not only because people cannot use it correctly. Many DX-ers do not care for it, but why not study it from the World Radio-TV Handbook or from How To Listen To the World?

Besides the signals strength (QSA), the type of disturbance should be indicated: BC-QRM, CW-QRM, RTTY-QRM, QRN, QSB. As for QRK (readability), do not write it was "bad". It always is, one could almost say, for PTP-stations use SSB which cannot be received with very good quality on a domestic set not having BFO. Hence, mention if you use a communications receiver or not.

The following particulars must be indicated without exception in the report:

(i) Date and time of reception.
(ii) Frequency.
(iii) Description of the transmission.
(iv) Description of the reception quality.
(v) Type of receiver and antenna used.

Note that there could be a DIFFERENCE IN DATE in your country and that of the station. The time should be given in Greenwich Mean Time and/or the local time of the station. The frequency should be determined as accurately as possible. If not known exactly, indicate that your founded frequency is an estimation by adding "approximately". Never use "metres"!

Remember you are writing to a business-man. Preferably do not use any piece of paper you have at hand but use size A4 or half of it: A5. If you don't have a typewriter, write your letters as carefully and clearly as possible and use block letters for your name and address. Handwriting may differ from one country to another. When people at the station cannot read your address, you have only yourself to blame for not getting a QSL! Also, SIGN your letters and do not just type your name. Always send your reports by air mail with one or more international reply coupons. These should be used according to your own judgement. To most PTT Administrations it is just a waste of money. However, to small stations (or commercial stations) where perhaps a staff member answers the report for the sake of his own pleasure and at his own expense, they will be appreciated.

F. UTILITY DX-CLUBS

Only the larger DX-Clubs the world over, have a column in their DX-bulletin featuring the favourite types of utility-DX in a rather modest way. There exists no DX-Club exclusively dealing with the entire scope of utilities. In the entire world, however, there exists only one DX-Club dealing exclusively with a part of the utility communications stations, namely with the *genuine point-to-point* stations. This club, the Radio Communications DX-Club, was founded by some Swedish top DX-ers in 1961 and transferred to Holland in 1967.

Genuine Point-to-Point is defined by the RCDX as "radio telephone transmissions (A3-modulation) from one fixed landbased station on short wave between 2 and 30 MHz.

The Radio Communications DX-Club distinguishes the following categories of genuine Point-to-Point (all A3 modulation):

(i) National and International Fixed Public Services.
(ii) Military Fixed Communications Services.
(iii) Semi-military Fixed stations (scientific expeditions, satellite tracking stations, etc.)
(iv) Police Fixed Stations.
(v) Aeronautical fixed stations.
(vi) Stations operating fixed programme circuits.

However, it is not easy to become a member of the world's first and only PTP-club, (address cf. WRTH). In the past their information was misused by DX-ers who reported PTP-stations with bad reports just for a try and for fun, with the result that the PTP-stations concerned do not QSL any longer or send out worthless letters. Therefore the RCDXC' policy is not to get as many members as possible but to select some skilful active and advanced monitors in various countries of the world to assist in the promotion of PTP-DX. They have been forced to set some limits and restrictions to new members a.o. 25 genuine PTP-stations verified and contributing at least once a year.

G. EPILOGUE

Before you intend to venture your first step on utility-DX, please note two remarks:

(a) Be 100 per cent sincere. If you hear a utility station and you want to report it, do it in the way we mentioned in this article.

Please don't be a marplot, don't spoil the hobby of other enthusiastic DX-ers by sending out incorrect reception reports.

(b) Before you seriously try utility-DX, you are urged to check, what the laws in your country allow you to do in this field. In certain countries for instance Great Britain and Switzerland, listening to stations other than broadcasters and radio amateurs is a legal offence!

Chapter 9

SINGLE SIDEBAND RECEPTION

by Jim Vastenhoud

One exciting form of shortwave listening, or DX-ing if you prefer, is to tune in to the amateur bands and hear the chit-chat between hobbyists of faraway and sometimes exotic countries, exchanging technicalities or information on propagation conditions in their typical "amateur" jargon. Listening to the amateurs may be the first step towards becoming a "ham" yourself, but many DX-ers like listening to the hambands occasionally, turning to other forms of DX-ing at other times.

For various reasons, many amateur transmitters use a form of amplitude modulation (AM) which is called *single sideband,* or SSB for short. The reception of SSB signals is not possible with a domestic receiver, and requires special tuning skills, even with more elaborate equipment.

Understanding the ins and outs of SSB transmission and the accompanying receiver behaviour is the key to successful SSB reception.

It all starts with the amplitude modulation. In a normal broadcast transmitter, the carrier frequency is generated by a crystal oscillator or a frequency synthesizer. It is amplified in various stages, until it has the required radio frequency (RF) power.

The audio signal, which usually arrives at the transmitter input by commercial line or microwave link, is also amplified in various stages, called modulator stages. The two signals are only brought together after sufficient amplification.

In the process called amplitude modulation, the amplified audio controls the amplitude of the carrier. The resulting signal is entirely at radio frequency, and its momentary amplitude is determined by the audio.

If a 1 kHz tone was used as the audio signal, and a 1000 kHz (1 MHz) frequency as carrier, the resulting AM signal would show *three* signals: the carrier at 1000 kHz, one side frequency at 999 kHz and another side frequency at 1001 kHz.

If the audio signal consists of speech or music, with frequencies varying between 100 and 5000 hertz (Hz), the result of the modulating process is, besides the carrier, a *lower sideband* extending from 995-999.9 kHz and an *upper sideband* running from 1000.1-1005 kHz. See *figure 1*.

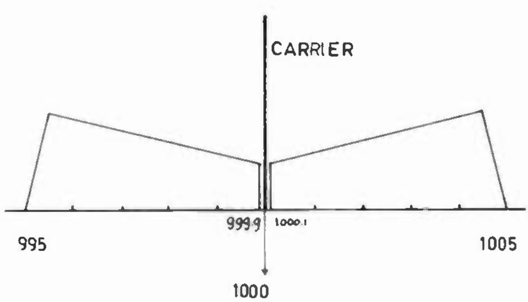


Fig. 1

The level of each sideband has a maximum equal to half the carrier level.

If that maximum happens to be the case, the momentary amplitude of the carrier will vary between zero and *twice* the carrier frequency amplitude. This is called: 100 percent *modulation depth*.

For normal audio signals, the *average* amplitude of the audio will be much lower than the maximum. Anyone who uses a tape recorder and has watched its level meter will know this.

This means that the ratio between the carrier level and the sideband level is usually more than 2:1, a fact which is important to keep in mind.

So far, this basic information on amplitude modulation, or normal AM, has resulted in a carrier, accompanied by a lower sideband extending towards lower radio frequencies, and an upper sideband extending into higher frequencies. The width of each sideband is equal to the audio range allowed to control the RF power amplifier of the transmitter. Together, the two sidebands cover *twice* the audio range.

A normal medium wave, or standard broadcast band transmitter has an RF bandwidth of 9 or 10 kHz, thus enabling the reception of audio signals of up to 4500 and 5000 Hz respectively.

The modern domestic receiver has an intermediate frequency (IF) passband of about 9 kHz, and is thus matched to the transmitter bandwidth.

Amateurs use modulating frequencies of up to 3000 Hz. Thus a ham AM phone transmitter will occupy a bandwidth of only 6 kHz.

By using a different kind of modulator – a so-called balanced modulator – it is possible to get a modulation product which consists of the upper and the lower sideband, but does not show the carrier. This is called DSB, *double sideband*. Both sidebands contain the same information.

Another form of AM, called ISB for *independent sideband*, shows two sidebands, balanced with respect to the same imaginary carrier, but now the lower sideband contains audio information which is different from that of the upper sideband.

ISB uses the same carrier to provide the RF for two independent audio signals.

Yet another form of amplitude modulation is called *compatible single sideband*, or CSSB, It consists of a carrier plus one sideband instead of two, thus saving precious frequency space of the radio spectrum.

Unlike DSB or ISB, CSSB can be received on a normal AM receiver, and the usefulness of CSSB has been tested for broadcast applications in the recent past with mixed results.

Single sideband, or SSB, as you will have guessed by now, consists of one RF sideband only. Amateurs use the lower sideband for 3.5 and 7 MHz operation, and the upper sideband in the 14, 21 and 28 MHz HF bands, and on VHF frequencies.

Normal "double sideband plus carrier" AM is the simplest form of amplitude modulation. It is also the easiest AM-mode to tune into: the carrier is located exactly at mid-band, and the sidebands extend symmetrically from it. This makes receiver tuning easy, and a simple automatic gain control (AGC or AVC, the "V" stands for "volume") can derive a control voltage from the ever present carrier to regulate the amplification rate of the front-end receiver circuits. Also, the carrier is needed in the process of *demodulation*, also called *detection*. The detector is a receiver circuit which separates the RF from the audio.

In CSSB, the carrier is there, and one sideband. Tuning, however, is more difficult, as the signal is no longer symmetrical. Also, the use of a smaller receiver bandwidth is recommended (5kHz) to ensure interference-free reception.

Before we turn to SSB reception, it is essential to show you a part of the block diagram of a receiver. The front end, comprising the antenna, oscillator and mixer circuits, is not shown, as it is not essential for SSB reception. See *figure 2*.

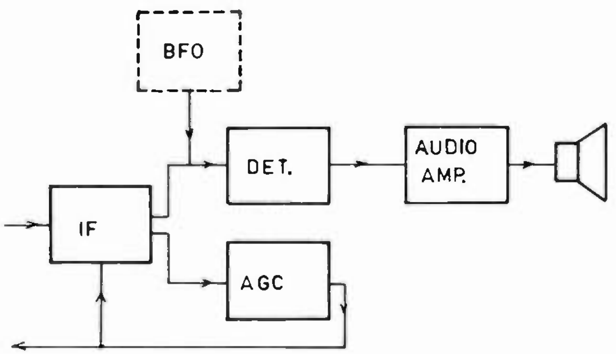


Fig. 2

The RF signal to which the front end of the receiver is tuned, is converted into an IF signal, usually in the vicinity of 450 kHz. The IF amplifiers are all tuned to this frequency, providing the receiver with the desired selectivity.

The amplified IF *carrier* controls the AGC circuit, which then produces the AGC voltage that controls the amplification of the front end and some of the IF circuits, thus maintaining a reasonably constant sound output of the receiver, even though the incoming antenna signals may vary considerably in level. Often, the AGC voltage also controls the signal strength indicator.

The lack of a carrier in the signal offered to the detector stage and the AGC stage, renders the receiver unsuitable for SSB processing, as the carrier is a necessary element in the demodulation process as well as in the forming of the AGC voltage. Incorrect functioning of the AGC unit results in uncontrolled RF signal amplification in the radio frequency and intermediate frequency sections of the receiver. So, what extra requirements are needced for a receiver which must also be suitable for SSB reception?

First and foremost, we need a *beat frequency oscillator* (BFO), sometimes called *carrier insertion oscillator* (CIO), which is able to insert a tiny carrier at the right place in the circuit, to aid in the demodulation process. The BFO delivers a signal equal – or nearly equal – to the intermediate frequency of the receiver, at a stage just prior to the demodulator.

The BFO signal will beat with any carrier within the IF passband of the receiver, producing a whistle, the pitch of which indicates the frequency-difference between the oscillator signal and the carrier of the incoming station.

However, no beat note will result in SSB reception of a single channel, as the carrier is not available. The BFO is used to replace the missing carrier, and to qualify for this task, it must be in the correct "place" with respect to the sideband, and it must be at the correct level, compared to that of the SSB signal.

These conditions, simple as they sound, have far-reaching consequences. In the first place, the frequency of the BFO as well as the receiver circuitry have to be electrically stable, to avoid "drifting" of the signal, resulting in the constant necessity for retuning.

Since the frequency tolerance for good detection is very small (100 Hz), many receivers – especially the domestic types – do not have the required circuit stability, especially in the higher frequency bands where even a percentage-wise small frequency drift results in a considerable frequency shift.

For reasonable demodulation action, the BFO level has to be about 6 to 10 times as strong as the SSB signal. This can be attained by switching from *automatic* gain control to *manual* gain control (MGC): the voltage which controls the front end amplification of the receiver is now regulated by hand instead of automatically. Another method to find the correct balance between signal level and BFO level, is to switch the AGC circuit off and to reduce the amplification of the front end circuits of the receiver by operating the RF gain control.

The ratio between BFO level and signal level is less critical, and the overall result of demodulation more distortion-free when a so-called *product-detector* is used.

The use of a product detector in combination with a BFO is almost a necessity, no matter how the various signal levels are controlled. A schematic diagram and building instructions of such a unit can be obtained free of charge from the English Section of Radio Nederland in Hilversum, the Netherlands (PO box 222).

The passband of a modern radio receiver is 6 to 9 kHz. For SSB, 3 kHz is recommended. A multipurpose receiver will thus be equipped with a variable or switchable bandwidth, on which 3 kHz is a position.

So, the practice of SSB tuning boils down to the following:

- switch off the AGC, or switch to MGC
- turn the volume control up
- turn the RF gain control halfway down
- switch the bandwidth-selector to 3 kHz
- tune into an SSB station for maximum "noise"
- turn on the BFO
- manoeuvre the station in the right position with respect to the BFO carrier. The sound will then be (nearly) intelligible. Both the tuning control or the BFO frequency control (if any) can be used
- adjust the RF gain and/or the MGC control.

If some of these operations cannot be carried out, don't panic, because there are still a few things you can do to obtain a provisional SSB reception.

Two conditions, however, have to be fulfilled: the receiver must be equipped with a BFO, and the circuit stability must be adequate. The latter may already be the case on some of the large SW portables, and on most communications-type receivers for amateur or general purpose.

If the AGC-circuit cannot be switched off, you could try to reduce the antenna input signal by using a small antenna, or by introducing an attenuation network in the antenna.

The audio spectrum at the receiver output can be limited by manipulating with the bass and treble controls, and this can have an effect which is more or less similar to that of bandwidth limitation with the "selectivity" or "bandwidth" switch. The combination of BFO + product detector can help a lot, as we have already pointed out. And, if you leave the connection of this unit to a professional, you might ask him to provide an MGC control as well.

Special SSB receivers have a modified AGC for SSB reception. Of course, it is hard to tell you in print how SSB tuning should be done. This rough approach is meant to show you *why* you have to carry out the various operations to arrive at acceptable SSB tuning. The receiver manual will give you additional information on this subject, if a BFO is part of the circuit. Apart from that, experience will show you how tuning into SSB stations is best and most simply achieved with *your* receiver. That, in fact, is the art of SSB tuning.

For *broadcast* listening, this form of single sideband is not usable at all, as tuning is too complex and time-consuming, and receiver circuits lack the required stability. If SSB is ever to be considered seriously for AM broadcast reception, another – less pure – form of SSB transmission will probably be chosen: single sideband with a "residual" carrier, merely acting as a "pilot" frequency, for the CIO of the receiver to lock into. Synchronizing circuits which can compare the two frequencies and vary the BFO frequency until it is in tune with the pilot frequency, are a standard item nowadays, and its mass production will only lead to a minor price adjustment of the receiver.

Still, tuning is different from AM, to which everyone is accustomed, and this raises the question of acceptance of single sideband with reduced carrier type modulation by the general public. So, it would seem that broadcast SSB is still far from being realized.

Chapter 10

LISTENING TO THE AMATEURS

by Roy Stevens, G2BVN, Radio Society of Great Britain

In the very early days of radio, around 1905, when spark gap transmitters and crystal receivers were the latest techniques, there were a small number of experimental stations owned and operated by private persons who were interested in the development of the, then, new science of radio. This handful of constructors and operators were the forerunners of the present amateur stations of which there are about 380,000 in the world today.

Since the earliest days amateurs have been responsible for development and progress in communications. It is a recognition of this fact that the Geneva Radio Regulations, 1959, which lay down world wide rules for all types of Radio communication, recognize amateur stations as a "service" in the following terms: "A service of self-training, inter-communication and technical investigations carried on by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest."

For frequency allocation purposes the International Telecommunications Union divides the world into 3 regions. Broadly, these are Region 1 – Europe and Africa; Region 2 – North and South America; Region 3 – Asia and Australasia.

The first wavelengths on which amateur stations were operated were those on which today the medium wave broadcasting stations are heard. After the original frequencies had been found suitable for communication purposes they were taken over by the broadcasters and the amateurs were given bands in that part of the frequency spectrum known as the short waves and lying between 1.5 and 30 MHz. It was generally assumed at that time that these wavelengths were unsuitable for long distance communication but it was not long before the amateurs were taking part in world wide conversations using only very low power equipment.

Bands used by amateurs:

The high frequency (or short wave) bands on which amateur stations may be heard differ slightly in various parts of the world and the following figures refer to Region 1 (Europe and Africa):

1800 to 2000 kHz (in some countries only)
3500 to 3800 kHz (80 metres)
7000 to 7100 kHz (40 metres)
14000 to 14350 kHz (20 metres)
21000 to 21450 kHz (15 metres)
28000 to 29700 kHz (10 metres)

It should be noted that the bands commencing at 1800 kHz and 3500 kHz are what is known as "shared" bands. This means that stations other than amateurs may be heard on these bands, and, in Region 1, fixed and mobile stations of many types will be heard. The remaining bands are known as "exclusive" bands and on these only amateur transmissions should be heard.

In addition to these bands the amateurs are able to use certain portions of the very high frequency (VHF) bands. The most popular allocations are between 144 and 146 MHz and between 430 and 440 MHz and these are often known as the 2 metre and 70 centimetre bands respectively. At one time these bands were not used to any great extent but technical progress has increased their popularity and they are now used, amongst other purposes, for listening to and communicating via space satellites. There are also other amateur bands still higher in frequency but to listen on these demands specialized equipment which the ordinary short wave listener will not usually possess.

How the bands are used:

1800 to 2000 kHz

This is used by only a few countries, but there are a large number of stations in the UK and the USA who may be heard when conditions are suitable. Amateurs generally use this band for short distance working up to 500 kms. or so, but under exceptional conditions stations from North

America may be heard, in addition to amateurs, ships and coast stations together with various beacons which are used for maritime radio navigation. The power which amateurs may use on this band is restricted, and consequently their signals may often not be very strong.

3500 to 3800 kHz

This is a very popular band and is used by stations all over the world. The listener will hear two types of conversations on this band. The first will be between stations who are generally within 500 kms of each other, whilst the other will be between stations who may be thousands of kilometres apart. During the hours of daylight one will generally hear only local and semi-local stations inside the distance mentioned, but after dark the range increases and stations up to 1500 kms. away may be heard. The band is generally better for long distance communication during the winter than during the summer, and under good conditions conversations between stations in Europe and stations in North America, Australia and New Zealand may be heard. As already mentioned this is a "shared" band and at times a number of non-amateur stations will be heard. These stations often operate with high power and can make listening conditions very unpleasant. However 80 metres is a good band for listening to both local and long distance conversations, when conditions are suitable, and the listener will generally find much of interest.

7000 to 7100 kHz

This is a band on which stations up to 1500 kms away may be heard during the hours of daylight with also the possibility of stations even further distant. In Europe this means that at the right time one can hear stations in the Near East and Africa. The best conditions for long distance communication occur after dark and at this time the possibilities of this band are world wide. However, there are many high powered broadcast stations transmitting on this band which was allocated by the ITU for exclusive amateur use.

These broadcasts create considerable interference, particularly during the evening hours, and make listening conditions difficult. However, when the broadcast stations are not active, particularly in the early morning, many long distance stations may be heard.

14000 to 14350 kHz

This is the band which carries most of the amateur long distance communication. Conditions vary according to the time of year and also the time of day, but generally one can always expect to hear some interesting signals. On a typical day, one would hear stations from the Pacific, Australia and New Zealand in the early mornings up to about 0900 GMT. After this time there would be stations from many European countries and during the early afternoon one would hear signals from the Near East and Asia. A little later stations from the Malaysia/Singapore area should be heard and around 1700 signals from Central and South Africa frequently make their appearance at good strength. Amateurs in North America may be heard at many different times on this band but conditions for their reception will often gradually improve during the evening, reaching a peak before midnight. Also at this time stations from the numerous South American countries will be heard.

21000 to 21450 kHz

This band often produces excellent signals from all parts of the world, but the reception conditions are greatly dependent upon sun spot activity. The pattern of reception during daylight hours is similar to that of the 20 metre band but conditions after dark are less productive and this band will close well before midnight (in Europe) unless there are exceptionally good conditions. There are fewer stations active on this band than on the other bands so far mentioned, and this often means that distant stations may be heard without the problem of interference. It is certain that this band will come into increasing use in the years ahead and it is one that should not be neglected.

28000 to 29700 kHz

In terms of frequency space this is the widest high frequency band available to amateurs. Unfortunately however, conditions are very variable and it is relatively little used in comparison with other high frequency amateur bands. However, when there is a reasonable level of sun spot activity stations from all parts of the world come in at excellent strengths and conditions for good long distance reception can often be better on this band than on all the others so far mentioned.

Generally, conditions are better during the winter months and during the hours of daylight. In the years immediately before and after the peak of a sun spot cycle listeners in Europe will hear many North American stations from both the Atlantic and Pacific coasts. However, reception is not confined to the transatlantic path and stations in Africa, Asia and Australia will be heard at good strength when conditions are suitable.

VHF bands:
The two bands that are most used by amateurs in this part of the frequency spectrum are 2 metres (144-146 MHz) and 70 centimetres (430-440 MHz).

Generally conversations on these bands are restricted to relatively short distances, i.e. up to a maximum of 500 kms, except when there are unusual propagation conditions. When these occur it is possible to hear stations located in many parts of Europe that are not normally received. A modern development for communication on these bands is the use of satellites carrying radio equipment.

These satellites carry beacon transmitters which operate continuously and Oscar III and Oscar IV also carried transponder units. These consist of equipment which receives a radio signal and re-transmits it on another frequency. By this means amateur stations have been able to communicate over distances far exceeding the normal possibilities for these VHF bands.

When can amateurs be heard?
Information has been given as to the wavelengths on which a listener may hear amateur stations and some indication of when these stations may be heard will prove useful. It will be appreciated that due to the time differences throughout the world a listener in Europe may be active when his counterpart in the USA is still asleep. When it is desired to listen for amateurs in a particular part of the world one should always consider whether in view of the time difference there is likely to be any activity.

Conditions on the bands up to 30 MHz are governed by 3 factors:

1. The stage of the sun spot cycle.
2. The time of year, and
3. Whether it is daylight, or darkness.

The sun spot activity runs in 11-year cycles and the last minimum occurred in July 1976. This means that for the next three to four years sun spot activity will increase giving rise to better conditions for long distance communication. There will be some alteration in propagation conditions (in Europe) according to the time of year and generally the Equinox periods give best conditions for reception. These are the periods of equal day and night in the Northern Hemisphere and occur in March and September. The effect of the time of year will be more or less noticed according to the stage of the sun spot cycle, but it is not possible to give definite predictions. Conditions vary considerably between the hours of daylight and darkness and the effect of this depends on the frequencies that are being used. For instance, on the 80-metre and 40-metre bands one would expect conditions for distant stations to improve during the hours of darkness but on 15 metres and 10 metres the reverse would be the case.

Transmissions from amateur stations
The location of amateur stations can be determined from the first part of the call sign that they use, i.e. the call ON4VY may be heard and reference to the list of prefixes (page 190) will show that ON4 is used by stations in Belgium. Following the prefix shown in the table there are usually an additional 1, 2 or 3 letters forming the personal call of each operator. The communications between amateur stations generally refer to the type of equipment in use, e.g. the transmitter, receiver and aerial, their location together with other personal information. When an amateur station reports the strength of the signals that he is hearing from the station with whom he is talking the RST Code will be used. The meanings of the letters and numerals forming this code are shown in the RST Code table. Another code which is frequently used by amateurs is the "Q" code, this was originally used by stations using telegraphy but many sections of it are used in speech transmissions and examples are given in the International Q Code table. Amateurs participate in scientific projects of many kinds and conversations will often be heard which deal with propagation conditions and the testing of various types of aerials.

When an amateur wishes to obtain written confirmation of the conversation over the air a QSL card will be sent. This QSL card contains details of the sender's stations and also the time, signal strength and other details relating to the conversation. This card may be sent direct to another station but often it is sent, with other cards, to a QSL Bureau. Most National Amateur Radio Societies maintain a QSL Bureau and the addresses of these are given in the accompanying table. The report from the listener to the amateur transmitting station should be as useful as possible. The listener should send his card or report to the QSL Bureau of the appropriate National Society, and they will be sent on from there to the individual station to whom they are addressed, for example, all QSL cards for stations in the UK should be sent to G2MI.

Suitable receiving equipment

Many listeners will have receivers of the type designed for listening to short wave broadcast stations. It is possible with some of the better receivers to successfully listen to amateur transmissions, but generally the results will not be entirely satisfactory. It will be appreciated that the power used by amateur stations is considerably less than that of broadcasters, and therefore a suitable receiver must have good sensitivy, in other words, it should be capable of picking up signals that sometimes may be of weak strength. Due to the large number of amateurs working in relatively narrow bands there are frequently severe problems of interference between stations, and in order to overcome these a receiver must have reasonable selectivity, i.e. to be capable of receiving a transmission without experiencing interference from other nearby stations. In order to facilitate the tuning-in of amateur stations the receiver should have a suitable operating dial with a slow motion arrangement. Ideally this calls for a gear operated dial rather than the type using a dial cord which is often jerky and uncertain in operation.

Another possible solution to the reception problems is the use of a short wave converter, the output of which is fed into the aerial terminal of a broadcast receiver. In this way one can have the use of a suitable dial and tuning arrangement on the converter and use the broadcast receiver as the i.f. amplifier and audio output.

A most important item of equipment in the listening station is an efficient aerial system. Without this, even an expensive communications receiver will be of little use. The aerial should be designed for the frequencies on which it is desired to receive amateur signals and the feeder should preferably be of the coaxial cable type matched to the input of the receiving equipment. Whatever type of aerial is used it should be located as high as possible and away from surrounding objects. The use of coaxial feeder will ensure that the pickup of electrical interference is kept to a minimum. In cases where it is difficult to erect an aerial which will match the receiver the problem can be overcome by the construction of a small aerial tuning unit. When it is desired to obtain the best results a directional aerial can be erected. This can either be a wire aerial so fixed as to provide the best reception in certain directions, or an aerial constructed from aluminium tubing and rotated electrically can be used. The latter type of aerial is known as a beam and is frequently used by amateurs for transmission and reception on the 14, 21 and 28 MHz bands.

Operating certificates:

There are many keen short wave listeners who have obtained a number of QSL cards from amateur transmitting stations and are able to use these cards in order to qualify for one of the many certificates or awards that are now available. The majority of the certificates are issued by the National Radio Societies of the various countries, e.g. EDR in Denmark, DARC in Germany, and RSGB in the United Kingdom. However, there are other certificates which are awarded by publishers of amateur radio magazines, but these are rather fewer in number. At the present time there are more than 600 certificates available to a licensed amateur. Generally an applicant shall be able to produce proof (in the form of QSL cards) of hearing a certain number of stations in a certain area, for instance the British Commonwealth. Radio Reception Award, issued by the RSGB requires that amateur stations in fifty of the various British Commonwealth call areas should have been heard. In order to claim this, and also the majority of the many other awards issued by the National Societies, it is generally necessary to send a list showing the stations heard, together with the appropriate QSL cards, and also return postage for the latter. Several years ago an organization was founded in the USA by Clif Evans K6BX, and called "The Short Wave Listener's Certificate Hunter's Club", usually abbreviated to "SWL-CHC". The objects of this Club are to encourage short wave listeners in the pursuit of their hobby and to promote good-will and common interests, and it now has a world-wide membership of persons interested in short wave listening. There is a book which contains details of practically all the certificates now available, and this is the "Directory of Certificates and Awards" published by K6BX. There is a complete issue of the Directory published quarterly during each year, and each issue costs $2.50 from K6BX (3212 Mesa Verde Road, Bonita, California 92002, USA).

Many listeners to amateur stations often become interested deeply and subsequently obtain a transmitting licence, however, there are many interesting projects sponsored by national societies and other organizations in which listeners are able to participate, thus performing work of a scientific nature in addition to enjoying an exciting hobby.

THE RST CODE

Readability

R1 Unreadable.
R2 Barely readable, occasional words distinguishable.
R3 Readable with considerable difficulty.
R4 Readable with practically no difficulty.
R5 Perfectly readable.

Signal Strength

S1 Faint, signals barely perceptible.
S2 Very weak signals.
S3 Weak signals.
S4 Fair signals.
S5 Fairly good signals.
S6 Good signals.
S7 Moderately strong signals.
S8 Strong signals.
S9 Extremely strong signals.

Tone

T1 Extremely rough hissing note.
T2 Very rough a.c. note, no trace of musicality.
T3 Rough, low-pitched a.c. note, slightly musical.
T4 Rather rough a.c. note, moderately musical.
T5 Musically modulated note.
T7 Near d.c. note, smooth ripple.
T8 Good d.c. note, just a trace of ripple.
T9 Purest d.c. note.

THE INTERNATIONAL Q CODE

The following Q signals taken from the official list are widely used by Amateurs.

QRG Will you tell me my exact frequency? Your exact frequency is.........kHz.
QRH Does my frequency vary? Your frequency varies.
QRI What is the tone of my transmission? The tone of your transmission is.........(amateur T1-T9).
QRK What is the readability of my signals? The readability of your signals is.........(amateur R1-R5).
QRO Shall I increase power? Increase power.
QRP Shall I decrease power? Decrease power.
QRT Shall I stop sending? Stop sending.
QRU Have you anything for me? I have nothing for you.
QRV Are you ready? I am ready.
QRX When will you call me again: I will call you again at.........hours.
QRZ Who is calling me? You are being called by.........(on kHz).
QSA What is the strength of my signals? The strength of your signals is.........(amateur S1-S9).
QSB Are my signals fading? Your signals are fading.
QSL Can you give me acknowledgement of receipt? I give you acknowledgement of receipt.
QTR What is the correct time? The correct time is.........hours.
QTH What is your location? My location is.........

Chapter 11

TELEVISION DX

by Veli Matti Kuparinen

Long Distance Television reception first became established as an alternative to short wave radio reception in the USA in the late 1940s and this hobby has spread rapidly among radio enthusiasts and DX listeners. Television as an audiovisual medium offers the enthusiasts an agreeable and interesting field since the screen of the television set presents a new dimension, that of the moving picture. In this article I should like to try and give further information on the fascinating world of television reception. This story is based on the experience of my fellow enthusiasts during a couple of years in Northern Europe and I do not claim that the knowledge contained herein is the final truth. In this article I will concentrate mainly on VHF (lower channels) reception. In this article I only want to give the basic information on long distance television reception, so that anyone interested in staring at the foreign and/or distant television programmes on the screen, can start his career within this attractive TV field. I think that TV DX is quite similar at least in the rest of Europe, so the following information can be used by many people.

As most readers know, only a limited number of local television stations are visible at reasonable strengths in their particular area. Tuning into other channels will often reveal somewhat weaker signals from adjoining transmission areas. At some favourable high locations a number of alternative programmes may be available at fair signal strengths, thus prompting the viewer to erect suitable aerials to enable reception of stronger and more consistent signals. A person is usually introduced to TV DX by the appearance via the local television station, of patterning or some similar effect, from another transmitter using the same frequency. Should the local TV station be on a frequency below 70 MHz, such interference may prove extremely severe especially during the summer months. The majority of viewers will endure this interference grudgingly, but occasionally an inquisitive viewer, when interference occurs, will make a point of tuning into alternative channels to view (after a fashion) these different programmes. If his interest is sustained, further efforts are usually made to improve his aerial system to receive the more difficult stations travelling over considerable distances.

Bands used for TV

Television signals are transmitted at VHF (Very High Frequency) or UHF (Ultra High Frequency). Such frequencies must be used for television due to the extremely wide bandwidths required to transmit high definition vision and sound information. Due to the use of VHF and UHF, television transmissions are limited to the area surrounding the transmitter, extending to the optical horizon and a little beyond at lower field strengths. With a few exceptions the same frequency bands are used in all countries for television transmissions. Band I extends from 41 to 68 MHz; this is followed by band III which covers the frequencies from 174 to 223 MHz, and bands IV and V (=UHF) which range from 470 to 960 MHz. Band II (87.5 to 100 MHz) is reserved for frequency modulation radio transmissions. The most distant television transmissions, as far as I know, are usually seen on the channels of Band I, and so I will pay most attention to the reception of the channels in question.

Propagation

There are five main types of reception usually encountered by the active TV DX-er, and these have been separated into each mode of propagation, and briefly described. A number of photographs included in this article are to illustrate the good quality of signals which can be achieved with relatively simple equipment.

a) *Tropospheric propagation*

Under normal atmospheric conditions the coverage area from a local television transmitter extends just beyond the optical horizon; at this point signals start to fall off in strength rapidly.

Viewers living in such a fringe area will have noticed that during certain conditions the signal improves considerably or they will notice interference from another transmitter. Such conditions are related to the prevailing state of the troposphere, which is that part of the Earth's atmosphere adjacent to the ground and extending upwards to about ten kilometres.

During certain meteorological conditions, an extension to the normal service areas may occur, signals being propagated for considerable distances, often sustained over a periods of days. A period of abnormal tropospheric propagation will often occur during very settled, warm anti-cyclonic weather conditions, usually during the summer months, although such conditions may prevail at any time of the year. During these settled anti-cyclonic conditions, a temperature inversion may occur soon after sunset, caused by the surface temperature dropping more rapidly than that of the air. Fog can often produce excellent propagation during settled periods, mainly during the autumn and winter months.

All the frequencies throughout bands I-V are affected to varying extents by abnormal tropospheric propagation. Band I frequencies generally tend to be less favourably propagated over the longer paths than those of band III frequencies. Reference to the synoptic charts, issued daily in newspapers, will normally show the possibilities of any abnormal tropospheric propagation. Reception is often favourable along a path parallel to the prevailing isobar pattern rather than across the pattern.

As the high pressure system moves away, another effect, tropospheric ducting, often occurs. Signals are ducted along the trailing edge of the system over some considerable distance. The upper air duct can be selective both in frequency and distance, often a distant transmitter is received, whereas a closer transmitter operating on the same frequency is by-passed.

Distances usually covered in these propagation modes can be up to 1,500 kilometres for both VHF and UHF signals. Exceptionally good signal strengths are sustained over sea water paths.

b) *Sporadic E*

By means of short wave radio it is possible to transmit signals to distant countries and around the world itself. Such communication is dependent upon a number of reflecting layers high above the earth's surface known as the E, F_1 and F_2 layers. The E layer lies at an approximate height of 100-120 kilometres, and under normal conditions reflects short wave signals, VHF and UHF signals passing straight through this layer and indeed F layers and are lost in space. At certain times, however, patches of the E layer become intensely ionized and reflect signals back to Earth at frequencies well into the VHF spectrum. During such conditions television transmissions in Bands I, II and very occasionally Band III are capable of being reflected, allowing reception at distances upwards of 800 kilometres.

The exact causes of Sporadic E are unknown, although various theories have been presented as to its origin. These have discussed meteor ionization, thunderstorms, ionospheric winds causing electron density fluctuations in the E layer, producing E layer irregularities which then serve as a reflecting surface; and effects resulting from sunspots.

Sporadic E produces a relatively small area of intense ionization in the E layer, sufficient to reflect frequencies up to 100 MHz. Sporadic E can occur at any time of the year, the most active period is during the summer months, from early May to September, the peak of activity centred around June. Some years a small peak has been noted in mid-winter. It has been also noted that favourable Sporadic E conditions have been experienced during periods of thundery weather.

The frequencies affected cover all of band I and extend into band II, but no instances of Sporadic E in band III have been seen. Distances covered for single hop reception are from 800-2,500 kilometres, ignoring any tropospheric effect at either end of the propagation path. It is unusual to experience skip distances of less than 800 kilometres. Double and triple hop reception can also occur. The duration of Sporadic E signals can range from a few minutes to several hours, often at sustained high signal strengths. For the beginner with littie experience of TV DX-ing, Sporadic E is recommended for initial experiments, as spectacular results can be obtained with the minimum of equipment.

c) *F_2 layer reflection*

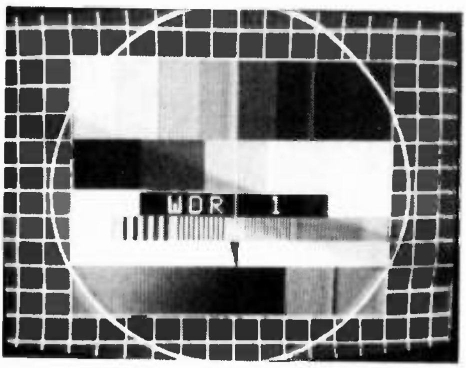
Sunspot activity reaches its peak of activity at approximately 11-yearly intervals, and falls again to a low figure. The rise to maximum solar activity is generally short, with a longer decreasing phase as activity falls. At times of high sunspot activity, the highest reflecting layer, the F_2 layer, becomes densely ionized by ultra-violet radiations from the sun. This allows incident high frequency signals to be reflected to Earth at considerable distances. At periods of high solar activity the MUF (Maximum Usable Frequency) rises and the F_2 layer is able to reflect signals over very long distances; a maximum single hop can reach up to 4,000 kilometres.

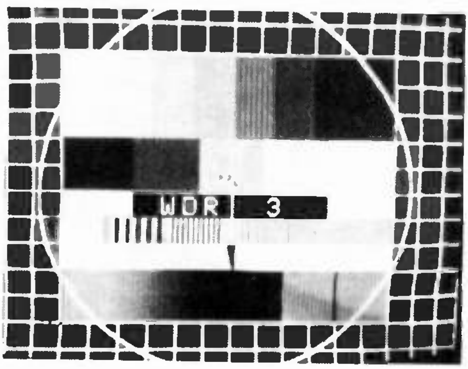
The MUF is generally higher during the winter period, than that of the summer period; and in all seasons the MUF has a peak of high frequency activity of several hours at noon. F_2 reception will often occur when noon is at some point on the propagation path between the transmission and receiving sites.

d) *Meteor shower reception*
The passage of a meteor through the E layer of the ionosphere leaves an ionized trail, often of sufficient density to enable an incident signal from Earth to be reflected back, its reflected strength and duration directly proportional to the electron density of the meteor trail in question. Such a trail will allow a strong reflection back to Earth. The times and directions of many meteors are entirely random, there being relatively constant meteor activity throughout the 24 hours, although there is greater activity over the early morning period.

Frequencies affected by meteor shower propagation tend to favour Band I. Distances covered by meteor shower are approximately 800-1,700 kilometres. The characteristic signal via meteor shower reflection is of a short burst, or rapid fluctuation in received signal strength over several seconds.

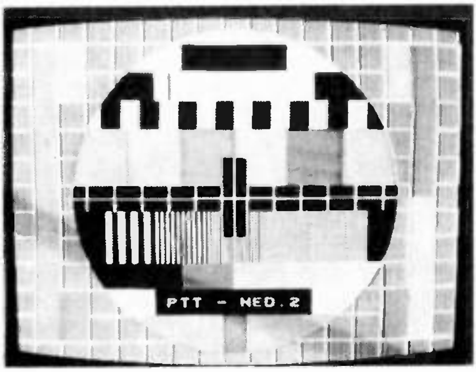
e) *Auroral reflection*
Auroral reflection is caused by solar flares and eruptions on the surface of the sun. This produces iniospheric and magnetic storms in the Earth's D, E and F layers, causing an Aurora, which can be seen visually as a display of light and appropriately known in Northern Europe as the Northern Lights. The Aurora produces a reflecting sheet, which lies in a more vertical plane and it is possible to obtain reflection on this sheet at VHF. As the auroral sheet lies to the North, it follows that the transmitted signal will be received from a northerly direction, rather than the true direction of the transmitter, which may be in another direction. Frequencies mainly affected are in Bands I and II. Vision signals tend to be poorly propagated via auroral reflection, generally with severe smearing and distortion.





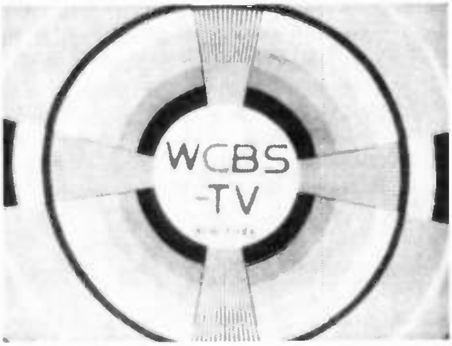
Equipment needed
The equipment used by the TV DX-er will vary considerably, depending on how deeply interested he is in the hobby. The television receiver intended for long distance reception can range from one of the older single standard receivers and modified to cater for the different standards. So the enthusiast can use a receiver intended only for normal domestic use.

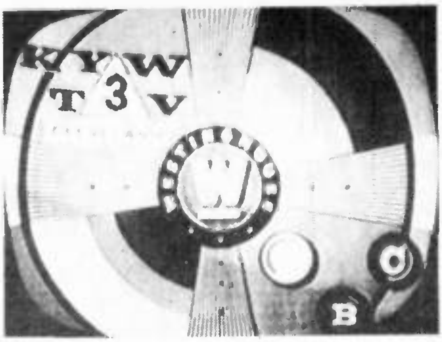
The types of aerial used by TV DX-ers vary widely, again depending on the interest created. Several enthusiasts concentrate on Sporadic E only, and in view of the strong signals at times encountered, use only simple arrays. Other DX-ers, interested in most modes of propagation, erect multi-element arrays for each band in question. The most simple aerial encountered for television reception is the half-wave dipole. This comprises a single rod cut to the appropriate operating frequency.



Station identification

To identify the source of long distance television transmissions is not a difficult problem, because fortunately at least within the European area a large number of stations have test transmissions throughout the day, commencing programme transmissions during the early evening. The test cards used during the daytime trade tests usually carry some form of identification, but unfortunately such cards are now and then interspersed with other standard patterns, such as colour bars, line sawtooths etc.





An interesting activity associated with TV DX is the photographing of received test cards etc. The ideal exposure is 1/30 second. The photographing on the television screen is done without a flash!

Chapter 12

ORGANIZING A DX-CLUB

by Gerry L. Dexter

Many DX-ers at one time in their careers, give some thought to starting their own club. Most come to the conclusion that such a project is too much work. Others decide, for one reason or another, to go ahead. These latter persons soon find out that running a club is, indeed, a lot of work, and often they wonder whether it is really worth the trouble.

If you are thinking about organizing your own club, here are a few thoughts on the subject which you may find to be of some help.

The ease with which you will be able to get your club organized, and your chance of success, depends to a large extent on the part of the world in which you live. If you live in a country where there are a lot of serious DX-ers, where the hobby is well-organized, you will find it a little easier because you undoubtedly will be able to get assistance from the national DX organization. If not, your job will be more difficult.

The pitfalls awaiting a new club are many. Far more clubs fail after only a few months or a year or two of operation than enjoy permanent success. Perhaps then, you should ask yourself a few questions.

Why do you want to start your own club? Is it just because you want to become well-known in the hobby? If your motive is anything but the most sincere desire to provide a useful service to your fellow hobbyists, your club's chances of success are very, very small, because you must be dedicated to run a club.

Will you be able to continue working for your club; continue running it on a permanent basis? Or will school work, or a job, or a wife interfere? Remember, once the club is in operation you have an obligation to provide your members with a regular service.

Have you given thought to the money necessary to start a club. Remember, you will either have to buy a mimeograph or otherwise arrange for publication. There will also be initial expenses for paper, stamps, envelopes and many other items. None of these can be paid for out of memberships since the items will be needed before the members join. Do you have a good typewriter, or will you have to buy one?

Is your interest, and length of time in the hobby sufficient enough and long enough to assure you that your interest is not just a passing fancy? Will you find yourself interested in something else next year and therefore have no desire to continue with the club?

What will your proposed club be able to offer DX-ers that existing clubs are not already offering on a quality basis? You must either offer something new in the way of subject coverage, or match and improve on the quality now being offered if your club is to be a success.

Have you considered the size of the DX following in your country? Are there enough DX-ers to support another club?

Have you done research on the bulletins of other clubs? In other words, do you know your competition?

Where will you find the editors for your bulletin? It takes more than just an interest in DX and possession of a typewriter to be a good editor.

Have you considered organizing on a regional or local level basis first and tailoring your club to the needs of the DX-ers in your coverage area? In this way you could concentrate on promoting meetings in the area and developing an interest in DX there.

If you've given a lot of thought to the above questions and you decide to go ahead, here are some tips you'll find valuable.

Select a name. This can be tied into the type of DX you plan to cover, and/or the geographic area you plan to serve. Keep the club name as short as possible so that it will be easier for people to remember. Be careful to select a name that will not be close to that of another club.

Government of your club is another point you will have to consider. You can run everything yourself, assign others to certain duties or positions, name a board of directors to advise you. Or you may wish to write a constitution. If so, be sure you follow it faithfully. Many DX-ers have said they are not concerned with how a club is run, just so long as the bulletin contains useful information, and arrives regularly and on time.

You should also be looking for editors for your bulletin. They should be well-versed in the fields they will be treating and, of course, have some ability to write. And, the better you know your prospective editors, at least by reputation, the less chance you'll have problems with not having their columns arrive when they are due. In any event, you should be prepared to do most of the editing yourself until your membership starts to grow and you have more people available to help you.

As you go along in your organizational process, you should begin collecting names and addresses of other DX-ers to whom you can send sample copies of your bulletin and from whom, the first members of your club will hopefully be gained.

Once this advance preparation has been done, it is time to put out your first bulletin. And, it is very important that it be your very best work. Like a manufacturer, this is your product and if you expect people to "buy" it will have to be the best quality of which you are capable.

After you have been in operation for a time, most other clubs will be happy to give you some free publicity about your new club. The same holds true for the DX programmes on many short wave broadcasting stations. You might also place advertisements in the *World Radio-TV Handbook*. You can get your club listed in the Club Directory of WRTH at no charge.

In addition to getting out your club publication each month, there are many other jobs involved. You will have to keep books, maintain membership records and expiration dates of memberships, answer a never-ending flow of mail from your members, purchase supplies, handle requests for sample bulletins, prepare address labels and the thousand and one jobs that must be done if a club is to be operated well.

Membership fees must be set with care. Don't set them too low. It may make membership attractive to those seeking a bargain, but you must have an adquate amount to enable you to operate. This amount should be figured by adding up all of your expenses, plus a reasonable amount to allow for emergencies and growth. Then you should set a desired minimum number of members. For instance, if you decide you will need $500 a year to operate, you will need at least one hundred members paying $5 a year in dues in order to meet your expenses.

In the end, organizing a club is not as difficult as maintaining a club and making it grow. Many of those who have achieved a successful club find it to be nearly a full-time job! But, if you give your idea a lot of thought, plan well and carefully; if you create a quality club bulletin with talented people to assist you; if you are willing to work very hard month after month, year after year, you'll have a good club, and a reasonable chance for real success.

SECTION II
"Getting ahead further"

Chapter 13

SHORTWAVE PROPAGATION

by Jim Vastenhoud

Electromagnetic radiation, which is produced by the transmitting antenna, travels in straight lines and with the speed of light. During their propagation, the waves are subject to influences by the natural environment. The character of these influences is dominated by a number of factors, such as the frequency of the electromagnetic radiation, the situation of the atmospheric and ionospheric environment, the ground conductivity, etc. In this chapter, we shall try to get some knowledge of the mechanism of propagation, because this determines our listening habits.

One can distinguish between "ground-wave" and "sky-wave". The sky wave, or ionospheric wave, makes use of the ionosphere, a system of invisible layers, usually situated more than 50 kilometres above the surface of the earth, where solar radiation is able to "ionize" the rare air molecules and atoms which are still present at this altitude. A sky-wave is thus a wave which is "reflected" back to earth by one of the ionospheric layers.

The ground-wave consists of that part of the radiated energy, which happens to travel closer to the ground. Its propagation can be influenced by ground reflections or scattering, or by tropospheric bending. Ground-waves can be distinguished into various categories, like the tropospheric-wave, the direct-wave and the surface-wave. The latter is worth having a closer look at.

The surface-wave is that component of the ground-wave which travels parallel to the ground. Its attenuation with distance depends largely on the electrical conductivity of the surface over which the wave travels. Water surfaces, like seas or lakes, and wet soil, have a relatively good conductivity, and thus favour the propagation of the surface wave. Poorly conducting surfaces, like desert or dry, rocky terrain, attenuate the wave much more than watery surfaces.

As long and medium wave propagation depends largely on ground-wave propagation, because the sky-wave is absorbed, it is important to locate LW and MW transmitting antennas on soil with a good electrical conductivity, or to improve the conductivity of the soil underneath the antenna by means of an artificial system of radials buried in the ground.

Sky-wave propagation is limited to a small range of the total radio spectrum, mainly situated between 3 and 30 MHz, with corresponding wavelengths between 100 and 10 metres, and known as the high frequency (HF) or shortwave part of the spectrum. To get a first and general idea about the nature of shortwave propagation, one can assume that the radiated electromagnetic field is allowed to propagate within a "duct", the upper limit of which is the highest situated and most strongly ionized layer, known as the "F_2-layer", and the lower limits is the earth's surface. As the height of the F_2-layer varies a little with the latitude on earth, and with the time of day or night, it can be said that the duct in which shortwave propagation takes place, varies in height between 250 and 400 km.

During the propagation, which is basically in straight lines, with "reflections" against the walls of the duct, the signal suffers from losses of various kinds. Scattering against irregularities on the surface of the earth, attenuating of signal by collisions with air molecules in the troposphere, weakening or scattering by ionospheric layers which are situated below the F_2-layer, reflection against the F_2-layer itself, and loss of intensity of the radio wave as it covers an ever increasing area, are the main sources of signal loss on the path between transmitting and receiving antenna.

As these general remarks do in no way explain the real problems of shortwave propagation, and the resulting erratic behaviour of the frequency selection of shortwave stations, a closer look at the mechanism of ionospheric propagation and the factors which determine it, is necessary.

The structure of the ionosphere

The blanket of air, which surrounds the earth, is very thin indeed. Mountain climbers who go to professional heights, have to use oxygen masks, jetliners are pressurized to enable comfortable breathing, and from manned spaceflights we know that a complete vacuum is relatively near: a few hundred kilometres up.

At altitudes of between 50 and 400 km, the air is already so rarified that radiation from outer space, particularly solar radiation, easily manages to ionize the remaining gas. This region is therefore called the ionosphere. In this process of ionization, the gas atoms split off one or more electrons, thus becoming ions themselves (an ion is an incomplete atom because of the loss or gain of electrons, a process by which it becomes either positively or negatively charged). If we now look at a graph indicating the ion density over the earth at different heights (*fig. 1*), we see that it varies considerably with the height, and that, moreover, its shape is irregular. These are clear concentrations of ions or, if you like, electrons, found at certain altitudes. In other words, different ionized layers are found above the earth.

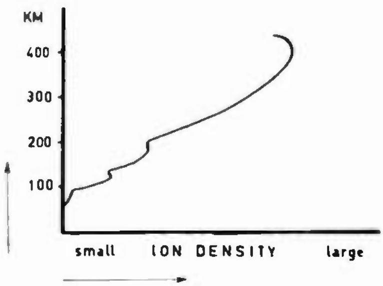


Fig. 1

The layer closest to us is the D-layer or D-region, existing roughly between 50 and 90 km (35 and 65 miles) up. It has a low degree of ionization and is easily penetrated by shortwave (high frequency, abbreviated HF) frequencies. It acts as an absorbent to medium waves, limiting their range in the daytime, and reflecting very low frequencies. It only subsists during the daytime, when it is subject to direct solar radiation. Although, as said, it is easily penetrated by high frequency signals, it still somewhat weakens these signals by slight absorption and scattering.

At an altitude of slightly more than 100 km we find the so-called E-layer (formerly called Heaviside layer). The concentration of electrons found here is also strongly dependent on the incidence of sunlight, although it does not completely disappear after sunset.

The variations found in the degree of ionization in a period of 24 hours are called the diurnal variations, and it will be clear that for given positions on earth, they depend on such factors as the time of day or night, and the season, because the period of daylight varies with the season, while the altitude to which the sun rises at noon also depends on the season.

Still on the subject of the E-layer, we might remark that it is responsible for evening- and night-time propagation of medium waves over distances of over 200 km, and frequently also for low shortwave band propagation for distances under 1000 km in the daytime. It plays the role of another absorbent for normal high frequency propagation, i.e. the waves which penetrate the E-layer when there is insufficient ionization, with the loss of some signal by absorption and scatter. After sunset, however, the importance of this layer for SW propagation declines quickly.

Mention should also be made of the E_S, or sporadic E-layer, irregular cloud-like formations of an unusually high degree of ionization which are sometimes found at altitudes slightly above the E-layer. As they have a disturbing effect on shortwave propagation, we will deal with them elsewhere in this book.

At a height of about 200 km is the F_1-layer, which can be found in the daytime. It has much the same characteristics and the E-layer, but exists at a greater height, merging with the F_2-layer at night. The importance of the F_1-layer is not very great, because it is penetrated by waves which also manage to pass the E-layer, and because as said, it only exists during the daytime.

The most important ionospheric layer for shortwave propagation is the so-called F_2-layer (formerly called Appleton layer), existing at altitudes of between 250 and 400 km).

The F-layer propagation mechanism

The F_2-layer is the principal reflecting region for long-distance high frequency communication. The high ionization density makes it capable of refracting the waves back to earth. The ionization at this height. is mainly due to the ultraviolet radiation of the sun, but because of the extremely low air density, which prevents a quick recombination of free ions and electrons, the layer is able to store received energy from the sun for many hours, and for this reason there is not such an extreme difference between its refractive properties during the day or the night; in fact the degree of ionization decreases slowly during the night, and needs a little time to evolve after sunrise.

Knowledge of this layer is extremely important for shortwave propagation, and extensive studies have been carried on for years in order to understand the behaviour of this layer. It is influenced by the time of day, by the season, and by sunspot activity in such a way that the density of ionization is increased by a high altitude of the sun and by a high sunspot activity, because a great amount of ultraviolet radiation stimulates ionization, and the refractive properties of the layer depend entirely on the density of ionization.

How must we visualize this process of the reflection, or refraction, of radio waves? Well, a mechanical equivalent can be helpful. Let us consider light waves. A well-known phenomenon of light waves, or light, is that it is refracted when it enters another material. When light waves, travelling in air, enter a material like glass or water, they are broken (refracted). This can be checked by dipping a stick in a pail of water. You will see that the stick appears to be bent at the surface. This effect is due to light refraction.

The same goes for high frequency propagation. In the ionized layer, electron density is constantly changing and so is the refraction index of the material subject to change. It means that the apparent reflective properties of the layer are due to a large number of small refractions. The path which the shortwave signal follows through the F_2-layer is in reality a curved one, the shape of the curve depending on the angle of incidence of the waves, on the ionization density of the layer, and of the frequency of the signal. One of these factors, the ionization density, is beyond our control and the selection of frequencies for shortwave propagation thus has to be adapted to it by knowledge of the transmitting antenna properties (radiation pattern) and of the highest frequency which is still returned by the ionosphere.

In order to be able to compose accurate shortwave forecasts for shortwave stations, a worldwide network of ionospheric vertical sounding stations exists. Basically, these contain a transmitter and a receiver combined with an antenna which radiates straight upwards. By means of this set-up it is possible to determine the height of the ionosphere and the highest frequency which is still reflected at vertical incidence. This frequency, found for the F_2-layer, is called the critical frequency (f_C). It varies with the time of day or night, depending on the density of ionization of the layer. Once the critical frequency is known, it is relatively easy to computate the maximum usable frequency or MUF for various angles of oblique incidence, which is the usual mode of ionospheric propagation for long-distance shortwave broadcasts.

A shortwave station which aims for maximum range, will use beam antennas which radiate either parallel to the ground, or as slightly elevated as possible. The curvature of the earth allows the beam to "take off" gently, after which it strikes the F_2-layer at a point which is at best 2,000 km away from the transmitter. This point is called the reflection point, or control point. The reflective properties at this point determine the highest frequency which can be used for the broadcast under consideration, which has a maximum range of 4,000 km and is known among shortwave broadcasters as a "one-hop transmission".

If the target area is further away and cannot be covered with a single hop transmission, more ground and ionospheric reflections are needed to cover the greater distance. We then speak about a multi-hop transmission. Such a path has more than one control point. For the prediction of the maximum usable frequency for the circuit, the ionization of all reflection points concerned have to be regarded. Usually, however, only the two terminal control points, situated at 2,000 km from the transmitter and the receiver respectively, are regarded.

In practice, shortwave broadcasts are limited to distances of about 10,000 km. Beyond this distance, the signal is weakened to such a degree that it will probably be drowned by other, stronger signals in the reception area. The propagation conditions can, under favourable conditions, make reception possible up to about 20,000 km.

The oblique-incidence MUF, used for long distance propagation, is usually indicated as MUF F_2 4,000. The number 4,000 indicates the maximum distance which can be covered in one hop.

If we determine the MUF F_2-4,000 every hour for a given circuit, it is possible to obtain a graphic representation of the variation of MUF with time, and we can determine the optimum frequency to be used for that circuit.

An example of such a graph, compiled for three circuits, is given in *figure 2*. The circuits run from the Netherlands to three cities in the world, and were prepared for the month of January under median sunspot conditions.

The shape of each curve is about equal, and determined by the length of the winter day in the northern hemisphere. Of course, the top for Sydney occurs earlier than the top for New York, as the control point for the direction Sydney is to the east of the Netherlands, while the control point for the New York circuit lies west of the Netherlands. In each case, the first control point,

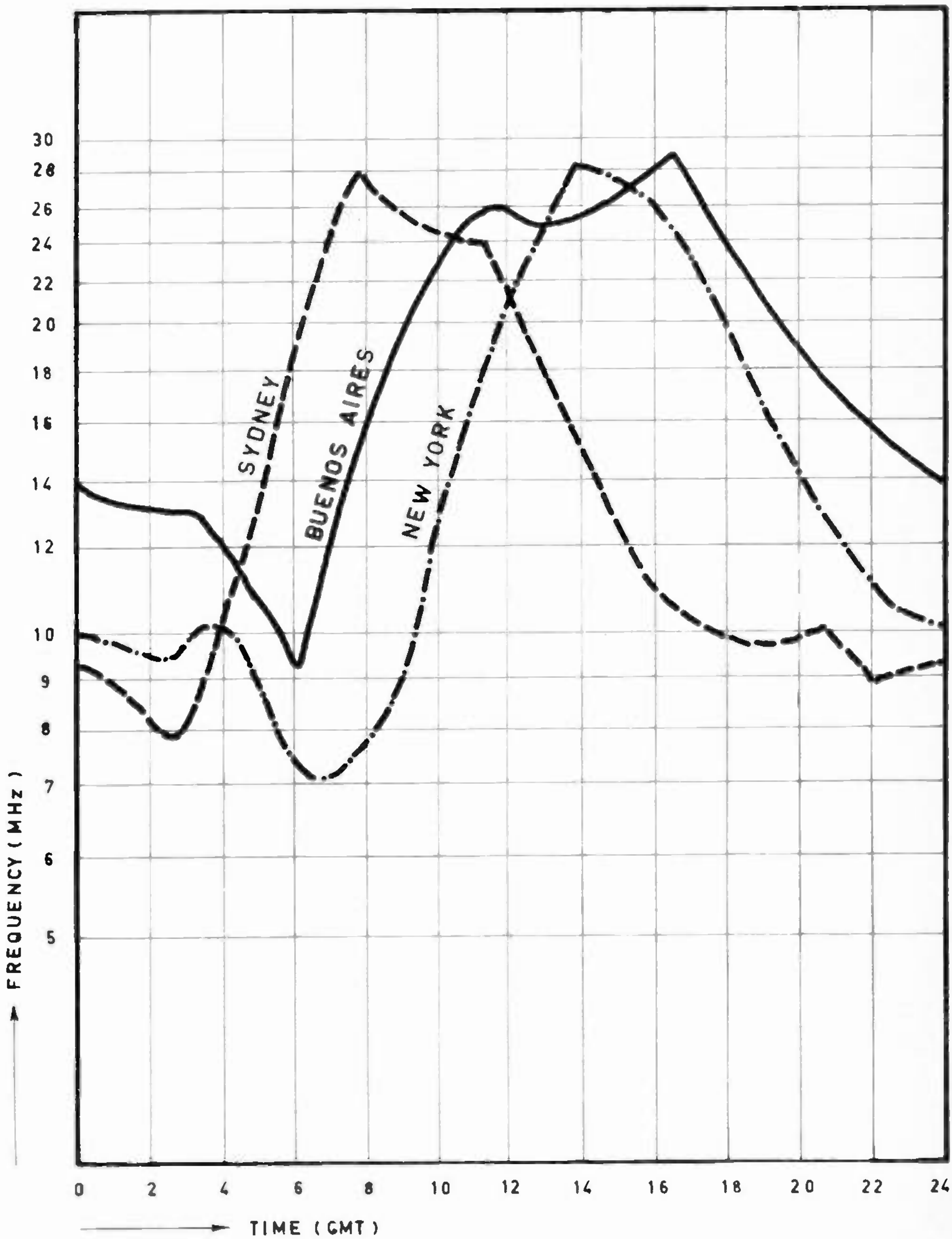


Fig. 2

closest to the transmitter, is meant. As the beam towards Buenos Aires goes to the southwest, the first control point is situated at a lower latitude than the others, and consequently the day is longer. This is reflected in the shape of the curve: the daylight portion is longer than for the other circuits.

As can be read from the graphs 21 or 17 MHz are suitable channels for all three circuits in the daytime, and 9 or 7 MHz are best for the night. The evening period shows a decline of the MUF, and the frequency choice is then determined by the time at which the programme ends. If, for instance, a broadcast for Buenos Aires ends at 0100 GMT, it is possible to use the 11 MHz (25 metre) band.

Similar prediction graphs can be drawn up for every citcuit, once ionospheric sounding data are known.

Limitations for the use of low frequencies

Now, why this preference for high shortwave frequencies? The casual observer will remark that any shortwave frequency well under the maximum usable frequency will do, and may have the additional advantage of giving reliable communication through all the seasons and sunspot activities. But that would be too optimistic. Frequency selection is not only limited on the high side of the shortwave spectrum, but also on the low side. There is not only a maximum usable frequency, but also a lowest usable frequency, or LUF, which is characteristic for any path and season. It is determined by various factors.

There is a great deal of energy lost in space on its way from the transmitter to the receiver. The total signal arriving at the receiving antenna, after reflections against the ionosphere, is composed of individual signals which have traversed different paths. During their journey, they have been subject to different kinds of path losses. Firstly, what is termed inverse distance squared spreading, simply caused by the spreading of energy from one point (the transmitting aerial). To limit unnecessary spreading, most shortwave stations use beam aerials, which have the property of directing the energy over a relatively small (20 to 30 degrees) horizontal angle, just enough to cover the target area. The use of a directional aerial gives signal gain in the direction preferred, but does not affect the spreading effect: the same amount of energy simply "fills" a wider area as it gets further away from the transmitter.

The second important source of signal loss is absorption in the ionosphere. This absorption mainly takes place in the D-region at heights between 50 and 80 km, and the amount is proportional to the length of the path in the layer; the longer the path, the more absorption. This means that absorption increases with the number of hops, and so also with the distance between the transmitter and the receiver. In middle latitudes (40°-70°), we can add that the amount of absorption per hop depends on such factors as the sunspot number, the angle of elevation of the ray (which depends on the transmitting antenna characteristics), on the frequency, and on the time of the day. To be more precise: absorption increases with the degree of ionization of the D-region, and with increasing sunspot activity; low frequencies are more susceptible to it than are high frequencies, and the longer the hop, the more absorption can be expected because of a low elevation of the signal and, consequently, a long traversing path of the D-layer. In the tropical regions, the influence of absorption tends to be greater than at higher latitudes. Absorption in this region is also influenced by the variability of the F-layer profile and other factors.

A third phenomenon of signal loss is focusing or defocusing, the result of convergence or divergence of rays which were in parallel originally. It is due to ionospheric distortion or deformation of the ionospheric layer, and can also be caused by underlying ionized regions, such as the E-layer.

And, as a fourth case for signal loss, there is always the scattering of signal, taking place at the penetration of ionospheric layers. The amount of scattering will depend on the degree of ionization of the penetrated layers, and will be inversely proportional to the frequency used (the higher the frequency, the less scattering occurs).

Together with the reflective ground losses, these factors determine what is called the lowest usable frequency for a specific circuit. It is possible to give a graphic representation of the LUF in the MUF-diagram for a given circuit and also certain arrangements regarding the effective radiated power of the transmitting antenna. However, the condition that the absorption decreases when the frequency increases is important for medium and small powered stations, because the higher the frequency, the more signal can be put in the receiving area with the same effective radiated power (ERP).

Under unfavourable conditions, the LUF can become so high that it touches or surpasses the MUF. Under those conditions, no shortwave communication is possible. These conditions can be reached on some long trajectories, where day-night transcients lower the MUF, while long parts of the path in daylight raise the LUF.

So, in the interest of maximum signal strength in the reception area, the operating frequency of a SW station is usually chosen as close to the MUF as possible.

Practical predictions

So far, the information given has been of a general nature, trying to establish some knowledge and feeling of the mechanism of shortwave propagation. The question is, how this knowledge can be directed at the practice of shortwave listening, so that the broadcast listener or DX-er can have at least a reasonable guess as to which wavebands give him or her the best chances for the reception of a remote station.

Let us begin by summarizing the information which is useful in this respect.

Firstly, it has become clear that the maximum usable frequency, which can be selected for a particular circuit, depends mainly on the dalight or night-time conditions on the path, falling between the two terminal control points, which are approximately 2,000 kilometres from each end of the circuit. If we have a daylight path, the frequency will be high, especially if it is a long trajectory. For shorter paths, like a one or two-hop circuit, the attenuation of the signal due to distance will not be of the same magnitude as for long paths, and we have some more manoeuvreing room for frequency selection. If the long path requires the use of a 21 MHz or 17 MHz channel (the wavebands are 13 and 16 metres respectively), a two-hop path may well be on frequencies in the 15 and 17 MHz bands (19, 16 metres), as broadcasters know that the 21 MHz band is only available on a limited number of receivers, thus limiting the potential audience.

During the night, when the ionization density decreases gradually, the frequency usage will be restricted to the lower bands, the longer wavelengths. This is now quite possible, because some major absorption sources, being the D and E region, have either ceased to exist, or have a much less harmful influence than during the daytime. So, for long-distance night-time transmissions, expect the 11 and 9 MHz bands (25 and 31 metres shortwave) to be prevalent.

Now, there is a substantial difference in frequency use during the various seasons. In summer, the sun has a prolonged influence on the ionosphere, resulting in high ionization densities and, consequently, the ionosphere's ability to reflect very high frequencies. In winter, however, the sun is over the horizon during a much shorter period, and the maximum usable frequencies will thus be lower than in summer, especially at night.

So far, we have devoted relatively little attention to the short, one-hop circuits. Yet, these are very important, especially for distances between 500 and 2,500 km, which are beyond the reach of the national medium wave transmitters and are the goals for many vacationers, who want to stay in contact with their homeland.

For short-distance shortwave broadcasting, the antenna elevation has to be increased. Also, it is customary to use transmitting antennas with a wider beamwidth, so as to cover a relatively large area. This is possible, because the signal strength of a one-hop transmission is usually superior to that of multi-hop transmissions, even if the transmitter power is small. Thus, it is justified to use high-elevation (20 to 40 degrees elevation angle) transmitting antennas, with 40 to 60 degrees horizontal beamwidth, or even omnidirectional antennas, which radiate an equally strong signal in all directions. The frequency choice of these one-hop broadcasts is again dependent on the reflective properties of the F_2 layer. As the angle of incidence of the ray is now larger than for long-distance transmissions, the reflective properties decrease. Instead of e.g. 21 MHz. 15 MHz will now be the highest frequency band still reflected. During the evening and night, the dark hours, the frequency use will soon be restricted to 9, 7 or 6 MHz (31, 41 or 49 metres), and in winter the 9 MHz band is likely to become too high, especially at close ranges.

Summarizing these data leads to the following table, which must be interpreted as some rules of thumb:

Expected shortwave frequency band usage under various conditions.

Distance (km)	Local summer		Local winter	
	day	night	day	night
500-2500	9-15 MHz	6-11 MHz	9-15 MHz	6- 7 MHz
> 2500	11-21 MHz	9-15 MHz	11-21 MHz	6-11 MHz

So far, little has been said about the effect of solar activity. The flow of energy from the sun is not constant, but varies in a period of roughly 11 years, which is known as the sunspot cycle. During one cycle, the number of observed sunspots, dark areas on the solar surface, varies from about zero to 100, and during some cycles even to about 200, resulting in substantial variations in the radiation of e.g. ultraviolet light, which is mainly responsible for the ionization of the F_1 and F_2 layers.

The direct influence of the sunspot number on the maximum usable frequencies has long been recognized, but for many broadcast listeners it is a rather puzzling factor in the determination of usable frequencies, and its influence is rather over-estimated. The table is compiled for mean sunspot conditions, roughly between sunspot number (SSN) 40 and 100. Such conditions occur about 80% of the time. Slightly better conditions, with higher frequency bands to be used, can occur between 1981 and 1983, while low sunspot conditions and consequently restrictions of frequency usage to lower bands than indicated, have to be predicted for the next "sunspot low", now estimated to fall around 1986 or 1987.

We are further aware of the limitations of the table, where specific circuits are concerned which are partly daylight and partly night circuits, because the signals travel in an easterly or westerly direction. Such considerations would lead to a much more elaborate table, with computerized predictions for various regions on earth during all times of day and night. Those data are available, and used by broadcasting stations to select the frequency bands which they will use. The selection of the frequency within the band is largely a matter of historic growth, of changes made in the past due to harmful interference from others, or adjustments made to arrive at a stable frequency usage, if possible around the year, so as to accommodate the listener.

With the knowledge acquired above, and with some imagination and initiative, you will be able to get a pretty good idea of the world-wide frequency usage of stations within a short time. We suggest that you buy a world globe, and that you consider the parameters (the variables) for each circuit, if reception is experienced. Soon, you will learn why that particular frequency band was selected. The knowledge and experience accumulated in this way, will help you with future DX-catches and train you in the hobby of long-distance shortwave listening.

Chapter 14

THE IONOSPHERE AND ITS VARIATIONS

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INTRODUCTION

The ionosphere is the region of the upper atmosphere, extending upwards from about 50 km above the earth, which is *ionized* (i.e. electrified), principally by the effects of solar radiations upon the atoms and molecules of rarefied gases. Free electrons are produced in the ionosphere in sufficient numbers to affect the propagation of radio waves.

The lower part of the ionosphere (from about 50 to 500 km above the earth) is the main medium for the propagation of HF transmissions on earth, and it also affects other radio frequencies from VLF to UHF. Propagation varies with the ionospheric conditions and with their effects on absorption, refraction, reflection and scattering of radio waves.

1. General remarks

HF propagation varies with the time, frequency, path and the distribution of ionization density (i.e. of free electrons) in the ionosphere, e.g., higher densities can reflect higher frequencies.

Ionization densities and their peak heights vary with time and location in a complex manner, particularly in the F region, due to a variety of causes. They are affected by the intensity and absorption of solar ionizing radiations and particles, by the earth's magnetic field, by winds and drifts, by electrical fields and by changes in the composition of upper air, etc. The variation in distribution of ionization throughout the ionosphere is controlled by a balance between the relative rates of production, loss and transport of electrons at various heights and locations. There are many processes, for example, free electrons can be *produced* by *photoionization* of atoms and molecules, by impact of solar radiations of sufficiently high energy (mainly in the ultraviolet and in the X-ray spectrum) and by *ionization* by charged particles (e.g. by galactic cosmic rays in the lower D region), etc. Free electrons thus produced can then disappear by *recombination* with positive ions in a variety of ways, by *attachment* to neutral gas atoms and molecules, or by *transport* due to winds, drifts, diffusion, etc. The dominant processes vary with height, time and location.

In the lower D and E regions of the ionosphere the air density is relatively high, and this results in a large reduction in ionization density at night. In the F region the air density is very low, and this is perhaps one of the reasons why F_2 ionization usually remains sufficiently high during the night to sustain shortwave propagation.

Factors such as geomagnetic field, thermal expansions, winds, etc., may greatly affect the world-wide distribution of ionization, particularly in the F region. For example, the polar ionosphere does not disappear during the long winter darkness, as might be expected, but is continually maintained, perhaps by ionization drifts from lower latitudes.

2. Exploration of the ionosphere

Ionospheric measurements can be made by different techniques both from the ground and from space. By the use of one of the best known methods, ionospheric data has been recorded over many years on a world-wide scale by a network of over 100 ground-based vertical incidence ionospheric sounding stations ("ionosondes"). (The first ionosonde was started in 1931 at Slough, England, and it is still in operation). In this radar technique, the frequency of very short duration pulses is varied in a few minutes from about 1 MHz up to about 25 MHz, and this is usually repeated at hourly intervals. With increasing frequency, each layer is explored in turn, and as the wave penetrates deeper into the ionosphere, so it is reflected from greater heights back

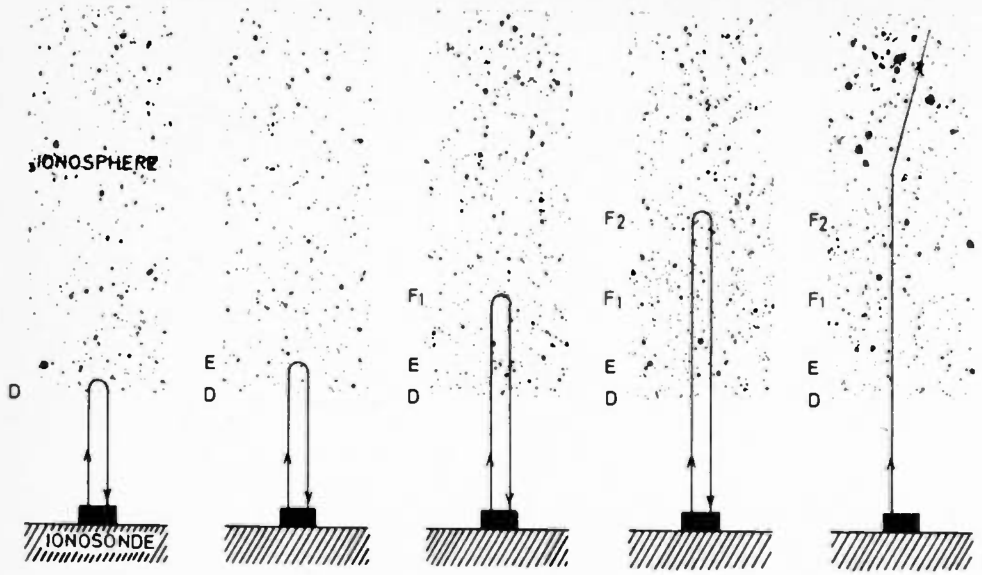


Fig.1 Vertical Incidence Sounding of the Ionosphere

As the frequency is increased, it is reflected by successively higher ionospheric layers and then escapes into space

to the ionosonde (*fig. 1*). The highest frequency which can be reflected at vertical incidence by a given layer is called its critical frequency (e.g. foE, foF_2). Frequencies exceeding the F_2 critical frequency escape into space (unless there is a very dense E_S layer below).

The delay time of the return pulse for a given frequency (f) gives its "virtual height" of reflection in the ionosphere (h′). The variations of h′ with f are displayed on the ionosonde cathode ray tube, and the filmed records thus obtained ("ionograms") are used to measure critical frequencies, heights of ionization peaks, and other parameters of ionospheric layers. Ionograms can also be used to derive the variation of ionization density with the true height ("Nh profiles").

With the accumulation of this regular data over many years, the variations of the ionosphere with location, time and solar cycle could be mapped on a world-wide scale as, for example, in "The CCIR Atlas of Ionospheric Characteristics" (CCIR Report No. 340-2), thus providing the basis for the calculation of shortwave predictions. However, such maps are still incomplete, because there are very few ionosondes in some parts of the world, and because interpolation of data from widely separated ionosondes may lead to serious errors, e.g., in the ocean areas, etc.

Many other techniques for exploring the ionosphere are now in operation, and there is a wide measure of international standardization and cooperation. The *ground-based* techniques include oblique incidence ionosondes, over the horizon radar, ionospheric back and forward scatter, absorption measurements and incoherent scatter (using high power VHF and UHF radar transmitters), etc. The *space-based* techniques include the use of rockets and satellites for direct measurements of the ionosphere, satellite "top-side" ionosondes (since 1962), release of chemicals in the ionosphere and studies of the radar signals reflected by the moon, etc. In addition, a very wide range of associated astronomical and terrestrial variations is being continually monitored. These methods have resulted in a more thorough exploration of the ionosphere. The picture which is gradually emerging is that of a very complex and dynamic medium, the study of which involves many different sciences (such as physics, meteorology, chemistry, astronomy, mathematics, etc.) and which cannot be treated in isolation from other geophysical and astronomical phenomena.

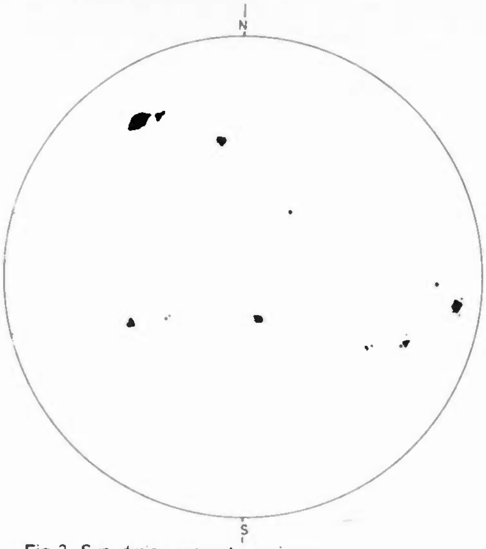


Fig. 2 Sun during sunspot maximum

3. Sunspot cycle

The sun is subject to long-term periodic variations, of which the "sunspot cycle" is the best known for its effects on the ionosphere. By convention, a sunspot cycle begins at its *minimum*, i.e., the period which very few or no spots appear on the sun. After a few years, spots may become very numerous (*fig. 2*), and the cycle then reaches its *maximum*. Afterwards, the cycle declines (usually more slowly) towards the minimum of the next cycle. Sunspot cycles recur on average about every eleven years, although their duration and the values of their maxima may vary considerably.

Various incidences of solar activity are measured at many observatories, e.g., sunspot number R is derived daily from the count of sunspots. R can indicate the variations of solar activity over a longer period by using the average monthly values of R, or the 12-monthly average values (e.g. R_{12}-Zürich Smoothed Sunspot Number).

If R_{12} values are plotted over many years, it will be seen that the successive sunspot cycles are by no means identical. For example, Figure 3 shows the last three cycles superimposed on one another in such a way that their periods of rise and of decline, and the values of their maxima can be directly compared. It will be seen that whilst the values of their minima are very similar, this is not the case for the maxima. For instance, the 1958 maximum of cycle No. 19 was the highest every recorded (records extend well over 200 years), and it was almost double that of the following cycle No. 20. However, this latter cycle lasted for about $1\frac{1}{2}$ years longer than the two previous cycles. Figure 3 also shows that after the last minimum of 1976, the current cycle No. 21 has now begun to rise towards its maximum.

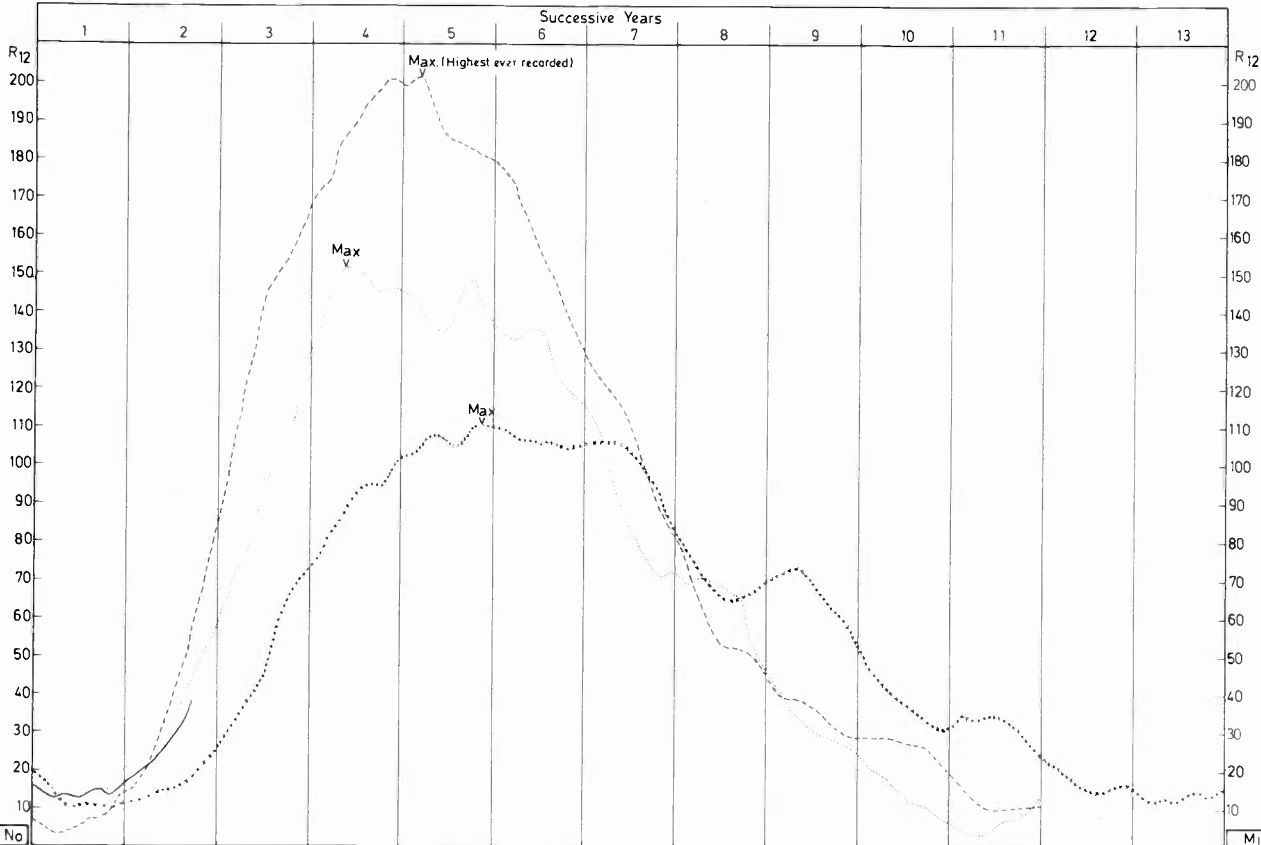
The effects of the sunspot cycle upon the ionosphere are due to the increase in the intensity of the solar ionizing radiations (mainly ultraviolet and X-ray, and also corpuscular) with the solar activity, and the consequent increase in the ionization of the ionospheric layers, and particularly of F_2. This increase varies with the time, location and height in a complex and an indirect way, e.g., doubling of solar activity will not result in doubling of the F_2 ionization density of its critical frequency foF_2 at a given location and time, but in much smaller corresponding increases.

It follows that during sunspot maximum conditions, the ionosphere can generally reflect shortwaves on higher frequencies than during sunspot minimum conditions (*figs. 4b, 5 and 6*). Therefore, during low levels of solar activity the lower HF bands have to be used, resulting in greater waveband congestion, and in much greater sensitivity of transmissions to the effects of ionospheric disturbances.

The predictions of shortwave frequencies over the sunspot cycle have to take into account the forecast of basic indices for ionospheric propagation. Such indices are regularly issued a few months ahead by various organizations, e.g., solar index (R_{12}) by the Zürich Observatory, ionospheric index (I_{F_2}) by Appleton Laboratory, Slough, etc.

4. Critical frequency

The highest radio frequency which can be reflected at *vertical incidence* (*fig. 1*) at a given time and location by an ionospheric layer is called its *critical frequency* (e.g. foE, foF_2), and it corresponds to the peak ionization density of that layer. The approximate relation is given by the formula $fo = 9\sqrt{N}$, where fo is the critical frequency of the layer in Hz, and N is its free electron density per m^3. For example, typical day peak densities in the upper D layer are about $10^9/m^3$, in the E layer about $10^{11}/m^3$, and in the F_2 layer about $10^{12}/m^3$, corresponding to critical frequencies of about 0.3 MHz, 3 MHz and 9 MHz respectively. The ionization peaks in the D, E, F_1 and F_2 layers occur typically around 80, 110, 180 and 300 km. All these values are subject to considerable variations, particularly in the F_2 layer.



Cycle No													Min	Max
18	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954			1944 Feb	1947 May
19 -----	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964			1954 Apr	1958 Mar
20 ••••••	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1964 Oct	1968 Nov
21 ——	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1976 Jun	

Fig. 3 Sunspot Cycles Nos. 18, 19, 20 and 21 Zürich Smoothed Sunspot Number R_{12}

Cycles shown superimposed, starting with minimum year

Critical frequencies vary with the time and location. Broadly speaking, the main *time* variations are diurnal, seasonal and annual (sunspot cycle), and the main *geographical* variations depend upon magnetic latitude, e.g., there are low, temperate and high latitude zones. Figures 5 and 6 show the diurnal variations over sunspot cycle No. 19 in June, and in December of the critical frequencies of the E and of the F_2 layers respectively, as measured at four selected ionosonde stations in these zones. Sunspot cycle No. 19 was the highest ever recorded, so that the corresponding variation in the values of critical frequencies is not likely to be exceeded for a long time in the future during the succeeding cycles. Figures 5 and 6 show that the foE variations are much more similar than the foF_2 variations.

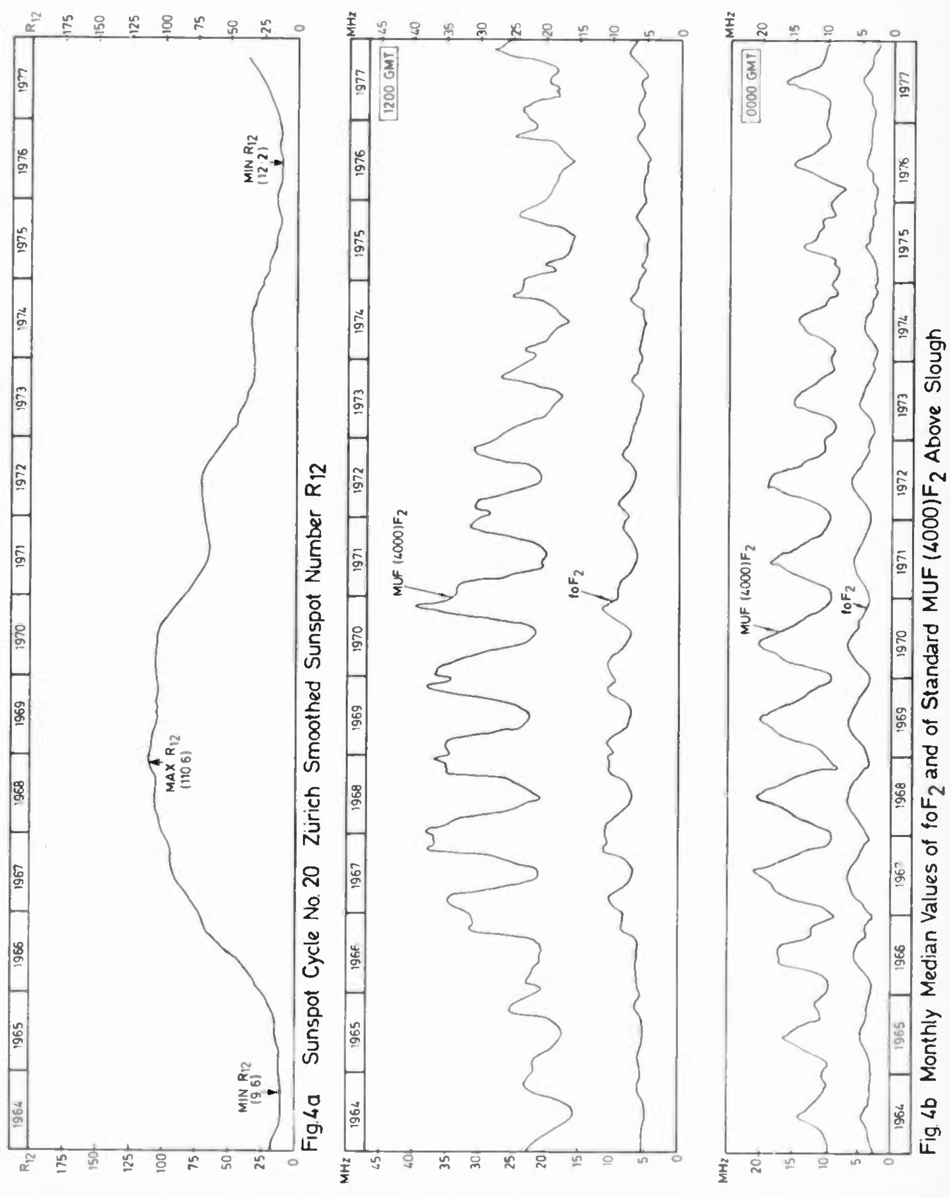


Fig.4a Sunspot Cycle No. 20 Zürich Smoothed Sunspot Number R_{12}

Fig.4b Monthly Median Values of foF_2 and of Standard MUF (4000)F_2 Above Slough

5. Ionospheric layers and their variations

5.1. **General.** The ionosphere is a continuous medium but, as it displays different characteristics at various heights, it has been divided by historical convention into D, E and F *regions*. The ionization, which is formed in these regions, is separated into similarly named *layers*. Generally, D layer cannot reflect shortwaves but can only absorb them, whilst the upper layers can both absorb and reflect them, the F_2 layer often being the main reflecting layer.

The D region extends from about 50 to about 90 km above the earth, and it contains the D layer.

The E region extends from about 90 to about 130 km, and it contains "normal" E and Sporadic E layers.

The F region extends upwards from about 130 km merging at much greater heights with the magnetosphere (a vast region around the earth in which the geomagnetic field controls the movements of charged particles). During the summer day it may contain F_1 layer between about 130 and 210 km, and F_2 layer above it, but both merge into a single layer during the night. That part of the F_2 layer which lies below about 500 km affects the propogation of shortwaves on earth.

5.2. **D Layer.** Its lower part, below about 65-70 km has usually very low ionization density, which is perhaps mainly maintained by the galactic cosmic rays. During the day ionization in its upper part increases rapidly with height (probably mainly due to solar ultraviolet and X-ray radiation and complex atomic processes) until it gradually merges with the E layer. D Layer ionization is too low for the reflection of shortwaves, or for its exploration by vertical incidence ionosondes. However, at such low heights the air density is relatively high, so that free electrons collide very frequently with the neutral gas molecules (e.g. *collision frequency* at 80 km is about 10^6/sec). This often results in greater loss of energy, i.e., absorption of shortwaves in the daytime D layer than in the higher layers. Generally speaking, such absorption increases as the frequency is decreased, so that sky wave propagation on MF is almost completely absorbed during the day. This is also the reason why in shortwave practice it is often desirable to operate on the highest possible frequency.

5.2.1. **Variations.** D layer occurs mainly during the day, and at night it almost disappears (owing to rapid loss rate of free electrons at low heights). Consequently, ionospheric absorption, particularly on MF and HF bands, is then considerably reduced, and this results in much greater availability of radio transmissions at night.

D layer ionization is usually at its maximum during local summer, but anomalously high absorption periods can occur during local winter. The effects of the sunspot cycle vary with the height of ionization. In the lower part of the D region, below about 70 km, peak density is reached during sunspot minimum. This is because the main ionizing radiation at these heights, i.e., the galactic cosmic rays, increase in intensity as the shielding effects of the sun are reduced during the solar minimum. In the upper part of the D region, peak density is reached during sunspot maximum, because the intensity of the ionizing solar ultraviolet and X-ray radiations increases with the solar activity.

Daytime D layer ionization usually increases towards lower latitudes.

Following the appearance of flares on the sun, the D layer ionization density and its extent can be temporarily greatly increased, causing Shortwave Fadeouts (SWF's) and, very occasionally, polar blackouts (PCA's).

5.3. **E Layer.** The normal E layer is principally due to the ionizing action of the solar ultraviolet and X-ray radiations mainly upon the oxygen and nitrogen molecules (O_2 and N_2). Its ionization density increases with the height of the sun in the sky (as given by its zenithal angle) and with the sunspot cycle. Due to this *solar control*, the E layer variations are more or less regular, and can be predicted relatively accurately for a given solar zenithal angle and predicted sunspot number R_{12}. E layer can reflect shortwaves during the day only, but it can be the controlling layer up to distances of about 2,000 km, particularly during local summer.

5.3.1. **Variations.** During the day, E layer ionization increases rapidly after the local sunrise, reaches its peak around noon, and then decreases at an accelerating rate towards the local sunset (*fig. 5*), attaining a residual level of only about 1% of the peak noon density after a few hours.

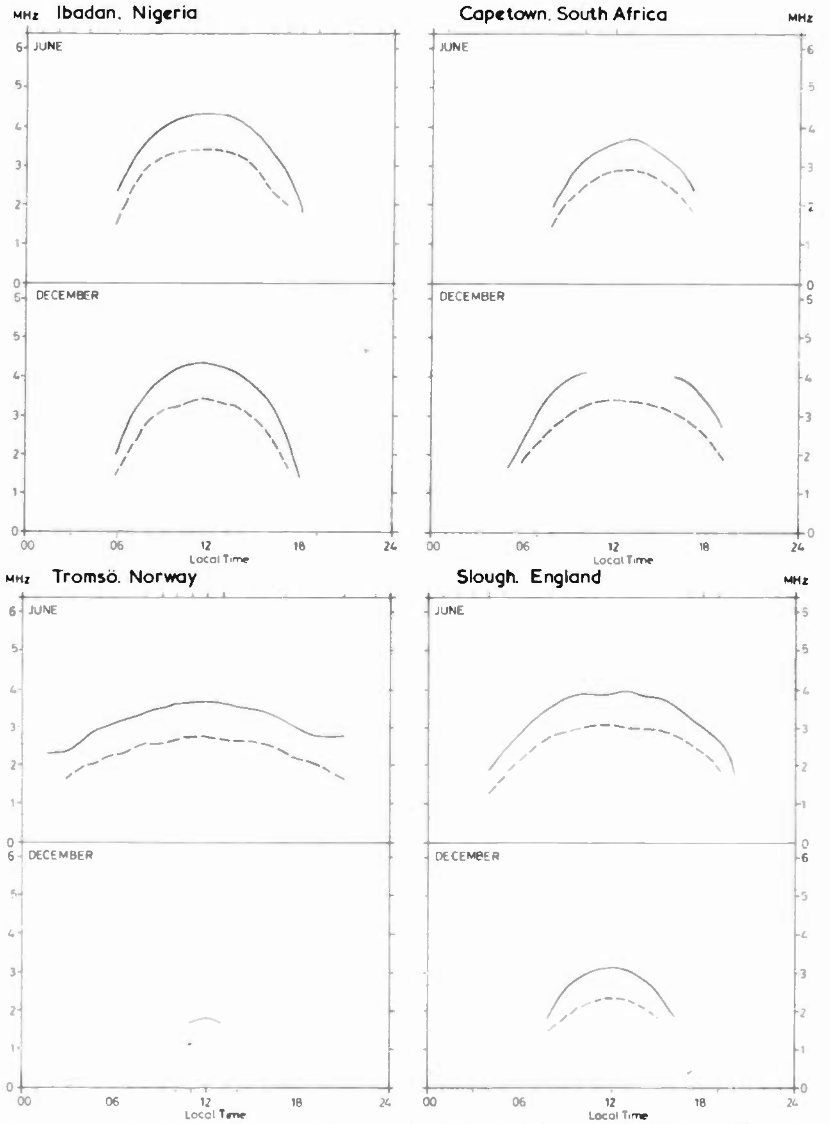


Fig. 5 Frequency Variations of the E Layer (Median foE) ——— Sunspot Maximum 1957 - - - - - - - Sunspot Minimum 1954

This level is too low to sustain HF propagation, but it is generally high enough to reflect LF and MF transmissions, thereby extending their night-time range. The day to day variation in the values of foE for a given hour and location is relatively small, particularly when compared with the corresponding variations in the E_S and F_2 layers.

The E layer ionization densities and critical frequencies reach their peaks during local summer. However, in the low latitudes the seasonal differences can be very small (e.g. at Ibadan in December and June, *fig. 5*). During winter days, E layer may be present only briefly in high latitudes, due to the greatly reduced length of day, (e.g. at Tromsö in December, *fig 5*).

Sunspot cycle variation in the foE values is fairly regular, being of the order of 30%, which is not particularly large, e.g., during sunspot maximum, peak noon foE values are only about 1 MHz higher than during sunspot minimum (*fig. 5*).

As the ionization density of the E layer varies with the height of the sun in the sky, its critical frequencies are highest in the tropics.

5.4. **Sporadic E layer (E_S).** This occurs irregularly within the E region and it usually consists of very thin (about 1 km) clouds or sheets of intense ionization, embedded within the normal E layer. A times, E_S ionization is so dense, that not only will it reflect HF transmissions on bands as high or even higher than the F_2 layer, but also VHF transmissions (but seldom above 70 MHz). There are three main types of Sporadic E, which are predominant in the high, temperate and and equatorial magnetic latitudes respectively.

5.4.1. **High-latitude E_S.** This includes the intense auroral and the much weaker polar cap E_S. It occurs above 60° geomagnetic latitude with a maximum at about 69°, and it is probably due to the effects of the precipitation of the electrons (with the energies of the order of tens of keV) upon the auroral E region. It is present throughout the year, but *mainly at night*, and there is little seasonal variation.

5.4.2. **Temperate E_S.** This may be predominantly caused by the compression of ionization by upper air winds (due to the rapid changes in their directions with height-wind shear), and perhaps by the presence of meteoric ions.

Temperate E_S is usually most frequent during the day. Its maximum occurs often during local summer, and its minimum in local winter or early spring. For example, its incidence, as observed in Southern England, increases very suddenly in May, reaches its maximum in June or July, and decreases very sharply after September. The annual variation in the incidence of E_S appears to be irregular, although there may be some connection with the sunspot cycle.

Critical frequencies of E_S can change very rapidly and irregularly with time and location, even in a matter of minutes or kilometres, and a statistical approach is needed to study its variations. Reflections from Sporadic E in all zones can be of different types, e.g., strong "specular" reflections by dense E_S sheets, which "blanket" the layers above it, or weak and scattered reflections, due to uneven distribution of E_S ionization. Regular communication via E_S on long paths is very unreliable.

5.4.3. **Equatorial E_S.** This may be caused by the effects of intense currents circulating above low magnetic latitudes ("equatorial electrojet"). It occurs within a narrow and rather variable belt within about $\pm 5°$ from the magnetic dip equator, mainly during the day, and its seasonal variation is small. This layer is usually transparent to HF and VHF transmissions, which penetrate through the gaps in its very patchy structure, even though the daytime critical frequencies can often reach 10 MHz or more. Consequently, scattered reflections are more common than specular, as blanketing forms of E_S above dip equator are reduced by a factor of 10 compared with the Temperate E_S.

5.5. **F_1 Layer.** This layer appears mainly during summer days in middle latitudes, as a lower ledge in F region ionization. It is ionized by the same solar ultraviolet and X-ray radiations as the F_2 layer above, and the maximum rate of free electron production occurs at F_1 heights. However, the loss rate of electrons is so much greater in the F_1 layer than in F_2 that peak ionization occurs at F_2 and not at F_1 heights. Like the E layer, the F_1 layer shows a marked dependence on the solar zenithal angle. F_1 can be a controlling layer for shortwave propagation up to distances of about 3,000 km.

5.5.1. **Variations.** Variations in foF_1 values are very similar to those of foE, with diurnal maxima around noon, seasonal maxima in summer, and peak values at sunspot maximum. This is due to the solar control of the E and F_1 layers. As this control is different for each layer, foF_1 values are somewhat higher than the corresponding noon foE values in middle latitudes, by about 1 to 2 MHz.

5.6. **E_2 Layer.** This is the highest and usually the most highly ionized layer of the ionosphere. The F_2 region is ionized by the solar ultraviolet and X-ray radiations, acting mainly on oxygen atoms (O) and nitrogen molecules (N_2). As stated before, the rate of free electron production is highest in the lowest part of the F region (corresponding at times to the F_1 layer). However, the rate of production of free electrons decreases much faster with height than their loss rate. This leads to an increase in the F_2 ionization with height, until its peak density is reached, usually between 200 and 500 km. Above these heights, diffusion processes become important, so that F_2

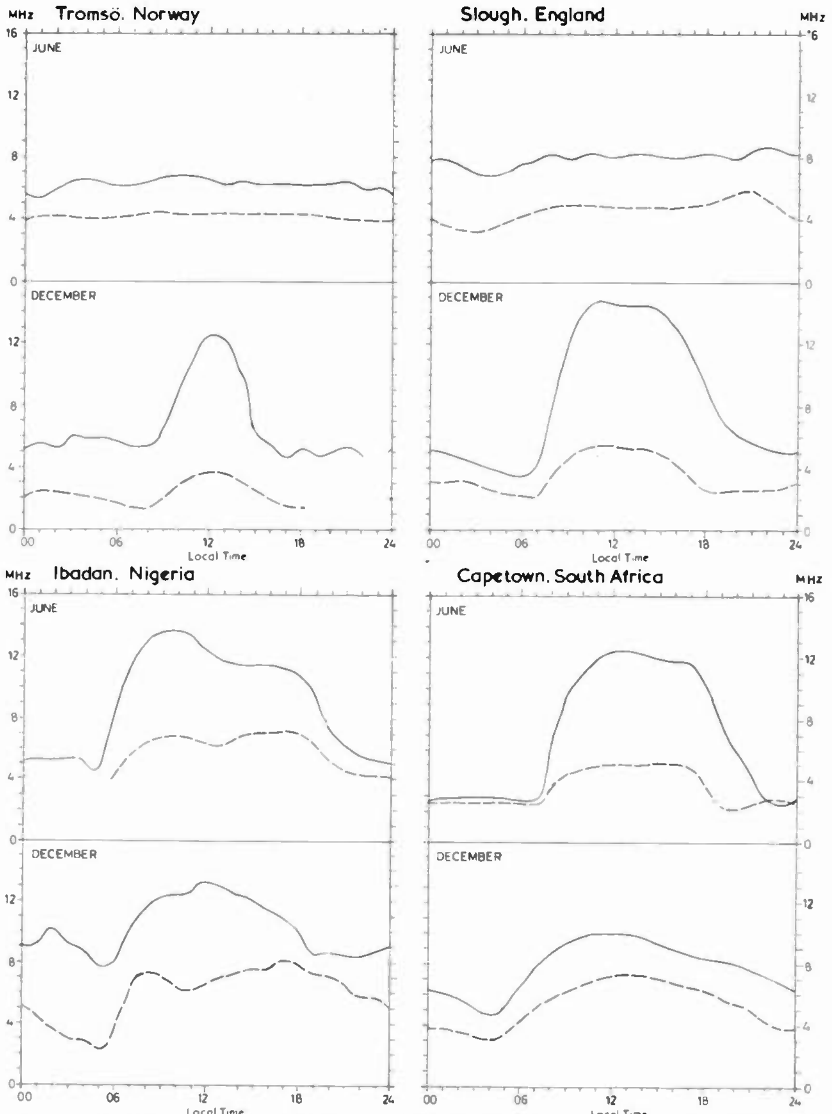


Fig. 6 Frequency Variations of the F_2 Layer (Median foF_2) ——— Sunspot Maximum 1957 - - - - - - Sunspot Minimum 1954

ionization begins to decrease with height, but more slowly than below the peak. This ionization extends to very great heights (i.e. thousands of km), varying with the latitude and merging into the magnetosphere.

Generally speaking, whilst both the E and F_1 layers show a marked degree of solar control, this is not the case for the F_2 layer. Its ionization density and the height of its peak vary in a complex manner with time and location, due to the interplay of many different factors. In more detail, apart from solar dependence, the F_2 layer is also controlled by the earth's magnetic field and is subject to dynamic and other effects, caused by heating, upper air winds and drifts, electrical fields, diffusion, and changes in the chemical composition of upper air, etc. This results, firstly, in much greater short-time (e.g. day to day) and short distance variations in the F_2 ionization density than in the normal lower layers and, secondly, in much more complex temporal and geographical variations, as shown in Figure 6 (leading to a number of anomalies discussed below).

The F_2 layer is usually the main reflecting layer of the ionosphere for shortwave transmissions, and an example of HF predictions is shown in *Figure 7*. Although the limiting range of the F_2 single-hop modes is of the order of 4,000 km, this is often exceeded, due to the presence of ionospheric tilts, to abnormally great peak heights, and to trapping between the E and F_2 layers, etc. Although long distance HF propagation at night is usually effected by multiple reflections from the F_2 layer (*fig. 8*), during the day, lower layers may also be involved.

5.6.1. **Variations.** Figures 4b and 6 show diurnal variations in foF_2 values. It will be seen that the maximum foF_2 values often occur outside local noon (this is the F_2 Diurnal Anomaly), e.g., in temperate latitudes during local summer, as at Slough in June. Diurnal variation depends upon location and season, being, for example, much more marked in winter than in summer at temperate latitudes.

During the night, F_2 ionization usually decreases, falling to its lowest values before local sunrise, but at such great heights it usually remains sufficiently dense to maintain shortwave propagation, although at lower frequencies than during the day.

The seasonal variation in foF_2 values depends upon latitude, its range being often smaller in the tropics than elsewhere. In temperate latitudes, noon foF_2 values can be very much larger in winter than in summer (F_2 Seasonal Anomaly) but the midnight values are greater in summer than in winter – Figures 4b and 6. Diurnal variations can change, and also increase with solar activity (e.g. at Slough in winter). There is also a world-wide annual anomaly in F_2 ionization densities, which in Northern temperate latitudes increases the difference between the daytime winter and summer foF_2 values, but decreases it in the corresponding southern latitudes.

The magnitude of foF_2 variations with the sunspot cycle depends upon the time, location and sunspot number in a rather complex manner, ranging from relatively small changes (e.g. Capetown, June night – Figure 6) to very considerable increases (e.g. Slough, December noon – about 3 to 1 ratio between 1957 and 1954 values – Figure 6). The variation during sunspot cycle No. 20 in the Slough (S. England) measured monthly, noon and midnight foF_2 values and in the corresponding derived F_2 MUFs (for 4,000 km distance with its centre above Slough) is shown in Figures 4a and b.

World-wide distribution of F_2 ionization density is rather complex showing irregular latitudinal and longitudinal variations, and a marked control by the geomagnetic field.

There is a tendency for highest densities to occur in the tropics, although this is not always the case. In these regions there is very large variation in ionization with latitude, and during the day, very dense ionization regions appear North and South of the magnetic equator. This equatorial trough anomaly is due to the "fountain effect" caused by the electrical fields of the electrojet, which drives the ionization away from the magnetic equator.

In very high latitudes, F_2 ionization is less dense but it may be subject to considerable geographic variations. F_2 ionization is maintained there even during the long polar darkness.

6. Maximum Usable Frequency – MUF

If on a given path at a given time the frequency of a shortwave transmission exceeds a value called *Maximum Usable Frequency (MUF)*, the radio wave will penetrate the ionosphere and its reception may become impossible.

"Operational MUF" is defined as "the highest frequency that permits acceptable operation between given points at a given time and under specified conditions." This is an instantaneous actual value, and its variation with time may often be very large, for example for F_2 layer propagation. (N.B. *Maximum Observable Frequency, MOF*, is the highest frequency at which a signal is observable on an oblique incidence ionogram).

Therefore shortwave predictions have to take into account this variability in MUF values, particularly for long term operation. For example, *Monthly Median Standard MUF* is the frequency which, according to predictions, will be reflected by the ionosphere on *50%* of the days in the month, over a given hour, month and year. MUF for a given single hop path is given by the product fo × M(d), where fo is the predicted critical frequency of the ionospheric layer at the reflection point of the path, and M(d) is the corresponding predicted MUF factor for that point for the path distance. MUF factor, and hence MUF, usually increase with distance up to the limit of a single-hop mode, and an example of the variations of predicted MUFs with distance is given

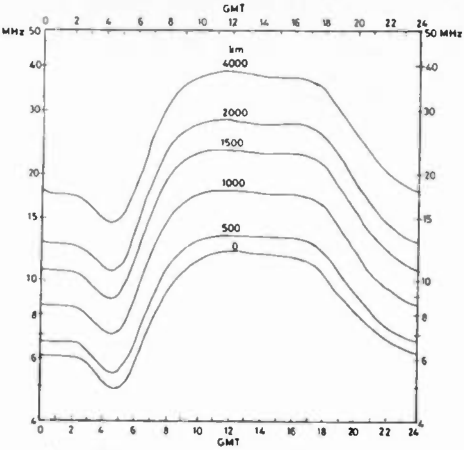


Fig.7 I.F.R.B. MUF Predictions for March R_{12} =125
Longitude 0° Latitude 45° N

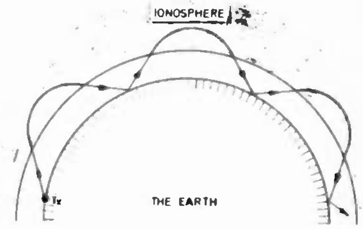


Fig.8 Multihop HF Propagation

in Figure 7. MUF factor is equal to 1 for vertical incidence propagation, increases to about 5 for reflection by the E layer for a path length of 2,000 km, and is about 3 to 4 for reflection by the F_2 layer for a path length of 4,000 km. These distances are typical limiting ranges for single-hop propagation via these layers, due to the earth's curvature, but they may be at times exceeded in the case of the F_2 layer, due to ionospheric tilts (e.g. on transequatorial paths), E-F_2 trapping, etc. MUF factors for the E layer for a given distance are usually assumed to be constant, due to the relatively small variation in its height. However, MUF factors for the F layer paths vary with the time and locality, owing to considerable changes in its height. The ionospheric parameters measured by ionosonde stations include the F_2 MUF for a 3,000 km path, M(3,000)F_2 and factors for other single-hop distances can be derived from this value.

Ionospheric atlases (e.g. CCIR Report 340-2) show world maps of predicted ionospheric characteristics. MUFs for the E and F_1 hops can be obtained from the monthly charts of the solar zenith angle and the predicted sunspot number R_{12} for a given month. MUFs for the F_2 hops are obtained from the world prediction charts of the F_2 critical frequencies and of the corresponding F_2 MUF values for 4,000 km long paths. These monthly charts are provided at two-hourly intervals for each month of the year for sunspot numbers $R_{12} = 0$ and $R_{12} = 100$. The F_2 MUF for a given path, time and a predicted sunspot number can then be derived from the charts by interpolation.

As stated before, Monthly Median Standard MUF is a frequency which is predicted for propagation at a given hour for only 50% of the days in the month, and thus it cannot be expected to provide regular reception. Therefore, predictions for services such as broadcasting often make use of *Optimum Working Frequency* (FOT), i.e., the frequency which is predicted for propagation at a given hour on *90%* of the days in the month.

In the case of the E layer, it is assumed that FOT = 0.95 MUF for all times and locations, owing to the relatively small day to day variations for a given hour in its critical frequencies. For the F_2 layer, such variations are much greater and more irregular, with the FOT $\simeq$ 0.7 to 0.9, depending upon sunspot number R_{12}, season, and the midpath latitude and local time. The well known approximation FOT = 0.85 MUF may also be used as a rough guide.

It may be of interest to note that if a frequency is to be predicted for propagation at a given hour on only 10% of the days in the month (e.g. for radio amateurs), then the E MUF should be multiplied by 1.05, and the F_2 MUF by about 1.1 to 1.4, according to the parameters mentioned before.

7. Shortwave predictions

Shortwaves are usually reflected by the ionosphere along more than just one propagation path. The simplest modes are those by multiple reflections from one layer, e.g., F_2 (Figure 8 – an idealized picture), but often lower layers may also be involved in successive reflections, e.g., E or E_S.

Usually, the received signal consists of many modes, arriving almost simultaneously by different paths, and the resultant mode pattern may be changing continually. Therefore, although in the past, long term monthly shortwave predictions consisted mostly of MUF or FOT values, the modern prediction methods have to provide much more information about the probability of existence of various propagation modes on available HF bands, about their field strengths and about their probability of exceeding the required signal to noise ratio (power and aerial characteristics have also to be considered). These methods cannot be described here in detail, but they are used on a statistical basis for the evaluation of the system performance on a given path, and for the selection of frequencies for best reception on the basis of highest probable reception "reliability", provided that propagation modes exist and have the desired signal strength, and that an allowance is made for multipath tolerance. Such frequencies may be below the predicted FOT values.

These techniques are also useful in planning new HF services and estimating the required transmitter power and the best type of aerials.

Shortwave predictions are now being made using computer programmes. Even more detailed calculations have to be made for the so-called ray-tracing, i.e., the prediction of the ray path in the ionosphere for a given frequency and given distribution of its ionization with height and distance. Ray tracing can be used to determine the optimum take-off angle at the transmitter and the angle of arrival at the receiver, and the calculations show that the picture of ionospheric reflection by symmetrical hops is greatly over-simplified.

Another improvement in prediction techniques can be obtained by comparing the predicted values with reception data over long periods, and this has shown in the past some consistent errors, e.g., the predicted MUFs were often too low on the UK to Singapore circuit.

Chapter 15

AN ANATOMY OF FADING

by Basil 'Pip' Duke

In his excellent book "Ionospheric Radio Waves", Kenneth Davies, Professor-Adjoint in the Department of Electrical Engineering, University of Colorado, says:

"The amplitude of a radio wave reflected from the ionosphere will depend on several factors. These include:

1. ionospheric absorption
2. distance attenuation
3. ionospheric focusing or defocusing
4. polarization of the characteristic waves and of the transmitting and receiving antennas – and –
5. fading."

In this article, we will dissect item (5) "fading" in order to determine the following:

(i) a definition of fading
(ii) some of the better known types of fading
(iii) the causes of these types of fading
(iv) fading and your shortwave activities

Finally, some methods of reducing the effects of fading on the reception of long-distance HF radio signals.

Definition of Fading

Fading is a general characteristic of short radio waves reflected by the ionosphere. Generally speaking, the strength of a received signal is a function of the relative positions of the transmitter and receiver. But a third factor must be considered – the ionosphere. It is known that the ionosphere is seldom, if ever still. It changes with time for a number of reasons. There are changes in its electron density profile, random motions of high-density "clouds" of ionization, structural changes in height due to temperature variations, short-term variations in ion density due to solar radiation activity, medium-term activity due to diurnal variations and long-term variations due to seasonal changes in ionospheric density. Because of these and other ionospheric variations, the strength of the signal at the receiver fluctuates with time as the electro-magnetic radio wave moves past the receiving antenna. The period of a fade can vary from a fraction of a second to an hour or more, depending upon the type and cause of the fading. Thus, fading can be summarily defined as those variations in signal strength which are usually present during shortwave reception.

Various types of Fading

(a) Rythmic fading refers to those regular and recurring variations in signal strength usually encountered when HF reception conditions are normal or near normal.

(b) Random fading refers to those irregular changes in signal strength encountered most of the time on HF ionospheric transmission paths.

(c) Selective fading is due to the wave path length varying with the frequency used. It is particularly serious for broadcasting services.

(d) Flutter fading is often encountered on trans-auroral circuits, that is on transmission paths passing through or near the north and south auroral zones. Both sidebands of an AM transmission are affected. The fluctuations in signal strength are so fast as to cause the audio components of the signal to oscillate in a rhythmic fashion. As a matter of interest, the author has experienced auroral flutter so rapid, in Northern Canada, as to constitute a "rumble" type of fading. In effect, the signal strength remains high but the modulation (or programme) is thoroughly garbled.

(e) MUF fading is the term applied by radio physicists and engineers to the "beating" between signals when the transmitted wave is just about to penetrate the ionosphere. It is most observed around sunrise and sunset.

(f) Polarization fading (sometimes called Faraday fading) results from variations in the polarization of the two wave components, i.e., the ordinary and the extraordinary waves, relative to the orientation of the receiving antenna.
(g) Interference fading will appear, to a ground observer, to come from a diffused general area rather than from a discreet point of the ionosphere.
(h) Multipath fading is the term used by engineers and physicists to describe the structure of the transmission path of a received signal. The signal reaches the receiving antenna by means of more than one mode or route.
(i) Scintillation fading is a term employed in communications engineering using VHF waves, i.e., frequencies between 30 to 300 MHz. It is used to describe amplitude and phase fluctuations of these very short waves when transmitted from a source outside the ionosphere to the earth, e.g., cosmic waves from deep space or from an artificial satellite through the ionosphere.

Causes of the various types of fading
(a) *Rhythmic fading*. The ionization of any part of a layer in the ionosphere is continually changing. Similarly, on quiet days on earth there is turbulence in our ground atmosphere even when the weather appears to be quite stable. Thus, the degree of ionospheric absorption is continually changing and radio waves entering the ionosphere at slightly different angles will be reflected at slightly different angles. Their wave components will vary with this degree of refraction. Sometimes these wave components will be "in phase" at the receiving antenna, sometimes they will be "out of phase". The result is a continually varying signal strength even when transmission conditions, via the ionosphere, are relatively stable. When these variations appear to be regulated in sequence, we have a condition of rhythmic fading.
(b) *Random fading*. Caused by interference between components of the electro-magnetic wave. Due to phase differences between the individual "rays" of the signal, the value of the signal at the receiving antenna will vary at any given instant. Two or more "bundles" or "rays" arriving simultaneously will increase the field strength of the carrier wave. However, when these components arrive out of phase with each other, they interact and reduce the carrier wave strength. Thus, two rays of equal amplitude but 180 degrees out of phase could produce zero field (signal) strength at the receiver antenna. Thus, it is the phase of these different rays which will determine the resultant field strength at the receiver and, interference between the rays will cause the signal to vary in a random manner.
(c) *Selective fading*. This type of fading may vary for frequencies only a few hundred hertz apart. This means that when propagation conditions are different for waves of only slightly varying frequency, i.e., a voice or music modulated wave with audio sidebands which differ in frequency from the carrier wave, the carrier and sideband frequencies may not be propagated through the ionosphere with the same relationship of phase and amplitude they possessed at the transmitter. It should be remembered that transmission path length, via the ionosphere, varies with frequency. Thus, the degree or severity of fading will vary with different frequencies. The intelligence or quality of a modulated carrier wave depends upon the different audio and radio frequencies making up the complete package possessing the same relationship at the receiver as they had in the studio, or at the transmitter.
(d) *Flutter fading*. Usually due to reflection of the radio wave by a very unstable and turbulent ionosphere. The fluctuations in field strength are very fast and are probably caused by ionospheric storms. The variation in intensity of the received signal is very rapid, at times almost a low-frequency rumble. Very disturbed conditions in the F layer cause the audio frequency component of the signal to oscillate or flutter at a period of about 0.1 to 0.01 seconds at say, 10 MHz.
(e) *MUF fading*. The highest frequency which is usable over a given distance is the Maximum Usable Frequency for that circuit or transmission path. We are aware that signal strength generally is a function of the relative positions of the transmitter, the receiver and the ionosphere. If the reflecting layer decreases in height the skip distance of the circuit will move out towards the receiver from the transmitter, taking with it the skip distance interference patter. Should layer height then increase, it will return towards the transmitter and the received signal will thus fluctuate.

(f) *Polarization fading*. At a certain stage of its passage through the ionosphere, the radio wave or ray splits into two components known as the "ordinary" ray and the "extraordinary" ray.

Each behaves differently. They are polarized differently, travel through the ionosphere at different velocities and on different paths, and each requires different ionization densities for refraction back to earth. When subjected to ionospheric absorption, their amplitudes will, in general, be different. The polarization of the component waves is elliptical. Owing to the variations in ionization density during their ionospheric transit, the axes of this elliptical polarization will rotate and polarization fading occurs. For communications engineers, it is the ordinary wave which is significant for relating frequency (MUF) to the transmission path.

(g) *Interference fading*. Interference in this instance should not be confused with man-made interference, or QRM. Here we are using the term in its geophysical sense. Or, as the radio physicist refers to it, as ionospheric interference. It is assumed that under normal, i.e., quiet conditions the ionosphere varies slowly from day to night, from season to season and from year to year in the solar cycle. However, daily measurements of electron density distribution indicate relatively small magnitude variations. These density variations cause the ionospheric radio wave to scatter a very small fraction of its power. The power of this "scattered" wave is proportional to the difference in electron density of the uneven "patch" to its surrounding more normal electron densities. In the E layer, these "patches" have been measured at over one kilometre in length and, in the F region areas of 20 km or more are quite general. These patches or clouds of irregular electron density drift just as clouds do in the atmosphere nearer earth. It is the interaction of the "scattered" and the normal electro-magnetic waves, i.e., variations in the diffraction pattern which causes fading of the earth-going or reflected radio wave.

(h) *Multipath fading*. To the ionospheric scientist, this term applies to fading caused by the radio wave taking more than one path, or using more than one ionospheric layer for its refraction back to earth. Thus, a received signal could consist of a wave reflected back to earth via the E layer and the F_1 and F_2 layers. Should either or all of these layers vary, the signal at the receiver will also vary, i.e., fade. To communications engineers, multipath fading can also mean reception of an HF signal by two completely different geographical circuits. A radio signal from Montreal, under certain propagation conditions, may reach Sidney, Australia, via the short path westward from Canada over the Pacific or, almost simultaneously, via the long path, that is eastwards from Canada over Europe, South Asia and Western Australia. The time variation between the arrival of the short and long path waves will cause fading at the receiver which can often sound hollow or "barn-like". To the TV engineer, multipath fading is usually due to reflections of the VHF-type signal off buildings and this additional signal interferes with reception of the direct signal. Usually only the video portion of the signal is affected and this can be seen in the form of "ghosts". Many TV viewers have experienced a very temporary example of this type of interference when an aircraft passes overhead and temporarily reflects the TV signal into the receiving antenna which then feeds two signals into the receiver, the direct and indirect waves. Drastic and rapid fading results.

(i) *Scintillation fading*. When an electro-magnetic wave, that is a radio wave, passes through the ionosphere, the energy in the wave front is re-distributed and, for a short time, the different components of the wave front will actually be travelling in different directions. The different parts of the front will interact with each other and the wave's amplitude will vary. In effect, the relative phases of the different "wavelets" comprising the wave front will vary due to their different directions of propagation. The amplitude of the wave will increase when these wavelets combine and decrease when they interfere negatively or destructively. This type of fading is seldom experienced in the HF bands. It is more common in the VHF and UHF bands.

Fading and your shortwave activities

During your shortwave listening, you will certainly experience at least one of the foregoing types of fading. Except for distances of a few miles, all HF radio communication and this includes shortwave broadcasting, is by means of sky wave. That is a radio wave reflected by the ionosphere. Fading may be fast or slow. The former type will be experienced when the ionosphere is unstable and the latter under "quiet" propagation conditions. The two main characteristics of fading are:

Speed – usually known as the fading rate, described as fast, moderate, slow, etc.

Amplitude – usually called the depth of fade and it is described as shallow, moderate, deep, etc.

It is realized that with the usual type of domestic shortwave receiver, and even with most communications receivers, it is quite difficult to determine the fading rate and depth (speed and amplitude) with accuracy. Flutter fading for example is often too rapid for professional measuring equipment such as pen-chart recorders to plot. However, as a guide, the table shown below may have some value. Many radio stations today have settled on the SIO reception code (Signal Strength, Interference and Overall merit of the signal) as sufficient information for evaluation of their coverage. Radio-Canada International employs this system on its reception forms which are sent out to the listener. However, members of the Radio-Canada Shortwave Club are usually more technically minded and they use a special report form, (supplied by the Club) which employs the SINFO code: Signal strength, Interference, Noise (man-made), Fading and Overall rating. Fading details are:

Frequency of fading F/M=fades per minute

5 – Nil	0-1	F/M
4 – Slow	1-5	,,
3 – Moderate	5-20	,,
2 – Fast	20-60	,,
1 – Very fast	greater than 60	,,

Usually a note on fading amplitude is enough, i.e. "fading shallow" or "fading very deep" etc. With practice, the table should provide the necessary parameters to permit you to supply all the information on fading which a radio station may reasonably expect from its listeners.

Some Methods of Reducing Fading Effects

We now know that fading of radio signals, especially rapid fading, degrades reception, sometimes to a degree as to render the received signal useless. However, some characteristics of fading can themselves be used to minimize their detrimental effects. For example, the variations in space, frequency, mode, time and polarization can be utilized. Engineers refer to these methods as diversity reception systems. Some of them can be simplified to improve your reception.

Space diversity. This method is used very often by communication companies and broadcasting organizations operating, receiving or monitoring stations. We should note here that diversity reception briefly means the reception of the same intelligence over two or more transmission paths (or circuits) which have different characteristics. Space diversity reception recognizes this principle and so the receiving antennas are spaced as far apart as conditions will permit at the receiving site. Certainly the distance between antennas should be in the order of three wavelengths or more, based on the lowest frequency to be monitored. Thus, identical antennas located several wavelengths apart will indicate uncorrelated fading characteristics of the same received signal. The output of both antenna systems is fed, via a multi-coupler to the diversity receiving equipment which automatically selects the optimum output of the antennas. A simplified system can be erected and the output of each antenna selected manually after monitoring at the receiver.

Frequency diversity. This reception system too is often used professionally in conjunction with the diversity method. In addition to separate but identical antenna systems used at the receiving station, two or more frequencies are used to transmit the information, traffic or programme. Here, a receiver is tuned to each frequency carrying the required signal and, via a combining unit, the frequency diversity receiving equipment automatically selects the channel with optimum output. Due to the lack of correlation over a circuit operated on different frequencies, the possibility exists of the carrier-wave and side bands not fading simultaneously on each channel. As this lack of correlation is a function of frequency, as we have seen earlier, one of the frequencies operating the circuit is usually received. This reception system is usually combined with space diversity by communications companies to reduce error rates. This method of reception may also be simplified for home use by tuning two receivers, fed by different antennas separated as much as possible, to two different frequencies carrying the same programme.

Polarization diversity. Also used for reception of sky waves. Polarization fading can be reduced by using two identical antennas oriented at right angles or in a V configuration. This system is based on the principle that fading due to tumbling polarization on any antenna positioned at right angles (or orthogonally) to another will not be correlated with that on the other antenna.

Tests using pairs of doublet antennas in different orthogonal configurations, e.g. L's, T's, X's and so on have indicated that they do not have to be vertical or horizontal. Unfortunately, it is extremely difficult to achieve any real directivity with any of these configurations. A simple home polarization diversity system would be two whip or vertical antennas arranged in a "V". Hence, the inverted "V" antenna. Another configuration would be the sloping "L".

Time diversity. Used by communicaion companies on their HF circuits. As signals fade in time, the characters and numbers in a message are repeated. Another time diversity system automatically adjusts the transmitted information rate to conditions prevailing on the circuit.

From this brief investigation into some fading parameters and characteristics, it is hoped that you will have some indication of the problems facing the HF engineer in designing or operating equipment for shortwave radio communications. The subject is a very complex one calling for further prolonged investigation, especially in the field of direction receiving antennas. Meanwhile, perhaps this account of fading will encourage the SWL and DX-er to experiment with his own reception. This treatment of the subject is certainly not exhaustive nor is it meant to be. For example, we have not discussed fading due to "Spread F" or that due to various types of ionospheric storms. These will have to wait for another time. However, you will surely have a better idea of the vast scope of fading phenomena and perhaps, a desire to read into the subject on your own.

Chapter 16

SUNSPOTS AND YOU

Courtesy: Radio Canada International

Before we can understand the nature of sunspots and how they affect shortwave reception, we must know something about our sun. Our sun is unique in one respect at least. It is the one star in the whole universe whose surface we can see. All the other stars, even the nearest and largest, are so remote that even the giant 200 inch telescope at Mount Palomar in California can see them only as distant points of light. Radio physicists and shortwave engineers, as well as astronomers, study the sun because some solar disturbances have a profound affect on shortwave communications, and sunspots are one type of solar disturbance.

To the astronomer our sun is a star of spectral type G, which is in the middle of the range of these types of stars. Its luminosity is neither very high nor very low. It doesn't have marked peculiarities. In fact, our sun is a very ordinary star in the Milky Way system. It is not even centrally placed in the disk of 100,000 million stars. The sun is located about two thirds of the distance from the centre of our galaxy towards the rim. It is in one of the outer spiral arms. Astronomers have measured the sun as being 149.5 million km (about 93 million miles) distant from the earth. This measurement is believed to be correct to about 10,000 miles. A ray of light or sunshine takes 500 seconds or 8.3 minutes to reach the earth. The sun itself is made up of various levels, solar levels, and although it is a spherical ball of matter held together by gravity, it is not entirely featureless. The temperature of the lowest level is estimated to be in the order of 24 million degrees Kelvin. (Lord Kelvin was a British physicist who died about the turn of the century. He invented the system of thermal measurement named after him.)

The next level travelling outward from the centre is the photosphere, and that is about 700,000 kilometres (about 430,000 miles) from the sun's centre. The photosphere is probably the most important level to us since it is from it that we get the greater part of our light and heat. The temperature of this region of the sun is estimated to be about 6,000° Kelvin. The photosphere is a very thin layer or level, perhaps no more than 100 to 200 kilometres in depth. Because the photosphere is an extremely thin layer, it gives the sun its sharp outline, somewhat similar to a solid surface. It is at this level in the photosphere that sunspots occur. We will come back to the photosphere when we start to talk about sunspots in more detail. Still travelling outwards from the centre of the sun, the next layer or level we come to is known as the reversing layer, so-called because it is a layer of cooler gas, about 1,000 kilometres deep (about 620 miles). The layer above the reversing layer is the chromosphere. It is about 12,000 kilometres above the photosphere and solar physicists have measured a temperature of about 30,000 degrees Kelvin for this region.

The level above the chromosphere is the Corona, the extended outer atmosphere of the sun. It is impossible to see the Corona in ordinary light because it is so nebulous. However, during a total eclipse, photographs have been taken of this halo around the sun. The Corona temperature is estimated to be in the region of one million degrees Kelvin. So there we have the various solar levels.

Sunspots were first observed by the Chinese before Galileo and his invention of the telescope in 1610. In fact, it is known that the Chinese observed sunspots many years before Christ was born. In 1612 Galileo used the telescope to make sketches of the solar disc showing many large sunspots. However, it was not until the middle of the 18th Century that a number of astronomers in Europe began to keep regular records of sunspots. Hendrick Schwaber of Germany, a chemist and an amateur astronomer, discovered the eleven-year cycle of sunspot activity. Schwaber recorded his daily count of sunspots using a small telescope and, after several years, he found that the number of spots varied in a regular cycle.

After watching the sun daily for almost 20 years, Schwaber came to the conclusion that sunspot activity reached a peak, declined to a minimum and then climbed to another peak of maximum activity, over a time span of about 10½ years. Wolf, the Director of the Zurich

Observatory at the time, realized the necessity for arriving at some standard means of counting sunspots and he produced the formula still in use today, which is known as the sunspot number or the "Wolf" number "R".

A careful examination of the solar surface shows there is a large amount of fine structure. This structure, in appearance has been compared to rice grains or willow leaves. We will stay with the rice grains description because the term "granulation" is now used by astronomers to describe the sun's visible surface, the photosphere. Each of these granules or grains is roughly circular in shape and has a diameter of about 1,500 km (approximately 930 miles) and a life of only a few minutes. The surface brightness of any granule may be as much as 10 per cent greater than that of the surrounding solar surface. As one granule fades away, another takes its place. Rather like rice boiling in a pot of water. Slow motion films of the sun, taken at the Pic-du-Midi Observatory in France by the late Dr. Bernard Lyot, give a vivid impression of this boiling action. The granules are believed to be the tops of convection currents which originate in the lower layers of the sun, (that is, below the photosphere) which transport the sun's heat to the surface through the chromosphere and the corona into outer space. This upward motion of the granules has been calculated at a velocity in the order of one km per second. It is a kind of turbulent motion with hot bright gases moving rapidly upward and cooler darker gas downward. Sometimes, these granules separate to form a dark area between them and this dark area is known as a "pore". When several of these pores unite, a sunspot is born. Observation of sunspots has revealed that the photosphere is rotating, but this rotation is not like that of a solid body, since the sun's rotation is faster at the solar equator than it is at high or low solar latitudes. Scientists who have observed the movement of sunspots across the solar disc always from east to west have found that the period of rotation of the sun is 26.89 days, or, in round figures, 27 days. This is known as the 27-day rotation period. Thus a spot born on the extreme east edge of the sun, or as the astronomers call it, the east limb, appears to drift westward across the centre of the sun, to the extreme west limb and then disappear as the sun rotates. If it is a large spot or groups of spots, it will reappear about 13 days later again at the sun's extreme east limb where it was first observed. This complete rotary movement takes about 27 days. For this reason, a number of natural phenomena here on earth believed to be influenced by sunspots have a periodicity of 27 days. The lifetime of a sunspot can vary from a few hours to many weeks. Each fully developed spot consists of two distinct regions. The dark inner region, the umbra, is surrounded by a more luminous region, the penumbra. Rather like a fried egg! Except that the yolk is black instead of yellow. The boundaries between the umbra and the penumbra and between the penumbra and the surrounding photosphere are surprisingly sharp. When observed under the best conditions, the penumbra has the appearance of white hot threads.

Large sunspots are to some extent hollows in the photosphere; and it has been suggested by some scientists that these penumbra (or threads) are a sectional view of the convection currents whose tops we spoke of earlier as granulation. Astronomers say that the temperature inside a spot is about 1,000° lower than outside it. All sunspots have strong magnetic fields whose field strength decreases from the centre to a very small value not far outside the penumbra. The history of a sunspot group is really only one facet of a story involving a number of known phenomena.

In the early stages of the development of a sunspot, the pores tend to cluster around 2 centres of activity known as the "leading" and the "following" spots. Since the sun rotates on its axis from east to west, the leading spot is the most westerly of the pair. During the first few days these two spots move rapidly apart, almost as if they were repelling one another, and at the same time each grows in size. The leading spot has an average life four times that of its follower, which is usually irregular in shape and decays quickly after reaching its maximum size. The leader spot is more compact and regular in shape and dwindles slowly. After about the 10th day, the leader and follower approach each other. The follower disappears and the leader takes on a rounder shape and may persist for weeks before gradually disappearing. The size of a sunspot can vary from a small one of a few thousand miles to huge spots many times the size of our own planet earth.

The cause of sunspots is still unknown, but one of the most important discoveries about them occurred in 1908 when Dr. George Hale of the Mount Wilson Observatory in California, photographed sunspots in enough detail to show that large spots are often surrounded by great whirling masses of gas. In 1914, Dr. Hale made another important discovery when he proved that sunspots often have magnetic fields much more powerful than the magnetic field surrounding our earth. Working from these two discoveries, physicists have developed what is perhaps a partial explanation or theory for sunspots. Many of them believe that they are caused by strong magnetic fields lying deep within the interior of the sun. Huge energies generated by these magnetic fields sometimes break through to the sun's visible surface, the photosphere. These magnetic eruptions on reaching the photosphere have a strong magnetic field in their centres. These, in turn, cause certain changes in this electrified gas. The temperature drops below that of the sun which results in a visible contrast, a dark area which is identified as a sunspot.

Sunspot count

Now, as to the actual sunspot count, the degree of the sun's spottedness at any time can be measured by counting the spots or by noting their total area. We know from past records and current observations that the number of sunspots varies from day to day and from year to year. Also the number of spots counted and their area depends, to some extent, upon the observer and his telescope. According to Dr. Waldmeier of the Zurich Observatory, in the year 1848 Rudolf Wolf, then the Director of the Observatory, introduced the relative sunspot numbers as a measure of sunspot activity. They are based on the striking fact that sunspots very often appear in groups. It is seldom that the sun's face shows only one spot, unless it is a giant probably formed from a number of smaller spots. The Wolf formula is $R=k\ (10g+f)$, where "g" is the number of sunspot groups and "f" the number of actual spots whether in groups or not. The constant "k" has a value which depends upon the type of telescope used and the viewing conditions. Dr. Waldmeier says that Wolf carried out his observations with a Fraunhofer refractor telescope of 8 cm aperture and 110 on focal length with a magnification of 64 giving the "k" constant a value of 1. Wolf considered that the "g" number alone did not represent a satisfactory measure of sunspot activity because the sizes of the sunspot groups differed greatly. Considering this and other circumstances, he showed that the multiplier 10 which multiplies "g", the observed number of sunspot groups, gave greater weight to the large groups, which he believed to be a more important indicator of solar activity than short-lived small spots. The Fraunhofer refractor telescope is still in use today at the Zurich Observatory. Observations from around the world are collected at the Observatory in Zurich and examined before the final sunspot number is compiled for that day. Although in the Wolf formula the R number may seem to be a rather arbitrary method of determining the sunspot count, it has proved to be a satisfactory measure of solar activity. Over the years it has shown a high degree of correlation with other related phenomena, for example, the electron density in the ionosphere.

As said earlier some sunspots were very large and others were in comparison rather small. The largest group on record crossed the sun's central meridian on 7 April 1947. Its maximum area was over 7,000 million square miles. Another huge sunspot group was observed at its maximum size on February 6, 1946 when it exceeded 6,000 million square miles. By the way, a warning to budding astronomers; never study sunspots directly either with the naked eye or through a telescope pointed at the sun. Professional astronomers use a telescope arranged so that the sun's image is projected on to a circle of paper or opaque plastic about 18 inches in diameter. It is this projection which is studied and not the direct sun. This is necessary to protect the eyes. Although the umbra or centre of the sunspot looks black, it is in fact quite luminous and has a temperature of about 4,500°K. The umbra looks dark because of the contrast between it and the photosphere whose surface is about 1,500° higher in temperature (6,000°K). We could say that a sun-spot is a type of refrigerating mechanism capable of holding a large region of the photosphere at a lower temperature than normal for many days and sometimes weeks.

Under reasonably normal conditions the sunspot number over the course of an 11-year cycle ranges from "0" (sunspot minimum conditions) to about 200 (sunspot maximum conditions). However, experience has shown that a 12-month running average sunspot number is the best indicator of ionospheric propagation conditions. This smoothed number takes into account the Zurich monthly sunspot numbers for a 12-month period. This is necessary because the daily numbers show great variations as do the monthly numbers. For example, by actual observation, the Zurich observed sunspot number for January 1970 was 115, for February it was 130, in March it had dropped to 102, in April 1970 it had risen slightly to 109 and for May it had shot up to 131. Thus, it is easy to see that even the monthly average number shows pronounced variations. It is true that the daily variations have been greatly eliminated, but the monthly still show too strong a fluctuation to be really useful in forecasting. The elimination of these variations is necessary for many purposes and especially so if we wish to obtain a sunspot activity curve which ascends from minimum to maximum and descends from maximum to minimum activity as smoothly as possible. Such a smoothed sunspot cycle curve gives a truer picture of long-term solar activity. It is this smoothed sunspot number plotted over many years which clearly shows the famous 11-year cycle. This solar cycle has a number of terrestrial effects and the most important of which is on the ionosphere, which in turn affects radio communications.

It would be important economically and scientifically if it was possible to forecast future sunspot numbers or sunspot activity with some degree of accuracy. The 11-year cycle provides some guidance, but even with this the irregularities between cycles reduces its usefulness. Some cycles have a sunspot high of over 200 while others hardly reach 130, that is the maximum count of each cycle. Some empirical knowledge has been gained in the last few years and it is possible to make fair predictions of average trends in solar activity a few years in advance but there is as yet practically no knowledge available relating to the prediction of the occurrence of the individual spots. Daily and monthly sunspot numbers are available from many sources. A complete listing can be obtained monthly from the Director, the Zurich Observatory, Sternwarte, Zurich, Switzerland.

The observational knowledge concerning sunspot is detailed and precise. In contrast the theoretical explanation of the cause and construction of sunspots is speculative and controversial. One fact which still requires explanation is the comparatively low temperature of a sunspot (4,500°K) compared with the surrounding surface of the photosphere (6,000°K). Why this 1,500° difference? It is, of course, this contrast in temperature which makes the sunspot visible as a dark area in the light of the sun's visible surface. What causes it and how does it work? The sunspot cycle is the most reliable index of the ionosphere's refractive efficiency, that is its capability for reflecting short radio waves earthwards. That is why predictions of sunspot activity are used in the preparation of ionospheric propagation predictions used for scheduling shortwave frequencies. For more than 25 years, ionospheric predictions of high frequency radio propagation have been issued by the Institute for Telecommunication Sciences at Boulder, Colorado and other ionospheric radio propagation groups around the world. The significance of the relative sunspot numbers lies in the fact that they provide the longest continuous solar index on record. They are available immediately after their observation and this is important for the prediction of terrestrial phenomena which are influenced by solar activity.

Chapter 17

IONOSPHERIC DISTURBANCES

by L. J. Prechner, B.Sc., M.I.E.E.

Introduction

In addition to the relatively regular variations, the ionosphere is subject to disturbances which may adversely affect shortwave propogation. Very broadly, such disturbances can be divided into IONOSPHERIC STORMS, SHORTWAVE FADEOUTS and POLAR DISTURBANCES.

1. Ionospheric Storms

1.1. **General Remarks.** Apart from a wide range of electromagnetic radiations, the sun is also continually emitting into space charged particles of various energies, the so-called solar wind. The mean velocity of this wind varies considerably, but it is about 400 km/sec if the sun is "quiet".

However, this velocity may greatly increase during disturbed conditions on the sun, for example when a solar flare occurs, and space probes have shown that this increase is often followed by disturbances in the earth's magnetic field ("magnetic storms"), by disturbances in the ionosphere ("ionospheric storms"), and also by other associated geophysical phenomena (such as the aurorae). These events are caused by a complex interaction of the solar wind with the earth's magnetosphere and upper atmosphere, resulting in the deflection of solar particles by the earth's magnetic field towards the auroral zones. (In more more detail, this field drives the charged particles towards the auroral zones, either through narrow gaps in the sunlit part of the magnetosphere – which surrounds the earth to very large distances – or back towards the earth from the dark part of the magnetosphere). The accompanying heating of the auroral zones (principally in the E region) is probably due to the circulation of large electric currents (*"electrojets"*, set up by the electrical fields in the magnetosphere), and also to the impact of energetic particles.

The ionosphere is then affected in a complex way, particularly in the F_2 region. There are various theories to explain the origin of the ionospheric storms, and perhaps each of them may be of importance. These theories include changes in the electrical fields, changes in the circulation of the upper air winds towards the equator, and consequent changes in the chemical composition of the upper air (the O/N_2 ratio affects the relative rates of production and of loss of free electrons, and hence it also alters the F_2 ionization density). There will also be expansion and diffusion processes in the F_2 layer, resulting in changes in ionization density over large areas. In some regions, shortwave propagation may then be adversely affected by the consequent *decrease* in ionization density. In the lower latitudes, such propagation may even be improved, because the winds may lift ionization to greater heights, where the electron loss rate will be reduced, and consequently ionization density will be increased.

The world-wide pattern and behaviour of ionospheric storms depends in a complex way on many factors, such as magnetic latitude, time of day, season, year, etc.

The effects of ionospheric storms on shortwave transmissions vary with the solar cycle, with the storms being most frequent during high solar activity. However, they may be more troublesome when they occur during low solar activity years, due to the limited range of HF bands which will propagate. Also shortwave transmissions on the high latitude paths are those which are most severely affected by the ionospheric storms.

1.2. Sources of Fast Solar Particles

As mentioned earlier, streams of fast solar particles may be emitted into space during flares, that is very hot regions, which often appear on the sun's surface during years of high solar activity. Flares usually occur near sunspots, particularly if these are large, or are magnetically complex.

Flares may be due to a very sudden release of magnetic energy, and they usually last for a very brief period, seldom exceeding an hour or so. They can vary greatly in their intensity and in their effects on the earth's ionosphere. Flares emit greatly enhanced extreme ultra-violet and X-ray radiation, and they also cause ejection of particles from the solar atmosphere. These intense X-rays from the flare may cause within a few minutes Shortwave Fadeouts (SWF's) on the sunlit part of the earth. SWF's may then be followed one to a few days later by magnetic and ionospheric storms, caused by the arrival of charged particles from the solar flare regions. However, no storms will occur if these particles miss the earth, or if the flares are not sufficiently intensive.

Not all storms are caused by solar flares, as there are other sources of fast solar particles. Some of these sources are remarkably persistent, and may result in the 27-day recurrent magnetic and ionospheric storms. A recent theory links such storms with long-lived "coronal holes", that is rarified regions in the sun's outer atmosphere, the corona.

As the sun's axial rotation period with respect to the earth is about 27 days (synodic rotation period), the simplest analogy for the recurrence of these storms would be that of a rotating water jet spraying a plant at regular intervals.

1.3. Types of Storms

Ionospheric storms may be broadly divided into *isolated* and *recurrent* types. Storms may also have both *positive* (i.e., increase in F_2 ionization, often at the commencement) and *negative* (i.e., decrease in F_2 ionization) phases.

1.3.1. **Isolated Storms,** i.e., non-recurrent storms are often, but not always, associated with the effects of the solar flares. Such storms are prevalent during the high levels of solar activity, and can be at times very intense.

1.3.2. **27-day Recurrent Storms.** These storms can be remarkably persistent as they may regularly recur from periods of up to one year or even more. The duration of a single storm during a recurrence series usually lasts for several days, and it tends to get shorter towards the end of the series. 27-day recurrent storms are most frequent during the declining phase of the solar activity, that is usually a few years after the solar maximum. The length of this delay may vary from cycle to cycle.

1.4. Storm Variations

1.4.1. **Geographical.** the effects and the incidence of ionospheric storms vary considerably with the locality. They are usually most severe in and near the auroral zones, because the earth's magnetic field tends to deflect the electrified particles streaming from the sun towards these regions. The reception of shortwave transmissions on paths crossing or approaching the auroral zones is therefore most adversely affected, e.g., for paths between Europe and North America. Usually, the low latitude paths are the least affected by ionospheric storms.

1.4.2. **Time.** The incidence of ionospheric storms, as observed in *Southern England* has shown the following characteristics:–

Their duration may be as short as a few hours, or as long as a week or more. *The onset* of some of the isolated storms can be very rapid ("sudden-commencement" type storms) and they can begin at any time, although they frequently start in the evenings. The effects on shortwave transmissions are usually more severe during night time, due to a lower margin of propagationally viable HF bands. Their seasonal incidence is highest during the winter and equinoctial months, and their *incidence during the solar cycle* is highest a few years after the sunspot maximum, due to the overlapping incidence of the isolated and recurrent storms during the solar cycle.

Figure 1 on page 109 shows in histogram form the Zürich mean annual sunspot numbers from 1944 to 1977, covering solar cycles Nos. 18, 19, 20 and the beginning of the current cycle No. 21. Histograms are also given for the annual percentage incidence of magnetically disturbed days in Southern England and of the propagation disturbances as recorded over the Westerly paths by the BBC in Southern England. Figure 1 also shows that during all three cycles the maximum incidence in magnetic and propagation disturbances, as observed in the UK, did not coincide with the sunspot maximum, but occurred a few years afterwards.

2. Shortwave Fadeouts (SWF's)

2.1. **General Remarks.** The D layer (which is about 80 km above the earth) plays a considerable part in the absorption of shortwave propagation on sunlit paths, particularly on the lower frequencies. During the hours of darkness the D layer almost disappears and so does its absorption (except at times in lower latitudes). However, on daytime paths the D layer is subject to short-lived disturbances due to solar flares, which result in almost simultaneous ionospheric events, collectively called "SUDDEN IONOSPHERIC DISTURBANCES" (SID's). These may affect in different ways the propagation of radio waves from VLF to VHF. For example, on HF transmissions there occur "SHORTWAVE FADEOUTS" (SWF's) which are caused by the sudden large increases in the D layer absorption. As mentioned before, SWF's follow the appearance of flares on the sun, particularly if they are large or very intense (not every flare is followed by an SWF). SWF's are produced in the following way: The intense X-ray radiation from the flare may cause in the D layer abnormally high ionisation, and this will in turn result in a sudden and often very considerable increase in the absorption of shortwaves in this layer. This is because at the relatively low D region heights the collision frequency of free electrons with neutral molecules is very high, and an increase in ionization density will result in still greater extraction of energy from the radio waves, hence in greater absorption losses.

It is fortunate for shortwave reception that solar flares and their enhanced hard X-ray emissions last for such a short time (seldom more than an hour or so). The resulting extra ionization and absorption produced by the flare in the D region also disappears fairly quickly (due to the relatively high gas density at these lower heights), and the shortwave reception soon recovers normality. SWF's vary greatly in their intensity, with the lower HF frequency bands being most affected. Occasionally, on some paths, all operational HF frequencies may be rendered unusable, resulting temporarily in a total fadeout.

2.2. SWF Variations

2.2.1. **Geographical.** SWF's are normally observed only on those paths which are wholly or partially in daylight.

2.2.2. **Time.** The incidence of SWF's, as observed in Southern England, has shown the following characteristics:—

The *onset* is often very sudden and violent, followed by a less rapid recovery phase. The duration of a typical SWF is very brief, usually about half an hour or less, although very occasionally they may last for a few hours. The incidence of SWF's usually follows closely the *solar cycle*, as shown in *figure 1*, peaking during the years of high solar activity and almost disappearing during the years of low solar activity. This corresponds to the incidence of solar flares during the solar cycle.

3. Polar Disturbances

Shortwave propagation in high latitude regions may also be affected by *Polar Cap Absorption Events* (PCA's) and *Auroral Disturbances*.

3.1. **Polar Cap Absorption Events (PCA's).** These are mainly caused by the emission of very energetic particles (mainly protons of energies >10 MeV) by some of the very large solar flares. These particles may take as little as tens of minutes to travel to earth, although usually it is much longer. They are guided by the earth's magnetic field towards the so called polar caps (generally above the auroral zones), where they penetrate right down to the D layer, thereby greatly increasing its ionization, and hence the absorption of shortwaves, etc. This results at times in these high latitudes in a total radio wave blackout. The *duration* of PCA's may be from a few hours to a few days, as energetic solar particles can continue to arrive over a relatively long period of time, due to storage effects in space.

The *occurrence* of PCA's is relatively rare, except towards sunspot maximum, when about 10 PCA's per year on average have been recorded.

3.2. **Auroral Disturbances.** These are much more frequent and often more localized than the PCA's and they usually occur around auroral zones, e.g., N. Norway. They may be caused by an intense "rain" of charged particles (e.g., electrons of energies of tens of keV) on the ionosphere, resulting in the increase in the D layer absorption and the deterioration in shortwave propagation, for example, in occasional "auroral blackouts".

Chapter 18

SKIP

by Jim Vastenhoud

Most shortwave listeners are familiar with the term "skip distance", "skip-zone" or "dead zone", indicating the area where no signal is heard from a particular shortwave station, due to the fact that it happens to be beyond the ground-wave range, and not yet within the sky-wave range. *See figure 1.*

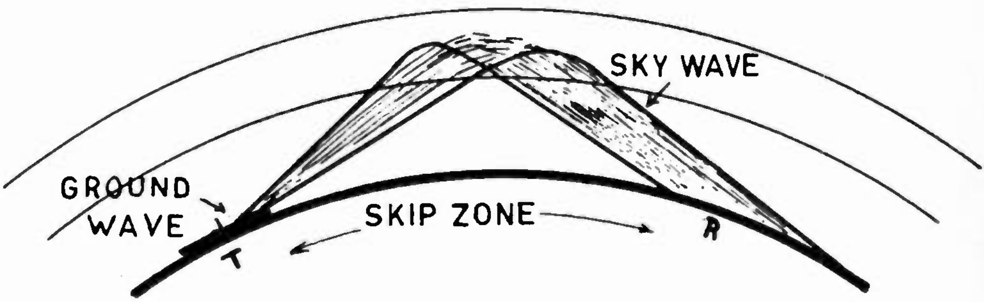


Fig. 1

The ground-wave range of shortwave stations is relatively small, as these frequencies are strongly subjected to ground losses. A rule-of-thumb is to estimate the ground-wave range in kilometres being equal to the wavelength in metres. So, 30 km ground-wave range can be expected for a 31 metre (9 MHz) band station.

The first touch-down of the sky-wave is not so easily determined, as it depends on two important factors: the elevation angle of the transmitting antenna, and the reflective properties of the ionosphere at the point of signal impact.

It will be clear that the skip can be expected to be long for low elevation, narrow-beam antennas. If such an antenna has an elevation angle of 7 degrees, and a vertical beamwidth of 12 degrees (both are realistic values for long-distance antennas), the point where the signal hits the F_2-layer closest to the transmitter, will depend on the local height of this layer, and could be 1,400 km from the transmitter. Assuming a symmetrical reflection, the first touch-down of the signal can then be projected some 2,800 km from the transmitter. The signal thus "skips" 2,800 km before the first touch-down.

In this case, the skip distance is determined by the radiation characteristics of the transmitting antenna. More often, however, the skip depends on the ionospheric situation.

As has been outlined elsewhere, the reflective properties of the F_2-layer are measured with ionosondes, ground-based stations which radiate pulses of gradually increasing frequencies straight upwards, and register the return echos from the ionosphere. The highest frequency which is still returned at vertical incidence, is called the critical frequency (f_C).

To extrapolate the reflective properties of the layer for oblique incidence, the secant law is applied. Thus, it is found that the oblique incidence at 10 degrees elevation angle of the signal, and a critical frequency of 7 MHz, produces a MUF F_2 4,000 of about 40 MHz.

Although the numbers given above are not worthwhile, they illustrate that the ability of the F_2-layer to reflect high frequencies, decreases as the elevation angle increases. Thus, it may be found that a 15 MHz frequency is returned from the ionosphere, as long as the elevation angle of the radiation remains lower than 20 degrees. If we lower the frequency to 11 MHz, the ionosphere may be able to return signals which were sent upwards at a 40 degree angle, etc.

This means that the skip distance is, at any moment of the day or night, dependent on the reflective properties of the F_2-layer, of the angle of incidence of the rays, and the frequency used.

The practical consequences are that skip distances are longer in winter than in summer. In winter, an 11 MHz frequency can even have a 1,000 km skip at 1100 local time, and at night, even 6 MHz may skip 1,000 km, due to the low ionization density of the layer. This means that, especially in the temperate zones of the earth, shortwave stations will have trouble in covering nearby target areas in the late evening and the night hours during the winter season, especially under low sunspot conditions.

Also, in winter, the skip of high frequencies can be substantial in the daytime. Skips of 1,800 km have been observed on 15 MHz frequencies, virtually leaving an area with a radius of 1,800 km uncovered.

This consequence of ionospheric propagation is used by some broadcasters, who work co-channel with a station situated in their target area, knowing that the skip protects them from interference. The small area which is covered by the ground-wave of the station in the target area, is then the only area where interference will occur.

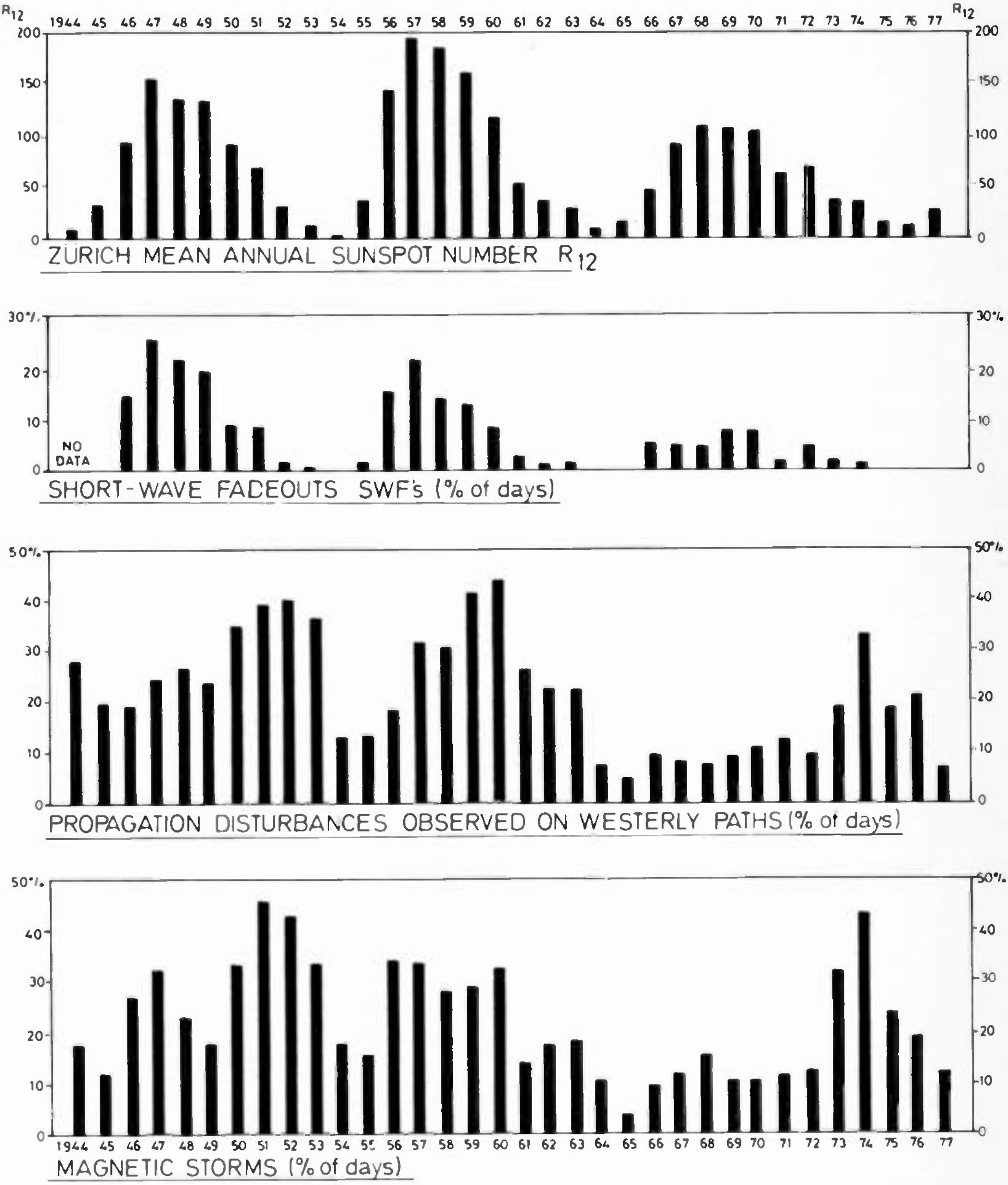


Fig. 1: Sunspot Cycles Nos. 18, 19, 20 & 21 (1944-1977) and Propagational and Magnetic Disturbances in Southern England

Chapter 19

JAMMING AND KINDRED TOPICS

by Gerard A. Casey

Jamming may be defined as deliberate interference by a second party in an attempt to prevent radio reception of a broadcast on a given channel by the first party. Most shortwave listeners recognize it as a noise which has been likened to that of a petrol engine generator; it has the unfortunate property of "splashing over" and affecting channels adjacent to the one being jammed. Primarily a shortwave manifestation, jamming may also, in Europe and Asia, be observed on medium wave channels. On shortwave frequencies the problem it presents is acute not only by reason of its effect on nearby frequencies but also, because of the very nature of shortwaves and their propagation, by the fact that jamming may literally be heard worldwide when conditions are right. The problem is particularly troublesome in Europe, which contains many of the target areas of the jammers. At certain times of the day, whole sections, amounting to 50 kHz and more in width, of some of the European shortwave bands are completely filled with jamming noise, and consequently are lost to the listener. The problem is less serious for the North and South American listener, who has the advantage of lying geographically half a world away from the target area being jammed.

Jamming is, of course, no new phenomenon; cases were known in the early thirties on medium waves and their number increased as the Second World War approached. The war itself resulted in substantial refinements in jamming technique, which was by then widespread and had been extended to shortwaves. Such practise also provided the allies (above all the BBC) with considerable experience in overcoming enemy measures taken to prevent transmission of their broadcasts.

It is a truism that a totalitarian regime, or any regime whose leaders are in strict operation of the government, controls all sources of information – even the most innocent. Any attempts to break this control are at best resisted, at worst forcibly prevented. One aspect of such totalitarian control of the information media is the attempt to prevent local inhabitants from hearing certain broadcasts originating outside the national borders. As will be seen, the contents of such broadcasts do not necessarily amount to direct propaganda, but their very existence breaks the information monopoly exercised by the local governments.

Broadcast jamming in 1978 is largely, but not entirely, a product of the Cold War. Broadly speaking, the question is that of Western broadcasts being jammed by the Communist East Bloc nations. According to the severity of phases of the Cold War, jamming will be more or less widely practised. A sub-variety of this "mainstream" jamming is the current mutual jamming of broadcasts between the USSR and the People's Republic of China. Apart from its use in the Cold War, jamming may well be practised by a legitimate government against clandestine transmitters operating within or without the national boundaries or even (as happened a few years ago in the British Isles) against pirate "pop" stations. The Middle East and Vietnam are also areas where, for reasons which are not always connected with the Cold War, jamming is carried out on an irregular and not always efficient basis.

It would be extremely difficult to give, in the scope of this short article, an exhaustive answer to the question: "who jams who?" Briefly, it may be said that the BBC and the Voice of America, together with Deutsche Welle, Radio Nacional de España, Vatican Radio and certain other organizations are jammed on a regular but selective basis (that of language) by the USSR and a coterie of East European Bloc nations. Radio Free Europe and Radio Liberty are two consistent targets of the jamming operations by these nations. The USSR jams transmissions in Russian from Communist China, which, in turn, jams Chinese-language broadcasts from the USSR. The Chinese do not jam the BBC. In another part of the world, the Spanish Government still jams Radio España Independente and the Basque nationalist Radio Euzkadie. There are times when the BBC's Arabic language service is jammed, and also when inter-Arab transmissions in the Middle East are jammed, depending on the political climate in that region. In Vietnam, intermittent jamming occurs in the Hanoi area.

To the shortwave listener, who audits foreign broadcasts either for entertainment, instruction, information or merely as a hobby, the extent of worldwide jamming is not only extremely regrettable, but also intensely irritating. Apart from the ethical question of the right of one nation to censor the airwaves of another, there remains the fact that jamming spills over to adjacent channels and often either wipes out reception of weak signals from remote corners of the world, or prevents reception of a favourite programme from a favourite station. Sometimes, ludicrous errors are noted, such as when a jammer transmits on a wrong frequency or transmits by error on the same frequency being used by its own organization for beaming propaganda.

In the case of East European Bloc jamming, the average listener rarely realises the effort and cost of the jamming enterprise. As a fairly simple examble, let one imagine a point in time when the BBC, the Voice of America, and probably several other national stations are transmitting in, say, the Russian language; he must then understand that the Russian jamming organization not only has to jam every frequency being used to carry such transmissions (and there will be several in use by each national broadcaster), but that it must also put down a blanket of noise in every locality of any importance) – and Russia is a mighty big country! The implication of this simple example is evident: such an effort requires vast technical resources and is a tremendous and costly operation. Behind the interference being broadcast lies a control organization of a scale not easily imagined, but consisting of platoons of technicians needed to operate and maintain the apparatus, and behind them of numerous executives who must decide strategically as well as tactically what is to be jammed.

Concerning the effects of jamming, certain principles (one might almost call them psychological rules) were established during the Second World War, and the passage of time has served to refine and reinforce them. These rules might be summarized as follows:

1. It is impossible to prevent, at all times, fairly widespread listening despite all counter-measures. In occupied Europe during the Second World War, considerable effort was applied to this end without success, and the part played by allied broadcasting and its effects on Axis occupied countries is historically well known. There is no reason to believe that the even greater jamming efforts made since 1946 have been any more successful in preventing listening to Western broadcasts.

2. No blanket jamming system, therefore, will ever give complete coverage, particularly in rural or mountain zones, and on shortwaves.

3. The stations being jammed must exercise the greatest care to broadcast the truth objectively and impartially, even when it is unfavourable to their own national interests. This principle was established by the BBC (and later on by the VoA) early in the Second World War, and was further put to the test in the Hungarian crisis of 1956. It is now a principle tried and confirmed by the passage of time.

4. As a corollary to point No. 3, the listener will go to great lengths to pick up such programmes and his determination, far from being weakened by jamming, becomes greater and more passionate than ever – even, in extreme cases, to the consequence of being executed for listening to such stations.

Radio Free Europe/Radio Liberty

The shortwave station which seems to attract the most severe intentional jamming, is undoubtedly RFE/RL. It is a (fairly recent) merger of two US-supported stations, Radio Free Europe and Radio Liberty. The two stations had different target areas, though they were close enough: RFE covered Poland, Hungary, Czechoslovakia, Rumania and Bulgaria, while RL aimed its broadcasts at different parts of the Soviet Union.

Many shortwave listeners, especially those living in countries which have a strong tradition of neutrality, take the view that jamming would be considerably lessened if RFE/RL would cease its activities. This opinion favours the view of the political systems which operate the jamming stations and brandish the transmissions of RFE/RL as "propaganda".

However, both organizations have about 25 years experience and a proper view would at least require the analysis of what is actually being broadcast. To find out what developed in this period, a short historical survey.

From their inception in the early fifties until the fateful year 1956, it could indeed be said that the output of Radio Liberty and Radio Free Europe, then still two separate organizations, was crude, naive, brash, and offensive to the Eastern Bloc powers. During 1956, however, there

Read the Radio Hear the World

National Panasonic now has three models in its renowned DR series, the series of radios that offer Direct Readout of frequency for precise tuning convenience. These 3 intercontinental multiband models let you choose among a wealth of features to meet your wants and needs: digital or precise mechanical frequency readout, a wide range of bands, and so much more. Three new models for the very best in all-band listening pleasure!

DR28

The DR28 might well be your choice for a portable radio because it's got so much to offer. The digital frequency readout for all 6 bands (FM/MW/LW/ $SW_1 \sim SW_3$) tells you precisely the tuned frequency with unerring accuracy, right down to a single kHz. You can be sure of maximum reception conditions, thanks to the wide/narrow bandwidth selector. Special new I^2L circuitry does the work of about 2,000 transistors, and with higher reliability. Tuning is easy — and so precise — on all 6 bands, thanks to the new tuning mechanism with an all-gear drive system similar to that used on high-level communications equipment. Two-speed tuning is also included of course. Other features are the BFO pitch control, the RF gain control for MW and SW, the separate bass and treble controls, and a tuning/battery strength meter.

DR48

This double superheterodyne 10-band FM/AM receiver features digital frequency readout by LED display to tell you exactly where you are on the SW bands with incredible accuracy right down to 1kHz. Optimum selectivity for all reception conditions is ensured by the wide/narrow bandwidth selector which employs 4-element ladder-type ceramic filters in the narrow bandwidth circuitry.

Thanks to two intermediate frequencies, RF gain control, advanced IC's in the IF stage and FET's in the RF circuitry, the DR48 gives you the sensitivity, stability and selectivity needed to pick up the stations that used to get away. The easy-to-read linear tuning dials are coupled to two separate tuning controls, one of which is equipped with 2-speed tuning for SW bands 2 ~ 7.

Accuracy and linearity over the entire frequency spectrum are guaranteed by the 3-ganged variable tuning capacitor and input-tuned RF amplifier. But that's just part of the story. Try out the DR48 and hear the rest.

DR22

The heart of the DR22 direct-readout mechanism is the all-gear drive system, the same kind used in professional communications equipment. This not only eliminates tuning backlash but can be quickly frequency calibrated for pinpoint accuracy with the help of crystal markers. Wide/narrow bandwidth selection, RF gain control, a 3-way meter, SW spread dial ... these are just a few of the features reflecting the precision circuitry of this 8-band FM/AM double superheterodyne receiver that will bring you the world.

DR Series

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occurred the uprising in Hungary. Rightly or wrongly, many Hungarian listeners gained the impression that promises of American intervention (itself a most crude and unsophisticated notion) were being made through these two stations. As a result of such painful misinterpretations, a considerable change had to be made in these stations' organization and programming. In other words, both Radio Liberty and Radio Free Europe had learned the hard way what the BBC and perhaps the VoA might have told them from their own experience over the 16 years since 1939, namely, that unless broadcasting were objective and balanced, tragedies and misapprehensions were bound to happen in times of crisis and the stations would acquire the reputation of being unreliable. So, as a result of the 1956 Hungarian crisis, the programming of both Radio Liberty and Radio Free Europe was made more responsible and, more important still, they began to employ real professionalism, in the sense of broadcasting as an art.

In 1972, we find that these two stations' programming has changed out of all recognition from its early days. Radio Liberty has programmes of a high intellectual content aimed at the "take-over" generation in Russia – the up-and-coming cadres of youth who will be that nation's leaders in the near future. It was, for example, this station which first brought to the attention of intellectuals inside Russia the existence of the works of Aleksandr Solzhenitsyn (later to obtain a Nobel Prize). Regular programming each week contains large portions of material which can only be described as "heavy weight" intellectually. Radio Free Europe has, of course, a much wider broadcast spectrum than Radio Liberty. To begin with, it broadcasts not only in the Slavic languages but also in Rumanian, and has a large German service. Its programming is very bright, indeed sparkling, in style. The programme presentation and part of the content seem influenced by the style of the commercial, French-speaking, Europe No. 1. Apart from its bias towards the younger generations, Radio Free Europe has built up a striking capacity for being first with the news. When, as has been said at the beginning of this article, a state has control of all sources of information, it follows that the state's own output of news is often stale and unimaginative. This fact has been rather cleverly used by Radio Free Europe to exploit not only the great popular thirst for news in Eastern Europe, but also the enormous popular interest in sports – particularly in East Germany where the DDR has a commanding world position in athletics. Great efforts have been made to provide a most comprehensive and rapid coverage of sports. Thus, if the "mix" put out by Radio Free Europe consists of sports, pop music, and beat music, and impeccable attention to full news coverage and commentary, some idea of its impact versus that of local state radio can be gained, jamming notwithstanding. The news-gathering arrangements at Radio Free Europe are very "American" in their constant desire to be first with the news, and indeed the station pulled off a considerable "scoop" when, on the evening of December 15, 1970, while monitoring the output of two Polish domestic synchronized transmissions on 1304 kHz medium wave, it noted one of them (Gdansk) broadcasting an appeal for local calm (thus indicating that civil disorders had occurred). In consequence, Radio Free Europe was able to report to the world in general, and to Polish listeners in particular, the first news of such trouble – all of which must have been highly embarrassing to the Polish State radio network.

The "Complete Angler" of the airwaves (the real shortwave listener) ought not only to be a master of fishing the other and an expert on reception, but he ought also to be a connoisseur of broadcasting techniques. By this last criterion, the output of RFE/RL must be considered high-class broadcasting in the modern manner. It is quite likely to be as much for this last reason, as for any resons of crude propaganda, that both stations are so regularly jammed by the Eastern Bloc. Thus it may be less the fact that the two stations broadcast *all* the news as quickly and fully as possible, but more the fact that they are so much better broadcasters than the local state radio, which results in their being so systematically jammed and denigrated. Simply stated, this is what broadcasting is all about – to acquire and hold a large audience; it is precisely this capability in which the two stations are so successful. This last tenet is occasionally forgotten by broadcasters. A situation similar to that discussed above occurred a decade ago in France where the state popular radio programming had become stodgy. The French-language long wave Radio Luxembourg and Radio Europe No. 1 provided powerful competition for the state radio and succeeded for a time in stealing a large proportion of its audience especially among the young and those who for political reasons had cause to dislike the state radio. However, the French state radio reacted, not by repressive measures such as jamming, but by brightening up its own programmes and beating the opposition at its own game. The net result was rather better broadcasting for the overall population. Yet another such effect was observed when the "Pop"

Pirate stations in England gave the BBC a great deal of competition, as a result of which important changes were made in the BBC's popular music programming. It is interesting to note, incidentally, that the final step taken by the British administration (but not, it should be noted, by the BBC itself) was to use jamming to eliminate the last of the pirates.

Jamming: what can be done about it?

What then, can the intelligent shortwave listener who is not actually living in a target-area for jamming do to attenuate this most annoying and rather absurd barrier to good listening? In practise, very little of real value can be done, although two partial solutions may be attempted. These are:

1. That insofar as possible, the receiving equipment should have as much selectivity as can be afforded. In these modern days of high-power transmitters and choked-up jammed shortwave bands, it might be argued with elegance that selectivity is more important than sensitivity in a shortwave receiver. Another useful idea is to employ a Collins filter in the antenna arrangement, as this enables accurate peaking on the desired channel and not on the jammed frequency beside it. Other arrangements which increase selectivity, such as the use of a pre-selector, and the ability to vary the bandwidth received, are also of prime importance.
2. That some sort of directivity in the aerial systems is also essential. In the case of medium wave jamming this may often be obtained by the use of a loop-antenna, especially of the sort that incorporates a pre-amp. Such antennas were greatly favoured in continental Europe before the invention of the ferrite rod. They may often be found in junk-shops, flea-markets, etc. and may be refurbished at little cost.
3. Look for the highest possible frequency, which will just propagate the signal from across the border, while rendering regional jammers useless due to skip conditions.

On shortwaves the need for directivity is just as great as that on medium wavelengths but as the jamming is being received from several different sources at once, with different modes of polarization, it will be understood that directivity is hard to achieve. It is useful at times to have two different types of antenna (as different as possible in characteristics) if there is room for them. Apart from the differing nature of the antennas (dipole, longwire, beverage, whip), some attention should be paid to their having two quite contrasting radiation angles (one low, one high). Then, by switching from one to the other, it is often possible to effect some improvement – either in reception of the wanted signal or in attenuation of the jamming signals.

Should a really strong desired signal be undergoing interference by adjacent sideband QRM from a jammer, it is occasionally helpful to uncouple the entire aerial array completely and to stick a small rod or screwdriver into the aerial-socket. A selective receiver may then pick up a sufficient portion of the desired signal to permit its adequate reception, while at the same time (with a bit of luck) being insensitive to the jamming. Similarly, receivers with telescopic antennas can have the antenna retracted or extended until a fair balance is found, and the chosen signal is received. If, however, a jammer is on the chosen frequency, or there is little selectivity in the receiver, very little can be done; this is even more true when the desired signal is of only mediocre strength.

It is the writer's personal opinion that the only real cure for jamming is to stop it at its source. In this direction, it is felt, more could be done by some of the International Radio organizations which, for more than a quarter of a century, have had their heads in the sand, ostrich-like, and avoided this problem. While the need for diplomacy and an absence of emotionalism in approaching such a problem is well understood, the fact remains that a stronger position toward jamming could easily be taken by these organizations. The major world broadcasters, too, could do much more than they have.

Conclusion: The only adequate solution to the jamming situation is to convince all those engaged in broadcasting and politics that the practice of jamming is of no real or practical value. 30 years of intensive jamming by one political group or another have not stopped 30 years of listening nor the dissemination of new political ideas during that time. Nor, presumably, will an additional 30 years be any more effective in suppressing undesired news, views, or philosophies. To the real shortwave enthusiast who is part fisherman, part technician, and part connoisseur of broadcasting as an art, the practice of jamming will always cry out as a crime, no matter who commits it. It remains an offence against that very earnest and beautiful tenet of world broadcasting: "Nation shall speak peace unto nation."

Chapter 20

SHORTWAVE RECEIVING ANTENNAS

by Jim Vastenhoud

Getting used to antenna terminology

There is no basic difference between transmitting and receiving antennas, if we overlook the power handling capacity factor. So what can be said about the one can also go for the other. In fact, all terms used in antenna engineering refer to the transmitting antenna.

The transmitting antenna transforms the radio frequency in the output circuit of the transmitter into a wave field that is radiated into surrounding space. This antenna thus forms a "load" to the transmitter, in which power is lost by radiation. The fictitious resistance, in which this power is dissipated, is an important antenna characteristic. It is called the *radiation resistance*.

Most professional antennas are so-called *resonant* antennas, cut to specific length to have maximum performance for a limited frequency range only. An antenna at resonant length will usually have a radiation resistance which is close to the antenna *input impedance*. Off resonance, however, the antenna behaves like a resistance with an inductive or capacitive reactance in series – the inductive or capacitive character depending on the antenna dimensions with respect to the wavelength radiated or received – and the antenna input impedance will then be higher than the radiation resistance.

The antenna input impedance is an important factor in antenna engineering.

The function of a receiving antenna is to extract the maximum power from the passing wave field of the desired station, while intercepting a minimum of unwanted signals, both from other stations and from natural or man-made noise.

This requirement can hardly ever be fulfilled because the variety of conditions presenting themselves at the antenna are so complex, and sometimes even contradictory. We have to know a good deal more about antenna theory and wave propagation to be able to cope with at least part of them.

In the first place, the distance between the transmitter and the receiver is important. There is an inverse relationship betwen field strength and distance, due to the expansion of the wave in all directions, whereby the energy becomes distributed over an ever increasing volume of space. Thus a better antenna is required for the reception of a faraway transmitter than for the reception of a nearby transmitter. We speak of "nearby" in shortwave when the area can be covered by a one-hop transmission. An antenna radiates two kinds of wave fields: a magnetic field and an electric field. In fact it is better to speak of an electro-magnetic field, as one cannot exist without the other. The plane in which the *electric* part of the wave is radiated, determines the so-called *polarization* of the antenna.

Usually, shortwave transmitting antennas are *horizontally* polarized. This would, in fact, determine the position of the receiving antenna as horizontal too, if we want maximum results, but in practice, polarization becomes random after the energy has been reflected a couple of times off the ionosphere, and for distant shortwave reception the position of the receiving antenna is therefore rather determined by local possibilities than by the polarization of the transmitting antenna. An exception has to be made for nearby stations, as polarization is not substantially spoiled after one ionospheric reflection. For all-purpose antennas, the listeners will therefore still prefer an antenna that is more or less horizontally suspended. In the horizontal plane, the geographical direction in which the antenna wire points is called the *wire axis*.

The *antenna length* is usually expressed in *wavelengths* symbolized by the greek letter λ. As you know there is a fixed relationship between frequency and wavelength:

frequency (MHz) × wavelength (m) =300.

A generally applied antenna is the half-wave type, which has a mechanical length (between the terminal insulators) of about one-half wavelength. It is also usual to express antenna length in *electrical degrees*. As one full wavelength is equal to 360 degrees, a $\frac{1}{2}\lambda$ antenna is about 180 degrees, and a $\frac{1}{4}\lambda$ antenna about 90 degrees. In practice, the half-wave antenna has a mechanical length that is usually about 5 per cent shorter than expected, due to the *end effect*, caused by e.g. the proximity of the insulators, which add capacity to the system. So, the *exact* length of a half-wave antenna can, under varying circumstances, be 176 degrees, or 172 degrees, as the end-effect increases with the frequency.

We must differentiate between *directional* antennas, and *non-directional* or *omni-directional* types. The most common among these is the *isotropic* radiator, theoretically a no-loss antenna which radiates uniformly in all directions. It is used here to define certain characteristics of antennas. In practice, antennas can be purely non-directional at one frequency, but show a sharp preference for the reception of signals from a specific direction at other frequencies.

Which brings us to the *radiation patterns* of an antenna.

Usually, two are given (*figs. 1 and 2*), and they show the cones of radiation emerging from the antenna in different directions. One is the horizontal radiation pattern, which shows the projection of the so-called *lobes* in the horizontal plane (as seen from above), and the other is the vertical radiation pattern, which shows the projection of the lobes in the vertical plane. A lobe is simply a cone of radiation, the shape of which represents the amount of energy put into it.

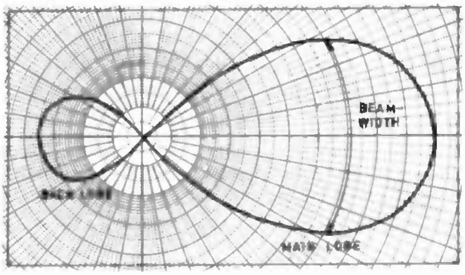


Fig. 1

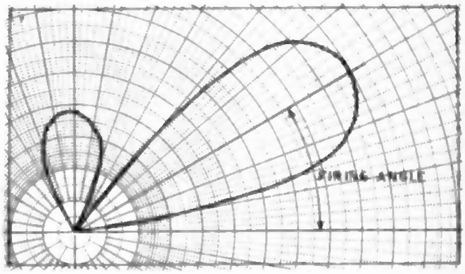


Fig. 2

Most antennas have radiation patterns (*polar diagrams*) with one *main lobe*, and a number of *side-lobes*. The geographical direction in which the maximum of the main lobe points is called the *azimuth* of the antenna. It is expressed in degrees from true North. So East is 90 degrees, South 180 degrees and West 270 degrees. It is possible to determine the bearing between two positions on earth by the use of a globe, and a piece of string to interconnect them. The azimuth of a directional antenna system for any of the two positions can now be read.

As you can see from *figure 2*, one antenna can have several lobes. In this case they were drawn for the vertical plane. Each lobe has a different *elevation angle* (other terms used: *firing* angle and *radiation* angle): the angle between the longest vector in the lobe, and the earth plane. In between the lobes are *nulls:* any signals that might arrive at the receiving antenna under such an elevation will not be received at all. In the principal plane of radiation, the *beamwidth* can be defined by the angular width of the pattern at points where the *power* is decreased to half that at the centre of the *beam* (main lobe). These are the so-called half-power points, where the power is 3 dB (decibels) down.

It must be noted that any given radiation pattern applies to an antenna at one given frequency only, and under certain other conditions such as the distance to the (assumedly) "perfectly conducting" ground. For deviating frequencies, the polar pattern can be totally different.

Apart from a beamwidth, the antenna usually also has a certain *bandwidth*. This is the range of frequencies within which the antenna operates satisfactorily within pre-determined limits. These limits can, for example, represent the deterioration of the antenna input impedance by the appearance of reactive values off resonance, or be caused by changes in pattern direction or pattern shape. It is possible to extend the bandwidth of some types of antenna by special measures, such as the increase of its cross-section relative to its length.

A *directive* antenna can boast a certain *gain*, which can be defined as the ratio of maximum radiation intensity (field strength) of the antenna to the ratio of maximum radiation intensity from an isotropic radiator. Both have to be measured in the same direction. The gain is given in decibels (dB).

Gain is closely associated with *directivity*. If no signal losses occur in the antenna, they are even equal.

The *front-to-back* ratio is the last antenna characteristic which we would like to mention in this short introduction of antenna terminology. It shows the relation between the energy, or field strength that is radiated in the forward direction – the main lobe – to the energy that is lost on backward radiation. If both are equal, as will be the case for many shortwave receiving antennas, front-to-back ratio is equal to unity.

Transmission lines

The connection between the transmitter, or the receiver, and the antenna proper, is taken care of by the *transmission line,* also known as *feeder line,* usually shortened to *feeder.*

The feeder is the non-radiating part of the antenna system. There are three different kinds of feeders:

- the single wire feeder
- the parallel line feeder
- the coaxial or concentric transmission line.

Usually, the single wire feeder is seen as part of the antenna, because most single wire feeders do radiate. Still, it is sensible to make the distinction, to prevent confusion. The other two transmission line types do not radiate, if they are properly connected.

The parallel line feeder consists of two conductors of an equal diameter, running parallel at a fixed mutual distance. It is commercially available and known as twin lead, twin line, ribbon or tubular twin line. Usually, the two conductors are separated by a dielectric (insulation) of polethylene or polypropylene. As some of these insulation materials "age", thus gradually changing the properties of the line, some people go for air insulation or for foam-filled tubular line. Air-insulated parallel transmission line is commercially available in some countries, but can otherwise be home-made by the application of spreader insulators, applied at fixed distances, that keep the wires apart. More details about this will be given later.

Coaxial cable is always round, and consists of a centre conductor, surrounded by a layer of high quality insulation material. This, in turn, is covered by a braided metal outer conductor, which thus forms a screen around the centre wire. A vinyl jacket is mostly used to protect the cable from the weather and from easy damage.

Both types of transmission line are shown in *figure 3.*

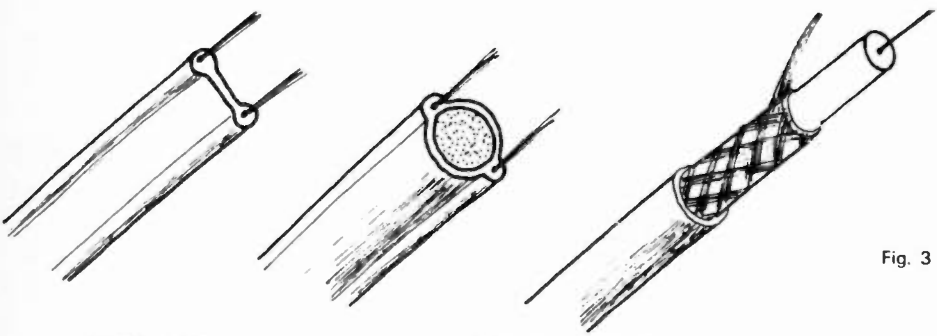


Fig. 3

TWIN LINE COAXIAL CABLE

In a parallel wire line, the conductors carry equal but oppositely directed voltages and currents. That makes it a symmetrical or balanced line.

The coaxial line functions differently. Here, the current passes through the centre conductor, and returns through the screening braid. The coaxial cable is an unbalanced line.

Balanced transmission lines are usually applied in combination with symmetrical antennas, and coaxial cable with unbalanced antennas.

Before we arrive at some practical applications of both types of line, it is essential to give more information about the important characteristics of transmission lines.

Because of distributed inductances and capacitances, imposed by the metal conductors, transmission lines of infinite length show a resistance which is known as the *characteristic impedance.* Lines of finite lengths, however, can show impedance values which greatly differ from the characteristic impedance, except when the line is terminated by a load which is equal to the characteristic impedance. This property is often made use of in antenna engineering. It means that, if a transmission line is connected to an antenna which happens to have the same input impedance as the characteristic impedance of the cable, no signal losses will occur due to standing waves, and a loss-free (except normal "ohmic" losses due to the electrical resistance of the wires) transfer of energy can take place. The line is then said to be *matched*, and it can have an arbitrary length.

If the line were not properly matched, it shows an impedance which depends on its length, and on the frequency applied. It is interesting to know that a transmission line of a half wavelength, or multiples of $\frac{1}{2}\lambda$, shows an imput impedance which is equal to the impedance of the load connected to it at the other end, no matter what the characteristic impedance of the line happens to be. It means, e.g. that we can match a 500 ohm antenna to a 500 ohm receiver input for one waveband, if we use a transmission line in between which is $\frac{1}{2}\lambda$, or multiples of it, long. The feeder has now become a *tuned* line.

There is a slight hazard built in, however, called the *velocity factor* of the line. It indicates the ratio of the wave propagation speed along the line to the velocity in free space. This means that the actual length of a $\frac{1}{2}\lambda$ piece of line is actually shorter. The shortening factor or velocity factor has to be applied in order to arrive at the exact practical length. The velocity factor is known for all commercial types of transmission line, and usually varies from 0.6 for coaxial cables to 0.98 for air-insulated twin line. So, the half wavelength piece of line between our 500 ohm antenna and 500 ohm antenna input of the receiver, actually has a length of $\frac{1}{2}\lambda \times$ the velocity factor!

Short pieces of transmission line, a quarter wave long, can act as resonant circuits, showing a very high impedance when the piece of line is shorted at one end, and a very low impedance if the line is left open. Pieces of transmission line which are shorter than $\frac{1}{4}\lambda$ (multiplied by the velocity factor), act as inductances when the ends are connected, and as capacitances when the ends are left open. These properties of transmission lines are, as you will realize, coupled to definite frequencies. They are used in antenna engineering as so-called *stubs* in sub-matching a transmission line to an antenna, which input impedance does not match the characteristic impedance of the line. By using stubs, made of transmission line, parallel to the antenna connections, we are able to cancel or "tune out" unwanted reactances, thus artificially matching the system for the one frequency band under consideration.

So far, the theoretical knowledge acquired on transmission lines has not helped us very much. In fact, it has only enlarged our problems, because we have learned that the application of feeders introduces, in practically all cases, a frequency-dependent element which we consider undesirable for our hobby, as it should cover all bands.

This is true. The unpleasant surprise going with the introduction of tuned (resonant) antennas and the application of two-wire feeders is that we always sacrifice versatility against extra advantages on one or two wavebands only.

So, if you want to stick to that omnidirectional and universally applicable antenna, you better switch over to our chapter "A practical introduction to shortwave antennas."

If, however, the subject still interests you, we invite you to join us for some practical applications of what we've learned so far.

Practical applications

How do we apply the knowledge just acquired, to get ourselves the most suitable antenna system? By combining things in a practical way.

First, we have indeed to decide whether or not we want a directional antenna system, basically fit for one waveband only. Then, we must have a look at the best solution, using our own receiver as a reference. It is necessary to read the instruction manual of the set carefully, and to look for data concerning the external antenna connection.

If the set has no external antenna jack, there isn't much we can do, apart from adding an additional antenna signal by coupling the signal wire feeder of an outdoor antenna inductively to the receiver's telescopic rod by wrapping its end around it. For this purpose, the outdoor antenna has to be terminated by a piece of insulated wire, to avoid a direct metallic contact.

If the receiver has an external antenna connection, and no external earth (ground) connection, there is room for a single wire feeder as described in the introductory article on shortwave antennas, mentioned above. In many cases, it is possible to have an external earth connection added if necessary.

A domestic type receiver which is equipped with jacks for external ground and antenna connections, can be used for the connection of both balanced and unbalanced feeders. In case a twin line is connected to the radio, it does not matter which of the conductors is hooked up to the antenna jack, and which to the ground jack. If however, a coaxial line is used as a feeder, the screening braid is always connected to the ground jack, and the centre conductor to the antenna jack.

If nothing is said about the antenna input impedance of the receiver, one can safely conclude that the value is not critical, usually rather high, and subject to some experimenting to find the best matching conditions. In many cases, it turns out that 300 or 600 ohm twin lines do give the best results, especially if these lines form a matched system with antennas of similar input impedance.

Some radios have two antenna inputs, for the connection of a balanced line, plus a ground terminal. Usually, the connection of the ground terminal is not necessary if twin line is used. The manual of the receiver will provide particulars for the best antenna connection, and it is recommended to follow these.

Modern communications receivers have unbalanced antenna inputs of 50 or 75 ohms. Best results are then obtained by using 50 or 75 ohm coaxial line, in combination with an unbalanced antenna. For practical purposes, however, it is acceptable to combine a 75 ohm coaxial cable to a symmetrical antenna with approximately the same input impedance, especially if listening is usually done on frequencies below 20 MHz.

The connection of the ground jack to a real ground can be advantageous for the antenna performance of a single wire antenna, especially if the reception site is on dry, sandy or rocky ground, which has a relatively bad conductivity. A proper receiver ground can be made by burying a strip of copper of about 2 metres long and 2 to 5 cm wide, in the ground. The top of the strip is connected to the receiver by a short and sturdy wire, the rest of the strip goes down into a trench of about 3 feet deep, preferably covered with some charcoal before the hole is filled, and watered from time to time to improve the ground contact of the copper strip.

Commercial transmission lines are available in a number of standardized types. Coaxial lines usually have a characteristic impedance of 50 or 75 ohms, while twin lead is available in 240 or 300 ohm values, which are frequently used in television antenna installations. In some countries, 75 ohms parallel lines is also available. If not, this value can sometimes be approached by using parallel-wire lampcord with plastic insulation.

Open wire twin line is commercially available too, but can also be home-made. In the reference-section of this book, data will be given for air-insulated twin line for various characteristic impedances, so as to enable you to make your own feeder and to select its impedance to match that of your antenna.

In the USA it has become customary to indicate a coaxial line by its army code number, usually using the prefix "RG".

RG 8 is a 50 ohm line, available in two versions: A/AU and foam dielectric. The first type has a velocity factor of 0.66, and the latter of 0.80. RG 11/A-AU is a 75 ohm line, and so is RG 59. RG 58 is again a 50 ohm line, available in both the A-AU and foam dielectric versions.

If coaxial line is used as antenna feeder, the use of a low-loss type is recommended. A good type is the RG 8 foam dielectric, with a line loss of 0.62 dB per 100 feet (30 metres) length at 15 MHz. The RG 11 is a good 75 ohm line. It is recommended to ask for the attenuation data and the velocity factor when buying coaxial cable.

On the subject of resonant antennas, some information has already been gathered in other chapters of this book. The basic resonant antenna, which is applicable for a shortwave, television and FM, is the half-wave dipole. Its characteristics are described in detail in the chapter on television antennas. For shortwave, dipoles are usually made of wire instead of tubing, which does not induce a basic difference. As the wavelength of shortwaves is much longer than that of the various FM and TV channels, the dimensions are, of course, different. So is the relative distance to the ground. In a FM or TV antenna system, the antenna is usually a number of wavelengths above ground. For shortwave, however, this is hardly the case, as the height above ground determines both the radiation resistance of the dipole and its elevation angle. The optimum suspension height for the dipole seems to be 0.5λ above the ground. The radiation resistance is then 73 ohms, and the elevation angle about 30 degrees.

The most universal application for shortwave broadcasting seems to be the use of a folded dipole, which has an input impedance of nearly 300 ohms, in combination with a 300 ohm twin line. Dipole and transmission lines are then matched, and on many domestic receivers the transfer of energy is expected to be relatively good.

For receivers with a 75 or 70 ohm antenna input impedance, the single dipole can be combined with 75 ohm twin line or, if this cannot be obtained, 75 ohm coaxial cable. For 50 ohm antenna inputs, the use of 50 ohm coaxial cable seems to be practical, and it is preferably to be coupled to a 50 ohm antenna. This preference of using matched systems has the advantage that we can use an arbitrary length of feeder. The other practical solution is to use a fixed length of feeder, with an *electrical* length of $\frac{1}{2}\lambda$, between the antenna input of the receiver and an antenna of the same impedance. The *physical* length of the $\frac{1}{2}\lambda$ tuned feeder is equal to the product of $\frac{1}{2}\lambda$ and the velocity factor of the line.

Many shortwave listeners prefer a tuned antenna system for the 19 metre band, as this is the widest shortwave broadcasting band, and has an interesting amateur band practically alongside.

It is possible, and practical, to improve the performance of the dipole by the use of a parasitic "reflector", similar to the practice with television antennas. The dipole then has an improved gain in the forward direction, and suffers less from signals arriving from the rear of the antenna. Such an array of a dipole (single or folded) with a parasitic wire reflector of predetermined length running parallel to it at 0.22 λ "behind" the dipole, as seen from the transmitter, is usually called a *beam antenna*, or parasitic beam. Details are again given in the chapter on television antennas.

Another application of the dipole is the multiband dipole. It is tuned to a number of different wavebands, by combining dipoles cut for each of these bands, via a common centre insulator. See *figure 4*.

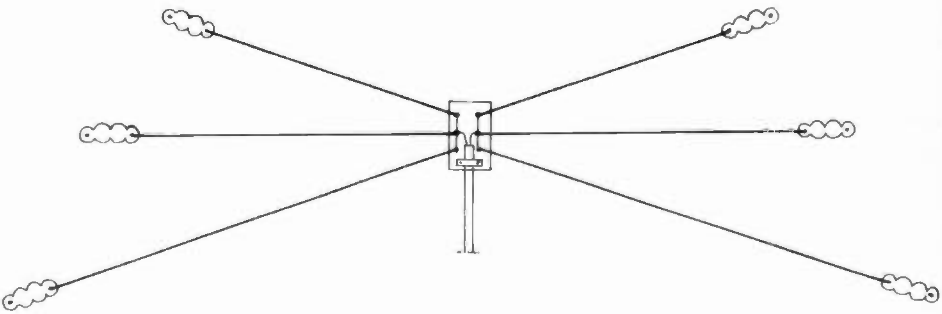


Fig. 4

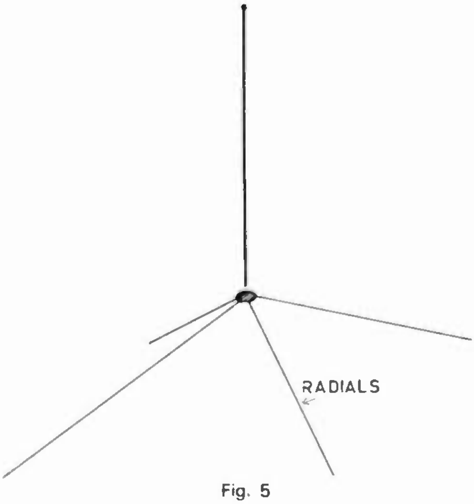


Fig. 5

The centre conductor can be connected to a 75 ohms coaxial or twin line, to provide the best matching to the dipole combination. If you have the room for this antenna, it is worth giving it a try.

What is a good resonant antenna with a 50 ohm input impedance? Apart from the parasitic elements, an antenna type which is relatively easy to install and even easier to make free-standing, is the vertical rod with an electrical length of $\frac{1}{4}\lambda$, and an artificial ground plane at its base, consisting of four so-called radials, which also have lengths of $\frac{1}{4}\lambda$. Such an antenna is unbalanced, and is normally fed by a coaxial line. The centre conductor of the coaxial cable is connected to the vertical rod or whip, and the screening braid to the four radials. See *figure 5*.

The angle which the radials make with the vertical radiator, determines the input impedance of the antenna. To arrive at approximately 50 ohms, the radials have to be bent downwards, till they make angles of about 135° with the vertical rod.

The shape of the antenna makes it suitable for installation on top of a roof, on the side of a chimney or any other suitable place, where the antenna has some air. Below the radials, which form an artificial ground plane, obstructions are tolerable.

The *ground plane* antenna is omnidirectional in the horizontal plane, but does have a definite directional pattern (for the resonant frequency band) in the vertical plane. The main lobe shows preference for signals arriving at angles of between 10° and 30° with the horizontal plane, thus being rather insensitive to signals arriving from the street level, where many interfering noises come from. In the practical execution, the vertical radiator is 2.5% shorter than $\frac{1}{4}\lambda$, while the radials can be cut at lengths of exactly $\frac{1}{4}\lambda$.

The vertical rod is usually made of aluminium, but can also be manufactured by using a flexible hollow tube of the correct length, in which a wire is hidden. Fibreglass is an excellent material for this purpose. If you cannot obtain a hollow tube, take a rod instead and tape the wire to the side. Avoid terminating the rod or the wire at the top in a sharp point. In case a rod is used, round its top with a file, or solder a small metal disc or ball on top. If a wire is used, take 2 cm extra, and bend them downwards at the top, soldering the end to the upcoming wire.

The base of the vertical rod can be fixed by using a strong ceramic insulator, or by using two ceramic stand-off insulators which are fixed at a mutual distance of approximately 1 metre near the bottom end of the rod. The radials of a shortwave ground plane antenna are usually made of wire, although there is no objection against the use of the rods for them as well. The wires are interconnected just below the base of the radiator, e.g. by using a metal disc or a metal ring, from which the radials are evenly distributed in space, each radial pointing down at an angle of 45° with the horizontal plane. The radials are terminated by strain insulators.

The largest practical ground plane may be cut for the 19 metre broadcast band, the radiator then has a length of 4.79 metres.

If we want a ground plane antenna cut for a lower frequency band, it seems appropriate to limit the length of the vertical rod to a decent size, and to make up for the lack of length by adding additional inductance. This is usually done at the base, where a so-called *loading coil* is introduced between the centre conductor of the coaxial cable, and the antenna rod. The loading coil will match the antenna to the line, but the antenna performance will slightly decrease, as the captive properties of the antenna have been reduced.

To arrive at the desired Q, shortwave loading coils are usually wound on plastic cylinders of about 5 cm (2") diameter. The number of turns depends on the frequency and the length of the rod. They are mutually spaced by a distance equal to the wire diameter. In books for radio amateurs, e.g. the ARRL Antenna Book*, you can find more details about loading coils, and about various other antenna types as well.

To conclude this chapter, as far as the subject of resonant antennas is concerned, a word about one of the most popular and best simple beam antennas in use, the *cubical quad* antenna.

Basically, the cubical quad or "quad", is a variation of the folded dipole. This can be readily understood if we reshape the folded dipole, which has two limbs of $\frac{1}{2}\lambda$ long, into four limbs of $\frac{1}{4}\lambda$ long, thus forming a square loop (*fig. 6*). If we feed this loop in the centre of the lower horizontal conductor, the antenna impedance will be approximately 125 ohms, and its gain in the main lobes, which extend perpendicular to the plane of the loop, will be slightly higher than the gain of the folded dipole.

The full advantage of the cubical quad antenna will be reached if we take the trouble to make a so-called two-element quad, consisting of a radiator as shown in figure 7, backed up by a reflector of exactly the same shape and slightly larger dimensions, placed parallel to the driven element and also positioned vertically.

The proximity of the parasitic reflector, which is a completely closed wire loop, will lower the input resistance of the driven element (radiator). To obtain an optimum gain and matching for a 75 ohm balanced line, the single-band two element quad has the following particulars: side length of the driven element: 0.257λ, side length of the closed loop reflector 0.265λ, element spacing 0.125λ. The gain of the two-element quad will be about 7 dB, the horizontal beamwidth about 60°. For best results, the lower limb of the driven element must be approximately 0.5λ above ground. This can, if necessary, be reduced to 0.25λ, and will result in a shift in elevation angle of the antenna from 28° to about 40°, thus making it a little less suitable for long-distance reception. *Figure 7* shows the schematic outline of the two-element quad.

*American Radio Relay League, Newington, Conn., USA.

Fig. 6

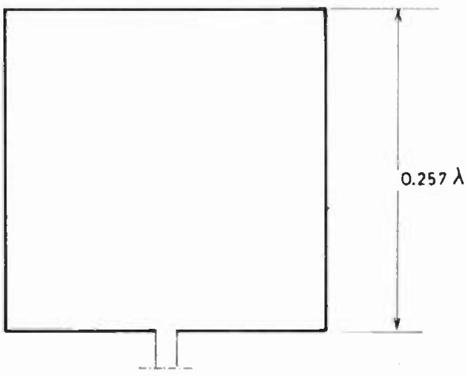
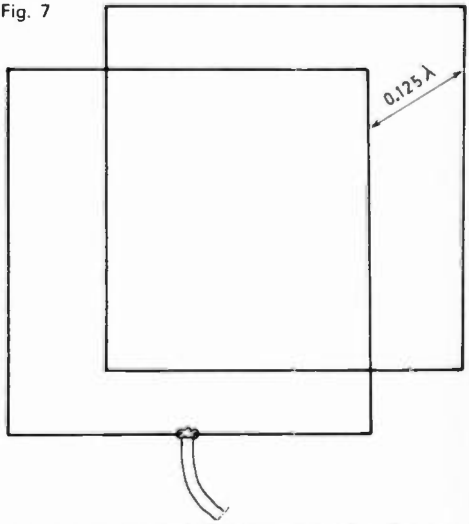


Fig. 7



The practical realization of the antenna requires some mechanical thinking. Usually, the two loops are supported by fibreglass, wooden or bamboo crosses. They, in turn, are then fixed to a horizontal boom, which is fixed to a vertical pole. In books for radio amateurs, construction details for various quads are given. Also there is a nice little book on quad antennas by William I. Orr (Radio Publications, Wilton, Conn., USA), which gives not only details about two-element quads, but on multi-element quads and multi-band quads as well.

Long-wire antennas

Most antenna types used for shortwave reception by listeners and amateurs are either ½ wavelength long or of abritrary length. In the latter case, the antenna length seldom exceeds 15 metres (approximately 45 feet) but even so it can still be regarded as short, because it is less than 1 wavelength for the 19 metre band, which is 15 MHz, and only a ½ wavelength for the 3 metre (9 MHz) band.

A long-wire antenna should be at least one wavelength long, but the advantages of a long-wire will only begin to pay off when it is at least 2 wavelengths long.

All long-wire antennas have some properties in common. The first is that their radiation pattern or, if you like, their directional sensitivity, is rather complicated. If we consider, however, the main lobe, it can be said that the angle, which the lobe of maximum sensitivity makes with the wire, becomes smaller as the wire is made longer. This so-called wave angle or angle of maximum radiation is 54 degrees for an antenna of 1 wavelength long; 36 degrees for 2 wavelengths, and is reduced further as the antenna becomes longer: 25 degrees for 4 wavelengths, 20 degrees for 6 wavelengths, etc. So if an antenna of two wavelengths long is placed horizontally, it will be most sensitive for signals arriving at angles of 36 degrees off the wire.

A second general property of long-wire antennas is that their gain increases as the wire length increases. If the antenna is 1 wavelength long, it is 1.2 times as sensitive in its main lobe as a non-directional wire antenna. If it is 2 wavelengths long, the sensitivity for the main lobe has increased to 1.4 times that of a non-directional type; to 2.1 times if the wire is 4 wavelengths long; the power gain becomes 3.1 times that of a non-directional type when the wire is 6 wavelengths long, and increases still further as the wire length increases.

Long-wire antennas are basically available in two versions: the so-called "resonant" or "harmonic" types, and the "non-resonant" types.

As we have already dealt with the resonant antennas extensively, we will now deal with some non-resonant types only.

The fact that non-resonant long-wires are essentially *travelling wave* antennas, while all resonant types are standing-wave types, makes all non-resonant antennas useful for a broad frequency spectrum. The frequency ratio between the highest and the lowest frequency for which it gives good performance is about 2:1.

Also, non-resonant antennas, which can be distinguished from resonant long-wire antennas by their terminating resistances at the far ends of the antenna, are unidirectional in the direction of the wire-axis of the antenna. The antenna thus has its greatest sensitivity roughly in the direction in which the antenna points. For long distance reception, a globe is needed to determine the azimuth of the antenna.

The long-wire or Beverage antenna is the simplest of the non-resonant types. It is a horizontal wire, supported on poles at a height of about 5 metres above the ground, and preferably two or more wavelengths long. The far end of the antenna is connected to ground via a non-inductive 500 ohm resistor. For receiving purposes, a 5 watt carbon resistor is recommended. See *figure 8*.

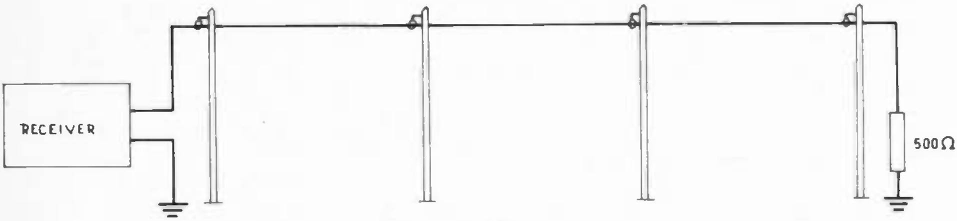


Fig. 8

The efficiency of the antenna is best when the receiver is also grounded. A good ground can be obtained by burying a strip of copper, approximately 5 feet by $1\frac{1}{2}$ or 2 inches, about 3 feet in the ground. Some charcoal around the copper before filling up the hole will help, as well as keeping the place wet by watering it from time to time in dry weather.

If you build the Beverage, you will need two grounds, one near the receiver and one at the terminal of the far end of the antenna. Strange as it may sound, the Beverage works best over poorly conducting grounds (something for the man in the desert, or on the savannah!).

The input impedance of the Beverage antenna is about 500 ohms, a value suitable for many domestic receivers with an antenna and a ground connection. The feeder to the antenna is short – as the antenna is rather low – and can be a single wire type. The ground lead must be kept as short as possible! A second antenna type which has earned considerable popularity among those who have the space to erect them, is the *obtuse V*.

The obtuse V-antenna can be built in a resonant and in a non-resonant version. It is probably better known as the "inverted V". The highest point of the antenna is the apex of the V, while both the termination near the receiver and the termination at the far end of the antenna are close to the ground. If the antenna is executed with a 500 ohm terminating resistor, as is usual for non-resonant antennas, the inverted V is unidirectional, being most sensitive to signals coming from the direction in which the wire points. See *figure 9*.

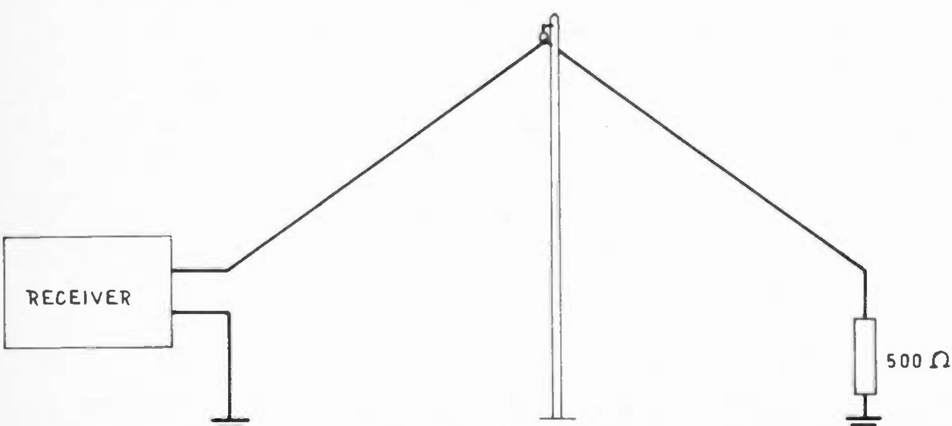


Fig. 9

The apex angle, which is the angle between the wires, depends on the length of the legs. If they are 1 wavelength long, the angle is 90 degrees. For 2 wavelengths, it increases to 110 degrees, thus making the V look longer and lower. The antenna has a gain that is superior to the single long-wire, and it can be made bi-directional by omitting the terminal (500 ohms) resistor. We then have the resonant inverted V, but – due to its configuration – still a wide-band type.

Although the choice of shortwave antennas presented in this chapter is limited, we hope nevertheless that it will help you in selecting a good antenna system, matched to your purposes. More information on antennas can be found in books for radio amateurs. They can be readily adapted for shortwave broadcast listening by using the formulas given in this chapter.

Chapter 21

OFF-BEAM TRANSMISSIONS

by P. V. D. M. Martins, Senior Engineer, Radio RSA

Annually shortwave broadcasters receive letters from astonished listeners informing them that they have been able to receive programmes from distant broadcasting stations although these broadcasts were intended for an entirely different listening area. A broadcast from Europe directed to the USA for instance, may be received in Southern Africa; or alternatively a broadcast from Southern Africa directed to the USA may be heard by listeners in the United Kingdom or in Australia. It is only natural that many listeners are puzzled by this phenomenon and wish to know how this is possible.

To fully understand this, one should have some concept of the propagation medium through which the radio signals have to traverse and the functioning of transmitting antennae used by broadcasters.

Long distance broadcasting in the high frequency bands is made possible purely by virtue of the refracting ability of the ionosphere. Under favourable conditions a radio transmission reaching the ionosphere will be bent earthward and will return to earth at a great distance from the transmitting station. Radio transmissions that follow such a path through the ionosphere and back to earth are known as sky wave transmissions. The mechanics of sky wave propagation are complex, the dominant physical phenomenon being refraction and not reflection, as commonly referred to. The ionosphere consists of a region in the upper atmosphere where free electrons are produced by the ionizing effect of ultraviolet light and X-rays from the sun. The ionized region commences at approximately 60 km above the surface of the earth and extends to approximately 420 km. Due to radiation from the sun, primarily ultraviolet radiation, the height and density of the ionosphere does not remain constant, but varies significantly with the time of day, season of the year and the approximate eleven-year cycle of sunspot activity. The ionization density of the ionosphere tends to peak at various heights above the earth due to differences in the physical properties of the atmosphere at different heights. The levels at which the electron density reach a maximum are termed layers and these are identified as D, E, F_1 and F_2 layers in order of increasing height and ionization density. (Refer to *figure 1.*) The number of layers, their heights and their ionization or electron density vary both geographically and with time.

The most significant for long distance broadcasting is the F_1 and F_2 layers which, at night, combine to form one layer. A radio wave coming up from the earth's surface will first enter an area of comparatively low density and eventually enter an area of greater electron density where it will meet an adverse force presenting some opposition to its travel. The term refraction stems from the fact that the direction of travel of the wave is changed in its course after entering a medium differing in density from one through which it has already passed. The wave will thus be turned away from its original path and, providing the density of the medium and the frequency are suitable, a point will be reached where the wave will be turned from its original route and eventually will be completely turned and leave the ionosphere at a similar angle as that of entry.

The descending wave will reach the earth's surface at some distance from the transmitting station leaving a skip distance between the transmitting station and point of reception. Within this distance the only signals that can be received are those due to the direct wave travelling along the earth's surface. There will thus be an area of no reception – usually referred to as the silent zone as the ground wave from the transmitting station is restricted to relatively short distances as compared to the sky wave. When the descending wave strikes the surface of the earth, it is reflected with an angle of reflection equal to the angle of incidence, the reflective ability depending upon the texture of the particular area of the earth's surface. Sea water, for instance, is a good reflector, followed by pastoral land, while desert areas may be regarded as poor, the reflecting ability being determined by different conductivity values. The wave will thus travel up again to the ionosphere, be refracted again and return to earth still further away, giving rise to another zone of silence. In this manner radio waves may travel over large distances in a number of hops.

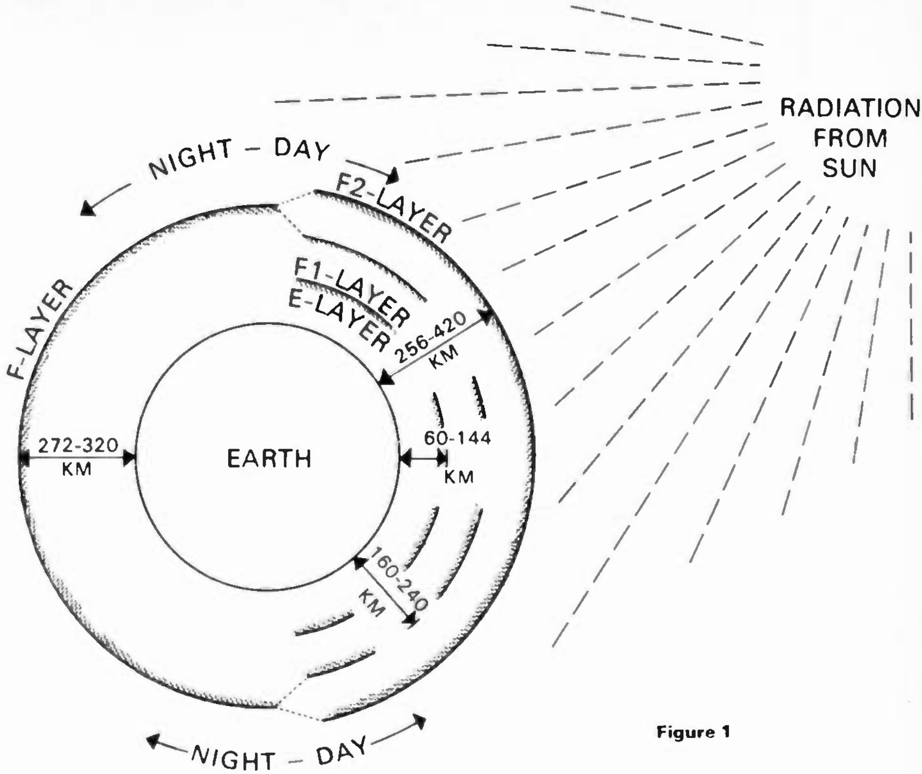


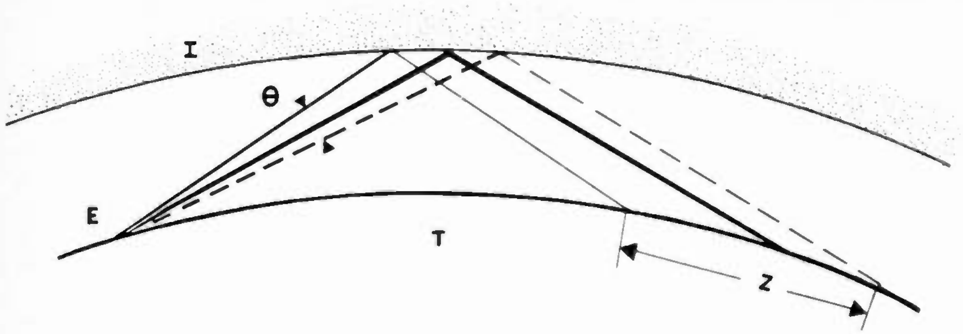
Figure 1

The maximum distance for one hop is approximately 4,000 km. The distance of the first hop from the transmitter and the consecutive hops will depend on the frequency of the transmission, the angle at which the radio wave enters the ionosphere and the ionization density of the ionosphere at the various points of refraction. For long distance broadcasting the antenna has to be designed so as to permit a low angle of radiation, approximately 12 degrees, while a domestic service broadcast will have a higher angle of radiation, approximately 60 degrees. The antenna is designed in such a manner that the beam width of the radiated waves in the horizontal and vertical plane will permit reception over an area or areas as required by the broadcaster. The width of the first reception zone or depth of the reception area will be determined by all the factors thus far mentioned and for an average long distance broadcast would probably be 800 to 1,500 km. The width of the second reception zone and consecutive reception zones will increase, the width of the silent zones decreasing correspondingly.

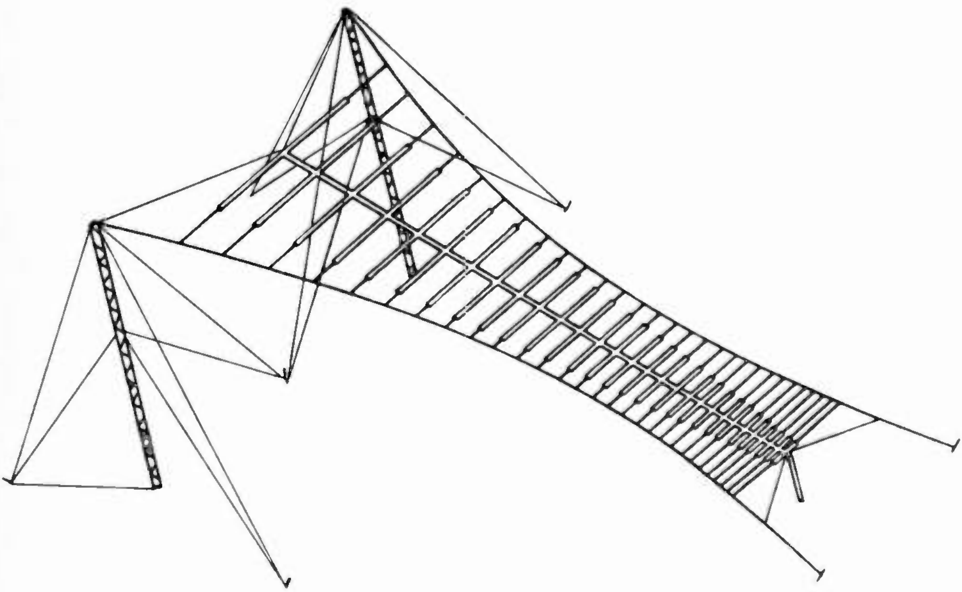
It is not strictly correct to assume that no signals can be received in the silent zones, but the signal intensity in these areas is very low and for practical purposes may be neglected. Finally, it should be noted that the ionosphere sets upper and lower limits of frequency usage. The higher frequencies will tend to penetrate the ionosphere while the lower frequencies will be absorbed. The frequency selection must be between these limits so that desirable signal levels are obtained in the respective listening areas of the broadcasting station.

Now that we have briefly discussed the mechanics of the ionosphere, we are ready to take a closer look at the antennae used by broadcasters. Before entering into the subject, it should be stressed that the functioning and design of antennae are extremely complex and involve many mathematical calculations beyond the scope of this article. Only the basic concepts will thus be dealt with in an endeavour to explain how transmissions may be heard in listening areas for which they were not intended.

A transmitting antenna may be defined as an electrical conductor of specific design. The antenna acts as a load to the transmitter's radio frequency or range of frequencies. As it is an electrical conductor it is endowed with distributed inductance and capacitance and consequently



Refraction from ionosphere
E=Broadcasting transmitter
T=Earth
Z=Reception zone
θ=Zenithal beamwidth



Log-periodic antenna

behaves as a resonant circuit. Its characteristics are such that it serves as an outlet for the high frequency energy produced by the transmitter.

The function of directional antennae is to concentrate the available high frequency power towards the ionosphere in such a manner that the radiated power may take full advantage of the propagational properties of the ionosphere, so that the optimum reception is ensured in the respective listening areas of the transmitting station. The directive properties and antenna gain are therefore of prime importance to the long distance broadcaster. It is desirable that the total high frequency power produced by the transmitter be directed by means of the antenna system to the intended listening area or areas, rather than being scattered in all directions.

A large number of antenna configurations are available to the broadcaster. At present the most popular for long distance broadcasting seems to be the curtain antenna, while for short distances the log-periodic is favoured. The curtain antenna has a concentrated beam, with low angle of radiation, while the log-periodic generally exhibits a much wider radiation pattern, both in the horizontal and vertical plane with relatively high angle of elevation. The former can be slewed electronically so that the beam may be directed to a new target area. One disadvantage of the curtain antenna is that it is frequency conscious and more than one antenna is thus necessary for the various frequency bands used by the transmitting station. Designs utilizing folded dipoles which will operate on up to four adjacent broadcasting bands are available. The log-periodic antenna on the other hand is "frequency independent" and can operate on any number of frequencies according to design.

Before discussing the principle of operation of directional antennae, it is necessary to consider the resonant halfwave antenna termed either a dipole or doublet, which is one of the simplest and most fundamental of radiating systems. The dipole consists of two collinear conductors and is the unit from which many more complex forms of antennae are constructed. Practically all antennae used by broadcasters are related to the dipole. The collinear conductors are fed at the centre, coupled to the transmitter by means of an appropriate feeder arrangement. The feeder and antenna must have specific lengths so that relatively negligible power is lost in the feeder, permitting maximum radiation by the antenna. The length of the dipole antenna must be comparable to the wavelength of the frequency to be radiated. From the viewpoint of economics it is desirable to use the shortest possible elements, as this will be a saving when considering costs of masts, available land, materials and installations. The shortest practical length is almost equal to half the wavelength of the radio wave. This may be best understood by considering that the electric charge during one cycle of oscillation of the frequency used, will traverse the length of a half-wavelength dipole in both directions. The electric charge therefore travels twice the length of the half-wavelength dipole, the distance travelled thus being equal to one wavelength. In practice however, the dipole elements are slightly shorter than the theoretical length due to end "effects". The relation between frequency and wavelength is apparent from the following formula: $\lambda=300{,}000{,}000/f$ where λ is the wavelength in metres and f the frequency in hertz. This stems from the fact that radio waves travel at the same speed as light, namely 300,000,000 metres per second.

The half-wavelength dipole may be considered a bi-directional antenna. Its radiation pattern is not uniform in all directions but varies with the angle with respect to the axis of the antenna wire. The radiation is most intense in directions perpendicular to the wire and zero along the direction of the wire with intermediate values at intermediate angles. (Refer to *figure 2.*) The radiation pattern is a representation of the directivity of the antenna. Various types of radiation patterns may be obtained by combining individual dipoles into an array. The basis for all directivity control in antenna arrays is by means of wave interference. By feeding power to individual dipoles simultaneously, it is possible to make the radiation from the elements reinforce one another in a single direction so that a beam is formed. In other directions the radiation tends to cancel so that a power gain is obtained in one direction at the expense of radiation in other directions. At present this is the most straight forward method known to control radiated power.

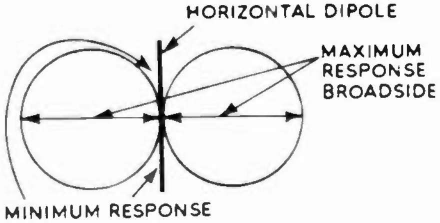


Fig. 2
Dipole radiation pattern

Curtain antennae are made up of individual half wavelength dipoles. The dipoles are strung end to end in the horizontal plane so that they all lie on the same straight line. Identical dipoles are strung above or below the first row at half-wavelength intervals. When power from the transmitter is fed into the dipoles so that they carry co-phased current, in other words, so that their individual radiations are in phase, the radiation from the array will cancel at a point vertically above the array; at a distant point in the horizontal plane, at right angles to the line of the array the effect of the individual dipoles will be additive, giving rise to increased directivity. The horizontal width, i.e. number of bays of the array, determines the horizontal (azimuthal) beamwidth of the high frequency radiated power, while the number of rows in the vertical plane, together with the mean height of the array above ground determines the angle of elevation and vertical (zenithal) beamwidth.

A single curtain of dipoles fed with the appropriate feeder arrangements from the transmitter, in such a manner that all the dipoles are electrically in phase, will be bi-directional, with two beams 180° apart. By hanging an identical curtain of dipoles, a quarter wavelength behind the radiator curtain, the radiated waves from the radiator curtain will travel towards the second curtain and be reflected back towards the radiator curtain. The reflected waves will reinforce the waves from the radiator curtain in the forward direction towards the listening area, and cancel in the backward direction. The reflector curtain may also be provided with a feeder so that tuning is possible to minimize radiation in the backward direction. It is then also possible to reverse the direction of the beam by 180° by connecting the transmitter to the reflector curtain, so that it will act as the radiator while the other curtain then acts as the reflector.

Half section of a typical antenna array used for shortwave broadcasting is shown in *figure 3*. The curtain is made up of four bays, each consisting of four individual half-wavelength dipoles stacked at half-wavelength intervals above one another. Identical reflector dipoles are spaced a quarter wavelength behind the radiator curtain, each curtain containing 16 individual dipoles.

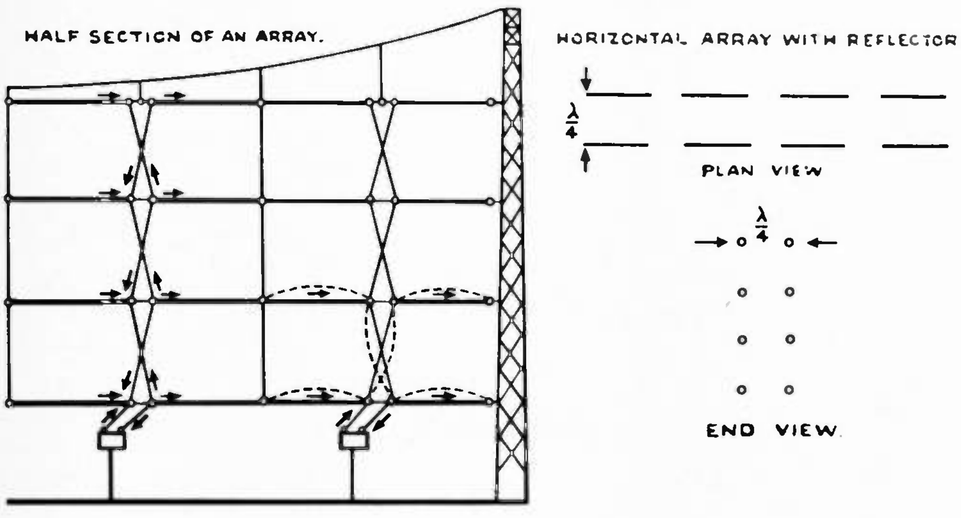
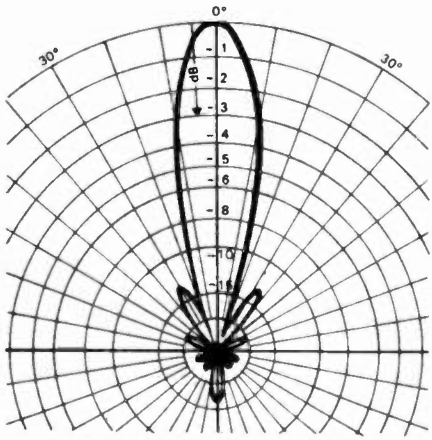


Fig. 3
Curtain antenna – arrows indicating co-phased currents

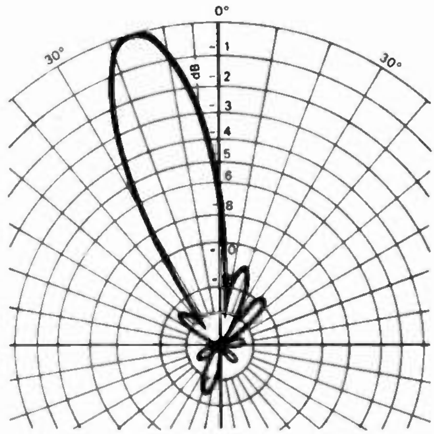
The rear curtain of dipole reflectors may be replaced by a grid reflector (screen), but reversing of the radiation pattern is then not possible. The feeder arrangement at the base of the antenna is usually arranged in such a manner that the phase of currents fed to each of the half sections of the curtain, that is, two bays, may be advanced or delayed in relation to that being fed to the adjoining bays. The effect of this is to slew the radiated beam either to the left or right of the normal direction. This is achieved by increasing the length of feeder from the transmitter to one half of the curtain while correspondingly decreasing the length of feeder to the other half. In this manner it is possible to electrically slew the azimuthal pattern through ± 15° to ± 30°. (Refer to *figures 4, 5 and 6.*)

In the main direction of transmission the curtain antenna under discussion will have a power gain which is about 100 times as much as that obtained with a half-wavelength dipole. For simplicity, engineers prefer to use the term decibel when expressing gain. An antenna which increases the power 100 times will be referred to as an antenna with gain of 20 dB. If a 250 kilowatt transmitter were used in conjunction with the said antenna, the power would be



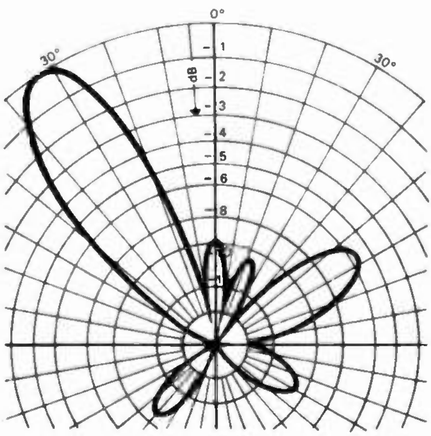
17.8MHz, slew 0°

Figure 4



17.8MHz, slew 15°

Figure 5



17.8 MHz, slew 30°

Figure 6

Plan view
Azimuthal radiation patterns 0° through 30° slew.

amplified 100 times and the end result is that 25 million watts of power is radiated in the direction of the main target area. For the purpose of calculation of radiated power engineers prefer to talk of lobes. A three dimensional representation of a main radiating lobe is given in *figure 7*. The perimeter of the main lobe is referred to as 3 dB points or half-power points. The main radiating lobe will reach into the ionosphere at a low angle of elevation, and as mentioned under the discussion on propagation, will be refracted back to earth. The reception zone reached in this manner will be the main target area and is the area where maximum signal level is experienced.

Although time and care is taken when designing and constructing antennae to ensure that maximum radiation is directed in the direction of the main lobe, power, at considerably reduced levels, is also radiated in a sideward direction and in a direction directly opposite to the main lobe. In the normal condition, that is when the curtain antenna is radiating straight ahead with no slewing introduced, the sideward and backward radiated lobes will be small. (Refer to *figure 4*.)

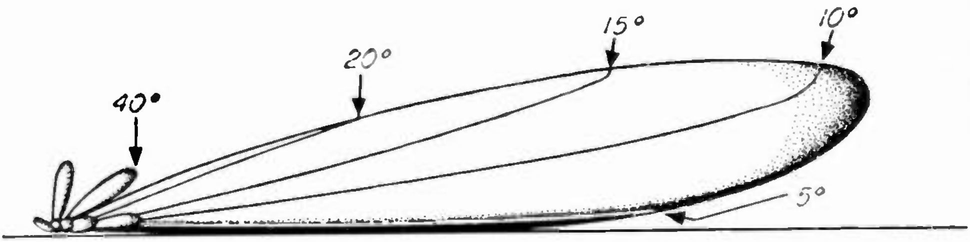


Fig. 7
Three-dimensional radiation pattern

When maximum slewing is introduced these radiations will increase and result in larger side lobes. (Refer to *figure 6*.) The power in the side lobes can reach up to 25 per cent of the power of the main lobe, whereas the power in the back lobe could reach up to 10 per cent of that radiated in the main lobe. As in the case of the main lobe the side lobes, ionospheric conditions permitting, will propagate favourably. It is then possible for listeners living in areas touched by the side or backward lobes, to receive a transmission even though it is not intended for their specific area. The main lobe may also provide reception to listeners in more than one area. For example, a transmission from South Africa directed to Europe, depending on the time of day, etc., may reach Europe on the third hop, providing simultaneous reception for listeners in Central Africa on the first hop and North Africa on the second hop. Any one of these areas may be the target area at the time of broadcast, with the other listeners joining in, or alternatively the broadcasting station may take advantage of this phenomenon and broadcast programmes simultaneously to all three listening areas. Similarly, a transmission from Europe to North Africa may be heard in Southern Africa, or alternatively, the side lobe of a transmission from the United Kingdom directed to North America and the Caribbean may provide reception for listeners in Africa.

Reception of transmission received in the off-beam areas could easily suffer interference due to lack of signal strength and in certain instances may be completely suppressed by a nearby station or more powerful station operating on the same frequency. It does, however, permit one to listen to broadcasts directed to other parts of the world and this in itself makes listening to the world all the more interesting.

Chapter 22

MEDIUM-WAVE PROPAGATION

by Gordon Nelson, National Radio Club, USA

The medium wave broadcasting band extending from 525 kHz to 1610 kHz offers the skilled and patient listener some of the most interesting and challenging long distance reception in the entire DX hobby. Long distance propagation of MW signals is a comparatively little understood phenomenon and is quite different in many respects from the transmission of signals on higher frequencies. Just as the pioneering radio amateurs of the 1920's were surprised to discover that reception on the "short waves" was very different than what they were accustomed to on the low frequencies then in use, MW listeners have long been aware of the characteristic and distinct nature of MW propagation. While long distance reception is considerably more difficult on MW than on higher frequencies on a miles-per-watt basis, world-wide reception of MW stations is perfectly possible for the knowledgeable and properly equipped listener. A number of the top MW experts in various parts of the world would have heard MW stations in more than 100 countries in the past few years – this in spite of increasing interference from nearby broadcasting stations (more than 5,000 in North America alone!) and local electrical noise.

While many millions of words have been written to describe shortwave reception, almost no serious scientific research has been conducted on the types of long distance MW reception of interest to the MW listener. Due to a combination of historical and technical factors, what little scientific research has been done on long distance MW propagation has been concerned almost exclusively with determining "average conditions". These engineering studies have produced the graphs of "average MW conditions" used by various governments in the allocation of new stations. But, on the other hand, the MW listener is interested primarily in *unusual* and *uncommon* reception conditions. Despite the unfortunate lack of scientific research on the causes of unusual MW reception, enough of the relevant factors are known to permit an understanding of most of the basic seasonal and geographical patterns in long distance reception. While an understanding of these effects will not allow the listener to predict exactly when a particular station *will* be heard, it is often possible to *rule out* certain reception as impossible or at least highly unlikely.

Distinctive Aspects of Medium Wave Propagation

1. Groundwaves. Long distance MW propagation takes place by means of two entirely different and distinct mechanisms: groundwaves and skywaves. The groundwave, as the name implies, travels along the surface of the earth. At shortwave frequencies the groundwave component dies out very close to the transmitter. MW groundwaves, however, are often audible at considerable distances from the station. During the daylight hours, when the skywave component of the MW signal is usually completely absorbed by the ionosphere, all over-the-horizon reception takes place by means of the groundwave. Because the MW groundwave can be propagated over moderately large distances and is not subject to fading, most of the MW broadcasters throughout the world make use of special vertical transmitting antennas designed to increase the amount of signal power actually radiated in the groundwave. For a particular MW transmitter power, the factor which determines just how rapidly the groundwave dies out with increasing distance from the transmitter is the *conductivity* of the ground between the station and the receiving site. The better the conductivity of the ground the further the groundwave will carry. Sandy or rocky earth is the poorest for groundwave propagation and sea water is the best. In regions of the world such as the Caribbean where the sea is particularly saline (and thus more conductive), daytime groundwave reception of stations as much as 1,000 miles distant is possible with the transmitting powers in use today. Under the same conditions a groundwave signal passing over rocky ground instead would carry only about one quarter of the distance. Groundwave propagation is noticeably better on the bottom of the MW band than at the top.

One of the interesting consequences of the extensive propagation of MW signals is the existence of the so-called "white zone" which may occur roughly 50-400 miles from the station. In the middle part of the day the skywave component of the signal is totally absorbed in the lower ionosphere and steady reception of relatively close stations takes place completely by groundwave. As the skywave absorption begins to disappear about the time of dusk, a significant amount of skywave signals begins to reach the ground far from the transmitter. In places where *both* groundwave and skywave signals are present – the "white zone" – interference between these two signal components produces severe fading and distortion in the received signal. Thus it happens that stations which had been received with strong and clear signals during the day often develop a characteristic and severe fading from sunset onward. Since MW propagation over great distances – more than about 1,000 miles – takes place entirely by means of skywaves, groundwave propagation is not of great importance except for daytime reception of stations within this distance. Figure 3a illustrates the origin of the "white zone".

2. Skywaves. The same ionospheric structures (the "D", "E" and "F" regions) which make shortwave reception possible also control MW propagation. There is a considerable difference between SW and MW reception, however, because of the much greater wavelengths of MW signals compared to the dimensions of ionospheric structures and because of the frequency dependence of ionospheric absorption. Relatively small ionospheric structures (such as meteor trails, for example) which can exert a strong influence on SW transmission often have little effect on MW signals whose wavelength can be as much as 50 times as great. Therefore some ionospheric phenomena important on SW are of little or no concern on MW, and vice-versa. Except in a few special cases, there is very little correlation between reception of a particular station on MW and SW. The many distinctive features of MW reception are the reason that forecasts of SW conditions, such as those transmitted by WWV, are not meant to apply to frequencies below about 3 MHz.

A basic fact of fundamental importance to the understanding of MW propagation over great distances is the observation that MW signals almost inevitably propagate on or quite close to *great circle paths*. The shortest path between two points on the surface of the earth is the great circle path, but considerable confusion can arise if the DX-er attempts to determine great circle paths by looking at an ordinary Mercator projection map. On an ordinary flat map of the world, for example, it would appear that the shortest distance between Japan and Europe would be a path through the centre of North America. This is an illusion produced by the type of map projection used, however, and the great circle path in this case actually passes almost directly over the North Pole. Unless you happen to be fortunate enough to live near one of the few places on earth for which azimuthal maps have been constructed, the easiest way to visualize great circles is with the aid of an ordinary world globe. A piece of string stretched tautly between two points on the surface of a globe will lie along a great circle and thus represents the MW signal path between the two points. The importance of being able to visualize great circle paths will become obvious shortly.

Figure 3a—1. *Daytime.* Skywave signals for MW stations are absorbed in the "D" region at Point A. Long distance propagation proceeds by groundwave only and signals are steady.

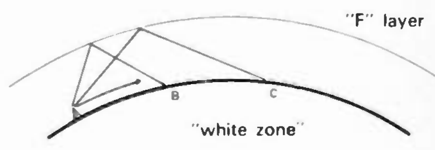


Figure 3a—2. *Night-time.* The "D" layer absorption has disappeared and skywave signals appear far from the transmitter site. Interference between the groundwave and skywave begins at point B where the first skywave returns, and extends to point C where the groundwave dies out. Severe distortion and fading occurs in the region between these points.

Ionospheric radio signals *tend* to propagate along great circle paths not because such a path represents the shortest distance (although this is the case), but because of the symmetry of the ionosphere around the earth. If the ionospheric layers responsible for skywave signal return are visualized as spherical mirrors at fixed heights above the earth, it is obvious that radio signals will be "reflected" with no lateral displacements and will therefore follow paths which look like great circles along the surface of the earth. For signals with large wavelengths (i.e. low frequencies) the ionosphere appears particularly "smooth" and the analogy of the spherical mirror is quite good – such signals travel quite close to great circle paths. On higher frequencies, however, the irregularities and fine structures of the ionosphere begin to become significant and propagation along *deviated paths* (i.e. not great circles) becomes common. Scattering and auroral reflection become increasingly important on the higher SW frequencies and as a result SW signals often arrive at the receiving site via a number of different paths simultaneously. This is one reason that long distance MW signals tend to be steadier than their high frequency counterparts. One practical result of the marked tendency of MW signals to follow great circle paths is that radio direction-finding is much more reliable and accurate on MW than on SW. The author has made a large number of direction-finding measurements of the direction of arrival of MW signals from many distant transatlantic stations over the past 5 years. These measurements show that long-distance MW signals almost inevitably follow very close to the great circle path between transmitter and receiver. Shortwave direction-finding studies, however, have long indicated that auroral reflection and scattering commonly result in propagation along deviated paths on higher frequencies. The benefit for the MW listener is twofold: he thus knows in advance the path taken by a particular MW signal, and can make highly accurate direction-finding measurements with simple equipment to aid in the identification of unknown stations.

Another important factor useful in explaining MW reception patterns is the effect of daylight on the absorption of MW signals in the lower parts of the ionosphere. The same ultra-violet and X-ray radiation from the sun responsible for ionizing the upper layers of the atmosphere also ionizes the lower levels of the ionosphere – particularly the "D" and "E" regions. The ionization produced in these regions by direct solar illumination absorbs radio signals very strongly at MW frequencies and thus renders daytime skywave propagation impossible under normal conditions. Most of this highly absorbing ionization disappears as soon as the ionosphere is not longer in daylight, however, and this region rapidly becomes "transparent" to MW signals after local sunset. Because dawn and dusk occur at a different time in the ionosphere than on the ground, the terms *ionospheric dawn* and *ionospheric dusk* are used to denote the instants when the ionosphere emerges from and enters into the earth's shadow above a particular point. For purposes of visualizing the seasonal patterns in MW reception it is permissible to assume that dawn or dusk occurs at the same time in the ionosphere as it does on the ground. This means that the sunrise boundary (i.e. the line defining sunrise) may be considered to represent roughly the boundary past which skywave absorption becomes important.

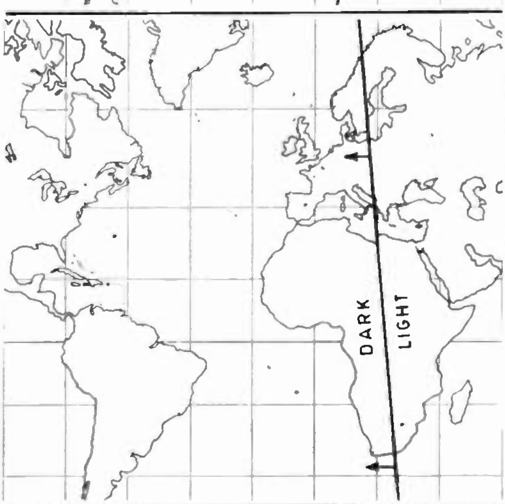
It is not to be inferred that dawn at the transmitter site will inevitably produce a complete fade-out of the signal in question, however. Just how rapidly absorption builds up at dawn and dies out at dusk depends upon many factors including station location, signal path, solar activity, frequency, and season. The effect of dawn-induced absorption on a particular reception naturally depends upon how powerful the station is: the slightest bit of dawn-induced absorption will immediately reduce what was originally a very weak signal to inaudibility. An extremely powerful signal, on the other hand, will require much more absorption before it becomes inaudible and will remain audible for a longer time after dawn. The greater the amount of daylight in the path of interest, the less likely the reception will be. A rough rule-of-thumb useful for predicting the likelihood of a particular long distance MW reception is as follows: if there are more than about 90 minutes of daylight in the great circle path reception is unlikely regardless of transmitter power. For signals which were originally weak, reception more than about 30 minutes after dawn at the transmitter is very unlikely. This explains why the "long-path echo" often heard on SW and resulting from propagation on paths which circle the earth more than once is unheard on MW: on MW the long-path signal is inevitably completely absorbed in the daylight regions which it must traverse.

Long distance skywave propagation in the mid-day is possible only under very special conditions: through the perpetual dusk of the polar regions during local winter, when extremely powerful transmitters are employed, and sometimes for a few days around the date of the winter solstice in middle latitudes.

Figure 3b. *Seasonal patterns in reception.* At a particular hour the location of the sunrise boundary changes from season to season. Similar patterns may be predicted for other parts of the world with the aid of a world globe.

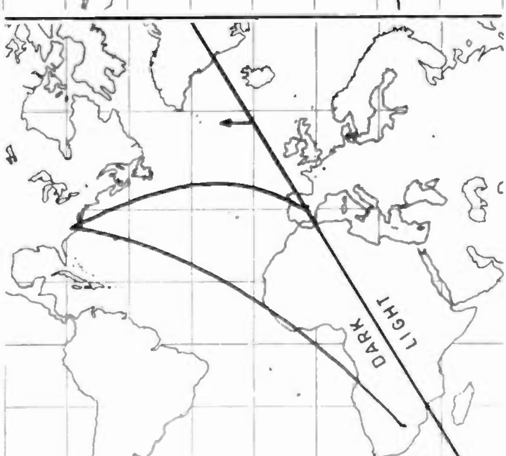
Mid-winter

0430 GMT on the day of the winter solstice, December 21. On this date the sunrise boundary reaches its greatest Eastward tilt, thus leaving a full darkness path to Europe as far East as Moscow at 0430. East Africa has been in daylight for several hours at this time, making reception impossible. As the sunrise boundary moves toward the West, Western Europe remains in darkness even after dawn-induced fadeout has occurred in West Africa. As the season advances, the sunrise boundary tilt is reduced daily as the Equinox is reached.



Equinox

0430 on the day of the Equinox, either March 21 or September 23. On these dates the light-dark boundary is oriented directly North-South. As the sunrise boundary moves West, Africa and East Europe first fade out, followed by most of West Africa and Central Europe. As the season advances into summer, the sunrise boundary tilts increasingly to the West, reaching its extreme orientation during mid-summer.



Mid-summer

0430 on the day of the summer solstice, June 21. The sunrise boundary is now at its maximum Westward tilt. As the boundary moves toward the West, dawn first occurs in Europe. By 0430 all but Easternmost Europe is in daylight, whereas a full darkness path from most of Africa to North America remains open. Dawn-induced fadeout occurs in Barcelona some 20 minutes before it occurs in Mozambique, thus leaving Lourenço Marques clear on 737. Within an hour, all Europeans have faded out, leaving the African stations alone on the TA channels. Stations in West Africa remain audible long after the Europeans have faded out.

Seasonal and Geographical Patterns in Long

Once the two basic factors outlined above (great circle propagation and ionospheric absorption in regions illuminated by daylight) are understood, many of the basic recurring seasonal patterns associated with MW reception become apparent by merely looking at the location of the sunrise boundary at different times on various dates. As an example, *figure 3b* explains the basic seasonal pattern in reception of East African and European stations in North America.

Analogous seasonal patterns in MW reception for other parts of the world become apparent after a few minutes of thought with a world globe and an almanac of sunrise and sunset times. The changing orientation of the day-night boundary is the basic factor controlling *seasonal variation* in reception patterns.

Many listeners have missed receptions from certain parts of the world because of the natural tendency to suspend active listening during the summer "static season". While the severity of local thunderstorms often does increase during the local summer in many regions of the world, there are some remarkably quiet nights when transequatorial reception is possible during the course of many summers. Some of the author's most distant receptions (including Botswana and Mozambique) have occurred during the height of the summer. Summertime is often the only season when reception from certain areas is possible because of schedule and interference considerations.

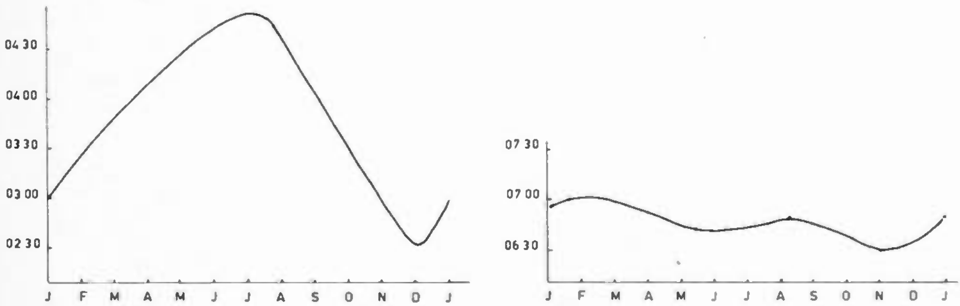


Figure 3c. It is possible to produce very good predictions of the time of fade-out produced by dawn at the transmitter site for some stations. These graphs were produced by an electronic computer which solves the equations describing the absorption at ionospheric dawn. These are the *latest* times that 20 db of absorption will have been produced – fade-out may occur earlier of course. Actual reception agrees within a few minutes with the predicted times for these stations.

The author has had considerable success in *calculating* the fade-out times of many stations in Southern Europe and Africa by using an electronic computer to determine in advance the effects of the onset of ionospheric dawn for particular signal paths, frequencies, and dates. This technique is still under development but it has already produced predictions of fade-out times (or, more precisely, the time at which the signal will have undergone 20 decibels of solar-induced absorption) which consistently agree with actual receptions within a few minutes. *Figure 3c* gives two examples of the computer-predicted 20 dB fade times for African stations.

Fade-out times actually observed for these stations agree with the predictions within a few minutes. The much greater seasonal variation in the fade-out time for Mozambique is due to the accented effect of sunrise times at higher latitudes. These predictions are not valid for stations on high latitude paths during mid-winter, however, because of the unusually slow build-up on dawn-induced absorption caused by the low level of average illumination during daylight hours. Ionospheric and not surface dawn times must be used in such calculations.

Unpredictable Patterns in MW Reception

While many of the seasonal variations in MW reception are easily understood once the basic patterns in the location of the day-night boundary are visualized, complete *prediction* of MW reception is far beyond the scope of present technology. The same somewhat random factor controls day-to-day and week-to-week variation in reception on both MW and SW – namely solar activity. Although the precise sequence of events linking a disturbance on the surface of the sun to the structure of the ionosphere – and thus ultimately to MW reception – is not presently understood, some of the factors are well enough known to be of considerable use to the MW listener. The relationship of auroral activity to MW propagation is of particularly great interest, because it permits a certain degree of prediction for some receptions. The connection between auroral activity and MW propagation, while somewhat indirect, helps to explain many interesting receptions on high latitude paths.

Figure 3d outlines the sequence of events linking solar activity to MW reception.

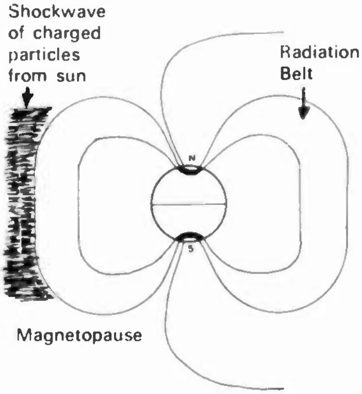


Figure 3d. The expanding shockwave of charged particles from the sun strikes the earth's magnetic field in the Magnetopause region after travelling for 20-40 hours through space. Charged particles from the Van Allen radiation belts are precipitated into the ionosphere above the auroral zones in both hemispheres. Such an even produces geomagnetic disturbances and absorption of MW signals in the auroral zones.

Solar activity (usually associated with flares and sunspots) produces a rapidly expanding shockwave of charged particles, primarily protons and electrons. After travelling through space for 20 to 40 hours, the expanding cloud of charged particles reaches the outer reaches of the earth's magnetic field in the region called the *magnetopause*. While most of the particles in this "solar wind" are swept aside by the earth's protective magnetic field, some particles are captured and take up temporary residence in the Van Allen radiation belts before ultimately reaching the ionosphere. The impact of this solar wind with the earth's magnetic field produces great disturbances within the magnetic cavity containing the earth and results in the displacement or *precipitation* of some of the particles from the radiation belts into the ionosphere along lines of the terrestrial magnetic field. Because of the shape of the earth's magnetic field, most of these charged particles eventually fall into the upper atmosphere above the so-called *auroral zones*. For our purposes, the Northern auroral zone appears as an oval-shaped ring centred roughly on the North Magnetic Pole. An equivalent zone exists simultaneously in the Southern hemisphere.

This hail of charged particles resulting from disturbances in the radiation belts produces a number of different phenomena. Sometimes, but not always, a *visual aurora* will be produced – the familiar Northern and Southern Lights. Whether or not a visual aurora is present, the precipitating charged particles constitute an enormous electrical current in the ionosphere. This current in turn produces an intense magnetic field which can be observed on earth as a disturbance in the strength and direction of the terrestrial magnetic field. These *geomagnetic disturbances* are recorded by a world-wide network of scientific institutions.

Of particular concern to the MW DX-er is the intense absorption of MW signals in the lower ionosphere (particularly in the "D" and "E" regions) over the auroral zones produced by the precipitating particles. The heavier the precipitation of particles the greater the geomagnetic disturbance and the greater the absorption of MW signals in the auroral region. During a severe disturbance, the effective size of the auroral zone increases and the zones extend further away from the Magnetic Poles than usual. Under these conditions the absorption region may extend far into the temperate zones and signal paths usually outside the auroral zones may be strongly affected. As a general rule, the region of MW absorption associated with auroral-geomagnetic activity extends much further from the Magnetic Poles than does the region of visual aurora. High frequency SW signals can often be reflected from the aurora during events of this type, but MW signals are usually totally absorbed. SW direction-finding naturally becomes very unreliable when auroral reflection is present, but MW signals continue to propagate largely along great circle paths because the auroral absorption tends to mask whatever deviated MW paths might be present.

In addition to the propagation differences caused by the greater wavelengths of MW signals, study of MW reception is further complicated by a very important but extremely hard to describe phenomenon called *magnetoionic splitting*. When a radio signal passes through an ionized gas such as the ionosphere in the presence of a magnetic field, the radio wave forces the charged particles (particularly the electrons) to move in spiral paths. At one and only one frequency (the exact value depends only on the strength of the earth's magnetic field at the point in question), the motions of the electrons are exactly in resonance or synchrony with the radio wave. The frequency at which this occurs is called the *gyromagnetic* frequency. At and near this frequency the incident radio wave may be totally absorbed and its energy converted into heat in the ionosphere. Exactly what will happen to a particular signal on a frequency near the gyromagnetic frequency depends upon whether the signal at that point is travelling parallel or perpendicular to the terrestrial magnetic field, or more exactly, upon the angle between the two. Because of this complication, some signal paths may exhibit non-reciprocity, i.e. a receiver at point A may hear a station at point B, but not vice-versa. This is in marked contrast with the behaviour of signals on the higher frequencies where reciprocity is usually complete. Through historical accident the MW band encompasses most of the gyromagnetic frequencies found throughout the world: since the strength of the earth's magnetic field varies from place to place, so does the gyromagnetic frequency. It reaches a minimum of about 680 kHz over Brazil and a maximum of about 1700 kHz near New Zealand. Because of the existence of this phenomenon, MW propagation is in a very real sense unique. Much serious study remains before the complete implications of the magnetoionic effect for MW DX-ing are completely understood. Very powerful clues to the solution to the problem of complete prediction of MW reception may well lie hidden in the formidable mathematical complexities of the magnetoionic equations, but it will require many years of study before this question will be fully resolved.

The MW listener interested in minimizing the number of fruitless hours spent listening for a particular station should try the following techniques. Study the seasonal variations in the position of the day-night boundary on a world globe, and familiarize yourself with the great circle paths to the stations of interest. Study the World Radio-TV Handbook's station schedules to determine possible times of reception. Make use of the worldwide predictions of geomagnetic-auroral disturbances transmitted by WWV and WWVH to anticipate auroral effects. Study past reception in the light of the information presented here and see how these factors have influenced reception patterns at your particular location.

VHF/UHF PROPAGATION

by Jim Vastenhoud

The propagation of radio signals in the VHF and UHF ranges is usually limited to the line of sight. As the earth is round, this means that – on flat ground – a circular coverage pattern will show on the map. The height of the transmitting antenna then determines the range of the station, which is about equal to its optical horizon.

The application of a high receiving antenna can extend the range of a VHF or UHF station, and there is a simple formula to computate it:

$$\text{range (km)} = 4.1\ (\sqrt{H_t} + \sqrt{H_r}).$$

H_t and H_r indicate the heights of the transmitting antennas and receiving antenna above ground, in metres. Conversion of the range into miles is easy, as 5 miles about equals 8 kilometres (km).

Figure 1 illustrates the limitations of line-of-sight communications.

Fig. 1

In hilly or mountainous countries, engineers take advantage of the terrain undulations to erect the TV or FM antenna tower at a high spot, from where the service area is conveniently covered. The elevation difference between the transmitting and receiving locations has then to be added to arrive at the right calculation.

In hilly or mountainous countries, engineers take advantage of the terrain undulations to erect the TV or FM antenna tower at a high spot, from where the service area is conveniently covered. The elevation difference between the transmitting and receiving locations has then to be added to arrive at the right calculation.

Line-of-sight conditions between transmitting and receiving antennas will limit the range of the average FM or TV station to about 50 miles. Reception at a more distant point from the transmitter is possible when the signal is relayed; picked up by a repeater station and rebroadcast on a different frequency, or if terrain conditions favour a remote pickup, or under extraordinary favourable propagation conditions.

Extraordinary favourable propagation conditions, which make reception of VHF or UHF signals well over the optical horizon of the television antenna possible can develop under specific conditions and will affect different parts of the spectrum under consideration. The following extraordinary modes of VHF/UHF propagation can be distinguished:

- trophospheric propagation
- ionospheric propagation via the sporadic E-layer
- meteor trail reflection
- ionospheric propagation via the F_2-layer

In the chapter on television DX, its author has already touched on these subjects. Here, we shall dwell a little bit longer on some of them, thus hoping to provide you with some additional information to improve your chances for successful usage of these propagation modes.

Trophospheric propagation over the optical horizon is possible during extraordinary conditions in the troposphere, the "blanket" of air which surrounds the earth and has a thickness of about 6 km (4 miles) at the poles, 11 km in the temperature regions, and about 18 km at the equator.

The troposphere is a stage of the weather: the transportation of water and warmth under the ever-varying energy-flow from the sun. Tropospheric "reflection" by multiple refraction of VHF and UHF signals depends on the *refraction index* of the air. Under normal conditions, the refraction index, which depends largely on the temperature and humidity of the air, decreases slowly with height. If it changes quickly over a relatively small difference in altitude, we can experience extraordinary VHF and UHF propagation. Such favourable conditions for TV and FM-signal propagation are generated quite easily in some areas but seldom occur in others. They are purely regional, sometimes even local, and depend on anomalies in the temperature and moisture division of the air, mostly in the lower atmosphere. They are also favoured by specific geographic situations, like river flows. We speak about a phenomenon called *temperature inversion.*

A temperature inversion occurs when, for some reason, the temperature decrease with increasing height is interrupted by a – rather sharp – rise of temperature over a small height difference. This disturbance of the normal pattern can be caused quite easily: just think of a layer of fog that is warmed from above by the sun. In the fog-layer, the temperature division is about normal, but its upper side has a higher temperature than the air immediately below, and thus temperature inversion is formed. It is not the inversion itself, but the sudden change in the refraction index of the air at the separation plane, that causes the VHF or UHF radio signal to reflect.

More temperature inversions above each other are also observed, and in such cases the radio wave can be propagated by reflection between those imaginary planes, which now form a kind of "duct". The duct just described, and formed by two layers (which must have certain dimensions and a certain minimum distance for effective reflection!) is called a *free duct*. If reflection takes place between one inversion and the earth, this is called a *surface duct*.

Now that we know that temperature inversions are important causes of abnormal refraction indexes in the air, it might be interesting to list the most important causes of such inversions:

1. After a sunny day, the earth starts to radiate heat into space, causing an abnormal temperature division above its surface. These radiation inversions occur especially in winter and are found above rocky or sandy ground, and above the snow, but never over the sea.
2. During anticyclonic, quiet weather, slow air masses descending to earth warm up because the air pressure increases near the earth's surface. Temperature inversions frequently occur at the lower side of such air masses.
3. For countries bordering the sea, cold breezes arriving over relatively warm sea water are frequently the cause of an inversion. The lower air has a much higher moisture degree than the upper air, and an inversion occurs at the plane of separation. These inversions also frequently occur above tropical waters.
4. Short-lived inversions can be formed during weather changes, especially movements of the air between high and low pressure areas.

In the temperate regions of the earth, good TV-DX in the UHF bands is frequently possible in the fall and winter, especially during quiet, foggy weather. In general, such DX covers distances up to 600 km, or 400 miles. After some experience with TV-DX, you will find that it is possible to enjoy the hobby successfully in more cases than anticipated, and you learn to judge by experience when there is a chance for TV-DX, and when there is not.

Also, as you will probably experience, the higher VHF frequencies usually benefit more from this propagation mode than the lower frequencies. However, these lower frequencies of the VHF range, notably those in broadcast bands I and II, sometimes benefit from a different propagation mode which is equally erratic but more season bound: sporadic-E layer propagation.

Ionospheric reflections of VHF signals in the given range are usually produced by *sporadic-E* clouds, which can sometimes be found at heights of about 100 km, slightly above the altitude of the normal E-layer. They can extend the range of a station considerably. The occurrence of sporadic-E can not yet be predicted, but investigations carried out on a world-wide basis have revealed interesting details about the frequency of occurrence in various seasons. The ionization of the sporadic-E "layer" is not always sufficient to reflect frequencies as high as 100 MHz; lower frequencies have a better chance to benefit from this propagation mode (which is a headache to international frequency planners for these bands).

Generally speaking, conditions for sporadic-E are better and more frequent in the northern hemisphere than south of the equator. The summer months offer the best conditions. They prevail in the daytime, usually between 0800 and 1900 hours local time, with second best conditions between 1900 and 2300 hours.

In some regions, sporadic-E conditions are better than in others. In Japan, China and South Asia for instance, exceptionally high occurrence rates are found, sometimes as high as 20%. In the USA, and in Europe, sporadic-E seems to be less active.

If we review the latitude, it turns out that best sporadic-E conditions are reserved for those living between 20 and 40 degrees northern latitude.

If we turn to other seasons, the conditions are substantially less than during the summer. In winter, the best general period lies between 1200 and 1900 hours local time, but the frequency of occurrence is only one fifth of that in summer. During the equinox months: March/April and September/October, conditions are about equal to those in winter, but they do prevail at other times, usually between 1600 and 1900 hours.

As sporadic-E propagation occurs over a larger area than tropospheric propagation, some DX-ers have made it a habit to inform their colleagues by telephone as soon as these conditions appear. Some Clubs even operate a "sporadic-E watch", to enable their members to get the most out of these extraordinary propagation conditions, which make DX-catches possible up to distances of about 1,500 km (1,000 miles).

Meteor trail reflections can affect VHF waves in the frequency range up to 110 MHz. The reflections are made possible by ionized meteor trails, which form in the upper atmosphere at heights of 80 to 100 km, when a meteorite travels in the direction of the earth, heats up by the increased air resistance, and finally burns up.

Most particles from space which enter the atmosphere of the earth, totally disintegrate on their way through the atmosphere. In this process the ionized meteor trail is formed. It can have a lifetimes of a few seconds.

The greatest contribution to meteor trails comes from random particles called "sporadic" meteors.

During some seasons, meteor activity is greater than normal, and meteor showers increase the number of impacts. Well known are the arietids, the perseids, and the aquarids, which occur between the beginning of June and the end of August, three months which already show a peak in meteor activity. For DX-ing the best time of day is rather unfavourable; between midnight and 0800 local time, and so is the season: May through September.

The height at which the meteor trails prevail, determines the largest distance to be covered by oblique-incidence waves from VHF stations: about 1,000 km or 600 miles. Most meteor trail propagation takes place in the lower part of the VHF range and can favour the reception of band I television stations far over the optical horizon.

F_2-layer propagation of VHF signals is rare, and only occurs when the MUF (see chapter on shortwave propagation) is very high. In practice, this can occur during the daylight hours, under extremely high sunspot conditions, and between latitudes of 40° north and 40° south. The most important single factor to keep an eye on for F_2-propagation, is the sunspot number, which is broadcast periodically by some shortwave stations, and can be found in electronics and amateur magazines. As long as the sunspot number stays below 100, chances for F-layer propagation are negligible, at 150 they are really coming, and at 200 they are a certainty.

F_2-propagation makes real long-distance reception of band I television stations possible. Although one-hop reception, which covers distances up to 3,500 km, is more frequent and also better than multi-hop reception, one famous case during the 1958 sunspot all-time high revealed the reception of BBC-TV in South Africa!

Chapter 24

TV-ANTENNAS

by Jim Vastenhoud

The antenna types used for television reception are mostly directive: they favour signals coming from certain discrete directions, while being insensitive to waves arriving from other angles.

Someone who's interests are in TV-DX-ing, should know some of the more important characteristics of television antennas, in order to get the best results with his hobby.

First, let us introduce some antenna data and antenna terminology.

The standard antenna or "radiator" type used for both VHF-FM and TV reception, is the dipole.

Basically, a dipole is a half-wave, or $\frac{1}{2}\lambda$-antenna: its physical length is equal to half the wavelength of the station to which it is tuned. To calculate the length of a dipole, you must know the mid-band frequency of the station which you want to receive. This frequency, in turn, depends on the TV standard and the channel number used by the station. The different TV standards used throughout the world, as well as the channel allocation of each standard, can be found in the reference section of this book.

If the vision carrier of a station is on 197.25 MHz, and the audio carrier on 202.25 MHz, the mid-band frequency of this channel is about 200 MHz.

The corresponding wavelength, indicated by the greek letter lambda (λ) and expressed in metres (m), can be found by applying a simple formula:

$$\text{wavelength (m)} = \frac{300}{\text{frequency (MHz)}}$$

In our example, the corresponding wavelength will thus be:

$$\frac{300}{200} = 1.5 \text{ metres.}$$

The theoretical dipole length will then be 1.5/2 = 0.75 m, or 75 centimetres (1 inch = 2.54 cm), since the dipole is a half-wave antenna.

The actual dipole length used for this frequency, however, will be a little bit less, due to the so-called velocity or shortening factor, which is determined by practical values like the diameter or gauge of the tubing used for making the antenna. This will further be dealt with later on.

The dipole antenna consists of two rods, or wires, of exactly the same length, which extend on both sides of the centre insulator. The dipole dimensions given encompass the distance between the extremes of each rod, thus automatically including the centre insulator. See *figure 1*.

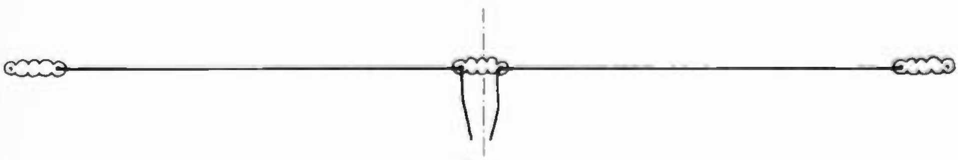


Fig. 1

A dipole has a number of electrical properties, which are important to know.

The directional characteristics are usually represented in so-called polar diagrams. These show cross-sections of the antenna patterns, which give us indications about the way the antenna should be positioned with respect to the transmitter. Usually, a dipole is placed horizontally (parallel to the earth's surface), as most TV-transmitting antennas are horizontally polarized, meaning that the electrical component of the radiated electro-magnetic field runs parallel to the ground.

Figure 2 gives an indication of the horizontal dipole pattern in space. It looks somewhat like a doughnut, or like a tyre for a dune buggy.

For easy interpretation of the directional characteristics, it is customary to present either the horizontal polar diagram or the vertical polar diagram. The characteristics given for the horizontal plane are usually more interesting for us to know. For the dipole antenna, they more or less represent a lazy figure 8. See *figure 3*.

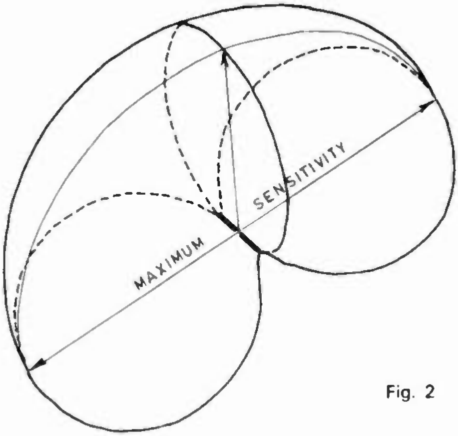


Fig. 2

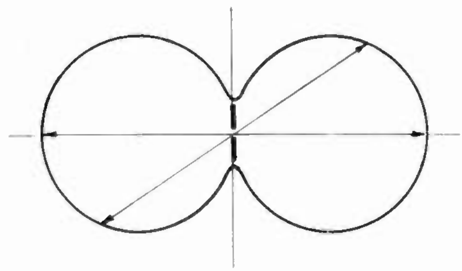


Fig. 3

For the sake of clarity, the antenna itself is represented in the centre. The relative sensitivity of the dipole can be obtained by drawing arrows from the centre of the figure. The longest possible arrows are those which stand perpendicular to the antenna axis. This means that the dipole antenna is most sensitive for signals received broadside from it.

Other conclusions are: the antenna is equally sensitive in both directions, and the sensitivity drops off gradually at other angles, becoming zero in the direction of the antenna axis. The dipole must thus preferably be positioned at right angles to the signal from the desired station!

An antenna which is equally sensitive in all directions, is called an isotropic antenna. A dipole, which shows a definite preference for signals arriving broadside from the antenna, is called a directional antenna.

To express the relation in sensitivity between the two, a unit called "decibel" is used. The decibel or dB is a simple means to express the gain in relation to a certain fixed standard. The isotropic antenna is such a standard, it has zero gain. The dipole has a gain of 2.14 dB over the isotropic antenna, when measured in the direction of greatest sensitivity. The word "gain" is a little bit misleading, as there is no real amplification, but a superior sensitivity of the antenna over a standard antenna.

Usually, antenna gain is expressed in relation to the isotropic source.

Some manufacturers, however, use the dipole itself as a standard reference antenna. In such cases, one must add 2.14 dB to the stated gain to reach the gain over the isotropic antenna. For those who want to convert "gain" into fieldstrength ratios, we give the conversion formula:

$$\text{antenna gain (dB)} = 20 \log \frac{\text{fieldstrength produced by antenna in forward direction}}{\text{fieldstrength produced by reference antenna in the same direction.}}$$

There are other important antenna characteristics. We will mention them in short.

The beamwidth is defined as the angle between those values of the polar diagram, where the gain has dropped to 0.7 of this maximum value.

Figure 4 illustrates this.

If the sensitivity of the antenna in both main directions is not equal, we can express the ratio between the forward and the backward "lobe" of the polar diagram. This is also done in dB, and it is called the "front-to-back" ratio. The front-to-back ratio is important if the signal pickup from the rear of the antenna is not required.

Although you will seldom be confronted with the bandwidth of an antenna, it is good to know what it means.

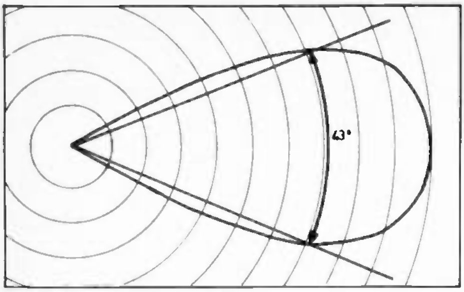


Fig. 4

As the dipole is basically tuned to one discrete frequency, determined by its dimensions, we determine the bandwidth of the antenna as the ratio between the frequency range where the gain is 0.7 or more of the maximum gain at the resonant frequency of the antenna. So, if the antenna is resonant at (tuned to) 100 MHz, and has a range between 97 and 103 MHz where the gain is 0.7 or better of the maximum gain, the bandwidth of the antenna is

$$\frac{103\text{-}97}{100} = \frac{6}{100} = 0.06, \text{ or 6 percent.}$$

The diameter of the tubing used for making the antenna, is an important determining factor for the bandwidth of the antenna. The larger the diameter, the greater the bandwidth. The consequence, however, is a slight reduction in gain.

An important characteristic of an antenna is its feed impedance. A resonant antenna shows a certain resistive value, which is determined by its radiating efficiency (all terms in antenna technology refer to transmitting antennas) and its electrical losses. It is a resistance which the connecting feeder line (or transmission line) "sees".

For the dipole, this is 73 ohms. If such a dipole is connected to a feedline it is essential to choose 73 ohm line for that purpose, to avoid signal losses due to "mismatch", resulting in reflective losses at the line terminals.

As many television sets have an antenna input impedance of 300 ohms, it is often necessary to increase the antenna impedance. A very common way to raise the antenna impedance four times, to about 300 ohms, is to run a metal rod of a diameter equal to that of the antenna parallel to it, and to interconnect the ends as shown in *figure 5*.

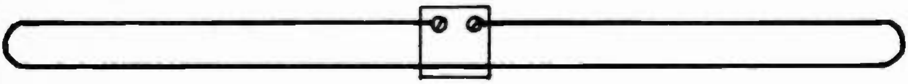


Fig. 5

If we want to raise the antenna impedance to nine times its original value, about 650 ohms, a second rod can be installed.

Later we will deal with methods to obtain antenna impedances of intermediary values.

With this basic antenna knowledge, let us have a look at some commercially available antenna types.

It will be easy to recognize the dipole as the heart of most antenna arrays. For the sake of good matching to the input of the receiver, a folded dipole is mostly applied. To take the best advantage of the passing wavefield at the desired channel, the dipole action is assisted by so-called directors and reflectors. These are rods, running parallel to the dipole at individually distinct distances. Their lengths are selected so as to increase the field strength of the desired signal at the position of the dipole (*fig. 6*).

Such an array of a dipole, reflector rod and director rods is called a Yagi array, or Yagi-Uda antenna. It is basically a narrow-band antenna, with a high gain in the forward direction, that is the direction broadside to the dipole itself. This gain can be between about 5 dB for a simple 3-element Yagi to 22 dB for a 20-element Yagi array.*

Though the Yagi is the basic VHF or UHF antenna, other different types have been developed to suit alternative conditions.

Some examples.

The Yagi is a narrow band narrow beam type. Sometimes people will need a narrow band wide beam antenna, or a wide band narrow beam type. Sometimes, the TV viewer will suffer so much from the interference caused by passing traffic that he needs an antenna which does not pick up street noise at all. For all these purposes, separate antennas or antenna arrays have been developed and are on the market. Let's mention some of the types, and their most significant properties.

*dB stands for "decibel". See the reference section of this book.

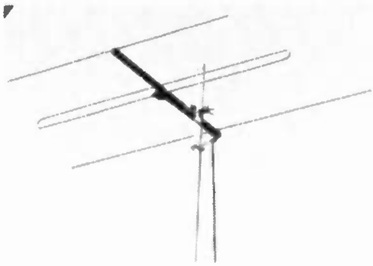


Fig. 6

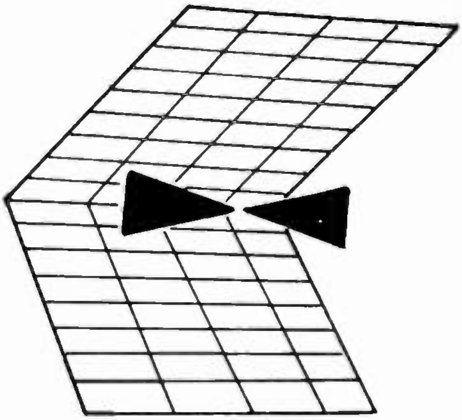


Fig. 7

The corner-reflector antenna (*fig. 7*) consists of a dipole, placed before two screens (grids) that intersect at an angle of 90 degrees. These screens are usually constructed from rods, placed at small distances, or in the form of a mesh, which acts to reflect signals to the dipole, and to shield the dipole from signals coming from the back of the antenna. (The reflection planes are about 5 to 10% wider than the length of the radiator.) The corner reflector antenna therefore has an excellent front-to-back ratio (it does not pick up signals from behind), a relatively wide beamwidth of about 60 degrees in the horizontal plane, and a moderate gain of about 12 dB.

The dipole/vertex spacing should be kept at 0.35λ. The feed impedance of the antenna is then about 70 ohms for the single dipole, or 300 ohms for the folded dipole.

If you want to screen the antenna from street noise emerging from passing vehicles and streetcars, you should select a stacked array. Usually, this consists of a number of dipoles, normally two (VHF) or four (UHF), placed above each other. (Figure 8.) This array is placed before a vertical screen, so as to prevent it from picking up radiation from the back. It has a good vertical directivity, so that it does not pick up signals from above, or below. This makes it insensitive to street noise.

In this form however, the antenna has a rather substantial beamwidth in the horizontal plane. If we want to decrease this we can place a couple of these stacks next to each other. An antenna with two stacks of 4 antenna each placed side by side before a screen, is called a bow-tie antenna. The name stems from the biconical, bow-tie shaped dipoles used. It has a narrow beamwidth, good gain and an excellent front-to-back ratio.

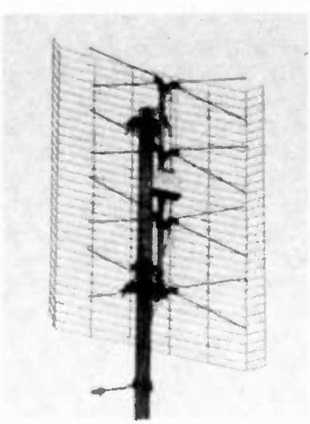


Fig. 8

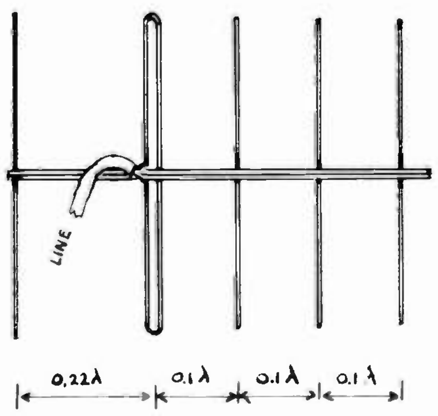


Fig. 9

Commercial Yagis are available in various shapes of different properties: the broadband Yagi, which can be recognized because it has a greater mutual distance between the directors, and the interlaced high- and low-band Yagi for two channels, one in the VHF and one in the UHF-band. The gain of the first, broadband type, is lower than the single channel Yagi, but the interlaced type does not suffer from this disadvantage.

In the commercially available TV-antennas, you will come across log-periodic types as well. These can be recognized by their V-shape caused by their elements becoming shorter towards the apex (which points in the direction of the transmitter), and the fact that they are fed (usually by a 75 ohms coaxial cable) at the apex of the V. These logarithmic-periodical arrays are basically broadband types, e.g. designed for the entire UHF-band, which is an advantage to the DX-er because it limits the number of antennas required for the hobby in the UHF-field. The gain of the log-per antenna will not be excessively high, a good value is 16 dB. Log-per antennas are hard to make, but reasonable in price. We must thus advise you to buy one, if you need it for your hobby.

In selecting an antenna, be careful to note its impedance, its gain, its sturdiness and resistance to mechanical loads (pigeons, high winds), its installation problems, and the TV channel or TV channels to which it is tuned.

For television DX, you will need an elaborate antenna system. Some important considerations on antennas are:

- for a high gain, you need a multi-element antenna,
- for the best front-to-back ratio, you need a screen behind the antenna,
- in the case of traffic interference, you need an antenna with a narrow vertical angle, preferably a stacked array.
- In general, a wide-band antenna has a lower gain than a narrow-band antenna with the same number of elements.

In most cases, it is possible to buy an adequate antenna system after careful study of the catalogues or folders. In some cases, you will have to rely on your own judgement for the construction of a good antenna. The Yagi-array (*fig. 9*) will then prove to be the best antenna for you.

Basically, it is a narrow-band antenna suitable for one TV channel in the VHF band and about 3 adjacent channels in the UHF-band. Its heart is the folded dipole. The dimensions of this dipole are small enough to make the antenna out of aluminium or copper rod of about 5 to 10 mm diameter and the central support of U-profile aluminium, or wood. For the VHF channels, the distance between the upper and lower conductor of the folded dipole can be kept at 10 cm (4 inches), for UHF it is slightly smaller, about 6 cm ($2\frac{1}{2}$ inches). The folded dipole must be fed by a 240 or 300 ohm parallel feedline (ribbon, twin lead). Its efficiency is good for VHF, but decreases as the frequency increases. That's why you need a relatively simple, 3 element antenna, for FM-DX, but, for example, a 20-element type (one dipole, one reflector and 18 directors) for fringe-area UHF-DX.

The dipole itself must be well insulated from its support, but for the parasitic elements like the directors and the reflector this is not necessary.

Its dimensions depend on the mid-frequency of the channel, and its mechanical length is about 5% shorter than half the wavelength to which it is tuned, as long as the quotient of the wavelength and the diameter of the tubing of which the antenna is constructed, is between 500 and 750. So if 8 mm ø tubing is used for the dipole, it is 5% shorter than half the wavelength to which it is tuned for wavelengths between 4 and 6 metres, or frequencies between 75 and 50 MHz.

To improve the directional sensitivity, known as the "gain" of the antenna, a reflector rod is placed parallel to the dipole at 0.22 behind it; "behind" as seen from the transmitter.

The reflector is 5% longer than the dipole itself. The addition of this parasitic element lowers the impedance of the antenna, but not enough to make special measures necessary. The addition of one "director", placed at 0.1 before the antenna (as seen from the transmitter), will further improve the gain of the antenna, thereby narrowing its horizontal beamwidth.

The antenna impedance now decreases to about 110 ohms, so that special measures are necessary to "match" the antenna impedance to that of the feeder line in order to avoid signal loss through reflection. More directors spaced at mutual distances of 0.1 will lead to different characteristics in the forward direction, perpendicular to the "driven element", which is the dipole. The beamwidth will be further narrowed, and the gain increased.

In general, it can be stated that a 5-element Yagi array is sufficient for fringe area VHF-DX, but for the same result on UHF you need a 20 or 22 element Yagi antenna.

For this purpose, we are listing some data on the dimensions of narrow-band Yagis for various channels in the VHF band.

Velocity (shortening) factor k, to observe when making your own FM or TV antenna

quotient: $\frac{\text{Wavelength}}{\text{diameter of dipole tubing (in metres or feet)}}$	k
100	0.91
200	0.93
300	0.94
500	0.95
1000	0.96

Example: for a mid-channel frequency of 200 MHz, the wavelength is 300/200 = 1.5 metres, or 1,500 mm.
If 10 mm ø tubing is used for the dipole, the ratio between these two works out at 1500/10 = 150. This results in a "k" or velocity factor of about 0.92.

Dimensions of some Yagi antennas:

Folded dipole with reflector

length of radiator (= folded dipole): $\frac{\lambda \times k}{2}$

length of reflector rod: 1.05 × × k

distance radiator-dipole: 0.22 ×

antenna impedance: 240 ohms

gain: 5 dB

Folded dipole with reflector and director

length of radiator: as above

length of reflector: as above

distance radiator-reflector: as above

length of director rod: $0.95 \times \frac{\lambda \times k}{2}$

distance dipole-director: $0.1 \times \lambda$

antenna impedance: 110 ohms

antenna gain: 7 dB

Folded dipole with reflector and two directors

for dimensions of radiator, reflector, director and their respective distances: see above

length of second director: $0.93 \times \frac{\lambda \times k}{2}$

mutual distance of directors: $0.1 \times \lambda$

antenna impedance: 40 ohms

antenna gain: 10 dB

Installing the Antenna

One of the first considerations for an antenna is: where can it be placed so that it works the most effectively? The answer is: as free-standing as possible, away from obstacles in the direction of the transmitter(s), away from local interference sources (such as street traffic), while the feeder line should be limited in length to avoid signal losses. Of course, these are in many cases contradictory factors, and a different solution may present itself, depending on the local situation.

Usually, the television antenna is mounted on a pole. In many countries, this pole is a hollow tube of about $1\frac{1}{2}$ to 2 inches in diameter, depending on the weight and size of the antenna. Aluminium or galvanized steel is most often used.

The length of the antenna pole depends on the local needs, but for DX-ing you will certainly need a considerable length of tubing. If it exceeds 3 metres (10 feet) in length above its last support, it should be guyed. A 10 metre antenna mast needs to be guyed every 3 metres, the highest guy kept about 2 to 3 metres (6 to 10 ft) from the antenna, to avoid it from forming part of the antenna system and thus spoiling the directional characteristics.

Usually, three guys are used at every level, distributed evenly around the mast. A metal ring around the mast can act to hold one end of a guy; the other end runs to a fixed point. One of the guys runs in the direction of the prevailing wind; all guys run downwards, at angles of about 45 degrees.

Good guy wires are those that can stand the strain imposed on them by high winds tugging at the antenna. Also they must resist corrosion for a long time: plastic covered twisted steel wire, or copper-clad steel wire, are recommended. Turnbuckles can be used to keep the guys at the correct tension.

Usually, three or four anchors are used for all the guy wires, depending on local conditions.

It has become a habit to anchor TV antenna masts to chimneys. Although it is a bad habit, it is understandable, because the chimney is usually the highest point of the house, and because it is relatively simple to fix a mast to it. We advise you to try another support for your antenna if the chimney is used as such, because the gases emerging from it contain sulphur-dioxide, which forms an active acid when it settles on wet surfaces. Also, most chimneys are of a bad quality, and the constant wind-forces working on it through the TV mast, will jerk the cement between the bricks loose, and cause it to fall down in the long run. If you have to use the chimney as a support, fix the antenna mast to a support by means of U-clamps or U-bolts. The support is tied to the chimney with two steel straps or steel wires, running around it and reinforced at the 4 corners of the chimney.

A TV antenna mast can also be mounted on the roof at another suitable spot – suitable with respect to running its feeder line – or it can be fixed to a wall of the house. Many variations exist, and the most practical solution will depend on local conditions.

The choice of the transmission line is difficult.

Twin line (ribbon, twin lead, parallel line) usually has a characteristic impedance of 240 or 300 ohms. This line has the lowest loss, which is important if the antenna is mounted high up. The best twin lines are tubular foam filled or open wire parallel line types, which keep their characteristics during changing weather conditions and "age" only slightly in use.

In some places, screened 300 ohm twin line can be obtained. This transmission line is used in areas with extremely high local interference levels. It must, however, be stressed that screened ribbon introduces considerable signal losses if applied at a substantial length.

Coaxial cable is also in use as television transmission line. It has taken some time for this type of transmission cable to become popular, because its low 72 ohm characteristic impedance is a drawback, as many television sets have antenna input impedances of about 300 ohms, so that extra "matching" measures are necessary to obtain a good signal transfer between transmission line and receiver, and sometimes also between transmission line and antenna. However, handy 4:1 matching transformers have been developed to make up for this. Although they do give some signal loss, the advantages of the application of coaxial cable instead of twin lead, being the absolute insensitivity to local interference and the easy installation, have boosted its popularity. In the case of large television installations, where booster amplifiers have to be used to compensate for signal losses in the transmission line, coaxial cable is almost universally applied. In smaller antenna installations, VHF television installations and FM radio antenna systems, the twin line usually wins because of its lower signal losses and its suitable 240 or 300 ohm characteristic impedance, which matches that of the receiver input.

While coaxial line can be laid as desired, without any precautions being taken, twin line is rather exacting in the way it runs from the antenna to the receiver. It has to be kept at a distance of about 10 cm (4″) from normally non-conducting surfaces, and at 15 to 20 cm (6 to 8 inches) from large metal surfaces, like gutters, steel windows etc.

Stand-off insulators are normally used at mutual distances of 1.20 m (4 ft). The twin line must be strung taut between them, and it is also recommended to twist the cable a few times in one direction between two insulators, and in the opposite direction between the next two, thus limiting the pickup of unwanted local noise.

Transmission line losses depend on the type of cable applied, and on the frequency. A small table, given below, will provide measured data for line lengths of 100 metres, or about 300 feet.

Transmission line losses at various frequencies.

	50 MHz	100 MHz	200 MHz	800 MHz
300 ohm twin line	4 dB	6 dB	8 dB	16 dB
screened 300 ohm line	8 dB	12 dB	18 dB	35 dB
coaxial cable	6 dB	11 dB	15 dB	30 dB

Matching

In order to obtain a maximum signal transfer between antenna and receiver, it is necessary to "match" the line impedance to the antenna input impedance of the receiver, and to the input impedance of the antenna. If this is not done properly, standing waves will appear on the transmission line, resulting in a loss of signal, which can become prohibitive if the "mismatch" is serious. Thus, it is important to deal with this subject.

Most matching problems will occur when the antenna, the transmission line and the antenna input of the receiver show different impedances. Please note that we have:

- antennas which can have a wide variety in input impedance, depending on the type of radiator used and the number of parasitic elements applied. Usually, the impedance of a commercially acquired antenna is known. Most TV antennas are balanced.
- transmission lines that have either 300 or 75 ohms characteristic impedance, and are either balanced or unbalanced.
- balanced receiver inputs of 300 ohms for both the VHF and the UHF bands, or one universal 75 ohms unbalanced antenna input for both bands.

This means that matching and/or balancing might be necessary at either end of the transmission line.

Matching transformers with an impedance ratio 1:4 or 4:1 are available. Although they are commercially known as matching transformers, their real name is *balun*, for *bal*anced to *un*balanced transformer. Four-to-one baluns are universally applied between the coaxial line and the receiver input. At the upper end of the coaxial cable, a booster amplifier is usually connected, to boost the antenna signal *before* it enters the cable. These boosters, or mast-mounted antenna pre-amplifiers, are available in wide-band versions and as narrow-band boosters. They also perform the impedance matching and the balancing.

When twin line is used, no matching is necessary at the receiver end, because the characteristic impedance of the line and the antenna input of the receiver have the same value: 300 ohms. A mismatch resulting from using a 240 ohm line, is considered acceptable.

Near the antenna, matching is needed if a parasitic array is used, because the antenna impedance has been lowered by the application of parasitic radiators like the reflector and the directors. The practical data for home-built antennas give you information about the reduction factors.

To cope with this, two measures are possible:

- the insertion of a quarter-wave transformer between the antenna and the feed line
- the increase of the folded dipole impedance, by the application of two conductors of *different* rather than *equal* diameter, whereby the lower conductor always has the smaller diameter.

The quarter-wave transformer consists of two thin rods of copper or brass, usually 2 to 4 mm in diameter, which are a quarter-wave long, and which are positioned strictly parallel at a critical distance, which is determined by the input impedance of the line (Z_l) and the input impedance of the antenna (Z_a). The impedance of the matching section is equal to the square root of the product of the two impedances $Z_t = \sqrt{Z_l \times Z_a}$

where: Z_l = impedance of line, Z_a = impedance of antenna.

So, for a 300 ohm line and a 40 ohm antenna impedance, the characteristic impedance of the line that composes the quarter-wave transformer must be $\sqrt{300 \times 40} = 106$ ohms.

To find the distance of the copper rods that form the quarter-wave transformer, use the formula:

$$Z_t = 276 \log \frac{2d}{c}$$

where: d is the centre to centre distance between the conductors, while c is the diameter of each conductor, in the same units.

It is advisable to keep the rods at an equal distance by the application of some plastic, teflon or polypropylene spreader insulators, which can be home-made. Basically, this can be regarded as "air insulation". One end of the transformer is connected to the antenna via two short, bare wires, and at the other end to the transmission line.

In many cases, especially for VHF applications, it is simpler and less complicated to increase the antenna input impedance itself. The idea is to arrive at a 300 ohm (appx) input impedance for the antenna system, by compensating the decreasing effect of the proximity of parasitic elements, by the increasing effect of using a thicker piece of tubing for the parallel conductor (the upper conductor) of the folded dipole. Various configurations are listed in the table below.

quotient $\frac{d_2}{d_1}$	Centre to centre distance of conductors (metres)						
	.0005	.001	.003	.005	0.01	0.02	0.03
1 (equal)	300	300	300	300	300	300	300
1.5	450	450	430	420	360	310	300
2	650	650	575	525	450	375	350
2.5	880	870	800	720	575	480	440
3	1150	1120	1000	900	750	600	520
3.5	1440	1420	1220	1080	900	720	610

d_2 = diameter of upper conductor
d_1 = diameter of lower conductor
= wavelength in metres

If a folded dipole with different conductor sizes is made, take care for a smooth transition between them. Usually, the ends of the lower conductor, which is initially made somewhat longer than the upper conductor of the dipole, are bent upwards and soldered to the upper conductor's ends.

Maintain a constant spacing between the two conductors by using spreader insulators, which can be home-made out of teflon or polypropylene rod. Usually, 4 or 6 of them are enough.

The table is only of interest to those who build the antenna themselves. However, many DX-ers will find it easier, more convenient and even cheaper to buy an antenna ready made. If you do so, check its impedance, so that you will not have the trouble of matching it to your TV line. Also make sure that its mechanical strength is enough to support your neighbour's pigeon! And, of course, see that your ribbon, or tubular cable, or coaxial lead has a characteristic impedance equal to the antenna input impedance of the TV set. Bear in mind that all matching, though necessary, leads to signal loss. If you want to DX with the antenna, avoid too much matching, and make sure that you have a high quality transmission line, with a type of insulation that keeps its characteristics over a long time.

Now that we have dealt with all the individual details of the television antenna, it is about time to say something about the layout of a DX antenna system.

As we know, height is of the utmost importance. The consequence of a high positioned antenna, however, is that you need a long feeder, and this causes signal loss. For normal TV reception, we can easily find a compromise, but for TV-DX or FM-DX we usually cannot afford signal loss, so we have to do something about it.

The antenna amplifier, also known as the signal booster or the pre-amplifier, is the answer to this problem. As it serves primarily to compensate signal losses in the feeder line, it has to be mounted near the antenna, at the upper end of the antenna cable. Usually, these signal boosters are solid state (transistorized) devices, fed via the antenna cable by a low DC-voltage, which in turn is generated in a small mains-fed power unit. The gain of the antenna amplifier may vary between about 16 dB for a wide-band type, to 30 dB for a single channel or narow-band type.

Signal boosters can be applied at both ends of the feeder line, and indeed the second, "receiver end" booster can sometimes bring in a signal that would otherwise stay below the threshold of visibility

Booster amplifiers do not only amplify the antenna signal, but many of them also match the amplified signal to an unbalanced 75 ohm coaxial line.

The number of antennas and their respective heights which you need, depends on your location. It has become customary to use one high gain broadband antenna for the entire UHF band at the top of the mast, and to make it rotatable. This can be effected by a (selsyn controlled) rotor, mounted at the top of a mast. It is able to rotate a short extension mast, on which the UHF antenna is mounted.

The rotor is operated via a control box – which is mains (line) operated and placed near the TV-set. A multi-wire cable connects the rotor and its control box. It is usually run through the antenna mast, or taped to it. To prevent the feeder line from twisting around the mast the swing of the rotor is usually limited to one turn only (and back).

If the number of UHF stations within 400 miles is limited, it may be cheaper to install two or three narrow-band Yagis. The disadvantage of this, however, is that you will have to reverse the antenna connections if you want to use another antenna, as the receiver has only one UHF antenna input.

You can put the VHF antennas below the UHF antenna. For maximum gain, you will probably have to decide on narrow-band types, which you can mount either in a fixed position, or make them rotatable as well by using one rotor for the greater part of the mast. The solution you decide upon depends entirely on the presence of TV transmitters within some 1,000 miles, and the properties (gain, beamwidth) of your antennas.

The vertical distance of two TV antennas should be at least equal to half the dipole length of the longest of the two under consideration. Otherwise, you will adversely influence their radiation pattern.

As you can see from data given earlier, feeder line losses increase with higher frequencies. This means that you will need a booster amplifier for almost any UHF-DX antenna, but you can probably do without it on your VHF antennas, providing you use the proper type of transmission line.

Now, a word in general about TV couplers, splitters and filters.

A TV coupler is used for coupling two or more television or FM receivers to the same antenna. You might call it a distribution amplifier. There is no harm in using this, if it is of a high quality so that it does not produce noise.

A splitter is used for coupling different TV antennas (UHF and VHF) to the same transmission line. Although this looks advantageous from an installation point of view, it should be borne in mind that passive splitters cause a signal loss of about 3 dB. This makes them more or less unsuitable for DX-activities.

Filters, usually passive as well, are devices that suppress some frequencies and let others pass. They are available in many versions, to suppress bands that are not desirable or would cause interference to the reception.

After the antenna installation is ready, it has to be tuned up. This is done with the help of a TV receiver. To set the fixed antennas for maximum performance, they have to be well directed. This is done while the station is on the air, so that you can check on reception variations with different antenna directions.

The antenna line-up method usually applied is to have one man on the roof, and the other at the receiver in the room. Together, they determine the two positions of the antenna at which its performance starts to deteriorate (increase of noise in the picture, usually visible as "snow", an apparent increase of "granules" in the picture, and best visible in its grey-tones).

Once the two positions at which the signal starts to drop off are determined, fix the antenna in the position exactly half way between these two positions. You will then have maximum signal strength.

If you want to receive two stations with one antenna, try to position the antenna so that it pulls them both in at about equal signal strength.

The TV receiver

After the antenna system is properly tuned, we turn to the receiver. Many people do not tune their TV sets correctly. Here are some hints for making sure.

First, switch the receiver on, and allow it to warm up for at least 5 minutes, but preferably 15 minutes, to stabilize. Then use the channel selector to find a TV programme. Both picture and sound have to be present. Now, use the "fine tuning" knob (usually around or in the vicinity of the channel selector) to arrange for optimum sharpness (definition), with the sound still present at about maximum signal strength. If you observe horizontal bars that appear and disappear with the rhythm of speech or music, adjust the fine tuning knob until it is gone. You have then tuned the receiver correctly to the channel.

The picture has to be electrically stable (hard to judge when a film is shown). If it tends to "pull" to the right or the left at the top of the picture, adjust the "horizontal hold", and if it tends to "roll" either upwards or downward, adjust the "vertical hold". In many modern receivers, these vertical and horizontal holds are automatic, like the picture height and picture width controls. So, don't panic if you cannot find the knobs!

It is important to set the black and the white level properly. In order to achieve this, manipulate the "contrast" and "brightness" controls. Usually, the "contrast" indicates the tonal difference between the darker and lighter portions of the picture, while the "brightness" controls the top whites.

Both controls do not operate equally in all receivers. That' why we advise you to control both in order to reach a good white-to-black (contrast) range. Proceed as follows:

First look at the darkest parts of the picture. Make them darker, until you do not see a further darkening when you turn the knob anti-clockwise. Then, reverse the direction of control slightly, until you just notice a difference in shade for the darkest portions of the picture. You have now got the right black level.

Now, concentrate on the lightest portion of the screen. Turn the "brightness control" clockwise, until the whites start to flicker before your eyes. Then, reverse your control until this effect has just disappeared. You have now a correct white level.

Check whether the black level has remained the same. If not, correct it, until your results are satisfactory.

Make your adjustments neither in a fully lighted nor in a fully darkened room. The wall behind the receiver is best lit to somewhat less than the brightness of the screen. Many stations run test patterns to enable their viewers to adjust their receivers properly. It is worth while studying such a test chart, if you find one on the screen, and to ask the station to explain its configuration. This can help you considerably in judging the performance of your receiver.

It is very difficult to determine the quality of a television receiver by looking at the schematic diagram, even if you are familiar with them. It is therefore recommended to apply another way to determine your choice: comparison of the performance.

For television DX-ing, the sensitivity of the receiver is very important. It is mainly determined by the front-end stage of the set, called the *tuner*.

As practically all receivers will perform satisfactorily when connected to a good antenna, it is essential for your comparison test to use a small antenna and – if possible – to tune into a weak station. If two receivers are set up in the same way, there will be a difference in "noise" visible as "snow" in the picture. The grainier the picture is, the less sensitive the receiver. Do not only look at the picture as a whole, but also specific parts of the picture, especially greys or – in colour sets – reds.

A second test can be done if the test pattern, produced by the television transmitter before the programme starts, is available. Details to observe: are the circles of the test pattern round, even those put in the four corners? Does the receiver give sufficient resolution (reproduction of fine detail)? A 625-line receiver must have a horizontal resolution, read from the vertical wedges, up to about 400 lines, and a 525 line receiver up to 325 lines. The vertical resolution has to be even better: approximately 550 and 450 lines for the systems under consideration. It can be read from the horizontal wedges. If the vertical resolution fails, it means that interlacing is not correct, and this could mean serious circuit trouble.

The geometry of the image can be checked with the horizontal and vertical lines, which should run parallel over the complete height and width of the screen. Usually, they deviate slightly in the corners, but this is considered acceptable.

With the test pattern on, you may discover faults that do not show up otherwise. Try to correct them by the small knobs for "vertical and horizontal linearity", "picture height and picture width" etc, that can usually be found at the back of the receiver, or on the pc-board inside as screwdriver adjustments. However, be careful to avoid electric shock. If you adjust controls with a small screwdriver, always choose an insulated one, and always use one hand only, keeping the other behind your back.

You may also find the controls for vertical and horizontal hold at the back of the receiver. They serve to adjust the frequencies of the line and field deflection oscillators.

When DX-ing, you will certainly have to cope with weak signals. These signals are sometimes unable to synchronize the deflection circuits of the receiver, so that the picture will either "roll", fall sideways, or even both. In such cases, it helps to adjust the vertical and horizontal hold controls carefully.

If you see two images on the screen, the weaker of the two being to the right of the original image, you suffer from a spurious image or "ghost".

This results when the transmission reaches the antenna not only via the normal path, but also via one or even more reflections, probably from hills, tall buildings, or metal structures. By measuring the distance between the two pictures, it is possible to determine the length difference of the two paths, and this usually leads to the identification of the reflector, and to adquate measures (change of antenna direction, or application of a type with better characteristics).

Another experience may be that you hear sound, but the picture refuses to appear; or you locate a picture but cannot find any sound going with it. It is then likely that you have traced a station operating with a different television system, where the frequency separation between the vision and the sound carriers differs from that applied in your own country or region. Sometimes, however, there is another reason: your set can have different sensitivities for picture and sound, and the station can also use an odd power ratio between the vision and the audio carrier. Some systems use power ratios of 10 to 1, and others 2 to 1. As the receiver's circuits are matched to the local system, difficulties cannot be excluded off-hand.

Reporting

The purpose of reporting is to obtain some written form of reception verification. This may be either a regular QSL-card or a letter. In order to obtain such a verification, your report must be accurate, preferably couched in a friendly letter, and a request for a verification must be included.

The letter should be addressed to the station. In the World Radio and Television Handbook, you will find the names and addresses of the TV organizations of the world.

It may be difficult to find the correct department. At some stations, the "Public Relations" department will take care of verification, in other organizations it is the engineering staff, while it is also possible that the TV organization is purely a programme staff, while the transmitting facilities reside under another body. If you are not sure about the department to which you must direct your correspondence, suggest in your letter that, if it is wrongly addressed, the reader will direct it to the proper department.

A report to a TV station should contain (besides your own name and address):

- the date and time of reception
- the channel (and, if necessary, the system)
- details of the programme
- details of the picture and sound quality
- a request for verification

Information on the picture quality is usually given in a five-point grading scale, which runs:

5 = excellent
4 = good
3 = fair
2 = poor
1 = bad

If the reporter wants to give information on any adverse influences on the picture quality, he may use the *impairment scale* for that particular subject. This scale reads:

5 = imperceptible
4 = perceptible but not annoying

3 = visible, slightly annoying
2 = annoying
1 = very annoying

As TV signals do not propagate as far as shortwave signals, and also because TV networks and their frequency allocations are planned internationally, interference is not as common in TV-DX as it is in shortwave DX, Still, local interference, or herringbone-patterns on the screen resulting from another station operating on the same vision carrier frequency, are sometimes observed. The impairment scale can then act to merit each particular impairment separately.

Most DX-ers however, will also want to include a photograph of the screen, showing the "catch".

To obtain a good photograph, one should observe the following rules:

Set the shutter speed at 1/25th or 1/30th second, so that you will have one frame only.

Do not use a focal plane shutter, but a diaphragmatic shutter. Use film sensitivities between 17 and 23 DIN, that is between 50 and 200 ASA. Adjust the screen to normal brilliance, or even make the image a little "softer" (reduced contrast). Select the aperture between f4 and f8.

Put the camera preferably on a tripod, and operate it with a cable release. The distance between the screen and the camera should be selected so that the screen will just fill the whole negative. Usually, it will be between 3 and 6 feet, depending on the focal length of the lens.

If you have no experience in taking pictures from the screen, we suggest that you run one test film to try out which combination of camera and receiver contrast and brightness gives the best results. Have the film developed only; from the negatives you can figure out the best results. Once you have found your combination, mark the positions of the brightness and contrast knobs, and keep the lens aperture in mind so that you will be well armed for actual DX-conditions.

SECTION III
Some backgrounds

Chapter 25

SHORTWAVE BROADCASTING

by John H. Gayer, Member, International Frequency Registration Board
International Telecommunications Union.

The International Telecommunication Union is the international organization which, among its other functions, undertakes to facilitate the development and operation of all radio services. The authority for the work of the ITU derives from the provisions of its decisions taken by the competent Conference, and its terms of reference are set out in its Convention and its Radio Regulations as follows:

International Telecommunication Convention
Among the provisions of this Charter of the International Telecommunication Union are those which concern broadcasting, such as that the Union shall effect allocation of the radio frequency spectrum and registration of radio frequency assignments in order to avoid harmful interference between radio stations of different countries, and that it shall co-ordinate efforts to eliminate harmful interference and to improve the use made of the radio frequency spectrum. According to these provisions, stations must be established and operated in such a manner as not to cause harmful interference to the services of other Members operating in accordance with the appropriate regulations. Internal control of the stations is not the concern of the ITU.

Radio Regulations
The Table of Frequency Allocations is set out in these Regulations, which show the frequency bands allocated for the different services. The use of each individual frequency should be notified to the ITU, which must be informed of the particular characteristics of the stations. The use of the frequency shall be in conformity with the Convention, the Table of Frequency Allocations and other relevant provisions.

The bands allocated to the Broadcasting Service between 150 and 26100 kHz are shown in the table on the next page, (with some other services added by the editor).

As broadcasters need to select appropriate frequencies for their various services, taking into account radio propagation changes and also changes of the service areas and operation hours, the frequency notification procedure has been made very flexible. Four times each year, the International Frequency Registration Board of the International Telecommunication Union (ITU) publishes Tentative High Frequency Broadcasting Schedules. These show the frequencies used for each station for a specific reason. These schedules are kept up-to-date by means of weekly Circulars, and contain the important details of the projected transmissions in a graphical form, as shown in *figure 1*. Experience has shown that this information is very useful and provides a way by which interference can be foreseen and hence eliminated.

Due to the frequent changes in schedules of frequencies to be used, it is difficult to publish accurate lists of frequency usage well before the periods of operation. For this reason, lists which are published for the use of listeners, as contained in this book, show the probable use of frequencies. The specific time a particular frequency is really used and for which reception area may not always be in accordance with such general information.

Frequency band (kHz)	Allocation to the Broadcasting Service in:	Remarks The text in the brackets has been added by the editorial office
150- 255	ITU Reg. 1 (Europe & Africa)	Long Wave 150-160 kHz shared with Maritime Mob. sce. (Further Aeron., Maritime and Mob. sce. from 200-525 kHz.)
525- 1605	ITL Regions 1, 2 & 3 (world-wide)	Medium Wave. (Further 1800-2000 kHz Amateurs Reg. 2 only. 2850-3155 and 3400-3500 kHz Aeron. bds.).
3200- 3400	Trop. Zones of the World in ITU Reg. 1, 2 & 3	Tropical bd. (Further 3500-3800 kHz Amateur bd. and 3800-3950 kHz Aeron. and Amateur bd. and 3950-4000 kHz Reg. 2 only Amateur bd.).
3900- 3950	ITL Reg. 3 (Asia & Australia)	Shared with Aeron. sce's.
3950- 4000	ITU Reg. 1 & 3 (all areas exc. the Americas)	Shared with Fixed sce's.
4750- 5060	Trop. Zones of all 3 ITU regs.	Tropical bd. 4895-5005 kHz reserved Standard Freq. sce. (Further 5480-5730 kHz Aeron. sce.).
5950- 6200	ITU Reg. 1, 2 & 3 (world-wide)	Broadc. bd. exclusively. (Further 6200-6765 kHz Maritime and Aeron. sce's.).
7100- 7300	ITU Regs. 1 & 3 (world-wide exc. the Americas)	In the Americas allocated to Amateur sce. (Further 8195-8815 kHz Maritime sce.).
9500- 9775	ITU Regions 1, 2 & 3	Broadc. bd. exclusively. (Further 10000-10100 kHz and 11175-11400 kHz Aeron. bd.).
11700-11975	ITU Regions 1, 2 & 3	Broadc. bd. exclusively. (Further 12330-13360 kHz Maritime and Aeron. 14000-14350 kHz Amateur bd.).
15100-15450	ITU regions 1, 2 & 3	Broadc. bd. exclusively. (Further 16460-17360 kHz Maritime sce.).
17700-17900	ITU Regions 1, 2 & 3	Broadc. bd. exclusively. (Further 17900-18030 kHz Maritime sce. 21000-21450 kHz Amateur bd.).
21450-21750	ITU Regions 1, 2 & 3	Broadc. bd. exclusively. (Further 21850-22000 kHz Aeron. bd., 22000-22750 Maritime sce.).
25600-26100	ITU Regions 1, 2 & 3	Broadc. bd. exclusively. (Further 26100-28000 kHz Mobil sce., 28000-29700 kHz Amateur bd.).

The problem of finding a desired programme exists not only for the "shortwave hunters" but also for other listeners. Many listeners can continually receive the programme they are interested in on shortwave due to their geographical position and/or reception conditions. The ITU is continually involved; for example, recently a special regular monitoring programme was set up to establish the actual use of the shortwave bands.

A special Monitoring Summary is published several times a year as described below. The information includes observed frequency, station identification, reception area, remarks on interference or doubtful identification and hours of reception. (See *figure 2*). With such information, broadcasters have the necessary information required to improve their services by finding better frequencies or by changing transmission time or transmission characteristics. Furthermore, and very importantly, a record is established of the actual use and conditions of reception on the various frequencies. The four seasonal schedules are for the periods indicated below:

March Schedule (March-April)
May Schedule (May-August)
September Schedule (September-October)
November Schedule (November-February)

These four seasons are covered by taking monitoring observations for the special monitoring programme during the first and the last week of each schedule. Additionally, observations are taken during the seventh week of each four-monthly schedule. Each report is of about 60 pages, containing approximately 25,000 individual observations.

The tentative broadcasting schedules, the final broadcasting schedules and the special broadcasting summary are prepared and published for the use of telecommunication

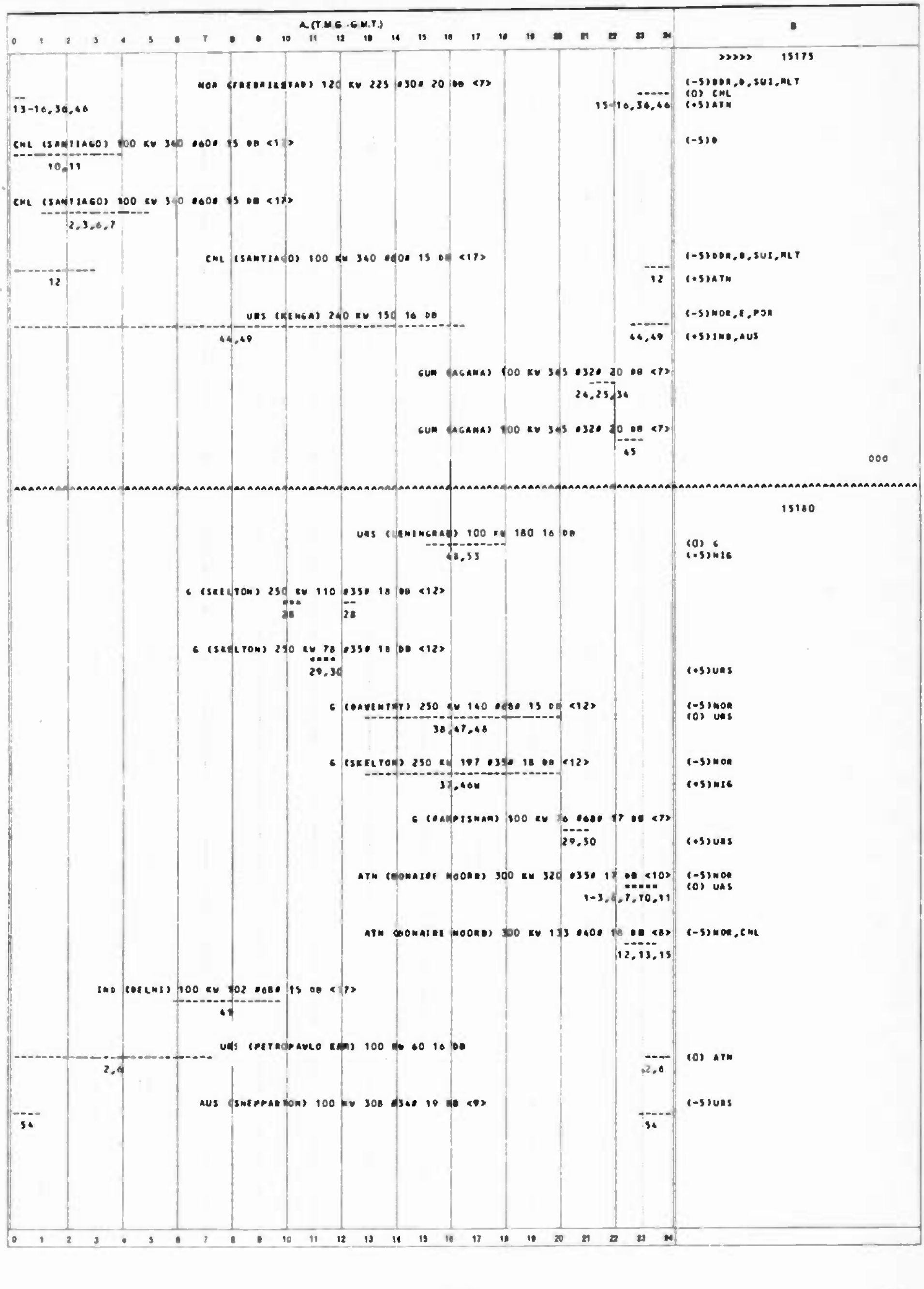


Fig. 1 A page from the Tentative High Frequency Broadcasting Schedule. Column B indicates possible interference from the lower and higher adjacent channel (± kHz) and the same frequency (0). The symbols, POR, NOR, are country abbreviations used by the I.T.U.

administrations and broadcasting organizations. However, as the information is of wide interest, subscriptions are available for these schedules. Application should be made to the Publication Service, General Secretariat, ITU, Geneva, Switzerland. (*Figure 1* shows a sample of this schedule for the frequencies. The data given are: Country, transmitting station, transmitter power, azimuth of antenna, horizontal beamwidth of antenna, antenna gain, and service area indicated in ITU zones nomenclature.

In view of the congestion of the shortwave broadcasting bands and the continued increase of services, purposeful listening becomes ever more complicated. Such listening is, of course, facilitated when listeners know the actual broadcasting schedules. This information is available in general publications, and direct from broadcasting organizations by mail.

From the experience of the first four years of the new shortwave broadcasting procedure, it is now realized how difficult it is to achieve good reception. However, when the physical quality limitations of shortwave broadcasting, such as fading, distortion, atmospheric noise, etc., are considered it will be appreciated that a high quality of reception ("high-fidelity") cannot be expected even in the absence of interference. Programmes demanding high acoustic quality, such as classical music, operas, theatre plays, etc., highlight the deficiencies of shortwave compared with other media. To eliminate fading – often very deep – broadcasters normally try to modulate the emission 100%, even for piano passages. For high standard cultural programmes a receiving bandwidth of 15 kHz is certainly desirable, but with such a wide bandwidth, the receiver will also receive signals from adjacent channels. A receiver bandwidth of 5-10 kHz, which to a certain extent will suppress sideband signals can only be compared in audio qualities to that of a telephone network.

It therefore seems reasonable for the shortwave bands to be used only for transmissions requiring small bandwidths, that is, speech. While the protection ratio of high grade cultural programmes should be in the order of 40 dB (i.e. the unwanted signal must be not more than 1/100 of the wanted signal), speech – especially when clipping devices are used – can be understood even if the unwanted signal level is as much as half the strength of the wanted signal.

Experienced shortwave listeners find they can pick up long distance transmissions by taking advantage of the peculiarities of radio propagation. The best hours are usually those before local sunrise and after local sunset. Before sunrise, the higher frequency bands are not suitable for short circuits (that is, for propagation paths which are not in sunlight). At this time, therefore, there is a good chance of long distance reception from the East. As the usable frequencies rise very rapidly with the dawn, this receiving discrimination in reception persists for about an hour. On the other hand, the usable frequencies do not diminish as rapidly after sunset and so there is a very good chance of receiving stations from the West for three hours or more while reception of local and regional as well as of Eastern stations is not possible.

Listeners aware of these facts and the many others involved, and who are willing to tolerate the difficult situation arising from the congestion within the bands will be able to enjoy listening to many interesting and useful transmissions from countries of all parts of the world.

The author wishes to thank W. Menzel for valuable assistance in the preparation of this article.

Chapter 26

THE MANAGEMENT OF THE RADIO SPECTRUM

by S. B. Duke

Like any flourishing concern, the radio spectrum has to be managed. That is, organized to get the most efficient use out of the assets available. With the radio spectrum, the assets are the limited number of frequency channels available. And like any business, the more complex it is the more sophisticated the management structure becomes, especially when the management effort is international in scope. In this article, we will examine the complex procedures which control the international use of the radio frequency spectrum.

One of the most difficult problems facing society today, especially a democratic society, is that of providing some means for the people as a whole to understand and so control, the many technical decisions made in their name. It is a simple fact that the non-technical man or woman simply does not understand, or have any knowledge of the problems involved, or the means by which scientists and engineers try to solve them. Therefore, without at least some degree of comprehension, the control exercised by society can be at best, only nominal. Therefore, the aim of this discussion is to help us arrive at a level of informed opinion sufficient to understand and comment usefully on one of the most serious crises facing human communications today. That is the chronic and now almost acute overcrowding of the radio spectrum. In our discussion we will examine some of the current methods of handling the problem. Telecommunication systems were discovered for mainly economic reasons and their subsequent forced growth occurred for the same reasons. Originally, the telegraph and telephone were used for business communications and it was not until the advent of radio broadcasting that electrical communications were used for entertainment. But whatever use an electrical communication system is put to, commercial, military or entertainment, it must be paid for. Broadcasting in some countries is paid for by collecting a licence fee from the listener or viewer, in other countries programme time is sold for advertising purposes and, in some parts of the world, a combination of both systems provides the necessary operating funds. Thus, since the system, whether communications or broadcasting, must be paid for, both the public as the system user and government organizations (or private companies) as the system operators, have a vested interest in the economic and efficient operation of the system.

There is a basic need to communicate. This has been demonstrated throughout human history, from the crude drawings on the walls of caves inhabited by earliest man to more modern means via smoke signals, the heliograph, semaphore and later the telegraph, radio and now masers and lasers. Even animals must communicate and some do it more efficiently than others. Man with his superior intelligence, communicates most efficiently, followed by the dolphin. As in other areas of human endeavour, the vital need to communicate has created great industries and work for millions of people and it has also created waste and pollution. Pollution and waste of the many valuable assets in the radio spectrum. Due to geophysical laws set by nature and at present beyond human control, the radio spectrum is finite. That is, it has certain limits. Thus, we must make the best possible use of the resources within those limits. They are fixed in number but the need for them is growing rapidly on a world-wide scale. Since there are no more of these assets available, what there are of them must be shared internationally and, if possible, equitably.

At present, there are no international frequency allocation plans for television. However, there are plans for the international sharing of radio frequencies but many large users of frequencies either do not have a place in this international communal effort, or are not party to the internationally agreed procedures thus partly defeating the object of the various sharing plans whether for medium frequency or high frequency radio.

Mankind is using up frequency space at an incredible speed and so forcing laboratory development into a race with the allocation rate of the available spectrum. Research and development is providing generating devices capable of operating at higher and higher frequencies but production is at a rate slower than the ever-increasing demand for frequencies. Inevitably, as generating devices get more and more sophisticated development and production rates get slow but the frequency allocation rate does not slow down. In fact it may even be speeding up! This does not mean that there are no more free channels or that sharing in some portions of the spectrum is no longer possible. It does point to the serious nature of the problem and the vital necessity for conserving what we already have and for putting our existing resources to the most efficient use through good international sharing plans. Like oil and fresh water, radio frequencies are a limited natural asset and like them, the supply is limited. We have seen that telecommunication systems which sprang from purely commercial motives, have now branched out into other areas such as education and entertainment broadcasting. These systems and their variations continue to grow rapidly on a national and international scale. The very nature of these radio systems and their potential for world-wide interference has made regulatory action a necessity, at national, and at international levels. International agreements in this very specialized technical field have been amongst the most successful achievements of international co-operation, thanks largely to international agencies such as the ITU, the International Telecommunication Union.

By 1927, long-distance communication by shortwave radio had become well established. So well established in fact, that to meet the increasing demand for frequencies for all users, the ITU organized an international radio conference in Washington, DC, to allocate blocks of the radio frequency spectrum between 10 kHz and 60 MHz to specific radio users such as the Fixed, Mobile and Broadcasting services. Incidentally, in the same year, 1927, the first commercial trans-Atlantic radio-telephone circuit was opened between the British GPO and the American Telegraph and Telephone Company. The early 1930s saw a rapid increase in the number of radio telephone circuits both for national and international users. In 1932 the telex service was introduced. By the outbreak of the Second World War, long distance HF (shortwave) radio communication had reached an advanced state. This rate of development was subjected to greater forced growth by the interest shown by the military in shortwave radio communications. The threat of severe interruption or even destruction of trans-Atlantic cables by enemy action no doubt helped to focus their attention on shortwave radio. Anyway, radio communications increased rapidly and of course the demand for frequencies. This caused inter-Service agencies to be set up to co-ordinate the assignment of frequencies to the many military users. After the war, commercial requirements took up the demand for frequencies from the military and so there was no let-up. By 1947 the congestion in the HF bands was so serious, the ITU convened an international radio conference in Atlantic City, New Jersey. The Atlantic City Radio Conference met to allocate the radio frequency spectrum between 10 kHz and 10500 MHz, with special reference to the HF portion, that is frequencies between 4 and 27.5 MHz. It is interesting to note that while the 1927 radio conference considered only frequencies between 10 kHz and 60 MHz, only twenty years later, the international meeting at Atlantic City was assigning blocks of frequencies up to 10500 MHz! That was the measure of the rate of development in radio communication demands and techniques. By the way, there were many other international radio conferences before Atlantic City. For example Madrid in 1932, Cairo in 1938, Bern, Berlin and so on.

One result of the 1947 conference was that more frequencies were assigned for the exclusive use of the aeronautical and maritime services that is, for airplanes and shipping. But perhaps the most important result of the Atlantic City Conference was the agreement to set up the IFRB (the International Frequency Registration Board) with headquarters in Geneva. The main task of the IFRB was the general management of the radio spectrum particularly the frequency assignments of individual radio stations operating on shortwave. Up to this time, countries simply notified the ITU of their frequency usage which was then entered in the International Bern List. No attempt was made to co-ordinate these requirements. The Bern List was a master register of frequencies and got its name because at that time, the ITU headquarters was located in Bern, Switzerland. Later on the ITU moved to Geneva where it still is today.

The demand for HF channels has been increasing for a variety of reasons. For example, the growing traffic on commercial radio links was accommodated by lengthening the scheduled time the circuits were open. Improved and more reliable propagation forecasting techniques was an important factor. Circuits which were only open an hour or two a day in 1940 are now operating for twelve hours a day and more. With changing propagation conditions on the circuit, frequency bands must be changed to maintain communication and while one transmitter is being returned, the traffic is carried on a second transmitter thus avoiding interruption to traffic on the circuit. This requires more frequencies. Also, many circuits are judged sufficiently important to justify the use of two or even three frequencies simultaneously as a guarantee against breaks in service. Shortwave broadcasters beam their programmes to distant and large target areas, sometimes to whole continents. To get adequate coverage of such large geographical areas often calls for two or even three frequencies, in different bands, all carrying the same programme. All these demands mean saturation of the radio frequency part of the spectrum in this decade. What then is being done to alleviate this acute overcrowding and what of the future? For our investigation of the problem, we will examine the shortwave broadcasting bands. Remember though, broadcasters are only one group of users of frequencies. We have mentioned others such as shipping, the military, commercial airlines, communication companies (the Fixed Services) and so on. We'll concentrate on broadcasting.

When I attended the IFRB seminar on "Frequency Management and the use of the Radio Frequency Spectrum" in Geneva in September 1970, to my mind, one of the best papers delivered (and there were many), was by my old friend George Jacobs, Chief of the Frequency and Propagation Division, Voice of America. It was on High Frequency Broadcasting in the 1970s and the congestion of the frequency spectrum. To be precise, although George Jacobs delivered the Paper (in very fine style too), it was written by him *and* his boss Ed Martin, Engineering Manager, Voice of America. Anyway, because their Paper contains so much of what is pertinent to our discussion of frequency management, I am going to quote freely from it for the next few minutes. I'm sure George and Ed won't mind and that they will forgive an old friend!

During the early 1970s, shortwave broadcasting, or HF broadcasting as we call it in the profession, celebrated its 50th anniversary. In half a century, it has grown from a single transmitter linking two continents (Europe and North America), into an activity which involves almost every country in the world – and some *1,300* radio transmitters. Martin and Jacobs reckon that there are presently about *124 million* radio receivers throughout the world that can receive high frequency (shortwave) broadcasts. As we already know, the radio spectrum is sub-divided into various bands of frequencies, medium wave, long wave, VHF (very high frequency) and so on. That part of the frequency spectrum between about 3 and 30 MHz is referred to as the HF (high frequency) spectrum, the shortwave spectrum, decametric waves or, very "in" professionally, just Band 7. In Band 7, a total of 2150 kHz in seven discrete bands between 5950 and 26100 kHz is assigned by the Radio Conference, Geneva 1959 exclusively to the broadcasting service on a world-wide basis.

Additionally, 300 kHz between 3900 to 4000 and 7100 to 7300 kHz is allocated for broadcasting in certain regions of the world but excluding Greenland, North, Central and South America and the Caribbean area. We call it Region 2. We should also bear in mind that in addition to international broadcasting, many countries use shortwave for domestic use, that is for broadcasts which are intended to reach listeners within the frontiers of that country in which the transmitters are located. Some examples are Moscow Home Service, Radio Australia, Radio South Africa, many Latin American countries and of course Radio Canada to the Canadian northland and the Canadian Arctic. At present over 100 countries are using more than 600 transmitters for this form of domestic broadcasting. It is popular in countries of very large geographical area and many developing countries because it is technically simple, cheap and effective. An efficiently operated high-power HF broadcast transmitter and a properly designed antenna system can cover a very wide area that would otherwise require dozens of medium wave (standard band) or VHF-FM transmitters and their attendant network line of microwave costs to obtain the same coverage. However, the bands we are most concerned with are those used primarily for international shortwave broadcasting. They are the 13, 16, 19, 25, 31, 41 and 49 metre bands.

Why is international shortwave broadcasting so important to so many countries that they are willing to continue to pour millions of dollars, pounds, marks, or roubles, or whatever into it? Well, in spite of TV, satellite communications, masers, lasers and all the other means of electronic mass communication, it is still the only broadcasting medium capable of direct, universal, personal and immediate communication between the peoples of the world. It is what really makes our world a global village. Only shortwave broadcasts are capable of spanning frontiers, crossing oceans, bridging continents, and sometimes, dodging censors! These are some of the reasons why so much shortwave activity is devoted to international broadcasts. One country beaming its programmes directly to listeners in another country often many thousands of miles away. At present, 94 countries are using over 700 transmitters for international broadcasting. A high percentage of these transmitters are 250 kW or more. Broadcasting in the international shortwave bands is highly competitive and it becomes more so each year.

What about you – the listener? Why *do* you listen to shortwave broadcasts? Well, Ed Martin and George Jacobs believe the shortwave listening audience is made up of two main groups, those who listen to domestic shortwave broadcasts, and those who listen to international shortwave broadcasts, with some cross-over between the two groups. The domestic audience is made up of those listeners who depend upon shortwave because it is their main source of information. Since they are not within range of a medium wave, long wave or VHF-FM radio station, they must tune to the shortwave bands if they want to hear any domestic radio at all. Place yourself in this group if you live in the Australian "outback", in certain regions of Africa, in rural areas of Latin America, or in very large areas of northern Canada and the Arctic and large areas of the USSR.

What about the international shortwave listening audience? Place yourself in this group if you already have medium wave, long wave or VHF-FM radio available but you tune to foreign broadcasts in the HF bands, by choice. Your reasons for doing so vary. Many listeners do so to supplement their sources of news and information, especially at times of national or international crises. Others do so for cultural reasons, or homesickness, or loneliness or for entertainment, or because it's their hobby, or a mixture of two or more of these reasons. Anyway, whatever the reason, here is an interesting statistic. A listener at practically any place on the globe, with a receiver capable of tuning the shortwave bands, say up to 20 MHz, would probably hear over 250 different HF broadcasting transmitters if he listens for a complete day. This would exceed by a very large amount, the number of VHF or medium wave stations that could be heard at the same place over the same period of time.

If we are now ready to accept the present popularity of shortwave broadcasting, what of its future? Well, as long as there is a need to be served it is safe to say that shortwave broadcasting should enjoy a secure and active future in many areas of the world. The number of receivers throughout the world is increasing rapidly, thanks largely to the transistor which is perhaps the most important invention for mankind since the printing press. If present trends continue, there should be well over *900 million* radio receivers throughout the world by the end of this decade, by 1980. Of these receivers, about 230 million will be capable of tuning to the shortwave bands. To put it simply, the potential audience for shortwave broadcasts should about double by the end of the seventies. And that is what the international broadcasting ballgame is all about!

If the shortwave bands are so crowded, and we have seen that they are, what about satellite broadcasting? That is broadcasting by radio from an artificial satellite? Well, while it is a subject of great interest, curiosity and a lot of controversy, such a satellite is not yet considered feasible. There remains to be solved many complex problems, technical, economic, political and operational before a direct broadcasting satellite will become practical. The following conclusion was drawn recently by a UN group of experts!

". . . direct broadcasting television signals into existing unaugmented home receivers on an operational basis is not foreseen for the period 1970-1985. This reflects the lack of technological means to transmit signals of sufficient strength from satellites."

And, for many reasons, direct broadcasting by artificial satellite to ordinary home receivers is more difficult by radio than by television. Not the least of these difficulties is the problem of finding suitable vacant frequencies. The problem of frequency congestion and interference is more serious in the high frequency broadcasting bands than in any of the other bands allocated to other users of the shortwave spectrum. At present more than 1,300 broadcast transmitters use the shortwave bands for a total of slightly more than 17,000 frequency hours *daily*. It has been estimated that the effective capacity of the shortwave broadcasting bands, taking into account daily variations in propagation conditions and assuming maximum sharing on a world-wide basis, is approximately 9,000 frequency hours daily during periods of high sunspot activity. During periods of low solar activity, the effective capacity of these bands is reduced to about 6,000 frequency hours daily. Thus, during the present period of relatively high sunspot activity, the demand for shortwave frequencies for broadcasting seriously exceeds the supply. As solar activity declines, and we are on the downward slope of the sunspot cycle now, by 1974 or 1975 an average of three broadcast transmitters will be competing for each available shortwave broadcasting frequency. Then how do we make any sense at all out of this chaotic situation which threatens to get much worse in the near future? The answer is, frequency planning. Or if you like, frequency management.

The International Radio Conference held in Atlantic City in 1947 recognized that a rational use of the shortwave broadcasting service could only be achieved through the orderly use of the frequencies assigned to the service. Accordingly, the Conference decided to establish a plan for the allocation of frequency hours to the shortwave broadcasting stations of the world. A ten-year international effort to develop a frequency-sharing plan for the shortwave broadcasting service began with another international High Frequency Broadcasting Conference held in Mexico City in 1949. This Conference conceived the idea of a plan which would be valid for a full solar cycle of 11 years and it would be based on countries' requirements for their shortwave broadcasting services.

However, the frequency requirements were so great that all the efforts made since 1947 to plan the use of this part of the radio spectrum have failed, at least in part. The Radio Conference of Geneva, 1959 adopted a new procedure for managing these frequencies by establishing a frequency schedule for each of the four seasons, that is for the summer, autumn, winter and spring. This frequency management procedure, in use today, is outlined in Article 10 of the Radio Regulations, Geneva, 1959. The same Regulations also considered the usable radio spectrum as extending to 40000 MHz. This was indeed a far cry from Atlantic City in 1947 only twelve years earlier, when the spectrum use was extended to 10500 MHz. But even if the usable part of the radio spectrum was extended fourfold in just over a decade, we must remember that the spectrum itself is a limited natural commodity. It must therefore, be shared. The ever-increasing demands for high frequencies require a very detailed sharing pattern and this is what the Article 10 procedure attempts to do, with partial success, for the shortwave broadcast services. Article 9 procedure attempts the same process for the Fixed Services (the point-to-point radio users) with perhaps more success.

Who administers and keeps an orderly record of all the frequencies demanded and used by countries (Administrations as we call them) and advises on conflicts of interests? It is the ITU, the International Telecommunication Union, and in particular a particular organ of the Union, the IFRB – the International Frequency Registration Board, both with their headquarters in Geneva.

What are these two organizations, the ITU and IFRB? What are their powers? The ITU is a voluntary association of independent countries whose government representatives meet periodically in Conferences and draw up, by mutual agreement, rules and regulations governing the conduct of telecommunication services – including HF broadcasting. The ITU is the oldest of the international organizations in the United Nations system. It was 100 years old in 1965. It is a specialized agency of the UN and has its origins in the early days of telegraph communications, before the telephone and radio were invented. In 1865 in Paris, a conference of 20 countries adopted the first Convention in the field of telecommunications and wrote the first Telegraph Regulations. The first ITU Radio Conference was held in Berlin in 1906. The Union is now one of the largest international organizations, with 137 member countries. It is responsible for applying the decisions of the United Nations within the field of telecommunications. The objects of the ITU, as defined by its Convention, are (a) to maintain and extend international co-operation for the improvement and rational use of telecommunications of all kinds; (b) to promote the development of technical facilities and their most efficient operation with a view to improving the efficiency of telecommunications services, increasing their usefulness and making them, so far as possible, generally available to the public; and (c) to harmonize the actions of nations in the attainment of these common ends.

One of the most important, perhaps *the* most important agency or department of the ITU is the IFRB, the International Frequency Registration Board, created at the international radio conference at Atlantic City, in the United States in 1947. While fully recognizing the sovereign right of each country to regulate its own telecommunications, the plenipotentiaries of the contracting government attending the conference agreed to conclude a Covention with a view to increasing the effectiveness of telecommunications. Article 2 of the Atlantic City Convention ruled that the seat of the Union (the ITU) and its permanent organs should be at Geneva. One of these permanent organs is the IFRB. Article 6 of the Final Acts of (to give the Convention its official title) "The International Telecommunication and Radio Conferences, Atlantic City, 1947", deals specifically with the essential duties of the then newly created International Frequency Registration Board. These are (a) to effect an orderly recording of frequency assignments made by the different countries so as to establish in accordance with the procedure provided for in the Radio Regulations, the date, purpose and technical characteristics of each of these assignments, with a view to ensuring formal international recognition thereof; (b) to furnish advice to Members and Associated Members with a view to the operation of the maximum practicable number of radio channels in those portions of the spectrum where harmful interference may occur. Those are the terms of reference of the IFRB. It is important to remember two points. The first is that the International Convention which gave birth to the IFRB (Atlantic City, 1947), fully recognized the sovereign right of each member country to regulate its telecommunications as it sees fit. The ITU and the IFRB assumed no absolute powers. They cannot order a government to stop transmitting or change frequency, even when that country is causing severe interference. Neither the ITU nor the IFRB have that kind of power. They can only suggest and recommend a course of action and hope the country concerned will co-operate. Very often, especially if a country considers the IFRB recommendation to be against its national interest, there is no co-operation, the IFRB's recommendation is not accepted and the Board must accept that situation. The second point to remember arises from the first point. The IFRB's function is to record those frequency assignments notified to it by member and associate member countries of the ITU. It advises and suggests in order to obtain some order and reduce interference as much as possible in the bands. The members of the Board itself are five in number, all nationals of different member countries of the ITU. They are elected to serve on the Board, not as representatives of their respective countries or region but as custodians of an international public trust.

We are now ready to examine in some detail, the IFRB's duties and in particular, the so-called "Article 10 procedure" which governs the assignment of frequencies to those international broadcasting organizations whose governments are members of the ITU. We can say then, that one of the main tasks of the IFRB is to decide whether those radio frequencies which countries assign to their radio stations and notify the Board, are in accordance with the Radio Regulations and whether the projected use of those frequencies will, or will not, cause harmful interference to other radio stations which are already in operation. Thus, the Board determines, but purely on a technical basis, the right of an Administration to use a given frequency for a specific purpose. Before going on I think we should now use the terminology used by the IFRB. They do not talk about countries. They use the term "Administrations". And that's what we will do too. So when you read the word "Administration", it means, country. The duties performed by the IFRB are technical as well as legal. At the Administrative Radio Conference of the ITU in Geneva, in 1959, the meeting adopted Regulations which governed the use of the radio spectrum which that meeting considered as extending to 40000 MHz or if you prefer, 40 GHz. These regulations are known today as the "Radio Regulations, Geneva 1959". We will refer to them again. The Geneva Conference also provided for the establishment of a Master International Frequency Register which went into effect on 1st May 1961. Also, new procedures were set up for recording by the IFRB, those frequencies notified to it by the member Administrations of the ITU. For shortwave broadcasting, provision was made for the forwarding of seasonal frequency schedules to the Board in advance of their actual date of use. These schedules are known as "tentative frequency schedules" (see *fig. 1*). The Board, after receiving all these schedules, has the responsibility for suggesting any time and frequency adjustments it considers necessary to improve the use of the HF broadcast bands in so far as it is practicable, to improve reception of the broadcast programmes. Incidentally, this Master Register is not an enormous sort of "Domesday Book", a giant ledger, it is a long room full of steel filing cabinets full of printed cards for feeding into computers which are located near by.

Now the Article 10 procedure mentioned earlier. On specific dates, four times a year, corresponding with seasonal propagation changes, Administrations send their projected high-frequency broadcast schedules to the IFRB some five months in advance of their implementation. These are the "*tentative* frequency schedules" we mentioned earlier. These schedules must list only those frequencies, not bands, but the individual frequencies which will be used during the season in question. These seasons are known as the "Winter Season" which

Montreal, 11.04.78

Radio Canada International

S 78 (Tentative "B")

FREQUENCY SCHEDULE

EFFECTIVE: 3 September 1978

DAV – DAVENTRY, ENGLAND

RCI – SACKVILLE, CANADA

SIN – SINES, PORTUGAL

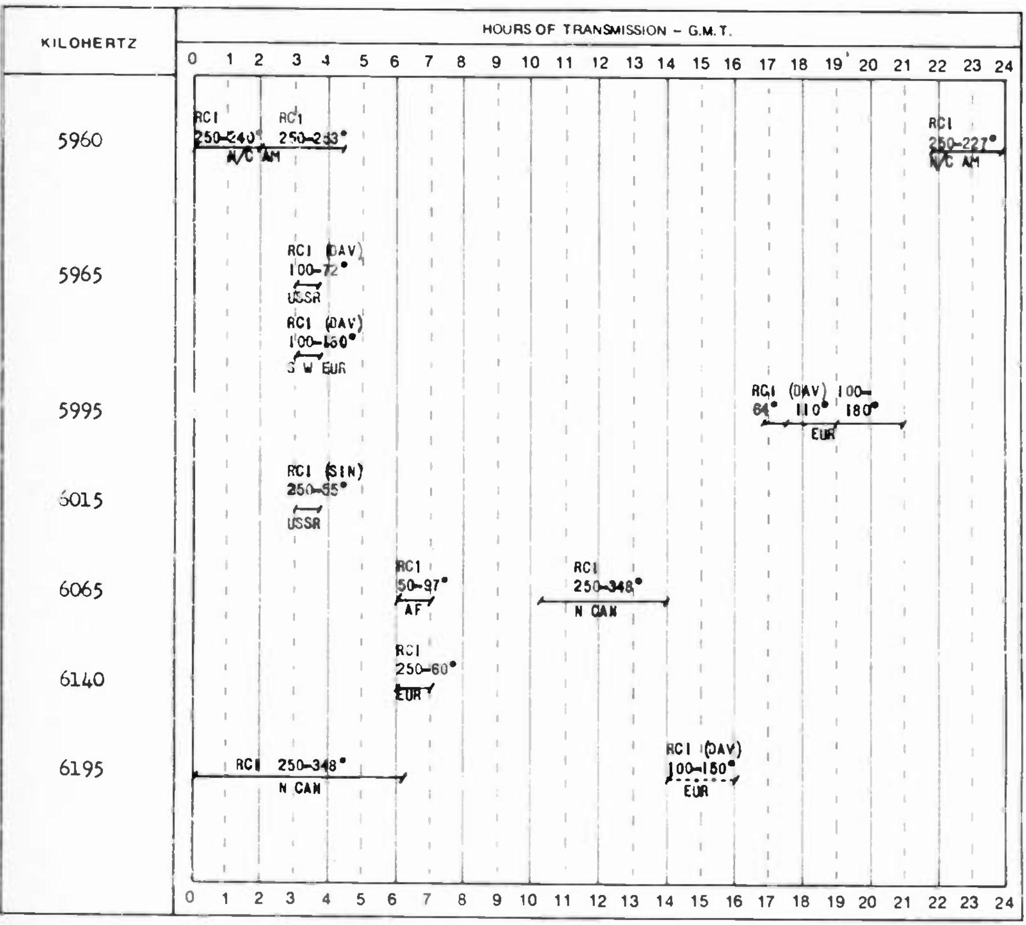


Fig. 1

starts on the first Sunday in November. The "Spring Season", which begins on the first Sunday in March. The "Summer Season" starts on the first Sunday in May and the Fall (or "Autumn Season"), which begins on the first Sunday in September. Thus the Winter seasonal schedule runs from November to March, the Spring seasonal frequency schedule runs from March to May, the Summer schedule from May to September and the Autumn schedule from September to November, when the Winter season begins again. Those are the seasonal schedules. The Board collects the seasonal schedule as it is received from Administrations – assembles and publishes them in the form of a "Tentative Frequency Schedule" (the "White Book" as we call it – because it's white in colour), and distributes copies to all the member countries – 137 of them. There are then, four of these "White Books" each year, each showing the *intended* frequency usage of the Administrations participating in the Geneva 1959 frequency management plan. We should remember that some countries do not participate in the Plan because they are not members of the United Nations and the ITU. The People's Republic of China is the largest of them all. Naturally the ideal technical plan would include all users of the radio spectrum and they would participate in the Article 10 procedure. Anyway, be that as it may, the Board distributes copies of the White Book to member countries about two months before that particular season begins. So, we can expect to get the winter season White Books some time in August or perhaps early September. The broadcasting organizations' engineers then examine this Tentative Frequency Schedule (the White Book) carefully to see (a) that their frequencies have been correctly entered for time, transmitter power, beam direction and target areas. And (b) for any incompatibilities, that is two stations on the same frequency at the same time to the same target area. Anyway, as the IFRB's own engineers have checked earlier, we will receive a notice from the Board recommending a frequency change should they notice an incompatibility and in each season schedule there are usually one or two, unfortunately! This procedure has worked surprisingly well and it has gone a long way to ease the chaotic conditions existing in the chronically overcrowded shortwave broadcasting bands. As one official of the IFRB said to me in September 1970, "The Article 10 procedure may not be perfect but at least it keeps a catastrophic situation from becoming anarchic". How true! Recognizing that the use of certain frequency bands was reaching saturation point, the Geneva Conference of 1959 appointed a "Panel of Experts" to study and recommend principles and measures which could reduce congestion in the frequency range from 4 to 27.5 MHz. The Panel's Final Report listed no less than 38 recommendations, many of which should help considerably to reduce some of the overcrowding in the shortwave bands. But back to the Article 10 procedure. After the end of each season the IFRB publishes a final version of their Tentative Frequency Schedule which reflects all the frequency changes notified to the Board since publication of the tentative schedule. This final schedule lists all these frequency changes and it's known as the "Pink Book" because it covers are pink in colour. So we have the White Book which lists *projected* frequency usage for each of the four propagation seasons and, after the conclusion of the season, the "Pink Book" listing *final* amendments. Additional to all this documentation, the Board issues a yearly HF Broadcasting Frequency List as a supplement to the International Frequency List which each year recapitulates the year before. And if you are now thoroughly confused, pity the poor shortwave engineer! But all this documentation is very important and oddly enough, it appears to work!

Although not a frequency assignment plan (it's a frequency *management* plan), the provisions of Article 10 of the Geneva Radio Regulations offer a number of advantages to Administrations participating in the plan. By means of the Tentative Schedule (the White Book) every Administration knows in advance, which frequencies will be used by other Administrations during each seasonal period. Thus, particular transmissions, time or frequency wise, can be modified at the suggestion of the IFRB, or at the discretion of the Administrations concerned, to avoid or at least reduce mutual interference before it occurs. Since all those Administrations who are participating in the frequency management plan are required to make their seasonal frequency changes at the same time and on the same date, the confusion inherent in seasonal frequency changes prior to the implementation of this co-ordination procedure has been greatly reduced. As Ed Martin and George Jacobs say in their Paper, "While this procedure does not limit the use of frequencies or guarantee the availability of interference-free frequencies for HF broadcasting, it does place the responsibility for effective use of the HF broadcasting bands directly on the member Administration of the ITU". And I think that this is where that particular responsibility belongs.

PROPAGATION PREDICTION CURVES

CIRCUIT: SACKVILLE - LONDON. MONTH: JUNE

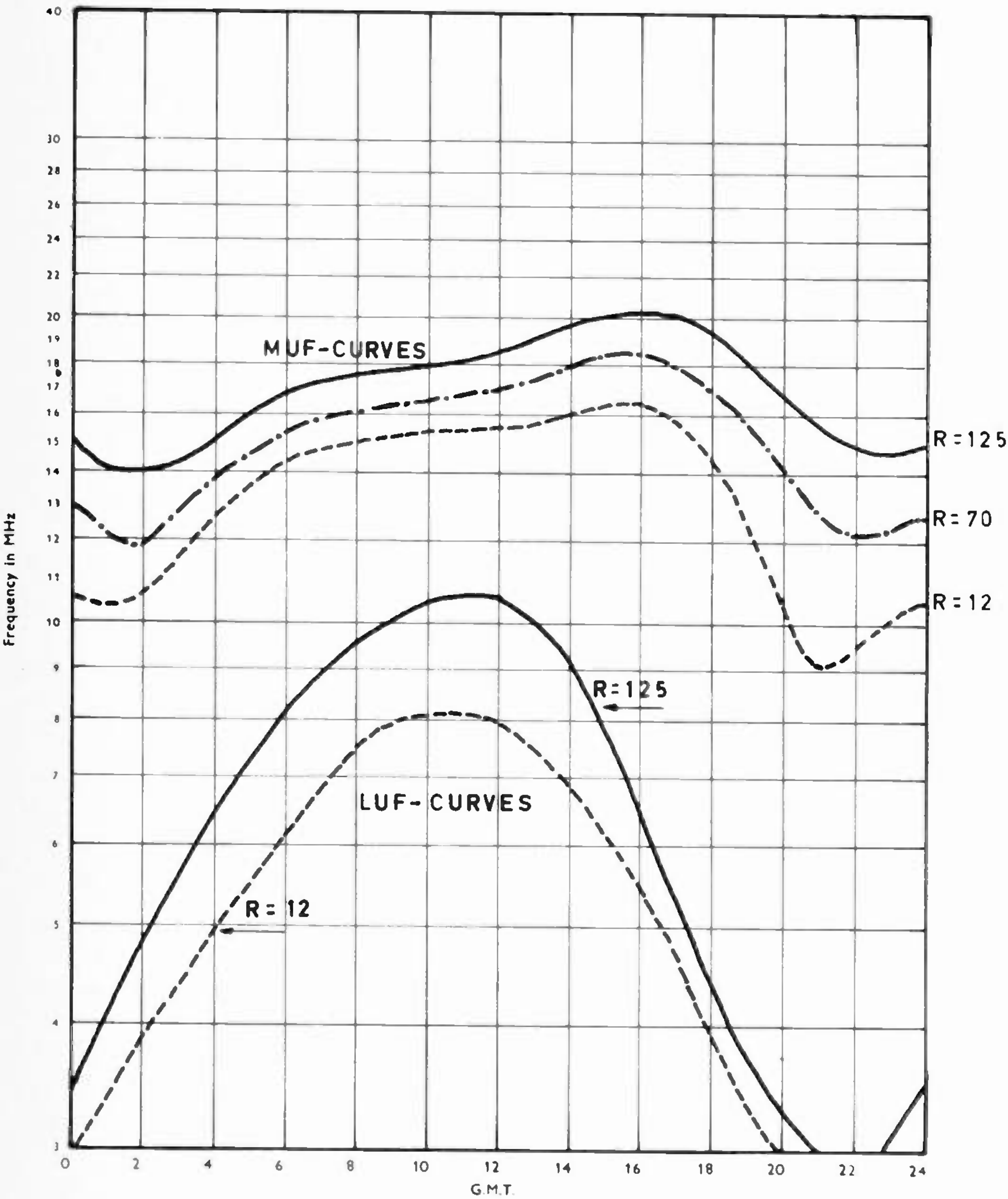


Fig. 2

Now is the time for us to illustrate how this frequency co-ordination plan works in practice. For our example we'll take the Sackville to London transmission path. We'll do it by steps. By the way, Sackville, New Brunswick, is where our shortwave transmitting plant is located.

i) First we determine the correct frequency bands to use for the season of the year, the sunspot activity count (the sunspot cycle) and the time of day. To do this, we use conventional ionospheric propagation prediction techniques (see *fig. 2*).

ii) Having selected the frequency *bands* for the circuit, we next choose actual frequencies in those bands. Here is where listeners' reception reports are useful because from them, we can determine the quality of coverage we obtained with our frequency usage of previous seasons. For example, if the reports indicated good reception on 11720 kHz at 21 hours GMT in the winter season, we would schedule that channel again for the next winter season. If reception reports indicated only poor to fair reception, then we would look for a replacement frequency. Radio Canada's transmissions to the various target areas are carried on a main frequency which is supported by a second frequency. Other broadcasting organizations, our own technical monitors and listeners provide us with a continuous inflow of detailed reception data which provides information on frequency usage patterns of other users, interference patterns, identification of interference, last-minute time and frequency changes and so on. All this information is continuously analyzed and plays its part in determining our frequency selection for each seasonal schedule.

iii) Our Tentative Frequency Schedule is prepared some five months before its implementation and then sent, on the proper forms (called "Forms of Notice"), to the Administration which is in our case the Department of Communications in Ottawa (see *fig. 3*). The Department, after noting our intended usage, forwards this information on to the IFRB in Geneva at least four-and-a-half months before the starting date of that particular schedule. By the way, the frequencies shown in the schedule are those that actually will be used for that seasonal period and they should be the minimum necessary to provide satisfactory reception in the areas of intended reception which are identified by CIRAF number (see page 186).

iv) The IFRB carries out a technical examination of these notifications of intended usage received from all the countries taking part in the Plan and it tries to improve the technical aspects of the schedule by recommending more compatible frequency sharing. The Board sends its recommendations for any changes to the Administrations concerned and a couple of months or so before the start date of the schedule, sends out its "White Book", the IFRB Tentative Frequency Schedule for that particular seasonal period.

v) When this schedule is received, we double check to see who is sharing our frequencies, or those adjacent to us. If we do not like what we see we make a last-minute frequency change and notify the new frequency to the IFRB, through the Department of Communications in the usual way. Or, we might decide to try the schedule and see how we get on for the first couple of weeks of the seasonal period and then makes changes, if necessary.

vi) The seasonal frequency schedules are implemented at 0100 hours GMT on the first Sunday of the seasonal period concerned. These periods are for the March Schedule, that's the Spring Season (march and April). May Schedule, that's the Summer Season (May, June, July and August). September Schedule, that's the Autumn Season (September and October). November Schedule, that's the Winter Season (November, December, January and February). After the end of each seasonal period, we notify the Board of those frequencies found to be unsatisfactory in actual operations and the reason for the unsatisfactory finding.

vii) After that, we start to prepare the next seasonal schedule going through all the procedures just described.

From this, you can see that international frequency management is a very sophisticated procedure calling for the prediction of frequencies many months in advance of their actual use. And, No. 658 of the Radio Regulations states:

"In applying the provisions of these Regulations, problems of harmful interference which may arise in frequency usage shall be resolved by Administrations by exercising the utmost goodwill and mutual co-operation."

When we remember that the ITU and the IFRB possess no real power to bring about an orderly use of the spectrum, goodwill and mutual co-operation are vital and even basic elements in any success the frequency management plan might have achieved. To sum up. Countries which participate in this international frequency co-ordination plan retain full sovereign rights

BC
6 Classe de la station

CANADA
a. Administration notificatrice

[X] *b.* Assignation pour la saison intéressée

[ ] *c.* Modification aux caractéristiques d'une assignation pour la saison.

[ ] *d.* Annulation d'une assignation pour la saison.

(*e*) Fiche No. 5
Date 09.02.78

17820 kHz
1a Fréquence assignée

kHz
1b Autre fréquence proposée

MHz
1c Bande de fréquences désirée

Saison : Mars [ ] Mai [78] Sept. [ ] Nov. [ ]
Année
Autre date :
2c Date de mise en service pendant la saison

3 Indicatif d'appel (signal d'identification)

SACKVILLE ,N.B.
4a Nom de la station d'émission

CANADA
4b Pays

64°19' W,45°53' N
4c Longitude et latitude de l'emplacement de l'émetteur

Zone(s) ou région(s) de réception 5a	Classe d'émission et largeur de bande nécessaire 7	Puissance en kW) 8	Caractéristiques de l'antenne d'émission: Azimut du rayonnement maximum 9a	Angle d'ouverture du lobe principal de rayonnement 9b	Gain de l'antenne (db) 9c	Angle de site 9d	Type d'antenne 9e	Horaire de fonctionnement (T.M.G.) 10	Autres fréquences utilisées simultanément pour le même programme à destination de la ou des même(s) région(s) 11	Renseignements supplémentaires
27,28	10A3	250	60	35	20	7.5	HR 4/4/1	1430-1800	11865,15325 kHz	
37,46-48,52,53,57	,,	50	97	35	17	9	HR 4/2/1	1800-2000	15260 kHz	
37,46-48,52,53,57	,,	250	97	35	17	9	HR 4/2/1	2100-2200	9530,11945, 15150 kHz	

Fig. 3

12b MDG B. Radio Canada International Adresse postale
Ofipostel Montreal,Canada Adresse télégraphique
de l'administration (article 14)

COORD/ BBC,VOA,RLN,FCC-USA,Radio Nederland, DW.
Autres renseignements

over their frequency planning. The ITU and the IFRB depend upon the goodwill and co-operation of those countries. The principle means of achieving their aim, at the disposal of the Union are: Giving information and advice to Administrations. Making studies and formulating suggestions. And, above all, persuading and patiently encouraging Administrations to do all they can, in the interests of international co-operation, to apply faithfully the Radio Regulations which they themselves have formulated and adopted at the various international radio conferences.

The ITU has five official languages. They are Chinese, English, French, Russian and Spanish. The final Acts of the international conferences and service documents are drawn up in these five languages. In case of dispute, the French text is taken as the authentic text. The three "day-to-day" working languages are English, French and Spanish and working documents, minutes of meetings and so on are written in these three languages. Oral discussion at conferences are conducted in English, French, Spanish and Russian, with simultaneous translations available. The staff employed by the ITU numbers just over 400 and it is the policy of the Union that this staff should be recruited on as wide a geographical basis as possible.

What of the future? Well, to appreciate the progress made in the particular area of international co-operation we have now examined, we can imagine what the situation might have been like in the shortwave bands in the absence of the Article 10 procedure. Since the date of its introduction, the number of hours of transmission notified to the IFRB has risen by about 30%. That's in just over ten years. There is no let-up in sight. What of broadcasting via satellites? The ITU considers that it will be difficult, if not actually impossible for satellite broadcasting and conventional broadcasting by ordinary ground stations to share frequency bands. So it seems that satellite broadcasting must have its own band of frequencies. But we should note that paragraph No. 422 of the Radio Regulations, Geneva 1959 states, "The establishment and use of broadcasting stations (sound broadcasting and television broadcasting stations) on board ships, aircraft *or any other floating or airborne objects outside national territories* is prohibited". I wonder how they are going to get around that one? Political interests, without doubt, underlay all discussions on broadcasting and especially international broadcasting. One of the main weaknesses of many international radio conferences has been that some of the main user countries were not represented. Therefore, their frequency requirements could not be included in the frequency management plan.

Fifty years ago radio frequencies above about 1500 kHz were left for the radio amateur to experiment with because they were believed to be of no value in providing communication services. But, following the discovery of the reflecting properties of the ionosphere, frequencies between 3 and 30 MHz have, until recently, been the basic means of providing channels for long-distance international radio communications. Even today, after the establishment of wide-band undersea cable routes and communication services by artificial satellite, the demand for interference-free shortwave frequencies to provide relatively inexpensive long-distance communications is very high. Communication satellites have already lightened the load for these Fixed Services in the shortwave part of the radio spectrum. Perhaps this new technique, together with the expanding capacity of the new undersea cable networks, may change the pattern of usage in the shortwave bands to permit a realistic consideration of the additional requirements of the broadcasting service? No international radio conference at which this possibility could be considered is foreseen for the next five years at least. That means more transmitter power, more "muscle" on the frequency to push aside interference in order to hold on to the channel. But as we said earlier in this article on frequency management, the present situation in the international shortwave broadcasting bands may be catastrophic but at least the Article 10 procedure prevents it from becoming anarchic. For the time being!

Chapter 27

IS THERE A FUTURE FOR SHORTWAVE BROADCASTING?

by Jim Vastenhoud

These days, with satellite communications coming of age, shortwave listeners and broadcasters alike are asking themselves this question, and for good reason, because there are vast differences between the conventional and this more modern means of communication, especially as regards the advanced quality and reliability of the latter. So it seems only natural for satellite communications to take over from shortwave, especially if the general public can easily receive the signals from the satellites.

The planned generation of broadcast satellites, to be launched within the next few years, will operate on frequencies in the 12000 MHz (12 GHz) frequency range, and will be received with a simple antenna directed upwards to a fixed point in the sky.

Such broadcast satellites will carry a respectable number of television and radio channels, all to be received directly by listeners and viewers, who will only need a relatively modest extension of their present equipment.

This extension, which may cost about 200 dollars, will initially consist of a 2 or 3 foot (about 90 cm) parabolic antenna, and a signal converter, which will not only boost the antenna signal, but will also convert it from 12 GHz to a lower frequency within the range of a normal TV or FM receiver.

Technologically speaking, the use of three "stationary" or "geostatic" broadcast satellites would give a worldwide coverage, while one strategically located satellite might already be able to cover a very extensive and important listening area, of the size of one-third of the world's surface. So using a satellite as repeater station for international broadcasting is, it would seem, just around the corner.

However, we've overlooked some essential points.

One of them is that it will take a considerable number of years for the majority of the listening or viewing audience to switch from shortwave to satellite, because of the price of the additional equipment.

Some information-hungry individuals in the wealthy part of the world may run for the novelty, but most people will have to wait until the equipment becomes available at a considerably reduced price. This aspect will at least ensure a gradual shift from shortwave to satellite. More serious, however, are the political implications. For reasons of their own, some countries will not allow their citizens to be subjected to satellite transmissions from foreign countries, and so far they have succeeded in effectively blocking the introduction of international broadcasting via satellite.

There are no signs of any short-term changes in this respect and it may take a long time before these political barriers are overcome. Until then, shortwave will remain the only direct and timely means of international broadcasting.

Meanwhile, the conditions for shortwave listening may show a considerable improvement in the not-too-distant future. The following are indications in this direction:

- The introduction of receivers with an accurate frequency readout, especially on shortwave. This does not only refer to the digital display of the frequency on the dial, but also to those sets which have a combination of bandspread and dial calibration at regular intervals. The number of portables and table-top sets with one of these features, has increased strongly in recent times.
- At the World Administrative Radio Conference in 1979, a substantial increase in shortwave broadcasting band allocations can be expected. Most of the band extensions, or new bands for shortwave broadcasting, will come at the expense of the fixed bands, as most point-to-point traffic is now running via satellite communications. This means that some

frequency space in the HF fixed bands will be available, and it can be expected that this will be granted to those frequency users in this spectrum who are in need of additional frequencies.

An extension of the frequency package for shortwave broadcasters would reduce the heavy band congestion which prevails at the moment, and will consequently improve listening conditions.

- Technological development will continue. Integrated circuits will become cheaper and will increasingly be applied in radio receivers. This will eventually lead to more sophisticated receivers at little extra cost. It is expected that the extra circuitry needed for easy tuning to single sideband transmissions, and the locking circuits to keep the receiver locked to the desired signal, will conquer the market as soon as a suitable standard for single sideband broadcasting (with reduced carrier) is accepted internationally.

  Such a development could contribute to a further reduction in band congestion, as the occupied bandwidth of an SSB signal is about half the bandwidth occupied by a normal AM signal, so that many more stations will then be able to operate interference-free, adding to the listening pleasure of the audience.

In the view of the author, these developments point clearly to the conclusion that shortwave broadcasting is going to stay for a long time, and will only become obsolete if a worldwide coverage is achieved with a means of mass communication giving better reliability and a better audio quality. But as long as the world remains divided in the use of broadcast satellites to reach this end, shortwave broadcasting will continue to justify its existence.

Chapter 28

AUDIENCE AND THEIR ATTITUDES

by Peter Herrmann (BBC Audience Research Dept)

Some 300,000 letters from all over the world reach the BBC in London every year. This giant postbag contains many warm tributes, some criticism and a virtual avalanche of questions in 40 languages. The BBC has built up a special relationship with its overseas listeners through correspondence. By studying the letters BBC Audience Research staff can produce a picture of likes and dislikes in programme content and general listener attitudes. But there are many other methods by which Audience Research assess the size, type and preference of the BBC's huge international audience. This article describes the systems used and highlights sharp contrasts in tastes among listeners.

Throughout the twenty-four hours of the day BBC broadcasts are emanating from Bush House in London in forty different languages to all parts of the world. Anyone passing by the outside of Bush House would never know of the hive of activity inside the building. Everyone inside must at some time or other have stopped and thought to themselves, "Is it worth it?" "Is there anyone out there in the wide unknown listening to our broadcasts?" This is where the audience research department steps in and shows its worth by producing all kinds of evidence of listening from a variety of sources. The two main questions about the audience which immediately spring to mind are how many people listen and what do they think of the programmes they hear.

The answer to the first one and the subsidiary questions arising from it can only be satisfactorily determined by some kind of statistical sample survey. The answer to the second question is much less cut and dried and several related but essentially different forms of research are used to glean as much knowledge as possible about the tastes of the audience. These pieces of information then gradually fit together just like a giant jigsaw to give a very comprehensive picture of a large and diverse audience. The techniques employed to obtain this information and to assess the nature and views of the audience are similar to those used in commercial research and are also used by other broadcasting stations around the world. They include the use of postal questionnaires and listener panels, group discussions, interviews, listener competitions and the analysis of listener correspondence. All these methods have their uses but perhaps one, more than any other, where the BBC is particularly fortunate is in the field of listener correspondence where the External Services enjoy a unique relationship with their many listeners.

Every day of the year nearly a thousand letters from listeners drop onto the desks of the External Services staff in London. The most encouraging aspect of this vast daily mailbag is that it means that a thousand people dotted all over the world from Jakarta to Vancouver, from Rio de Janeiro to Baghdad and from Belgrade to Accra have taken the trouble to sit down, put pen to paper and write to the BBC. This is by no means such a trivial decision as it sounds since to many listeners in poverty-stricken lands the purchase of a postage stamp may mean foregoing the next meal. The vast majority of letters received are of course concerned with the output of the External Services although at the same time this is not the sole reason for writing and some correspondents look to the BBC in the hope of finding help in all sorts of other matters completely divorced from broadcasting. Some letters are truly pathetic and are written by people who have probably never listened to the BBC but have heard and seen the three letters over the years and, in their own minds, have built up the BBC into an omnipotent miracle worker. It is the External Services' policy to reply to listeners whenever necessary and to send a personal reply wherever possible. Over the years this policy has helped to develop a special relationship between the External Services and their listeners and has also enhanced the reputation of the BBC.

In fact it might not be so far off the mark to make an analogy with the affectionate title of "Auntie" given to the BBC by radio listeners and television viewers in the British Isles. Certainly at times the reverence and respect shown in the correspondence received by the External Services is reminiscent of the kind of letter that might be written to a distant aunt. And again like any well loved aunt the BBC External Services are not forgotten at Christmas or on birthdays (such as the BBC's 50th Anniversary) when Bush House is inundated with cards, greetings and sometimes presents.

The BBC External Services' postbag consists of the kind of mail that any broadcasting station would receive and includes such items as demands for programme and frequency information and publicity material, record requests, reception reports and, of course, programme comments, criticism and suggestions. With many of the forty BBC External Services concentrating on news and current affairs it is not surprising that much of the mail referring to programme content concerns this output. These letters often contain personal expressions of gratitude and appreciation and underline how much many listeners depend on the BBC. Letters like this are not only a pleasure to receive but are easy to answer. Those containing constructive criticism need a good deal more care and thought before replying and various departments will need to be consulted and facts checked before a reply can be sent. The BBC External Services takes a great deal of pride in writing full replies to listeners whose letters contain criticism or suggestions for they realise the immense value these letters are as an aid to programming. Each one of these letters received whether a "pop" music request from a teenager in Finland or a complicated and involved criticism of a political commentary from a journalist in the Middle East adds a little more to the overall picture of the audience. Letters which contain programme comments are in addition an encouragement to producers in Bush House and are often the only contact they have with their audience. Some programmes encourage listener participation more than others and may even hold competitions while many of the services run their own "Letterbox" programmes which are based entirely on listeners' letters and comments. Audience research studies have shown that these programmes are particularly popular.

During the course of a year there are hardly any countries in the world from which the External Services do not receive letters. There are many factors which influence the volume of mail to any one of the BBC's External Services or from any particular country and it would certainly not be true to assume that the volume of mail is in any way indicative of the size of the actual audience or proportional to the length of a broadcast. Factors which affect the volume of mail include reception conditions, postage rates, the political climate in the target area for the broadcast and of course the content of the programmes themselves. It has long been observed that listeners in areas of political unrest are usually much more liable to write when times are hard and uncertain and when the BBC broadcasts take on an added importance in their lives, than at other times. Vietnam and the Middle East are particular examples which immediately spring to mind. In addition to these areas which are politicall unstable there are the totalitarian countries of the world where conditions may be comparatively steady but where it may be imprudent to communicate with a foreign broadcasting organization. Letters that do reach the BBC from these countries have often been through the censor's hands and there is evidence to show that replies to the listener are frequently stopped from reaching their destination. But letters from iron curtain countries are some of the most illuminating and interesting the BBC receive and extremely important in gauging the nature of the audience since other research methods are usually out of the question in these areas. Away from politics and current affairs, new fields and untapped markets are always being sought to attract and provoke new listeners and although these are harder to come by as time passes, one unfulfilled demand has recently been exposed by the amazing listener reaction to programmes of British "pop" music.

Even if all the outside forces encouraging listeners to write were constant it still requires the courage of the listener himself to do the deed and the propensity for writing seems to vary greatly all over the world. Some nationalities, for instance West Africans and those from the Indian sub-continent, need no encouragement whatsoever, while others, notably East Africans and some of the Far East Asian nationalities seem rather loath to write. And this extends further, with some nationalities quite happy to write with criticisms while to others the good name of the BBC appears sacred and no inducement will persuade them to comment unfavourably.

The numbers of letters to each of the BBC's language services is very dependent on the conditions mentioned before and to give individual figures for any of these services would be rather misleading. The distribution of letters to the World Service English broadcasts is of course strongly biased towards the English-speaking countries and the largest mailbags to this service usually come from the USA, Ghana, India and Nigeria.

It is a popular theory that those who write to broadcasting stations are probably not representative of the silent majority of listeners. But it is reassuring to note that the comments made in the letters received usually reflect the listening pattern indicated by survey results. One common thread which ties together letters from all parts of the world and to all the BBC's External Services is the universal praise for the news and current affairs output. In many countries the only source of uncensored news is via the external services of certain foreign radio stations and this is where the BBC scores over its eighty or so rivals in that it is one of the few completely independent external broadcasters. This prompts typical comments like this one from a BBC listener in Poland:

"Your broadcasts link us with the world outside. We would not miss the news or topical features telling us of world events which our own media often ignore or misrepresent."

But even in countries with a free press and where there are no controls over other media, the BBC news still evokes praise as this comment from a World Service listener in the USA shows:

"I particularly like your unbiased reporting of international news and find that I frequently receive news of happenings in the USA on the BBC before I hear them locally on radio or TV."

Listeners' views on other types of BBC External Services output are not necessarily universally similar to those expressed about news and current affairs and there are strong but diverse pockets of opinion on the different programmes held by various sub-groups of listeners. For instance pop music of any description is an anathema to many listeners over the age of thirty whereas for the younger generation the British pop scene leads the world and they want to hear all about it via the BBC. This situation provokes comments like the following which are impossible to resolve:

"I think your pop music programmes are really out of this world. In short, BBC pop music programmes are outstanding."

from a Moroccan student in Rabat. And:

"How can you insult adult intelligence with this frightful 'pop'! Over the years I am convinced you are broadcasting more and more 'pop' trash and less and less good music. Time to call a halt!"

from a listener in the Republic of South Africa.

Sport, like pop music, is another topic which drives some listeners to written outbursts of fury, while making others crave for more. Cricket, that peculiar English institution, is probably responsible for more knob-twiddling than any other type of output, with thousands of listeners in India eagerly seeking the BBC when commentary is being broadcast while thousands of other listeners are not interested. Some sports, such as association football are more widely played and so more acceptable, but in general sport brings programme planners the problem of satisfying listeners with such diametrically opposed views as:

"You devote too much time to sport. Not only do you have the regular sports programmes but on the occasion of any major sporting event you broadcast special programmes. It really is too much!"

from a Danish listener and:

"All sports programmes fascinate me. So much so that in my village my friends have wholeheartedly listened to them and take their hats off in appreciation."

from a listener in India.

Most other types of output do not suffer from adverse comment as do pop music and sport although they each enjoy different levels of popularity. Programmes on science and industry are enjoyed as much as any others and stimulate a great deal of mail. Listeners show particular interest in items on medical advances and these always result in requests for more information on new drugs or techniques mentioned in the programmes. Listeners are also interested in any new British goods on the market and programmes giving this kind of information are popular everywhere, especially in Africa, Southern Europe and South East Asia. As a listener on board ship in the Persian Gulf said:

". . . it is surprising the number of products which I would not have known about were it not for your 'New Ideas' programme . . ."

While another from Japan said:

"I always find the 'New Ideas' programme interesting. There is nothing like this programme on the other radio stations broadcasting in Japan, so please keep it up."

And many of the letters to these programmes come not from individuals but from companies and import agencies abroad.

Of all the BBC External Services, none is so diverse and extensive as the World Service which broadcasts twenty-four hours a day in English. Its audience, too, stretching to all corners of the earth, is made up of many more distinctive groups than any of the BBC language service audiences and consequently the letters received by it reflect these different views and tastes and are of great importance in assessing listener reaction. From the 1,000 or so letters addressed to the World Service each week it is quite easy to establish the type of audience it enjoys in each part of the world. For instance in Europe it is known that the audience is harder to classify than anywhere else. It includes a mixture of the traditional listeners who first heard the BBC in the Second World War and who write with comments like this from Holland:

"We would like to congratulate you and to thank you for all you did for our country during the last war. All the news about the war we heard from the BBC."

These listeners now enjoy drama, classical music, talks and cultural items, while the new young student listeners, particularly in Finland, West Germany and Eastern Europe, place pop music second in importance to news. From the Middle East letters concerning the political situation and the BBC's coverage of it dominate the mail, but there is also a significant amount of interest in cultured programmes. It is clear that the world Service listener in this area is very interested in documentaries, drama and classical music and the following comment from Israel is not unlike many received from this area:

"We find the choice and variety of programmes, as well as their presentation, really excellent but should like to hear more symphony concerts and operas direct from London."

The letters from West Africa reflect the thirst for knowledge of this group of listeners. They also show how much value listeners place on the presentation of programmes and the personalities associated with them and it is from this part of the world that newsreaders and announcers receive most of their fan-mail. Listeners here are also interested in pop music and sport but above all they want programmes to be bright and cheerful and their letters reflect their *joie de vivre* as does this comment from a listener in Nigeria:

"The most impressive thing about the BBC is the soft beautiful voice of the newsreader. Consequently the presentation of programmes by the BBC is second to none and therefore deserves a pat on the back."

Letters from other parts of Africa are not so forthcoming and slightly more sombre in nature.

Further east in the Indian sub-continent, letters are often prompted by political tension there and reflect life in a troubled part of the world. In their lighter moments Indian listeners enjoy hearing comedy series, quizzes, pop music and sport. This comment from a listener in Bombay is very typical:

"The quiz and panel game programmes are excellently set up and serve as a great relaxation after a day's work."

World Service correspondence from the Far East reflects a particular interest in education, science and in some parts, pop music. Above all, though, listeners in this part of the world are interested in anything British including the English voice. As a listener from Tokyo said:

"We in Japan are too insular. Please tell us more about Great Britain."

On the other side of the Pacific, letters from North America show appreciation of the World Service's documentaries, features and drama – commodities which listeners there do not seem to be able to find on their own ubiquitous local stations. This listener from Florida said what many other listeners from the USA have said before:

"Please continue your drama productions for they are virtually the only radio plays obtainable in this section of the world."

These are just a few examples of the comments received from listeners around the world; without them the picture of World Service listening would be much less complete.

The thousands of letters received by the BBC every year provide plenty of evidence of listening – but the trouble with this type of information is that it is haphazard and undirected. From this mass of correspondence it is obvious that there is potential available for more rigorous audience research if only the information supply could in some way be controlled and organized. This has in fact been done for many years by the formation of panels of listeners who regularly answer structured postal questionnaires. Panels of this type were first set up as long ago as 1948 and this method of research has grown in popularity over the years so that more than half of the BBC External Services use them. Listeners certainly seem to enjoy helping the BBC in their research and take it as a matter of great prestige to be selected to serve on a panel. Indeed, it has been noticed that some panel members have even gone so far as to have their own special notepaper headed "Member of BBC Listener Panel".

The size of panels used by the BBC External Services ranges from about 300 listeners in one target area for the smaller services to 2,500 listeners in almost all areas of the world for the World Service. In fact the World Service panel needs the help of a computer to process the information obtained from questionnaire operations. The recruiting method employed prevents BBC panels being representative of the audience as a whole, but they do comprise listeners of varying ages, occupations, and social backgrounds.

BBC listener panels are used mainly to obtain qualitative reaction from known listeners about the output rather than quantitative information. As such they are particularly useful for finding out about attitudes to the content, presentation and relevance of programmes. In addition listeners often make comments or suggestions in their letters and these can be tested out via the panels using them as a barometer of listener opinion. Certainly with audiences so spread out and distant from the source of the broadcasts, this research method is obviously the cheapest and most effective way of gathering together listeners for questioning. From a statistical standpoint these methods may be frowned upon but from a pragmatic view the audience research department can point to the fact that there has never been a case of opinions suggested by a panel subsequently being proved wrong in the light of other information.

These regular panel operations are supplemented by the despatch of *ad hoc* questionnaires sometimes to specific concentrated sub-samples of listeners and other times to large cross-sections who have never been contacted before. The opportunity is also taken to distribute questionnaires to visitors to international exhibitions and British Trade Fairs.

Other methods used to obtain qualitative information as to the nature of the audience include listener competitions and group discussions. The audience research value of competitions varies considerably but they are often useful in areas where listener response needs to be stimulated or in countries where it is impossible to carry out any other kinds of research. Group discussions, while simple in theory, are difficult to organize and it is not easy to obtain useful results from them.

Postal questionnaires, panels, competitions and the analysis of listener correspondence all add a little more to the picture of the world-wide audience but none of these methods can be used to estimate how many people actually listen to the BBC's External Services. Information of this nature can only be satisfactorily obtained by the use of structured sample surveys. In many parts of the world such surveys are not possible because of lack of research facilities or because of political restrictions. Even when surveys are arranged there are still many hurdles to overcome which would never be encountered if the survey was being carried out on home territory. Such factors as freak weather conditions, unknown religious festivals and insufficiently trained interviewers (all of which are beyond the control of BBC research staff miles away in London) can play havoc with interviewing while customs regulations, exchange regulations and processing difficulties can all cause headaches once the fieldwork is completed. So it would be foolish to claim that survey work carried out on behalf of the BBC External Services is always perfect.

The BBC has organized or received results of audience research surveys in over 50 countries in all parts of the world. Results from Europe are easiest to come by but as facilities improve all over the world other areas come within grasp and research has been carried out in places like Qatar, Abu Dhabi, Caracas, Java and Thailand. While, of course, the world-wide picture is far from complete these surveys do give a very good indication of the audience size in the areas sampled. Surveys cannot really be used for detailed questioning about programmes since the proportion of respondents identified in the sample as actual BBC listeners is usually on the small side and so this type of question would involve a great deal of wastage. Apart from indicating the numbers of listeners, surveys can be used for investigating listening times, radio and television set ownership and any other similar attributes which are common to the population being sampled.

With all these tools at its disposal the BBC's External Services audience research department can paint a very clear picture of the type of audience that each of the forty services enjoy.

Although it may not always be possible to give an indication of size, the type of audience, its programme preferences and needs are usually known and these provide an invaluable guide to producers and broadcasters when preparing their programmes. Just as a commercial organization selling nuts and bolts could not exist without its market research department nor could the BBC, and the External Services audience research department is essential if the BBC is to continue to provide appropriate and effective programming in a changing world.

SECTION IV

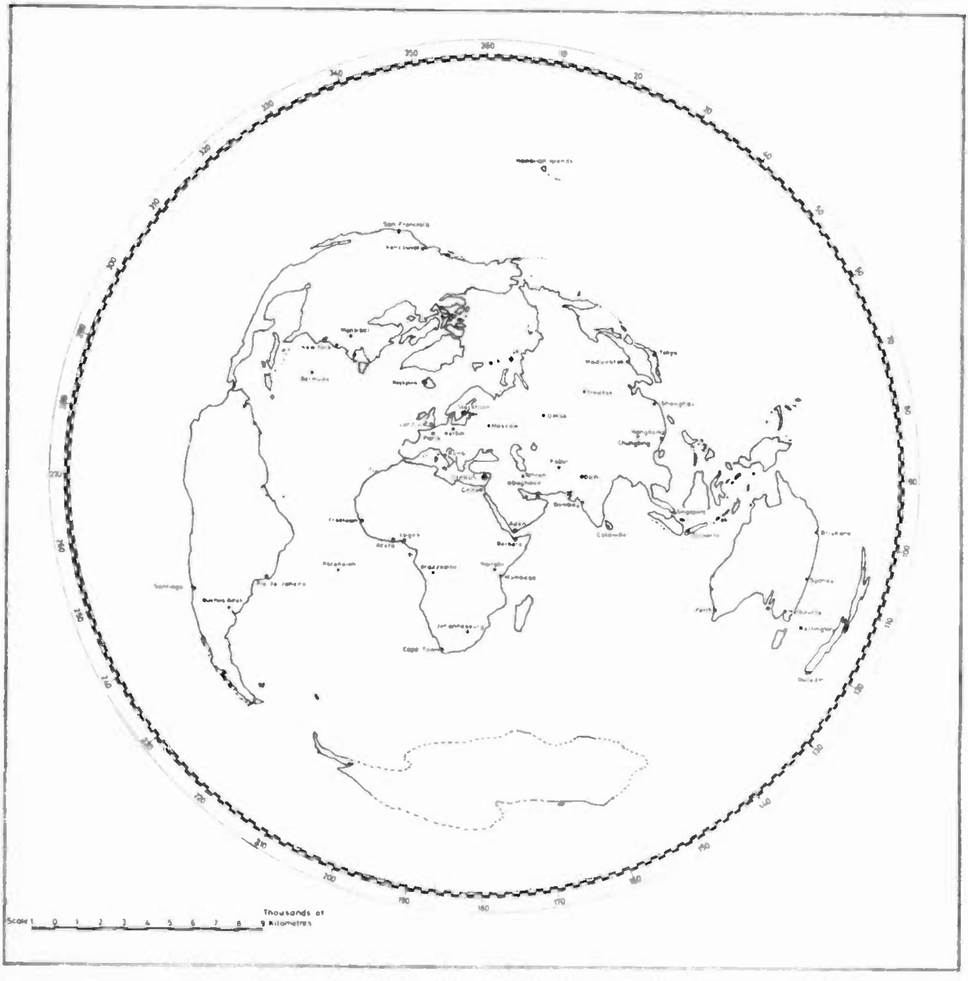
References

MAKE YOUR OWN AZIMUTHAL MAP

The azimuthal map can be very helpful in determining the directions from which radio signals arrive at the reception site, and will enable you to situate a directive antenna in the proper position with respect to those signals. Essentially, the azimuthal map shows your place in the centre of a circle, which represents the world. The antipodal point, which is the point on the opposite side of the earth from your location, is shown as a circle at a distance of 20,000 km.

If you want to prepare such a map for yourself, proceed as follows:

Draw a large circle on paper, and put 19 smaller concentric circles at equal mutual distances inside.



Moving away from your location then, the first circle will represent points 1,000 km away, the second, points 2,000 km away and so forth. To make the transfer of data easy, select the radius of the outer circle equal to e.g. $\frac{1}{2}$ or $\frac{1}{4}$ of half the circumference of a globe. This globe is needed to find the shapes of the various continents and the location of various important cities, and to transfer them to your map. Your tool for this can be a strip of paper, a flexible plastic ruler, a piece of 8mm film or a piece of magnetic tape, with a length of half the globe's circumference, and subdivided into 20 equal parts.

First, using your location as a centre of orientation, set your marks in a northerly direction, then a southerly direction, etc. The longitude and latitude lines of the globe will help you to find your bearings.

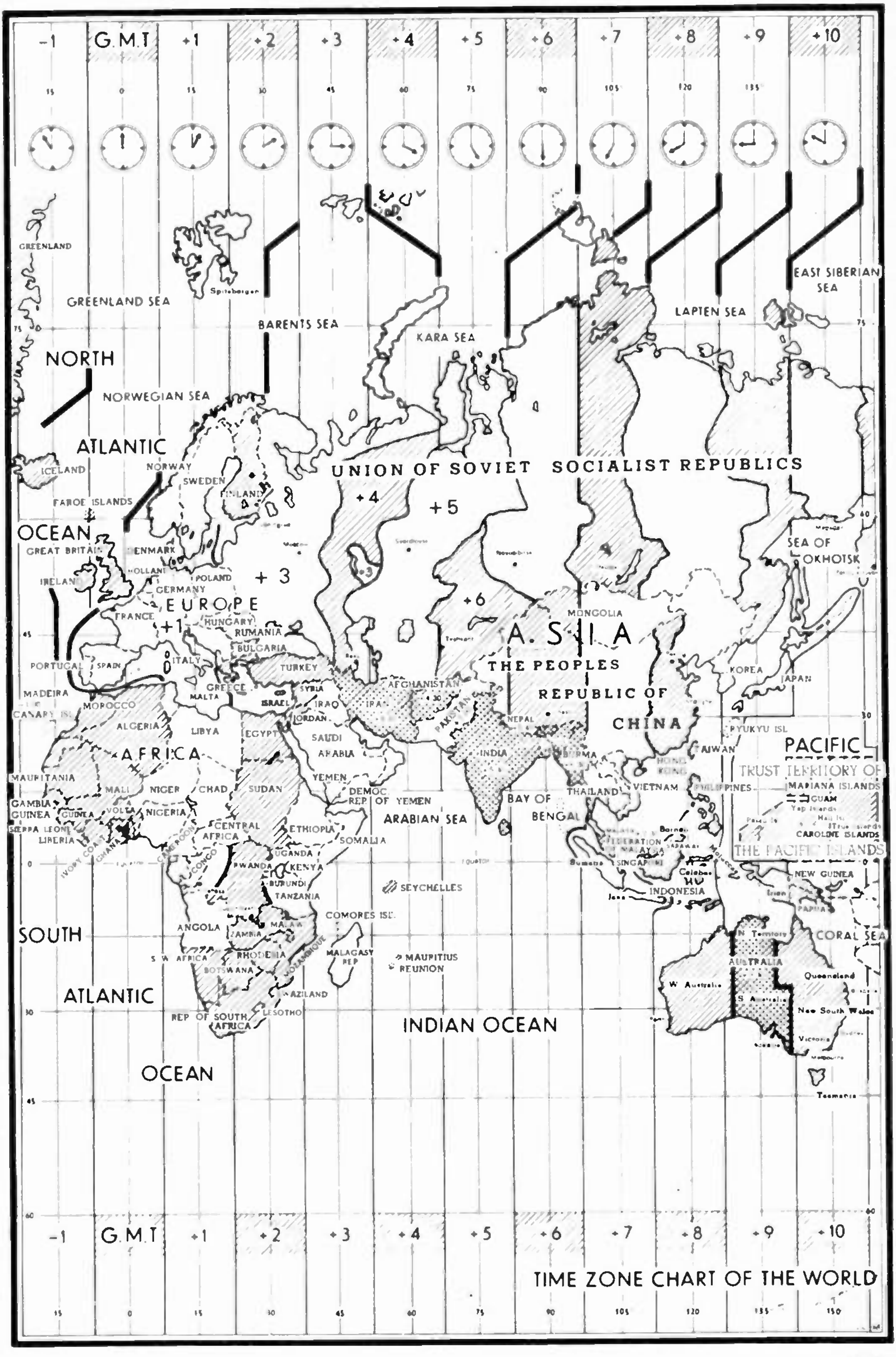
Using your tool, measure distances to landmarks, borders and important cities which you happen to come across, and transfer them to the appropriate places within your circle.

After you've worked the four main compass directions, start with the points within each of the four sectors now created on your map. A protractor or a triangle with angles of 30 and 60 degrees, or 45 degrees, will be helpful in getting accurate recordings of the angles between the four main directions (north, south, east, west, representing straight up and down, and sideways at right angles from the centre of the circle) and these locations, measured with your tool by connecting your location on the globe with the various points of interest. Entering these data into the map is then relatively easy, as long as the angle and the distance are correctly transferred.

An example of an azimuthal map, or map in azimuthal projection, is shown below. It is centred on the island of Cyprus in the Mediterranean, and is an arbitrary example, although it must be said that the centre location was chosen so that all major continents and islands are easily recognizable and are not too seriously distorted by the azimuthal projection method.

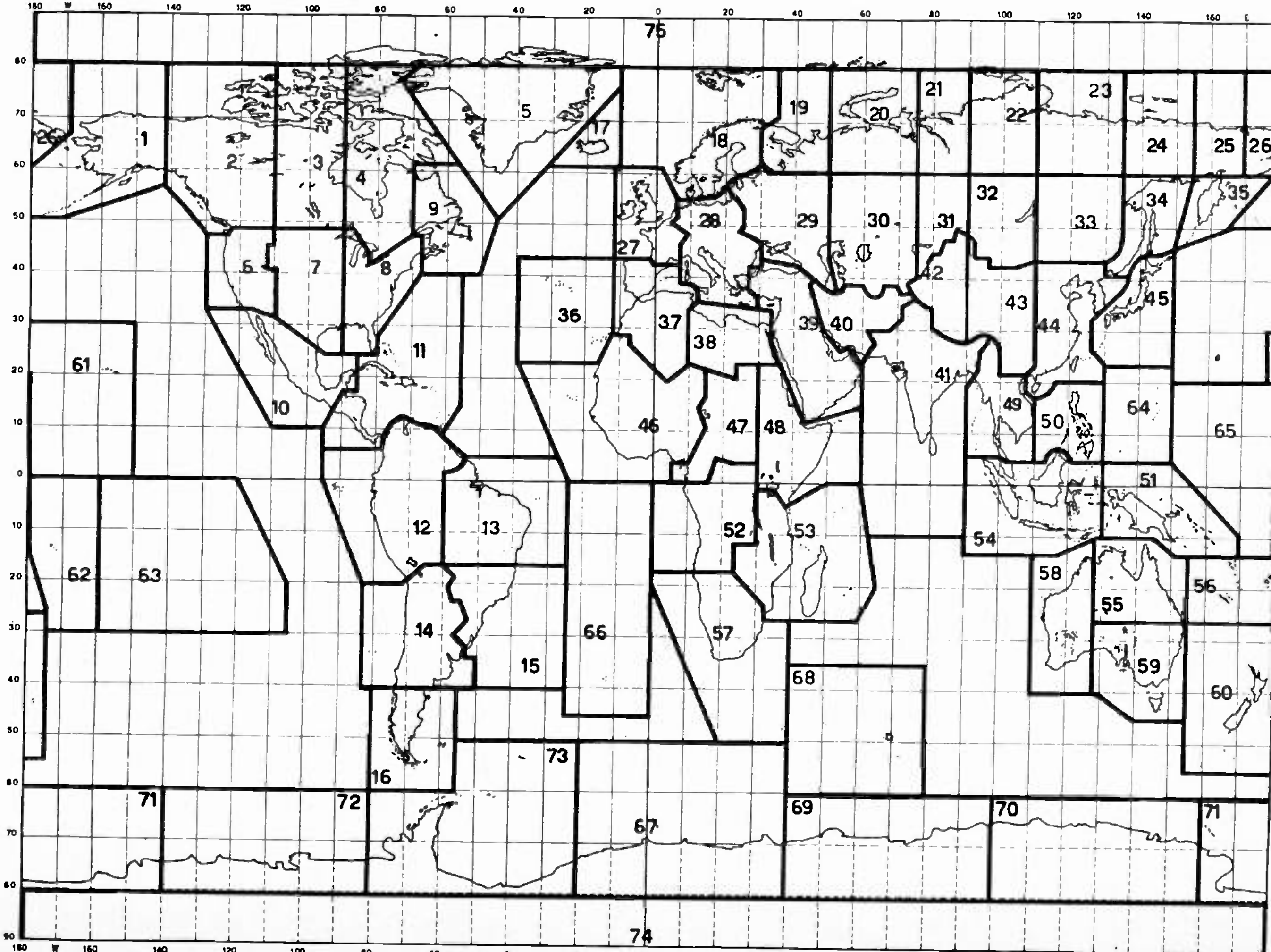
If the above text is not completely clear to you, this map can also be used by you as a model to try out the technique and compare the results.

TIME ZONE CHART OF THE WORLD


-1
G.M.T
+1
+2
+3
+4
+5
+6
+7
+8
+9
+10
GREENLAND
GREENLAND SEA
Spitsbergen
BARENTS SEA
KARA SEA
LAPTEN SEA
EAST SIBERIAN SEA
NORTH
NORWEGIAN SEA
ATLANTIC
ICELAND
NORWAY
SWEDEN
FINLAND
FAROE ISLANDS
OCEAN
GREAT BRITAIN
DENMARK
HOLLAND
IRELAND
POLAND
GERMANY
EUROPE
FRANCE
HUNGARY
RUMANIA
BULGARIA
PORTUGAL
SPAIN
ITALY
GREECE
MALTA
TURKEY
SYRIA
ISRAEL
IRAQ
JORDAN
IRAN
AFGHANISTAN
PAKISTAN
UNION OF SOVIET SOCIALIST REPUBLICS
SEA OF OKHOTSK
MONGOLIA
ASIA
THE PEOPLES REPUBLIC OF CHINA
KOREA
JAPAN
NEPAL
INDIA
BURMA
THAILAND
VIETNAM
TAIWAN
RYUKYU ISL
PHILIPPINES
PACIFIC
TRUST TERRITORY OF
MARIANA ISLANDS
GUAM
CAROLINE ISLANDS
THE PACIFIC ISLANDS
MADEIRA
CANARY ISL
MOROCCO
ALGERIA
LIBYA
EGYPT
SAUDI ARABIA
YEMEN
DEMOC. REP. OF YEMEN
ARABIAN SEA
BAY OF BENGAL
AFRICA
MAURITANIA
MALI
NIGER
CHAD
SUDAN
GAMBIA
GUINEA
SIERRA LEONE
LIBERIA
IVORY COAST
GHANA
VOLTA
NIGERIA
CAMEROON
CENTRAL AFRICA
ETHIOPIA
SOMALIA
UGANDA
KENYA
RWANDA
BURUNDI
TANZANIA
CONGO
SEYCHELLES
COMORES ISL.
ANGOLA
ZAMBIA
MALAWI
RHODESIA
S. W. AFRICA
BOTSWANA
MALAGASY REP
MAURITIUS
REUNION
SWAZILAND
LESOTHO
REP. OF SOUTH AFRICA
SINGAPORE
INDONESIA
NEW GUINEA
PAPUA
CORAL SEA
AUSTRALIA
W. Australia
Queensland
New South Wales
Victoria
Tasmania
SOUTH
ATLANTIC
OCEAN
INDIAN OCEAN
TIME ZONE CHART OF THE WORLD

CIRAF ZONES

(Reception areas of the World)



COPPER WIRE TABLE

The diameter of a wire determines not only its mechanical strength, but also its current carrying capacity. This wire table shows you not only the metric diameter in millimetres (1 mm = 1/1,000 m), but also the equivalent American (AWG) and British (SWG) wire gauges.

The table given below is valid for solid copper wire.

American Wire Gauge (AWG) No.	Nearest British Wire Gauge (SWG) No.	Diameter in mm	Continuous duty current (wire or cable in conduit or bundle) (amperes)
10	12	2.6	33
12	14	2.1	23
14	16	1.6	17
16	18	1.3	13
18	19	1.0	10
20	21	0.8	7.5
22	23	0.65	5
24	25	0.5	
26	27	0.4	
28	30	0.3	
30	33	0.25	

Make your own open wire transmission line

An excellent balanced transmission line can be home-made by using magnet wire and spreader insulators, applied at regular intervals along the line. These spreader insulators can be home-made from PVC or polypropylene (plastics), e.g. slices of plastic tubing, with holes drilled at the right distances to obtain the desired characteristic impedance (Z_O) of the line.

The table below provides the information for a wide variety of open wire transmission lines. In order to maintain the right Z_O along the line, it should be kept taut after installation!

Z_O (Ohms)	Centre-to-centre distance of conductors
75	1.25 x diameter
96	1.4 x diameter
150	1.9 x diameter
200	2.7 x diameter
240	4.0 x diameter

Z_O (Ohms)	Centre-to-centre distance of conductors
300	6.5 x diameter
350	9.5 x diameter
400	14 x diameter
450	21.5 x diameter
600	82 x diameter

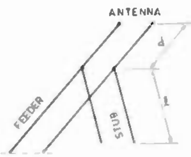
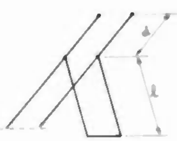
STUB MATCHING OF ANTENNAS

To prevent the loss of signal on the transmission line between the receiver (or transmitter) and the antenna, due to standing waves on the line, matching is necessary when the feedpoint impedance of the antenna and the characteristic impedance of the transmission line differ considerably.

One of the easiest methods for matching – because it does not require the use of measuring instruments – is the so-called stub matching. The stub is a short piece of transmission line of the same characteristics as the feedline used, connected parallel to it near the antenna.

The length of the stub (l) and the distance of the stub to the antenna proper (d) are given in *wavelengths*.

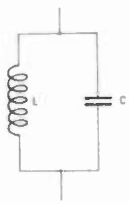
The so-called "open stub" (stub is left open at its free end) is used when the feedline impedance is higher than the antenna feedpoint impedance. The "closed stub" (the stub is short-circuited at its free end) is used when the characteristic impedance of the feeder is lower than the antenna feedpoint impedance).

	ratio: feedline impedance / antenna impedance	distance d	length stub l
Open stub 	10 6 4 3 2	0.05 0.06 0.075 0.085 0.095	0.195 0.18 0.155 0.14 0.095
Closed stub 	0.5 0.33 0.25 0.165 0.1	0.15 0.17 0.18 0.19 0.20	0.15 0.11 0.095 0.07 0.05

SIMPLE RESONANT CIRCUITS

Simple resonant circuits, consisting of a coil and a capacitor connected in parallel, do sometimes come in handy for trap circuits in antennas and for shortwave converter of RF amplifier circuits.

The data given below are based on a single layer coil, wound on a $\frac{5}{8}$ inch (16 mm) PVC or polypropylene former. The wire used for such a coil is usually enamelled copper wire, so-called magnet wire, with a diameter of 0.8 to 1 mm. For maximum coil quality, the turns should be mutually spaced at a distance which is approximately equal to the wire diameter.

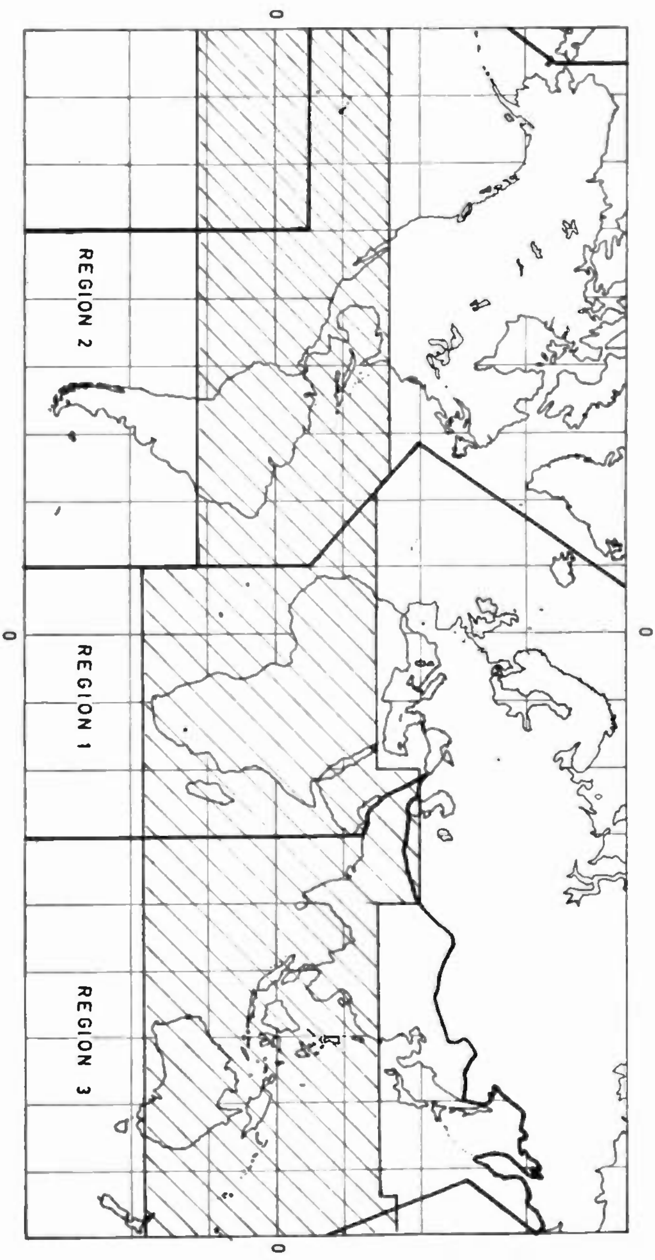
	number of turns on the former	approximate inductance μH	capacitance of parallel condenser pF or μμF	approximate resonance frequency MHz
	6	0.4	100	25
			140	22
			210	18
			480	12
	12	1.5	28	24
			40	20
			74	15
			165	10
			440	6
	18	2.3	34	15
			75	10
			210	6
			480	4
	24	3	18	15
			42	10
			115	6
			230	4
			470	3

AMATEUR PREFIXES

AC4	Tibet
AP	East Pakistan
AP	West Pakistan
BV, (C3)	Formosa
BY, (C)	China
CE	Chile
CE9	(See VP8)
CEØA—	Ea. Island
CM, CO	Cuba
CN2, 8, 9	Morocco
CP	Bolivia
CR4	Cape Verde Isl.
CR5	Port Guinea
CR5	Sao Thome
CR6	Angola
CR7	Mozambique
CR8	Port. Timor
CR9	Macao
CT1	Portugal
CT2	Azores
CT3	Madeira Islands
CX	Uruguay
DJ, DL, DM	Germany
DU	Philippine Isl.
EA	Spain
EA6	Balearic Isl.
EA8	Canary Isl.
EA9	Rio de Oro
EA9	Sp. Morocco
EAØ	Sp. Guinea
EI	Rep. of Ireland
EL	Liberia
EP, EQ	Iran
ET3	Ethiopia
F	France
FA, 7X2	Algeria
FB8	St. Paul Isl.
FC	Corsica
FG7	Guadeloupe
FH8	Comoro Isl.
FK8	New Caledonia
FL8	Fr. Somaliland
FM7	Martinique
FO8	Fr. Oceana
FR7	Glorioso Isl.
FR7	Juan de Nova
FR7	Reunion
FS7	Saint Martin
FU8, YJ1	N. Hebrides
FW8	Futuna Isl.
FY7	Fr. Guiana
G	England
GC	Guernsey
GC	Jersey Isl.
GD	Isle of Man
GI	North. Ireland
GM	Scotland
GW	Wales
HA	Hungary
HB	Switzerland
HC	Ecuador
HC8	Galapagos Isl.
HE	Liechtenstein
HH	Haiti
HI	Dominican Rep.
HK	Columbia
HKØ	Bajo Nuevo
HKØ	Malpelo Isl.
HKØ	San Andres
HL, HM	Korea
HP	Panama
HR	Honduras
HS	Thailand
HV	Vatican
HZ	Saudi Arabia
I1, IT1	Italy
IS1	Sardinia
JA, KA	Japan
JT1	Mongolia
JY	Jordan
K, W	USA
KC4	Navassa Isl.
KC6	E. Caroline Isl.
KG1	(See OX)
KG4	Guantanamo
KG6	Guam
KG6	Marcus Isl.
KG6	Mariana Isl.
KH6	Hawaiian Isl.
KH6	Kure Isl.
KJ6	Johnston Isl.
KL7	Alaska
KM6	Midway Isl.
KP4	Puerto Rico
KP6	Jarvis Isl.
KR6	Ryukyu Isl.
KS4B	Serrana Bank
KS4	Swan Isl.
KS6	America Samoa
KV4	Virgin Isl.
KW6	Wake Isl.
KX6	Marshall Isl.
KZ5	Canal Zone
LA	Jan Mayen
LA	Norway
LA	Svalbard
LU	Argentina
LU-Z	(See CE9, VP8)
LX	Luxembourg
LZ	Bulgaria
M1, 9A1	San Marino
MP4	Bahrein
MP4	Trucial Oman
OA	Peru
OD5	Lebanon
OE	Austria
OH	Finland
OHØ	Aland Isl.
OK	Czechoslovakia
ON4, 5	Belgium
OX, KG1	Greenland
OY	Faroe Isl.
OZ	Denmark
PAØ, PI1	Holland
PJ	Neth., Antilles
PJ2M—	Sint Maarten
PK	Indonesia
PX	Andorra
PY	Brazil
PYØ	Fernando de Noronha
PYØ	Trindade
PZ1	Surinam
SL, SM	Sweden
SP	Poland
ST2	Sudan
SU	Egypt
SV	Crete
SV	Dodecanese
SV	Greece
TA	Turkey
TF	Iceland
TG	Guatemala
TI	Costa Rica
TI9	Cocos Isl.
TJ	Cameroun
TL	C. African Rep.
TN	Congo Rep.
TR	Gabon Rep.
TT	Chad Rep.
TU	Ivory Coast
TY	Dahomey Rep.
TZ	Mali Rep.
UA1, 6, UN1	Eur. USSR
UA1	Franz Joseph Land
UA2	Kaliningradsk
UA9, Ø	Russian
UB5, UT5	Ukraine
UC2	White Russian
UD6	Azerbaijan
UF6	Georgia
UG6	Armenia
UH8	Turkoman
UI8	Uzbek
UJ8	Tadzhik
UL7	Kazakh
UM8	Kirghiz
UO5	Moldavia
UP2	Lithuania
UQ2	Latvia
UR2	Estonia
VE, VO	Canada
VK	Australia
VK9	Christmas Isl.
VK9	Cocos Isl.
VK9	Norfolk Isl.
VK9	Papua Terr.
VK9	New Guinea
VKØ	Masquarie Isl.
VO	(See VE)
VP1	Br. Honduras
VP2K	Anguilla
VP2V	Br. Virgin Isl.
VP2D	Dominica
VP2G	Granada
VP2M	Montserrat
VP2K	St. Kitts, Nevis
VP2L	St. Lucia
VP2S	St. Vincent
VP3	British Guiana
VP4	Trinidad & Tobago
VP5	Cayman Isl.
VP5	Turks Isl.
VP6	Barbados
VP7	Bahama Isl.
VP8	(See CE9)
VP8	Falkland Isl.
VP8, LU-Z	So. Georgia Isl.
VP8, LU-Z	So. Orkney Isl.
VP8, LU-Z, CE9	So. Shetland Isl.
VP8, LU-Z	So. Sandwich Isl.
VP9	Bermuda Isl.
VQ1	Zanzibar
VQ2	No. Rhodesia
VQ4	Kenya
VQ8	Cargados Carajos
VQ8	Chagos Isl.
VQ8	Mauritius
VQ8	Rodriguez Isl.
VQ9	Aldabra Isl.
VQ9	Seychelles
VR1	British Phoenix Isl.
VR1	Gilbert & Ellice Isl. & Ocean Isl.
VR2	Fiji Isl.
VR3	Christmas Isl.
VR4	Solomon Isl.
VR5	Tonga Isl.
VR6	Pitcairn Isl.
VS1	Singapore
VS4	Sarawak
VS5	Brunei
VS6	Hong Kong
VS9	Aden & Socotra
VS9M	Maldive Isl.
VU	Nicobar Isl.
VU	India
W	(See K)
XE, XF	Mexico
XF4	Revilla Gigedo
XT	Voltaic Rep.
XW8	Laos
XZ2	Burma
YA	Afghanistan
YI	Iraq
YK	Syria
YN, YNØ	Nicaragua
YO	Rumania
YS	Salvador
YU	Yugoslavia
YV	Venezuela
ZA	Albania
ZB1	Malta
ZB2	Gibraltar
ZC5	No. Borneo
ZC6	Palestine
ZD3	Gambia
ZD6	Nyasaland
ZD7	St. Helena
ZD8	Ascension Isl.
ZD9	Tristan Cunha
ZE	So. Rhodesia
ZK1	Cook Isl.
ZK1	Manihiki Isl.
ZL	Auckland Isl.
ZL	Chatham Isl.
ZL	New Zealand
ZM6	We. Samoa
ZP	Paraguay
ZS1, 2, 4, 5, 6	So. Africa
ZS2	Prince Edw. Isl.
ZS3	So. West Africa
ZS7	Swaziland
ZS8	Basutoland
ZS9	Bechuanaland
3A	Monaco
3V8	Tunisia
3W8	Vietnam
4S7	Ceylon
4W1	Yemen
4X4	Israel
5A	Libya

5B4 .... Cyprus
5H3 .... Tanganyika
5N2 .... Nigeria
5R8 .... Malagasya Rep.
5T .... Mauretania
5U7 .... Niger
5V .... Togo
5X5 .... Uganda
5Z4 .... Kenya
6O1, 2 .... Somali Rep.
6W8 .... Senegal Rep.
6Y .... Jamaica
7G1 .... Rep. of Guinea
7X2 .... (See FA)
9A1 .... (See M1)
9G1 .... Ghana
9K2 .... Kuwait
9K3 .... Kuvait/Saudi Arabia
9L1 .... Sierra Leone
9M2 .... Malaya
9N1 .... Nepal
9Q5 .... Rep. of Congo
9U5 .... Burundi
9X5 .... Rwanda
XU .... Cambodia

ITU REGIONS



DECIBELS

Decibels

A universal unit to express the ratio between two amounts of power, existing at two points, is the decibel (dB). The number of dB is by definition: $10 \log_{10} P_1/P_2$. If the ratio between P_1 and P_2 happens to be 100, the number of dB is equal to $10 \log_{10} 100 = 10 \times 2 = 20$. An audio amplifier with 1 milliwatt input and 1 watt output has an amplification of 30 dB ($\log_{10} 1{,}000 = 3$).

The unit is also used to express voltage and current ratios. The number of dB is then $20 \log_{10} V_1/V_2$.

It has become customary to express many characteristic properties of electronic components or units in dB's without mentioning the reference power or voltage to which the gain or amplification is taken. In audio engineering, the standard reference level is 1 milliwatt of power across 600 ohms, and the reference level is usually indicated by an extra letter behind the dB. 20 dBm means: 20 dB's relative to 1 milliwatt over a 600 ohm line.

In antenna engineering, the standard reference level is the isotropic (omnidirectional) antenna. An antenna with 12 dBi has a gain of 12 dB relative to the isotropic antenna.

Signal levels are sometimes expressed in dBu: the reference level is 1 microvolt per meter field strength.

In the following table, the decibels and the equivalent power ratios and voltage or current ratios are given.

Decibels	Power ratio	Voltage or Current ratio
1	1	1
3	2	1.41
5	3	1.78
10	10	3.16
13	20	4.47
15	30	5.62
20	100	10
30	1000	31.6

VARIOUS RECEPTION CODES

Comparison of signal strength indications used by DX-ers and radio amateurs.

The ratings are related to the signal input voltage at the antenna terminal of the receiver.

Signal level at antenna input of receiver (microvolts)	Corresponding value dB (dB's above 1µV)	S-rating (RST amateur code)	S-rating (SINPO DX code)
0.5		S1	
1	0	S2	
1.6		S3	
2.5		S4	1
5	14	S5	
10	20	S6	2
16		S7	
30	30	S8	
50	34	S9	3
150	44	S9 + 10 dB	3
500	54	S9 + 20 dB	4
1000	60		4
2000	66		5
5000	74	S9 + 40 dB	5

GLOSSARY OF USEFUL DX TERMS

Aerials

aerial coupler an Aerials device connected between the aerial and the receiver to improve the signal transfer.
aerial matching matching the aerial radiation resistance to the aerial input impedance of the receiver.
AWG (B & S) American Wire Gauge.
BWG Birmingham Wire Gauge.
coaxial cable assymmetrical transmission line consisting of a core wire situated in the centre of a cylindrical wire braid, from which it is insulated. The core is shielded from interference by the screening braid.
characteristic impedance the "resistance" which an electrical source will "see" when it is connected to an endless transmission line.
curtain array shortwave transmitting aerial consisting of an array of dipole aerials.
dB – decibel a unit to express power ratios, usually with respect to a basic level. Formula:

$$10 \log_{10} \frac{\text{output power}}{\text{input power}} \ldots \text{db (gain)}$$

dipole aerial symmetrical (balanced) aerial tuned to a wavelength approximately twice its mechanical length.
directive array aerial contraption designed to transmit to, or receive from, a predetermined direction.
gain signal gain derived by a certain type of aerial with respect to a basic aerial system, expressed in dB.
ground plane aerial tuned aerial system consisting of one vertical radiator and 4 horizontally – or downward pointed – radials which form an artificial ground plane. All elements are $\frac{1}{4}$ wavelength long.
half-wave aerial aerial with a physical length equal to about half the wavelength it is tuned into.
impedace matching "aerial matching".
loading coil spiralized wire added to the aerial (usually a vertical one) to compensate electrically for a too short mechanical length, usually to make it a $\frac{1}{4}$ wave tuned system.
long wire (L) aerial a non-resonant aerial used for general purpose shortwave reception.
matching unit see "aerial coupler".
multiband aerial aerial system designed for preferably the reception of a number of (SW) bands.
NBS British Standard wire gauge.
polar diagram a diagram showing the directional characteristics of an aerial in the horizontal plane.

radiation resistance the equivalent resistance of an aerial system. It gives an insight into the effectiveness of an aerial system (the higher the radiation resistance, the better).
rhombic aerial aerial shaped like a rhombic, showing a strongly directional pattern, and used for professional transmitting and receiving purposes.
ribbon parallel wire transmission line, usually with a characteristic impedance of 240-300 ohms.
rod aerial vertical aerial with rod-shaped conductor.
transmission line a system of conductors for the transfer of signals from transmitter to aerial, or from aerial to receiver.
twin lead, twin line see "ribbon".
whip aerial see "rod aerial".
wire gauge a table showing the connection between wire diameter and numeration of the standard, among other things like feet per pound, ohms per 1,000 feet or current carrying capacity.

Propagation

absorption weakening of signals caused by the atmosphere and by penetration of ionospheric layers.

CB Citizens Band – a small frequency range around 27 MHz for the purpose of low-power, short range wireless communication.

D-region ionospheric layer at about 50 km above the earth's surface during the daytime.

direct wave a signal received directly from the transmitting aerial by propagation along the earth's surface.

E-layer ionospheric layer at a height of about 90 km. Utilized for MW (Standard Broadcast) propagation in the dark hours.

F_2-layer ionospheric layer at about 300 km above the surface of the earth. It is the principal layer for the reflection of high frequency (SW) signals.

fading variations in the strength of the incoming signal due to propagation irregularities.

flare solar flare, a bright spot on the surface of the sun and responsible for the emission of huge quantities of radiation (gamma-rays, X-rays and ultraviolet light).

ground wave see "direct wave".

HF-range the frequency range between 3 and 30 MHz (100-10 metres).

impedance the apparent resistance that a component shows to an alternating current. The impedance of coils rises as the frequency increases, the impedance of condensers decreases with increasing frequency.

ionospheric layer a region above the surface of the earth where radiation from space (with the emphasis on solar radiation) produces ionization of atoms, thus creating free electrons and ions. During the night most ionospheric layers will disappear due to recombination of atoms.

ionospheric storm a heavy increase of atmospheric absorption due to energy particles from the sun, usually ejected by a solar flare. An ionospheric storm can disrupt shortwave traffic for days.

LF-range the frequency range between 30 and 300 kHz (10,000-1,000 m).

line-of-sight propagation restricted to the VHF and higher frequency bands, where signals are neither reflected by ionospheric layers nor guided by the surface of the earth, and can only travel in straight lines from transmitter to receiver when this path is unobstructed.

LUF Lowest Useful Frequency. Below this limit ionospheric absorption is likely to be excessive.

magnetic storm severe variations of the earth's magnetic field due to solar activity.

MF-range the frequency range between 300 and 3,000 kHz (1,000-100 m).

MUF Maximum Usable Frequency, defined as the frequency that will give satisfactory propagation between transmitter and receiver area for 50% of the time.

ionospheric "reflection" the phenomenon by which radiowaves from the earth are bent downwards by multiple refraction due to a varying degree of ionization within the ionospheric layer.

scatter the scattering of signals which occurs during penetration of ionospheric layers (SW) or in the atmosphere (VHF-UHF).

SID Sudden Ionospheric Disturbance, usually commencing simultaneously with the occurrence of a solar flare, causing momentous increase of absorption. SID's can last from a few minutes to a few hours.

skip distance the distance between the limit of the groundwave range and the nearest possibility of skywave reception.

sky-wave a radio wave reflected in the ionosphere.

sporadic E-layer an ionized layer occurring at a height of about 100 km high at irregular intervals, but with exceptionally reflective properties, even for frequencies above 30 MHz.

sunspot a dark area on the solar surface due to local cooling down caused by the penetration of strong magnetic fields.

sunspot-cycle the 11-year periodicity observed in the occurrence of sunspots and groups of sun-spots.

sunspot-number (R) a number indicating the activity of sunspots over a given period.

UHF-range the frequency range between 300-3,000 MHz (1-0.1 m).

VHF-range the frequency range between 30 and 300 MHz (10-1 m).

Wolf number (R) see "sunspot number".

Receivers, Auxiliary equipment

AC Alternating Current (example: the house current, or "mains").

AF Audio Frequencies (30-20,000 Hz).

AGC Automatic Gain Control.

AVC Automatic Volume Control (=AGC).

BFO Beat Frequency Oscillator, generates a carrier on or near the intermediate frequency, is necessary for the demodulation of SSB-signals and makes telegraphy (CW) signals audible.

converter unit which converts incoming signals to a suitable frequency. SW-converters usually convert HF-signals to a frequency in the MF region, so that the converter operates in conjunction with a medium wave (broadcast band) receiver to produce SW-signals.

crystal filter bandpass filter with a sharp selectivity and restricted IF-passband based on the properties of a quartz crystal.

CW Continuous Wave: telegraphy transmission derived by switching an unmodulated carrier on and off by the morse key.

DC Direct Current, provided by dry cells, car batteries etc.

detection separating the audio frequency signal from its carrier in the receiver.

demodulation see "detection".

double conversion in receiver circuitry: two different intermediate frequencies (one high, approximately 1.5 MHz, and one low, approximately 50 kHz) to improve receiver performance.

double super a receiver executed with double conversion.

DSB Double Side Band, one of the modulation systems applied in amplitude modulation for long, medium and short waves.

feedback coupling the output of a stage to the input, allowing part of the amplified signal to enter again into the input. Regenerative feedback: in phase; Degenerative feedback: 180 out of phase.

heterodyne high pitched tone resulting from two interfering carriers within the passband of the receiver.

HT High Tension, the anode voltage needed in valve executed receivers.

IF Intermediate Frequency, the frequency to which all incoming antenna signals in a receiver are converted. The IF is usually selected around 450 kHz.

image frequency the phenomenon that a station operating in the higher shortwave bands sometimes seems to appear twice in the band, at its original frequency and at a frequency which is twice the IF away from it. This second frequency is called the "image" or "ghost" frequency.

input impedance the AC-resistance which a signal source "sees" when it is connected to the input.

mechanical filter also called "mechanical resonance filter" or "ceramic filter". It is a unit where mechanical resonance is used to obtain excellent passband characteristics. Mechanical filters are usually applied in the IF-stage of the receiver.

mixer stage the stage where the incoming aerial signal is mixed with the local oscillator signal to produce intermediate frequency signals.

noise limiter a device whereby noise signals stronger than those of the tuned station are clipped.

noise suppressor a device whereby noise signals stronger than those of the tuned station are suppressed.

oscillator a unit in the superheterodyne-type receiver that produces an unmodulated carrier at a frequency which is equal to the tuned frequency above or below the intermediate frequency.

permeability tuning tuning by varying the permeability of the coils by varying the relative position of their cores.

pre-selector also called RF pre-amplifier, it is a stage which is situated between the aerial input plug and the mixer stage in high quality receivers. It adds sensitivity to the receiver and improves the image frequency protection.

product detector a detector stage for the demodulation of single side band (SSB) signals.

Q-fiver a unit which is connected to the IF section of the receiver from which the signal is tapped. In the unit it is converted to a lower IF, where better selectivity is easily obtainable. Thus, the Q-fiver improves selectivity to a degree determined by its IF-circuit.

Q-multiplier a stable regenerative unit which improves the selectivity of an intermediate frequency circuit by the principle of feedback.
RF Radio Frequency.
S-meter a device used for the indication of relative signal strengths.
selectivity the ability of a receiver or circuit to separate adjacent signals. The better the selectivity, the narrower the passband.
sensitivity the better a receiver is able to process weak signals, the greater its sensitivity.
signal-indicator a device used for the indication of incoming signal-strength. Examples are the magic eye, the S-meter.
squelch the audio squelch circuit cuts off receiver output when no signal is coming through the receiver.
SSB Single Side Band, contains only one modulated sideband signal when it is propagated.
stability the power of a receiver to limit its frequency drift after it is switched on.
superheterodyne a receiver working along the superheterodyne principle incorporates an oscillator stage, a mixer stage where the oscillator signal is mixed with the aerial signal, and one stable IF (intermediate frequency) results. The advantage of fixed tuned circuits is greater selectivity at less cost.
T-notch filter a filter with a very narrow resonance dip used e.g. to suppress heterodyne tones in the IF-passband.
transceiver a combination of a transmitter and a receiver.
VFO Variable Frequency Oscillator.

Reports

Abbreviations:

ADR	address
ANT	antenna, aerial
CW	continuous wave
DX	distance, long-distance radio reception or transmission
FM	frequency modulation
GB	good-bye
GM	good morning
GN	good night
GND	ground
HI	high; the DX expression of derision
ID, IDENT	identification
NR	number
OM	old man
PWR	power
RCD	received
RX	receiver
SIG	signal
SWL	shortwave listener
TNX	thanks
TVI	television interference
WX	weather
TX	transmitter
XTAL	crystal
73	best regards
88	love and kisses
AEST	Australian Eastern Standard Time
AM	amplitude modulation

bandwidth part of the spectrum which is allowed to pass.
carrier frequency frequency mentioned in station announcements, it is the frequency on which the audio signal "rides".
CET Central European Time.
caption reconnaissance picture of TV station or programme.
EST Eastern Standard Time.

FM Frequency Modulation.
GMT Greenwich Mean Time.
ham station amateur radio station.
heterodyne high pitched whistle resulting from two carriers within the passband of a receiver.
identification station announcement or signal.
interval signal see pause signal.
interference the reception of the desired station is hindered by another signal.
IRC International Reply Coupon.
kHz kilohertz = 1,000 hertz = 1,000 cycles per second.
local time the hour at the receiving station.
MHz megahertz; 1,000,000 Hz; 1,000,000 cycles per second.
pause signal reconnaiscance signal transmitted in between the programmes, especially during change overs etc., at the transmitter station.
point-to-point stations stations operating fixed public services in the fixed bands.
QSL-card card verifying the reception of a station, giving details about frequency, date and time of reception.
RTTY radioteletype.
Standard Frequency Station station operating on a frequency with a high standard of accuracy, usually providing accurate time signals as well, for scientific purposes.

Reception Codes

Q-code abbreviations used in telegraphy traffic, and adopted for DX-purposes, like:
QRK the intelligibility of your signals is . . . (followed by a cipher ranging from 5 for excellent to 1 for bad).
QRM you are being interfered with (followed by a cipher ranging from 5 for nil to 1 for severely); man-made interference.
QRN you are troubled by static (followed by a cipher as mentioned for QRM).
QSA the strength of your signals is (followed by a cipher as mentioned under QRK).
QSL can you acknowledge receipt?; verification.
QTH my location is . . .
QTR the correct time is . . .
RST-code R=readability, S=signal strength, T=tone. The "R" merits 1 for unreadable, 2 for barely readable, 3 for readable with considerably difficulty, 4 for readable with practically no difficulty and 5 for perfectly readable. The "S" has nine points: 1=faint signals, 2=very weak signals, 3=weak signals, 4=fair signals, 5=fairly good signals, 6=good signals, 7=moderately strong signals, 8=strong signals, 9=extremely strong signals.
The "T" reads between 1 and 9, but is not used for DX purposes.
SIO-code a shortened SINPO code. S stands for "signal strength", I for "interference" and O for "overall merit". All letters get a merit ranging between 1 and 5. A high number indicates a favourable condition.
SINPO-code recommended by the International Radio Consultative Committee, and adopted by many SW radio stations. See "SIO"-code. The N stands for "noise" and the P for "propagation disturbances" (fading, etc.).
verification card see "QSL-card".
voice mirror identification tape repeating station announcement for point-to-point stations.
wavelength the physical length of one wave of the radio signal. The conversion formula for frequencies into wavelengths and vice versa is: frequency (kHz)×wavelength (m)=300,000.

Standard frequency and time signal stations

Standard frequency and time signal stations combine an extraordinary frequency stability with accurate time indications, given at regular intervals. Sometimes, additional information, e.g. tones of certain frequencies, or ionospheric data, are also provided. Although standard frequency stations are primarily of importance to scientific institutes, they can be very useful for DX-ers, e.g. for receiver calibration.

Argentina

STATION LOL
Addr: Servicio de Hidrografia Naval, Observatorio Naval, Avenida Espana 2099, 1107 Buenos Aires, Argentina.
Standard Freq. and Signals: 5000kHz 2kW, 10000kHz 2kW, 15000kHz 2kW; 1100-1200, 1400-1500, 1700-2800, 2000-2100, 2300-2400. **Schedule:** 3 min. dash (1000 or 440cs alternately) beginning at 00.00, 00.05, 00.10, etc. followed by 2 min. ann. at the mins 03/04, 08-09, 13/14, etc. . . .("observatorio Naval Argentina . . .Horas . . . minutos"). TS transmission at min. 55-58 in each h – V. by QSL-folder.

Australia

STATION VNG TELECOM AUSTRALIA
Addr: VNG Time and Frequency Standards Section, Telecom Australia, 59 Little Collins Str, Melbourne, Vic. 3000, Australia. **Cable:** "Reslabs".
Stations: Lyndhurst: 4500kHz 0945-2130; 7500kHz 2245-2230; 12000kHz 2145-0930 (all 10kW).
The st. transmits seconds signals of 50 cycles of 1000Hz tone. The 59th second of each min. is omitted and the minute marker is 0.5 second long. Seconds 55 to 58 are shortened to 5 cycles. For mins 5, 10, 15, etc. seconds 50 to 58 are shorted to 5 cycles. The deviation of the signals from UTI is transmitted each minute using the method recommended by the CCIR. The average daily frequency deviation does not exceed $\pm$ 1 part in 10^{10}. Between seconds 20 and 50 of mins 15, 30, 45 and 60, a recording is played: "This is VNG Lyndhurst Victoria Australia on 4.5, 7.5 or 12MHz. VNG is a standard Frequency and Time Signal service of the Australian Telecommunications Commission. This is VNG Lyndhurst Victoria Australia on 4.5, 7.5 or 12MHz".

Canada

NATIONAL RESEARCH COUNCIL, Canada
Addr: R. Station CHU, National Research Council, Ottawa, Ontario, Canada. K1A OS1.
Stations: CHU 3330kHz 3kW; 7335kHz 10kW; 14670kHz 3kW (all antennas vertical).
TS: Continuous by voice and seconds pulses. Freq. and time signal control by cesium clock.
Ann: English: "CHU Canada, Eastern Standard Time . . .". French: "CHU Canada, Heure normal de l'est . . .". Identification of DUTI=$_4$UTI – UTC by split second code – V. by QSL-card. Re. welcomed – **Pub:** Station information free.

France

BUREAU INTERNATIONAL DE L'HEURE
Addr: 61 Avenue de l'Observatoire, 75014-Paris, France.
L.P: Dir. B. Guinot.
Stations: St. André de Corcy FTA91 91.15kHz 45kW: 0800, 0900, 0930, 1300, 2000, 2100, 2230; Sainte-Assise FTH42 7428kHz 6kW: 0900, 2100 – FTK77 10775kHz 6kW: 0800, 2000 – FTN87 1387kHz 6kW: 0930, 1300, 2230 – V. by QSL-card.

CENTRE NATIONAL D'ETUDES DES TELECOMMUNICATIONS
FFH. **Addr:** 38-40, rue du Général Leclerc, F-92131 Issy-les-Moulineaux, France. **Te:** (645)-4444.
Station: FFH 2500kHz 5kW: 0800-1625(Mon-Fri).
Ann: In Morse code after the 30th second of the 0th, 10th, 20th, 30th, 40th and 50th min – V. by letter.

Germany: DDR

TIME SIGNAL STATION NAUEN
Addr: Amt für Standardisierung, Messwesen und Warenprüfung der DDR, Staatlicher Zeit- und Frequenzdienst, Wallstr. 16, DDR – 1026 Berlin.
Station (DIZ): 4525kHz 5kW.
D.Prgr: 24h exc. 0815-0945 for maintenance if necessary. Type of transmission A1 type, second pulses of 0.1 s. duration, minute pulses of 0.5 s. duration. Additional information about the difference between the Universal Time UT 1 and the Coordinated Universal Time UTC, and also about the time of day (minute, hour) are encoded by double pulses in a special manner.

TIME SIGNAL STATIONS

TIME SIGNAL STATION ORANIENBURG
Addr: As for Time Signal Nauen.
Station (DGI): 185kHz 750kW.
D.Prgr: 30 seconds before 0600, 1200, 1800.
Type of transmission: Second pulses of 0.1 s. duration at the seconds 30-40, 45-50, 55-59, minute pulse of 0.5 s. duration.

Germany (Federal Republic)

DCF77, MAINFLINGEN, Germany
Addr: Physikalisch-Technische Bundesanstalt, 33 Braunschweig, Bundesallee 100, Fed. Rep. of Germany. **Cable:** Bundesphysik. **Te:** 5921.
L.P: Prof. Dr. h.c. G. Becker.
Station: DCF77 77.5kHz 50kW 24h second pulses, coded transmission of numbers of minute, hour, day, day of week, month and year in CET – **Pub:** Prgr. schedule on request – **V.** by letter.

GERMAN HYDROGRAPHIC INSTITUTE
Addr: P.O. Box 220, 2000 Hamburg-4, Federal Republic of Germany. **Te:** 311121. **Cable:** Hydrodienst, Hamburg. **Telex:** 211138 bmvhh.
L.P: Head Time Sce: Dr. H. Enslin.
Unmodulated time signals at 2355-0006 on DAN-2614kHz(2kW), DAO-2775kHz(2kW), DAM-6475.5kHz(5kW) (21/4-20/10); DAM-12763.5kHz(15kW) (21/4-20/10); DAM-4265kHz(5kW) (21/10-20/4); DAM-8638.5kHz(10kW) (21/10-20/4); 1155-1206 on 2614, 2775, 8638.5, 16980.4kHz(15kW) – **V.** by letter.

Great Britain

NATIONAL PHYSICAL LABORATORY (Gov.)
Addr: Div. of Electrical Science, Teddington, Middlesex, Gt. Britain. **Te:** 01-977 3222. **Cable:** Physics, Teddington.
MSF Standard Frequency Service

kHz	kW	
60	50	continuous
2500	5	continuous*
5000	5	continuous*
10000	5	continuous*

*continuous but tr. interrupted 6 times an h. at mins 5-9½, 15-19½, 25-29½, etc. The 60kHz service now provides BCD Time of Day information.
Ann: Call sign given twice in Morse code at minutes 9½-10, 19½-20, 29½-30 on the HF transmissions, and twice in the six seconds preceding the hour on the 60kHz transmission – **V.** by letter.

ROYAL GREENWICH OBSERVATORY
Addr: Time Dept, Herstmonceux Castle, Hailsham, Sussex, England BN27 1RP. **Te:** (032) 181-3171. **Cable:** Observer.
The international Time Signals are radiated by GBR 16kHz 750kW (radiated power: 60kW) (reserve: GBZ 19.6kHz) at 0300, 0900, 1500 and 2100.

Japan

STATION JJY
Addr: Radio Research Laboratories, Koganei 184, Tokyo, Japan.
L.P: Chief Freq. Standard Div: Y. Saburi.
Stations (all 2kW 24h): 2500kHz, 5000kHz, 10000kHz, 15000kHz.
All freqs are interrupted at 35-39 mins past each h. Mod. seconds pulses of 8 cycles of 1600Hz and 1000Hz tone. International code of DUTI, consisting of 45 ms-long pulses of 1600HZ, will be tr. during 0-15 sec in each min.
Ann: Every ten mins in each h. identifying signals are tr. consisting of call-sign in Morse code (twice), time in JST once in Morse code. Call-sign twice in voice, time in JST once in voice and grade of propagation warning in Morse code – **V.** by QSL-card.

South Africa

SOUTH AFRICAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
Addr: Precise Physical Measurements Division, National Physical Research Laboratory, CSIR, P.O. Box 395, Pretoria 001. **Te:** 74-9111. **Cable:** Navorsfis. **Telex:** 3-630SA.
Stations: Call ZUO (Olifantsfontein): 2500kHz 4kW: 1800-0400 daily; 5000kHz 4kW, 100MHz 0.05kW: 24h.
Time Signals: Continuous second pulses, consisting of 5 cycles of 1000Hz tone. The minute pulse is prolonged to ½ second.
Ann: In Morse code every 5 minutes: ZUO ZUO ZUO followed by the Universal time of the next minute – **V.** by QSL-card or letter.

United States

R. STN. WWV, WWVH, WWVB and WWVL (Gov.)

St. WWV, 2000 East County Rd. 58, Fort Collins, Colorado 80521, USA; St. WWVH, P.O. Box 417, Kekaha, Kauai, Hawaii 96752: WWVB, 2000 East County Rd. 58, Fort Collins, Colorado, USA.

L.P: Time and Freq. Sces Section: Sandra Howe. National Bureau of Standards, Boulder, Colo. 80302. Eng. in Charge: John B. Milton (WWV, WWVB). Eng. in Charge: Charles Trembath (WWVH).

Standard Radio Frequencies: WWV, 2500kHz 2.5kW, 5000kHz 10kW, 10000kHz 10kW, 15000kHz 10kW.

The broadc. are continuous night and day. WWVH 2500kHz 5kW, 5000kHz 10kW, 10000kHz 10kW, 15000kHz 10kW: Continuous – WWVB 60kHz 13kW: Continuous.

Programme: Effective 1 July 1971, the broadcast formats of WWV and WWVH were changed to include voice time ann. every min. instead of every five min. and to eliminate the Morse Code. To eliminate confusion between the two stations, the WWV ann. are made by a male and the WWVH ann. by a female. At WWV, commencing about 7½ seconds before the min. a male voice ann. of UTC (Coordinated Universal Time) is given as follows: "At the tone . . . hours . . . minutes UTC (Coordinated Universal Time)". At WWVH, commencing about 15 seconds before the min. a female voice ann. of UTC is similarly given. (The terms of "GMT" and "Z" are accepted as the general equivalents of UTC in navigation and communication).

Standard audio tones of 500 and 600Hz of 45-second duration are broadc. on alternate min. from each station. The beginning of each h. is identified by a 1500Hz tone of 0.8 second duration.

The Morse Code was deleted in the format. Ann. of weather information are given in plain language. At WWV weather information is given between the 8th and 9th and between the 9th and 10th and between the 10th and 11th min. At WWVH weather information is given between the 48th and 49th and between the 49th and 50th min. and between the 50th and 51st min. St. identification at WWV is given 1 min. after the h. and 31 min. after the h. St. identification at WWVH is given 1 min. before the h. and 29 min. after the h.

WWVB transmits a special BCD time code consisting of 10db carrier reductions each second (format on request).Transmitted phase will be advanced 45° for 5 min. each h. between 10 min. and 15 min. after the hours. No other identification will be given – **V.** by QSL-card or letter. **Pub:** Prgr. sched. on request.

ENGLISH-SPANISH CONVERSION LIST OF USEFUL TERMS IN REPORTING

AC	c.a.
AC hum	zumbido de c.a.
absorption	absorción
acoustic feedback	retroalimentación acústica
active antenna	antenna activa
adjacent channel interference	interferencia entre canales adyacentes
antenna/aerial	antena
antenna current	corriente de antena
antenna feed-impedance	resistencia de radiación de antena
air-core coil	bobina con núcleo de aire
air-gap	espacio de aire
to align	sintonizar ó alinear
alligator clip	pinza de conexión
American wire gauge (AWG)	calibre americano para alambres (AWG)
amplifier	amplificador
amplitude fading (AM)	desvanecimiento de amplitud (MA)
angle of arrival	ángulo de arribo
angle of elevation	ángulo de elevación
annealed wire	alambre recocido
announcer	locutor
antenna gain	ganancia de antena
aspect ratio (of TV) image)	relación dimensional de cuadro
assigned frequency	frequencia asignada
atmospheric interference (statics)	interferencias atmosféricas
attenuator	atenuador
audio frequency	audiofrecuencia
auroral zone	zona de aurora polar
automatic gain control	control automatico de ganancia
azimuth	acimut
background noise	ruido de fondo
band	banda
bandpass filter	filtro pasabanda
bandwidth	ancho de banda
beam	haz
beamwidth	amplitud del haz
bearing	rumbo
beat frequency	frecuencia de batido
beat note	tono de batido
bleeder resistor	resistencia de sangria
booster	reforzador
desired signal	señal deseada
detection (demodulation)	detección (demodulación)
detuning	asintonia
dial	carátula
diode	diodo
direct current (DC)	corriente continua (c.c.)
directional antenna	antena dirigida
directivity	directividad
discriminator	discriminador

distortion	distorsión
double sideband transmission	transmisión con dos bandes laterales
down lead	bajada de antena
dynamic loudspeaker	altavoz dinámico
E-layer	capa E
earth	tierra
electric field	campo eléctrico
electricity	electricidad
electrolytic capacitor	capacitor electrolittico
electromagnetic field	campo electromagnético
electron	electrón
electronics	electrónica
electrostatic precipitation	precipitación electrostática
enameled wire	alambre esmaltado
to fade	desvanecer
fading	desvanecimiento
to feed	alimentar
feeder	alimentador
field strength	intensidad de campo
HF broadcasting	radiodifusión por altas frecuencias
hop	salto
hum	zumbido
image frequency	frecuencia imagen
induction	inducción
input	entrada
insulated wire	hilo (conductor) aislado
interference	interferencia
intermediate frequency (IF)	frecuencia intermedia (FI)
IF amplifier	amplificador de FI
intermodulation	intermodulación
interval signal	señal de intervalo
ionization	ionización
ionosphere	ionósfera
ionospheric wave	onda ionizada
isotropic radiator	radiador isotrópico
jamming	radioperturbación
key	llave
knob	manija (perilla)
lightning arrester	pararrayos
line	línea
listener	radioyente
load	carga
loading coil	bobina de carga
local oscillator	oscilador local
long waves	ondas largas
long wire antenna	antenna unifilar larga
loop antenna	antena de cuadro
loudspeaker	altavoz
low pass filter	filtro pasa bajos
magnetic field	campo magnético
magnetic recording	registro magnético
magnetic storm	tempestad magnética
mains	linea de alimentación
man-made noise	ruido producido por el hombre
microphone	micrófono
to mismatch	desequilibrar
modulation	modulación

monitor	monitor
monitoring station	estación monitoria
multipath	trayectoria múltiple
network	red
night conditions	condiciones nocturnas
noise limiter	limitador de ruidos
omnidirectional antenna	antena omnidireccional
open wire line	línea aérea
outlet	salida
panel	tablero
parabolic reflector	reflector parabólico
parasitic antenna	antena parasítica
phase	fase
plug	clavija
plug-in coil	bobina intercambiable
pointer	puntero, indicador
polarity	polaridad
point-to-point circuit	circuito de punto a punto
potential	potencial
power	potencia
programme schedule	horario de programa
propagation	propagación
push-pull circuit	circuit de doble efecto
Q-factor	factor "Q" (factor de cadidad)
radial	radial
radiation pattern	patrón de radición
radiator	radiador
radio	radio
radio frequency (RF)	radiofrecuencia (RF)
radio noise	ruidos de radio
radio receiver	radioreceptor
radio wave	onda de radio
range	alcance
rated out	salida especificada
to rebroadcast	redifundir
receiver	receptor
record	disco, registro
recorder	registrador
reel	bobina
reflection	reflexión
refraction	refracción
relay station	estación relevadora
resonance	resonancia
rhombic antenna	antena rómbica
root mean square (RMS) value	raiz del valor medio de los cuadrados
rotor	rotor
to scatter	dispensar
scattering	dispersión
screening	blindaje
screened down lead	bajada de antena blindada
seasonal conditions	condiciones estacionales
selective fading	desvanecimiento selectivo
sender	transmisor
service area	área de servicio
shadow region	región de sombra
shared channel	canal compartido
short circuit	cortocircuito

shortwave	onda corta
signal	señal
single sideband transmission	transmisión con una sola banda lateral
site	situación
skip distance	distancia de salto
skip fading	desvanecimiento de salto
solar flare	protuberancia solar
solar flare disturbances	disturbios por las protuberancias solares
speech	conversación, discurso
stacking	apilado
stand-by	en espera
stand-off insulator	aislador de apoyo
standard frequency	frequencia patrón
strain insulator	aislador de tensión
stranded conductor	conductor de cable
stub	linea auxiliar corta
subcarrier	subportadora
sunspot	mancha solar
sunspot cycle	ciclo de actividad solar
sunspot number	indice de actividad solar
suppressor	supresor
switch	interruptor, conmutador
synchronization	sincronización
tank circuit	circuito tanque
tape	cinta
tape recording	registro en cinta
television	televisión
telex	telex
terminal	terminal
thermal noise	ruido térmico
time constant	constanto de tiempo
time signal	señal horaria
tinned wire	alambre estañado
tower (antenna)	torre de antena
transformer	transformador
transmitter	transmisor
tuned antenna	antena sintonizada
tuner	sintonizador
universal receiver	receptor universal
vertical antenna	antena vertical
VHF	muy alta frecuencia
vestigial sideband	banda lateral residual
vision frequency	videofrecuencia
visual range	alcance óptico
voltage	tensión
volume control	control de volumen
wave	onda
waveband	banda de frecuencias
wave trap	trampa de onda
wavelength	longitud de onda
wire-mesh screen	pantalla de malla de alambra
woofer	altavoz de gran potencia
Yagi antenna	antena Yagi
zero beat	polarizatión cero

SOME MAJOR FREQUENCIES BAND ALLOCATION LISTS

Frequency bands allocated to the broadcasting service in the various regions of the world.

Region 1	Region 2	Region 3
150- 285 kHz	—	—
525- 1605 kHz	525- 1605 kHz	525- 1605 kHz
2300- 2498 kHz*	2300- 2495 kHz*	2300- 2495 kHz*
3200- 3400 kHz*	3200- 3400 kHz*	3200- 3400 kHz*
3950- 4000 kHz	—	3950- 4000 kHz*
4750- 4995 kHz*	4750- 4995 kHz*	4750- 4995 kHz*
5005- 5060 kHz*	5005- 5060 kHz*	5005- 5060 kHz*
5950- 6200 kHz	5950- 6200 kHz	5950- 6200 kHz
7100- 7300 kHz	—	7100- 7300 kHz
9500- 9775 kHz	9500- 9775 kHz	9500- 9775 kHz
11700-11975 kHz	11700-11975 kHz	11700-11975 kHz
15100-15450 kHz	15100-15450 kHz	15100-15450 kHz
17700-17900 kHz	17700-17900 kHz	17700-17900 kHz
21450-21750 kHz	21450-21750 kHz	21450-21750 kHz
25600-26100 kHz	25600-26100 kHz	25600-26100 kHz
41- 68 MHz	54- 73 MHz	44- 50 MHz
—	—	54- 68 MHz
87.5- 100 MHz	75.4- 108 MHz	87- 108 MHz
174- 223 MHz	174- 216 MHz	170- 216 MHz
470- 960 MHz	470- 890 MHz	470- 585 MHz
		610- 960 MHz

*Usage limited to the tropical zone of the region concerned.

Frequency bands allocated to the amateur service in the various regions of the world.

Region 1	Region 2	Region 3
—	1800- 2000 kHz	1800- 2000 kHz
3500- 3800 kHz	3500- 4000 kHz	3500- 3900 kHz
7000- 7100 kHz	7000- 7300 kHz	7000- 7100 kHz
14000-14350 kHz	14000-14350 kHz	14000-14350 kHz
21000-21450 kHz	21000-21450 kHz	21000-21450 kHz
28- 29.7 MHz	28- 29.7 MHz	28- 29.7 MHz
—	50- 54 MHz	50- 54 MHz
144- 146 MHz	144- 148 MHz	144- 148 MHz
—	220- 225 MHz	—
430- 440 MHz	420- 450 MHz	420- 450 MHz
1215- 1300 MHz	1215- 1300 MHz	1215- 1300 MHz
2300- 2450 MHz	2300- 2450 MHz	2300- 2450 MHz
—	330- 3500 MHz	3300- 3500 MHz
5650- 5850 MHz	5650- 5925 MHz	5650- 5850 MHz

Frequency bands below 30 MHz allocated to the fixed services on an exclusive basis.

Region 1	Region 2	Region 3
—	160- 200 kHz	160- 200 kHz
4000- 4063 kHz	4000- 4063 kHz	4000- 4063 kHz
5060- 5250 kHz	5060- 5250 kHz	5060- 5250 kHz
5730- 5950 kHz	5730- 5950 kHz	5730- 5950 kHz
6765- 7000 kHz	6765- 7000 kHz	6765- 7000 kHz
7300- 8195 kHz	7300- 8195 kHz	7300- 8195 kHz
9040- 9500 kHz	9040- 9500 kHz	9040- 9500 kHz
9775- 9995 kHz	9775- 9995 kHz	9775- 9995 kHz
10100-11175 kHz	10100-11175 kHz	10100-11175 kHz
11400-11700 kHz	11400-11700 kHz	11400-11700 kHz
11975-12330 kHz	11975-12330 kHz	11975-12300 kHz
13360-14000 kHz	13360-14000 kHz	13360-14000 kHz
14350-14990 kHz	14350-14990 kHz	14350-14990 kHz
15450-16460 kHz	15450-16460 kHz	15450-16460 kHz
17360-17700 kHz	17360-17700 kHz	17360-17700 kHz
18030-19990 kHz	18030-19990 kHz	18030-19990 kHz
20010-21000 kHz	20010-21000 kHz	20010-21000 kHz
21750-21850 kHz	21750-21850 kHz	21750-21850 kHz
22720-23200 kHz	22720-23200 kHz	22720-23200 kHz

TELEVISION SYSTEMS

System indication	Number of lines per picture (frame)	Picture (frame) frequency (pictures/sec.)	Field frequency (fields/sec.)	Line frequency (lines/sec.)	RF channel bandwidth (MHz)	Sound carrier realtive to vision carrier (MHz)	Vision modulation	Sound modulation	Chief users
A	405	25	50	10125	5	– 3.5	A5C+	AM	UK
M	525	30	60	15750	6	+ 4.5	A5C–	FM	USA, Japan
N	625	25	50	15625	6	4.5	A5C–	FM	
B	625	25	50	15625	7	+ 5.5	A5C–	FM	Majority Cont. Europe
C	625	25	50	15625	7	+ 5.5	A5C+	AM	Belgium (north)
G	625	25	50	15625	8	+ 5.5	A5C–	FM	
H	625	25	50	15625	8	+ 5.5	A5C–	FM	
I	625	25	50	15625	8	6	A5C–	FM	Ireland
D, K, K1	625	25	50	15625	8	+ 6.5	A5C–	FM	USSR, most OIRT-members
L	625	25	50	15625	8	+ 6.5	A5C+	AM	
F	819	25	50	20475	7	+ 5.5	A5C+	AM	Belgium (south)
E	819	25	50	20475	14	10	A5C+	AM	France

TV SYSTEMS IN USE AROUND THE WORLD

Country	System used in bands: I-III	System used in bands: IV-V
Algeria	B, E	G, H
Argentina	N	N
Australia	B	—
Austria	B	G
Belgium	C, F	H
Benin	K1	K1
Bulgaria	D	K
Barundi	K1	K1
Cameroon	K1	K1
Canada	M	M
Central African Empire	K1	K1
Chad	K1	K1
Congo (Brazaville)	K1	K1
Cyrpus	—	H
Czechoslovakia	D	K
Denmark	B	G
Ethiopia	B	G
Finland	B	G
France	E	L
Gabon	K1	K1
Germany	B	G
Ghana	B, G	G
Greece	B	G
Guinea	K1	K1
Hungaria	D	K
Iceland	—	G
India	B	—
Indonesia	B	—
Iran	M	—
Ireland	A, I	I
Israel	B	H
Italy	B	G
Ivory Coast	K1	K1
Japan	M	M
Jordan	—	—
Kenya	B	G, I
Korea	M	—
Liberia	B	H
Libyan Arab Republic	B	G
Luxembourg	F	H
Madagascar	K1	K1
Malawi	B	G
Malaysia	B	G
Mali	K1	K1
Mauritania	K1	K1
Mexico	M	—
Monaco	E	L
Morocco	B	H
Netherlands	B	G
Netherlands Antilles	M	—
New Zealand	B	—
Niger	K1	K1
Nigeria	B	I
Norway	B	G
Pakistan	B	—
Panama	M	—
Poland	D	K
Portugal	B	G
Rhodesia	B	G
Roumania	D	K
Rwanda	K1	K1
Saudi Arabia	M	—
Senegal	K1	K1
Sierra Leone	B	G
Somali Republic	B	G
South Africa	I	I
Spain	B	G
Sweden	B	G
Switzerland	B	G
Tanzania	B, I	I
Togolese Republic	K1	K1
Turkey	—	H
Uganda	B	G
United Arab Republic (Egypt)	B	G, H
United Kingdom	A	I
United States of America	M	M
Upper Volta	K1	K1
Uruguay	N	—
USSR	D	K
Venezuela	M	—
Yugoslavia	B	G
Zaire	K1	K1
Zambia	B	G

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