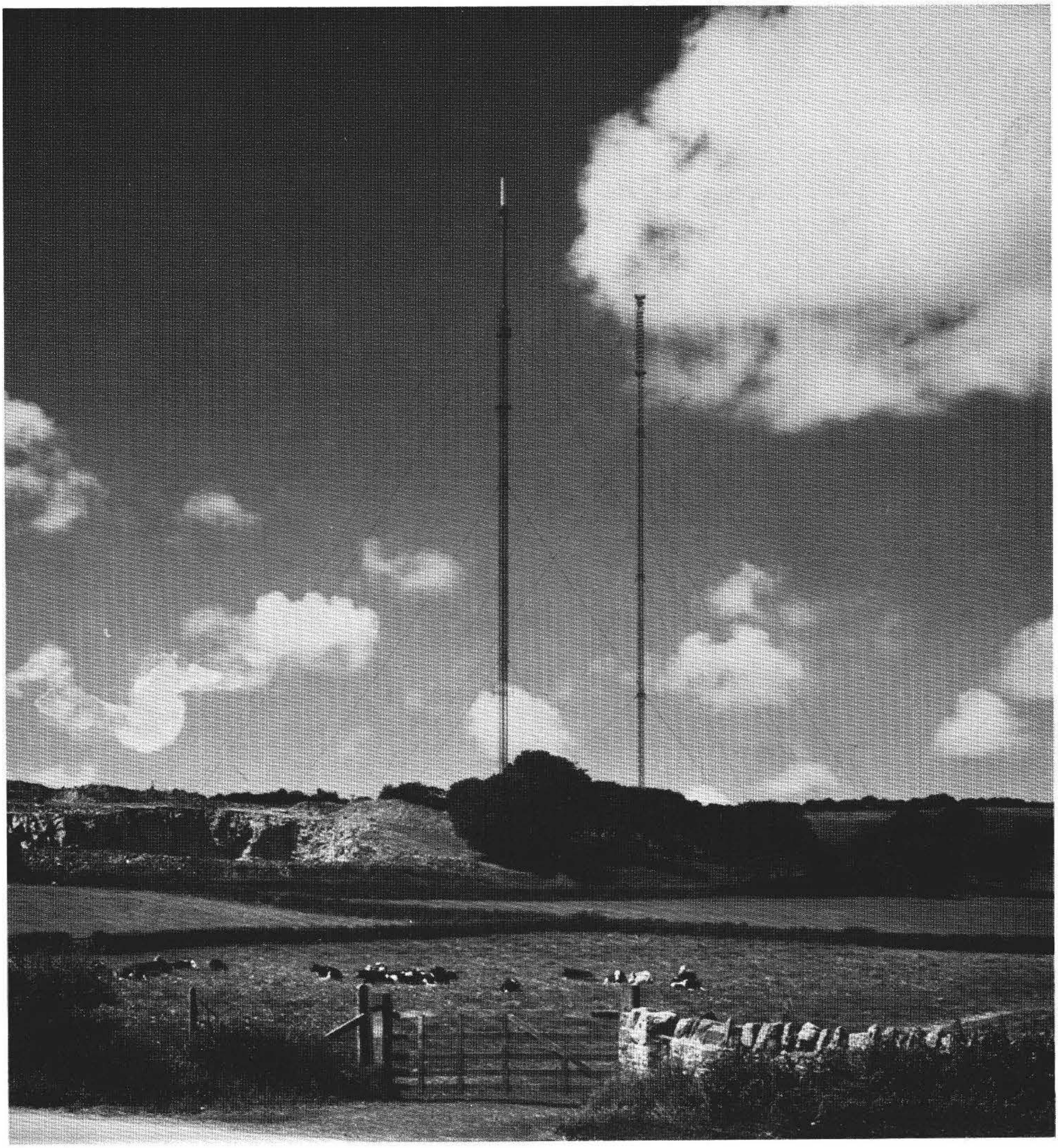
BBC ENGINEERING

MR MONTBATH

Number 99 August 1974



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Contents

The cover photograph shows the two masts of the Wenvoe transmitting station in the countryside five miles west of Cardiff.

The major contributions are preceded by individual lists of contents.

Editorial

The Computer in Broadcasting

In the beginning computers were designed by scientists for scientific purposes, and the commercial world has been trying to mould this machine to serve its purposes ever since. We may well say that there is nothing fundamentally wrong in this, but it has meant that often the real users have been dissatisfied and the public by and large disenchanted. There is little doubt that this has given the computer itself and the industry in general a bad name without getting to the root cause of the trouble.

The trend in the BBC as in many other organisations has been towards centralisation in terms of computer equipment, hardware and control. For jobs that can be batched and run on a scheduled basis this is undoubtedly the most cost-effective method, particularly where the turn-round of a day or so is not a critical factor and the optimum loading on the computer over twenty-four hours can be approached. Many commercial and accounting activities can be adequately provided for by this method. However, many jobs not amenable to this approach have had it imposed upon them, sometimes through economic pressures, sometimes through lack of appreciation of the real requirement and the identification of the real user, and sometimes through a lack of interest on the part of the user himself who did not understand what was happening to him. Fortunately in all these areas matters are improving. The cost of computing, although rising, is not doing so at the same inflationary rate as the rest of the economy. Systems can now be more orientated to the user's needs, perhaps by the use of a terminal located in his office. In this way, the user can have direct access to the system for calculations or to refer to any file of information that he has built up. Thus he appears at least to have some control over his destiny. There is also a greater interest on the part of people affected by the computer if only because of bitter experience of the shortcomings of earlier systems and a realisation that it is not quite such a black art as was previously supposed. All these stirrings augur well for the future.

Against this background many engineers can count themselves lucky in that, although the computing power needed for their projects cannot be provided by computers within their organisations largely on the grounds of cost, many of them do have access to the necessary power and data storage, when this is needed, by the use of terminals attached via Post Office lines to computer bureaux. Engineers have long believed that control of their own projects and a speedy response are essential when performing scientific calculations. Suitable facilities can provide both of these features together with adequate storage in the computer for programs and data painstakingly built up.

The demand for terminals, both visual display units and printers connected on-line, is increasing and soon the sophistication and speed of response on the existing types of terminal will leave something to be desired. Using modern techniques, more and more storage local to the terminal and built-in programmable features will be available at reasonable cost. These outposts of computing will grow and the trend will be towards decentralisation of hardware making the task of maintaining compatibility between systems more and more complex. This compatibility problem is not solely related to hardware in terms of codes, types of connection, and voltages used to represent a 'bit' or 'no bit'. It is an even greater problem for systems and programs needing to use common data and the ability of one system to have access to the files of another. This need must be identified and catered for at the outset of the system's design, using common methods, common languages and common standards. To achieve this a greater degree of discipline will have to be exercised than at present.

Few manufacturers currently provide equipment able to cope with a smooth transition between the various mixes of work while maintaining an optimum loading on the machine. The introduction of a communications processor between the on-line users and the main computer processor relieves the main processor of the routine work of servicing the remote terminals and marshalling the flow of data, thus leaving it more time to concentrate on batched work. Hopefully, the provision of such a processor within the BBC's facilities later this year will provide some relief in this way but even so the total system will still not have the capacity necessary, for example, to cope with the work of our research department that is covered in this issue of *BBC Engineering*.

In the development of computer systems the BBC's policy has been to use a bureau, until such time as the activity, which costs real money paid by the user department, reaches such a peak as to warrant an internal provision by upgrading the existing main computer. This is a fine theory, but unfortunately it can mean changes to the computer hardware causing disruption to the production work of existing users.

Improved methods of exploiting the computer's brain are constantly being thrust upon users by manufacturers in the shape of more and more sophistication in operating systems quite apart from major changes in the actual hardware. The user has very little choice in all this because software, i.e. programs written by the manufacturer in the shape of operating systems, need maintenance just as much as hardware and if the manufacturer decides the software is obsolete he can and will refuse to maintain it after a certain date. The user then has no choice but to move on to the next generation.

It is perhaps too much to hope for a period of stability in an industry that for all its sophistication is hardly a teenager.

Wenvoe – the BBC's Largest Television Station

A. E. Gallon
Transmitter Group

1 Introduction

The largest of the BBC's combined television and v.h.f. radio stations is Wenvoe. One of some 290 BBC transmitting stations, Wenvoe has a power consumption of $1\frac{1}{4}$MW to give a total effective radiated power of 1800 kW. The twenty-two operational transmitters are housed in a single-storey building with 2200 sqm of floor space, and there are two masts – one of 229 m and the other of 189 m. All in all, the transmitters and the 3500 items of ancillary equipment add up to a technical complex that places Wenvoe among the largest of the world's television stations.

Located five miles west of Cardiff, 400 feet above sea level on St Lythan's Down, Wenvoe serves a potential audience of four million with four BBC television and four v.h.f. radio services. This range of services, combined with the historical pattern of their introduction and the progress strides that has taken place in transmitter technology, has produced not only a large quantity, but also a unique range, of equipment. The story of Wenvoe reflects, to a large extent, the story of high-power v.h.f. and u.h.f. transmitting station development. Each phase of the installation illustrates one of the major steps that have been taking place, either in equipment technology or systems design, in the evolution of present-day u.h.f. transmitters from the pioneer v.h.f. equipment of the 1930s.

2 VHF services

2.1 Band I television

Opening in 1952, on 15 August, with a single v.h.f. service, Wenvoe provided South Wales and a large part of the West of England with television programmes for the first time. In common with the BBC's four other high-power Band I (41–68 MHz) stations designed in the late 1940s, the original Wenvoe station manifests a substantial number of improvements over its Alexandra Palace predecessor. The high-power vision transmitter, in particular, incorporated many of the techniques and innovations that had emerged from the intensive and fruitful development period of the war and early post-war years. Significant advantage was derived, for example, from improvements made in v.h.f. transmitter valves. In conjunction with the then recently-developed triple-tuned output and intervalve coupling circuits and the improved constructional techniques of earthed-grid amplifiers, these valves enabled output powers far in excess of those possible before the second world war to be attained. Developments in feedback techniques and the introduction of line clamp circuits produced further benefits. Of particular importance was the capability to exploit valve characteristics fully and the achievement of much-improved standards of overall stability.

In comparison with these equipment developments, the system design was less ambitious. It reflected the established radio broadcasting concept of employing a high-power transmitter to provide the service, with a low-power transmitter standing by to minimise the risk of a complete loss of transmission during fault conditions.

The basis of Wenvoe's Band I installation is an EMI 50 kW low-level modulated vision transmitter and an STC 12 kW Class B sound transmitter. Their individual r.f. power outputs are combined in a coaxial line combining unit which feeds, under normal conditions, the main Band I aerial system. The high-power equipment is backed up by a reserve Marconi 5 kW vision transmitter and a 1·25 kW sound transmitter, with reserve aerial facilities. The overall system is illustrated in Fig. 1. Whereas it is reasonably versatile – offering a number of alternatives for ensuring that the service is maintained during fault conditions – all switching has to be carried out manually. As a result, the systems design calls for full-time staff attendance throughout programme hours and necessitates breaks in service to effect switching.

2.2 Band II v.h.f. radio

These disadvantages and the further one of operating reserve equipment on a standby basis, with an associated under-utilisation of equipment, prompted the very different ap-

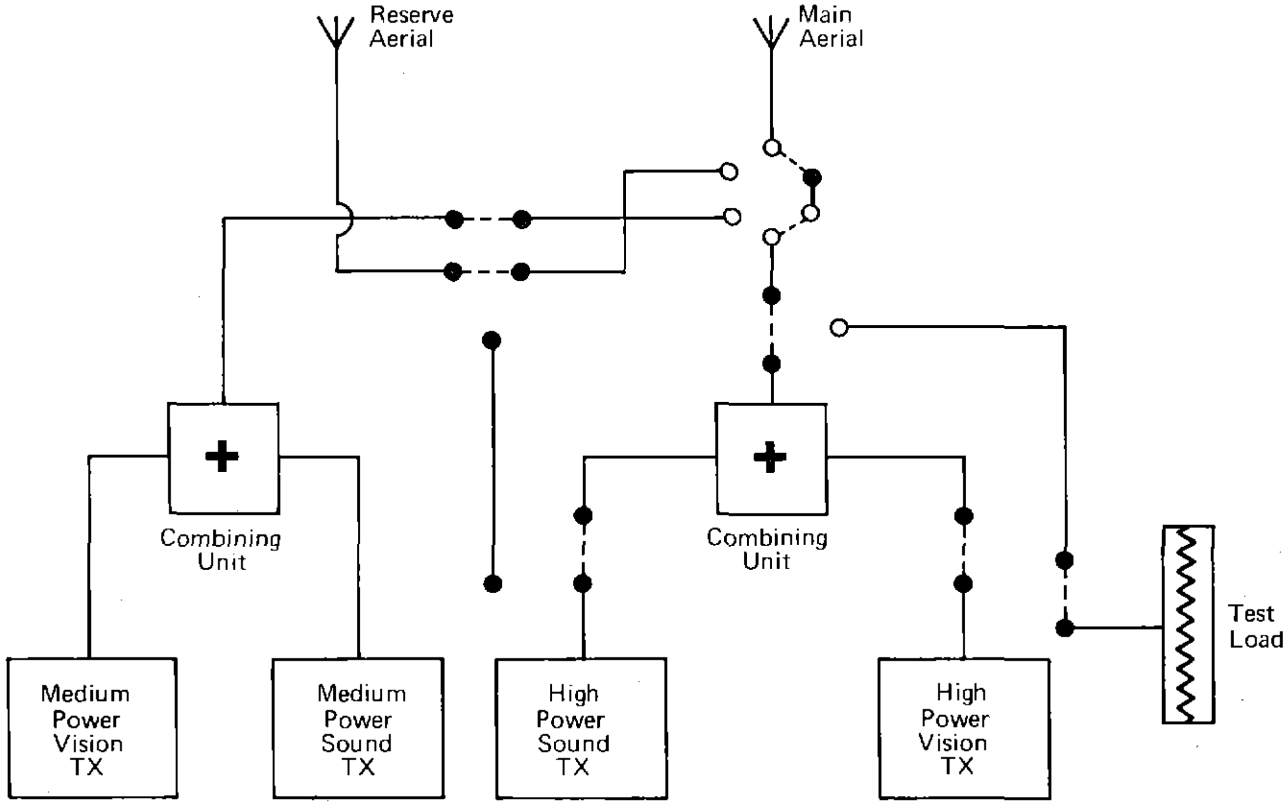


Fig. 1 *Wenvoe Band I System*

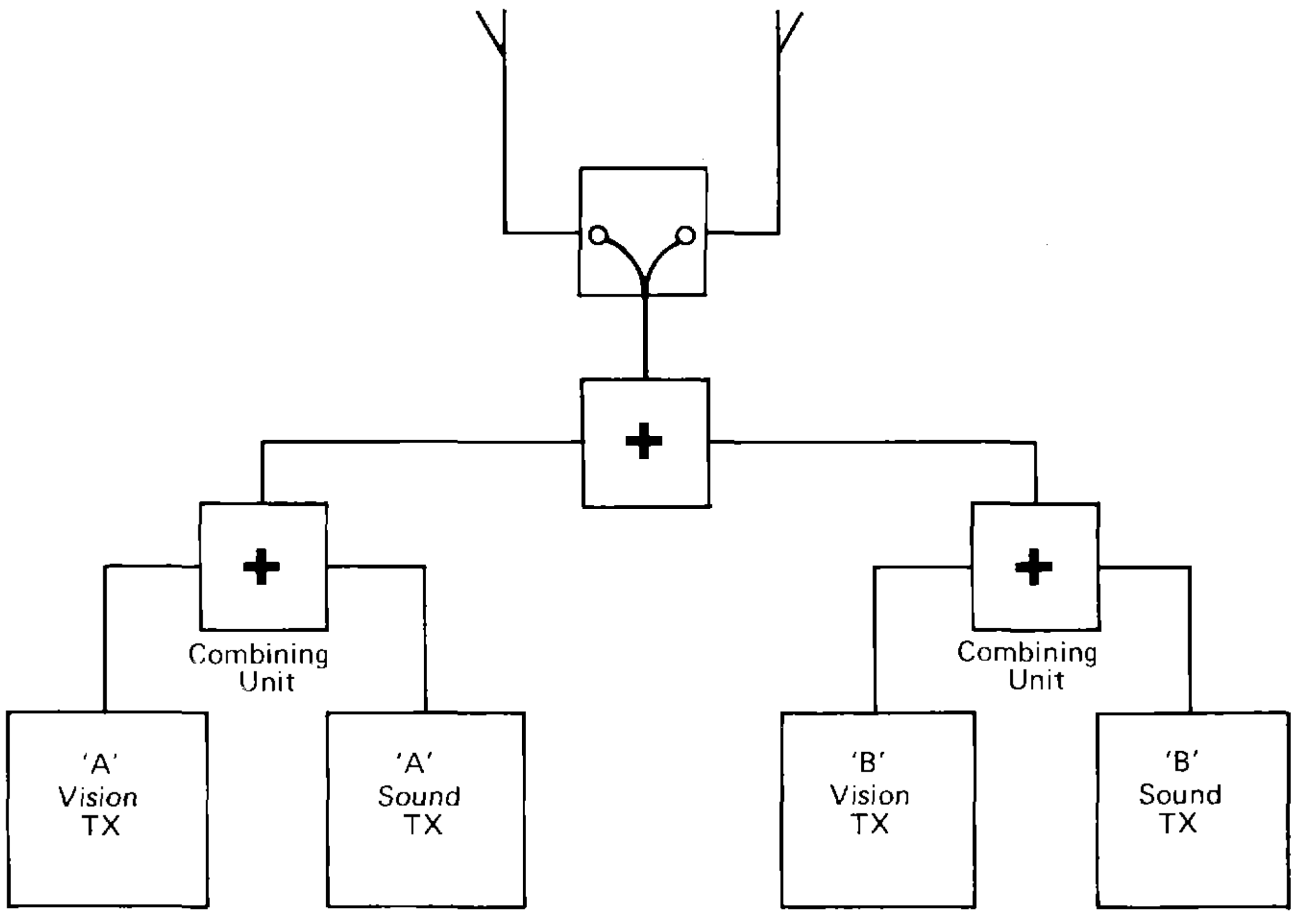


Fig. 2 Wenvoe Band III System

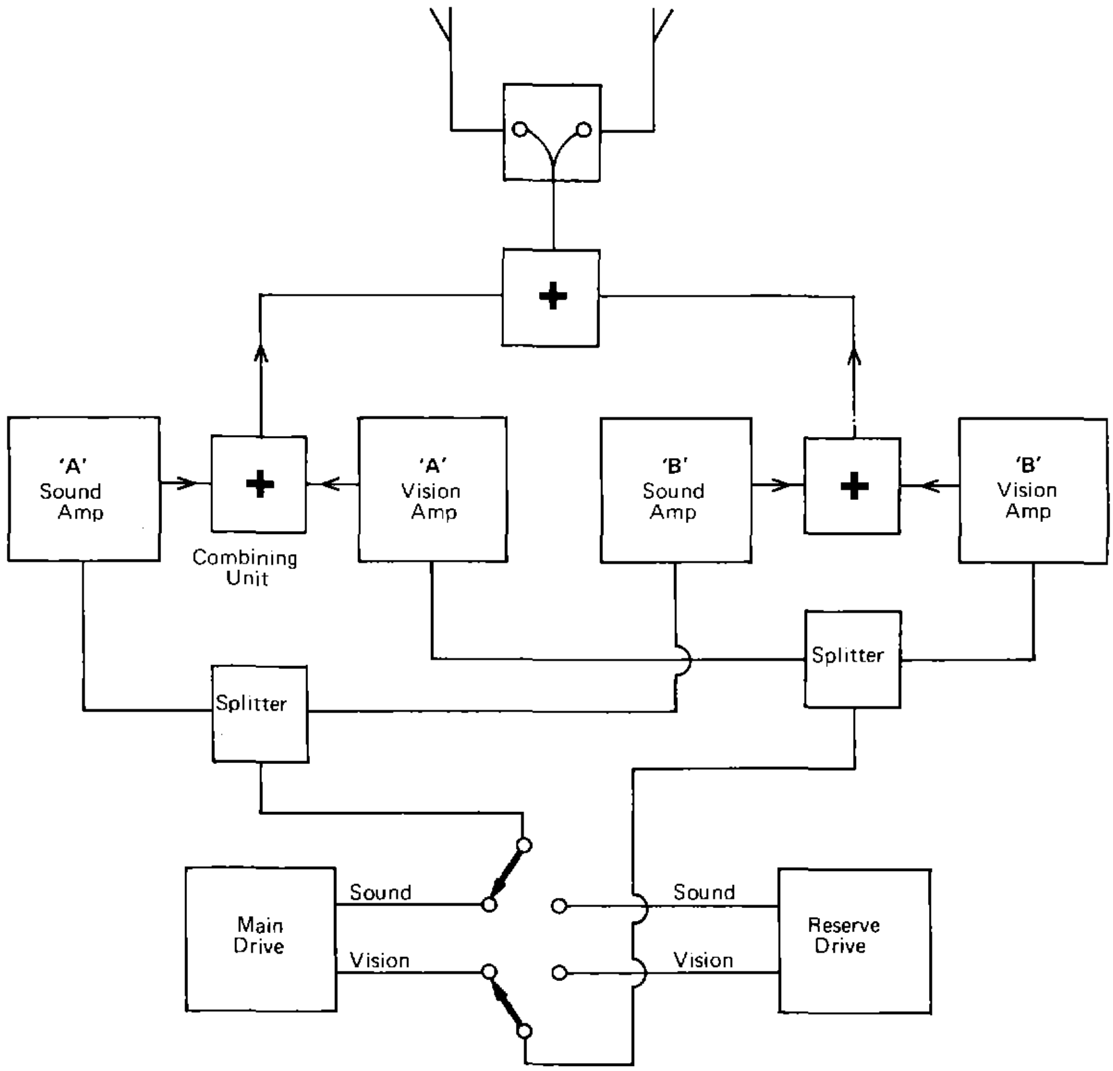


Fig. 3 Wenvoe BBC 2 UHF System

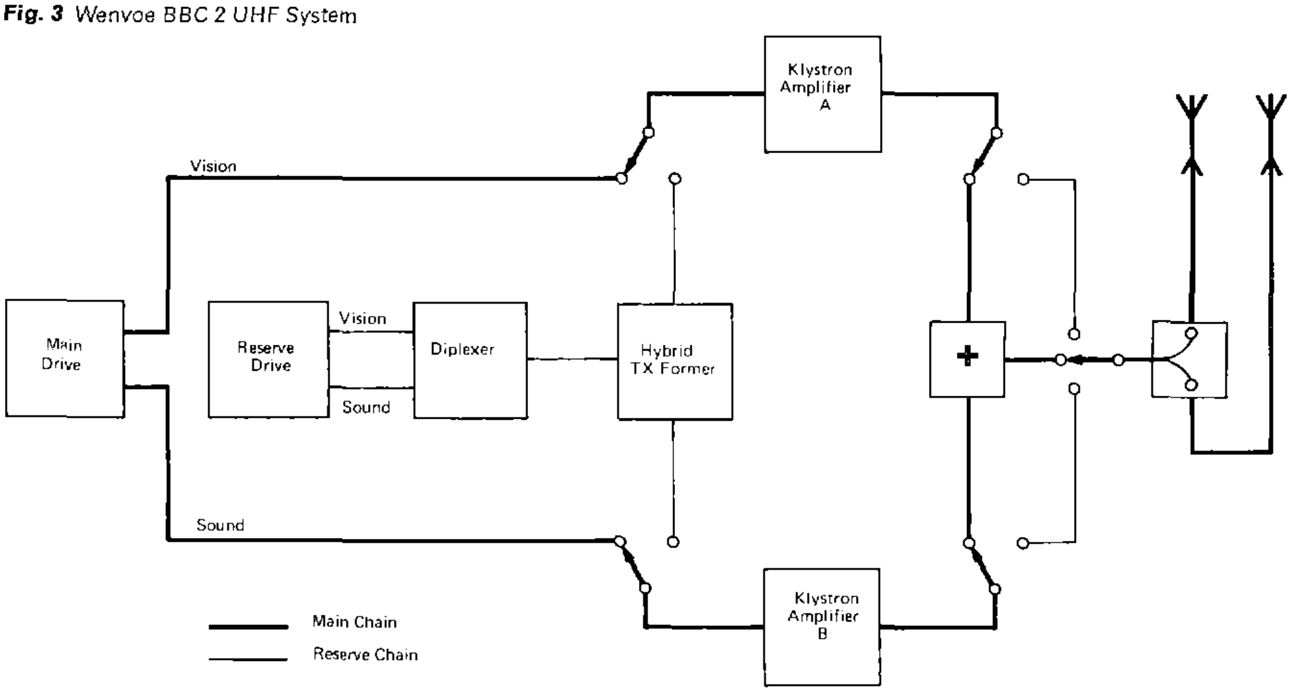


Fig. 4 Wenvoe BBC Wales UHF System

proach used in the system design of the Band II* v.h.f. radio installation. The aim – unattended automatic operation of the transmitters concurrently with optimum use of equipment – was achieved by employing two identical transmitter amplifiers for each service, operating them in parallel and independently of each other, and feeding their r.f. power outputs to separate halves of the Band II aerial. This arrangement was to become the standard method of operating v.h.f. and u.h.f. high power transmitters for a number of years.

The first of the four v.h.f. radio services, the Welsh Home Service – now Radio 4 (Wales) – was installed in 1955. The Light Programme and West of England Home Service – now Radios 2 and 4 – followed in 1956 and the radio installation was completed in 1959 when the Third Programme transmitters – now Radio 3 – came into service on 1 March.

2.3 Introduction of new regional services

By providing Home Service transmitters for both Wales and the West of England, these two geographically and culturally separate areas could be provided with their own regional v.h.f. radio programmes – a feature that had existed at m.f. for a number of years. By comparison, and in contrast also with other BBC Regions, the content of local television contributions from both Cardiff and Bristol was severely curtailed. The limitations of sharing a single television channel were to remain, however, until 1964 when a number of additional channels became available to the BBC. The opportunity was then taken to add a second transmitter service at Wenvoe and these new transmitters, operating in Band III (174–216 MHz), heralded the start of the separate BBC Wales Service and left the older Band I equipment to BBC-1 and BBC-West.

2.4 Band III television

In line with the accepted practice at this time, the BBC-Wales Band III transmitters were operated in the same manner as the v.h.f. radio equipment. Fig. 2 illustrates the basic system. Each half of the installation comprises a Marconi 10 kW vision transmitter amplifier and a 2·5 kW sound transmitter amplifier, their r.f. outputs being combined in Maxwell Bridge type combining units. Unlike the frequency-modulated Band II installation, however, the combined r.f. power outputs of the frequency-modulated television transmitters are not fed directly to the separate halves of the aerial system, but are fed instead via a diplexer. This arrangement prevents the vertical radiation pattern being affected by differences in the r.f. power output and video modulation level of either set of transmitters – a feature which minimises reception difficulties in areas where the vertical radiation pattern has minima.

The systems design of the Band III installation offers a number of advantages over its BBC-1 forerunner. For example, a failure of either vision or sound transmitter does not result in a break in service and the scheduling of planned maintenance is eased considerably since work may be spread throughout a longer period of the day than is permissible with the Band I transmitters. This arises since, in addition to being able to switch transmitters in and out of service without affecting the continuity of transmission, removal of one set of the Band III transmitters results in a more acceptable fall in output power than occurs when the reserve Band I installation is brought into service.

From the equipment standpoint, the Band III installation offers other advantages. Operating transmitters in parallel reduced the power output requirements of individual transmitters in relation to single-transmitter working and this arrangement, allied with improved techniques and the narrow bandwidth ratio resulting in the use of Band III, paved the way for transmitters of a less complex design. In addition, the transmitter cooling arrangements were simplified: the Band III transmitter valves employ air cooling whereas, in the Band I vision transmitter, the output valves are water-cooled.

* Nominally 87.5–100 MHz, but not all of this band is available for broadcasting.

3 UHF services

South Wales received its first colour programmes from Wenvoe in 1967. These transmissions were made from the BBC-2 u.h.f. equipment which had been brought into operation, transmitting monochrome programmes, two years earlier. Though not used to radiate colour programmes initially, the BBC-2 installation was designed to be 'colour capable'. The handling of colour transmissions demanded both higher performance and stability; requirements that led to the use of multi-cavity klystrons in preference to the established and more familiar tetrode final amplifiers. This brought an entirely new concept of transmitter technology to Wenvoe. The basis of the installation, illustrated in Fig. 3, is two sets of klystron amplifiers which are operated in parallel. The combined power output of each vision klystron (25 kW peak sync.) and sound klystron (5 kW) is fed into a splitter before being routed via 2-channel and then 4-channel combining units to the Band V (614–854 MHz aerial system – an arrangement that offers all the advantages of the Band III installation.

By 1970, when the BBC Wales service was duplicated at u.h.f., the BBC's method of operating such transmitters had been radically altered. Two 40 kW klystron amplifiers formed the basis, as shown in Fig. 3, of this particular installation, each amplifier being independently driven by separate vision and sound driver units. The sound and vision klystron outputs are combined in a two-channel combining unit, and the resulting output is fed to a diplexer unit. Failure of one of the klystrons or one of the main drive units automatically brings the reserve drive units into service. Under these conditions, the output of the reserve vision and sound drive units are combined, at low power, and fed to a single klystron – the non-faulty one – if it is a klystron failure that has initiated the switch to reserve conditions. The broadband capabilities of the klystron make this arrangement possible, but their inherent non-linearity makes it necessary to limit the power output to approximately one-fifth of normal in this mode of operation, to reduce intermodulation between the vision colour sub-carrier and the sound and vision carrier frequencies to acceptable proportions.

This method of operation, which is in accordance with a BBC Specification, results in a slightly greater reduction in output power under reserve conditions than occurs with the BBC-2 system. It also involves a short break in transmission – approximately ten seconds – but it saves the capital cost of two klystron amplifiers and it achieves a significant reduction in operating expenditure.

4 Staffing

Although these advances in transmitter technology and systems design made the growth and development of Wenvoe possible, the successful implementation of each phase of the installation owes much to the skills and enthusiasm of station staff.

A total of twenty-six staff are currently employed at Wenvoe – the number was only six fewer in 1952, when the station operated with a single service and their responsibilities now extend also to the maintenance of a number of unattended stations in the South Wales area. Of these twenty-six staff, twenty are Engineers or Technicians. Just over half of them are engaged on shift keeping duties that provide an engineering presence through the major part of programme transmission time. Their work includes all operational and monitoring commitments, attendance to fault conditions and the execution of certain items of scheduled maintenance. The remainder of the scheduled maintenance programme, the maintenance of unattended stations, special investigations and equipment modifications are carried out by maintenance support staff who, like the non-technical members of the Wenvoe staff, are employed predominantly on day work.

The content and pattern of this work has, of necessity, been subjected to continuing change. As additional equipment and new technologies have been introduced both at Wenvoe and at the increasing number of unattended stations in South Wales, maintenance practices have been rationalised, operational duties have been modified and equipment and systems adapted to accommodate each new situation.

5 Monitoring facilities

Of particular importance in this context has been the development of the station's monitoring facilities. The focal point of Wenvoe monitoring, and in fact of transmitter operations in South Wales, is the Band I control desk. The desk was originally designed to facilitate central control and monitoring of the Band I vision and sound transmitters – the aim being to provide a single operator with an overall view of the high power transmitter equipment and, at the same time, provide him with immediate access to both BBC studio staff and Post staff in Cardiff. Arrangements were also made for remote switching of the filament supplies in the reserve Band I transmitters.

The facilities have since been substantially extended. The reserve Band I transmitters can now, for example, be fully powered from the control desk and station staff have devised and installed a simple routing and monitoring system that permits, by means of push-button selection, assessment of the incoming and outgoing signals of all Wenvoe services.

Facilities for the monitoring of a number of unattended stations in the South Wales area have also been incorporated. Check receivers provide picture and audio monitoring of all remote stations from which 'off air' reception of Wenvoe is possible; the video and audio outputs of each receiver being routed into the monitoring system. Monitoring 'off air' at Wenvoe is achieved via Post Office exchange lines. Such stations are fitted with telephone indicator panels which, when interrogated by means of a telephone call, transmit a coded signal to the caller indicating the state of the station's equipment. A refinement of this system has recently been introduced at certain of these stations. It comprises an automatic calling device which, if a fault condition arises, automatically initiates a telephone call to Wenvoe, and when acknowledged by a suitable signal, transmits a coded message, identifying the faulty equipment.

Automatic monitoring is also utilised in respect of Wenvoe's own transmissions, BBC-designed monitors being provided for this purpose. These monitors are used to initiate the necessary switching action to close down defective equipment and, when practicable, to bring reserve facilities into service should the performance of any of Wenvoe's transmissions other than BBC-1 v.h.f. – which is manually controlled – deviate from a pre-set standard. Facilities are also available to enable the Band II, III and V transmitters to be controlled and monitored in their own transmitter halls – an essential requirement when adjusting performance and under certain fault situations.

Quality audio monitoring can be undertaken in a specially designed Quality Check Room – part of the original installation this, although the equipment has been refurbished since the station's opening and the source selection extended to embrace the additional services.

6 Test equipment

Developments in monitoring facilities have been closely allied to the developments in test equipment. There are now some 200 individual items of test equipment at Wenvoe ranging from simple test meters through a variety of waveform generators, counters, oscilloscopes and measuring devices to a sideband analyser and a spectrum analyser.

Much of the equipment has been designed for portable use – a necessary requirement in view of the versatility of application and the geographical spread of transmitter equipment both within the Wenvoe complex and in South Wales generally.

The development of this sophisticated range of portable equipment has gained appreciably from the advance of solid state technology, in terms of physical size, reliability and performance stability. These latter two features have also proved beneficial in other areas of the station's ancillary equipment as well as in the transmitters themselves.

7 Programme inputs

This has been particularly true in respect of programme input equipment. Substantial improvements in both performance and reliability have been achieved from the introduction of solid-state amplifiers, receivers, limiters, monitoring and switching devices, in comparison with their valve-type predecessors. Solid-state technology has also made possible the development of a number of important new devices, the most notable, within the programme input equipment, being the line store standards converter – in itself one of the major recent developments in television engineering.

Since all three video input feeds to the station are at 625-line standard, two line standards convertors are in continuous use during programme transmission time. One derives the 405-line input for the v.h.f. BBC-1 transmitters and the other the the 405-line input for the v.h.f. BBC-Wales equipment. The BBC-2 and BBC-Wales feeds are routed by coaxial line from Cardiff and the BBC-1 feed is obtained by means of 'off air' reception from Mendip. Of the transmitter audio inputs, only the four v.h.f. radio services are line fed. The introduction, in 1972, of 'sound in syncs' techniques obviated the requirement of separate audio feeds for television.

Inevitably, the combination of the Wenvoe site location in both geographical and topographical relationship to South Wales, and its close proximity to the Cardiff Studio Centre, has led to the station being in regular receipt of another type of programme feed – the television outside broadcast contribution. Wenvoe is, in fact, the collection point for television outside broadcasts in South Wales, two paraboloid aerials mounted at 176 m on the 229 m mast providing full 360° coverage of the catchment area. A receiver mounted at 176 m demodulates the 7 GHz signal and the video feed to Cardiff is via a coaxial cable.

8 Station power supplies

The other type of 'feed' into Wenvoe – the electrical mains supply – is provided by means of three 11kV three-phase power supplies feeders from the South Wales Electricity Board. Power is taken from only one of the three feeders at any given time and facilities have been incorporated for automatic changeover from the preferred feeder in the event of a fault condition.

The preferred feeder supply is terminated on the station's main 11kV busbar, which in turn feeds six 11kV/415V 500kVA transformers. The transmitters and their auxiliaries are supplied at 415V and the transmitter control circuits and programme input equipment is fed at 240V. Much of the transmitter control and programme input equipment supply is automatically regulated.

The increase in transmitter services and general growth of Wenvoe has resulted in the original power supply and distribution arrangements being extensively modified. In addition to three extra 11kV/415V 500kVA transformers and new h.v. and l.v. distribution boards, three 100kVA diesel alternators have been added. This standby power installation can, in the event of a failure of all three mains supplies, maintain at reduced output the Band I and III television services and the four Band II v.h.f. radio services.

9 Building and mast structures

The increase in transmitter services has also resulted in substantial alterations to the station building in relation to the 1952 layout. The original concept was a compact 'L'-shaped single-storey building, one leg of which housed the Band I high-power transmitters, the ancillary equipment and cooling plant, the control room, line termination room and component storage space. The other leg contained a workshop, heavy stores, battery room, switch room, offices, canteen and domestic services. An annexe to the main building housed the mains power supplies substation and the garage. The building shape was soon altered by the need to house first the reserve Band I equipment and then the Band II equipment. Further additions became necessary as the Band III and Band V installations were planned, each adding in their turn a further transmitter hall and attendant space to house ancillary equipment. In total, the building floor space has almost doubled in accommodating the additional services.

The original 229m mast carried both the Band I and Band II aerial systems – and later the Band V aerial systems – but was unable to accommodate the high-gain large-aperture aerial needed for the Band III transmissions. A second mast, 189m in height, was therefore added for this purpose.

The 229 m stayed mast comprises a lattice steel structure of 186 m, surmounted by a 33 m mild steel plate slotted cylinder – the Band II v.h.f. aerial – which is in turn capped by a top mast that supports the Band V aerials. The Band I aerials are mounted on the main mast structure below the Band II cylinder.

The 189 m mast is also a lattice steel structure and, like the 229 m mast, it is located on a steel ball and stayed by steel ropes. Of necessity, this second structure had to be in close proximity to the original and its precise location posed a particularly difficult problem. The eventual siting ensured that the reflective effects of either mast upon the radiated pattern of the other aerial systems were minimised. The Band V aerial is entirely above the 189 m mast and its performance is, therefore, unaffected by it.

In common with the transmitter equipment, the aerial systems at Wenvoe are, by virtue of their operating frequencies and pattern of introduction, a practical illustration of the technical advances that have taken place in this particular field of broadcasting engineering. In particular, they show the advances made in the development of high-gain aerials.

All told, there are now eight transmitting aerial systems at Wenvoe: the high-power Band I system, the reserve Band I system and the separate halves of each of the Band II, III and V systems, each of which is fed by independent feeders.

10 Postscript

In 1970, a postscript was added to BBC Wenvoe – IBA Wenvoe. In line with the co-siting arrangements for BBC and IBA u.h.f. transmissions, the Harlech television services began broadcasting from the Wenvoe site on 4 April.

Four u.h.f. transmitters, two vision and two sound, housed in a separate building, are remotely controlled and monitored from the nearby IBA St Hilary v.h.f. station. The vision and sound transmitter outputs are combined and fed into a diplexer – still within the IBA building – and the power output of the diplexer is introduced into the four-channel combining unit located in the BBC building.

The Harlech u.h.f. transmissions are radiated with the BBC-Wales and BBC-2 services from the common Band V aerial system; their power output pushes the total effective radiated power from the Wenvoe aerial systems well beyond 2MW.

The BBC General Election Computer System

R. G. Kelly, B.Sc.
Studio Capital Projects Department

Summary: This article describes the computer system which has been developed to aid the BBC's Current Affairs Group in producing a General Election results programme. The entire system is maintained in a state of readiness, and can be installed in the studio in a matter of days.

1 Introduction

The use of computers in presenting a General Election Results programme is not new. Both BBC and ITV channels used computers during the 1970 Election; on that occasion, however, the BBC used a computer bureau. The result was not entirely satisfactory and in the light of its 1970 experience, the BBC decided to produce the entire system using its own computer centre and under its own control.

Work on the computer system started in earnest at the beginning of 1973. The requirement stated at that time that it 'should be able to capture and present for transmission the constituency results together with the ability to analyse these results and to forecast the final outcome of the Election'. Such a system was developed during 1973 and brought to operational readiness in October of that year. A full studio rehearsal took place in January this year only five weeks before the February General Election was announced. The system which was used is available for use in future elections.

2 Computer hardware

2.1 General

The heart of the system is the BBC's Central Computer Complex which is half a mile from Television Centre. The input and output visual displays and printers are installed in the Election studio and connected to the Computer Centre by Post Office data communications circuits.

2.2 BBC central computer complex

At the time of the February Election, the BBC Central Computer Complex (see Fig. 1) consisted of an ICL1904A main frame processor with 192K words or core storage, and a cycle time of 750 n.secs. Further storage was available on one or more of the ten exchangeable disc transports each holding 60 million characters of information and on one of the eight magnetic tape decks. The system requires 84K words of core for its suite of programs and 300K words for its database held on disc, also one of the four-line printers (which are capable of printing at 1350 lines per minute) and a paper tape punch. All the computer terminals used are run on-line to the processor via two ICL communications scanners (see Fig. 3). Under normal circumstances the Computer Centre is used for a wide range of work including Corporation payroll, personnel records and programme planning schedules. For a General Election programme the machine is dedicated solely to that job. Some changes have been made in the central hardware complex since the election last February, but these would not affect the system which has been developed for election coverage.

2.3 Studio terminals

These terminals are of three types:

2.3.1 Moore Reed video terminals

The system requires a number of fast and reliable video terminals for the inputting of results and for displaying both the result and its analysis simultaneously in many different

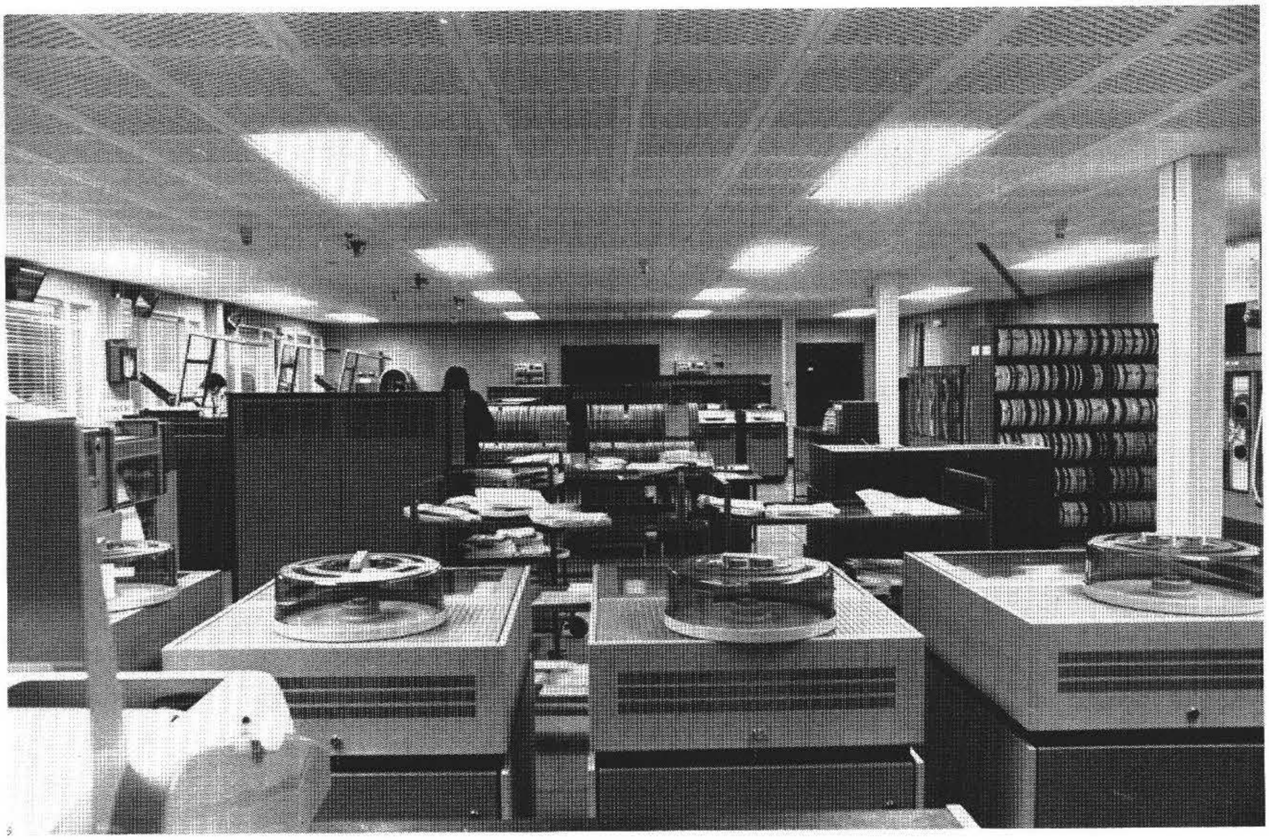


Fig. 1 General view of central computer complex

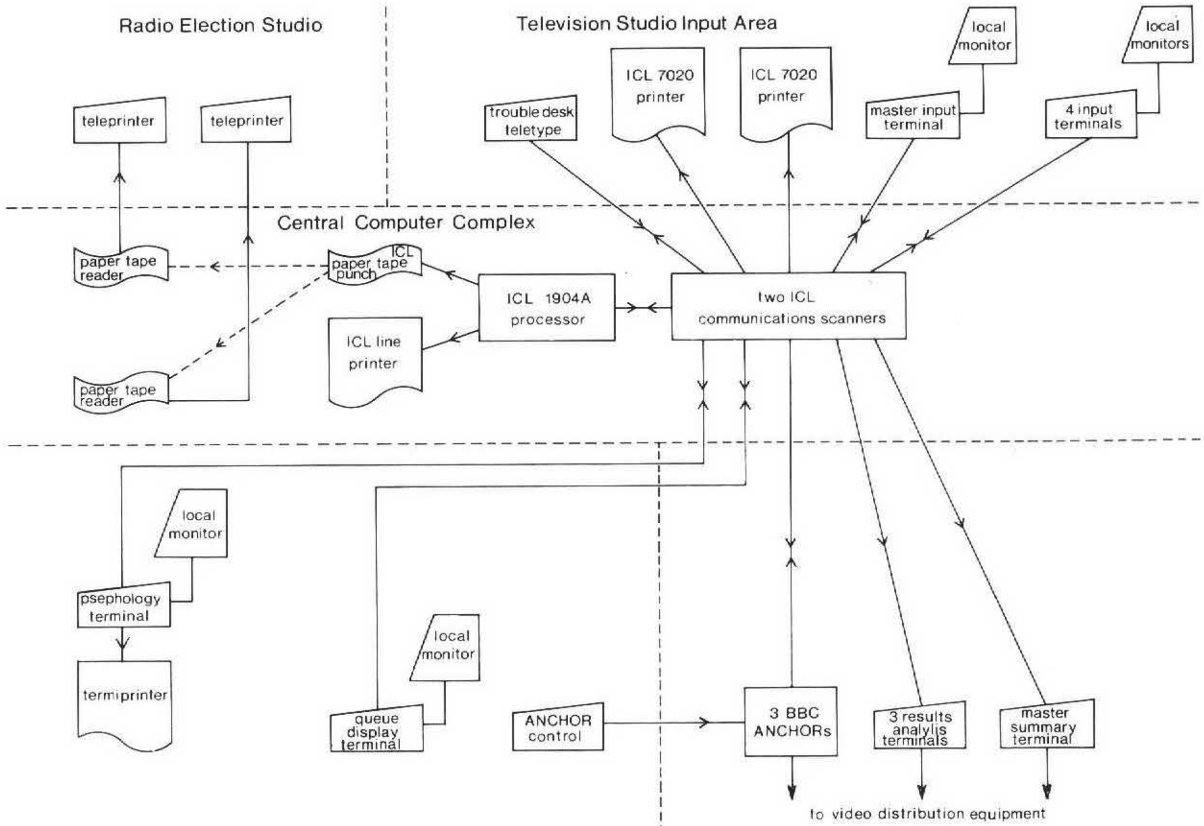


Fig. 2 System diagram. The arrows indicate the flow of data. For the sake of clarity the Post Office communications equipment has been omitted

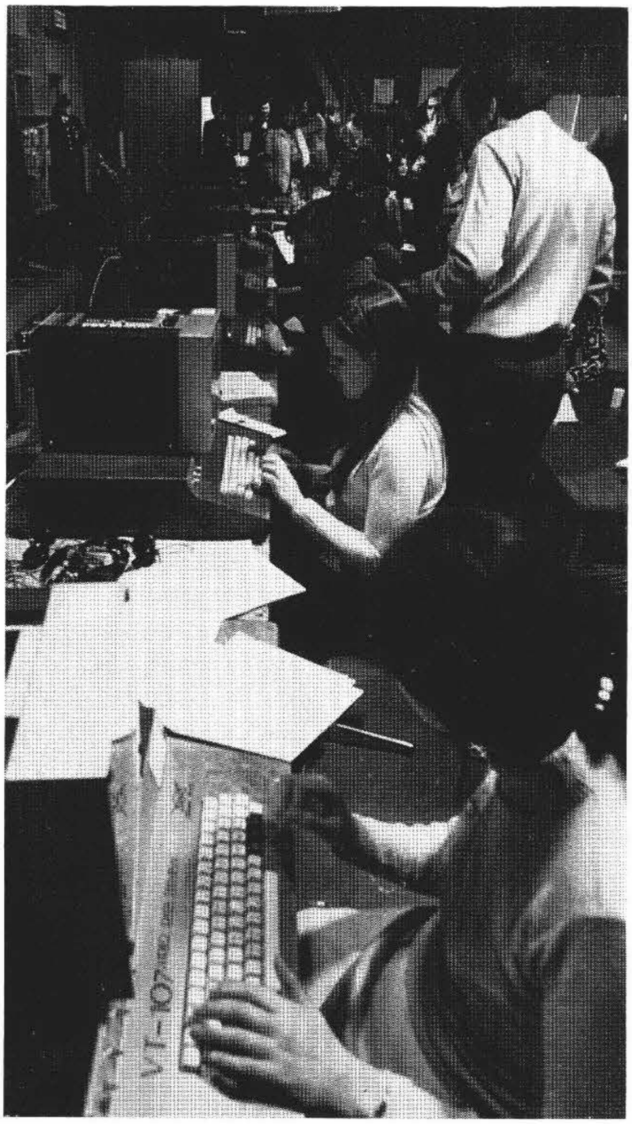


Fig. 3 Input terminals

locations in the studio. The Moore Reed VT 111 video terminal (see Fig. 2) which was chosen can transmit and receive data at speeds of up to 9600 baud and is capable of displaying twenty rows of sixty-four upper case characters per row.

Unlike most computer visual display units (VDU's) this terminal does not have its own cathode ray tube but produces a 624-line fifty-field non-interlaced video signal, each character of which is made from a 9 × 8 dot matrix. It is thus possible to route the video output of a single Moore Reed terminal for display on standard monitors in many areas using existing BBC resources.

For this system eleven Moore Reed visual display units are used and are run at 1200 baud in a half-duplex mode, i.e. data cannot be transmitted and received simultaneously. However it is possible to send an interrupt character to the central processor whilst it is outputting information before the output message is finished. For this reason the Post Office data communications circuits provided are full duplex circuits. Messages typed on the keyboard of the terminal can be edited before being transmitted to the central processor.

2.3.2 ANCHOR

The Moore Reed terminal, due to its non-interlaced signal and the large number of characters it displays, is not suitable for producing results captions for transmission to the viewer. For this purpose, the BBC's own character generator ANCHOR* is used. This device is normally used free-standing driven from a keyboard or paper tape, but can also be connected to a Post Office data transmission link. The results captions for the viewer are produced in this fashion by one of three ANCHORS connected on-line to the computer. To meet the specific requirements of the Election system the ANCHOR modem interface has been modified in order that the Results Director can, using an ANCHOR control box, indicate to the computer the current status of a particular result caption.

During the February Election the ANCHORs were operated in a 'Superlock' mode. Superlock is a system in which the ANCHORs are driven by a monochrome synchronous pulse generator which is 'Genlocked' to the output of the television studio mixer. The ANCHOR video signals are fed into a 'black-edged' generator the output of which can be mixed with a synchronous or non-synchronous source. Thus the computer generated results captions can be used with any of the Outside Broadcasts.

2.3.3 Printing terminals

Three types of printing terminals are used in the election studio. The first is an ICL Termiprinter, which can be connected to a Moore Reed visual display to make a hard copy of the information displayed on the screen. The Termiprinter has an impact chain printer mechanism and can print at thirty characters per second. The second type of printer used is the ICL7020 terminal. This consists of a controller and a line printer capable of printing up to 150 lines per minute. The third type of printing terminal is the standard ten-character per second teletype, which is used in the studio. This is not an integral part of the system but it is available for system testing and fault analysis (see Section 5).

2.4 Communications facilities

Data is transmitted between the computer centre and the television studio half a mile away by means of Post Office lines and modems. Fifteen 1200 baud circuits using Post Office modems type 1D are used for the Moore Reed terminals and the ANCHORs. Two 2400 baud circuits with modems type 7B are used for the ICL7020 printers. The Television Centre modems are rack-mounted and installed in the technical area. As a standby facility the modems 7B can if necessary be used on a direct exchange line and the Post Office switched network but at the reduced speed of 1200 baud. There is sufficient redundancy in the 1200 baud circuits that alternative connection by direct exchange line is not provided. The teletype described in 2.3.3 is connected via a 110 baud circuit using Post Office modems type 2B.

In addition to the data communications circuits, two reverse vision circuits are provided in order that engineers in the Computer Centre can monitor the outputs of the studio terminals. For trouble-shooting purposes, voice communica-

* See *BBC Engineering* No. 84, October 1970.

tion between the studio and the Computer Centre is provided by a 'hot line' intercom. In addition, extensions on the special fifty-way automatic exchange which was installed for general use in the Election studio are provided.

3 System configuration and operation

3.1 Input of results

The results are received from the 635 constituencies and given to the terminal operators in one of three ways:

(*a*) For declarations made during an outside broadcast, one of the operators is provided with a headphone feed of programme sound and the result is typed in as the returning officer makes the declaration.

(*b*) For constituencies not covered by outside broadcasts, the results are received in the studio by telephone on one of a number of lines. These results are written down by programme staff on specially prepared pro formae. Parallel feeds of the first five telephone lines are provided on headsets at the computer input terminals, each feed having an individual amplifier and volume control. Results received over these lines are input immediately to the central processor by the input operators.

(*c*) Results received on the remaining telephone lines and from other sources such as radio outside broadcasts are taken by the input operators from the pro formae mentioned above.

Although five Moore Reed terminals are used for inputting results (see Fig. 2) very little information has to be keyed in by an input operator. Only the Press Association number (which uniquely identifies a constituency) and special input labels – CON, LAB, LIB etc. (which uniquely identify the candidates) are required. The computer validates the votes keyed in and then presents a rolled display to the operator containing the constituency name, full candidates' names, party labels and votes recorded. It is now possible to verify that the result has been input correctly. As most of the input procedure is concerned with data transmitted from the central processor, the whole operation is very fast and up to eight results a minute can be input to the computer system.

One of the five input terminals is designated Master Input. Although this terminal can input results as described above, it also has additional facilities. Master Input can retrieve results from the central processor memory and if necessary correct them; the other input terminals can retrieve results for checking purposes but are not able to correct them. The Master Input is also the point from which studio control of the computer system is exercised by means of various commands made via this terminal. In addition, failure of any of the other input or output channels is reported by the central processor to the Master Input terminal.

3.2 Output of results

3.2.1 Results Director's display

After a result has been input to the computer the system files are up-dated and majority, percentage votes, turnout and swing are calculated. The result is allocated a priority and placed in the queue awaiting display. The purpose of the

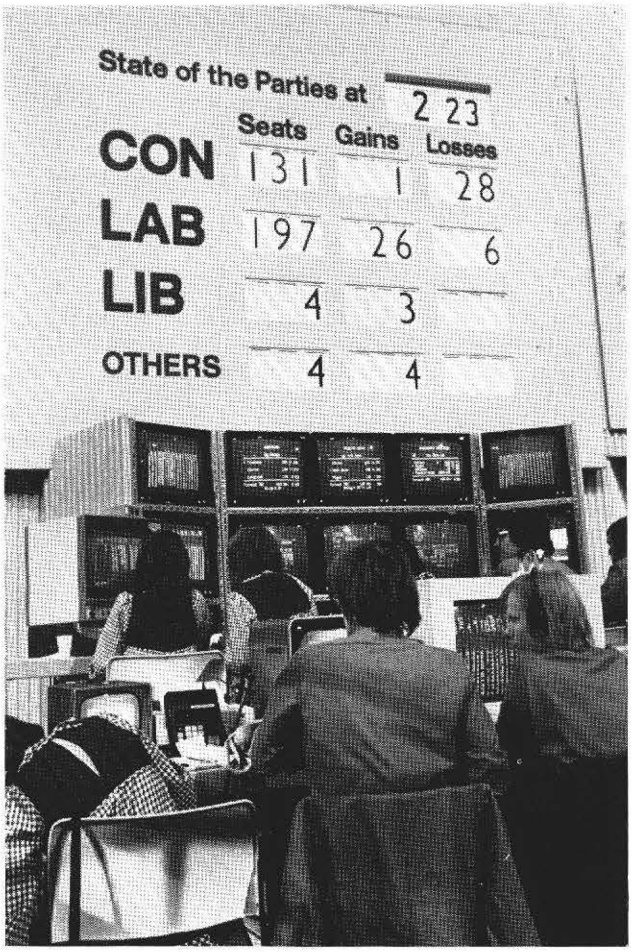


Fig. 4 Results director's desk. The Queue Display is on the left. The monitor stack shows the ANCHOR outputs in the middle of the top row and the Master Summary display at either end. The Results Analysis displays are on the second row

priority queue system is that the most interesting result should be presented first. In this way results captions for declarations made during outside broadcasts are given the highest priority in order that they may be used whilst the O.B. is still 'On Air'. The queue is displayed by a Moore Reed video terminal which together with its adjacent monitor is positioned on the Results Director's desk. This display is also provided on one of the Programme Editor's monitors. Although the computer has a priority allocated to each result, this may be modified by commands input using the Queue Display terminal.

Further facilities provided by this terminal are the ability to recall results which have already been shown and to call up results in groups of three. In the latter case all three results are shown on one display, the information being limited to the constituency name, the name of the winner and his majority. A full caption shows all the candidates and the votes they have polled together with swing and turnout percentages plus an indication if the seat has changed hands and which of the candidates is the retiring member.

There are three results channels and these display the first three results in the queue. Each channel consists of an ANCHOR to display the result for transmission and an associated Moore Reed video terminal to display the analysis

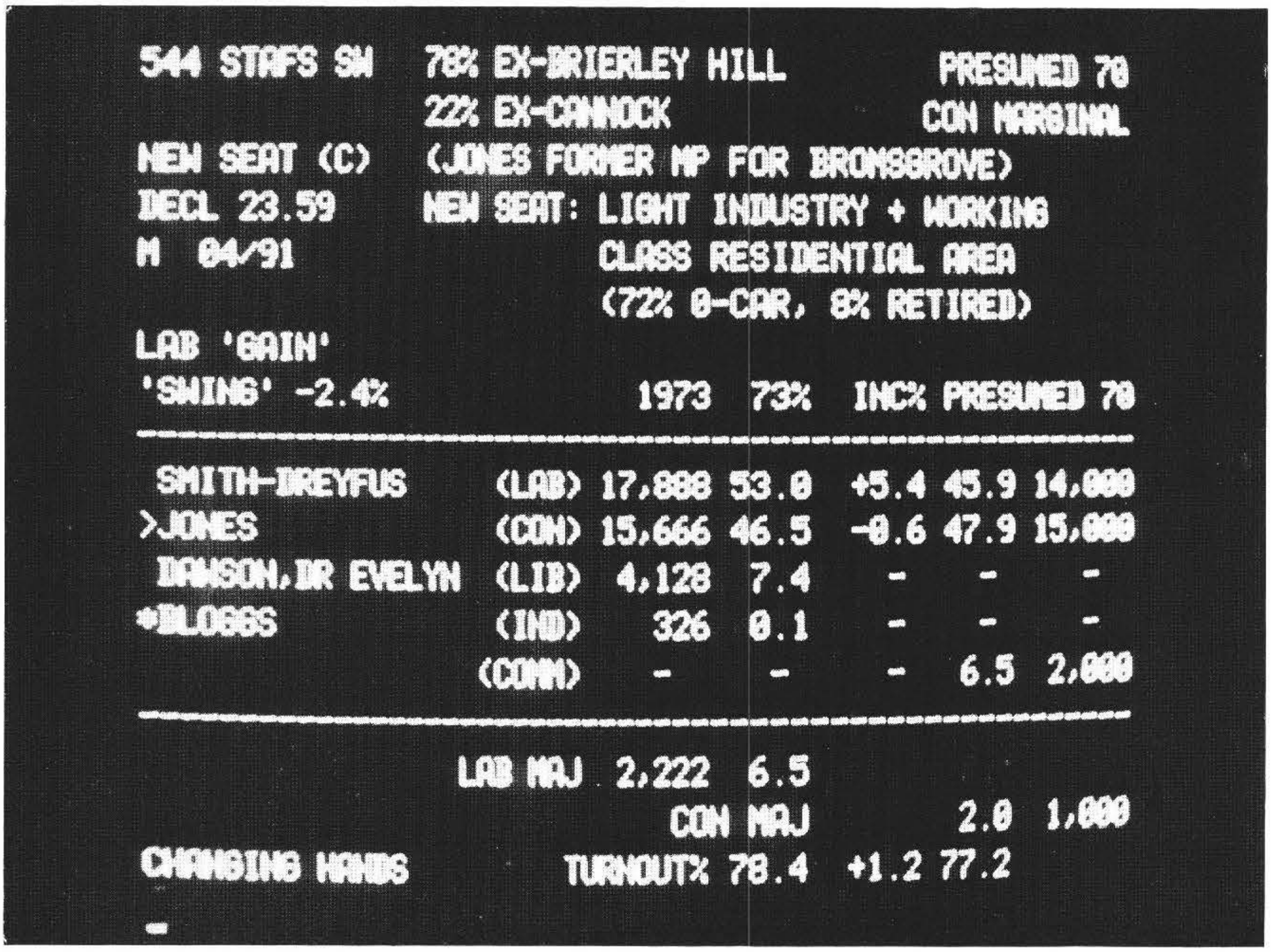


Fig. 5 Typical Results Analysis display. The results are hypothetical

of the result. All six of these displays are presented to the Results Director (see Fig. 4). Those captions that are required for transmission are frozen by the Results Director using the ANCHOR control box. Once a result is frozen it will not be overwritten by a result with a higher priority; all three results channels may be frozen simultaneously.

An ANCHOR has two video outputs, preview and main. The output shown to the Results Director is the preview feed. On receipt of the 'freeze' command, the central processor switches on the main ANCHOR output which is fed to the production control gallery. Using a further control the Results Director indicates to the Director in the control gallery which result he wishes to be transmitted first and when this result is taken On Air he indicates which of the remaining two channels is to be taken next. After a result has been shown or is no longer required a 'Kill' command is given to the central processor by means of the ANCHOR control box. Upon receiving this command the processor erases the ANCHOR display and its associated analysis and sends the next caption.

3.2.2 Programme presenters' displays

The primary purpose of the results analysis displays is as an aid to the programme presenters. Each display contains information such as a brief description of the constituency and the candidates plus the result at the previous Election. The answers to various calculations carried out on the current and previous results are also included (see Fig. 5).

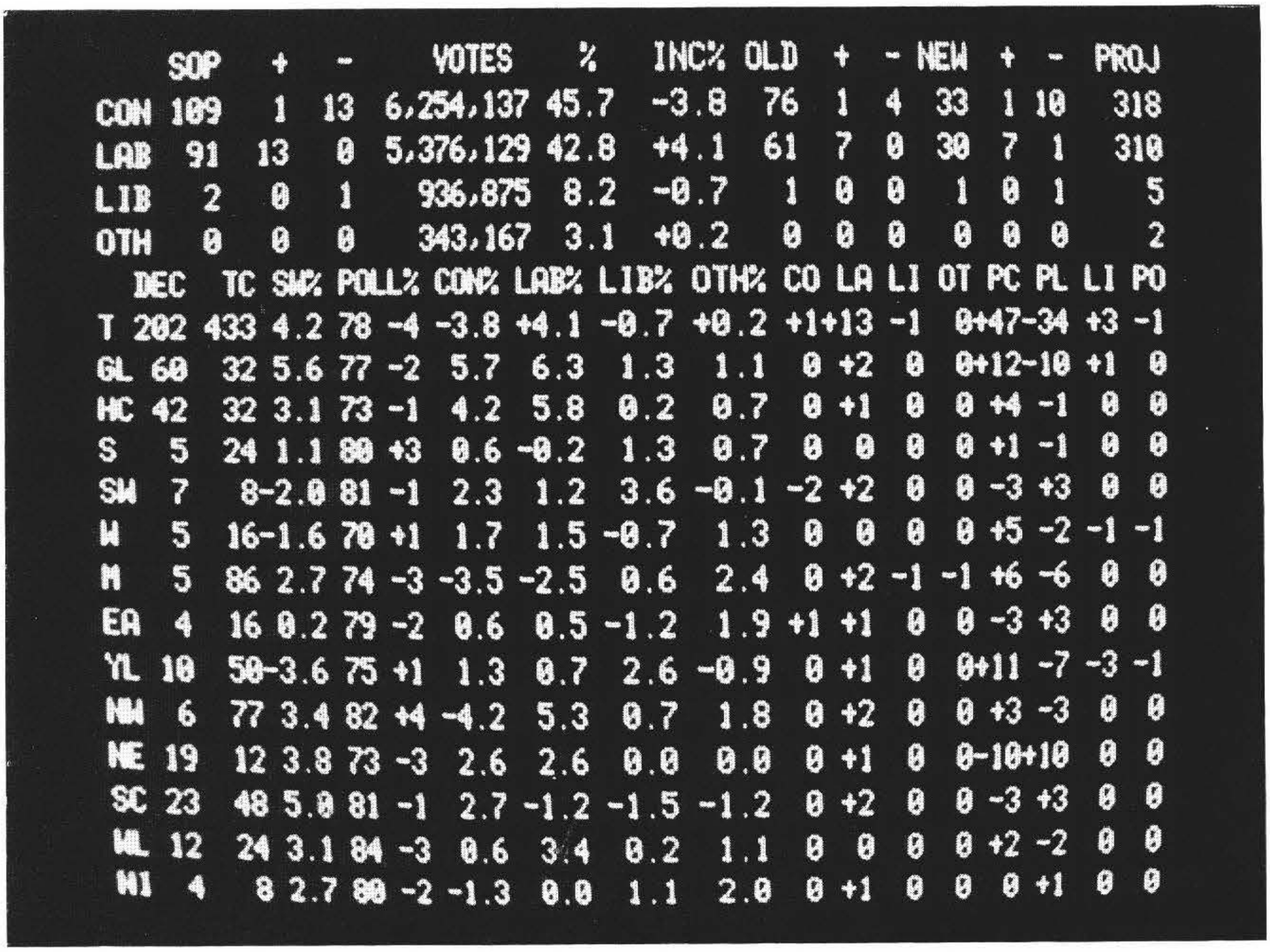
Physically it is not possible to provide monitors in front of the presenters for all the displays, so a special switching system is used. Each presenter has four monitors.

Transmission
Transmission Analysis
Preview ANCHOR
Preview Analysis

When performing a results sequence the Results Director operates the control indicating the first caption that should be taken and this result is displayed on the Preview ANCHOR and Preview Analysis monitors. Operation of the vision mixer in the gallery to take this caption On Air displays the ANCHOR caption on the transmission monitor and switches the analysis display onto the Transmission Analysis monitor. When the Results Director indicates the next caption to be taken this is displayed on the Preview ANCHOR and Preview Analysis monitors and so on.

3.2.3 Master summary

Possibly the most important display produced by the com-



	SOP	+	-	VOTES	%	INC%	OLD	+	-	NEW	+	-	PROJ
CON	109	1	13	6,254,137	45.7	-3.8	76	1	4	33	1	10	318
LAB	91	13	0	5,376,129	42.8	+4.1	61	7	0	30	7	1	310
LIB	2	0	1	936,875	8.2	-0.7	1	0	0	1	0	1	5
OTH	0	0	0	343,167	3.1	+0.2	0	0	0	0	0	0	2

	DEC	TC	SW%	POLL%		CON%	LAB%	LIB%	OTH%	CO	LA	LI	OT	PC	PL	LI	PO
T	202	433	4.2	78	-4	-3.8	+4.1	-0.7	+0.2	+1	+13	-1	0	+47	-34	+3	-1
GL	60	32	5.6	77	-2	5.7	6.3	1.3	1.1	0	+2	0	0	+12	-10	+1	0
HC	42	32	3.1	73	-1	4.2	5.8	0.2	0.7	0	+1	0	0	+4	-1	0	0
S	5	24	1.1	80	+3	0.6	-0.2	1.3	0.7	0	0	0	0	+1	-1	0	0
SW	7	8	-2.0	81	-1	2.3	1.2	3.6	-0.1	-2	+2	0	0	-3	+3	0	0
W	5	16	-1.6	70	+1	1.7	1.5	-0.7	1.3	0	0	0	0	+5	-2	-1	-1
M	5	86	2.7	74	-3	-3.5	-2.5	0.6	2.4	0	+2	-1	-1	+6	-6	0	0
EA	4	16	0.2	79	-2	0.6	0.5	-1.2	1.9	+1	+1	0	0	-3	+3	0	0
YL	10	50	-3.6	75	+1	1.3	0.7	2.6	-0.9	0	+1	0	0	+11	-7	-3	-1
NW	6	77	3.4	82	+4	-4.2	5.3	0.7	1.8	0	+2	0	0	+3	-3	0	0
NE	19	12	3.8	73	-3	2.6	2.6	0.0	0.0	0	+1	0	0	-10	+10	0	0
SC	23	48	5.0	81	-1	2.7	-1.2	-1.5	-1.2	0	+2	0	0	-3	+3	0	0
WL	12	24	3.1	84	-3	0.6	3.4	0.2	1.1	0	0	0	0	+2	-2	0	0
NI	4	8	2.7	80	-2	-1.3	0.0	1.1	2.0	0	+1	0	0	0	+1	0	0

Fig. 6 Typical Master Summary display. The results are hypothetical

puter system is Master Summary (see Fig. 6). Here a Moore Reed terminal displays a mass of information relating to the overall result of the Election. This information includes the state of the parties, total votes cast for each party and the computer prediction of the final outcome (see Section 3.3). The display is required by a large number of people including the programme presenters, their support staff and the programme staff operating the giant scoreboards.

3.2.4 Video distribution

The Moore Reed terminals producing the analysis displays and master summary are installed in the studio technical area together with the ANCHORS and the Post Office modems. The video outputs from the ANCHORS and the Moore Reed terminals are taken directly to a purpose-built video distribution bay; all destinations both inside and outside the studio are fed from this point.

The distribution bay incorporates three ten-channel video relay panels. Most of the computer-originated video signals are fed to these panels which are used for monitoring the performance of the computer system and trouble-shooting when necessary. Two of the relay panels are used locally by the studio 'trouble desk' (see Section 5) and the third is used to control one of the reverse video circuits which feed into Sulgrave House.

3.2.5 Hard copy activities

Two ICL7020 terminals are installed in the studio; one of which is connected to the computer program, and the other being installed as a standby (see Fig. 7). The terminal prints an analysis of each result as it is entered into the main processor's memory and also prints regional summaries every few minutes. The format of the analysis print-out is identical to that of the Moore Reed display. For 'second line' security purposes, the same information is also output onto one of the Computer Centre line printers.

The results analyses and the regional summaries are both output on paper tape in the Computer Centre. This paper tape is loaded onto the paper tape readers of one of two standard teleprinters and data are sent via two 110-baud circuits to the Radio Election Studio in Broadcasting House.

3.3 Prediction of the final results

The February Election was the time when Psephology became a household word. Because of the interest created by the Public Opinion Polls, the prediction of the final result became editorially important.

The largest individual program for the General Election computer system, namely 50K words, provides this prediction. A Moore Reed terminal is installed immediately adjacent to the programme presenters and is used by the

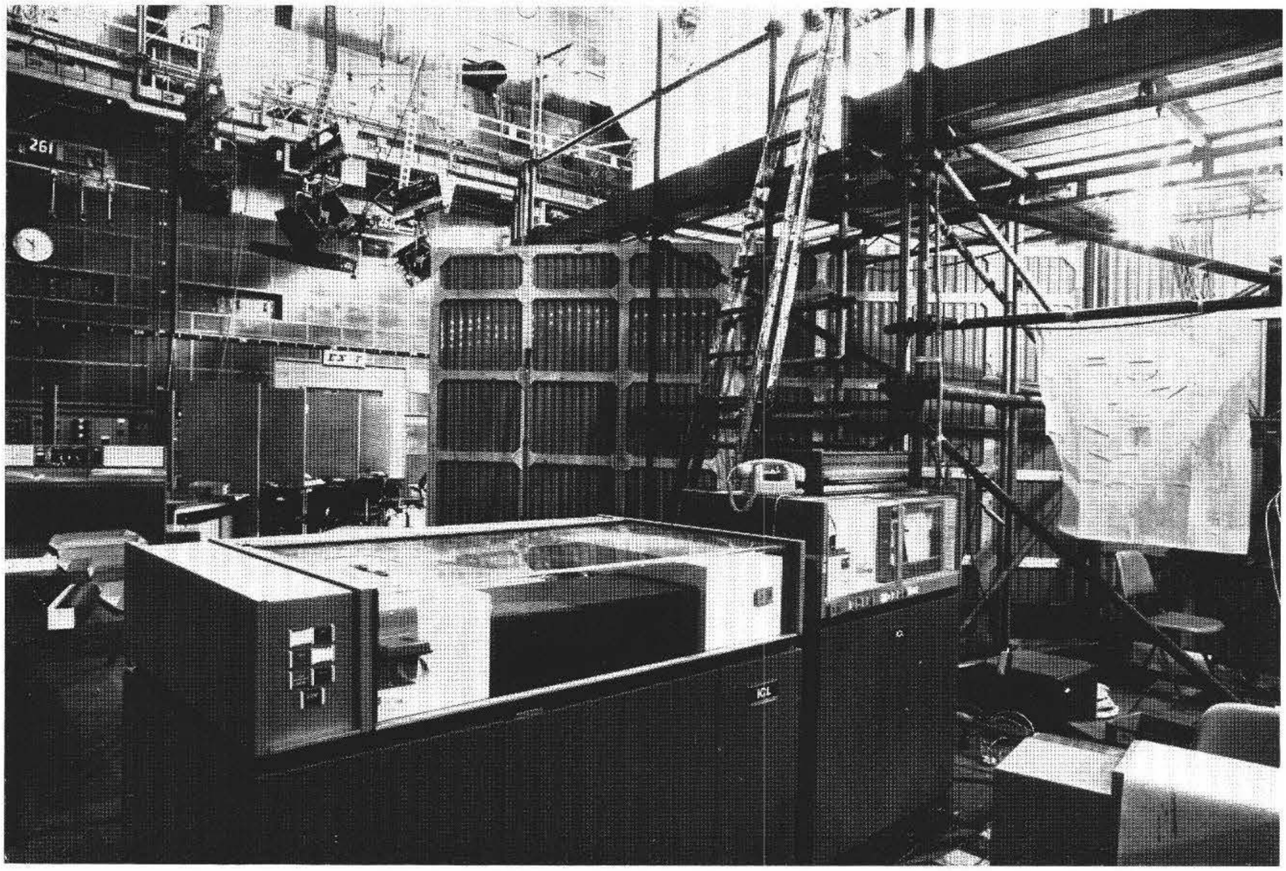


Fig. 7 ICL 7020 remote printing terminal

Psephologist to produce, by controlling the computer program, both the predicted result and an analysis of this result. If desired a hard copy of this analysis may be taken using the termiprinter described in Section 2.3.3 and this hard copy can then be passed to any of the presenters.

4 System design

4.1 General

Special consideration was given in the design to the speed, reliability and accuracy of the system. The last is essentially a software problem and is outside the scope of this article.

4.2 Speed

The system is capable of providing results captions very quickly. At 1200 baud the time taken to write a full screen of information on a Moore Reed display is 11 seconds. A full caption containing percentage swing and turnout is therefore available 11 seconds after a result has been input to the processor. From an editorial viewpoint, this is very important, particularly during the coverage of declarations made during outside broadcasts.

4.3 Reliability

Considerable effort was devoted in the design of the system to the problem of reliability. There is sufficient redundancy in the input, results analysis and ANCHOR channels for a failure in one of these not to cause undue difficulty. However, the failure of the Queue Display, Master Summary or Psephology would be more serious. For this reason it is possible by program, to re-allocate one of the input terminals to carry out these functions. This re-allocation is carried out by commands issued at the processor console in the Computer Centre. The output from the chosen input terminal is available on a video jackfield; in the event of failure it can be used to replace the video output of the failed Queue Display or Master Summary. Positions receiving these displays continue to be served after only a short break.

The most serious failure that can occur in the Computer Centre is that of the main processor as all the processor's peripherals are at least duplicated.

In order to continue to produce results captions during a breakdown all three ANCHOR channels are provided with keyboards and paper tape readers (see Fig. 8) which can be connected in place of the Post Office data communications circuits. Paper tapes are prepared using the computer prior to the Election programme and contain an entire caption with the exception of the votes cast. These plus a figure for the majority are added to the ANCHOR caption using the keyboard. It is thus possible to produce results captions fairly quickly. However, calculation of swing, turnout and other analysis has to be done manually using programmable calculators.

During the system trials in September 1973 a number of likely failures were simulated and recovery procedures were thoroughly rehearsed. In addition a number of simulated 'Elections' were run. There is no doubt that the trials and

Fig. 8 General view of Input Area. Input terminals are on the left, and the back-up area is bottom left. The ICL 7020 terminal is on the right with the computer trouble desk below.

Fig. 9 'Election 74' studio layout

rehearsals contributed a considerable amount to the smooth running of the system when it was eventually used on the night.

5 General Election: February 1974

As has been stated, the system was used during the Election Results Programme last February (see Fig. 9). For this occasion all other processing work was stopped at the Computer Centre and the system ran on a totally dedicated machine in order to eliminate any possibility of other programs corrupting the Election system's program. The studio operation of the system was supervised from a 'Trouble Desk' located in the studio near the input terminals (see Fig. 8.) It was equipped with monitors displaying the output of the relay panels described in 3.2.4, the teletype described in 2.3.3 and communications facilities to the Computer Centre. The Trouble Desk personnel consisted of Systems Analysts, Programmers and Engineers who were responsible for solving any faults that may arise. In practice the system ran from 10 p.m. on Election night until 6.30 p.m. the next day, during which time it halted once; this occurred during the Friday morning declarations and lasted for only ten minutes. The back-up system which ran throughout the programme was brought into action during this halt but was only required to produce one results caption which was introduced within 15 seconds. Only the lack of a swing figure in the caption indicated that anything was amiss.

The psephology program was very successful; after only 100 results it was correctly predicting a small Labour majority with the Liberals and 'others' holding the balance of power.

During the break in transmission between 4.30 and 6.30 a.m. all the results were recalled from the processor and displayed in threes by the ANCHORS. The results were recalled in alphabetical order and the captions recorded on a video tape which was transmitted twice on BBC-2 at 6.30 a.m. and again at 8.30 a.m.

6 Conclusion

The BBC's General Election computer system is an excellent example of the use of computers as an aid to programme production in broadcasting. In addition, it has shown that it is possible to design a computer system within a strict timetable and make it work first time. This would not have been possible without the co-operation of many groups of people both inside and outside the Corporation and the rapport between these groups marks a fine achievement by the BBC's Television Computer Projects Department.

It was originally intended to put the system into 'cold storage' after it had been used. However, the equipment side is under constant review in order that any major technical improvements might be incorporated. The system itself is ready for instant use should another General Election be called, which at the time of writing could be at any moment.

Acknowledgements

The author would like to express his sincere thanks to those colleagues who have helped in the preparation of this article.

A Computer Program for Calculating M.F. Sky-wave Interference

J. L. Eaton, B.Sc., M.I.E.E.
Research Department

Mrs A. M. Bunting
Formerly of Research Department

Summary: A short self-contained computer program for calculating sky-wave interference at m.f. has been written. The program employs a simple empirical law for calculating field-strength and makes a correction for the transmitting aerial vertical radiation pattern, the take-off angle being derived from the great circle distance and the number of 'hops'. Protected field-strengths are calculated for each wanted service area from the interference levels from individual co-channel and adjacent-channel sources, from all co-channel transmitters taken together, from all adjacent-channel transmitters taken together and from all co- and adjacent-channel transmitters taken together.

1 Introduction

This article describes a short program to compute m.f. sky-wave interference which has been designed as an aid in the preparation of international plans for m.f. broadcasting. Because it uses recognised prediction methods and is very economical to run, it could provide a ready means for testing a number of possible plans or be used to assist in the assessment of *ad hoc* modifications to these plans. For the calculations the transmitter information is read in from cards, permitting maximum flexibility in setting up new plans. The cards hold details of all the known transmitters to be considered from which any selection may be made to run the program. If required, the frequency of any station may be changed and various options are available which are explained in Section 3.

The purpose of the program is to assess the effect of co-channel and adjacent-channel interference by sky-wave propagation in service areas centered on any number of specified transmitters. (These are called the wanted transmitters). The program selects those transmitters which are co-channel and adjacent-channel with each wanted transmitter in turn and computes protected field-strengths based on the sky-wave interference from these interfering sources, separately and in combination. The combined effect of interfering sources is derived by taking a weighted sum of the interfering signal powers, the weighting being in accordance with protection ratios which are determined by the frequency spacing between the wanted and interfering carriers.

A distinction is made between interfering stations which are on precisely the same frequency as the wanted signal as to whether they will be carrying the same or different programme material. This affects the choice of the protection ratio.

2 The input cards

The transmitter input cards contain the following information:

(i) Frequency (a whole number of kHz)
(ii) Station number (numbered in frequency sets)
(iii) Station name)
(iv) Country
(v) Latitude and longitude
(vi) Transmitter power (in dB rel. 1 kW)
(vii) Programme code (this enables the program to distinguish between stations carrying the same or different programme material).

A set of change cards can be added to the transmitter cards to indicate frequency changes to selected stations. These additional cards also permit options on the selection of wanted and interfering transmitters by the program. The options are described in the next section.

3 Options

There are six options for running the program; five of these require that the option variable is set to the appropriate value on the change cards. If no change cards are included in the input the program will run in its basic form in which each station from the input set is treated as wanted in turn, co-channel and adjacent-channel stations are then selected from the remainder and treated as interfering sources.

3.1 'Cards'

When the option variable is set to 'CARDS' the total set of transmitters considered is restricted to those appearing in the change cards. Otherwise the program runs as above (frequency changes may, of course, be to the same frequency if no alteration is required).

3.2 'Single'

In this case only those stations listed by the change cards are considered as wanted; all stations which are input on existing sets or change cards are used as potential sources of interference.

3.3 'Europe', 'Africa' or 'Asia'

If the option variable is set to either of these continents wanted transmitters are only taken from the continent indicated.

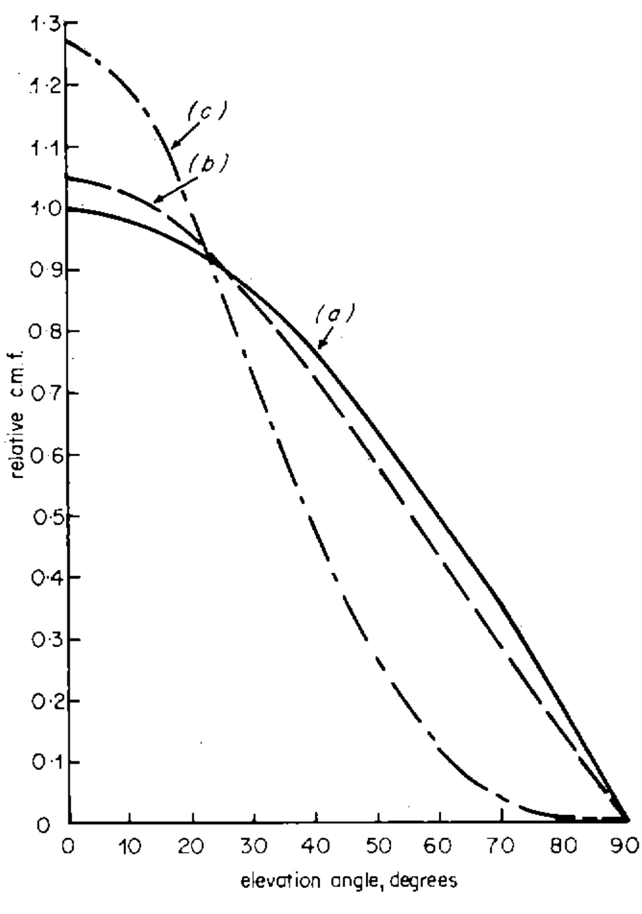


Fig. 1 Vertical radiation patterns for transmitting aerials normalised to c.m.f. = 300 V
(*a*) Short aerial (*b*) $\lambda/4$ aerial (*c*) $\lambda/2$ aerial

4 Vertical radiation pattern (VRP)

Three types of vertical mast-radiator aerials are provided for. These are 'short', '$\lambda/4$' and '$\lambda/2$' respectively. The v.r.p. corrections applied for these types follow the recognised EBU method[1] and are shown in Fig. 1. The correction to be used is chosen in accordance with the specified transmitter power.

Type 1, 'short', transmitter power ≤ 1 kW
Type 2, '$\lambda/4$', transmitter power >1 kW, <50 kW
Type 3, '$\lambda/2$', transmitter power ≥ 50 kW

This procedure has been adopted as the actual aerial types are not known in the majority of cases. In practice aerial heights tend to increase with transmitter power roughly in this way. These curves are normalised to a c.m.f. of 300V which is nominally that of a 1kW transmitter and a short aerial (100 per cent efficient) in the horizontal direction. The appropriate correction is applied by assuming that the reflection point in the ionosphere is 100 km above the surface of the Earth and calculating the take-off angle also taking into account the minimum number of 'hops' which are involved. The minimum number of 'hops' for each path is determined from the great circle distance. The radiation patterns are assumed to be identical on all bearings.

The v.r.p.s take no account of the reduction of field-strength at very small angles of elevation due to poor ground conductivity close to the aerial. This fact may introduce error in a small percentage of the field strength calculations but will not be serious for planning estimates.

5 The median field-strength

The median field-strength (dB rel. 1 μV/m) predicted for each transmitter in the wanted service area is calculated from a simple experimental* formula which is a function of the great circle distance only. This formula is known to be reasonably accurate for distances greater than 3000 km. Referring to Fig. 2 it is seen that it also corresponds closely to the CCIR[2] curve for distances less than 2500 km taken at a frequency of 1000 kHz. The frequency dependence of the CCIA estimate is weak and it appears that the proposed curve is very adequate at all distances for planning purposes.

A flow diagram for the field-strength sub-routine is given in Appendix III.

6 Interference weighting

The program specification requires that the protected field-strength in the service area should be calculated in view of each interfering transmitter taken individually and in view of all co-channel transmitters taken together and all adjacent-channel transmitters taken together. The combined effect of many interference sources is achieved by weighted signal power addition, the weighting curve of Fig. 3[3] being used for the purpose.† As specified, frequency spacings of up to 4 kHz cover co-channel sources; spacings from 5–10 kHz cover

* Contained in an interim document of the EBU which is not yet published.

† The protection ratios are being reconsidered and may be modified in the future.

adjacent-channel sources. A separate curve based on frequency spacings can be employed when it is necessary to distinguish between transmitters carrying the same or different programme material. In the present case the 'same programme' situation only applies when the interfering source has zero frequency spacing. The weighting curve is included in the program as a data statement. No interpolation is required as only integral values of the argument are allowed.

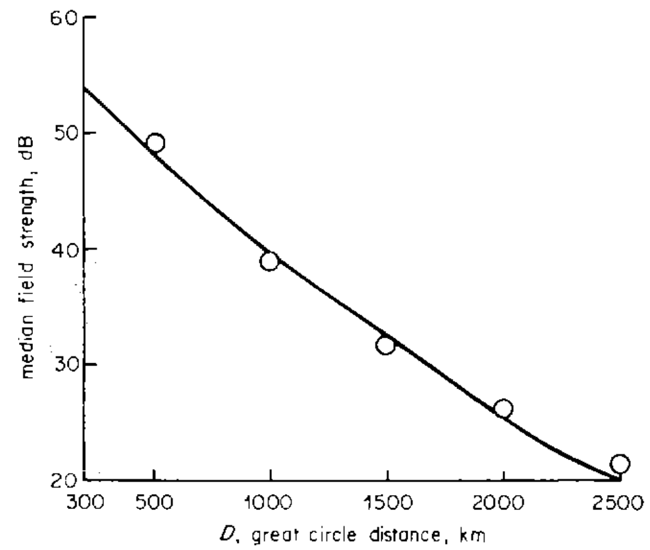


Fig. 2 Median field-strength with great circle distance for c.m.f. = 300 V, λ = 300 m

(1) Full line = $80{\cdot}2 - 10 \log_{10} D - 0{\cdot}00777\,\lambda^{-0{\cdot}26} D$ dB, CCIR curve

(2) Circles = $\dfrac{396}{4 + 0{\cdot}001D} - 40$ dB
empirical law used in the program

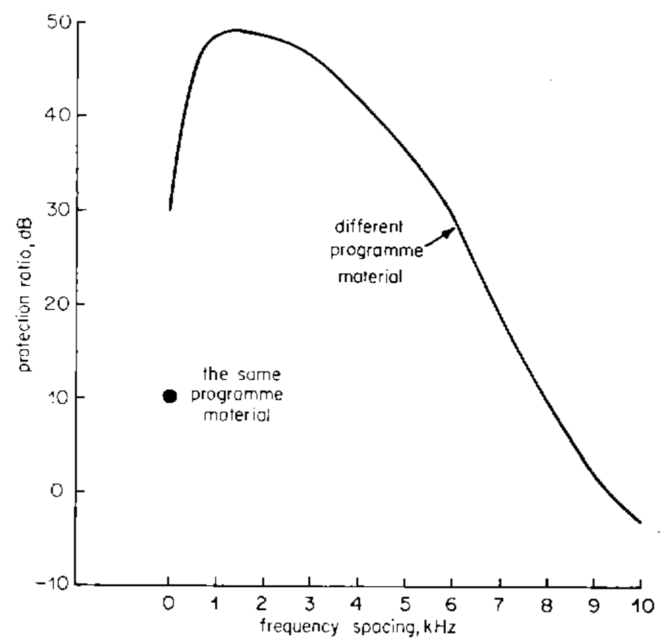


Fig. 3 Weighting curve (protection ratios) with frequency difference

7 Output

An example of line printer output is given in Appendix II. The output data includes, amongst other information:

(1) the name of the transmitter serving the wanted area; its frequency and code number:

(2) a list of all interfering transmitters which are either co-channel or adjacent-channel, their existing and newly assigned frequencies, the protected field-strength required in view of each one taken alone and the appropriate protection ratios:

(3) the protected field-strength required in view of all the co-channel interfering signals taken together:

(4) the protected field-strength required in view of all the adjacent-channel interfering signals taken together:

(5) the protected field-strength required in view of all the co-channel and adjacent-channel interfering signals taken together.

At the end of each run the number of equal protected fields for multiple co-channel, adjacent-channel and the combined cases are totalled in dB steps.

8 Discussion

The computer program described in the foregoing is intended as a tool for m.f. service planning on an international basis. More sophisticated programs are being considered for the future and these would be expected to contain extensive data banks of, for example, ground conductivity, magnetic dip angles, etc. It should be remembered, however, that computer data banks can be costly to store and handle in a program and the probability that the cost and complexity will be justified in terms of improvements in prediction will have to be carefully assessed. The short self-contained program described can easily be adapted for use on most computers and, therefore, it might be arranged to be available at international meetings as an on-the-spot aid to negotiations. The only subroutines required are those for standard mathematical functions.

9 References

1. Ionospheric propagation on long and medium waves, EBU Document TECH. 3081-E, March, 1962.
2. Sky-wave propagation curves between 300 km and 3,500 km at frequencies between 150 kHz and 1,600 kHz in the European broadcasting area. CCIR Report 264-1, XI Plenary Assembly, Oslo 1966, Vol. II, p. 297.
3. CCIR Recommendation 449/1, XIIth Plenary Assembly, New Delhi, 1970, Vol. V, Part 1, p. 25.

Appendix I

INPUT DATA (Cards)

A – EXISTING STATIONS

Variable Name	Format	
NTXS	I4	Total number of transmitters in existing set
KHZCOD	I6	Frequency and station number
NAMCUN	4A6	Name and country
ALAT	I4	
	I3	Latitude in degrees and minutes
	A1	(N or S)
ALONG	I4	
	I3	Longitude in degrees and minutes
	A1	(E or W)
POWDB	I3	Transmitter power in dBs
ISYNC	I3	Programme code

B – CHANGE CARDS

NFRE	I4	New frequency
NUMNEW	I2	Number of transmitters to be allocated this new frequency
IWAREA	A6	Option variable (see Section 3)
OLDFCD	I6	Frequency and number of station in existing situation, to be changed to NFRE (NUMNEW cards)

Appendix II

An example of line printer output

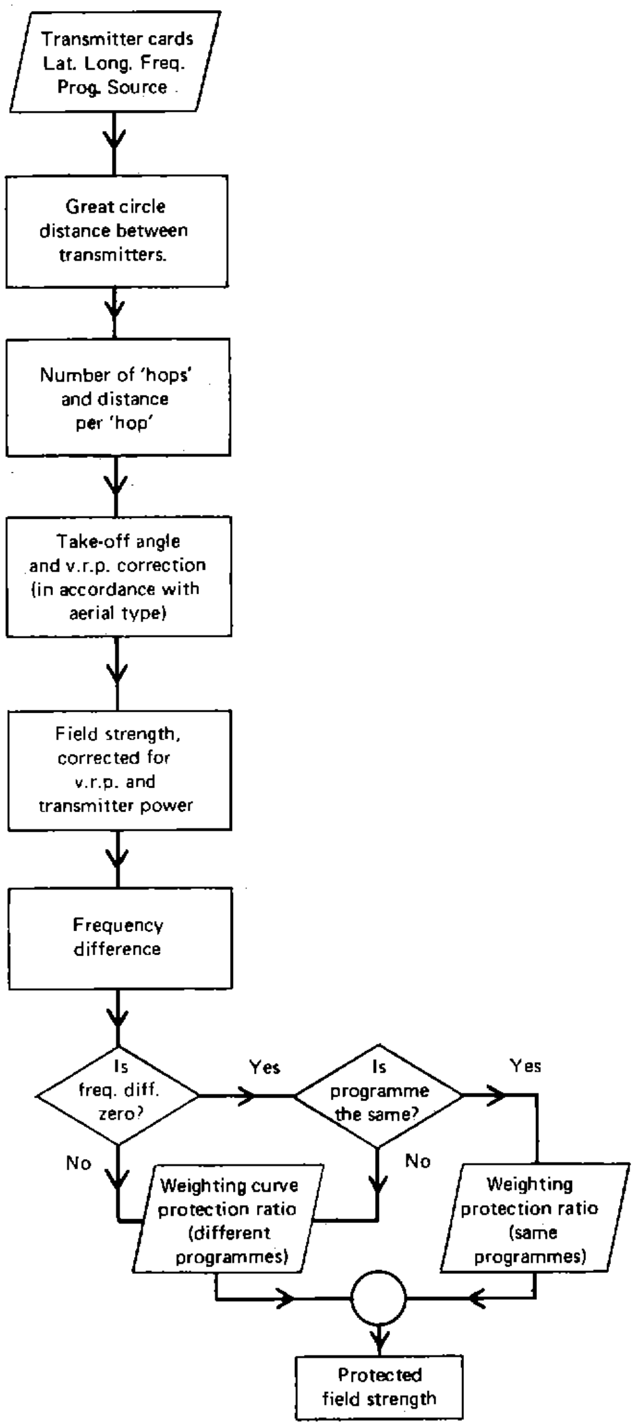
M.F.CALCULATION FOR RECEIVER DROITWICH G 121405 1214 0

NAME		EXISTING FREQ(KHZ)	NEW FREQ(KHZ)	DIST KM	POWER DB	PROT. RATIO	PFS DB	NAME		EXISTING FREQ(KHZ)	NEW FREQ(KHZ)	DIST KM	POWER DB	PROT. RATIO	PFS DB
BORDEAUX	F	120501	1205 1	826	20	2	65.5	AKKO	IRS	120502	1205 2	3659	10	2	24.1
KRAKOW	POL	120503	1205 3	1546	18	2	53.4	RZESZOW	POL	120504	1205 4	1720	18	2	51.3
SUBOTICA	YUG	120505	1205 5	1714	4	2	35.7	WASHFORD	G	121401	1214 1	150	18	10	65.6
BROOKMANS PARK	G	121402	1214 2	144	17	10	63.8	MOORSIDE EDGE	G	121403	1214 3	150	17	10	64.6
WESTERGLEN	G	121404	1214 4	425	16	10	74.0	BURGHEAD	G	121406	1214 6	508	13	10	68.4
LISNAGARVEY	G	121407	1214 7	560	10	10	68.6	TALLINN	URS	121408	1214 8	1837	23	30	82.9
TIRANA	ALB	121409	1214 9	2050	30	30	87.5	STARA ZAGORA	BUL	122301	1223 1	2341	15	2	39.7
MADRID	E	122302	1223 2	1335	17	2	55.1	RIMINI	I	122303	1223 3	1412	8	2	43.5
FALUN	S	122304	1223 4	1407	20	2	57.2								

MULTIPLE PFS(DB REL. 1 MUV/M) CO-CHANNEL 89.1 ADJACENT CHANNEL 66.6 CO- & ADJ. CHANNEL 89.1

Appendix III

Subroutine MFCALC



M.F. Network Planning. The Coverage under Daytime Conditions from a Network of Transmitters Arranged in a Uniform Lattice

R. A. Rowden, M.B.E., B.Sc.(Eng.), D.I.C., F.I.E.E.
Lately of Research Department – now retired

Summary: The article collates definitions of the various types of network where transmitters are arranged geographically over an area and a given number of frequency channels is available for use. The method of calculation of the coverage is described and useful formulae stated. An exemplary tabulation, for limited ranges of power, frequency, ground conductivity and distance, is attached.

1 Introduction

The object of this article is to explain the nature of the different types of networks of transmitters, to assemble, for reference purposes, the more useful formulae relating to networks and to give examples of the calculation of coverage.

As a starting point in planning a new network of transmitters it is often useful to assess the area coverage that would be realised under uniform conditions and on the assumption that there are no restrictions on the siting of transmitters. This theoretical ideal coverage can then be used as a standard of comparison with actual practical schemes limited in choice of site and affected by differences in ground conductivity over the service area.

2 Groundwave services by day

The groundwave services are of particular importance because the public tends to use sound broadcasting services by day and television services during the evening.

The methods and calculations apply only to propagation over ground of uniform conductivity and for cases where the frequency channels envisaged for a particular network of stations are relatively close to each other so that propagation differences with frequency are relatively small. Clearly this is a very idealised case because in most countries (and particularly within the British Isles) quite large differences in ground conductivity may occur from point to point.[1] For the same reason the results are likely to be more useful for estimating coverage from networks of low-power transmitters, relatively closely spaced, rather than over a large continental area.

All coverage estimates are in terms of the proportion of an area that can be covered by a given number of transmitters. The results can be interpreted as giving a lowest estimate of population served because with practical planning the proportion of population served will always exceed the proportion of area served, sometimes by a very large factor.

3 Definitions

Various authors have considered the arrangement of transmitters sited at the intersection of two sets of parallel lines, each set having uniform spacing between its lines.[2,3,4,5,6] Except for the general case of Ref. R, the analysis was until recent years applied to the television u.h.f. network planning particularly for the Stockholm Plan of 1961. More recently[7] the principles have been applied to m.f. planning, as in this report.

4 Uniform and non-uniform networks

Using two sets of uniformly spaced parallel straight lines the lattice may be said to be uniform, forming uniform networks of transmitters. Fig. 1 is an example of this type. A non-uni-

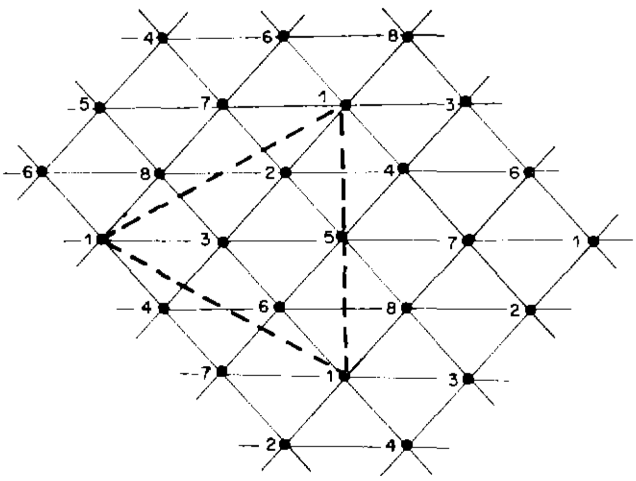


Fig. 1 A uniform linear network for eight channels

form lattice would be one in which the lines forming it may be either straight, parallel nor uniformly spaced. Fig. 2 being an example.[4]

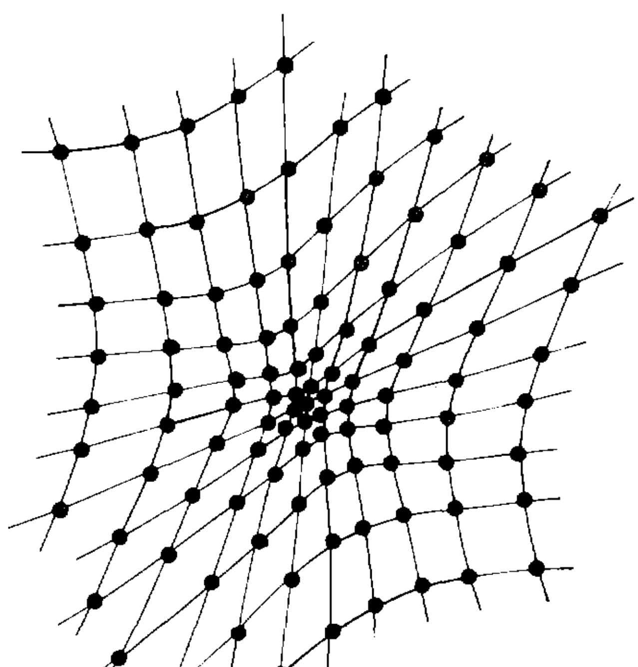


Fig. 2 Non-uniform network

Non-uniform networks might have an application in cases where, for reasons of population distribution or propagation changes, it might be desirable to vary the density of transmitter sites in different parts of a country or large area.

This report does not consider non-uniform networks further.

5 Linear uniform network

A network is said to be linear when, as for example in Fig. 1, the differences between the channel numbers of successive sites is the same along *any* straight line joining any points of the lattice. Differences are taken as positive numbers, adding the total number of channels, N, to any number if subtraction of the previous number in the line would give a negative result. E.g. (for nine channels) a sequence would be 1, 4, 7, 1, 4, 7 etc.

For purposes of planning it is usual for the channel numbers to indicate the sequential order of the carrier frequency allocations, which would generally, though not essentially, be equally spaced in frequency.

Linear networks are of most importance when it is necessary to try to ensure that the users of any particular station, allotted a particular frequency channel, are equally affected, as regards various forms of mutual interference and the direction from which the interference is propagated, as the user of any other station on a different channel. Under conditions of complete uniformity of ground conductivity etc., the use of linear networks will therefore ensure equality of service area between the various transmitters in the network. This strictly applies only to an infinite network; clearly geographical boundaries will cause some inequality in service area.

6 Non-linear uniform network

Bearing in mind that population is seldom, if ever, uniformly distributed over a large area it is not always necessary to attempt uniformity of service area between transmitters. A non-linear network,[5] i.e. one in which the channel number differences are not necessarily the same along the straight lines of the lattice, may have some advantages in particular cases, e.g. some pairs of stations occupying adjacent sites might occupy adjacent channels but not others, this situation sometimes being acceptable where a sparsely populated region intervenes in some parts of the whole area under consideration. Fig. 3, drawn to the same scale as Fig. 1, and for the

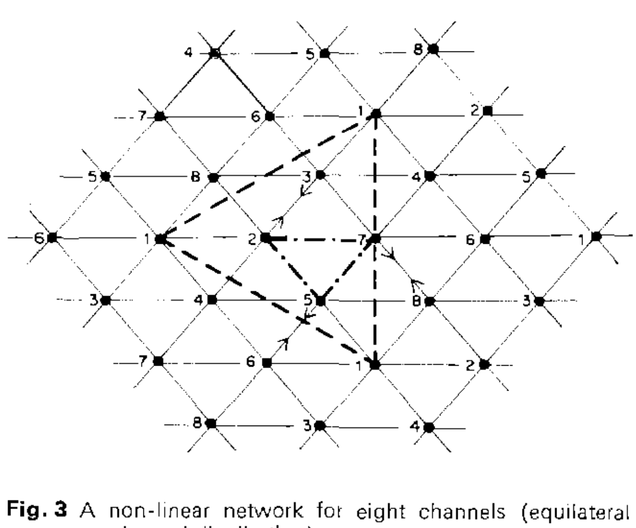


Fig. 3 A non-linear network for eight channels (equilateral co-channel distribution)

same number of channels, shows a non-linear uniform distribution. The arrows indicate the direction in which maximum adjacent channel interference is propagated and it is seen that there is variation both in magnitude and direction from channel to channel, which would not be so in the case of a linear network.

7 Equilateral site distribution network

This is represented by a lattice of equilateral triangles, each intersection representing the site of a transmitter. The lattice must be uniform, with the same spacing between the two sets of lines forming it and intersecting at 60°. Fig. 4 is an example of this case for a network of ten channels and the network is linear, as defined above. In this case, for ten channels, the lines joining the co-channel stations do not also form an equilateral triangle.

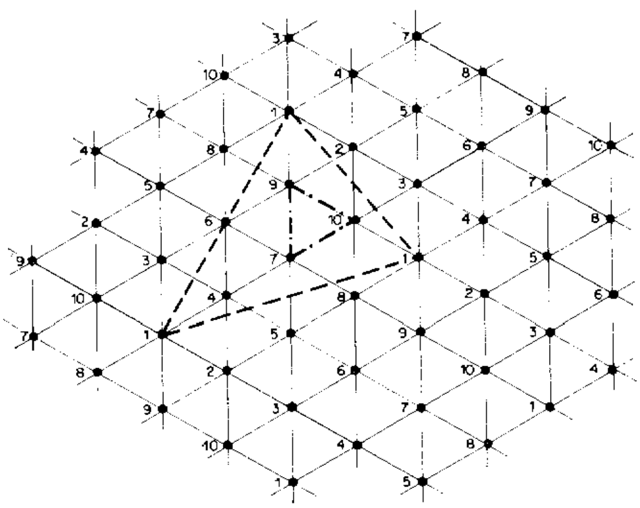


Fig. 4 An equilateral site distribution linear network for ten channels

8 Equilateral co-channel network

In this case the form of the lattice is such that when lines are drawn between sites using the same channel, then these lines form equilateral triangles. Under these conditions the 'elementary' triangles formed by lines joining adjacent transmitter sites may or may not also be equilateral. The distribution shown by the examples in Figs. 1 and 3 for eight channels, shows the co-channel triangles, as shown by the dashed lines, as equilateral, whereas the elementary triangles joining adjacent sites are not.

9 Regular network

If lines joining the co-channel sites of a system form equilateral triangles and lines joining the adjacent sites of the same system *also* form equilateral triangles, the network is said to be regular. This will only occur[6] when the number of channels N, satisfies the condition $N = a^2 + b^2 + ab$ where a and b are any positive integers or either is zero. A tabulation of such numbers is given in Section 10 below and in Ref. 6. Fig. 5 is an example of a regular network for nine channels and it should be noted that for this and some other numbers of channels, although regularity, as defined, can be achieved, the channel distribution is not linear. Linearity can only be achieved for this particular number of channels by a departure from regularity as shown in Figs. 6 and 7, the former arrangement providing linearity with equilateral site distribution and the latter giving linearity with equilateral co-channel distribution.

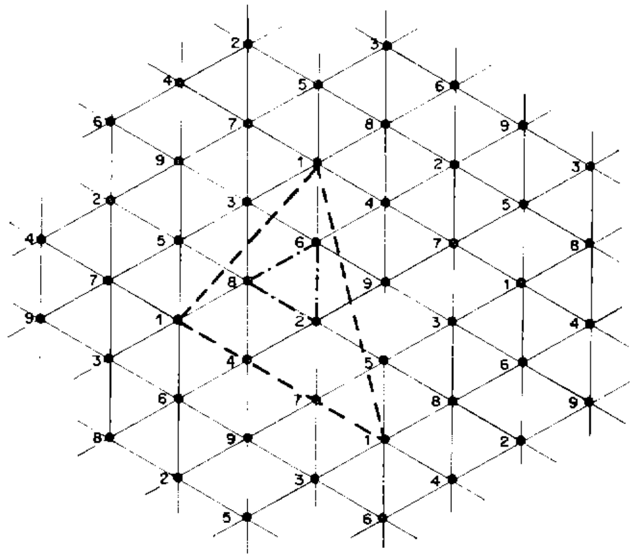


Fig. 5 Regular network for nine channels

10 Optimum network

A network which uses a site distribution and arrangement of the available channels in such a way that the greatest efficiency of coverage is obtained, may be said to be optimum. Efficiency

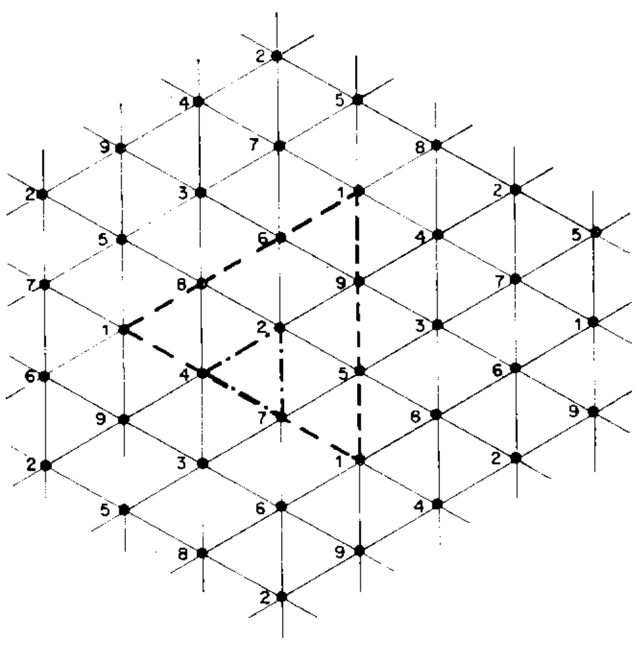


Fig. 6 Linear network for nine channels (equilateral site distribution)

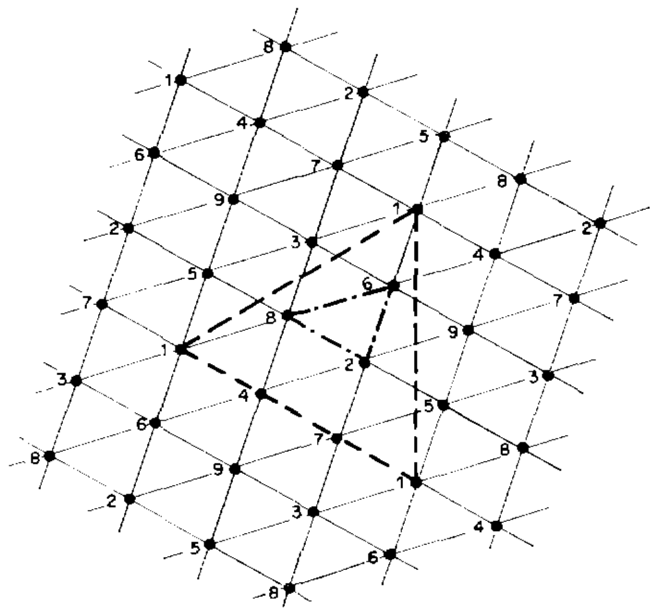


Fig. 7 Linear network for nine channels (equilateral co-channel distribution)

of coverage implies that there is minimum overlap of the service areas of each of the transmitters and that the mutual interference of various kinds, such as co-channel, adjacent channel and image channel, has been minimised and is in general of equal level in each of the service areas.

If a network is finite in extent and, as must be the case, uses a finite number of frequency channels, boundary effects and edge-of-band effects must to some extent unequalise the service areas of the transmitters sited near the boundaries of the area or using edge-of-band frequency channels.

To approach minimum overlap and equalisation of coverage the optimum network should, if possible, be made both regular and linear. Fig. 8 is an example of this case, shown for seven channels.

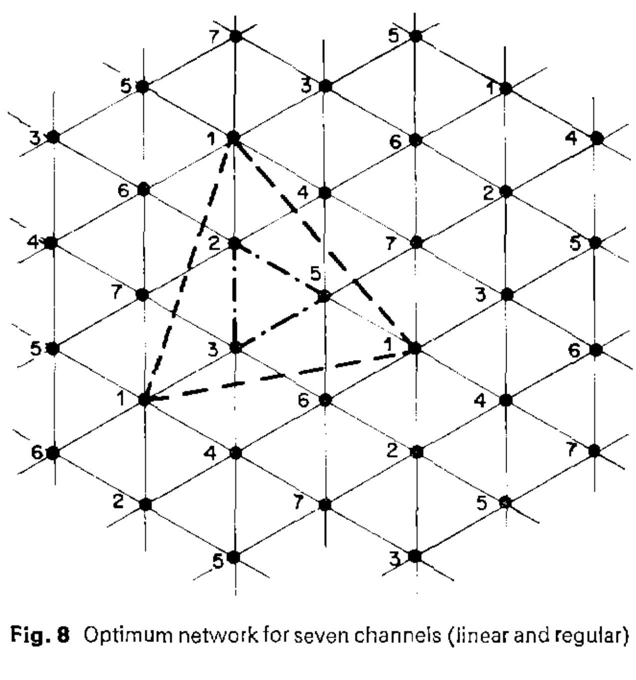


Fig. 8 Optimum network for seven channels (linear and regular)

The numbers of channels required for the formation of optimum networks, i.e. those both linear and regular, are derived from the formula

$$N = a^2 + b^2 - ab$$

where (1) a and b are integers (zero excluded)

(2) a and b must have no common factor

(3) values for N must also be prime to 9 e.g. 7, 13, 19, etc.

Considering now networks which are regular or regular and linear (i.e. optimum) we are able to construct the following list of numbers of channels in which (for numbers up to 150) those that form optimum networks are underlined:

$\underline{1}$, 3, 4, $\underline{7}$, 9, 12, $\underline{13}$, 16, $\underline{19}$, $\underline{21}$, 25, 27, 28, $\underline{31}$, 36, $\underline{37}$, $\underline{39}$, $\underline{43}$, 48, $\underline{49}$, 52, $\underline{57}$, $\underline{61}$, 63, 64, $\underline{67}$, $\underline{73}$, 75, 76, $\underline{79}$, 81, 84, $\underline{91}$, $\underline{93}$, $\underline{97}$, 100, $\underline{103}$, 108, $\underline{109}$, 111, 112, 117, 121, 124, $\underline{127}$, $\underline{129}$, $\underline{133}$, $\underline{139}$, 144, $\underline{147}$, 148

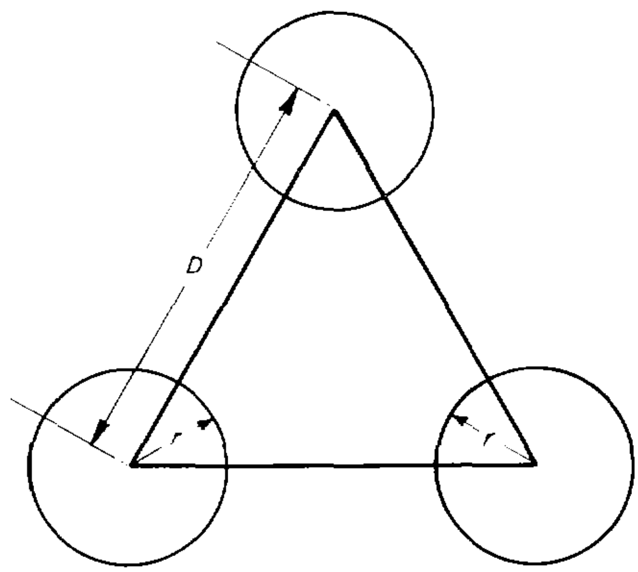


Fig. 9 Co-channel distance and service radius in a network

11 Calculation of groundwave coverage under idealised conditions

For this purpose it is assumed that the network will be a 'regular' network as defined above, with the lines joining the co-channel sites and the lines joining the adjacent sites both forming equilateral triangles.

Figs. 9 and 10 illustrate the meaning of the symbols used as defined below:

D = distance between the sites of co-channel stations in a regular equilateral network

r = service radius of each station. It can be either:

(*a*) the radial distance from each transmitting site to points where the field-strength of the transmitter exceeds the combined field-strengths from all other stations in the network by the required protection ratio, or (*b*) the radial distance to points where the field-strength falls to a value just sufficient to overcome man-made or atmospheric noise or some independent source of interference such as a distant transmission from a station not forming part of the network.

In case (*a*) r will be independent of the power of the transmitters and in case (*b*) r will increase with power.

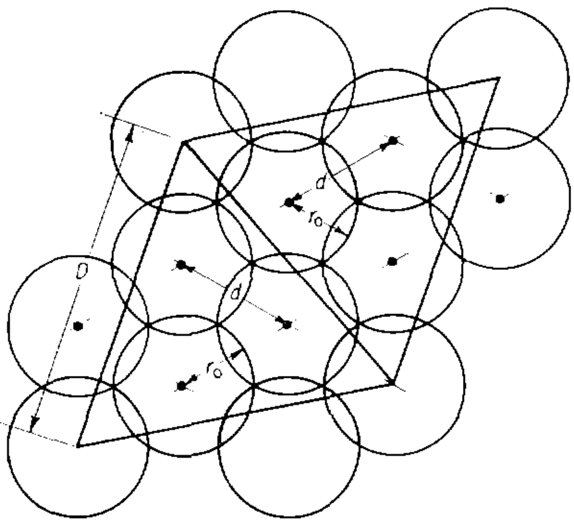


Fig. 10 Full coverage of an area by a regular network (seven channels)

In a theoretical paper[7] inter-station interference limits and noise-interference limits of service area are both taken into account and it will be clear that with relatively closely spaced co-channel stations noise will be less apparent than interference and vice-versa.

N = number of channels used in a 'regular' network = 1, 3, 4, 7, 9, 12, 13, 16 . . etc.[6]

d = separation between adjacent sites in the whole network (Fig. 10).

r_0 = the value for the service radius r such that the whole area is just covered, with minimum possible overlap (see Fig. 10).

The following general relationships then apply:

$$D = \sqrt{N}d \tag{1}$$

$$D = r_0\sqrt{3N} \tag{2}$$

Formula 1 is not used to calculate the actual coverage given by a particular network, it gives simply the distance between the adjacent sites in relation to the distance between the co-channel transmitters.

Formula 2 is useful for determining whether the number of channels available will give full area coverage. If r is the service range of each station, calculated, for example, by the method given below in Section 13, then the number of channels will be sufficient for full coverage if $r_0 \leqq r$, the value of r_0 having been calculated by means of formula 2.

Conversely, to determine the minimum number of channels required to give full coverage, the 'regular' numbers 1, 3, 4, 7 etc. should be inserted in Equation 2 successively to find which number gives a value for r_0 just below r. This procedure implies however that the co-channel distance D has already been determined; this is discussed in the following Section 12.

An example of a simple tabulation leading to the choice of the number of channels required for full coverage is now given:

e.g. D (co-channel spacing) = 230km (say)
r (calculated service range) = 46km (say)

N	$\sqrt{3N}$	$r_0 = \dfrac{D}{\sqrt{3N}}$
3	3	77 km
4	3·46	65·6km
7	4·58	50·4km
9	5·20	44·3
12	6·0	38·3

Thus minimum number of channels required = 9.

Note: Clearly if the requirements are *nearly* met by a lower number of channels it would be wasteful to employ the greater number theoretically required.

12 The co-channel separation distance *D*

Optimum values for this distance in the case of uniform networks can be determined by the methods given in in Ref. 7 (Eden and Minne) and the value will depend upon the required protection ratio, the power, frequency, ground conductivity σ and an agreed value for the 'noise limited' field-strength, E_{min} which will clearly depend upon the degree of natural or man-made noise. The value of the optimum co-channel separation distance will also depend upon whether reception is to be by

(*a*) groundwave under daytime conditions
(*b*) groundwave under night-time conditions
or (*c*) indirect wave under night-time conditions.

The word 'optimum' here implies that the maximum percentage coverage will be achieved per channel in each case.

The following is a table indicating some variations of optimum values for D met with using a limited selection of the parameters listed above. These figures apply only to a protection ratio of 40dB and are approximate.

The Eden–Minne paper[7] was particularly directed towards the problems of coverage by night and certain approximations were assumed to be valid.

The present article is concerned (Section 2 above) only with groundwave services by day and the results given in the Eden–Minne paper cannot accurately be extrapolated for cases where the transmitter powers are relatively low and where the protection ratios are considerably less than 40dB. Computer methods are desirable in these cases, where multiple interference effects must be allowed for and where it cannot be assumed (as in the method used by Eden and Minne) that the interference levels are approximately the same at the site of the wanted transmitter as at any other point within the service area.

Condition	Power kW	Co-channel distance D for 500kHz, $\sigma = 3$mmho/m $E_{min} = 67$dBμ	1500kHz, $\sigma = 1$mmho/m $E_{min} = 58$dBμ
(a) groundwave – daytime	1	340Kms	100Kms
	30	520Kms	180Kms
	1000	820Kms	320Kms
(b) groundwave – night	1	2000Kms	1200Kms
	30	3500Kms	1800Kms
	1000	5300Kms	2400Kms
(c) indirect wave – night	1	No service (E_{min} not exceeded)	No service
	30	4500Kms	4500Kms
	1000	6500Kms	6500Kms

13 Estimation of the groundwave service range of one station in an equilateral co-channel network

Fig. 11 shows the location of typical receiving points (A and B) at the edge of the service area of a 'wanted' station in relation to the position of some other stations in the network. The figure shows the position of the interfering co-channel transmitters in the first two 'rings' of these transmitters. In an extensive network there will be many more 'rings' of interfering transmitters located at the intersections of the lines of the equilateral triangular lattice.*

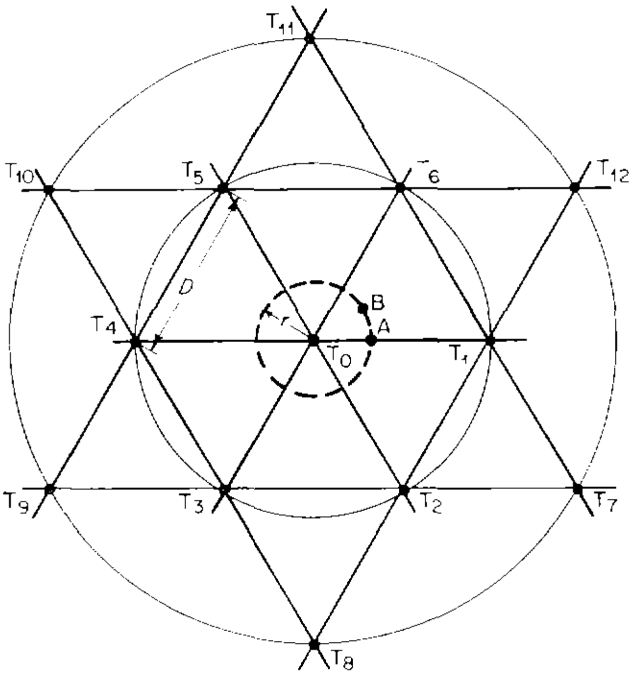


Fig. 11 Service range of a transmitter in a co-channel network

By definition the service area of the 'wanted' station T_0 will be the region bounded by the dashed line (approximately a circle) at any point on which the field strength of the wanted station T_0 will exceed the combined field of the other transmitters by the amount of the required protection ratio. By the use of a computer it is possible to calculate the service radius r of the wanted transmitter T_0, allowing for the combined effects (on a power addition basis) of all the transmitters in any number of 'rings' of interfering transmitters. This radius r will vary very slightly with the position of the receiving point A along the boundary of the service area, as defined above, between the position where A lies directly between T_0 and T_1 and when the receiving point is at position B, the direction T_0B making an angle of 30° with the line $T_0 T_1$.

* See, for example, Table II.

We are here concerned with groundwave propagation in the idealised case of uniformity conducting ground (not sea, as a network of transmitters with sea paths between is improbable). It will be seen that the major sources of interference to a receiving point such as A in Fig. 11 are the transmitters T_1, T_2 and T_6 particularly if a fairly low protection ratio is acceptable, making r a significant proportion of the co-channel distance D. In the case of a receiver at position B under similar conditions the major sources of interference will be transmitters T_1 and T_6. Because of the increased distance, the second and subsequent rings of interfering transmitters often will not contribute a significant amount to the combined interference of the nearest transmitters in the first ring.

14 Applications

If a low protection ratio is acceptable, as for example 10dB in the case of a synchronised network of common programme transmitters, the service radius r will be sufficiently accurately calculated if we take account of the combined interference from transmitters T_1, T_2 and T_6 only; taking the combined field E as

$$E = \sqrt{E_1^2 + 2E_2^2}$$

where E_1 is the field-strength at distance $D - r$ from transmitter T_1

and E_2 is the field strength at distance $\sqrt{D^2 + r^2 - Dr}$ from transmitters T_2 and T_6.

The computer can be programmed to calculate r for various co-channel distances D and for a given protection ratio and the use of this approximation will save some computer time.

However, if the protection ratio required is relatively high, say 30 dB or 40 dB as for the case of a co-channel network with transmitters radiating different programmes, r may be small compared with D and a significant contribution of interference may arise from all the six transmitters in the first ring and even from some or all the transmitters in the second ring, e.g. T_7 and T_{12} in Fig. 11. Under some conditions such as relatively close spacing of the co-channel station combined with high ground conductivity and the use of a frequency in the lower part of the band it may well be necessary to take into account the contributions of interference from transmitters in the second, third, or even rings of higher order. In this report, however, only the contributions from the first and second rings has been considered for the numerical examples (see Section 19).

15 Geometry of equilateral co-channel network

The following simple formulae give the distances of the too typical receiving points at A and B (see Fig. 11) from the six transmitters in the first ring contributing effectively to the total interference.

Let D = co-channel spacing in regular equilateral network
r = distance of receiver from wanted transmitter at 0 (see Fig. 11)

Then if receiver is at position A

Distance from T_1 $= D - r$

T_2 and T_6 $= \sqrt{D^2 + r^2 - Dr}$

T_3 and T_5 $= \sqrt{D^2 + r^2 + Dr}$

T_4 $= D + r$

If receiver is at position B

Distance from T_1 and T_6 $= \sqrt{D^2 + r^2 - 3Dr}$

T_2 and T_5 $= \sqrt{D^2 + r^2}$

T_3 and T_4 $= \sqrt{D^2 + r^2 + 3Dr}$

Also, if the receiver is at position A and is using a loop aerial correctly oriented towards the transmitter at T_0, the following reduction factors resulting from the cosine law aerial pattern may also be taken into account. As regards reception (interference) from transmitters T_1 and T_4, reduction factor = 1·0. As regards reception (interference) from transmitters T_2 and T_6

$$\text{reduction factor} = \frac{D - 2r}{2\sqrt{D^2 + r^2 - Dr}}$$

As regards reception (interference) from transmitters T_3 and T_5.

$$\text{reduction factor} = \frac{D + 2r}{2\sqrt{D^2 + r^2 + Dr}}$$

Similarly, if the receiver is at position B, the following reduction factors will apply.

As regards interference from T_1 and T_6

$$\text{reduction factor} = \frac{\sqrt{3}D - 2r}{2\sqrt{D^2 + r^2 - \sqrt{3}Dr}}$$

As regards interference from T_2 and T_5

$$\text{reduction factor} = \frac{r}{\sqrt{D^2 + r^2}}$$

As regards interference from T_3 and T_4

$$\text{reduction factor} = \frac{\sqrt{3}D + 2r}{2\sqrt{D^2 + r^2 + \sqrt{3}Dr}}$$

There is some doubt whether the loop receiving aerial reduction factors should be taken into account because most receivers with this type of aerial are used in indoor situations where the fields of the wanted and unwanted station are likely to be considerably distorted by the presence of house wiring etc. In computing service areas or percentage coverage on a conservative basis it is probably best to omit these factors from the calculation. This has been done in the case of the examples appended to this report.

16 Area coverage for single channel

Referring to Fig. 9 it will be seen that if the whole area is considered to be made up of a series of equilateral triangles the contribution of service of each station to each triangle is $\pi r^2/6$ from which it can be shown that the ratio of the area covered to the whole area is

$$\frac{2\pi}{\sqrt{3}} \cdot \frac{r^2}{D^2} \text{ or } 362{\cdot}8 \frac{r^2}{D^2} \%$$

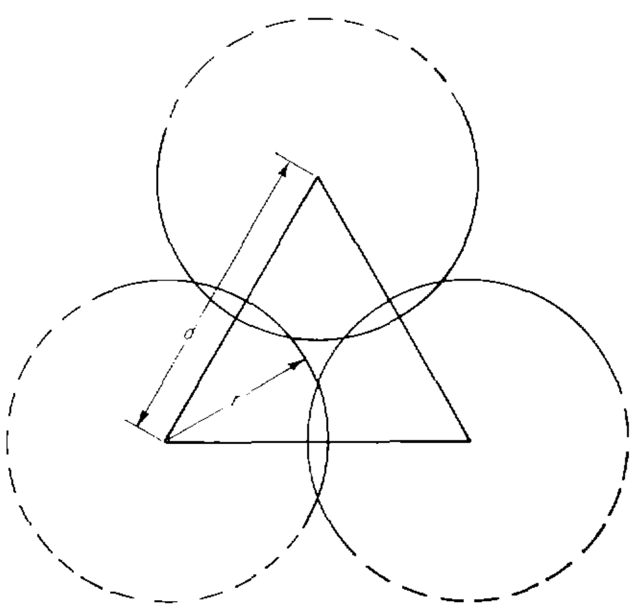


Fig. 12 Special case of overlapping service areas

The limit of validity of this formula is reached when $r = D/2$, i.e. when the service areas just meet but do not overlap. Clearly in the case of a single channel this condition never arises because at this point the protection ratio would be zero.

17 Area coverage of network using several channels

The overall percentage coverage for a network of N channels (involving equilateral co-channel networks) can also be calculated by the multiplication by N of the single channel coverage *provided* that the service ranges are such that no overlapping occurs, i.e. when $r<d/2$ the limit in these cases being 90·7 per cent (circles of equal radius touching but not overlapping.

On occasion it may be required to calculate the percentage area coverage where the actual dimensions are such that the service radius r is greater than half the distance between adjacent sites, i.e. where some overlapping occurs, as shown in Fig. 12, but not a sufficient case of $r = d\sqrt{3}$.

The relevant formula is:

$$C(\text{area coverage, \%}) = \frac{\frac{\pi}{2} - 3\theta + \frac{3}{2}\sin 2\theta}{3\cos^2\theta} \times 100$$

where $\theta = \cos^{-1}\frac{d}{2r}$ expressed in radians

Example:

$$d = 100\text{kms}$$
$$r = 54\text{kms}$$

Therefore $\cos\theta = \frac{d}{2r} = 0{\cdot}962$

$$\theta = 15{\cdot}93° = 0{\cdot}278 \text{ radians}$$
$$\sin^2\theta = 0{\cdot}528$$
$$\cos^2\theta = 0{\cdot}925$$

Substitution of these values in the formula above for C gives $C = 96{\cdot}05\%$.

18 Results for typical co-channel networks (computer output)

Table I, appended on the following pages, shows the results as computed area coverages (%), for three m.f. frequencies, two values of ground conductivity σ and four values of protection ratio, for various values of co-channel site separation in an equilateral co-channel network. Results are given for two values only of transmitter radiated power, viz, 1 kW and 10W. The Research Department Elliott 803 computer was not available long enough for results to be produced for other values of transmitter radiated power or for higher values of ground conductivity than $\sigma = 3$mmho/m.

The service range r is the distance from the wanted transmitter at which the wanted field E_w is attained, using the following formula to calculate E_w.

$$E_w = \sqrt{A^2\Sigma(E_1^2 + E_2^2 + E_3^2 + \ldots E_{12}^2) + 10{,}000E_n^2}$$

Where A = the required protection ratio against the combined interferences from the twelve transmitters in the first and second adjacent rings (see Fig. 11). In the tabulated results four values of the protection ratio A have been considered, viz. 40dB, 30dB, 20dB and 10dB. The first two of these can be taken to give reasonable and just acceptable limits of interference respectively, with different programmes radiated from all the transmitters radiated in the network, the third value, 20dB, would be quite unacceptable but the fourth value, represents a reasonable value of protection when a *common* programme is radiated from the transmitters in the network.

The value E_n is the noise field strength, which when multiplied by the appropriate protection ratio, gives the values of 'noise limited field strength' (see Ref. 7), which in Section 12 of this Report has been referred to as E_{min}. For the purpose of the tabulated examples of coverage given here we have taken the same three typical values of E_{min} as those used in the Eden and Minne paper,[7] viz. 67 dBμ (2·3 mV/m) at 500 kHz, *61 dBμ (1·1 mV/m) at 1000* kHz *and 58 dBμ (0·8 mV/m) at* 1500 kHz.

Where we are concerned with lower values of protection ratio A we have assumed, until such time as the results of any subjective tests on the relative annoyance of interfering r.f. signals and noise may become available, that a protection of 40dB shall, in all cases, be required against the RMS level of interfering noise, which is itself frequency dependent. That it is necessary to make some such assumption is clearly apparent where an r.f. protection ratio against other signals as low as 10dB can be accepted (common programme working) whereas in this latter case a wanted signal/noise ratio of 10dB would be quite unacceptable. In the formula above the significance of the numerical value 10000 in the second term is that it is the square of 100 (protection ratio 40dB).

In the case of all networks of co-channel transmitters it will be clear that when the stations are closely spaced the service range of each station is determined predominantly by the combined interference from the others in the network whereas with wide spacing of the sites the noise predominates and the interfering signals tend to have a negligible effect.

19 Choice of the network parameters (power, co-channel spacing) to give the best coverage

Examination of a set of tables such as Table I attached on pages 32–34 (which cover a limited range of powers and conductivity values) will, in general, reveal an 'optimum value' for the percentage *area* coverage $C\%$, in terms of co-channel separation distance and radiated powers. If the population were uniformly distributed over the whole area to be covered it would then be easy to decide the best values for the radiated powers and co-channel separation distance for a given known ground conductivity, it being assumed that for international planning reasons there was no choice of frequency. Having done this the number of channels required for full coverage could then be determined by the method given in Section 11, using the values of D and r taken from the tables. It is highly likely that if a high protection ratio were required, with separate programmes radiated from each station, an insufficient number of channels would be available to provide full coverage.

TABLE I

Explanation of symbols

D_{kms} — Co-channel site separation in kilometres
r_{kms} — Service range of each transmitter in kilometres
$C\%$ — Percentage area coverage for one channel
A_{eff} — Effective protection ratio, i.e.

$$\frac{E_w}{\sqrt{\Sigma(E_1^2+E_2^2+E_3^2+\dots E_{12}^2)+E_n^2}}$$

where E_w is the 'wanted' field-strength calculated from the formula given on page 8 and E_n is the RMS noise field-strength appropriate to the frequency given.

Service range and percent coverage per channel for 1 kW radiated
Signal protection ratio 40 dB

	$\sigma = 3$ mmho/m			$\sigma = 1$ mmho/m		
D_{kms}	r_{kms}	$C\%$	A_{eff}	r_{kms}	$C\%$	A_{eff}
Frequency 500kHz						
20	0·12	<0·1	40	0·28	0·1	40
40	0·37	<0·1	40	1·11	0·3	40
60	0·85	0·1	40	2·72	0·7	40
80	1·52	0·1	40	4·65	1·2	40
100	2·49	0·2	40	6·69	1·6	40
150	6·67	0·7	40	12·2	2·4	40
200	12·6	1·4	40	17·9	2·9	40
250	20·1	2·4	40	22·3	2·9	40
300	28·3	3·2	40	25·0	2·5	40
Frequency 1000kHz						
20	0·38	0·1	40	0·92	0·8	40
40	1·66	0·6	40	2·75	1·7	40
60	3·54	1·3	40	4·48	2·0	40
80	5·66	1·8	40	6·29	2·2	40
100	7·86	2·2	40	8·15	2·4	40
150	14·0	3·2	40	13·1	2·8	40
200	20·6	3·9	40	16·5	2·5	40
250	26·7	4·1	40	17·7	1·8	40
300	30·3	3·7	40	18·0	1·3	40
Frequency 1500kHz						
20	0·78	0·6	40	1·3	1·5	40
40	2·71	1·7	40	2·83	1·8	40
60	4·66	2·2	40	4·60	2·1	40
80	6·60	2·5	40	6·45	2·4	40
100	8·74	2·8	40	8·35	2·5	40
150	14·6	3·4	40	12·1	2·4	40
200	20·2	3·7	40	13·6	1·7	40
250	23·1	3·1	40	13·8	1·1	40
300	24·2	2·4	40	13·9	0·8	40

Service range and percent coverage per channel for 1 kW radiated
Signal protection 30 dB

	$\sigma = 3$ mmho/m			$\sigma = 1$ mmho/m		
D_{kms}	r_{kms}	$C\%$	A_{eff}	r_{kms}	$C\%$	A_{eff}
Frequency 500kHz						
20	0·38	0·1	30	0·85	0·7	30
40	1·19	0·3	30	3·07	2·1	30
60	2·49	0·6	30	6·42	4·1	30
80	4·49	1·1	30	9·73	5·4	30·1
100	7·18	1·9	30	13·0	6·2	30·2
150	16·0	4·1	30·2	0·3	6·6	31·5
200	26·1	6·2	30·6	24·5	5·4	34·3
250	35·5	7·3	31·6	26·0	3·9	37·2
300	42·0	7·1	33·6	26·5	2·8	39·0
Frequency 1000kHz						
20	1·10	1·1	30	30	3·7	30
40	4·04	3·7	30	5·02	5·7	30
60	7·41	5·5	30	7·88	6·3	30·1
80	10·9	6·7	30·1	10·7	6·5	30·4
100	14·3	7·4	30·2	13·4	6·5	31·2
150	22·8	8·4	31	17·1	4·7	35·1
200	29·0	7·6	33·5	18·1	3·0	38·4
250	31·4	5·7	36·8	18·2	1·9	39·6
300	32·1	4·1	39·0	18·3	1·4	39·9
Frequency 1500kHz						
20	1·92	3·4	30	2·37	5·1	30
40	5·21	6·2	30	5·18	6·1	30
60	8·23	6·8	30·1	7·94	6·4	30·3
80	11·4	7·4	30·2	10·4	6·1	31·2
100	14·6	7·7	30·5	12·1	5·3	32·9
150	21·2	7·2	32·7	13·7	3·0	37·6
200	23·7	5·1	36·9	14·0	1·8	39·5
250	24·3	3·4	39·2	14·0	1·1	39·9
300	24·2	2·4	29·8	13·9	0·8	≃40·0

Service range and percent coverage per channel for 1kW radiated
Signal protection ratio 20 dB

	$\sigma = 3$ mmho/m			$\sigma = 1$ mmho/m		
D_{kms}	r_{kms}	$C\%$	A_{eff}	r_{kms}	$C\%$	A_{eff}
Frequency 500kHz						
20	1·16	1·2	20	2·37	5·1	20
40	3·50	2·8	20	6·97	11·0	20·1
60	7·06	5·0	20	12·3	15·2	20·2
80	11·5	7·5	20·1	16·9	16·2	20·8
100	16·7	10·2	20·2	20·8	15·6	21·9
150	30·1	14·6	21	25·6	10·5	27·2
200	40·3	14·8	23·3	26·5	6·4	32·9
250	45·0	11·8	27·3	26·7	4·1	36·8
300	46·7	8·8	31·7	26·8	2·9	38·8

Frequency 1000kHz						
20	2·84	7·3	20	3·8	13·1	20
40	7·91	14·2	20	8·46	16·2	20·2
60	13·3	17·8	20·1	12·9	16·7	21·1
80	18·2	18·9	20·4	15·7	14·0	22·3
100	22·8	18·9	21·1	17·1	10·7	26·4
150	30·0	14·5	25·4	18·1	5·3	34
200	31·9	9·2	31·5	18·3	3·0	38·2
250	32·3	6·1	36·3	18·2	1·9	39·6
300	32·4	4·2	38·8	18·3	1·4	39·9
Frequency 1500kHz						
20	3·82	13·2	20	4·13	15·5	20
40	8·93	18·1	20·1	8·61	16·8	20·6
60	13·6	18·7	20·3	11·7	13·9	22·7
80	17·9	18·1	21·3	13·2	9·8	26·4
100	20·9	15·9	23·2	13·7	6·8	30·4
150	23·8	9·1	30·4	14·0	3·2	37·3
200	24·3	5·4	36·4	14·0	1·8	39·5
250	24·3	3·4	39	14·0	1·1	39·9
300	24·5	2·4	39·8	13·9	0·8	40

Service range and percent coverage per channel for 1kW radiated
Signal protection ratio 10dB

	$\sigma = 3$ mmho/m			$\sigma = 1$ mmho/m		
D_{kms}	r_{kms}	$C\%$	A_{eff}	r_{kms}	$C\%$	A_{eff}
Frequency 500kHz						
20	3·41	10·5	10	5·38	26·3	10
40	9·16	19·0	10	12·5	35·3	10·2
60	16·0	25·9	10·1	19·0	36·2	11·2
80	23·2	30·4	10·4	23·6	31·7	14
100	30·0	32·7	10·9	25·6	23·8	17·7
150	42·1	28·6	14·6	26·6	11·4	26·4
200	46·4	19·5	20·6	26·7	6·4	32·7
250	47·2	13·0	26·4	26·7	4·1	36·8
300	47·3	9·0	31·4	26·8	2·9	38·8
Frequency 1000kHz						
20	5·85	31·0	10	6·36	36·7	10
40	13·3	39·9	10·1	13·0	38·3	11·2
60	20·7	43·0	10·7	16·8	28·6	15·5
80	26·4	39·4	12·4	17·9	18·1	20·7
100	29·8	32·3	15·3	18·1	11·9	25·4
150	32·2	16·7	24	18·2	5·4	33·9
200	32·3	9·5	31·3	18·3	3·0	38·2
250	32·3	6·1	36·3	18·2	1·9	39·5
300	32·4	4·2	38·8	18·3	1·4	39·9
Frequency 1500kHz						
20	6·47	38·8	10	6·73	41·1	10·2
40	13·5	41·5	10·4	12·1	33·1	13·3
60	19·8	39·4	12·2	13·6	18·7	19·6
80	22·8	29·4	16	13·9	10·9	25·4
100	23·8	20·5	20·5	13·9	7·0	30·1
150	24·2	9·5	30	14·0	3·2	36·4
200	24·3	5·4	36·3	14·0	1·8	39·5
250	24·3	3·4	39·1	14·0	1·1	39·9
300	24·5	2·4	39·8	13·9	0·8	40

Service range and percent coverage per channel for 10W radiated
Signal protection ratio 40dB

	$\sigma = 3$ mmho/m			$\sigma = 1$ mmho/m		
D_{kms}	r_{kms}	$C\%$	A_{eff}	r_{kms}	$C\%$	A_{eff}
Frequency 500kHz						
20	0·12	0·0	40	0·28	0·1	40
40	0·37	0·0	40	1·11	0·3	40
60	0·85	0·1	40	2·67	0·7	40
80	1·52	0·1	40	4·26	1·0	40
100	2·49	0·2	40	5·62	1·1	40
150	5·93	0·6	40	7·25	0·8	40
200	8·69	0·7	40	7·52	0·5	40
250	10·1	0·6	40	7·69	0·3	40
300	10·4	0·4	40	7·47	0·2	40
Frequency 1000kHz						
20	0·38	0·1	40	0·92	0·8	40
40	1·66	0·6	40	2·71	1·7	40
60	3·49	1·2	40	4·13	1·7	40
80	5·43	1·7	40	5·04	1·4	40
100	7·18	1·9	40	5·52	1·1	40
150	9·59	1·5	40	5·79	0·5	40
200	10·3	1·0	40	5·76	0·3	40
250	10·4	0·6	40	5·74	0·2	40
300	10·4	0·4	40	5·71	0·1	40
Frequency 1500kHz						
20	0·79	0·6	40	1·3	1·5	40
40	2·71	1·7	40	2·71	1·7	40
60	4·54	2·1	40	3·84	1·5	40
80	6·05	2·1	40	4·34	1·1	40
100	7·08	1·8	40	4·44	0·7	40
150	7·98	1·0	40	4·61	0·3	40
200	8·11	0·6	40	4·59	0·2	40
250	8·18	0·4	40	4·52	0·1	40
300	8·06	0·3	40	4·54	0·1	40

Service range and percent coverage per channel for 10W radiated
Signal protection ratio 30dB

	$\sigma = 3$ mmho/m			$\sigma = 1$ mmho/m		
D_{kms}	r_{kms}	$C\%$	A_{eff}	r_{kms}	$C\%$	A_{eff}
Frequency 500kHz						
20	0·38	0·1	30	0·85	0·7	30
40	1·19	0·3	30	2·95	2·0	30·3
60	2·49	0·6	30·1	5·48	3·0	31·8
80	4·26	1·0	30·5	6·76	2·6	34·3
100	6·20	1·4	31·2	7·28	1·9	36·7
150	9·59	1·5	34·9	7·54	0·9	39·3
200	10·4	1·0	38·1	7·52	0·5	39·8
250	10·6	0·7	39·4	7·69	0·3	39·9
300	10·7	0·5	39·8	7·47	0·2	40

Frequency 1000kHz						
20	1·1	1·1	30	2·02	3·7	30·1
40	4·0	3·6	30·2	4·47	4·5	31·8
60	6·88	4·8	31·1	5·42	3·0	35·3
80	8·79	4·4	33	5·66	1·8	37·9
100	9·72	3·4	35·4	5·71	1·2	39·2
150	10·3	1·7	39	5·79	0·5	39·9
200	10·3	1·0	39·8	5·76	0·3	40
250	10·4	0·6	39·9	5·74	0·2	40
300	10·4	0·4	40	5·71	0·1	40
Frequency 1500kHz						
20	1·92	3·4	30	2·33	4·9	30·3
40	4·98	5·6	30·6	4·0	3·6	33·6
60	6·94	4·9	32·8	4·42	2·0	37·5
80	7·7	3·4	35·8	4·49	1·1	39·2
100	7·96	2·3	37·9	4·54	0·7	39·7
150	8·13	1·1	39·7	4·61	0·3	40
200	8·11	0·6	39·9	4·59	0·2	40
250	8·18	0·4	39·9	4·52	0·1	40
300	8·06	0·3	40	4·54	0·1	40

Service range and percent coverage per channel for 10W radiated
Signal protection ratio 20dB

	$\sigma = 3$ mmho/m			$\sigma = 1$ mmho/m		
D_{kms}	r_{kms}	$C\%$	A_{eff}	r_{kms}	$C\%$	A_{eff}
Frequency 500kHz						
20	1·16	1·2	20	2·33	4·9	20·2
40	3·38	2·6	20·3	5·8	7·6	22·5
60	6·18	3·9	21·3	7·24	5·3	28·1
80	8·48	4·1	23·5	7·54	3·2	32·9
100	9·72	3·4	26·5	7·57	2·1	36·1
150	10·6	1·8	33·9	7·54	0·9	39·2
200	10·6	1·0	37·9	7·52	0·5	39·8
250	10·6	0·7	39·4	7·69	0·3	39·9
300	10·7	0·5	39·8	7·47	0·2	40
Frequency 1000kHz						
20	2·82	7·2	20	3·62	11·9	20·8
40	7·25	11·9	21·4	5·57	7·0	28
60	9·58	9·2	25·9	5·77	3·4	34·3
80	10·1	5·8	30·7	5·74	1·9	37·7
100	10·3	3·9	34·5	5·81	1·2	39·1
150	10·3	1·7	38·9	5·79	0·5	39·9
200	10·4	1·0	39·8	5·76	0·3	40
250	10·4	0·6	39·9	5·74	0·2	40
300	10·4	0·4	40	5·71	0·1	40
Frequency 1500kHz						
20	3·76	12·8	20·2	3·62	11·9	22·4
40	7·21	11·8	24·1	4·47	4·5	31·8
60	7·94	6·4	30·3	4·54	2·1	37·1
80	8·09	3·7	34·9	4·57	1·2	39·1
100	8·06	2·4	37·7	4·54	0·7	39·7
150	8·13	1·1	39·7	4·61	0·3	40
200	8·11	0·6	39·9	4·59	0·2	40
250	8·18	0·4	40	4·52	0·1	40
300	8·06	0·3	40	4·54	0·1	40

Service range and percent coverage per channel for 10W radiated
Signal protection ratio 10dB

	$\sigma = 3$ mmho/m			$\sigma = 1$ mmho/m		
D_{kms}	r_{kms}	$C\%$	A_{eff}	r_{kms}	$C\%$	A_{eff}
Frequency 500kHz						
20	3·31	9·9	10·3	4·89	21·7	11·4
40	7·48	12·7	12·3	7·32	12·2	19·3
60	9·7	9·5	16·5	7·59	5·8	27·5
80	10·4	6·2	21·2	7·62	3·3	32·8
100	10·6	4·1	25·6	7·57	2·1	3·61
150	10·8	1·9	33·7	7·54	0·9	39·2
200	10·6	1·0	38	7·52	0·5	39·8
250	10·6	0·7	39·3	7·69	0·3	39·9
300	10·7	0·5	39·8	7·47	0·2	40
Frequency 1000kHz						
20	5·63	28·8	10·6	5·15	24·0	14·3
40	9·67	21·2	16·5	5·76	7·5	27·4
60	10·3	10·7	24·7	5·77	3·4	34·2
80	10·4	6·1	30·4	5·82	1·9	37·6
100	10·4	3·9	34·4	5·81	1·2	39·1
150	10·3	1·7	38·9	5·79	0·5	39·9
200	10·4	1·0	39·8	5·76	0·3	40
250	10·4	0·6	39·9	5·74	0·2	40
300	10·4	0·4	40	5·71	0·1	40
Frequency 1500kHz						
20	6·03	32·9	11·6	4·4	17·6	18·9
40	7·99	14·5	22·2	4·55	4·7	31·5
60	8·12	6·6	29·9	4·54	2·1	37·1
80	8·09	3·7	34·9	4·57	1·2	39
100	8·15	2·4	37·6	4·54	0·7	39·7
150	8·13	1·1	39·7	4·61	0·3	40
200	8·11	0·6	39·9	4·59	0·2	40
250	8·18	0·4	40	4·52	0·1	40
300	8·06	0·3	40	4·54	0·1	40

Under practical conditions, fortunately for service planning of this kind, the population is not uniformly distributed but tends to be grouped into 'conurbations' of one kind of another. Accepting the impossibility of full 'area' coverage we can now aim at a maximum percentage population coverage and the following procedures are suggested.

Using a population density map, or a specially prepared map showing the position of the centres of town or conurbations exceeding a certain minimum population (say, for example, 20000 inhabitants), a uniform lattice of parallel straight lines intersecting at 60° is roughly fitted to the map so that all the marked positions of the population centres lie at points of intersection of the lattice. The length of the sides of the equilateral triangles forming the lattice will then give the value of d (site separation distance), as defined in Section 11.

At this point it will be necessary to assume a value for N, the number of available channels and a starting point would be to take, successively, values for N of 1, 3 and 7 (giving optimum networks – see Section 10) and for each value to

TABLE II

Table to be used for the calculation of multiple interference within a uniform lattice of transmitters

Let D = side of equilateral triangle lattice, i.e. the minimum spacing between transmitter sites.
Let x = distance from wanted transmitter site to interfering transmitter sites in ring.

Ring Number	x/D	*Number of Transmitters in Ring*	*Cumulative Total of Interfering Transmitters*
1	1·0	6	6
2	1·73	6	12
3	2·0	6	18
4	2·65	12	30
5	3·0	6	36
6	3·46	6	42
7	3·61	12	54
8	4·0	6	60
9	4·36	12	72
10	4·58	12	84
11	5·0	6	90
12	5·20	6	96
13	5·29	12	108
14	5·57	12	120
15	6·0	6	126
16	6·08	12	138
17	6·25	12	150
18	6·56	12	162
19	6·93	6	168
20	7·0	18	186
21	7·21	12	198
22	7·55	12	210
23	7·81	12	222
24	7·94	12	234
25	8·0	6	240
26	8·19	12	252
27	8·54	12	264
28	8·66	6	270
29	8·72	12	282
30	8·89	12	294
31	9·0	6	300
32	9·17	12	312
33	9·34	24	336
34	9·64	12	348
35	9·85	12	360
36	10·0	6	366

calculate the co-channel separation distance from the formula (1) on page 5 viz. $D = \sqrt{N}.d$. Use of the tables, for the given conductivity and frequency and the required protection ratio will then show what service range r is obtained and by comparison what is the optimum radiated power. An alternative approach would be to decide what was the required service range, then to decide by inspection of the tables what was the necessary co-channel separation distance and optimum radiated power and then the number of channels necessary to achieve this by the use of the formula $D = \sqrt{N}.d$.

20 Conclusion

This article is incomplete as it stands since the computed table of service range and area coverage at present only covers two rather extreme values of transmitted radiated power and only two values of ground conductivity. The purpose of the report is that it should be an aid to understanding methods of planning a groundwave daylight service for a large number of small stations for purposes such as local broadcasting. Extended computer programmes could be developed to calculate actual population coverages from networks of various dimensions applied to the United Kingdom, using the available data bank of population enclosed within squares of 0·5 km side over the whole country.

Computer methods could also be established to select the number of interfering transmitters in the surrounding rings to be taken into account in calculating the approximate service range of the 'wanted' station; to achieve a given accuracy, more interfering transmitters will have to be allowed for where the frequency is low, the ground conductivity high, and the co-channel spacing smaller than is the case when the frequency is high, the conductivity low and the co-channel spacing large.

It has been pointed out that in the case of large networks, under daylight conditions, the only reason for neglecting the effects of the more distant interfering transmitters is that, due to ground attenuation, their individual field-strengths fall off more rapidly than on an 'inverse distance' ($1/R$) basis. Since the number of transmitters within an annulus of mean radius R tends to increase proportionally with the value of R, summation of the interference effects out to a large distance would give a divergent result but for the overriding effect of ground attenuation.

Should groundwave coverage of a large network of low-powered transmitters at night be investigated it will be necessary to bear in mind the fact that many more successive rings of interfering transmitters may contribute substantially to the mean interference at any point.

The author is grateful to his colleagues J. W. Head and R. W. Lee for considerable assistance with the mathematical theory and computer programming respectively.

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L.F. and M.F. Propagation: Sky-wave Field-strength Prediction

P. Knight, M.A., Ph.D., M.I.E.E.
Research Department

Summary: During the night, medium-frequency sky-waves propagate to great distances via the ionosphere. The report describes the various factors which affect the waves as they travel from transmitter to receiver. Several methods which can be used for estimating the strength of sky-wave signals are compared.

1 Introduction

This article is based on a lecture which was given at the three seminars organised by the International Telecommunications Union prior to the 1974 Frequency-Planning Conference. The purpose of the seminars was frequency planning to engineers who would be attending the 1974 Conference. Since the lecture was mainly concerned with field strength prediction, the various propagation curves and prediction methods which are available for planning are considered in detail. To assist in the better understanding of the differences which arise when waves propagate at various latitudes or in different directions, the factors which influence the strength of medium frequency sky waves are discussed. The diurnal, short-period and solar-cycle variations of signal strength which arise in practice are also described.

2 Field-strength variation

2.1 Diurnal variation

During the day, l.f. and m.f. sky-waves are absorbed by the ionosphere and are unable to propagate further. After sunset, however, the D region of the ionosphere, which absorbs the waves during the day, decays rapidly, and waves are then reflected with little loss from the higher E and F layers. Multi-hop propagation to great distances is the possible.

Fig. 1 shows how sky-wave field-strengths increase after sunset on most paths. The signal-strength increases by about 20dB in the two hours centred on sunset and then remains more steady. At sunrise the D region ionisation is re-established and the signal-strength decreases rapidly.*

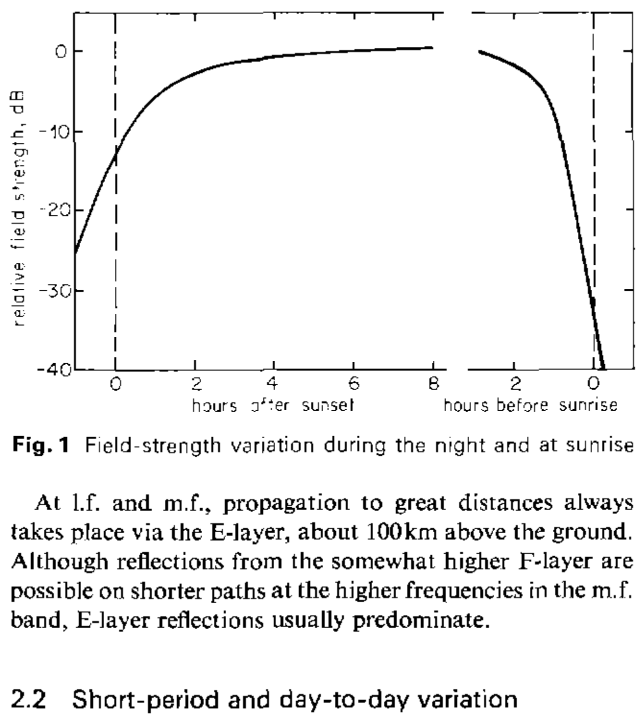

Fig. 1 Field-strength variation during the night and at sunrise

At l.f. and m.f., propagation to great distances always takes place via the E-layer, about 100km above the ground. Although reflections from the somewhat higher F-layer are possible on shorter paths at the higher frequencies in the m.f. band, E-layer reflections usually predominate.

2.2 Short-period and day-to-day variation

Because the ionosphere is a turbulent medium, the strength of sky-wave signals varies continually, the rate of variation depending on frequency and path length. At frequencies below 1 MHz, several minutes may elapse between consecutive maxima. On higher frequencies, however, several maxima may occur during one minute, especially on shorter paths where E- and F-layer reflections are present simultaneously. If a continuous recording is made for half an hour, the field-strength exceeded for 10 per cent of the time

* Fig. 1 shows field-strength variation in terms of the times at which the sun sets and rises at the ground below the ionospheric reflection point. On multi-paths the diurnal variation is controlled by the reflection point where the sun sets last or rises first.

(the quasi-maximum field-strength) will be found to be about 5dB greater than the field-strength exceeded for 50 per cent of the time (the median value).

If recordings are made for half-hour periods at the same time after sunset on a series of nights, the median value will be found to vary considerably from night to night. The median field-strength exceeded on 50 per cent of the nights is the measured value usually quoted, and is also the value derived from propagation curves and prediction formulae. The median field-strength exceeded on 10 per cent of the nights, however, is between 5 and 10dB greater than the stated value. Because of the combined effect of short-period and day-to-day variations, the field-strength exceeded for 10 per cent of the total time on a series of nights will be between 7 and 11dB higher than the overall median value usually stated. For planning purposes it is reasonable to assume that the field-strength exceeded for 10 per cent of the time is 10dB greater than the overall median.

Because of this day-to-day variation, measurements made on only one or two nights cannot be regarded as reliable. If the interference caused by a particular transmitter is to be evaluated, measurements must be made on a sufficient number of nights for the overall median value to be accurately determined.

2.3 Solar-cycle variation

An additional source of variation is caused by solar activity, field-strengths being lower at the peak of the solar cycle. In Europe the decrease at m.f. is found to be approximately $Rd \times 10^{-5}$dB, where R is the sunspot number (typically 150 at the peak of the solar cycle) and d is the path length in km[1]. In North America the decrease is much greater but in tropical regions it may be smaller. At l.f. there appears to be little or no variation. The field-strength decrease should be disregarded for planning purposes, because co-channel interference will be worse when solar activity is least ($R = 0$).

3 Factors which influence sky-wave field-strength

As the wave propagates from transmitter to receiver it is subject to a number of different types of loss which are illustrated in Fig. 2. These losses are considered in detail in this section.

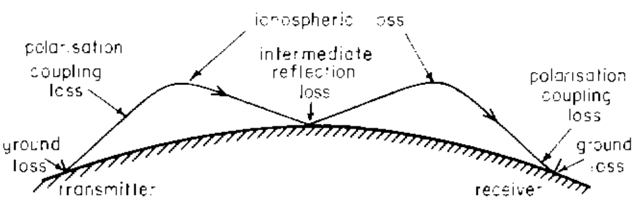

Fig. 2 Losses on a two-hop path

3.1 Ground loss at transmitter and receiver

Propagation curves such as those published by the CCIR usually apply to paths whose terminals are well inland. They therefore take account of the ground loss due to imperfect ground conductivity which occurs at transmitter and receiver.[2,3] Greater field-strengths will be observed, however, if either the transmitter or receiver is situated near the sea, provided the first (or last) part of the path lies over the sea. This increase occurs because sea water is a better conductor than land and reflects waves more efficiently, especially at the low angles which are important for long-distance propagation.

Fig. 3 shows the approximate increase which would occur at m.f. if ground of average conductivity (10mS/m) were replaced by sea water at either the transmitter or receiver;

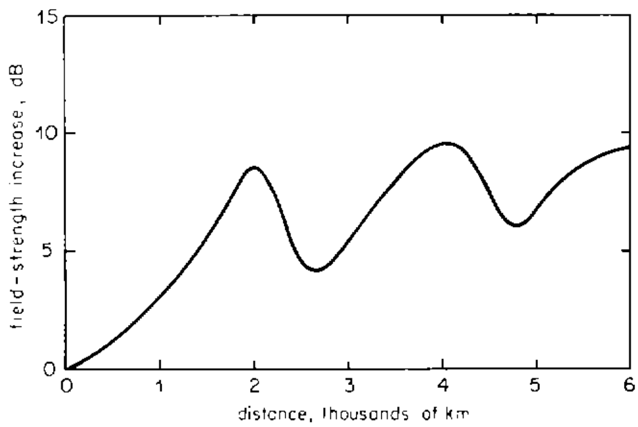

Fig. 3 Effect of replacing land, at transmitter or receiver, by sea

the increase will be doubled if both are near the sea. The increase rises to a maximum when the path length is about 2000km, because here the one-hop mode predominates and is propagated at a very low angle. The increase rises to a further maximum at about 4000km; here the two-hop mode predominates. For paths longer than 6000km the increase may be assumed to be 10dB when one terminal is near the sea or 20dB if both are close to the sea. Similar increases occur at l.f.

The full increase shown in Fig. 3 will only apply if the transmitter or receiver is within a few km of the sea. Fig. 4

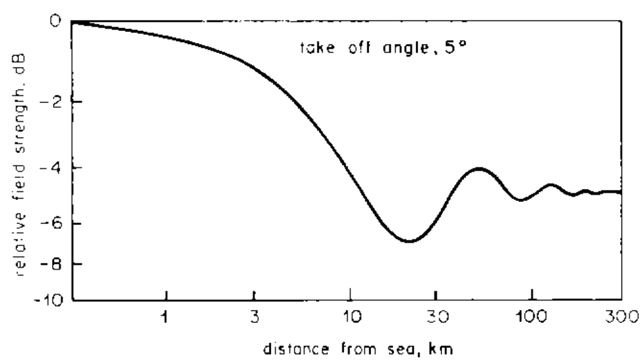

Fig. 4 Variation of field strength with distance from sea

shows how the field-strength depends on the actual distance from the sea (measured in the direction of propagation) when one terminal of a 1500km path is moved inland, assuming ground of average conductivity (10mS/m) and a frequency of 1 MHz.

3.2 Polarisation coupling loss

Conventional aerials radiate vertically-polarised waves. At m.f. the wave which is accepted by the ionosphere and which propagates further, usually has a different polarisation and may not be excited efficiently by the incident wave. The wave which emerges from the ionosphere is in general elliptically polarised and may not excite the listener's receiving aerial efficiently, because aerials near the ground are most sensitive to vertical polarisation.

The fraction of the incident power which is lost on entry into the ionosphere is called the polarisation coupling loss.[4] Further polarisation coupling loss occurs when the wave which emerges from the ionosphere induces a voltage in the receiving aerial. The coupling losses which occur at the two ends of the path are caused by essentially the same mechanism and are unchanged if the direction of propagation is reversed.

Polarisation coupling loss is caused by the Earth's magnetic field and therefore depends both on magnetic-dip angle and on the direction of propagation relative to magnetic north, as shown in Fig. 5. The major axis of the elliptically-

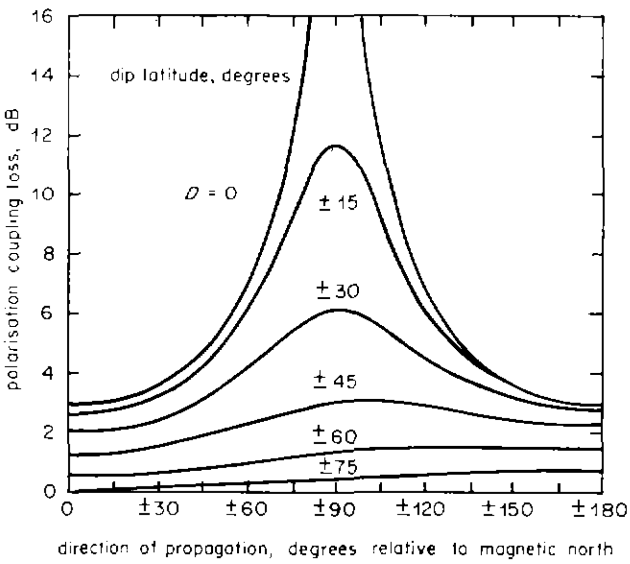

Fig. 5 Polarisation coupling loss

polarised wave which is accepted by the ionosphere, and also that of wave which emerges, is parallel to the direction of the Earth's magnetic field. Consequently polarisation coupling losses are low in temperate latitudes, because the Earth's magnetic field is almost vertical. At this magnetic equator, however, the Earth's field is horizontal and polarisation coupling losses on East–West paths are large.

Polarisation coupling loss does not occur outside the m.f. band because it is a consequence of the gyromagnetic frequency, which falls within the m.f. band.* The gyromagnetic frequency depends on the strength of the Earth's magnetic field, and varies from 1·5 MHz in temperate latitudes to 0·7 MHz in some parts of the equatorial region.

* The gyromagnetic frequency is the frequency with which electrons in motion spiral around the Earth's magnetic field lines. If the sense of rotation of an elliptically-polarised wave of similar frequency is such that it enhances this motion, power drawn from the wave will be transferred to the electrons and the wave will be rapidly attenuated. If the wave has the opposite sense of rotation, however, it will propagate with little attenuation.

3.3 Ionospheric loss

As mentioned in Section 2.1, sky-wave field-strengths increase after sunset because ionospheric losses decrease. Late at night the field-strength reaches its greatest value but some residual ionospheric loss remains. The residual loss on a long path may be considerable and it is therefore an important factor which must be taken into account.

It can be shown theoretically that ionospheric loss is least when the direction of propagation is parallel to the direction of the Earth's magnetic field. In equatorial regions, therefore, ionospheric losses for low-angle modes on north–south paths are smaller than on east–west paths, as shown in Fig. 6.

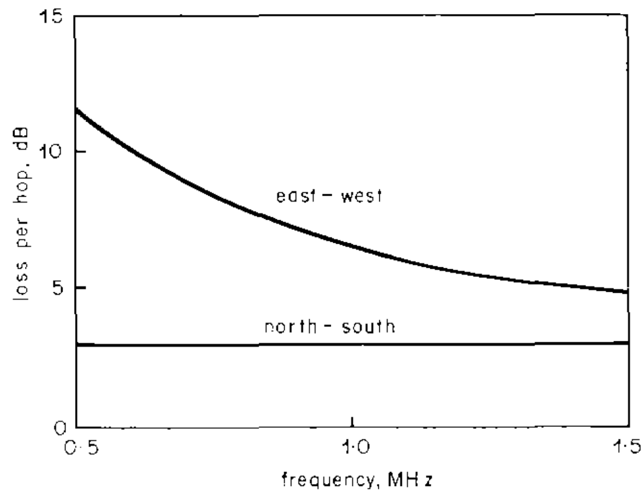

Fig. 6 Ionospheric loss at the magnetic equator

Since east–west propagation at all latitudes is perpendicular to the direction of the Earth's field, losses on east–west paths are independent of latitude outside the auroral zone.

Although the rate of attenuation in the ionosphere decreases with increasing frequency, waves of higher frequencies penetrate more deeply into the ionosphere and the distance traversed within the ionosphere is greater than at lower frequencies. Consequently the variation of the total loss with frequency is much smaller than would otherwise be the case. Fig. 6 shows that ionospheric loss is, in fact, almost independent of frequency within the m.f. band on north–south equatorial paths.

In the auroral zones, ionospheric losses are somewhat greater than those shown in Fig. 6. The auroral zones are centred on the magnetic poles and have an outer radius of about 4000 km. Areas which are affected by increased losses include Canada and the northern USA, the North Atlantic and the northern part of the USSR. In this region, ionospheric losses are independent of the direction of propagation because the Earth's magnetic field is almost vertical.

3.4 Intermediate reflection loss

Fig. 7 illustrates the reflection of a wave at the Earth's surface on a multi-hop path. When the wave is reflected its strength

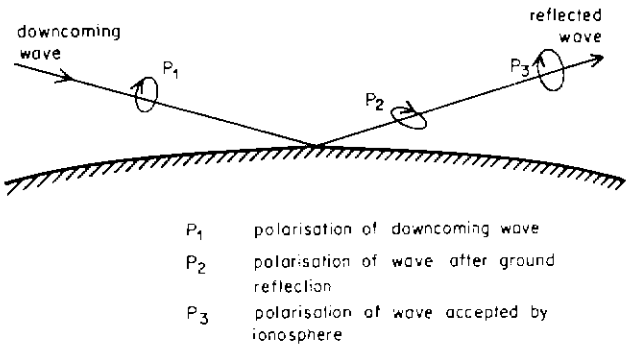

Fig. 7 Intermediate reflection loss

is reduced because of losses in the ground, and its polarisation is also modified. The polarisation of the reflected wave may differ from that required by the ionosphere on the next hop and polarisation coupling loss, similar to that described in Section 3.2, will occur at m.f. The sum of the ground reflection loss and the polarisation coupling loss is known as intermediate reflection loss.[4,5] It depends in a complicated way on the direction of propagation, on the direction of the Earth's magnetic field and on the ground constants at the reflection point.

There are three situations in which the loss may be large:

1. In temperate latitudes when the down-coming wave is reflected from land at an angle near the Brewster angle. The loss may depend on the direction of propagation, waves propagating towards the west suffering most loss.
2. For east–west propagation with sea reflection at 45° dip latitude.
3. For north–south propagation with sea reflection at the magnetic equator.

At l.f. only the ground reflection loss need be considered, and this is usually small.

4 Sky-wave field-strength prediction

For planning purposes, some method is required for estimating sky-wave field-strength. Possibilities range from the detailed calculation of all the losses described in Section 3, to the use of propagation curves derived from measurements.

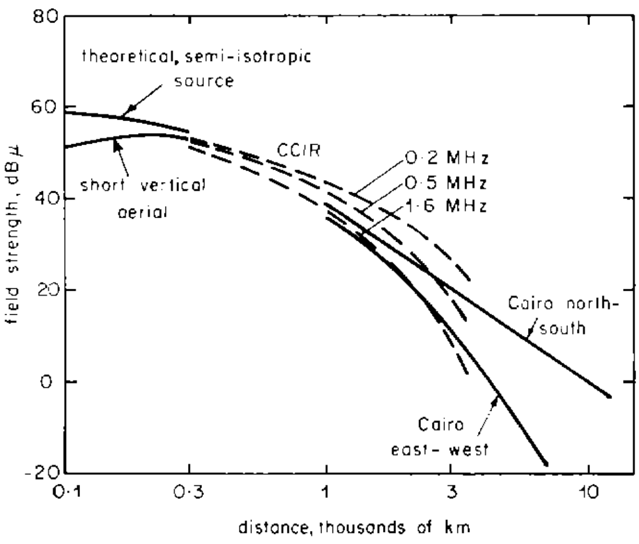

Fig. 8 Propagation curves

An extensive series of measurements over paths between Europe and North America, and over paths between North and South America, was made between 1934 and 1937. The two sets of measurements were used to produce separate curves for east–west and north–south propagation, shown in Fig. 8; these curves were agreed at the Cairo Conference in 1938. The curves shown in Fig. 8 are in fact 9dB lower than the original Cairo curves because the latter give quasi- maximum values; the curves shown in Fig. 8 therefore represent median field-strengths when 1kW is radiated from a short vertical aerial.

A further series of measurements was organised within Europe by the EBU between 1952 and 1960. The resulting propagation curves, also shown in Fig. 8, were adopted by the CCIR as Report 264, with a recommendation that they be used in the European Broadcasting Area. Other curves contained in Report 264 give corrections for the greater ionospheric loss near the auroral zone, and for the vertical radiation patterns and gains of typical transmitting aerials.

The CCIR curves apply to distances between 300 and 3500km. Measurements made in Europe at shorter distances show that the maximum field-strength which is likely to be observed during the night may be calculated by assuming that the ionosphere has a reflection coefficient of −10dB at m.f. and −15dB at l.f., at the high angles of incidence corresponding to short-distance propagation. Two curves for m.f. calculated on this basis are included in Fig. 8. One curve applies to a short vertical aerial radiating 1kW; the corresponding curve for l.f. would be 5dB lower. The other curve applies to a hypothetical semi-isotropic source producing the same field-strength, in all directions, as that produced by the short vertical aerial in the horizontal direction. Similar curves for a semi-isotropic source calculated on the same basis, which extend the CCIR curves to distances less than 300km, are given in Fig. 8 of CCIR Report 431[7]; slightly different extensions were used at the African Broadcasting Conference. Although a semi-isotropic source cannot be realised in practice it forms a convenient reference, especially when field-strengths at very short distances, due to high angle radiation, are being calculated.

At distances greater than 300km it is immaterial whether the source is a short vertical aerial, a semi-isotropic source or a vertical aerial up to $0{\cdot}25\lambda$ high. If the transmitting aerial is higher than $0{\cdot}25\lambda$, or if the aerial has horizontal directivity, the field-strengths given by the curves should be increased by the aerial gain in the direction of interest; the resulting field-strength then corresponds to the expected value when 1kW is radiated.

Fig. 8 shows that there are certain discrepancies between the three sets of curves and the question which arises is: which curves should be used? For planning purposes, curves represenatative of average conditions are the most convenient; corrections such as those shown in Figs. 3 and 5 can then be applied in special circumstances.

For distances less than 300km, in temperate latitudes, propagation curves calculated by assuming that the ionosphere has reflection coefficients of −10dB at m.f. and −15dB at l.f. give reasonable estimates of the highest median field-strengths which are likely to be observed, and are therefore useful for predicting maximum interference levels. If the curves are used for planning a sky-wave broadcasting service, however, account should be taken of the fact that field-strengths may, at times, be considerably less than the values given by the propagation curves. Field-strengths may be up to 20dB lower if the wave is about to penetrate the E-layer, or about 6 dB lower if it is reflected from the F-layer.

The CCIR curves apply to distances between 300 and 3500 km and were derived from measurements made within this range. There is no justification for extrapolating them to greater distances, and it has been shown that serious errors result if this is done.[7] The variation of field-strength with frequency shown by the CCIR curves is now thought to be too great; it is possible that the variation with frequency is unimportant, at least within the m.f. band.

The Cairo curves were derived entirely from measurements made at m.f. and there is therefore no justification for using them for l.f., although they may not be seriously in error at l.f. No dependence on frequency within the m.f. band was observed. The north-south curve may not represent average conditions because one of the terminals used for the measurements was situated near the sea; a more representative north–south curve would perhaps be 10dB lower. The east–west curve does not represent average conditions either because all the paths measured were across the North Atlantic and were close to the auroral zone. More recent measurements suggest that the difference between north–south and east–west paths, away from the auroral zone, is much less than the Cairo curves indicate.

The problem of producing simplified propagation curves or formulae valid for all distances is being actively pursued by the CCIR. One possibility, which has been proposed by the USSR[9] and which is being studied further, is the derivation from measurements of a formula in the following form:

$$E = \underbrace{115 - 20\log_{10}d}_{\text{unattenuated field-strength}} \quad \underbrace{-T}_{\text{terminal losses}} \quad \underbrace{-kd}_{\text{path attenuation}}$$

where E is the field-strength in dB relative to 1 μV/m and d is the distance in km via the ionosphere, approximately equal to the path length for distances greater than 1000km. The terminal loss T would be of the order of 10dB except on east–west paths near the magnetic equator, where polarisation coupling loss is large. The constant k will probably be a function of geomagnetic latitude, direction of propagation, frequency and sunspot number. Corrections of the form shown in Fig. 3 would then be applied if the transmitter or receiver is situated near the sea.

Another possibility would be the use of the wave-hop method[5] developed by the BBC. In this method all the losses which arise as the wave propagates from transmitter to receiver are calculated separately and are subtracted from the unattenuated field-strength. The calculation is performed for for all the propagation modes which are likely to contribute to the received signal; if two or more modes are found to be of comparable strength, their powers are added. Although the wave-hop method is laborious to use in its present form, its adaptation to a digital computer is thought to be feasible. For the time being its use should be confined to paths which are outside the range of validity of propagation curves or formulae, or where their accuracy is doubtful.

One situation where propagation curves would not be expected to apply arises when horizontal transmitting aerials are used for short-distance broadcasting via the ionosphere. Although radiation at the low angles corresponding to long-distance propagation is greatly reduced, waves can propagate to considerable distances by high-angle multi-hop modes, which are strongly excited. Recent EBU measurements of a particular horizontally-polarised transmission have shown that these modes can in fact produce field-strengths comparable with those due to a vertical aerial radiating the same power, and this has been confirmed by wave-hop calculations.

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M.F. Aerials: The Determination of Ground-wave C.M.F. and Mean Ground Conductivity from Radial Field Measurements by an Optimisation Technique

J. L. Eaton, B.sc., M.I.E.E.
Research Department

Summary: A computing method for obtaining c.m.f. and average ground conductivity values from sets of ground-wave measurements taken on radials from an m.f. aerial should be valuable in assessing the performance of new arrays in the future. A suitable optimisation technique which can be employed for this purpose and be realised as a computer program is described.

1 Introduction

A rule-of-thumb method has been in general use for estimating the ground-wave c.m.f.* and mean ground conductivity from sets of radial field measurements within a distance of about 5km from an m.f. aerial. If E is the field measured at distance d, the method is to plot log (Ed) against d on graph paper and to obtain the required results from the best-fit straight line drawn through the plotted points. This procedure can lead to very poor estimates of c.m.f., especially when the effective ground conductivity is low and the frequency is at the top of the band. The purpose of this report is to describe an improved method suitable for the assessment of aerial per-

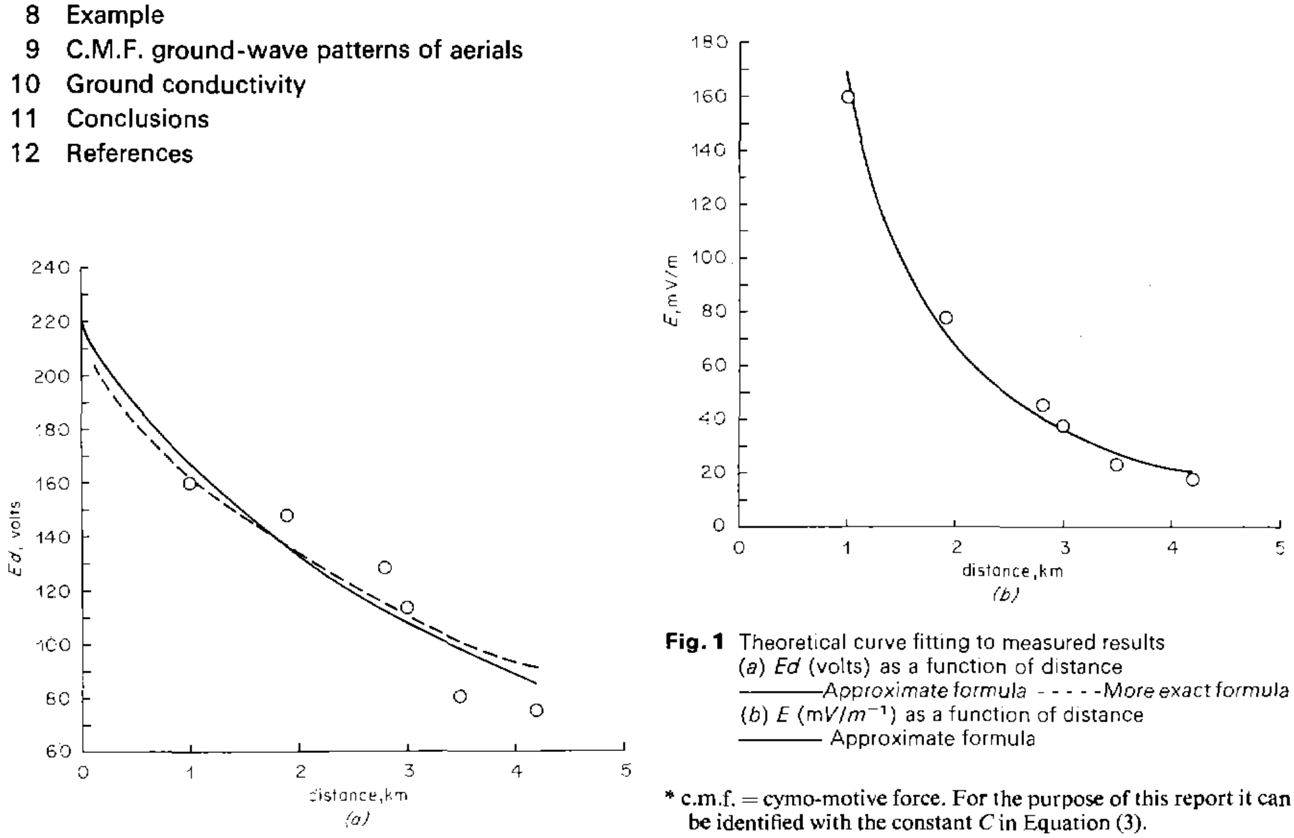


Fig. 1 Theoretical curve fitting to measured results
(*a*) *Ed* (volts) as a function of distance
———— Approximate formula - - - - More exact formula
(*b*) *E* (mV/m^{-1}) as a function of distance
———— Approximate formula

* c.m.f. = cymo-motive force. For the purpose of this report it can be identified with the constant C in Equation (3).

formance. It uses a non-iterative optimisation technique which can readily be realised as a computer program. This method can use any known theoretical attenuation function and optimises a scaling factor (equivalent to c.m.f.) and the ground conductivity value to give the minimum value of accumulated squared difference from the measured values of field-strength. The final values of these quantities are obtained by interpolation.

It is assumed that fields will be measured over the ground (not at sea) and therefore it is possible to limit the expected values of conductivity and dielectric constant.

2 The attenuation function

The ground-wave field-strength for short distances (but greater than about 5λ) can be expressed approximately as

$$E = \frac{2E_0}{d}\mathrm{A}(p) \quad (Vm^{-1}) \tag{1}$$

where $\mathrm{A}(p)$, the attenuation function,

$$= \frac{2+0{\cdot}3p}{2+p(1+0{\cdot}6p)} \quad -\sqrt{\frac{p}{2}}\, e^{-5p/8}.\sin b$$

In this approximation p is a numerical distance and b is a parameter. Both are defined below. This empirical function, due to Norton[1,2] gives a good approximation to a more exact function as can be seen by reference to Fig. 1(a). A more exact expression derived from the theory of Sommerfield is

$$\mathrm{A}(s) = |1 + \mathrm{j}\sqrt{\pi s}\,.\,\mathrm{e}^{-s}.\,\mathrm{erfc}\,(-\mathrm{j}\sqrt{s})|$$

where $\mathrm{erfc}(z)$ is the complex error function complement which is tabulated,[3] and $S = pe^{jb}$.

We see that the product Ed is equal to $2E_0$ at $P = 0$, $(d = 0)$. $2E_0$ can therefore be identified with the aerial c.m.f. (Volts). Given the ground conductivity σ (milli Siemen m^{-1}), permittivity ϵ (farad m^{-1}) and the frequency f(Hz) the following quantities are required:

$$x = (1{\cdot}8 \times 10^7)\sigma/f \quad (\text{farad}\, m^{-1})$$

$$\tan b = \frac{(\epsilon + \epsilon_0)}{\epsilon_0 x}$$

$$p = \frac{\pi}{x\lambda}.\cos b\,.\,d. = kd$$

The above formulae refer to vertical polarisation only. Horizontal polarisation is not covered in this report although a similar set of procedures can be devised for it.

3 Ground permittivity

The permittivity of different types of ground is, of course, not a well defined function of conductivity. In temperate climates, however, there is a tendency for permittivity to increase with conductivity which is probably due to increasing water content in the soil. In cities and built-up areas 'real' conductivities and permittivities must be replaced by 'effective' values both of which are low. Rather than use a fixed typical or mean value of permittivity (as is done in CCIR Recommendation 368–1 for example), improved accuracy can be secured by expressing the relative permittivity as a single valued function of conductivity. Thus

$$\frac{\epsilon}{\epsilon_0} = 20(1 - \mathrm{e}^{-0{\cdot}23\sigma}) \tag{2}$$

$$\sigma = \text{conductivity in mS, m}^{-1}$$

This formula will not necessarily give the correct value of permittivity in a place of a fixed value but its justification is that on the average smaller errors will be incurred if it is adopted. Fig. 2 shows a plot of this function together with some typical examples of points corresponding to various types of terrain.

4 Measured *Ed* values

Restating the basic formula in a slightly different form:

$$V = Ed = CA(kd) \quad (\text{Volts}) \tag{3}$$

It will be assumed that a set of measured values of Ed is available which has been taken on a radial from a vertical transmitting aerial within a range of approximately 5–200 wavelengths. The given data are therefore a set of points (d_r, V_r) $r = 1, 2 \ldots$ n at the frequency of the test transmission. Owing to practical measuring difficulties the number of measurement points may be limited to about a dozen and often less.

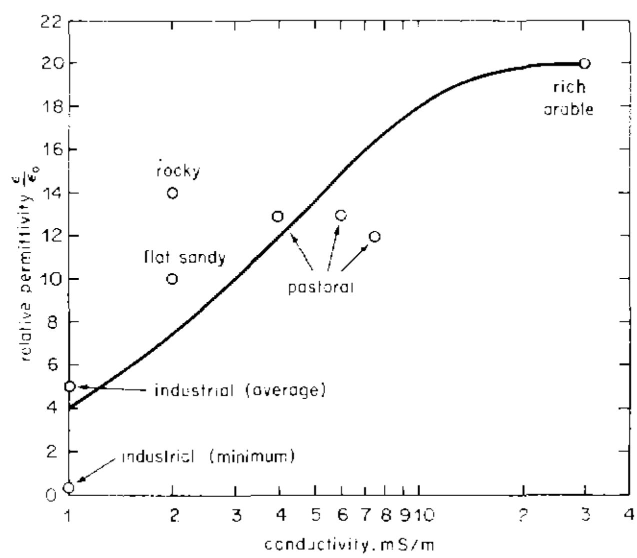


Fig. 2 Assumed relationship between conductivity and relative permittivity for overland paths

5 Optimisation method

5.1 Step 1

Choose $\{\sigma_s\}$, a set of values of conductivity in the range $0{\cdot}1 \leqslant \sigma \leqslant 20$, say. It is convenient, as far as possible, to have roughly equal increments between the chosen values of σ and a set of about fifteen to twenty is sufficient. Calculate corresponding values of k giving the set $\{k_s\}$. From these values a set of values of the attenuation function can be found from the formula in Section 2.

$$\{\mathrm{A}_{sr}\} = \{\mathrm{A}(k_s d_r)\}$$

These values and the points (d_r, V_r) form the arrays on which the optimisation procedure is based.

5.2 Step 2

$\{C_s\}$ is next derived where

$$C_s = \sum_{r=1}^{r=n} A_{sr} V_r / \sum_{r=1}^{r=n} (A_{sr})^2$$

This process scales the theoretical V-curves for each of the conductivity values by adjusting the multiplying constant C in expression (3) to minimise the sum of squared differences.

5.3 Step 3

This step involves the calculation of the sum of squared differences between measured and calculated values of V.

Thus
$$\delta_s^2 = \sum_{r=1}^{r=n} [V_r - C_s A_{sr}]^2$$

giving $\{\delta_s^2\}$.

6 Functional dependence on conductivity

The multiplier C in Equation (3) is to be thought of as equivalent to the c.m.f. of the aerial system which is being measured. In reality this multiplier has a fixed value determined by the aerial system but in the optimisation process its value changes as different values of conductivity are assumed. In the present context it may therefore be considered as dependent upon the conductivity. It follows that both the multiplier C and the squared difference variable are functions of the conductivity only which means that a one-dimensional interpolation may be used to obtain the best estimate of conductivity and c.m.f. as explained in the next section.

7 Interpolation

The value of conductivity which corresponds to the minimum of δ^2 can be found to good accuracy by means of parabolic interpolation. The interpolation involves the point (δ_l^2 σ_l) giving the minimal calculated value and the neighbouring points on either side. It can be shown that the interpolated value of σ will be an accurate estimate of that value for which δ^2 is a minimum. Having found this optimal value of σ, the best estimate for C (the c.m.f.) may be obtained by linear interpolation or by applying Step 2 (Section 5.2) for this single value of conductivity.

7.1 Step 4

Min $\{\delta_s^2\}$ is found and, if this is a single member of the set, δ_l say, the points (δ_{l-1}^2, σ_{l-1}) (δ_l^2, σ_l) and (δ_{l+1}^2, σ_{l+1}) are noted and interpolation carried out. The optimal value of σ is given by:

$$2\sigma = \frac{(\sigma_l^2 - \sigma_{l+1}^2)(\delta_{l-1}^2 - \delta_l^2) - (\sigma_{l-1}^2 - \sigma_l^2)(\delta_l^2 - \delta_{l+1}^2)}{(\sigma_l - \sigma_{l+1})(\delta_{l-1}^2 - \delta_l^2) - (\sigma_{l-1} - \sigma_l)(\delta_l^2 - \delta_{l+1}^2)}$$

If there are two sequential members of $\{\delta_s^2\}$ having the same minimal value* either may be chosen as δ_l^2. The likelihood of more than two sequential members having the same value is negligible. If the minimal value belongs to either end member (but not both) it can be taken as the actual minimum. In this event, however, note should be made of the fact that the range of conductivity values may be inadequate. If nominally equal minimal values are possessed by separated members it should be inferred that the measured results are too erratic for smoothing to be applied.

7.2 Step 5

Given the optimal value of σ, obtain the optimal value of C by linear interpolation or by the application of Step 2 for the single optimal value of σ.

8 Example

Fig. 1 shows the result of applying the process to six radial field-strength measurements taken from a service broadcast aerial operating at a frequency of 1457kHz. From the measurements the aerial c.m.f. (in the radial direction) is found to be 221·9V and the effective ground conductivity to be 3·07mS m^{-1}. This is fairly low value of conductivity but the path of the radial is known to pass over undulating ground which is well covered with banks of trees and buildings and this no doubt accounts for this fact at the relatively high frequency.

The dotted curve in Fig. 1(*a*) shows a plot of the more exact function mentioned in Section 2 derived from curves given in Reference 1.

9 C.M.F. ground-wave patterns of aerials

One of the principal applications for the process described in the preceding sections is the calculation of c.m.f. ground-wave patterns of vertical m.f. aerials from a series of measurements. This application will be particularly important when new directional arrays are being set to work and the amplitude and phases of their drive currents are being critically adjusted. The advantage of the process is that it minimises ground attenuation effects in the estimation of aerial performance.

10 Ground conductivity

In the author's opinion calculation of m.f. ground-wave services often assume values of effective ground conductivity which are too high when the operating frequency is at the top of the m.f. band (above 1 MHz). Ground undulations, trees, buildings and other irregularities cause increased attenuation whereas predictions are often based on surface stratum values of conductivity and measurements made at low frequencies. Application of the optimisation process to measured fields from aerials could lead to improved estimates for the average conductivity to be assumed in future work.

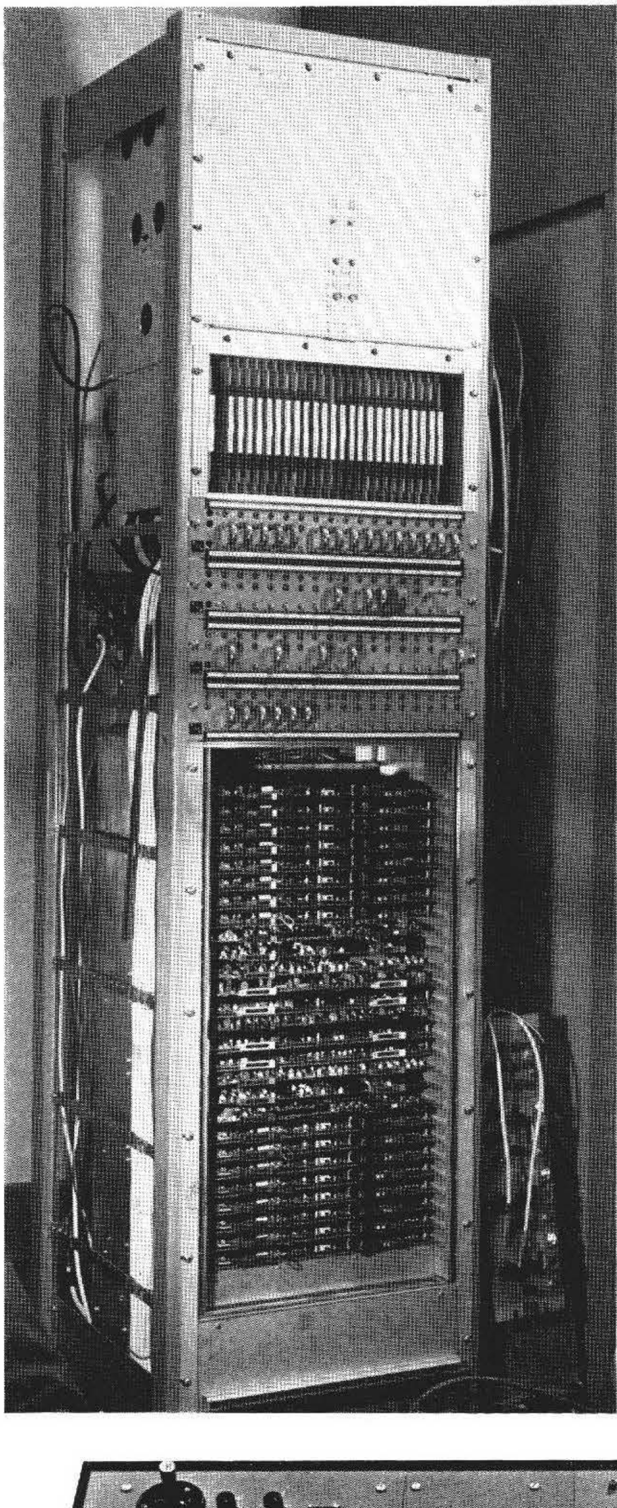
* The possibility of this occurrence will clearly depend on the number of significant figures which are available.

11 Conclusions

An explicit non-iterative optimisation process has been described for obtaining the ground-wave c.m.f. values and local effective ground conductivity of vertical m.f. aerials from measurements. The accuracy of the method as a curve-fitting process is believed to be good and its application in assessing the performance of new m.f. arrays in the future will, it is hoped, be valuable.

12 References

1. Norton, R. A. 1936. The propagation of radio waves over the surface of the earth and in the upper atmosphere (Part I). *Proc. IRE*, 1936, **24**, 10, pp. 1367–87.
2. Norton, R. A. 1941. The calculation of ground-wave field intensity over a finitely conducting spherical earth. *Proc. IRE*, 1941, **29**, 12, pp. 623–39.
3. Abramowitz, M. *and* Stegan, I. A. 1964. Handbook of mathematical functions. Dover, New York, 1964.



Vision-mixing Equipment for Major Studios

The EP5/512 vision-mixing equipment has been developed for use in major production studios. It is compact and incorporates a number of facilities not found in earlier vision mixers.

The mixer comprises sixteen channels in two banks of eight; for normal operation, the inputs to corresponding channels in the two banks are paralleled to eight signal sources. The signal in each channel can be controlled either by a fader or by a 'cut' button, the change of mode between CUT and MIX for the whole bank being made by the operation of a push-button switch or by 'topping' a fader. A gated fading technique is employed to enable the signals in any or all of the sixteen mixer channels to be superimposed without causing distortion of the synchronising waveform.

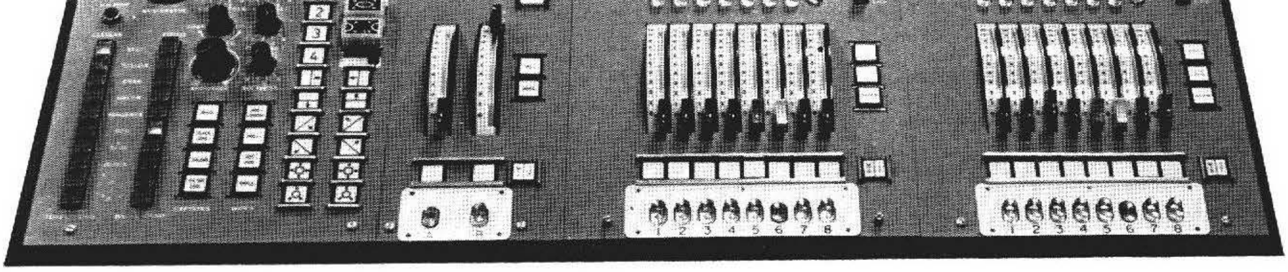
The equipment offers the following special effects:

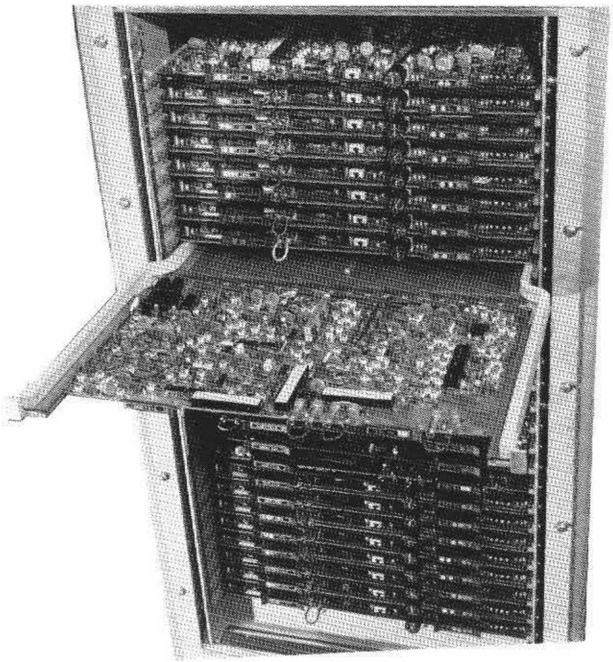
* Either colour-separation or caption overlay facilities on both banks.
* The addition of all-round black edges to a monochrome caption or of contrasting-coloured edges to a coloured caption. (The equipment includes a colour synthesiser.)
* A comprehensive selection of wipe patterns.
* The addition of ripple to the wipe patterns, with variable frequency and amplitude.
* The production of multiple (up to $\times 8$) wipe patterns in either direction.
* Variation of the position of the wipe pattern on the screen by means of a joystick control.

Each channel of the mixer includes integral synchronisation monitoring and provision for automatic colour subcattier phase correction with a range of ± 10 degrees.

The mixer control desk has keys for the selection of commonly-used wipe patterns, but a range of small modules that plug into the control panel alongside the wipe-selection keys enable the number of wipe patterns available to be expanded to up to 106 basic patterns, not including multiples. Unlike most existing vision mixers, this new equipment includes a

Left: Prototype vision-mixer electronics bay with front covers removed to show electronics boards. Shown, top to bottom, are: power supplies, logic units, coaxial jack-fields and electronics boards.
Below: Control-desk panels showing typical arrangement of control panels (prototypes).



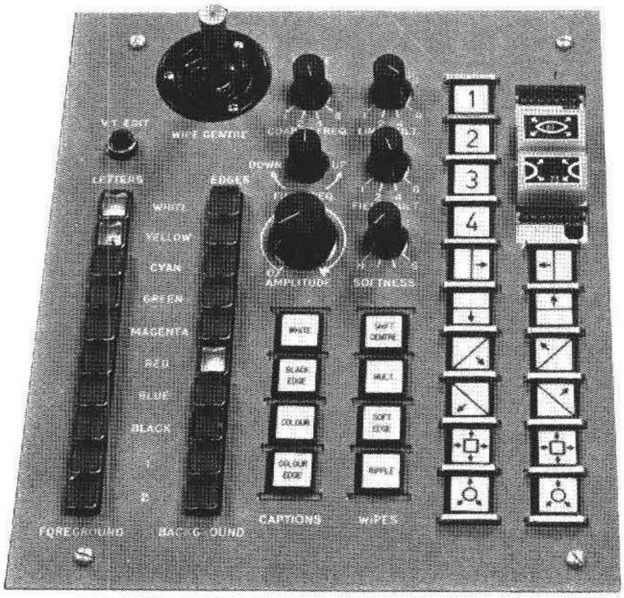


Mixer electronics board with protective screens removed to show assembly. The board shown is one of the two group mixer boards.

facility for multiple-iris wipe-patterns. All wipe-patterns are available with soft-edges of 4° of hardness.

Either matrixed or decoded signals can be used for colour-separation overlay (the mixer includes two internal PAL decoders), and any of the incoming signals can be used either as the foreground or as a source of the overlay switching-signal. The colour synthesiser and all-round black edges can be controlled by sync pulses from a superlocked generator, so that coloured and edged captions can be added to a non-sync picture at the output of the mixer. The mixer uses additive mixing, limiters being incorporated to ensure that the amplitude of the luminance or chrominance component of the mixer output signal does not exceed the specified waveform tolerances.

The equipment comprises a control desk and separate electronic units for bay mounting. These are the mixer electronics, the logic and control circuits and the power supplier. The mixer electronics unit contains twenty-seven horizontal



Detail of Effects Control-panel showing, left, the colour synthesiser, centre, the caption controls and, right, the wipe-selection keys. Two of the plug-in wipe-selection modules are shown at the right-hand corner of the panel.

printed-circuit boards, plugged into a 'mother' board at the rear of the unit and withdrawable from the front. This electronics unit is 755 mm (17 U) high and 425 mm deep. The logic circuits are contained in an Imhof CDX panel, 222 mm (5 U) high. Separate power suppliers with independent mains inputs are provided for the circuits of the two banks; these are contained in a unit occupying 445 mm of bay height. Also available is a bay-mounting engineering control panel, carrying a simplified version of the operational control facilities.

Time-dependent Video Equaliser

The time-dependent video equaliser type EQ1M/522 has been developed to solve the difficulty presented, during some international-relay programmes, by a video signal with synchronising pulses which have been processed at some point on the route of the circuit and are therefore well-shaped, while the picture-information requires l.f. and h.f. correction. Such correction, if applied in the normal manner, would distort the synchronising-pulses and possibly render them unacceptable.

In this equipment, the incoming signal is split into three feeds. Two of these are applied to the inputs of a video switch-unit after one of them has undergone the necessary corrections to the picture-information in a video line equaliser. The third signal-feed is applied to a synchronising-pulse separator and delay-unit, in which are derived pulses which drive the video switch-unit so as to produce an output-signal comprising picture-information from the equalised signal-feed and synchronising-pulses from the unequalised feed.

The equipment comprises ten units constructed as plug-in modules on 178 mm-high chassis of the binary metric modular chassis-system. The units occupy one-and-a-half general-purpose panels of the system, for mounting on a standard 483 mm bay. Those units forming the video line equaliser are coded collectively EQ5M/537 and can be accommodated in a single general-purpose panel.

Audio Reference-level Generator

The audio reference-level generator GE1/13 is a battery-powered portable oscillator with a (nominally) zero-level output at a frequency of 400 Hz. It has been designed primarily for use by mobile maintenance-teams for the checking of peak-programme meters, but is suitable for most applications in which an accurate zero-level source is required.

The output level of the generator is stabilised against changes in ambient temperature, time, load-impedance and battery-potential. The batteries, which are contained within the unit, are of a high-capacity type which last for approximately one year of normal use. As a safeguard against premature discharge of the batteries should the generator inadvertently be left connected after use, a 'timed-operation' facility is incorporated by which it is automatically switched-off after operating for approximately ten minutes. When this happens, a new period of operation can be initiated immediately by means of a push-button. The timing-facility incorporates an arrangement to prevent the generator from working when the battery-potential is not within the correct range for the operation of the circuits.

The generator comprises a printed-circuit board and two dry-cell batteries in a diecast box measuring 190 mm by 120 mm by 60 mm. The output is delivered via a P.O.-type jack; the insertion of a plug into this jack is necessary before the circuits of the generator can be switched on.

General data

Power-requirement:	D.C. at 13 V–18 V, supplied by two batteries type PP9
Operating temperature-range:	0°C–45°C
Output-frequency:	400 Hz $\pm$ 40 Hz
Output level:	0 dB (0·7746 V r.m.s.) $\pm$ 0·25 dB
Output-signal waveform:	Sinusoidal, with 2nd harmonic $-$40 dB and 3rd harmonic $-$50 dB (approx.)
Dimensions:	190 mm $\times$ 120 mm $\times$ 60 mm
Weight:	1·1 Kg

Earth-leakage Circuit-breaker Breaking-time Tester

Most earth-leakage circuit-breakers are designed to open within 30 milliseconds if an earth-leakage current (e.g. through the body of a person in accidental contact with a circuit) rises to 30 mA. The TE4/1 tester provides a means of checking the time taken for a circuit-breaker to operate.

The instrument is portable and self-contained, and is powered by a small internal sealed secondary battery which is maintained in a charged condition by means of current drawn from the mains circuit under test. It is intended primarily for use with portable equipment, in which earthing failures are particularly likely to occur, but it is also of value in any situation where an a.c. mains supply is drawn through an earth-leakage circuit-breaker. It should be noted, however, that in the design of the tester it has been assumed that safety regulations relating to the wiring of the mains outlet and circuit-breaker have been observed.

Before the tester is used, a short check-sequence is initiated by means of push-buttons on the unit to ensure that an earth connection exists and that the light-emitting diode indicators and their drive circuits in the unit are operative. This ensures that the tester is in order, is correctly connected to the mains supply, and that its internal battery is charged. The test is then made by pressing a further button.

The operation of the circuit-breaker is checked against an internal pre-set timing-circuit which is accurate to within $\pm$2 ms. If the circuit-breaker is satisfactory, one of the diodes (green) glows for about twenty seconds; if not, a red diode glows for a similar period after the green diode has flashed momentarily.

In the tester illustrated above, the test-current and the time-reference are determined by fixed, internal components. If the tester were to be used in applications where different currents and times were necessary, it would be possible to modify the tester so that both the current and time were adjustable.

As illustrated, the tester is housed in a small plastic case measuring approximately 200 m $\times$ 200 mm $\times$ 110 mm deep; the lid of the case can be used to shield the light-emitting diodes from direct sunlight.

Publications available from Engineering Information Department

Information Sheets on the following subjects can be obtained from Head of Engineering Information Department, Broadcasting House, London W1A 1AA, and are available free of charge, except where otherwise indicated.

General

9002 Wavebands and Frequencies Allocated to Broadcasting in the United Kingdom

Television

4006 UHF Television Reception

9003 Television Channels and Nominal Carrier Frequencies

2701 Television Interference from Distant Transmitting Stations

4101 Television Receiving Aerials

4306 Test Card F

2001 Transmitting Stations, 405-line Services (BBC-1 and BBC Wales): Channels, Polarisation, and Powers

2901 Transmitting Stations, 405-line Services (BBC-1 and BBC Wales): Map of Locations

4003 Transmitting Stations, 625-line Services: Channels, Polarisation, and Powers

4919 Main Transmitting Stations, 625-line Services: Map of Locations

2020 405-line Television: Nominal Specification of Transmitted Waveform

4202 625-line Television (Colour and Monochrome): Brief Specification of Transmitted Waveform

How to receive BBC TV – 625 lines and colour

Radio

1042 BBC Local Radio Transmitting Stations (MF2 VHF): Frequencies and Powers

1701 Medium-wave Radio Services: Interference

1603 Stereophonic Broadcasting: Brief Description

1604 Stereophonic Broadcasting: Technical Details of Pilot-tone System

1605 Stereophonic Broadcasting: Test Tone Transmissions

1034 VHF Radio Transmitting Stations: Frequencies and Powers

1919 VHF Radio Transmitting Stations: Map of Locations

Service Area Maps

Individual maps showing the service areas for many radio and television transmitters are also available.

Specification of Television Standards for 625-Line System I Transmissions

A detailed specification of the 625-line PAL colour-television signal transmitted in the United Kingdom is published jointly by the British Broadcasting Corporation and the Independent Broadcasting Authority, and can be obtained for 50p post free from Head of Engineering Information Department, Broadcasting House, London W1A 1AA.