The Lenkurt Demodulator

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THE USE OF RADIO FREQUENCY SPECTRUM

by Common Carriers

Among mankinds many natural resources, one, the radio frequency spectrum, is so abstract it can neither be seen, felt, nor heard. Yet, despite its abstract character, this resource is so valuable that most national governments have appointed regulatory bodies to supervise its use. Also, international agreements have been made so that all countries can obtain the maximum use of radio without interfering with each other.

This article discusses the radio frequencies available to common carrier (telephone companies) and industrial users of point-to-point radio. It points out some of the factors which should be considered in making use of this spectrum.

For practical purposes, the radio spectrum consists of frequencies from about 10,000 to more than 100,000 million cycles per second (100,000 megacycles). Within this range much of the world's long distance communications are transmitted.

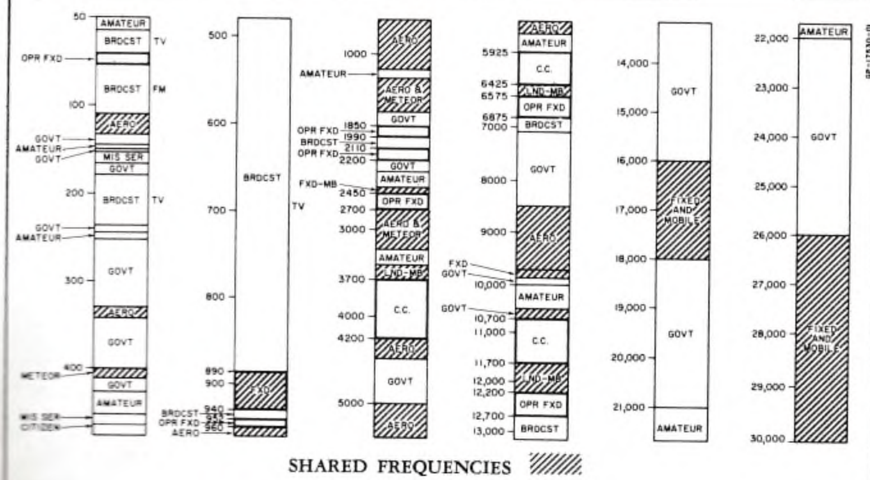
At present, only the spectrum from about 10,000 cycles to 10,000 megacycles has been put to commercial use. However, the constant demand for greater use of the frequency spectrum is giving impetus to intensive research aimed at increasing the practicability of higher frequency communication.

Many different individuals and organizations use the radio spectrum for message communication, radio and television broadcasting, remote control and supervision, and other services.

To make certain that anyone with a legitimate need for radio frequencies can obtain and use them without interference, the Federal Communications Commission of the United States was created by Congress to establish a system of licensing and allocation of the frequency spectrum. Similar agencies have been established for the same purpose in other countries. The licenses and allocations are based on need, history of use, and technical practicability. Fig. 1 shows a simplified chart of the existing allocations in the United States. More detailed information can be obtained from Title 47, Part 2 of the rules and regulations of the Federal Communications Commission.

The frequency allocation chart shows several different major classes of service covering every possible known use of radio energy. Telephone company use of the radio spectrum for the transmission of messages falls under the classification of common carrier. Railroads, pipelines, and other industrial users of radio fall under the industrial classification. Both fixed and mobile service allocations are available. Multichannel point-to-point radio and microwave systems are, of course, fixed types of service.

Telephone companies can operate fixed systems in the frequency bands from 890 to 940, 3700 to 4200, 5925 to 6425, and 10,700 to 11,700 megacycles. In addition some operation, necessarily restricted because of bandwidth, is permitted from 2450 to 2500 megacycles. The total usable frequency spectrum available for fixed point-to-point transmission of public correspondence (telephone and telegraph messages) is approximately 2100 megacycles. The 16,000 to 18,000 and 26,000 to 36,000 megacycle bands are also available for common carrier fixed service, although operation in these bands does not appear likely within the foreseeable future. Industrial fixed allocations, which include land transportation, public safety, marine, and aviation, are bands from 952 to 960, 1850 to 1990, 2110 to 2200, 2450 to 2700, 6575 to 6875, and 12,200 to 12,700 megacycles. The total presently usable spectrum for industrial fixed service is 1288 megacycles.



ABBREVIATIONS

AERO	Aeronautical Services	FXD	Fixed
MIS SER	Miscellaneous Services	LND-MB	Land-Mob
GOVT	Government	C. C.	Common Carrier
BRDCST	Broadcast	METEOR	Meteorological
OPR FXD	Operation Fixed (fixed services not for public correspondence)	FXD-MB	Fixed-Mob

COURTESY OF THE RADIO SERVICE COMMITTEE
UNITED STATES INDEPENDENT TELEPHONE ASSOCIATION

FIG. 1. Simplified frequency allocation chart for the United States of America. Only allocations above 50 megacycles are shown.

Present Usage

At present, most of the common carrier usage of the radio spectrum is in the 890-940 and 3700-4200 megacycle bands. Some common carriers are also operating in the 2450-2500 and the 5925-6425 megacycle bands. There are no common carriers operating in the 10,700-11,700 megacycle band, although some experimental work is being done in this range. In certain areas, some common carrier fixed installations are using special frequencies of about 80, 150, and 450 megacycles.

The special 80 megacycle allocation is for inter-island communications in Hawaii. The 150, 450, and 2500 megacycle bands are currently being used in some rather restricted applications.

Industrial use of the radio spectrum generally follows the same pattern as common carrier use. The lower frequencies are generally being used more than the higher frequencies.

Of the various bands available for common carrier, the 890-940 megacycle band is mostly used for small-to-medium numbers of telephone voice channels (up to 720 for non-repeatered systems). More than 20 companies are now using or installing Lenkurt 900 megacycle Type 72 equipment for the transmission of from 4 to 120 channels over routes up to about 200 miles long.

The 4000 megacycle band is more commonly used for longhaul backbone routes and for television. This is the band used by the Bell System on its TD2 routes.

Although only 50 megacycles wide, the 890-940 megacycle band has gained its popularity because of several important advantages inherent in systems operating below 1000 megacycles. Perhaps the greatest advantage of these systems is their use of conventional types of circuitry and components. Most of the circuits and components of Lenkurt 900-megacycle radio systems are similar to those used in the more familiar low-frequency radio and carrier equipment. They can be maintained with ordinary test equipment and without extensive training in new techniques. Typical 900 megacycle transmitting equipment is shown in Fig. 2. The only components of this equipment that differ appreciably from low-frequency radio and carrier are the cavity filters shown near the top of the left-hand rack.

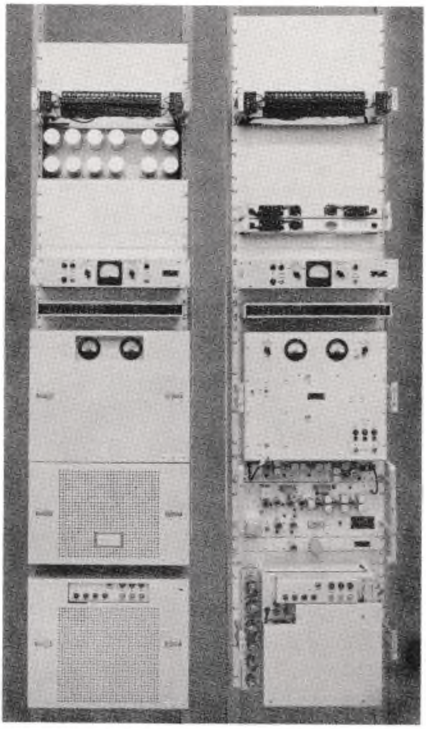


***FIG. 2.** Two Type 72 transmitter assemblies arranged to transmit over a common antenna.*

A second important advantage of the 900 megacycle band is its reliable propagation characteristics. Signals transmitted at 900 megacycles have been found to be less affected by atmospherics (refraction and reflection effects) than signals transmitted at 4000, 6000, or 11,000 megacycles. The free-space attenuation between antennas is also less at 900 megacycles than at higher frequencies. However, the greater antenna gains obtainable at higher frequencies often tend to offset this advantage.

Despite the desirable features of 900 megacycle equipment, both the common carrier band from 890 to 940 megacycles and the industrial band from 952 to 960 megacycles are relatively narrow. For this reason, these bands are rather restricted in voice channel capacity. In the 890-940 megacycle range, a total of 720 two-way voice channels can be transmitted over a single-hop Lenkurt system. With multi-hop systems, a channel capacity of 360 can be obtained. In the 952-960 megacycle band for industrial fixed service, approximately 120 voice channels can be transmitted over a single path.

Higher Frequencies

Above 960 megacycles, the allocation that best meets the present requirements of the majority of common carrier users is the 5925-6425 megacycle band. Of course, the 4000 megacycle band is much used throughout the United States by the Bell System for their nation-wide television networks. However, outside the Bell network, little if any equipment has been designed and manufactured for this band. Industrial users have a band from 6575 to 6875 megacycles, and three bands in the vicinity of 2000 megacycles. Many narrow-band voice and telemetering circuits are operated in these bands.

The chief advantage of the 6000 megacycle band for common carrier use is its generous allocation of frequency spectrum. The 500 megacycles available are sufficient to permit operation of several wide-band radio channels over a common path. With the proper radio and channelizing equipment, each radio channel can carry several hundred voice-frequency telephone channels. This is sufficient capacity to fulfill the telephone channel requirements of most common carriers for many years to come.

Although the 6000-megacycle band is valuable for its large channel capacity, it has some features which at present tend to retard its use among the smaller common carriers. This results from unfamiliar types of equipment and techniques, and also from somewhat more difficult engineering techniques. These retarding influences will undoubtedly be overcome as the industry becomes more adept in the use of the higher radio-frequency spectrum.

From an equipment point of view, the big difference between 900 and 6000 megacycle equipment is the use of waveguides instead of coaxial transmission lines, and the use of klystrons or other cavity-type tubes instead of conventional vacuum tubes. Typical 6000 megacycle components are shown in Fig. 3.

Future Use

As the need for point-to-point fixed communications grows, so will the need for wise use of the frequency spectrum. In the years to come, the 6000 and 11,000 megacycles bands will have to be used more and more. Lenkurt is currently developing a 6000 megacycle system that will be capable of transmitting up to 240 voice channels over a single radio channel. The new system will supplement the company's existing line of 80, 450, and 900 megacycle radio, but will not in any way take its place. The primary application of the new 6000 megacycle system will be for short-haul transmission over routes requiring a larger number of channels than 900 megacycle equipment is capable of providing.

Some consideration has also been given to the practicality of a *space carrier* system. Space carrier envisions the direct transmission of carrier channels by radio, but without first frequency or amplitude modulating a radio carrier wave. In essence, space carrier is single-sideband suppressed-carrier radio transmission. Such a method of operation would greatly increase the utility of existing spectrum allocated to common carrier and industrial fixed services.

Although radio is today one of man's most important long-distance communication methods, its use is really just beginning. In the future, more and more telephone companies and industrial users are expected to turn to point-to-point radio as a solution to their communications problems. In doing so, they will probably find it desirable to use the lower frequency spectrum first. This will enable them to obtain all the natural advantages and more familiar technology inherent in low-frequency radio operation. Then, as interference problems or the lack of channel capacity require, expansion can be made into the higher frequency bands. The progressive use of higher radio frequencies is in line with the experience which has been had in the use of wire-line carrier frequencies.

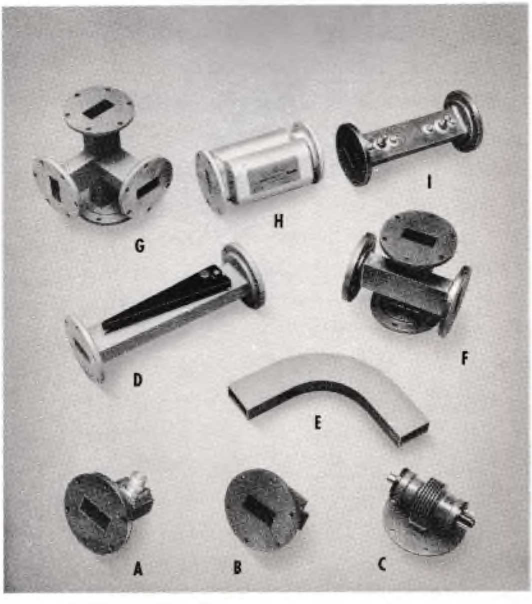


FIG. 3. Typical 6000 megacycle microwave components: (a) waveguide-to-cable (coaxial) junction, (b) line termination (load), (c) klystron vacuum tube, (d) variable attenuator, (e) curved section of waveguide, (f) directional cross-coupler (also a hybrid device), (g) waveguide hybrid (Magic T), (h) isolater (permits energy to flow in only one direction), (i) bandpass filter.

SUPPRESSED-CARRIER SINGLE-SIDEBAND

One of two methods of transmission is ordinarily used in amplitude modulated carrier communication systems. In one case, the carrier and both sidebands are transmitted. In the other case, the carrier is suppressed and either the lower or the upper sideband is transmitted. Since the latter method is most frequently employed, particularly for toll carrier, it is interesting to briefly consider some of the factors which make suppressed-carrier single-sideband transmission a preferred technique.

When a carrier wave is modulated by a complex speech wave, the ratio of average carrier power to average sideband power can become very substantial in magnitude. For the particular case of 100 percent modulation, this ratio is equal to the ratio of peak power to average power in the modulating wave.

If talker volumes are not controlled and vary as in ordinary telephony, the power in speech peaks can be as much as 31 db above the average speech power for very short intervals of time. The carrier power in the modulated wave must, therefore, be much greater than the average power in either of its associated sidebands. Consequently, circuit components in transmitted-carrier systems must be capable of handling relatively large amounts of steady carrier power without appreciably impairing speech quality.

In some systems the carrier, after being used for modulation, is transmitted at a reduced level. At the receiver, the reduced-level carrier is separated from the signal with filters and then amplified sufficiently to give satisfactory demodulation. This method of reduced-level carrier transmission has features that are common to both suppressed and transmitted-carrier systems.

When the carrier is suppressed (by the use of balanced modulators, filters, or by both), one of the sidebands can be transmitted at a level comparable to that which would otherwise be employed for transmitting the carrier. However, suppressed-carrier transmission requires carrier oscillators at both the transmitting and the receiving terminals of a system. The frequencies of the two oscillators must be adequately controlled at all times, since any substantial difference between the modulating and demodulating carrier frequencies causes distortion.

In modern types of carrier—for example, Lenkurt's 45-class equipment—close carrier frequency synchronization is obtained through the use of precision crystal-controlled oscillators. These oscillators have a frequency deviation of only about one part in a million, or about 0.2 of a cycle deviation at 150 kc.

Advantages of Suppressed-Carrier

A transmitted-carrier system offers some simplification in circuitry, and avoids the frequency control problem inherent in suppressed-carrier operation. However, the power-handling capacity of its amplifiers, filters, and other circuit components must be substantially greater (because of the transmitted carrier) to obtain a signal output equivalent to that of a suppressed-carrier system.

Since power-handling capacity is subject to both physical and economic considerations, sidebands cannot—in general—be transmitted at as high levels when the carrier is transmitted as they can when the carrier is suppressed. Consequently, greater signal-to-noise ratios are practicable with suppressed-carrier transmission. This method of transmission also enables intermodulation effects to be reduced to a greater extent—other factors being equal.

However, suppressed-carrier is not ordinarily as economical with respect to circuit components as transmitted-carrier.

Sideband Transmission

Transmitted-carrier systems usually employ double-sideband transmission—that is, both the lower and upper sidebands are transmitted with the carrier. With suppressed-carrier transmission, only the lower or the upper sideband is transmitted, depending upon the frequency allocation of the particular system involved. Consequently, single-sideband transmission requires only one-half the frequency space to transmit the same amount of information.

From a noise standpoint, double-sideband transmission is about 3 db to 6 db less susceptive to the effects of noise for equal sideband levels. However, because the single sideband of a suppressed-carrier system can be transmitted at a higher level, the greater signal-to-noise ratio thus obtained substantially offsets the double-sideband noise advantage.

Single-sideband transmission is subject to some frequency and phase distortion in the region adjacent to the carrier because of the necessary filter cutoff characteristic in that region. A filter having a sufficiently sharp cutoff to minimize this effect could be used, but such a filter is relatively costly and is not justified for ordinary speech transmission.

Double-sideband transmission avoids these effects since filter attenuation in the carrier frequency region does not differ substantially from that in other portions of the passband. In addition, somewhat more economical filter designs are practicable. However, these advantages are obtained by sacrificing frequency space.

In addition to sacrificing frequency space, double-sideband systems are subject to the requirement that the two sidebands add *in-phase.* This means that the circuit components must have sufficiently linear phase characteristics to obtain satisfactory performance.

Conclusion.

Both methods of transmission have advantages as well as disadvantages. However, suppressed-carrier single-sideband transmission has become the preferred technique in carrier system design, particularly for toll usage. This is because of its outstanding advantages with respect to the conservation of frequency space, with an accompanying economy in line treatment; improved signal-to-noise ratios; and better control of intermodulation effects with economical types of equipment.

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Carrier and Microwave Dictionary

Textbooks and other sources of information pertaining to carrier and microwave radio communication often contain technical terms whose meanings require definition. DEMODULATOR readers may therefore be interested in receiving the copy of Lenkurt's CARRIER AND MICROWAVE DICTIONARY which is being mailed to them this month. In addition to defining a large number of terms as simply as possible, the dictionary contains an appendix consisting of various charts, graphs, and nomographs which it is believed will be of interest.

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