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Telecommunications in the Next Thirty Years

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U.D.C. 654.1."313"

The next thirty years will see vast changes to the structure and significance of the telecommunications network. This will cause changes to the way of life of the whole population and will need a continuous and alert appraisal of possibilities by telecommunications engineers to ensure that the system develops in such a way that opportunities are not lost. Among the exciting prospects foreseen by the author are development of sophisticated information and management control systems which will provide auxiliary power for the human mind comparable with that provided by the industrial revolution for human physical power. The author concludes on a cautionary note by commenting that economic factors are likely to prove more restrictive than lack of technological capability.

INTRODUCTION

For the first fifty years or so of its existence telecommunications offered little besides the telegraph service and the telephone service. These, in the last decade or so, have been joined by the telex service and for a great many people these simple communication forms represent the limit of their experience of a telecommunications service.

But we now stand on the threshold of a new era in telecommunications in which a very wide range of new services has become technically possible. Some of these are of such great potential importance to the community at large, that any studies of the long-term future trends of the various activities of the community, be they commercial, industrial, governmental, or social, cannot be made meaningfully without consideration of their impact. In the business environment telecommunication services can no longer be considered separately from other aspects of organization but are becoming so interwoven with organizational concepts that they must be considered as an integral part of the total planning activity.

The Background of Telecommunications

There is a correlation between communications and the degree of success achieved by different civilizations. The city states of ancient Greece made a far greater contribution to the advance of civilization than millennia of scattered rural agricultural communities before them. This was largely because many lively minds were brought together into compact population units—relieved partially or wholly from the labours necessary for personal survival—thus creating the conditions under which ideas could be exchanged freely, and thereby be extended and enriched.

The material prosperity of Rome owed its success partly to the development of physical communication systems which were greatly superior to those of its contemporaries.

The swing in the U.K. from a basically agricultural economy to an industrially-based economy, which was initiated by the industrial revolution, made communications still more important to national progress. It was increasingly necessary to ensure the free flow of raw materials inwards, the outward dissemination of knowledge about the availability of the manufactured products, and the subsequent distribution of those products. As both the scale of operations and the complexity of the products grew, the need to control and correlate the various facets of the production process became steadily more important. But telecommunications matched to the control of dispersed activity were not available, and this was in part responsible for the growth of single product cities and areas. The tragic social consequences of this area-dependence on single products are now clear, and all postwar U.K. governments, irrespective of political outlook, have committed themselves to policies of industrial redistribution and diversification to try and avoid repetitions of the human sufferings caused by the localized impact of national economic setbacks. The possibility of achieving this socially desirable end, open to us but denied to our predecessors, lies largely in the availability of adequate communications. Modern telecommunications, in particular, add a new dimension to the means available for the solution of the problems.

Although the telephone service is, and will remain for many years, the largest single element of P.O. business, our function is very much wider than this and embraces telecommunications in all its various facets, national and international, voice, vision and data. The benefits and opportunities presented by ever-widening telecommunications horizon must be put at the service of industry, commerce, and the public. It now seems certain that well within the foreseeable future, speech will take second place to other telecommunication services in terms of volume of information conveyed and of revenue earned.

THE SPRINGS OF ECONOMIC GROWTH

The traditional industries of the industrial revolution were based on the use of coal and steam, and the development of textiles and machine tools. During the 19th century the foundations of the industries of the first half of the 20th century were laid based upon the development of steel and electricity, organic chemicals, and the internal combustion engine. From these sources have sprung the great growth industries of the middle 20th century. The petrochemical industry has created new materials that have unobtrusively infiltrated every facet of life in the developed countries; the motor car has had far reaching social consequences, seen perhaps at their most extreme in Los Angeles. Three of the four major industries of the early industrial revolution, cotton, coal, and railways, have declined sharply since the turn of this century and steel, the fourth, shows signs of following suit. Figure 1 illustrates the pattern of events for the coal industry. Although in 1967 the automotive and aircraft industries contributed over £1,000M to the gross national product of the U.K., and motor vehicles alone contributed 10 per cent of our exports, nobody who has observed London, New York, or Los Angeles at the rush hour can doubt that the scope for further major

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expansion of domestic consumption of the products of the motor car industry in their present form is limited. Modern society is dedicated to economic growth and, to sustain this, must be constantly watching for the signs of impending decline in currently expanding industries, and seeking the most promising avenues for re-deployment of resources. Although western society is at present production orientated, with the United States in the lead and the European nations

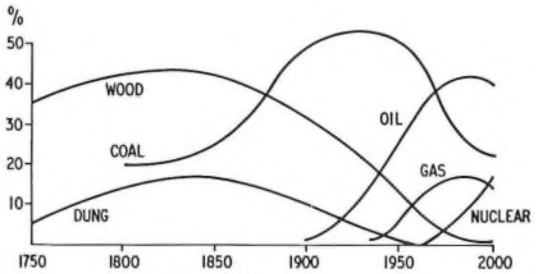


FIG. 1—World energy sources

still striving to expand their production capacity and efficiency, the time is already in sight when the United States will have surplus production capacity and it is looking forward to the "post-industrial society". Knowledge is becoming the key to power, and increasingly, the ability of a country to maintain, and advance, its prosperity will depend upon "knowledge industries". This is one of the reasons for the anxiety felt in many countries about the migration of some of their most talented citizens to centres of excellence in other, more highly developed, countries. The problem affects both developed countries, whose preoccupation is in maintaining their position in the posperity league table, and the developing countries who desperately need skilled people to lead their struggle against poverty.

In the search for the new industries which will form the mainstay of the most advanced societies in 30 years' time it seems likely that one of the most significant will be the "information industry". At present this hardly exists. It has its roots in the invention of the computer but the influence of the latter on society, large as it has been, is still small compared with its ultimate destiny. The products of this industry will be vast interconnected management systems, information systems, control systems and data banks which will penetrate deeper and deeper into the fabric of our society.

The importance of the telecommunications industry is assured for many decades ahead because not only is it itself one of the knowledge industries, but it also must provide the essential infra-structure for the information industry.

COMPUTERS AND TELECOMMUNICATIONS

Computers and telecommunications are both concerned with information, its collection, its storage, its processing and its dissemination. Fig. 2, for which I am indebted to Mr. F. J. M. Laver, shows how they are interlinked and also draws attention to their important relationship to the whole field of control. The first steps are now being taken in our factories towards the completely automatic control of processes. Some industries, notably the petroleum and chemical industries, are considerably in advance of others in the introduction of these techniques but they seem destined to spread to most areas of manufacturing. Increasingly, after their establishment on the local scale, the control of the operations will be exerted remotely from computers operating over data transmission facilities acting on the basis of information received from many other locations. Management too, in its control of the organizations for which it is responsible, will increasingly rely upon the computer to pre-process the vast amount of data relevant to its decisions. The interrelationships of these data are becoming so complex, and the volume of data so great, that managerial decisions of adequate

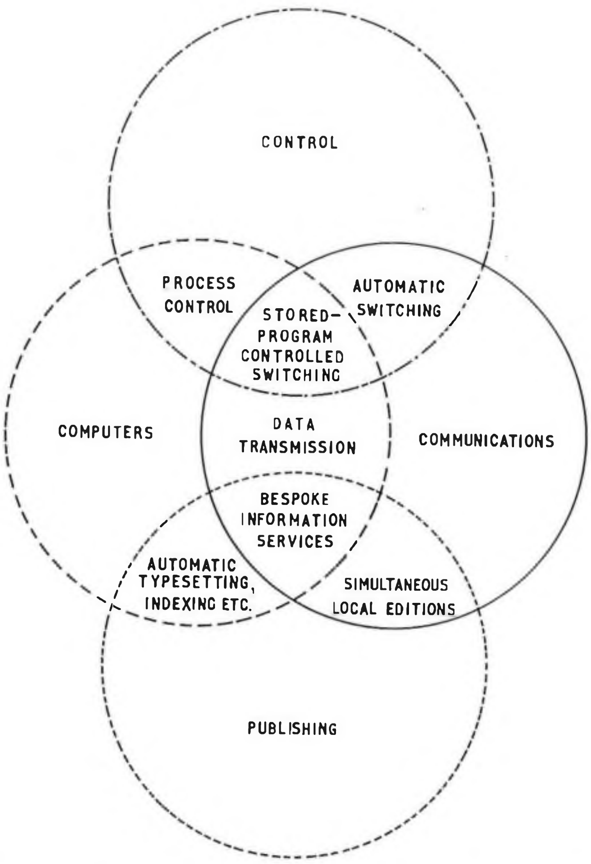


FIG. 2—Relationship between control, computers, communications and publishing

quality to sustain the profitability and efficiency of the business operation will no longer be possible on an unaided personal, intuitive, basis. The decisions remain the manager's responsibility, but the machines must aid him.

Industrialization arose from the invention of the steam engine which, for the first time in history, gave men a significant advance over unaided muscle power. The information industry, similarly, will give for the first time a major enhancement of the unaided capability of the mind.

THE PRINTED WORD

The fourth inter-locking area that Fig. 2 shows is the obvious link between publishing and the information processing and dissemination capabilities of computers and communications. We face, however, new problems in this area. There is an information explosion which threatens to engulf us and nowhere is this more true than in the realm of scientific publishing. The number of scientific journals subscribed to by the National Lending Library at Boston Spa was 20,000 in 1965 and rose to 26,000 in 1967 and this figures does not include trade journals which have no significant scientific element. It has been estimated that there are nearly 10,000,000 scientific papers in existence. A quarter of a million chemical abstracts were added to the collection in 1967 and nearly a third of a million will be added during 1970. This enormous volume of material which pours out every year cannot possibly be appraised and assimilated by working scientists. If we are to avoid being completely overwhelmed and committing resources to the duplication of already known results simply because we are ignorant of the fact that they *are* known results, means must be found of bringing machines to our aid. The computer can help in the automatic classification of material, its storage, and its selective retrieval under interrogation from remote locations. The full-automatic library with the ability to deliver copy directly into the home or office is still many years away, but the incentive to achieve it is growing and solutions are in sight for most of the technical problems involved.

In the everyday world of publishing, similar possibilities are opening up with the application of computer type-setting which, aided by telecommunications, can be operated remotely. There are many obvious possibilities for simultaneous type-setting in a number of locations of material originating from a single source, with the capability of blending national and local news and national and local advertising. Since the delivery of newspapers involves high labour costs and inefficient use of labour there is an obvious incentive to eliminate physical distribution to the home and one day, perhaps, we may see the printing process carried out in the home with the information coming over data links. From here it is a perfectly feasible proposition, from a technical point of view, for the customer to have a considerable element of choice in the type of material that is printed for him so that the balance of the resulting document would vary considerably from one customer to another. But, perhaps, in suggesting personalized newspapers, we stray too far into the next century.

The provision of an electronic mail service, in which letters are reproduced in the addressee's premises after transmission over a switched network, may become practicable towards the end of the century. There seems no possibility of this being provided economically in the near future, but the long-term prospects are encouraging. Terminal costs and transmission costs are the keys. Facsimile devices using new techniques are in the research stage, and the switched broadband network that will certainly exist by the end of the century could have a major effect on transmission costs.

THE KEYPHONE

Amongst developments likely to enter service soon is the push-button telephone or keyphone. Within a few decades we may expect to see this completely displace the dial telephone and this apparently trivial innovation may eventually prove to have the most far-reaching consequences, immensely broadening existing views of the application of the telephone. With its aid not only can the telephone call be set up, but it can subsequently be used for the remote control of apparatus of many sorts. For example, provided the keyphone is of the type generating m.f. signals, it can be used to send small quantities of data to a remote computer and the computer can respond by sending back program-controlled voice responses from a library of pre-recorded words. The system designer decides what meaning to give to each button and some systems have been devised allowing the meaning to be changed during the call. This opens the door to such possibilities as automatic-ordering facilities from small retailers, travelling salesmen, part-time sales agents, and even direct from members of the public, automatic interrogation of credit records, automatic credit transfers and bank-account interrogation facilities, automatic-reservation schemes for hotels, theatres, airlines and sophisticated information systems in which dialogue between the caller and the answering computer is necessary to identify the precise subject on which information is required. Problems concerned with malicious and fraudulent use of such systems obviously exist, but a variety of techniques has already been devised to protect against these. The common characteristic of all these schemes is that they employ the standard push-button telephone instrument so that no additional capital cost is involved on subscribers' premises. Thus, the number of locations which will form suitable data entry points for these new systems will grow rapidly.

The card-reading repertory dialler[1] is a device which enables subscribers to set up frequently-made calls quickly and easily. A small plastic card, about 4 in $\times$ 2 in, has holes punched in it to represent the digits of the desired number and the appropriate pulses are sent to line when this card is pressed into the slot on the instrument. A variant of this type of instrument sending m.f. signals to the line instead of strowger impulses, makes an ideal complement to the keyphone as a data source. The user can transmit fixed data to the distant party by inserting pre-punched cards, supplementing this with variable data inserted via the push buttons. Such a facility opens up innumerable additional possibilities and particularly facilitates the identification of individuals to authenticate instructions. The application to the whole field of credit transactions will be obvious.

Looking back from the year 2000 it may well appear that the introduction of the keyphone marked the turning point away from the simple telephone instrument towards the complete communications terminal.

IMAGE TRANSMISSION

It was said earlier in this article that speech is likely to take second place to other telecommunication services at some time in the future. The importance of data transmission for the economic future of the country has already been mentioned and the datel services are currently growing at about 100 per cent per annum. At present most data transmission requirements are met by services provided over the switched telephone network, but already requirements for higher speeds are becoming evident and an experimental 48 kb/s service between London, Birmingham and Manchester is about to start. From the point of view of the ultimate size of the transmission network, however, the explosion will come when there is a demand, which can be satisfied economically, for widespread switched image distribution systems. These represent a whole class of services of which video conference facilities (Confravision), information retrieval display services, video shopping and viewphone are examples. The latter is a telephone system incorporating a television-type display of the face of the distant party and the additional value that it confers by comparison with voice only is the subject of keen debate. Like automatic transmission on motor cars, a superficial examination suggests that it adds little to the basic function and yet with the automatic gearbox it was found that, once experienced, the public demand was substantial. Those that did not have it tended to say they did not need or want it; those that had it did not want to give it up. A similar reaction has been reported from those who have used experimental viewphone services in a trial installation in the United States. Many variants of this service are possible and two are particularly interesting. A conference facility linking several viewphones can be arranged and voice switching of the picture can be used so that it is always the speaker's face that is presented on the remote screens whilst his screen continues to display the face of the previous speaker. By switching the instrument to a slow-scan mode, high definition could be obtained for the display of text and small static objects. On present cost estimates it is difficult to see how a viewphone service could be commercially viable, but the falling cost of equipment due to technological innovation, coupled with the rising general level of individual affluence, must eventually reach a point which changes the outlook. There is a variety of factors which suggest that such services will be well established before the end of the century. This will be the big watershed because the demands of a viewphone service on transmission capacity multiply by about 100 those of the purely voice service. If only 1 per cent of all calls were viewphone calls it would double the bandwidth required in the transmission network, and if only 5 per cent of calls were viewphone calls they would completely dominate the scene. Such massive demands for bandwidth add stimulus to the current research program directed towards new transmission media, particularly those employing circular waveguides and optical fibres which share the characteristic of providing massive information transmission capacity.

THE IMPACT ON SYSTEM DESIGN

We are facing a period of unprecedented growth not only in the volume of the services that we offer but also, and perhaps more important, in the diversity of their nature. We must recognize that the demands for telecommunication services are likely, in the future, to change in their nature more frequently and more rapidly than in the past and our new systems must therefore be responsive to this situation. This will need a substantial change in our philosophical approach to system design. At any particular moment in time it is easy to produce a "lowest cost" system and there will undoubtedly be strong pressure to do so. But the danger is that we shall thereby make ourselves the prisoners of a particular system design and a particular technology. We must aim to cultivate the technology of flexibility and produce concepts which will permit the exploitation of new ideas as these evolve without rigid dependence on preconception of all the services and facilities that will be required. Some of the most promising avenues can already be seen.

Digital transmission[2] offers advantages over analogue transmission because it is more basic in character. The transmission characteristics of analogue systems have to be related to the requirements of the waveform to be transmitted but when digital transmission is used these problems are mainly transferred from the transmission path to the analogue-to-digital conversion equipment, thus leading to a more nearly universal transmission system. Furthermore, it is probable that frequently in the future the signals to be transmitted will be generated directly in digital form. Quantization in digital systems confers great advantages in terms of the reduction of transmission and switching impairments, but neither of these advantages is sufficient to displace analogue transmission for existing services in disregard of economic comparisons. We already see, and must expect to continue to see for some time, the "sailing ship effect" in operation. The effective life span of the sailing ship was extended by a period of very active development initiated after the steamship had been invented in direct response to the competition from the new technology. A new technique always has to struggle before its inherent superiority overhauls the improvements that can still be made by the application of great ingenuity to the further development of the old.

The separation of signalling channels from the information-transmission channels in the system and the use of stored-program control of switching plant, are two other concepts that may prove important in the search for flexibility. The latter may permit common hardware to be used in different applications, so leading to economies of scale in production, and permiting the administration to offer new facilities, and modify existing ones, by changes to programs rather than to equipment. This is, of course, the source of the computer's extraordinary versatility. There will undoubtedly be many difficulties on the way, and not all the high hopes will be realized as quickly as the enthusiast would wish, but the continuous fall in storage costs, which will directly affect the economics of stored-program control systems, and in transmission costs, which will facilitate the aggregation of control functions to secure economics of scale, are strong supports for this approach.

ECONOMIC CONSIDERATIONS

Studies have shown a marked correlation between telephone density and gross national product per head for a large number of countries having widely different circumstances. This is illustrated in Fig. 3. There seems to be an element of positive feedback in the situation: wealthy countries can better afford an extensive and highly-developed telephone system and the possession of such a system, by contributing to industrial efficiency, contributes to the creation of wealth.

Telecommunications in the U.K. is big business by any standards and, as Fig. 4 shows, revenue quadrupled between 1953 and 1968. Moreover, there is more to it than the absolute growth because the importance of telecommunications relative to other sectors of the economy is growing, as is shown by the lower graph in Fig. 4 in which the revenue is expressed as a percentage of gross national product (G.N.P.). Investment,

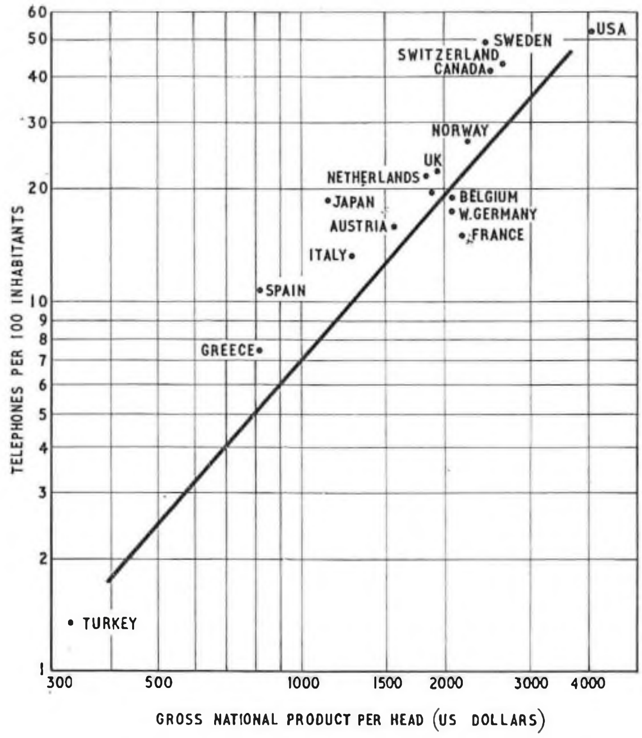
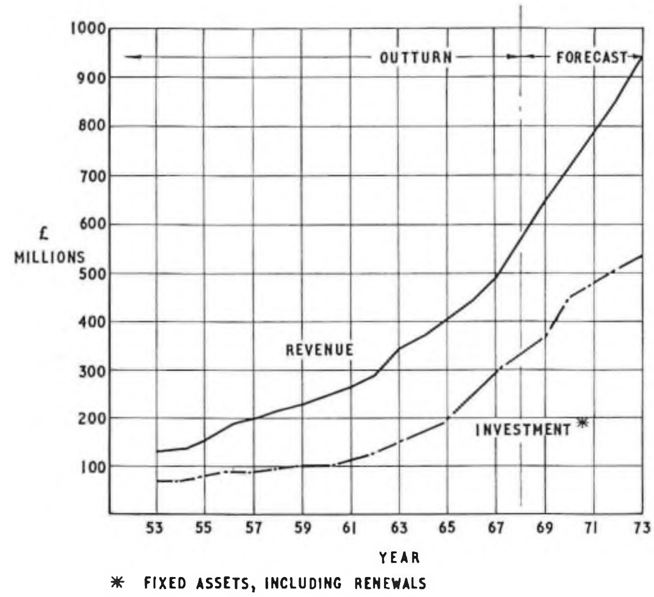
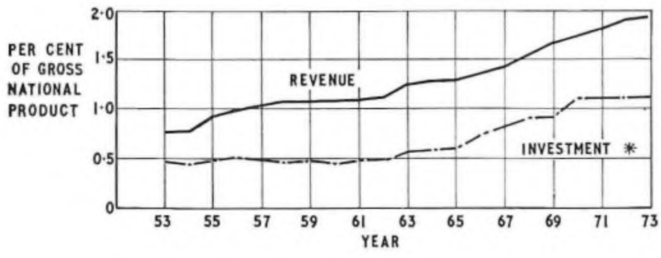


FIG. 3.—Telephone density and the gross national product per head, 1967



(a) Absolute value for U.K. in £



(b) Per cent of Gross National Product

FIG. 4.—Telecommunication revenue and investment

too, is rising rapidly and the curves show how our investment program is planned to rise from a little under ½ per cent of the G.N.P. to a little over 1 per cent of the G.N.P. The scale of these investments serves to remind us that not everything that is technically possible can be pursued with limited resources. The telecommunication services and facilities that can be foreseen as becoming technically possible before the end of the century, include a great many more than it has been possible to mention here, and the time of introduction of many of these, indeed whether some of them will be introduced at all, is likely to be determined more by consideration of their economic viability than their technical possibility. New services must justify themselves in the marketplace. Inevitably some proposals will fail to measure up to this stern criterion but this may have the result of stimulating further endeavours to achieve the same end in more economical ways so that the proposed service may eventually be encompassed within the limited resources available.

CONCLUSION

The picture for the next thirty years then, is one of massive growth and the progressive introduction of many new services, particularly non-speech services. As the requirements for man-machine and machine-machine data communications are met, and widespread switched image-distribution systems of various sorts are introduced, the total information capacity of the network in the year 2000 will make today's already large network look small.

Economic considerations will force us to exercise the utmost technological ingenuity to reduce costs. At the same time we must cultivate the technology of flexibility and channel our forward thinking towards those concepts which contribute most towards a total telecommunications capability that will be responsive to new demands and receptive to new technologies. We must beware of the temptation to adopt highly-restrictive solutions to our problems because they appear to offer short-term economic attractions. We shall be laying the foundations of the system which our successors will inherit; we owe it to them that we lay them well.

References

1 SIMMONDS, T. G., and BURTON, R. G. Repertory Diallers. *In this issue.*

2 WHYTE, J. S., Pulse Code Modulation. *P.O.E.E.J.* Vol. 54, p. 86, July 1961.

Book Review

"Introduction to Telephony and Telegraphy." E. H. Jolley, O.B.E., C.Eng., F.I.E.E. Pitman and Sons Ltd. x+ 413 pp. 445 ill. 75s.

The author addresses this book to students preparing for the City and Guilds of London Institutes' examinations in Elementary Telecommunications Practice, and Telephony and Telegraphy 'A'. These people will be embarrassed by the scope and depth of the treatment which offers its readers more information than they will need if success at these examinations is their sole objective. Other readers having more general interest will welcome the endeavour to produce a comprehensive treatment that adds interest by tracing the origins and development of the techniques and apparatus now in current use. The size and cost of the book might lead those with the wider interests to expect information on line contruction and transmission plant practice, but this is merely touched upon in chapter 6 to the extent that this is necessary to explain the paths available for d.c. and a.c. signalling systems.

Much of the information assembled in this book has been seen in earlier works, to which the author gives acknowledgement. In one instance this has perpetuated a mistake of an earlier work in wrongly ascribing the drive-cutting function of a 2000-type group selector to the CD relay instead of the HA or HB relay (page 289). Unfortunately most examination candidates (and presumably lecturers also) do not recognize this as a mistake. The real merit of the new book is the alignment of telephone and telegraph practices within each chapter heading; this allows the similarities and divergences to be presented in a manner that has not been attempted elsewhere.

Doubtless this book will make its greatest appeal to the intending City and Guilds examination candidates and it is regrettable that the author has not been able to do more by way of simplified illustrations. The illustrations he gives are mostly admirable for conveying a full understanding of the textual descriptions, but to reproduce this knowledge in an examination-room situation requires an ability to refine a sketch down to essential principles rather than a fuller pictorial presentation. The type of examination candidate to whom the author addresses himself is unlikely to have this ability, or, alternatively, to reproduce, with adequate draughtsmanship, many of the illustrations he will find in this book. There is undoubtedly room, in any further editions, for more sketches of the type shown in Fig. 8.11 which presents the principle of reverse action selector drive. The circuit sketches are mostly adequate in this respect, but there is room for something better here and there. For instance, the principle of coordinate switching in a cordless PMBX which is presented in Fig. 7.29 could usefully have been preceded by a more fundamental presentation of cross-point switching, particularly as this historic technique is now taking on a new importance. Incidentally, Fig. 7.29 is misleading to readers at an introductory level. The capacitors shunting the speech path are unlikely to be recognized as being necessary to improve side-tone balance on extension-to-extension calls.

The book contains many photographs of telephone and telegraph apparatus but it is questionable whether they yield sufficient information to justify the cost of their inclusion—they certainly should not be duplicated as is the case with Figs. 4.31 and 8.1.

Many lecturers teaching the City and Guilds syllabuses reproduced in Appendix 4 find difficulty in interpreting the depth of treatment that is intended. They will be misled if they lean too much on the author's interpretation. His enthusiasm for completeness leads him in many instance to spill over into later years of study that are at least one, and sometimes two, years removed from the syllabuses he reproduces.

C. H. J. F.

The TXE3 Experimental Electronic Exchange System

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U.D.C. 621.395.722: 621.395.345

The TXE3 electronic exchange switching system is an experimental development of an early reed-relay system, TXE1, and was designed to meet the requirements of large telephone exchanges. This article describes the TXE3 system, a model of which has been operated successfully in public service for more than a year.

INTRODUCTION

The TXE3 experimental electronic exchange was designed to meet the requirements of large telephone exchanges serving between 2,000 and 20,000 lines. It was designed to fulfil the functions of either director or non-director local exchanges. Its switching network makes use of the dry-reed relay as a switching crosspoint, and this network is controlled by a number of identical common processors. Both the switching network and the exchange control employ novel methods of achieving system security and facility flexibility.

HISTORY

TXE3 is the second step in a development that began with the Leighton Buzzard reed electronic exchange (TXE1),[1] which was designed under the Joint Electronic Research Committee agreement, and is now in public service. The experience gained led to the TXE3 system, a full-scale trial model of which has been operating successfully for over a year.

The guiding principles formulated for the design of TXE3 included the following:

(*a*) The security of the exchange should not be dependent upon infallible fault detection and changeover equipment.

(*b*) The design should not be dependent upon the successful use of new techniques or components; only well-tried techniques should be used.

(*c*) The choice of technique should depend upon the availability of experienced design effort and the need to minimize liaison problems between circuit designers.

(*d*) A programmed control should be used, which would permit flexibility of application and facility provision. A further advantage of the programmed control would be that hardware design of the control could proceed in parallel with, and substantially independently of, the resolution of the details of its operations.

(*e*) The system should be for exchanges of about 2,000 lines and upwards.

(*f*) The system should be capable of providing and subsequently extending any exchange in this range.

(*g*) The growth of all parts of the exchange should be possible in convenient steps.

(*h*) The system should contain the potential for further development, and be able to incorporate new techniques as they become approved.

At the outset of the TXE3 work certain possible features

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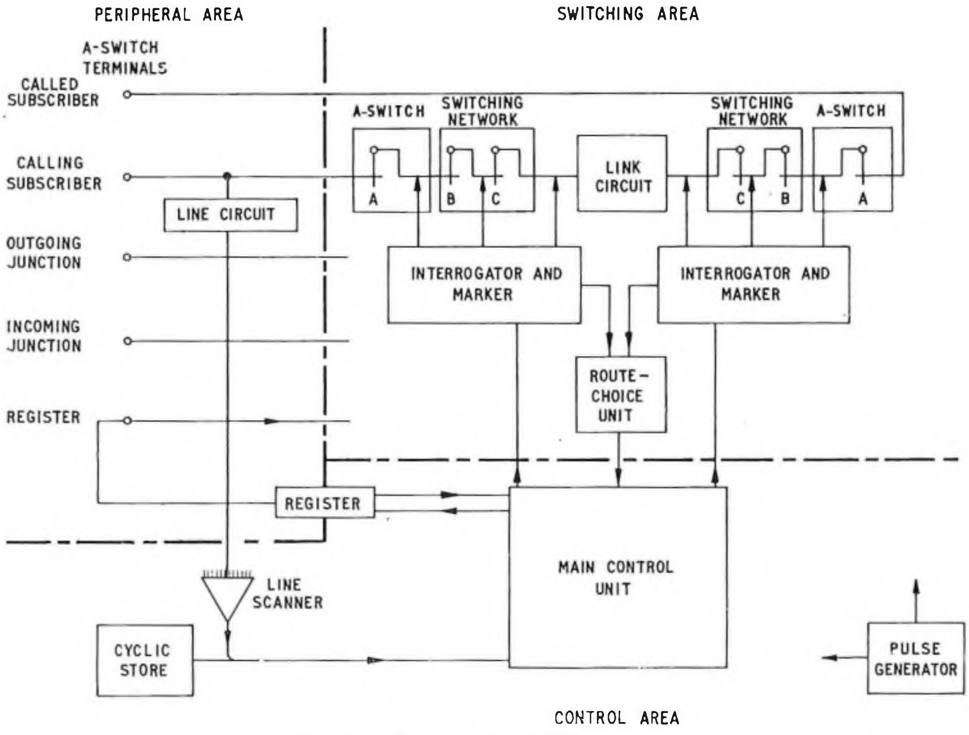

FIG. 1—Block diagram of a TXE3 exchange

were omitted which, despite their potential advantages, could not be included without overloading the design effort then available. At a later stage, when the TXE3 design work was nearly complete, a detailed study confirmed the desirability and feasibility of these features. These and further improvements are being incorporated in a later development, TXE4.

GENERAL DESCRIPTION

Fig. 1 is a simple block diagram of a TXE3 exchange, showing the essential features required to establish a local call. The main functional blocks are:

(*a*) the line circuit, which detects when a subscriber lifts his receiver to make a call,

(*b*) the line scanner, which cyclically examines the line circuits and extends calling conditions sequentially to the control,

(*c*) the cyclic store which operates in synchronism with the line scanner and presents class-of-service and directory-number information to the control,

(*d*) the main control unit (MCU), which, in response to information from the scanner, cyclic store, and the subscriber via the register, controls the setting of all connexions through the exchange,

(*e*) the register, which receives and stores dialled information from the subscriber and passes it to the MCU,

(*f*) the interrogator-marker, which performs the following two functions:

(*i*) it responds to instructions from the MCU and acts as an interrogator seeking suitable paths through the exchange and signalling these to the route-choice unit,

(*ii*) it responds to different instructions from the MCU and acts as a marker switching a particular path through the exchange,

(*g*) the route-choice unit (RCU), which receives information after interrogation regarding all possible paths through the exchange, selects one over which the connexion is to be made and passes its identity to the MCU,

(*h*) the switching network, which consists of reed-relay matrix switches,

(*i*) the link circuits, which provide a point at which supervision can be provided.

At the left-hand side of Fig. 1, a subscriber's line is shown connected to an A-switch terminal which has a line circuit associated with it. When the subscriber calls, the line circuit produces an output signal which is available to the line scanner. The scanner scans all lines in sequence and detects a calling condition when it arises. At the same time as the line is scanned the cyclic store provides information about the particular line, for example, its class of service, its directory number and its position within the switching network of the exchange (equipment number).

The main control unit continuously monitors the outputs of the scanner and cyclic stores, and when a calling condition is detected it records all information relevant to the calling line. The MCU now selects one of its registers for connexion to the calling subscriber. Knowing the equipment number of this register and of the calling line, the MCU instructs the interrogator-marker to interrogate the possible paths between the two to determine which paths are free. One of the possible paths is selected by the route-choice unit and its identity is signalled to the MCU. The MCU next instructs the interrogator-marker to mark (i.e. to switch) the selected path between the two equipments. With the path connected, the subscriber receives dial tone from the register and can proceed to dial. This part of the setting-up process is completed in about 150 ms.

When the calling subscriber has dialled the full directory number of the wanted subscriber, the register passes this information to the MCU. By examining the output of the cyclic store the MCU can detect when the line with this directory number is being scanned, and because the equipment number is also available at this time, a translation between directory number and equipment number is obtained.

The MCU can now go through an interrogate, route-choice and marking cycle, similar to the one described previously, to connect the calling subscriber to the called subscriber. Metering, supervision and transmission-bridge facilities are obtained in the link circuit, which is situated between the two C-switches.

The exchange can be conveniently divided into three main areas; the switching area, the control area and the peripherals.

THE SWITCHING AREA

Switching Network

The switching equipment is provided in units which are each divided into sub-units. Each sub-unit is self-contained and consists of two two-stage networks of B-coordinate and C-coordinate switch arrays, one for local traffic (the local sub-unit) and the other for junction traffic (the junction sub-unit), and an interrogator-marker which interrogates and marks paths through the two networks. Switching networks of this type and interrogation and marking principles have been described in eariler articles.[2,3]

The switching network can be considered as stratified and some of the terms used in connexion with the exchange originate from this concept. The sub-units of a unit can be four, six or eight in number, and are thought of as strata or "planes". A plane thus extends throughout all the units of the switching network, and is composed of one sub-unit from each unit, as shown in Fig. 2.

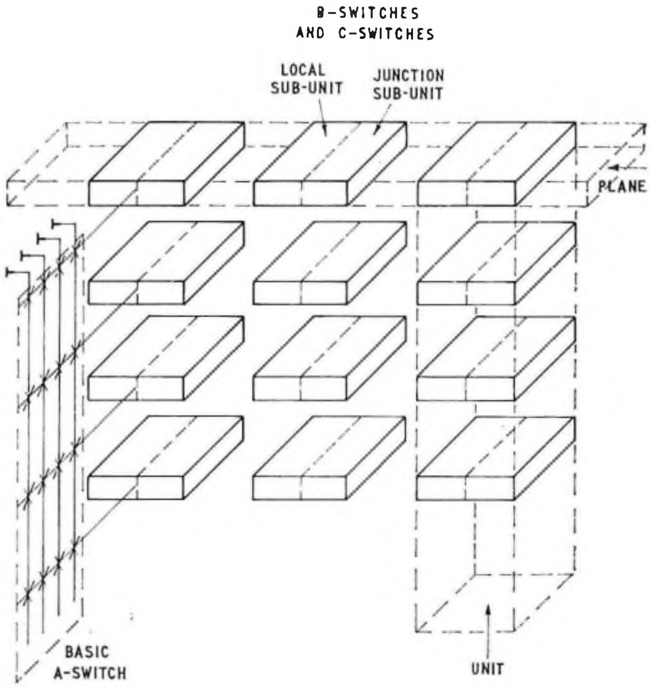

FIG. 2—Schematic diagram of the switching network for a 3 unit 4 plane exchange

Each subscriber is provided with an A-switch cross-point, giving access to the local sub-unit of each plane of the unit to which he is connected. Similarly, junction terminations are given access to the junction sub-units through a junction A-switch. These terminations could be mixed with subscriber connexions, but it is simpler to give subscribers and junctions access to their own B-switch and C-switch arrays via separate A-switches.

The distinction between local and junction terminations is not one of function alone, but also one of traffic loading. Terminations with a low traffic occupancy are connected to the local sub-unit, and those with a high occupancy, such as registers, senders and junction relay-sets, are connected to the junction sub-unit. This simplifies the design of the switching network and enables a uniform traffic loading to be provided at the centre of the exchange.

The two B-switch and C-switch arrays are inter-connected internally to provide full accessibility between C-switch outlets and B-switch inlets, as shown in Fig. 3. This diagram shows such a network for five 5 × 4 B-switches and four 5 × 4 C-switches. A range of sizes has been designed to cater for different traffic-capacity requirements, and slight differences exist between the local and junction arrays to cater for the different traffic-concentration requirements referred to above.

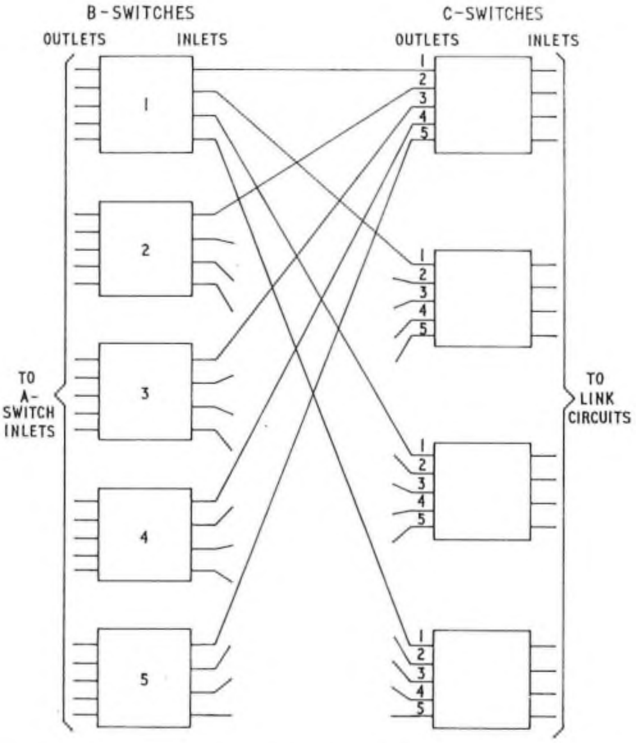

FIG. 3—Switching network of the type used in local and junction sub-units

The A-Switch

The telephone traffic generated by different subscribers connected to the exchange may vary over a wide range. The switching units to which they have access, however, are designed with a predetermined traffic capacity. The A-switch, therefore, not only provides access for each subscriber to each of the sub-units within the unit, but also concentrates the subscriber traffic to fully load the B-switches and C-switches.

The basic A-switch has 4 outlets (subscribers) and 4, 6 or 8 inlets (B-switch outlets), depending upon whether the exchange has 4, 6 or 8 planes. These four subscribers, therefore, share a common group of B-switch outlets, one on each sub-unit. Ten of these basic switches are associated together, providing the switching capability between 40 subscribers and 10 B-switch outlets on each plane, and the required concentration is achieved by wiring up to 6 of these blocks of 10 switches in parallel.

The design of the junction A-switch follows similar principles, though the basic switch in this case is 2 × 4, 2 × 6 or 2 × 8, again dependent upon the number of planes.

Equipment Number

In step-by-step exchanges the routing of calls through the exchange is achieved by making direct use of the digits of the directory number (DN). Each selector is stepped by the appropriate digit, requiring only the directory number for the routing of calls. In switching networks of the sort shown in Fig. 3, there is no such direct correlation between the path and the DN.

A particular B-switch is connected to similarly-numbered C-switch outlets on all C-switches. For example, B-switch number one of Fig. 3 is connected to the first C-switch outlet of all the C-switches. Therefore, a particular A-switch can be reached by reference to the C-switch outlet identifying the B-switch to which it is connected, and the identity of the B-switch outlet on which it appears. Hence, a particular termination is identified by these two numbers together with the identity of the particular A-switch outlet. This unique number is referred to as an equipment number (EN). This EN is stored with the DN in the cyclic store, providing the translation capability between EN and DN previously mentioned. All terminations, therefore, whether they are connected to the local or the junction sub-units, have a unique EN identity within the exchange.

By making use of the equipment number of one termination, a connexion can be established between this termination and one C-switch inlet on one plane of the unit on which it appears. A complete connexion through the exchange entails switching two such paths, the two C-switch inlets being joined by a link circuit.

Link Circuits

To simplify control problems, link circuits are used only to connect together C-switch inlets on adjacent planes; any given plane having access to the plane above and the plane below. Some link circuits are connected between the sub-units of adjacent planes within the same unit, and others between the sub-units of adjacent planes in different units.

A single design of link circuit could be used for all types of connexion, but it is more convenient to separate within-exchange call-supervision, which can be standardized, from the supervision provided for outgoing junction calls which may vary widely in different locations and for different services. This separation also reduces complications in interworking with other types of exchange. The simplest and most flexible way of splitting the requirements for supervision is to supervise outgoing calls at terminating equipments such as junction relay-sets. These are connected to A-switch terminals, and to leave the centrally-located link circuits to deal with other calls. However, the switching plan requires a link circuit to be inserted on all connexions. To avoid the use of a supervisory bridge in both the link circuit and the junction relay-set on an outgoing or tandem connexion, provision has been made for inserting either a through-type link, without a supervisory bridge, or a bridge-type link, depending upon the particular connexion being made. For convenience, the two types of link circuit have been combined physically with appropriate

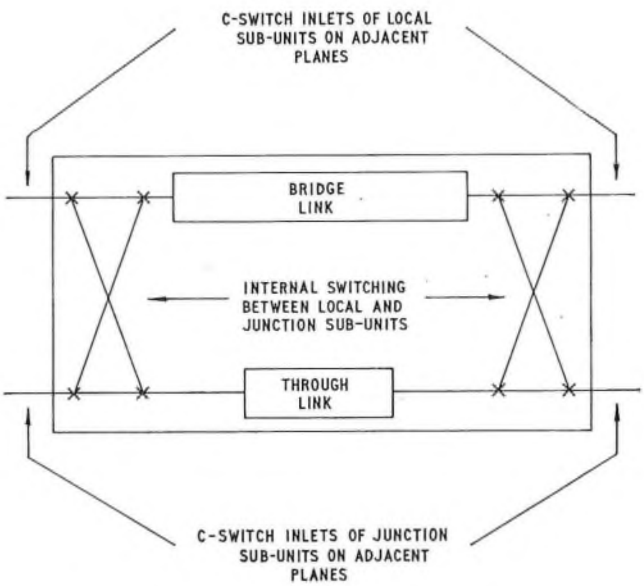

FIG. 4—A combined link circuit

in-built switching facilities. This combined link circuit has two C-switch inlet appearances on either side, one on the local sub-unit and one on the junction sub-unit, as indicated in Fig. 4. Also, for efficiency, the link circuit is reversible in the sense that the C-switch inlets on both sides may be used for connexions to either the called or calling subscribers. The schematic arrangement of a combined link circuit is illustrated in Fig. 4.

Interrogation, Route Choice and Marking

These functions are basically part of the control equipment, but in order to increase the security of the system this part of the control has been dispersed so that each sub-unit has its own interrogation and marking equipment.

Path selection is made a function of the instantaneous state of the network. In operation, the main control unit signals the equipment numbers of the two A-switch terminals to be inter-connected, to all the interrogator-markers. Those interrogator-markers having access to the indicated A-switch terminals, respond by accepting the equipment numbers, and interrogating all possible paths open to them for the desired connexion between the C-switch inlets in the sub-unit, and the required termination. The result of the interrogation is signalled to the common route-choice unit which then selects a suitable path and signals it to the MCU. The MCU responds by issuing instructions to the two interrogator-markers (now operating as markers) to set up the desired connexion.

THE CONTROL AREA

The Pulse Generator

This is common to the exchange and does not vary appreciably with the size of the exchange. It consists of four identical sections operating in parallel. These provide a range of synchronized clock signals via combining gates, which are designed to provide a correct output, even if one section completely fails.

The basic clock speed is 84 kHz, providing a basic time slot of 12 μs duration, which is a very slow speed in terms of present-day techniques. Nevertheless, this slow speed of operation of the whole exchange has permitted one of the overall design objectives to be met, namely that of using only well-tried techniques.

Cyclic Stores and Line Scanners

The cyclic store is arranged to cycle all the terminal addresses it controls, regardless of the activity of the exchange. For each address in succession the cyclic store presents at its output terminals a block of data, which typically consists of the directory number, the equipment number, and the class of service of that particular line termination.

Each cyclic store and line scanner has capacity for scanning 960 subscriber's terminals every 156 ms, 252 outgoing junction-type terminals every 36 ms, and 168 incoming junction-type terminals every 12 ms. The differences in the scanning intervals arise from service requirements. The incoming junction, in particular, has a short interval of 12 ms to ensure that an incoming call can be recognized quickly, and to avoid the possible loss of incoming dial pulses due to delay in setting a connexion to a register. Cyclic stores can also provide a translation between dialled digits and routing digits, when this is required.

The cyclic store is a particular form of Dimond-ring translator, and consists of an array of 14 rows of ten toroidal transformers. It is flexible in that any subscriber's line circuit may be given any directory number, equipment number or class of service, merely by threading a wire through the appropriate transformers in the field. The store is essentially permanent in the sense that once a subscriber's wire has been threaded through the field it cannot be changed accidentally or by a fault.

The cyclic store and line scanner operate in synchronism so that as each wire in the cyclic store is pulsed, the appropriate line terminal is scanned. Each line terminal is equipped with a simple gate, which when pulsed, according to the condition of the line, either transmits or does not transmit corresponding signals to the scan highways.

Main Control Unit

The main control unit is a specially designed computer whose peripheral input and output equipments are: the cyclic store, the scanner, the interrogator-markers and the registers. In most commerical computers the program is loaded by means of punched tape, and is held by ferrite storage; the program of the MCU, however, is held as a semi-permanent wired Dimond-ring field, similar to that used in the cyclic store. By modifying the appropriate wires in this field, modifications to the "computer" program can be readily incorporated, and hence operating and facility requirements can be readily revised. The store provides capacity for 2,000 words of computer program, each word consisting of nine decimal digits. Hence the Dimond-ring field consists of nine rows, each of ten toroidal transformers. Six of these nine decimal digits constitute an instruction to the computer concerning the function to be performed at a particular step of the program, while the other three digits provide the address of the next step of the program that has to be used. The MCU operates in such a way that at each step in the program, there are two possible following steps. Which of these following steps is selected depends upon the function performed within the computer as a result of the six instruction digits of that particular program step. Thus, although only three decimal digits are available for address, the use of the "one or other" result from within the computer enables the program to be extended to 2,000 steps.

In practice a number of main control units are provided, and the information from all the cyclic stores and scanners is available to all of them as shown in Fig. 5. Consequently,

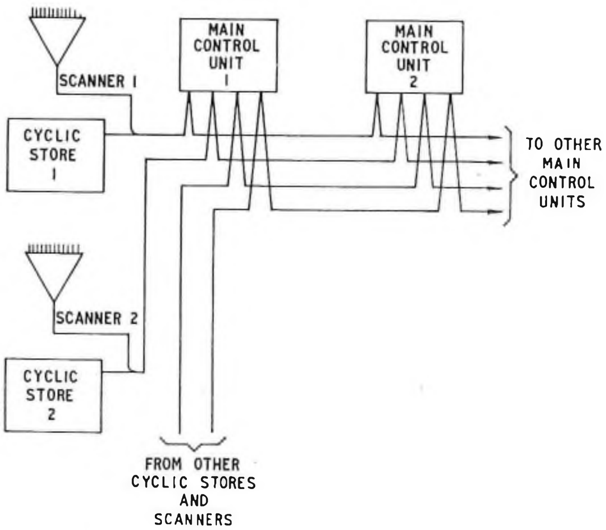

FIG. 5—Information highways between scanners, cyclic stores and main control units

any demand for service is offered to all the MCUs but, at any one time only one is instructed to look for new calls. When a call originates, the nominated MCU accepts this call, and another free MCU is nominated to look for further calls. Even if new calls do not originate, the nomination is passed on at intervals. This minimizes the chance that a call failure due to a processing misoperation will be repeated in a follow-on attempt, as the probability that the second attempt will make use of the same control is small.

This arrangement of main control units confers several important advantages. Firstly, an exchange isolation due to a processor fault cannot occur; service, albeit of a poorer quality, is still available with all but one MCU faulty. Secondly, the number of MCU required is broadly proportional to the total-traffic loading, except for lightly-loaded exchanges. Hence the cost of control equipment is made approximately proportional to the traffic to be switched. Thirdly, maintenance work may be carried out on any single MCU without affecting the traffic capacity of the exchange.

Registers

A separate block of registers, up to 30 in number depending upon the traffic loading, is associated with each main control unit. The registers are conventional in that they perform, within themselves, functions such as dial-pulse detection, pulse timing, digit storage and digit sending. They do not, however, process their own data, this operation being one of the functions of the MCU with which they are associated.

When a call is allotted to a particular MCU, that unit assigns a free register within its group, and issues orders to the network to connect the calling subscriber's A-switch terminal to the A-switch terminal of the register, after which dial tone is returned. No further action is required by the MCU until dialled digits are received, and the MCU, having recorded the state of the call in its temporary memory, continues with other operations. When the register eventually has something significant to handle, for example if one digit has been fully received and stored, it produces a signal indicating that data needs attention. The main control unit acknowledges the signal, accepts the data in question, and after processing this data in accordance with its program, issues appropriate orders to the register; for example, "wait for two more digits". It again records the state of the call in its temporary memory and leaves the call for other work. Eventually, when sufficient digits have been received, setting-up instructions are issued to the network.

The registers are in fact register-senders, and are able to generate loop-disconnect pulse trains as directed by the main control unit instructions. The sender facility permits dial-pulse trains to be stored and repeated to line as they are received, or a translation consisting of additional routing digits to be inserted; in the latter case the register stores the received dial-pulse trains for subsequent transmission to line after the additional routing digits have been sent.

For calls requiring merely standard loop-disconnect signalling, only the register-sender is required in the connexion during setting up. However, if new methods of signalling are to be used in the future, these would be accommodated by providing a separate sender, and by making appropriate changes to the program of the main control unit so that the special sender would be included in any connexion requiring it.

Registers are designed to carry out many checks of setting-up operations. If any check fails the failure is noted by the main control unit which, if necessary, via its program, records and prints out details of the failure. When a first attempt fails, further attempts at setting up are made without the subscriber's knowledge.

PERIPHERAL EQUIPMENT

In addition to subscriber's line circuits, incoming and outgoing junction relay-sets and registers, there are numerous other peripheral equipments, such as coin-and-fee-checking and trunk-offering relay-sets. In general these circuits have a direct equivalent in step-by-step exchanges, and therefore new designs were not undertaken; existing designs were modified to satisfy the working conditions of TXE3.

SERIAL TRUNKING

An important feature of the TXE3 system is that of serial trunking. This concept enables a general-purpose switching network to be used, separate equipments providing all the various facility requirements being connected at the periphery of the exchange. In establishing individual calls the main control unit causes these peripheral equipments to be trunked into the circuit as dictated by the requirements of the subscriber. New facilities can be incorporated by providing an additional peripheral relay-set, and by changing the MCU program to enable the MCU to trunk the new relay-set into the calls requiring it.

The simplest serial-trunking sequence is that for an own-exchange call (Fig. 6) which involves two connexions through

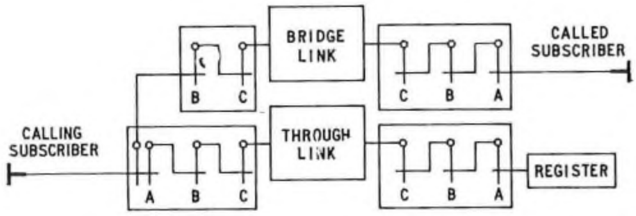

FIG. 6—Serial-trunking sequence for an own-exchange call

the network. Firstly, a connexion between the calling circuit and the register, via an A-switch, B-switch and C-switch, a link circuit and C-switch, B-switch and A-switch, and secondly, a connexion between the calling and called circuits using a similar switching pattern to the first. Once the final connexion has been established and checked by the register, the first connexion is released.

An outgoing-junction call is more complicated and involves, four connexions through the network (Fig. 7). The first,

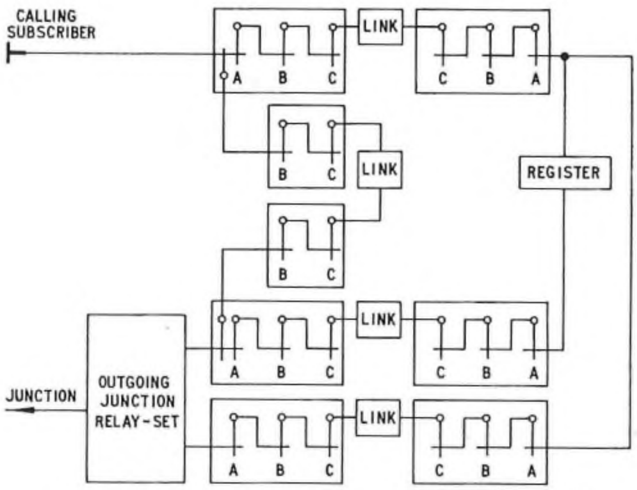

FIG. 7—Serial-trunking sequence for an outgoing call

between the calling circuit and the register, is identical to that described above. The second and third, are connexions between the calling circuit and the outgoing-junction relay-set, and between the outgoing-junction relay-set and the register. These form a path in parallel with the first, permitting the first connexion to be released. A fourth connexion is made between the register and a separate terminal of the outgoing-junction relay-set, to permit routing digits to be sent.

The register also has two terminals which permit digits to be sent over the junction at the same time as digits are being received from the subscriber. When the register has completed sending, all paths other than that between the subscriber and the outgoing junction are released.

THE TXE 3 MODEL EXCHANGE

In order to verify the design principles of the system that has been described, a small laboratory model, which incorporated all the functional units of a full-size exchange, was built in central London. Later it was extended with further switches and peripheral equipment, to enable it to be used for a public-service trial.

The field-trial model has been provided with switching capacity for approximately 200 subscribers, whilst the quantity of control equipment is approximately that required for a 1,000-line exchange. One hundred of the subscribers comprise a block of final-selector numbers from a nearby director exchange. Half of these numbers are service lines and the remainder are high-calling-rate public subscribers in the City of London. A further group of 100 numbers, primarily for testing purposes, are also available on the model. Lines in this block of numbers have full outgoing facilities, but are available only for incoming calls from other lines connected to TXE3.

The TXE3 model exchange was brought into public service on 29 April 1968. On no occassion since that time has it proved essential to restore the subscribers to Strowger working in order to maintain their service, although there have been a few instances when this has been done for engineering reasons. A close watch has been kept on the service given by the TXE3 exchange, and from these observations and reports, it is apparent that the performance is well up to expectations.

Centralized Service Observation (CSO) results for calls originating from TXE3 subscribers indicate a failure rate significantly better than that for the area as a whole. As virtually all the calls originating on the model are outgoing from the model, the TXE3 equipment comprises only a small part of the connexion. For this reason, no dramatic change in CSO results could be expected and the fact that this has occurred is therefore most encouraging.

Faults in the equipment have arisen, but the security arrangements and repeat-attempt feature have in general prevented these from affecting service. Most of the faults which have occurred have been traced to faulty soldered or wire-wrapped connexions, and to faulty reed-relay contacts. The majority of the wiring faults are attributable to the intense activity during the commissioning period, while many of the reed contacts are early samples and not representative of production types. However, the number of wiring and reed-contact faults have been steadily declining since the equipment went into public service.

The validity of the electronic circuit design has been proved by the low failure rate of electronic components (9 failures out of a total of approximately 150,000 components), which is several times better than the anticipated figure.

Since November 1968, the equipment has been left to operate unattended except for weekly checks to confirm that all the equipment is functioning correctly. Exchange alarms are extended in the normal way, and the maintenance staff are called if they are required.

CONCLUSIONS

The TXE3 design permits growth in subscribers' lines to be met by providing additional cyclic stores, scanners and line circuits; and traffic growth to be met independently by the addition of switches, switching units and main control units.

Security of the system has been achieved by the division of the switching network into a number of planes, and the division of the control equipment into a number of main control units. Any call can be controlled by any main control unit and switched through any plane. Thus the failure of an individual plane or an individual main control unit will not result in a loss of service.

The flexibility of the program control in conjunction with serial-trunking techniques has been demonstrated in two respects. Firstly, the main control units were designed and manufactured before the final details of the operation of the exchange had been settled, thus reducing the development time. Secondly, at a late stage in the commissioning of the trial model the decision was made to change from non-director working to a director public-service trial. This change in the operation of the exchange was readily achieved by means of changes to the program of the main control units.

The basic design objective was to produce a design of telephone exchange making use of the switching and control principles that have been described. It was realized before the TXE3 design commenced that certain areas were suitable for the application of more advanced techniques, such as serial-processing of registers and supervisory relay-sets. These were omitted from the TXE3 design so that all the available design effort could be concentrated on the main objectives. Once the TXE3 design was complete these further features, together with other refinements, were incorporated into the design of TXE4.

ACKNOWLEDGEMENTS

The authors wish to acknowledge that the development described in this article was a joint effort by many colleagues within the Post Office and the telephone industry.

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A New System for the Detection of V.H.F. Sound-Radio Receivers and V.H.F. and U.H.F. Television Receivers

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U.D.C. 621.376.33: 621.376.93: 621.396.22: 621.396.62

Following the introduction of television broadcasting in the u.h.f. bands IV and V an attempt was made to extend the frequency range of the existing television detectors to enable them to detect receivers tuned to programs in the new bands. Early field trials showed that, because the effects of reflections are much more serious at ultra-high frequencies than at very-high frequencies, the existing system was unsuitable at the higher frequencies. A new detection system that will detect v.h.f. radio receivers and v.h.f. and u.h.f. television receivers has now been developed. Eleven vehicles fitted with the new system are being provided to bring the complement of television detectors up to two per Telecommunications Region.

INTRODUCTION

The existing detection system for television and v.h.f. radio receivers,[1] which was introduced by the Post Office in January 1963, has proved very effective in practice, and has resulted in a great decrease in licence evasion. The success of the detectors resulted in requests from Telecommunications Regions for additional units, and led to a decision to double the numbers from one to two per Region. Prior to this decision the introduction of television broadcasting in bands IV and V had led to experiments to determine the possibility of extending the frequency range of the existing detectors to make them suitable for use in detecting receivers tuned to the new television channels.

The existing detection system relies on conventional direction-finding techniques in which fundamental or harmonic radiation from the frequency-changing oscillator of a superheterodyne receiver is displayed on the screen of a panoramic receiver, and the position of the receiver is determined at relatively short range by a series of cross-bearings. At ranges of between about 40 and 100 ft it is easily possible with this system to determine the position of a v.h.f. receiver with a lateral accuracy of a few feet, and this is sufficient in almost all locations to determine with certainty the dwelling in which it is located. The direction-finding aerial, which is mounted on the roof of a Morris Oxford Traveller, is a tilted dipole in a corner reflector. The aerial is elliptically polarized and has a half-power beam-width which varies with frequency from about 45° at the high-frequency end to about 90° at the low-frequency end of its range. This design is not capable of further development to increase its frequency range.

A number of alternative aerial-configurations were tried in an effort to develop a broadband aerial which would be usable over the frequency range 150–950 MHz, but it proved impossible to construct a practical aerial of reasonable physical size with sufficient gain and electrical accuracy over the whole frequency range.

From experience of measurement of oscillator radiation in connexion with the determination of interference limits in the new u.h.f. bands, it was known that existing band I and III television tuners radiated detectable amounts of energy at harmonic frequencies as high as the tenth. Oscillator radiations from modern v.h.f. radio and television receivers at the fundamental frequency cover a frequency range of approximately 77–240 MHz, and, therefore, harmonics from the sixth to the second, respectively, appear in bands IV and V. It is thus possible, if the system can be made sufficiently sensitive, to detect v.h.f. sound-radio and television receivers by the harmonics of their frequency-changing oscillators that appear in bands IV and V. This considerably reduces the frequency range over which the aerial must operate, and simplifies its development.

The most suitable aerial design for the u.h.f. bands appeared to be a balanced log-periodic spiral aerial.[2] A laboratory prototype was constructed using an expanded-polystyrene former with elements of thin copper tape. This aerial has a directive gain of about 10dB, a half-power beam width of 40°, and an electrical axis which lies along the centre of the aerial throughout the frequency range of interest. When used in conjunction with the existing equipment, in which the v.h.f. tuner had been replaced with an u.h.f. tuner, the results on an open test site were excellent. Unfortunately, when the equipment was subsequently mounted in a vehicle and tried out under field conditions, it was found that because of the multiplicity of reflections, it was impossible to say with any certainty where a particular television receiver was located. It was concluded, therefore, that the conventional system, employing cross-bearings, would have to be abandoned and that a new system would have to be evolved.

A NEW TECHNIQUE OF DETECTION

Perhaps the best way to introduce the detection technique used in the new detector, is to review the problems which had to be overcome. The radiation from a television-receiving installation takes place from the chassis of the tuner, the outer conductor of the feeder, and from the aerial, but, fortunately, the chassis radiation is predominant. The radiation usually has a complicated pattern, with a number of well-defined maxima and minima. The polarization of the resultant waves is random. In addition, as a consequence of the need to avoid interference with receivers tuned to channels in bands IV or V from receivers tuned to channels in band I or III, the oscillator radiation of newer receivers is considerably lower than that of older receivers. Measurement of the radiation from a number of modern receivers with transistor tuners has shown that, making allowance for the attenuation of buildings, it is necessary to be able to detect a field strength of the order of 10 μV/m at a range of about 10 metres.

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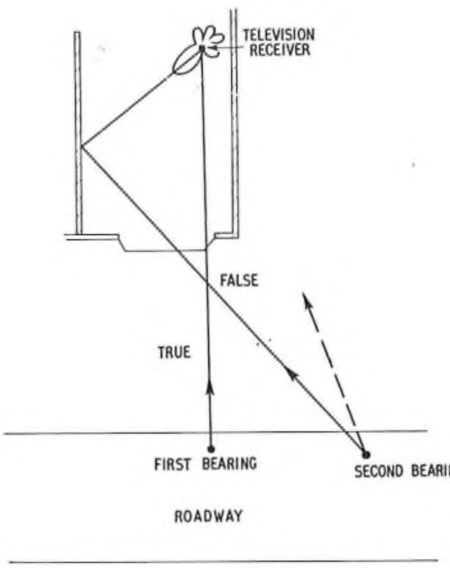
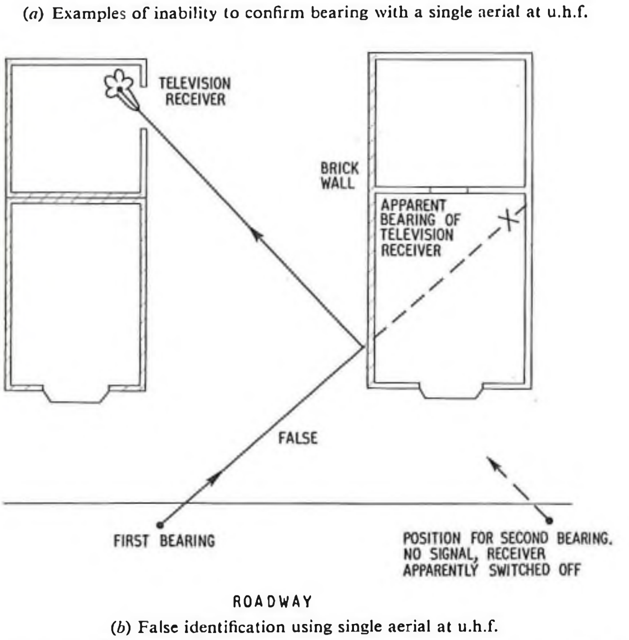
The complicated pattern of the receiver-chassis radiation, combined with the strong reflections from walls, gutter pipes, lamp posts, etc., poses three main problems.

(*i*) Owing to the combination of the direct and reflected waves, a series of closely-spaced minima and maxima occur along a path parallel to the front of the dwellings, i.e. along the roadway in front of a row of houses. Consequently, with a single rotating direction-finding aerial in one position it is possible for the signal reflected from some object, even one on the opposite side of the road from the position of the television receiver, to appear to be stronger than the direct signal. Moving the detector a short distance to another position may change the apparent bearing by anything up to 180°. In practice, this makes it very difficult to decide with certainty from which dwelling or even from which side of a road the signals originate.

(*ii*) Fig. 1 illustrates two other aspects of this problem, in which the combination of a good reflecting surface, the radiation pattern of the receiver and the attenuation of walls can give rise to a reflected wave which has a greater amplitude than the direct wave. In Fig. 1(*a*) the combination is shown giving rise to inability to confirm what can be seen to be a true first bearing. Fig. 1(*b*) shows that the combination can also rise to a false first bearing, which subsequently may be misinterpreted as a true bearing that has been implicitly confirmed by a guilty householder switching off his receiver on the approach of the detector.



(*a*) Examples of inability to confirm bearing with a single aerial at u.h.f.



(*b*) False identification using single aerial at u.h.f.

FIG. 1—Difficulty of locating television receiver due to reflected waves

(*iii*) The television receiver may have a nearly-uniform radiation pattern.

In this instance the walls and objects in a room create a multiplicity of reflections that are equivalent to the diffusing or scattering of the wave, and give rise to vague bearings extending over many degrees of arc. With the old system of detection this condition only arises when the television receiver is at a comparatively great distance, and the operators are taught to disregard such signals.

Requirements of New System

The first requirement of the new system is that it should discriminate against signals which arrive at other than in a relatively narrow angle in front of the aerial.

The second requirement is that, since it is impossible to take accurate crossbearings, the position of the television receiver, i.e. its approximate range and bearing, must be found from the shape or form of a suitable display.

Principles of Operation of New System

When two similar isotropic aerials are arranged in space, d metres apart, and energized in phase with equal power, the field strength E, at angle θ to the line joining the aerials, is given by

$$E = 2E_a \cos\left(\frac{\pi d}{\lambda}\cos\theta\right)$$

Where E_a is the field strength due to either aerial on its own. The ratio E/E_a is known as the array factor n,

$$\text{and hence } n = 2\cos\left(\frac{\pi d}{\lambda}\cos\theta).\right)$$

If d is made equal to 6 λ,

then $n = 2\cos\ (6\pi\cos\theta)$.

$n = 0$ when $\cos\theta = \frac{1}{12}, \frac{3}{12}, \frac{5}{12}, \frac{7}{12}, \frac{9}{12}, \frac{11}{12}, \ldots$

i.e. when $\theta = 85\cdot3°, 75\cdot5°, 65\cdot5°, 54\cdot5°, 41\cdot4°, 23\cdot8$, etc., and has maximum values when

$\cos\theta = 0, \frac{1}{6}, \frac{2}{6}, \frac{3}{6}, \frac{4}{6}, \frac{5}{6}, \frac{6}{6}, \ldots$

i.e. when $\theta = 90°$, $80\cdot4°, 70\cdot8°, 60°, 48\cdot5°, 33\cdot5°$, 0°, etc.

Fig. 2 shows the basic principle of the new system. If the isotropic aerials are replaced by two aerials each of which has one radiation lobe, then the radiation pattern due to either of these aerials singly will be modified by the array factor n. The result, for a pair of aerials each having a single lobe with a half-power beam width of 40°, is shown in Fig. 2(*a*). The radiation pattern shown consists of seven main lobes. There are in fact 13 lobes, but the remaining six are sufficiently low in amplitude to be neglected.

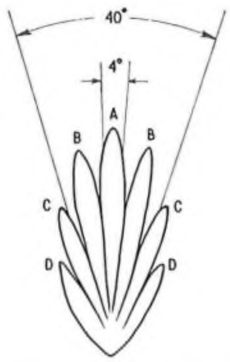
The spaced aerials, mounted on the roof of a vehicle, are moved past the location of a radio or television receiver, and the rectified output from the aerials is displayed on a cathode-ray tube in which the X-deflection is made proportional to the distance travelled by the vehicle.

As the maximum of each lobe points directly to the receiver, Fig. 2(*b*), the spot on the cathode-ray tube will be deflected as shown in Fig. 2(*c*). The separations A′B′, A′C′ and A′D′ on the screen are proportional to the distances AB, AC and AD along the direction of travel of the vehicle. If R is the distance from the receiver to the aerials along a path normal to the direction of travel then

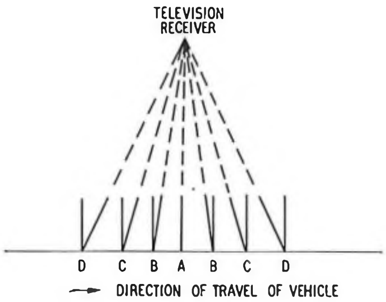
$R = \text{AB}\tan\theta_1, = \text{AC}\tan\theta_2 = \text{AD}\tan\theta_3$, where θ_1 θ_2 and θ_3 are the angles of maximum radiation of the aerial as derived above.

$\therefore R = \text{AB}\tan(80\cdot4°) = \text{AC}\tan(70\cdot8°) = \text{AD}\tan(60°)$

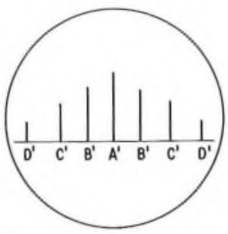
A distinct and recognizable pattern in which the range R is



(a) Radiation pattern from an ideal array



(b) Positions of maximum indications as aerial is moved past television receiver



(c) Corresponding positions of maxima on cathode-ray tube display. The X deflection is proportional to the distance travelled by the vehicle; the Y deflection is proportional to the amplitude of the received signal

FIG. 2—Basic principle of new system

proportional to the spacing A′B′, A′C′ and A′D′ is thus formed on the screen.

To complete detection it is necessary only to add marks to the trace to indicate the position of the suspected premises. This is done by the operator by means of a press-button as the vehicle passes the boundaries of the house.

The trace is photographed as it is formed, and, by the application of an adjustable graticule to the completed positive print, the response of the aerial to the direct ray can be recognized. The graticule consists of a frame in which nine nylon threads are held in tension between two pairs of moving arms. As the arms are moved, the distance between each wire and a fixed central wire varies so that it is always proportional to the product of the range and the cotangent of the respective lobe angle. An approximate range scale is marked on the fixed central arm and calibrated to correspond to the scale of the photographs.

When the graticule is applied to a photograph and adjusted for best fit, it thus enables the unique pattern of the direct wave to be recognized, and the approximate range of the television receiver to be determined.

Performance of the System in the Presence of Reflections

As the aerial is fixed and cannot be rotated by the operator, reflections arriving from directions outside a 40° angle on one side of the detector are rejected.

Reflections within the 40° angle fall into two main categories. The first category, in which a wall behind the receiver forms a good reflecting surface, is shown in Fig. 3. Here the response

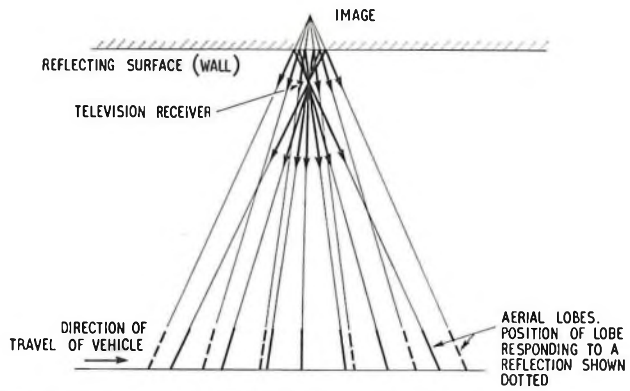
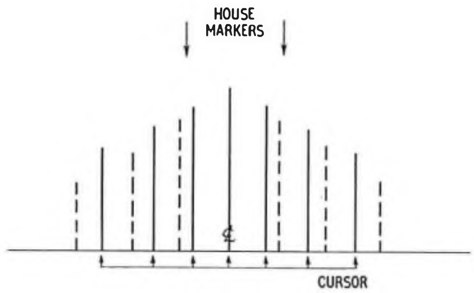
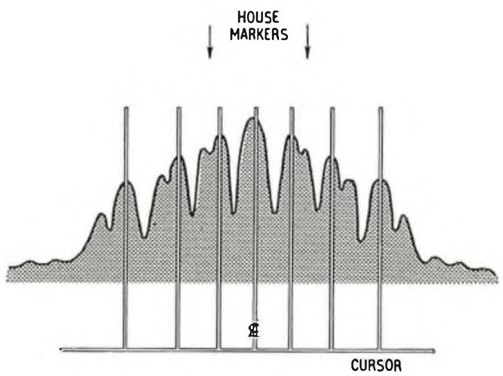


FIG. 3—The positions of additional maxima due to reflections from a wall behind the television receiver.



Note: Responses due to reflections shown dotted
(a) Positions of maxima



(b) Appearance of the actual display with the cursor in position

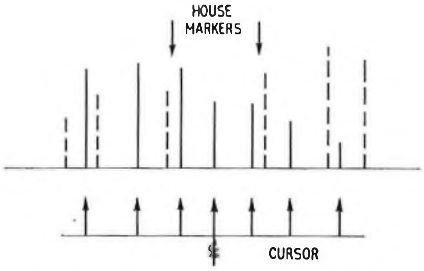
FIG. 4—The effect on the display of a reflecting surface behind the television receiver

of the aerial is as if two television receivers operating on precisely the same frequency were placed one behind the other, and the display is, therefore, effectively a combination of two signals: one from the direct, and the other from the reflected, wave. The positions of maxima of the resultant response are shown in Fig. 4(*a*). With a practical system, however, it is not possible to achieve such sharp indications, and the corresponding display appears as shown in Fig. 4(*b*). When the graticule is adjusted to the approximate range, applied to the photograph, and then re-adjusted for best fit, the position of the centre can be determined as shown. The house markers, also shown in Fig. 4(*b*), then confirm the location of the receiver.

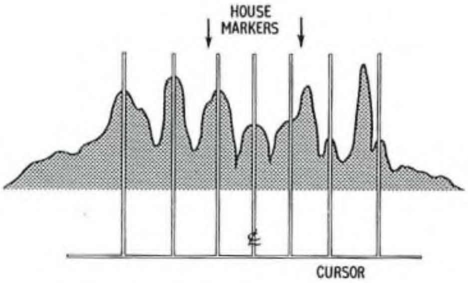
The second category is of multiple reflections. Again, by use of the graticule, it is possible to recognize the regular pattern due to the direct ray.

The Effect of the Complicated Radiation Pattern of a Television Receiver

As has already been mentioned, television receivers have complicated radiation patterns consisting of a number of maxima and minima. The resultant detector display may be distorted in amplitude in any number of different ways. The different attenuations of various parts of the building in which the television receiver is situated also cause distortion. A typical display which is affected in this way and which has also a number of reflections is shown in Fig. 5. At first sight,



Note: Responses due to reflection shown dotted
(*a*) Positions of maxima



(*b*) Appearance of the actual display with the cursor in position

FIG. 5—Typical effects of television radiation pattern, building attenuation and random reflections

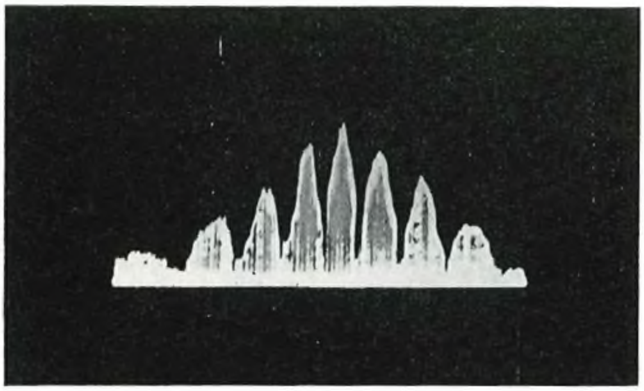
this display looks unintelligible, but the application of the graticule makes it possible to detect the regular shape of that part of the display due to the direct wave, and the location of the receiver, which is on the line indicated by the centre lobe, may be determined. Fig. 6 shows examples of displays taken in various locations.

Preliminary Detection of a Signal

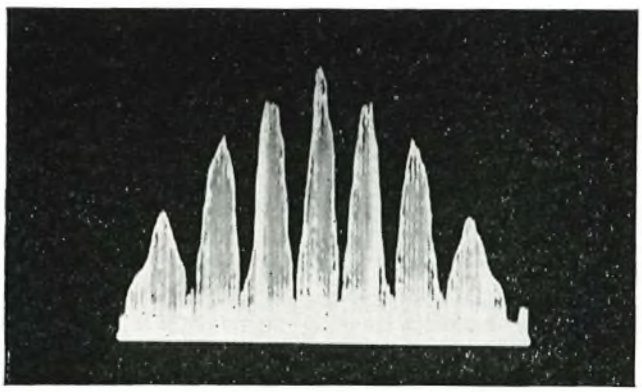
Because the main aerial has very sharp lobes and is not rotatable, it is not convenient to use it for the preliminary identifications of a signal. This is done by using an auxiliary aerial that consists of a pair of broadband dipoles mounted one on each side of a common reflector. By means of a switch, a comparison is made between the amplitude of the waves arriving at each dipole, and, by moving the vehicle a short distance, it is usually possible to distinguish the direct wave from a wave reflected from the building opposite. By this means it is normally possible to avoid making a confirmatory run past a dwelling to eliminate a signal that is due to a reflection.

DESCRIPTION OF THE NEW DETECTOR

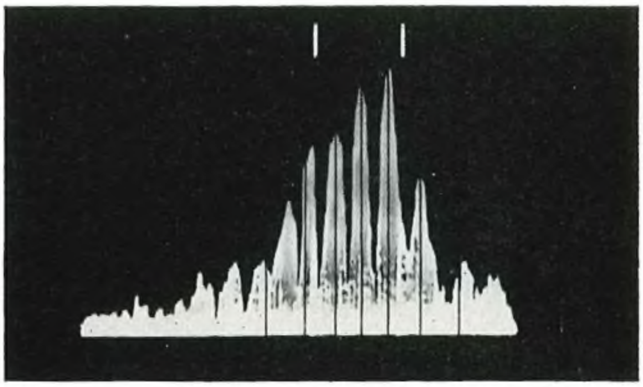
In designing the new detector the following major factors were taken into account.



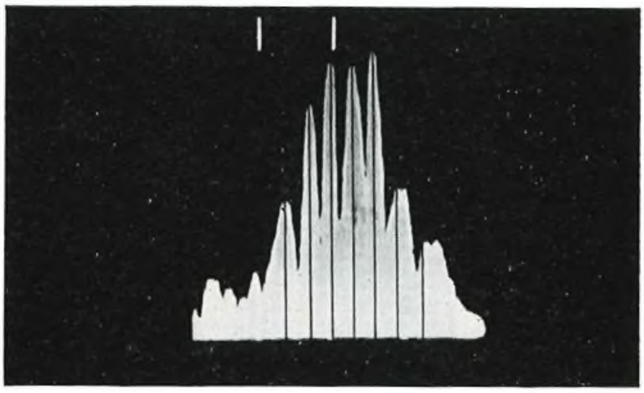
(*a*) A perfect display, range 25 ft.



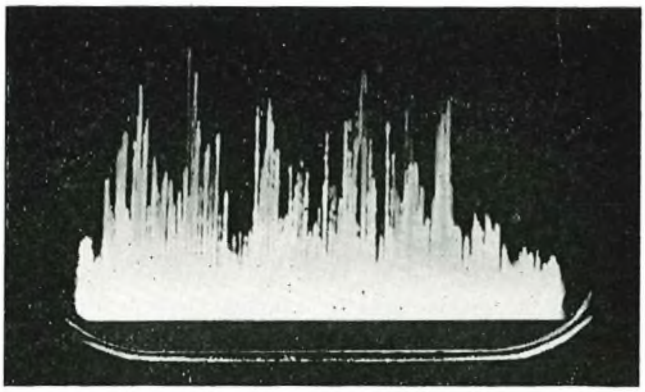
(*b*) A perfect display, range 75 ft.



(*c*) A confirmed detection at normal range in the presence of reflections



(*d*) The receiver is shown to be in an adjacent dwelling (the centre lobe is outside the house markers).



(*e*) A preliminary detection is shown to be due to a reflected wave (no recognizable pattern)

FIG. 6—Examples of typical displays photographed during field trials

(*a*) The television detector vehicle showing the aerials in the operating position

(*b*) A view of the interior of the vehicle showing the operating position

FIG. 7—The new television-detector vehicle

(*i*) The need to accommodate the large aerial system on the roof of the vehicle.

(*ii*) The necessity of mounting the aerial high enough to look over the rows of parked vehicles that are normally found on almost all suburban roads,

(*iii*) The provision of adequate seating space to accommodate press representatives for demonstrations,

(*iv*) The need to prevent condensation on side and rear windows in unfavourable conditions,

(*v*) The need to ensure a smooth take off and reasonably constant slow speed during detection runs,

(*vi*) The need for adequate engine cooling to prevent engine overheating when idling or slow running. This is important because, to prevent battery drain, the vehicle engine must be running when the equipment is in use.

(*vii*) The advantage of solid-state circuits in all parts of the equipment.

Fig. 7 shows the complete detector vehicle and its interior layout.

Aerial Array

Two of the log-periodic spiral aerials which had been developed for the earlier trial are used to give the radiation pattern described in Fig. 2.

The radiation pattern of each individual aerial is approximately proportional to $\cos^5 \theta$ in both the vertical and the horizontal planes. The aerials are circularly polarized and have an impedance of 140 ohms, a half-power beam width of 40°, a back-to-front ratio of 20–25 dB and a gain of 8–10 dB with respect to a linearly-polarized half-wavelength dipole. All the parameters are constant over the frequency range of 470–860 MHz.

When the two aerials are mounted a number of wavelengths apart in a broadside array, the single 40° main lobe that would be achieved by each aerial individually is broken up into a number of separate narrow closely-spaced lobes of the required pattern. To achieve the pattern shown in Fig. 2 over the required frequency range it is necessary to maintain a constant spacing of six wavelengths, and this is done by automatically varying the distance between the aerials as the receiver is tuned throughout the frequency range. A spacing of6ft was chosen as the maximum that could be accommodated on the roof of the vehicle for frequencies at the lower end of the range of frequencies of interest.

Each of the aerials is made by winding two elements consisting of ¼in × 0·005in copper tape on a truncated-cone former of polyurethane foam of nominal density 1·5lb/ft.[3] The formers, with spiral indentations for the conductors, are made from expanded polyurethane cast in a fibre-glass mould. The mould was made from a plug turned out of solid mahogany with shallow spiral indentations cut into its surface to take the copper tape. This type of construction provides strong lightweight aerials with parameters which vary very little from aerial to aerial. The tangent of the dielectric loss-angle and dielectric constant of the expanded polyurethane are such that the performance of the aerials are not sensibly degraded by the presence of the former. To prevent deterioration of performance by moisture and industrial grime the windings are protected by a thin spray of polyurethane varnish and a shrunk-on sleeve of thin black polythene.

An integral feeder in the centre of the former connects the nose end of each winding to a rear termination plate which forms the rear support for the aerial. The feeder is made up from the conductor and dielectric of a conventional semi-air-spaced coaxial cable, enclosed in a suitable copper tube. Two such tubes, soldered together lengthwise make a balanced coaxial pair. This pair is inserted into a fibre-glass tube which provides longitudinal rigidity for the completed aerial. P.T.F.E.* is used at the nose to provide the connexion block for the copper tapes and the feeder.

The aerial windings have a constant pitch-angle of 80°, and the expanded polyurethane former has a taper of 2°, giving a length of nearly 6ft, and front and rear diameters of 2¾in and 7½in, respectively.

Active baluns are used to match the balanced 140-ohm log-periodic aerials to the 75-ohm feeders. This enables the impedance transformation to be made with a small voltage gain. Each balun consists of two transistors in a long-tailed pair configuration followed by two common-emitter direct-coupled stages. An *RC* filter is used in the input to restrict the frequency range. Power is fed to the baluns from the receiver via the coaxial feeder.

Feeders and Associated Equipment

The unbalanced feeders from the main aerial array are brought together in a combining unit mounted on the roof plate of the vehicle, and one unbalanced feeder takes the combined signals through the roof to the receiver.

The forward aerial has a movement of approximately 6 λ, and to prevent tangling and wear on the feeder it is automatically wound and unwound on a cable drum which runs alongside the moving aerial-mounting. Correct tension in the feeder is maintained by a toothed rim on the drum, which runs in a matching rack on the vehicle roof-plate. A rotating joint in the centre of the drum obviates twisting of the cable.

To ensure correct phasing of the signals from the aerials at the receiver input, the feeder lengths from the aerials to the combining unit must be identical. This is ensured by including a balancing length of 75-ohm feeder between the rear aerial and the combining unit.

The auxiliary sensing broadband dipoles are constructed from sheet brass, and are mounted vertically on the centre of the roof of the vehicle, one on each side of a common reflector.

The Panoramic Receiver

The panoramic receiver (Fig. 8) is a solid-state triple-superheterodyne receiver with radio-frequency and first frequency-changing sections consisting of a commerical u.h.f. television tuner. The tuner used has a conversion gain of not less than 15 dB and a noise figure better than 7dB throughout the frequency range of 470–860 MHz. The first intermediate frequency is 33·5 MHz.

The tuner output is fed through a low-pass filter to two shaping amplifiers, with an 8 MHz pass band. A 50 Hz saw-tooth generator provides horizontal deflection for the visual display and varies the sweep-oscillator frequency by $\pm$ 4 MHz by acting on a varactor diode. The oscillator centre frequency is 46·5 MHz, giving a second intermediate frequency of 13 MHz. After further amplification the signal is converted to 1 MHz by a 14 MHz crystal-controlled oscillator and associated mixer. It is then amplified in the main i.f. strip, which has a bandwidth of 20 kHz. This narrow-band amplifier ensures good resolution and signal-to-noise ratio. The output signal is rectified and passed on to the vertical-deflection amplifier and thence to the cathode-ray tubes.

A manual gain control with a variation of 80dB is applied to the first i.f. stages, and a preset output-level control is provided at the rectifier output. Sweep-width variation from zero to 8 MHz is provided by a variable potentiometer on the output of the sweep amplifier. Two other facilities for maintenance purposes only are a centre-frequency adjustment and a crystal marker to enable the sweep to be centred on 33·5 MHz.

The performance of the receiver is such that the input for unity signal-to-noise ratio at the output is -10 dB relative to 1 μV, giving an overall sensitivity of the order of 2 μV/m.

Two visual displays are used. The first is the normal display of the panoramic receiver, which enables the operator to make the initial detection and to adjust the frequency and gain of the receiver to bring the wanted signal to the centre of the tube at the correct amplitude. The Y-plates of this tube are connected in parallel to the Y-plates of a second cathode-ray tube, which is used for recording the display. This second tube is mounted below the face of the operator's console so that a polaroid camera can be mounted without projecting dangerously above the console, and loading and unloading of the film is facilitated.

The X-deflection of the recording tube is obtained from a pulse generator that is driven by an additional vehicle-speedometer cable. A rotating toothed disk interrupts a light source, causing a phototransistor in a Schmitt-trigger circuit to produce pulses. These pulses are used to generate a staircase waveform which, after shaping and amplification, deflects the electron beam in the X-axis at a rate which is proportional to road speed. One excursion of the beam across the face of the tube is made when the vehicle travels 100 ft, and the time taken to produce a complete oscillogram is normally about 15 seconds. Automatic blanking of the trace eliminates the need for a shutter on the camera. Development time is 15–20 seconds.

* P.T.F.E.—Polytetrafluorethylene.

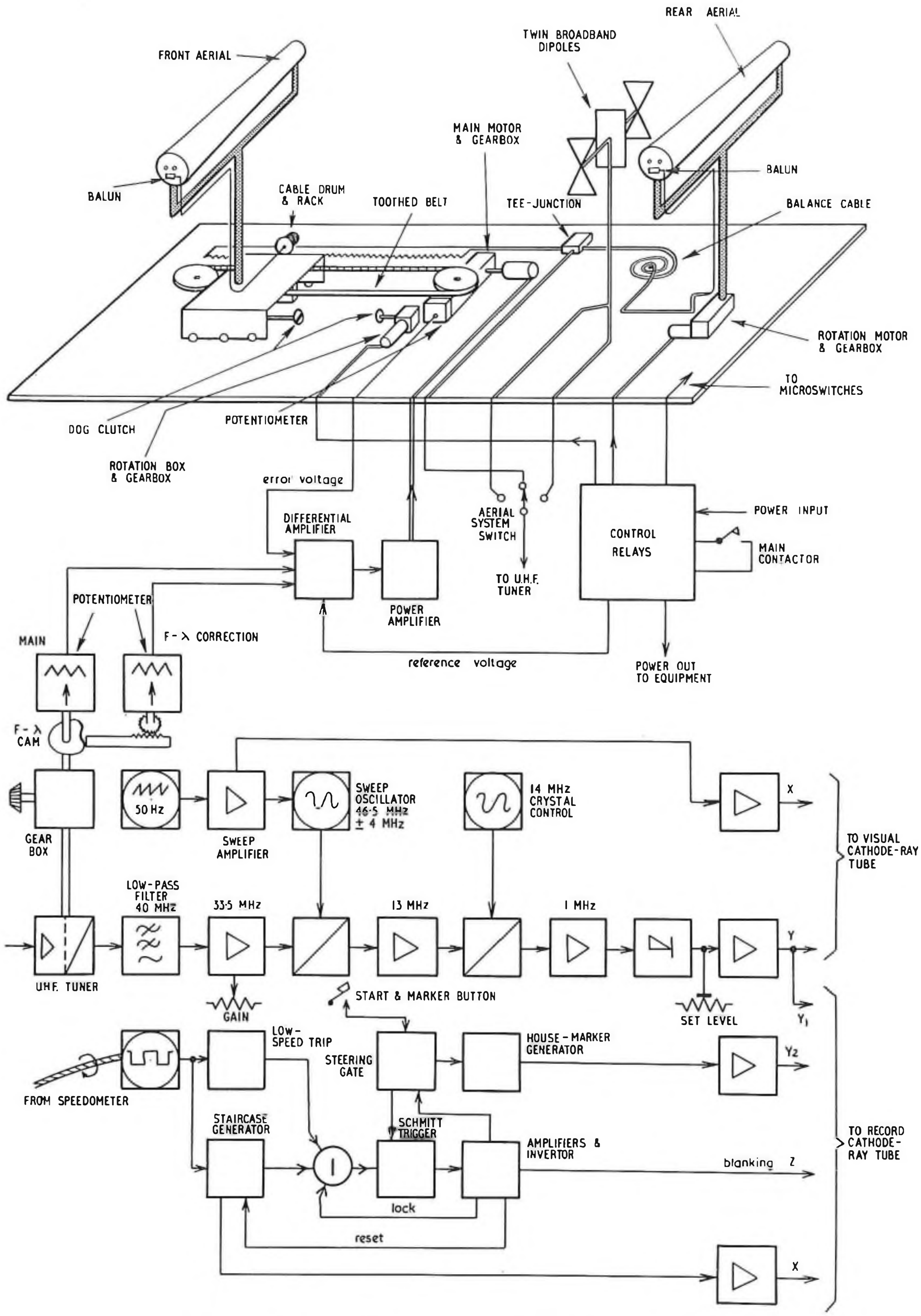


FIG. 8—Schematic layout of the mechanical and electrical systems of the detector

AERIAL MOVEMENT, CONTROL CIRCUITS, AND POWER

Aerial Movements

The aerial movements are arranged as shown in Fig. 8.

Two separate movements are required. When the vehicle is not on a detection run the aerials are parked in line along the centre of the roof. Prior to operation it is therefore necessary to rotate them to face either the near side or offside of the vehicle. Normally, detection is arranged to take place on the nearside of the vehicle but, in a one-way street, it may be necessary to work on the offside. The rotation of the aerials is carried out by two cam-and-microswitch-controlled d.c. shunt-wound motors via worm-and-wheel gears to ensure that the aerials are locked in position when the power is disconnected from the motors.

The second movement is the linear movement of the front aerial which is necessary to obtain the constant spacing of 6λ between the aerials. The front aerial is mounted on a light trolley, which moves on wheels on two Z-section rails. The trolley is fastened to an endless toothed-belt driven by a third d.c. shunt-wound motor.

Control Circuits

The positioning of the front aerial is controlled by a d.c. servo system. The u.h.f. tuner shaft is coupled directly to one potentiometer and via a shaped cam to a second potentiometer, which provides a correction voltage to convert from the straight-line frequency law of the tuner capacitor to the straight-line wavelength law required for the linear movement of the aerial. A third potentiometer is coupled to the main-motor gear-box to provide an error voltage. The three voltages are combined in a differential amplifier with a reference voltage from a Zener diode. The differential output is fed via two Schmitt-trigger circuits, which are included to prevent hunting, to switch a high-power transistor bridge. This controls the power fed to the d.c. motor, to drive the aerial in the required direction.

Operator's Controls and Display

The operator's controls are mounted on a display panel on a console. To connect power to the detector, the vehicle ignition must be switched on, and the aerial position switch must be at PARK. In this condition the main on/off switch in the ON position connects power to the equipment. When the on/off switch is set to OFF, power is not disconnected from the servo system until the aerials return to the parked position. In case of an emergency such as fire, an EMERGENCY OFF position on the switch is used to disconnect all power from the equipment. Pilot lamps and an aerial-position indicator are provided to let the operator see at a glance the position of the aerials.

The panoramic receiver has three controls: frequency setting with associated digital-logging display, gain, and sweep width. Brilliance, focus and beam-shift controls are provided for the cathode-ray tubes, and an aerial-control switch is fitted to select the main or either of the auxiliary sensing aerials.

Power

Power is provided by two heavy-duty 6-volt batteries in series. The batteries also provide for the normal electrical system of the vehicle and are charged by the vehicle alternator. A 230-volt 50 Hz supply obtained from a solid-state invertor is used to power the panoramic receiver and the power unit for the cathode-ray tube displays. Low-voltage supplies for the transistor circuits are obtained from the display power pack.

DETECTION VEHICLE

The equipment is installed in a modified 2500 Series, Commer general-service vehicle. A dummy roof houses the aerial-movement mechanism. To prevent water entering the dummy roof and being driven into the mechanism by the forward movement of the vehicle, the slot necessary to allow fore-and-aft movement of the front aerial is closed by a heavy-duty zip-fastened neoprene cover. Two sliders are used: one is mounted on the front of the aerial support, the other on the rear. The cover is thus opened in front of the aerial and closed behind it as the aerial moves. A purpose-built console in the body of the vehicle provides the operating position. Extra seats are fitted for use of passengers during demonstrations.

The inside and roof of the vehicles are lined with washable plastic to give a good appearance and reduce condensation. Hot air from an additional vehicle heater is ducted to the side windows to prevent misting and to the dummy roof to prevent the seizing which would occur if the moisture formed by condensation were allowed to freeze in low air temperatures. The exterior of the vehicle is pale blue in colour with red sign-writing, and the interior is 2-tone grey. The vehicle is fitted with automatic transmission in order to give smooth take off and slow speed during detection runs.

CONCLUSION

A new system of television detection has been designed, and a working prototype produced by the Post Office Radio Regulatory Division. The production models are being manufactured by a contractor. The equipment is of modular construction to facilitate fault finding and reduce out-of-service time by the replacement of faulty modules by spares. It is expected that the new transistor receivers will have a lower fault liability than the old thermionic-valve receivers.

The new detection equipment enables an accurate location of v.h.f. and u.h.f. television receivers to be made in the presence of reflections, and the sensitivity allows for the low levels of radiation from modern transistor tuners.

ACKNOWLEDGEMENT

Acknowledgement is made to Messrs. Vosper Ltd., Portsmouth, for the details of their improvements to the mechanical design of the aerial-movement mechanism and for their assistance in the design of the servo-mechanism.

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A Modem for the Datel 2400 Service—Datel Modem No. 7A

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U.D.C. 621.376.4:621.394.4

The Datel 2400 Service enables serial binary digital data signals to be transmitted over special-quality telephone-type circuits at a rate of 2,400 bits/s. The modem used for this new service employs 4-phase differential modulation, and semiconductor integrated circuits are used extensively for the control circuits as well as for the modulator and demodulator. The use of active filters contributes to economy of weight and size in a modem that offers very comprehensive data-transmission facilities.

INTRODUCTION

The Datel 2400 Service has recently been introduced by the British Post Office to replace the Datel 2000 Service, which provided point-to-point circuits suitable for data-transmission rates up to 2,400 bits/s.[1] The actual transmission rate that could be achieved on any particular circuit could not be guaranteed, however, because the overall performance was also dependent on the design of the modems used, and these modems were provided by the customer.

The new service, by using a Post Office modem—the Datel Modem No. 7A—in association with special-quality point-to-point circuits similar to those used for the Datel 2000 Service, provides a guaranteed synchronous transmission rate of 2,400 bits/s in each direction. In addition, a 75 bits/s asynchronous channel can also be derived in each direction of transmission, if required.

To provide a standby service in the event of interruption of the 4-wire circuit, the modem enables the customer to obtain 600 or 1,200 bits/s synchronous transmission over the public telephone-switching network, or over a 2-wire private circuit. This facility can be used to provide either half-duplex 600 or 1,200 bits/s transmission or to combine 600 or 1,200 bits/s transmission in one direction with 75 bits/s in the other.

Separate telephones are provided for association with the 4-wire private circuit and the exchange line. The telephone associated with the private circuit is of the local-battery type, and the modem provides a suitably-smoothed power supply for the transmitter.

A simplified functional block diagram of the modem is shown in Fig. 1.

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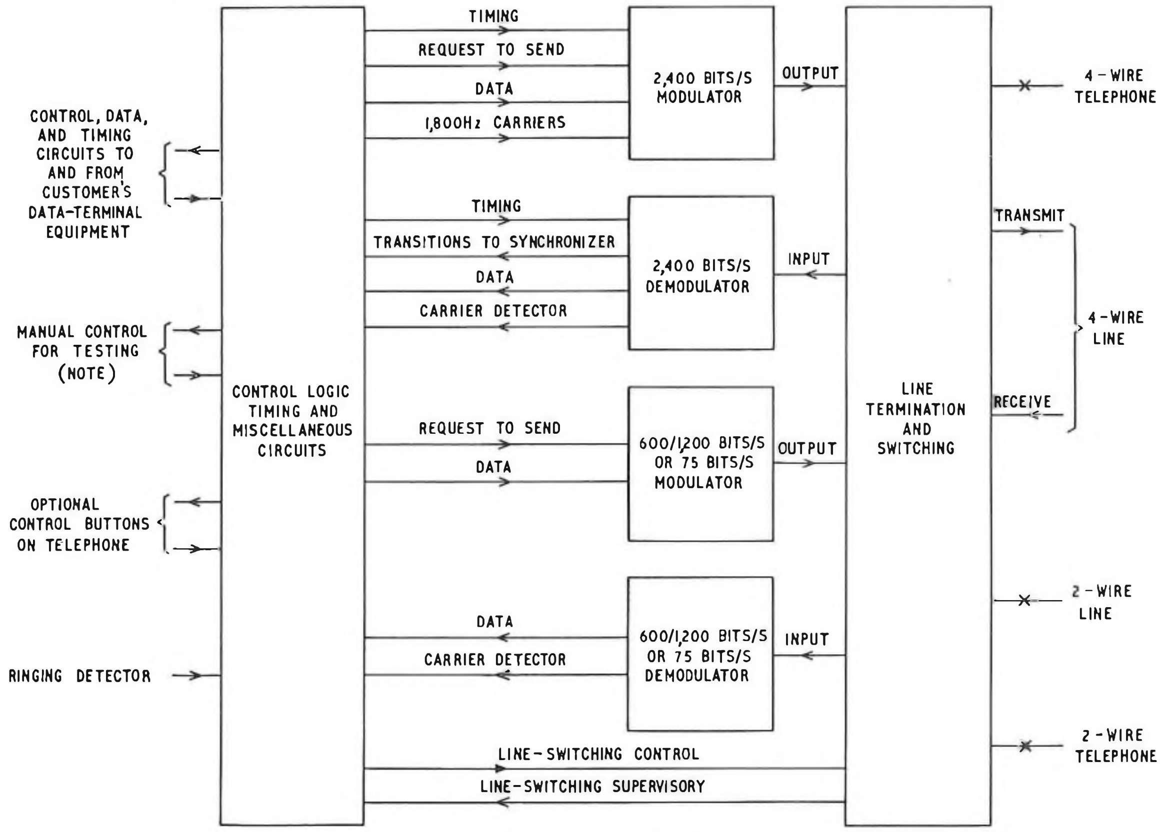


Note: Test key on rear of modem

FIG. 1—Simplified functional block diagram of Datel Modem No. 7A

Outline of 2,400 Bits/s Transmission System

The maximum rate of modulation in bauds and the serial binary transmission rate in bits/s practicable on a given transmission path are directly proportional to the bandwidth available.[2] The rate of information transmission in bits/s may, however, be increased by making each line-signal element represent one of, say, four conditions, providing that there is an adequate signal-to-noise ratio and that the loss/frequency and group-delay/frequency characteristics of the transmission path are carefully controlled.[3] With the Datel Modem No. 7A, the modulation rate is 1,200 bauds, but information is conveyed at a rate of 2,400 bits/s by making a pair of data-signal elements correspond to one of four possible phase shifts of the carrier (0°, −90°, −180° or −270°) every $\frac{1}{1,200}$ of a second (see Table 1).[4] This technique is known as 4-phase differential modulation, and results in a

TABLE 1
Line-Signal Phase Changes

Pair of Data-Signal Elements (dibit)	Phase Change
00	0°
10	−90°
11	−180°
01	−270°

double-sideband line signal. The carrier frequency must therefore be located in the centre of the available transmission band, which for a Post Office high-quality speech-band circuit is 1,800 Hz. The information is recovered at the receiver by comparing the phase of the carrier preceding the instant of modulation with that following it.

The nature of the 4-phase differential modulation technique used in the Modem No. 7A, in which pairs of data signal-elements are identified by phase changes of the carrier signal, requires that the transmission be synchronous, i.e. that both the modulator and demodulator must be controlled by timing signals in such a way that the individual data-signal elements can be correctly identified in the demodulation process.

The use of 4-wire private circuits for the Datel 2400 Service enables full duplex 2,400 bits/s transmission to be achieved.

Interconnexion with Data Terminal Equipment

The Modem No. 7A is controlled from the data-terminal equipment by d.c. interconnecting circuits, usually referred to as interchange circuits, that conform to the international standards for such circuits.[5] These interchange circuits include the data-signal transmission connexions as well as control and timing circuits, and the purpose and electrical characteristics of each circuit are closely defined.

GENERAL DESCRIPTION OF MODEM

The Datel Modem No. 7A is intended for desk mounting, and the external styling (Fig. 2) follows current Post Office practice for datel modems; the case has 2-tone grey finish. The modem is 17 in wide × 17 in deep × 13 in high, and this enables the case to contain two 62-type shelves (Fig. 3) accommodating plug-in modules on which the major functional units are mounted.

Extensive use is made in the control unit and in the 2,400 bits/s modulator and demodulator of both digital and linear semiconductor integrated circuits. The 2,400 bits/s modulator and demodulator also incorporate active filters, which allow savings in weight and volume by avoiding the use of coils.

The modem operates from a.c. mains supplies, and the power unit provides d.c. supplies at +12, −12, +24 and +5 volts and also an isolated 5-volt, 50 mA quiet supply for powering the telephone transmitter associated with the private circuit. Further d.c. supplies of +6, −6, +7·5 and −7·5 volts are derived in the control unit by means of Zener diodes.

FOUR-PHASE DIFFERENTIAL 2400 BITS/S MODULATOR

A 4-phase differentially-modulated signal may be produced by the quadrature-channel technique, which is illustrated by the phasor diagrams of Fig. 4. Two double-sideband suppressed-carrier amplitude modulators are used. A bipolar constant-amplitude modulation signal applied to either of these modulators will effect multiplication of the carrier by either +1 or −1, thus producing an output which has the carrier frequency in one or other of two phases 180° apart. The 1,800 Hz carriers supplied to the two modulators in the Modem No. 7A are in phase quadrature, and, therefore, the possible output phases of the P and Q channel modulators will be as shown in Fig. 4(*a*) and (*b*). Since the P and Q channel modulator outputs have the phase relationship described and have the same amplitude, they may be added together to form a line signal having one of four phases spaced by 90°, as shown in Fig. 4(*c*).

The arrangement of the circuits is shown in block form in Fig. 5. It is required that the data should be encoded into line-signal phase changes, as shown in Table 1. Consideration of Fig. 4(*c*) shows that −90° phase shift of line signal is achieved by reversing the phase of whichever channel has leading phase. Thus, for example, if the existing line signal is in phase $P^- Q^+$, i.e. when the P channel is leading the

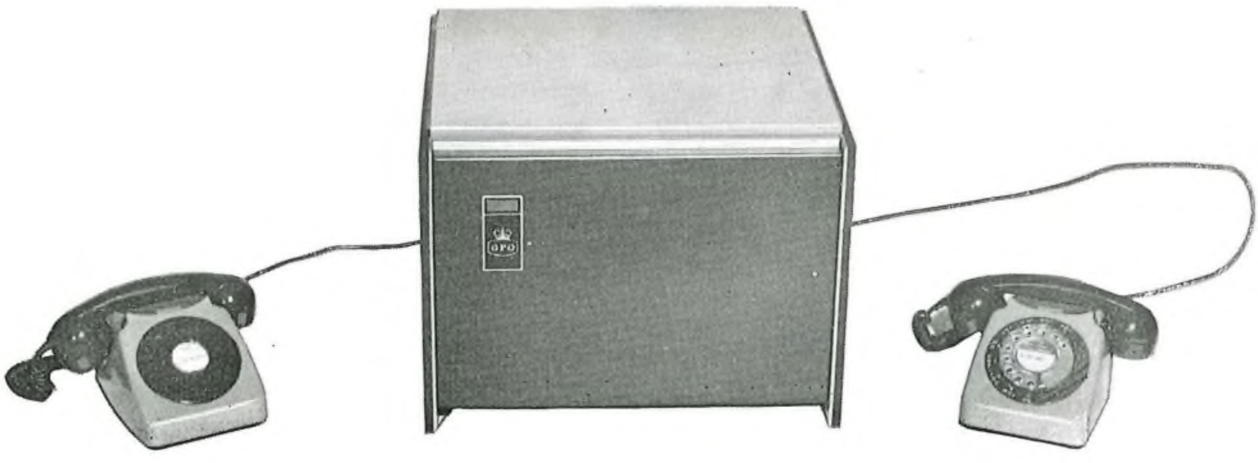
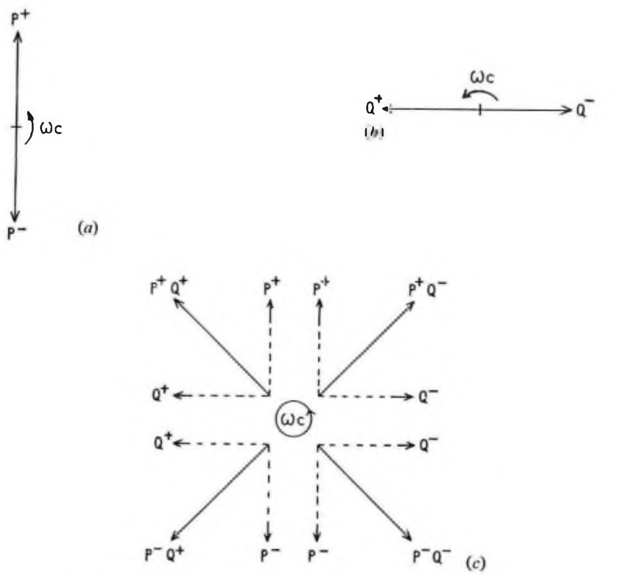


FIG. 2—Datel Modem No. 7A

FIG. 3—Datel Modem No. 7A with cover removed



(a) P-channel outputs
(b) Q-channel outputs
(c) Four phases obtained by phasor addition of P and Q outputs

FIG. 4—Phasor diagrams of quadrature channel technique for 4-phase differential modulation

Q, a −90° phase shift requires a change to phase P+ Q+. This is brought about by reversing the polarity of the modulation input to the P (leading) channel modulator. Similarly, a −180° phase change is made by reversing the phase of both channels, and a −270° one by reversing the phase of the lagging channel. The coding logic, therefore, has the function of examining each pair of consecutive bits (dibits) in the data stream to be transmitted, determining the phase shift required and making the appropriate polarity changes on the inputs to the P and Q modulators. These polarity changes depend both on the dibit to be transmitted and on the existing state of the P and Q channels. They are produced by a set of gates that compare the dibit information held in a 2-stage shift-register clocked at the bit rate, with the channel-state information held in a pair of bistable circuits clocked at the dibit rate.

The encoding process described above makes it necessary for the system to be operated synchronously. So that each dibit may be determined, the encoder must have foreknowledge of the sampling instants for inspecting the 2,400 bits/s data stream to be transmitted. The transitions of the data signal are aligned in the data-terminal equipment with the positive-going edges of the transmitter signal-element timing waveform, as shown in Fig. 6, so that the negative-going edges of the timing occur at the mid-points of the data-signal elements, that is, at the sampling instants in question. The transmitter signal-element timing is in fact used to clock the 2-stage shift-register into which the transmitted data stream is fed, and the dibits are determined by the inspection of this shift register.

The P and Q channel modulation signals are passed from the encoding logic through level-clamping circuits which ensure that the modulator outputs both have the same amplitude in order to produce the correct 4-phase signal. The inputs to the modulators are passed through low-pass filters, whose outputs are attenuated by 3 dB relative to the passband at 900 Hz. These filters suppress unwanted harmonics, thus preventing modulation foldover* and the transmission of extraneous sidebands to line. The modulator outputs are summed across a potentiometer and then passed through a gating circuit operated from the REQUEST TO SEND control logic; this enables the line signal to be suppressed when the REQUEST TO SEND circuit is turned off. An output amplifier and low-pass line filter with a 3 dB point at 3,000 Hz complete the 2,400 bits/s modulator.

A mathematical treatment of the modulation process is

* Modulation foldover—the effect produced by a lower sideband that deviates from the carrier frequency by an amount greater than the carrier frequency, producing a virtual negative frequency that appears in antiphase as an interfering signal.

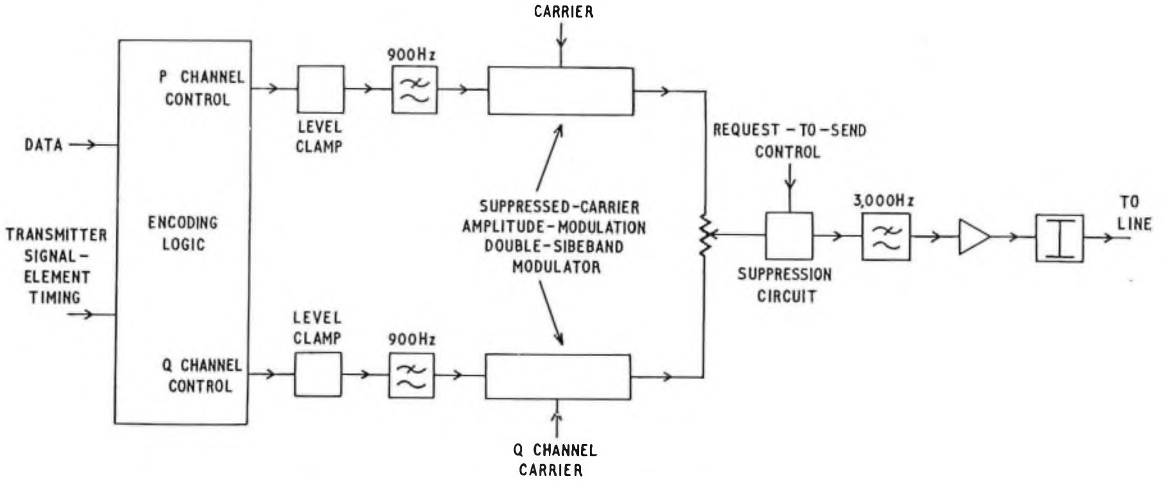


FIG. 5—Block schematic diagram of 4-phase differential modulator

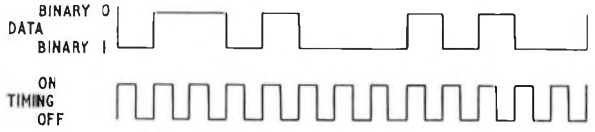
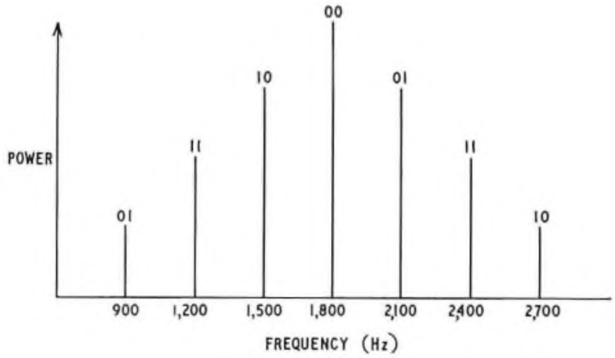
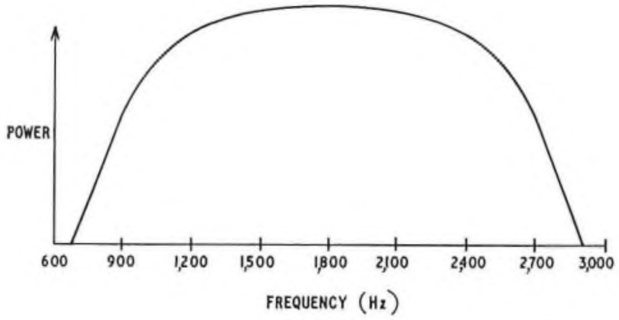


FIG. 6—Alignment of data and timing waveforms



(*a*) Continuous repetitive dibits



(*b*) Random modulation

FIG. 7—Frequency spectra of 2,400 bits/s line signal

contained in Appendix 1. When a 0° phase change is made, the line signal consists only of an 1,800 Hz tone, but when continuous −90°, −180° or −270° phase changes are made, two frequency components are transmitted to line. The two frequency components are necessary so that, by using an intermodulation process, the 1,800 Hz carrier may be recovered at the demodulator for use in the detectors. The frequency spectra of the line signal for continuous repetitive dibits and also for random modulation are shown in Fig. 7.

2,400 BITS/S DEMODULATOR

The 2,400 bits/s demodulator circuit arrangements are shown in block form in Fig. 8. While operating in a converse manner to the modulator, to which it is very similar, it also includes circuits for the automatic control of input level and for carrier recovery.

The principle of demodulation is that of coherent detection. As shown in Appendix 2, it is possible, by processes of intermodulation of the line signal and selective filtering, to obtain a component of four times the carrier frequency which is phase-invariant no matter which of the four possible phase changes is received. This phase-invariant signal may be divided down to the carrier frequency, yielding a local carrier which, although it may be arbitrarily in one of four absolute phases, is coherent with the line signal in that it is always some odd multiple of 45° out of phase with the line signal. Thus, for example, referring again to Fig. 4, if the line signal has one of the four phases shown in (*c*), the recovered carrier will have one of the four phases shown in (*a*) or (*b*), and it is a completely arbitrary matter which of them it is. A 90° phase-shifting circuit is used to obtain a quadrature recovered carrier so that, if, for example, the main one has phase P^+, the quadrature one will have phase Q^+. These two recovered carriers are used to demodulate the line signal in a manner exactly converse to the operation of the modulator. The baseband demodulator outputs are then decoded in the opposite way to which they were encoded in the modulator.

Considering the demodulator circuits in more detail, the incoming signal, after filtering and amplification, is fed to the carrier-detector circuit and to an automatic gain control (a.g.c.) amplifier, which provides constant input level to the detectors and the carrier-recovery circuit within a range of received line signal from +1 dBm to −49 dBm. A feature of the a.g.c. is that, in order to cater for operation on polling systems in which a relatively high-level input signal may be quickly followed by a relatively low-level one from a different source that might otherwise be blocked due to the a.g.c. response time, the gain is reset to maximum whenever the carrier detector switches off. The carrier-recovery system, described in principle above and analysed in Appendix 2, consists first of all of a full-wave rectifier which generates first-order intermodulation products of the line signal. This is followed by an amplifier and a low-Q resonant circuit that rejects components outside the range 3·0–4·2 kHz. Second-order intermodulation products are generated by a second full-wave rectifier, the output of which is coupled into a high-Q 7·2 kHz resonant circuit which selects the phase-invariant component of four times the carrier frequency. The quadrature recovered carriers are then derived from this by conventional frequency-dividing circuits.

The a.g.c. amplifier output is also fed to the two detectors, which are very similar to the P and Q channel modulators that generate the line signal. The baseband (or data-signal) outputs of these detectors are filtered in low-pass filters identical with those in the modulator. The filter outputs are squared in linear integrated-circuit differential amplifiers and

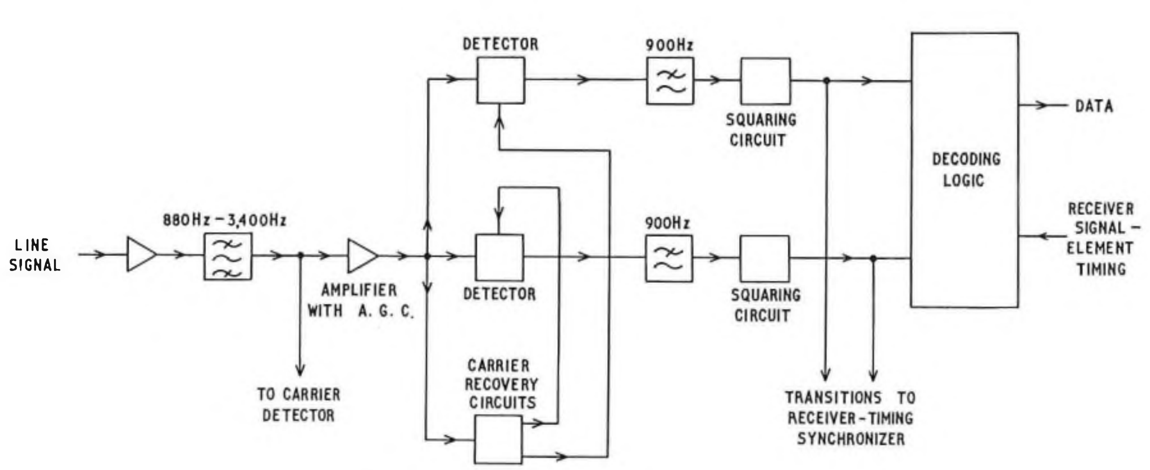


FIG. 8—Block schematic diagram of 2,400 bits/s demodulator

then passed as unregenerated digital baseband signals to the decoder and to the synchronizer in the control unit. The decoder is clocked by receiver timing which is aligned with the transitions of the unregenerated digital baseband signals, as described later in the section on the timing system. The decoder, which performs precisely the converse function of the encoder, compares the binary states of the detector outputs during one signal-element period with those in the next period by inspecting the states of the 2-stage shift register associated with each detector output. These shift-registers are clocked at the dibit rate. The decisions of the inspecting gates are used to set up the states of the output shift register, which is clocked at the bit rate and whose end product is the 2,400 bits/second received data stream.

TIMING

A block diagram of the timing system is shown in Fig. 9, and Fig. 10 shows most of the timing-system integrated-circuit logic mounted on printed-circuit boards in one of the control-unit modules.

The common section of the timing system contains a crystal-controlled oscillator driving a number of frequency-divider stages that produce various input frequencies for the timing-rate selection circuits and also the 1·8 kHz quadrature carrier frequencies for the 2,400 bits/s modulator. The timing-rate selection is controlled by the conditions on the SELECT STANDBY and SIGNALLING RATE SELECTOR interchange circuits so that when the SELECT STANDBY circuit is OFF, a frequency of 230·4 kHz (i.e. 96 × 2,400 Hz) is fed out to the transmitter and receiver timing sections, and when SELECT STANDBY is ON, the frequency is either 115·2 kHz (i.e. 96 × 1,200 Hz) for SIGNALLING RATE SELECTOR ON or 57·6 kHz (i.e. 96 × 600 Hz) for SIGNALLING RATE SELECTOR OFF. Timing rates corresponding to 3,600 and 1,800 bits/s operation (345·6 kHz and 172·8 kHz, respectively) are also provided for experimental purposes.

The transmitter timing may be derived either from the common timing section via divide-by-96 circuits, or from an external source (the customer's data-terminal equipment) or from the receiver timing.

The receiver timing is always derived from the common timing, but must be aligned or synchronized with the transitions of the incoming line signal. Each zero-crossing of the baseband data signals received from the demodulator causes

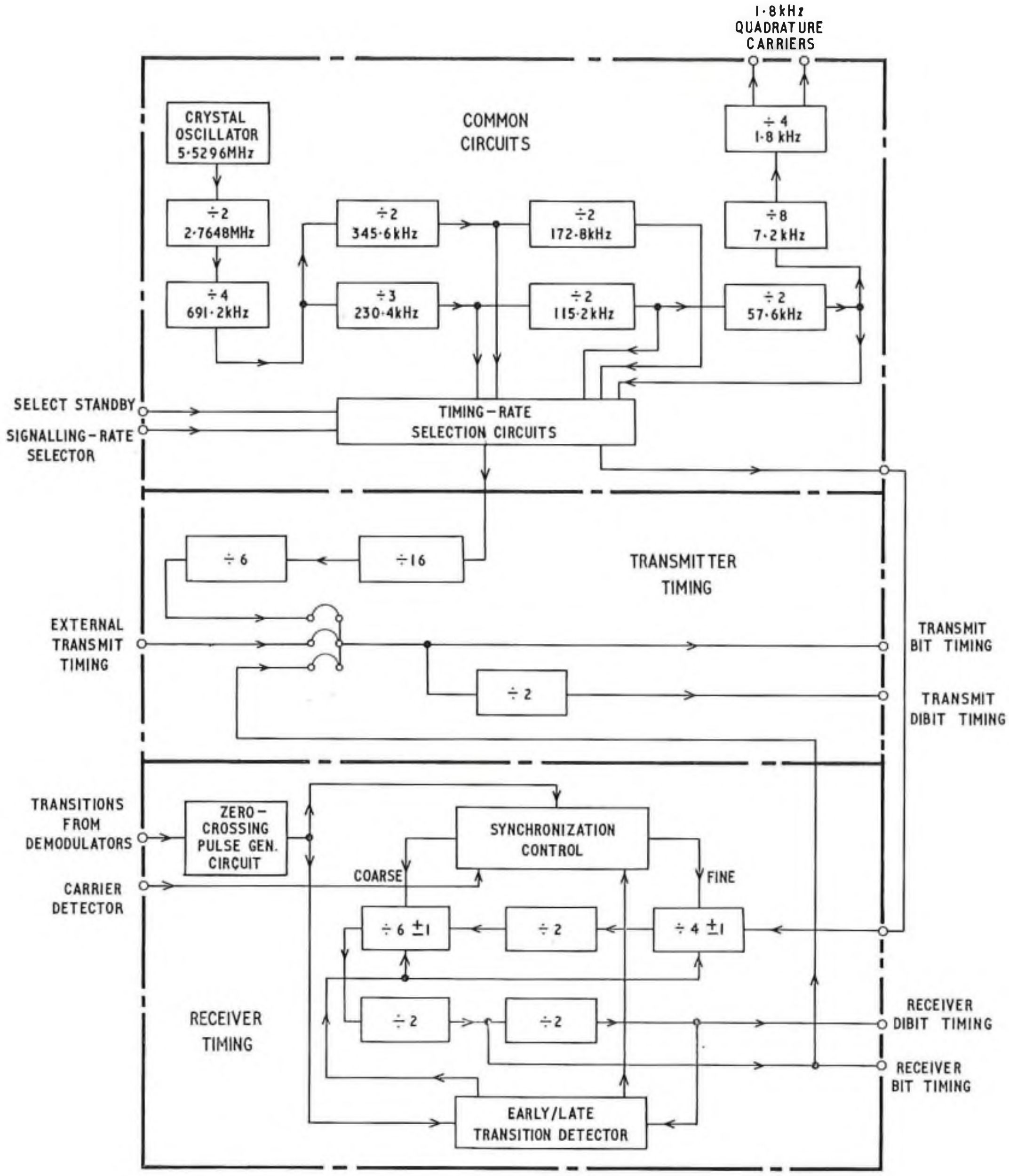


FIG. 9—Block schematic diagram of timing system

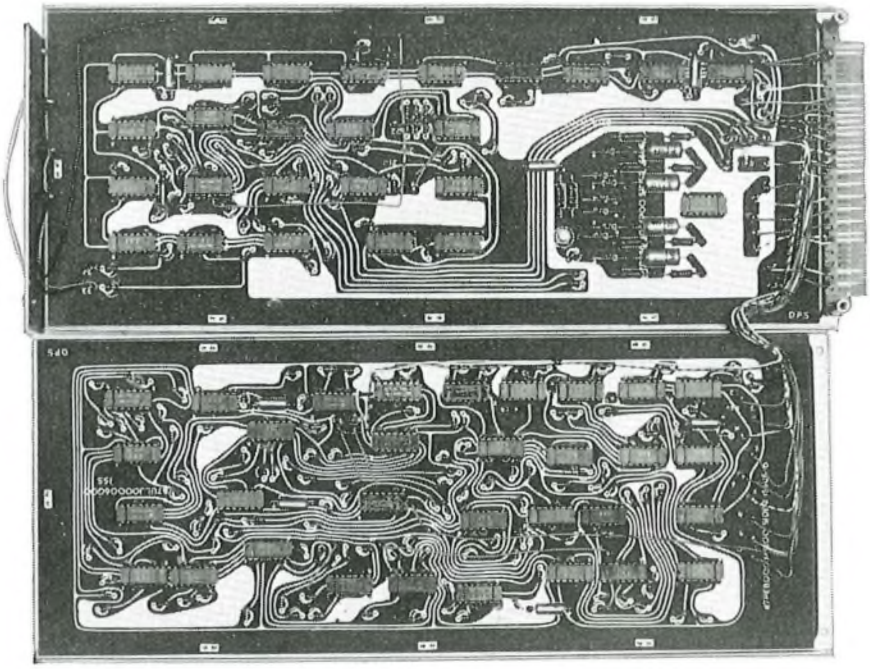


FIG.10—Timing-system integrated-circuit logic mounted on printed-circuit boards

a pulse to be generated in the receiver-timing unit, and the phase of the receiver-timing signal is then compared with this. Depending on whether the receiver-timing transitions are found to be late or early with respect to the zero-crossing pulse, the phase of the receiver timing is then advanced or retarded by one step. The following considerations determine the size of this step. If it is relatively large, the time to attain synchronism after switch-on is minimized, but the jitter produced by the phase-stepping, which appears as telegraph distortion of the received data output, is quite considerable. Conversely, small phase-correction steps will result in minimal distortion of the received-data output, but the initial synchronizing time will be relatively long.

In order to keep both the synchronizing time and the received data distortion within acceptable limits, a coarse/fine synchronizing system has been adopted for the Datel Modem No. 7A. When the incoming carrier signal is detected at the demodulator, phase-correction steps, equal to 4 per cent of a line signal-element, are taken for each baseband zero-crossing pulse until three consecutive phase comparisons show that the transitions of the receiver timing are within ± 8 per cent of a line-signal element of correct alignment with the baseband zero-crossings. The size of the phase-correction steps is then reduced to $\frac{1}{2}$ per cent of a line-signal element to minimize distortion of the received data output.

ANCILLARY MODULATORS AND DEMODULATORS

The modulators and demodulators used for the 75 bits/s channel and for the 600 or 1,200 bits/s standby circuit are similar to those used for the Datel 600 Service.[6] In the Datel Modem No. 7A, however, the 600 or 1,200 bits/s channel operates synchronously, so that it can be used in a similar manner to the 2,400 bits/s channel. The timing circuits are those already described in the previous section.

INTERCHANGE CIRCUITS

As already mentioned, the Datel Modem No. 7A is controlled by the customer's data-terminal equipment via interchange circuits conforming to internationally agreed recommendations. The functions of these circuits have already been described. For the Modem No. 7A, however, the following four additional circuits are employed.

(*i*) The SELECT STANDBY circuit enables the data-terminal equipment to select the use of 600 or 1,200 bits/s data transmission channels on a 2-wire line as an alternative to the 2,400 bits/s transmission on a 4-wire line. It selects the modulator and demodulator to be used, the line-switching relay to be controlled and the rate of operation of the timing circuits.

(*ii*) The STANDBY INDICATOR circuit indicates to the customer's data-terminal equipment that the modem has been switched to the 2-wire line.

(*iii*) The TRANSMITTER SIGNAL-ELEMENT TIMING circuit is used to clock the transmitted data into the synchronously-operated modulator. Either the modem or the customer's data-terminal equipment may originate the signals on this circuit. These signals are periodic square waves of frequency 2,400, 1,200 or 600 Hz, depending on the transmission rate of the data channel in use. The transitions of the waveform on the transmitted-data interchange circuit occur simultaneously with the positive-going transitions of the waveform on the transmitter signal-element timing interchange circuit, so that the negative-going transitions on the latter circuit define to the modulator the optimum sampling points for the data on the former circuit.

(*iv*) RECEIVER SIGNAL-ELEMENT TIMING. Signals on this circuit are derived in the modem from a local clock which is aligned to the transitions of the incoming-data signal. The waveform bears a relation to the received data which is similar to the relationship between the transmitter signal-element timing and the transmitted data. The receiver signal-element timing is used in the customer's data-terminal equipment to clock in the received data.

The interchange circuits employ nominal ± 6-volt signals. The $+6$-volt signals have the significance of ON or binary 0, and the -6-volt signals signify OFF or binary 1. The circuits accepting signals from the customer's data-terminal equipment are, however, designed to operate satisfactorily over the ranges $+3$ to $+25$ volts and -3 to -25 volts. Digital integrated circuits are used extensively in the control unit, and these operate at logic levels of 0 volts for binary 0 and $+5$ volts for binary 1. Voltage level-changing circuits are, therefore, necessary between the control-unit logic and the interchange circuits and, also, wherever the control unit is linked to other units which employ different voltage levels, such as the modulators, demodulators and the ringing-detector. As an example, the ringing-detector circuit is shown in Fig. 11. Whenever this circuit detects ringing current in the bell circuit of the telephone, it presents an output of +5 volts d.c. to the control-unit logic. The output is 0 volts when no ringing current is present.

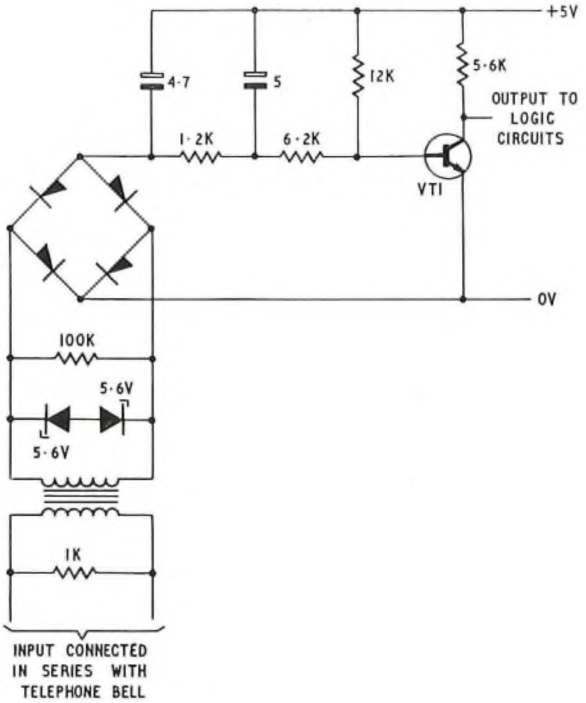


FIG. 11—Ringing-detector circuit

LINE CONTROL

The 4-wire and 2-wire lines are switched between their associated telephones and the modem by relays that are operated by outputs from integrated circuit logic. The inputs to this logic are, firstly, the SELECT STANDBY interchange circuit, which determines whether the 4-wire line relay or the 2-wire line relay is to be operated, and, secondly, the line-switching control, which may be any one of the following.

(*a*) CONNECT DATA SET TO LINE working, controlled entirely from the data-terminal equipment. In this mode, an ON condition on the CONNECT DATA SET TO LINE interchange circuit causes the appropriate relay to switch the modem to line. The relay is released by an OFF condition on the same interchange circuit.

(*b*) CONNECT DATA SET TO LINE working, controlled from a button on the telephone. When the button is locked down, an 0-volt condition is applied to the logic and the 4-wire or 2-wire line-switching relay operates. When the button is released, the line is switched back to the telephone.

(*c*) DATA TERMINAL READY working. The data-terminal equipment applies an ON condition to the DATA TERMINAL READY interchange circuit whenever it is ready to receive or transmit data. Nothing happens until either a non-locking button on the telephone is momentarily operated or, if the SELECT STANDBY interchange circuit is ON to condition the modem to work on the 2-wire line, the ringing-detector circuit operates. Then the modem is switched to line, and stays so until the lock-up logic circuit is released by an OFF condition on the DATA TERMINAL READY interchange circuit.

REMOTE TESTING

Simply-operated test facilities are incorporated in the modem so that a go/no-go test of the modulators and demodulators may be made from a remote location (e.g. a Post Office datel test centre) over the public telephone-switching network. The test circuits are divided into two sections, known as Test A and Test B. The Test A circuits are used for checking the modulator and demodulator normally associated with the 4-wire line, and the Test B circuits for checking the modulator and demodulator normally associated with the 2-wire line.

When the interface connector is unplugged, access is obtained to a 1000-type double-throw miniature lever key. If this is operated to the TEST A position, the appropriate modulator and demodulator are connected to the 2-wire line through a hybrid transformer, and the demodulator data output is connected to the modulator input. If a 2,400 bits/s modulator and demodulator are both fitted, there is an inversion of data between the demodulator and the modulator, and an oscillation is set up by feedback of the modulator output through the hybrid transformer back to the demodulator. This oscillation may be monitored over the line from the test centre. If a 75 bits/s return-channel modulator or demodulator is fitted, signals are sent out from and returned to the test centre, passing from demodulator to modulator without inversion. When the key is operated to the TEST B position, similar connexions are made to the modulator and demodulator normally associated with the 2-wire line. If a 600/1,200 bits/s modulator and demodulator are fitted, an oscillation is set up by hybrid feedback and inversion, as in the case of the 2,400 bits/s modulator and demodulator.

PERFORMANCE

The 2,400 bits/s channel of the Datel Modem No. 7A has back-to-back performance of better than 1 error in 10^5 bits at a signal-to-noise ratio of 13 dB for 3 kHz-band-limited uniform-spectrum random noise. Initial experience with the modem has shown that it performs very satisfactorily at 2,400 bits/s on special-quality private circuits.

CONCLUSIONS

The Datel Modem No. 7A is a valuable addition to the range of Post Office datel equipment in that it doubles the maximum rate of data transmission available with Post Office modems. It will enable much more efficient use to be made of private circuits and a much wider range of terminal equipments, especially computer peripheral apparatus, to be connected.

ACKNOWLEDGEMENT

The Datel Modem No. 7A was developed to a British Post Office specification by the Integrated Electronic Systems Division of Standard Telephones and Cables, Ltd.

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APPENDIX 1

Line Signals Obtained by 4-phase Differential Modulation Using Phase Shifts $-n\pi/2$ where $n = 0, 1, 2$ or 3

Referring to the description of the 2,400 bits/s modulator and to Fig. 4, −90° and −270° phase shifts are obtained by changing the polarity of the input to one modulator or the other. For continuous −90° or −270° phase shifts, the carriers are modulated alternately, so that the inputs to the modulators are 300 Hz signals in phase quadrature, each channel being modulated every 1/600 s. The baseband filters will pass the 300 Hz fundamental and the third harmonic. For continuous $-180°$ phase shifts, both channels are modulated simultaneously every 1/1200 s and thus the inputs to the modulators are 600 Hz signals. The baseband filter passes only the 600 Hz fundamental.

Carrier amplitude $= A_c$,
Carrier frequency $= \omega_c$,
Lagging carrier P $= A_c \sin(\omega_c t - \pi/4)$,
Leading carrier Q $= A_c \sin(\omega_c t + \pi/4)$,
Modulation amplitude $= A_m$, and
Modulation frequency $= \omega_m$.

The line signal frequencies can then be derived as follows.

Continuous −90° Phase Shifts

P modulator output $= A_c \sin(\omega_c t - \pi/4)\,[A_m \sin \omega_m t + \frac{A_m}{3}\sin 3\omega_m t]$

Q modulator output $= A_c \sin(\omega_c t + \pi/4)[A_m \sin(\omega_m t + \pi/2) + \frac{A_m}{3}\sin(3\omega_m t - \pi/2)]$

Line signal = P modulator output + Q modulator output,

$$= A_c A_m \cos[(\omega_c - \omega_m)t - \pi/4)] - \frac{A_c A_m}{3}\cos[(\omega_c + 3\omega_m)t - \pi/4]$$

Since $\omega_c = 1{,}800$ Hz and $\omega_m = 300$ Hz, the line frequencies are 1,500 Hz and 2,700 Hz.

Continuous −180° Phase Shifts

P modulator output $= A_c \sin(\omega_c t - \pi/4)\, A_m \sin \omega_m t$
Q modulator output $= A_c \sin(\omega_c t + \pi/4)\, A_m \sin(\omega_m t + \pi)$
Line signal = P modulator output + Q modulator output,

$$= \frac{A_c A_m}{\sqrt{2}}\cos[(\omega_c - \omega_m)t - \pi/2] + \frac{A_c A_m}{\sqrt{2}}\cos[(\omega_c + \omega_m)t + \pi/2]$$

Since $\omega_c = 1{,}800$ Hz and $\omega_m = 600$ Hz, the line frequencies are 1,200 Hz and 2,400 Hz.

Continuous −270° Phase shifts

P modulator output $= A_c \sin(\omega_c t - \pi/4)[A_m \sin \omega_m t + \frac{A_m}{3}\sin 3\omega_m t]$

Q modulator output $= A_c \sin(\omega_c t + \pi/4)\,[A_m \sin(\omega_m t - \pi/2) + \frac{A_m}{3}\sin(3\omega_m t + \pi/2)]$

Line signal = P modulator output + Q modulator output,

$$= A_c A_m \cos[(\omega_c + \omega_m)t + 3\pi/4] + \frac{A_c A_m}{3}\cos[(\omega_c - 3\omega_m)t - \pi/4]$$

Since $\omega_c = 1{,}800$ Hz and $\omega_m = 300$ Hz, then line frequencies are 2,100 Hz and 900 Hz.

APPENDIX 2

Carrier Recovery

For list of symbols see Appendix 1.

Continuous −90° Phase Shifts

The line signal $= A_c A_m \cos[(\omega_c - \omega_m)t - \pi/4] - \frac{A_c A_m}{3}\cos[(\omega_c + 3\omega_m)t - \pi/4]$

The first-order intermodulation products = [line signal]^2

$$= A_c^2 A_m^2 \{\tfrac{1}{2} + \tfrac{1}{2}\cos[(2\omega_c - 2\,\omega_m)t - \pi/2] + \tfrac{1}{18} + \tfrac{1}{18}\cos[(2\omega_c + 6\omega_m) - \pi/2] - \tfrac{1}{3}\cos[(2\omega_c + 2\omega_m)t - \pi/2] - \tfrac{1}{3}\cos 4\omega_m t\}$$

The low-Q resonant circuit eliminates components outside the band 3·0–4·2 kHz. $\omega_c = 1{,}800$ Hz and $\omega_m = 300$ Hz, therefore the input to the second rectifier is

$$A_c^2 A_m^2 \{\tfrac{1}{2}\cos[(2\omega_c - 2\omega_m)t - \pi/2] - \tfrac{1}{3}\cos[(2\omega_c + 2\omega_m)t - \pi/2]\}$$

The second-order intermodulation products = [input to second rectifier]^2

$$= A_c^4 A_m^4 \{\tfrac{1}{8} + \tfrac{1}{8}\cos[(4\omega_c - 4\omega_m)t - \pi] - \tfrac{1}{18} - \tfrac{1}{18}\cos[(4\omega_c + 4\omega_m)t - \pi] + \tfrac{1}{6}\cos 4\omega_c t - \tfrac{1}{6}\cos 4\omega_m t\}$$

The 7·2 kHz high-Q resonant circuit selects the component $4\omega_c$.

Continuous −180° Phase Shifts

The line signal $= \frac{A_c A_m}{\sqrt{2}}\cos[(\omega_c - \omega_m)t - \pi/2] + \frac{A_c A_m}{\sqrt{2}}\cos[(\omega_c + \omega_m)t + \pi/2]$

First-order intermodulation products = [line signal]^2

$$= \frac{A_c^2 A_m^2}{2}\{\tfrac{1}{2} + \tfrac{1}{2}\cos[(2\omega_c - 2\omega_m)t - \pi] + \tfrac{1}{2} + \tfrac{1}{2}\cos[(2\omega_c + 2\omega_m)t + \pi] + \cos 2\omega_c t + \cos[2\omega_m t + \pi]\}$$

Low-Q resonant circuit eliminates components outside the band 3·0–4·2 kHz. $\omega_c = 1{,}800$ Hz and $\omega_m = 600$ Hz, therefore the input to the second rectifier is $\frac{A_c^2 A_m^2}{2}\cos 2\omega_c t$.

The second-order intermodulation products = [input to second rectifier]^2

$$= \frac{A_c^4 A_m^4}{8}(1 + \cos 4\,\omega_c t)$$

The 7·2 kHz high-Q resonant circuit selects the component $4\,\omega_c$.

Continuous −270° Phase Shifts

The calculation, using the expression for the line signal derived in Appendix 1, is similar to that for the −90° and −180° phase shifts.

Send-Terminal Equipment and Receivers for V.H.F. Closed-Circuit Television

P. W. LINES, C.ENG., M.I.E.E.†

U.D.C. 621.397.9:621.396.62.029.6

The introduction of educational television as a service offered by the Post Office has necessitated the development of a range of equipment suitable for providing such a service. This article describes the send-terminal equipment and some features of the television receivers that are used in association with the Coaxial Distribution System 140/1. It is complementary to earlier articles in recent issues of the Journal.

INTRODUCTION

Closed-circuit television networks are being increasingly used for educational purposes, and the type of u.h.f. network being provided by the British Post Office to meet this demand has already been described in general terms.[1,2] This article describes the send-terminal equipment in more detail.

The send-terminal, or modulating, equipment, takes up to nine 625-line video and associated sound inputs, and produces modulated output signals for feeding into the distribution network. The receivers incorporate front-end tuner units that have the appropriate channel-selecting coils and an improved immunity to unwanted signals to reduce the risk of a channel being unusable due to external interference. The Post Office is concerned directly with the provision of the send-terminal equipment for networks, but only with specifying the performance of the receiving channel-tuner units, as these are obtained as an integral part of the receivers purchased or rented by the customer.

CHANNEL STANDARDS

The channel standards adopted are in accordance with the C.C.I.R.‡ system I 625-line recommendations, as used for broadcasting in the United Kingdom. Each vision carrier is amplitude modulated by a video signal, and, initially, an output containing both upper and lower sidebands is produced. As both sidebands contain the same information, one of them can, in theory at least, be dispensed with, but the vision carrier must remain, as this is essential for the retention of the d.c. and low-frequency components of the video signal. Fig. 1 can be regarded as showing the ideal amplitude response of a receiver, while Fig. 2 shows the required bandwidth of the transmitted channel. It is necessary to retain 1·25 MHz of the lower sideband, because the vestigial shaping-characteristic of the receiver amplitude response extends to this frequency. Negative modulation is employed for the vision channel, i.e. an increase in the level of the modulating signal causes a reduction of the level of the modulated carrier. The frequency-modulated sound carrier is 6 MHz above the vision carrier.

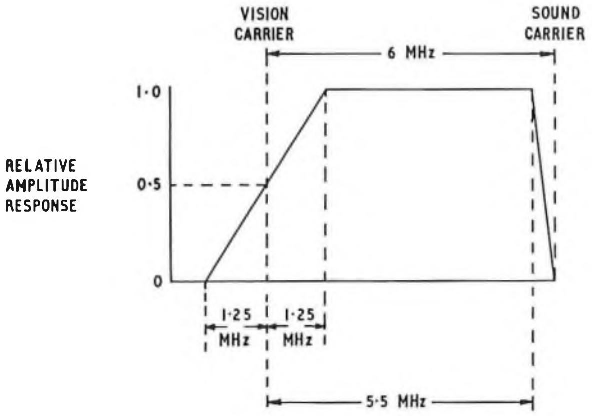


FIG. 1—Amplitude response of an ideal 625-line v.h.f. television receiver

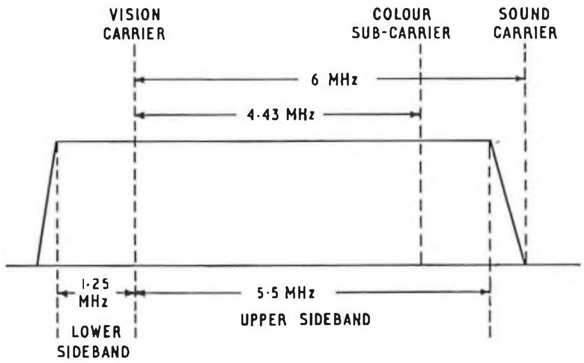


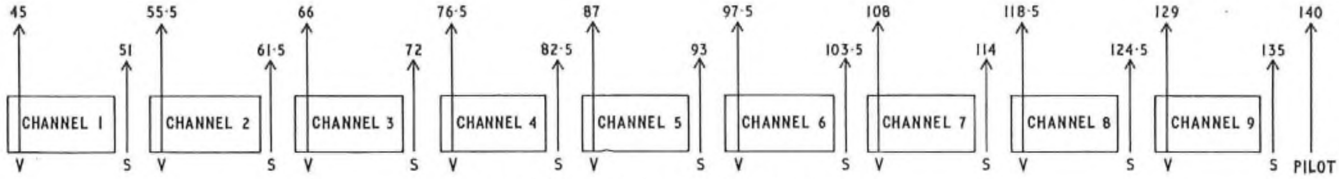
FIG. 2—Frequency band of a transmitted 625-line v.h.f. television channel

FREQUENCY SPECTRUM

The transmission band of the distribution system extends from 40–140 MHz, and can accommodate nine 625-line television channels to colour standards. The choice of vision carrier frequencies was determined by the characteristics of modern v.h.f.–u.h.f. television receivers and also by certain intermodulation-distortion products of the line system.

The standard frequency spacing between 625-line broadcast television channels is 8 MHz, but, because of the risk of interference, adjacent broadcast channels are not allocated in a common primary-service area. It is, therefore, reasonable, for closed-circuit applications, for the channel spacing to be increased so that adjacent-channel working is practicable without introducing undue complexity in the television receivers. Each receiver incorporates a tuner unit, which selects the wanted channel and translates it to a common intermediate-frequency (i.f.) band, where it is amplified and then detected

† Line and Radio Branch, Telecommunications Development Department, Telecommunications Headquarters.
‡ International Radio Consultative Committee.



V—Vision carrier; S—Sound carrier

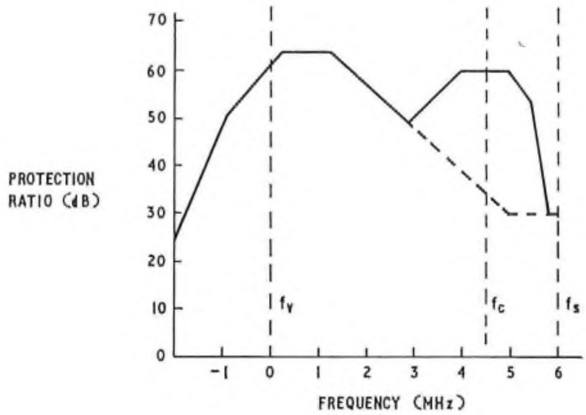
FIG. 3—Frequency spectrum (MHz)

to provide a video output. The 625-line i.f. of the vision carrier is 39·5 MHz, and that of the sound carrier 33·5 MHz. The translating process is accomplished by mixing the wanted input channel with a high-level local-oscillator signal in the tuner.

The general design and construction of the tuners is such that the local oscillator will produce a certain amount of radiation, and, in particular, send back unwanted signals to the tuner input and, hence, into the coaxial distribution wiring. Although each receiver should be isolated from all others by at least 36 dB, this would not generally be sufficient to avoid pattern interference on television pictures if the local-oscillator signal from one receiver happened to fall within a channel to which another receiver was tuned. Hence, the channel frequencies have been chosen so that local-oscillator frequencies either fall in the gaps between channels or above the transmission band altogether.

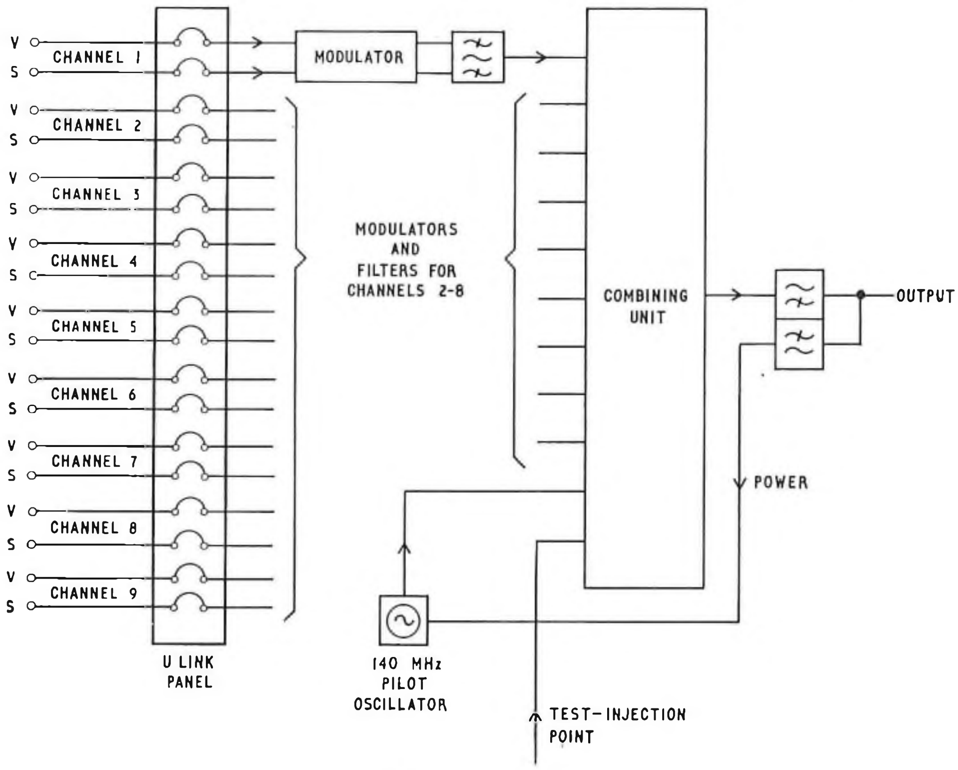
It can be shown that, for a 625-line vision-carrier intermediate frequency of 39·5 MHz, a spacing between vision carriers of 10·5 MHz is a suitable choice. Fig. 3 shows such a spectrum, and, as an example, the local oscillator frequency of channel 1 is 84·5 MHz (45 + 39·5 MHz), and this falls between channels 4 and 5. This 10·5 MHz spacing is also sufficient to avoid adjacent-channel interference troubles.

The spectrum has also been chosen as a result of line-system considerations, in particular, the effect of second-order intermodulation distortion has been minimized. Fig. 4 shows the protection limits adopted for a 625-line colour channel against sinusoidal interference. The protection ratio is the ratio of the r.m.s. value of the vision carrier to the r.m.s. value of an interfering signal. It is apparent that when second-order products fall within a channel their subjective effects will be minimized by arranging for these products to fall at about 3 MHz above the vision-carrier frequency. The dominant sources of second-order intermodulation will be the vision carriers. From the spectrum (Fig. 3), the difference products fall 3 MHz below a vision carrier, i.e. between two channels, and the sum products will fall at 3 MHz above a vision carrier. This will give an improvement of some 10–15 dB compared with an interfering signal at, say,



f_v—Vision carrier; f_c—Chrominance carrier; f_s—Sound carrier

FIG. 4—625-line channel-protection ratio limits



V—Vision S—sound

FIG. 5—Block diagram of send-terminal equipment

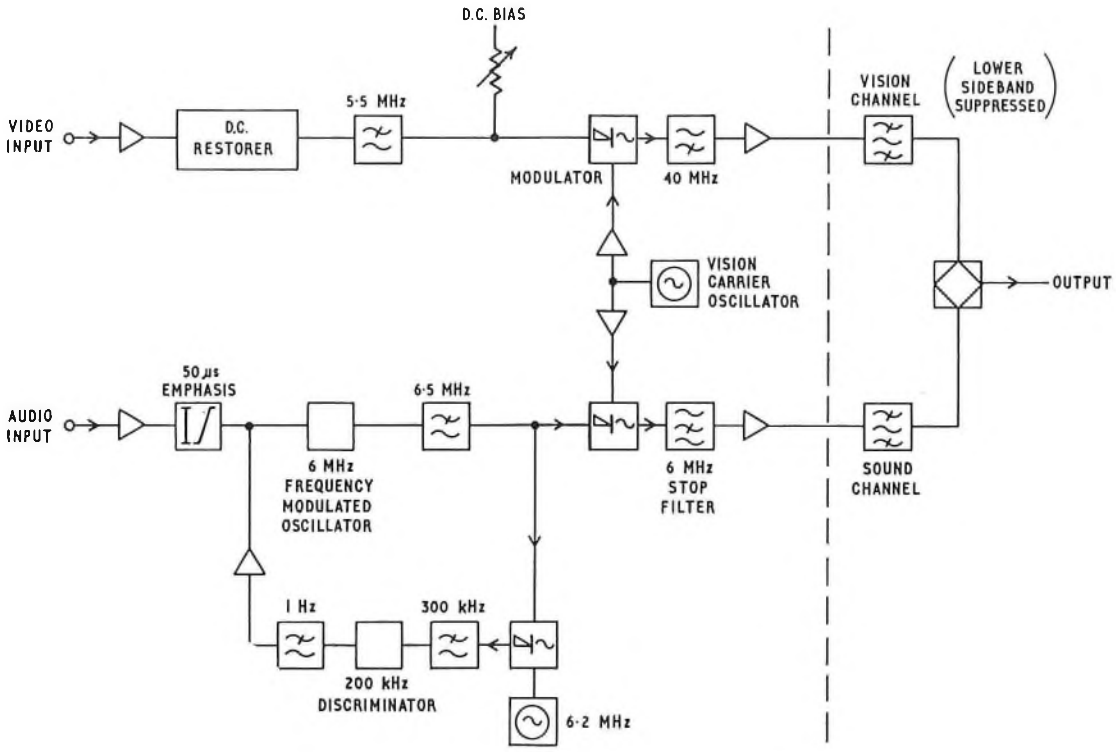


FIG. 6—Block diagram of channel modulator and filter panels

0·5 MHz above a vision carrier. The other possible sources of intermodulation interference are sound carriers, which are 12 dB below their associated vision carriers, and colour sub-carriers, which should be at least 14 dB below their associated vision carriers. The second-order intermodulation products are possibly the most difficult to control in practice, and there would be some merit in a future system design that had a spectrum wholly contained within one octave, so as to avoid the problem altogether.

Any of the upper three channels may be used for distributing 405-line programs, if required. Careful choice of the 405-line vision and sound-carrier frequencies, the vision carrier being 1·5 MHz above, and the sound carrier 2 MHz below, the corresponding 625-line vision carrier, ensures that the second-order intermodulation products of the line system are still kept under control. The local-oscillator frequencies for these upper three channels fall out of band, and do not, therefore, present a hazard.

SEND-TERMINAL EQUIPMENT

A block diagram of the send-terminal equipment is shown in Fig. 5. A photograph of the 62-type rack which mounts the equipment was contained in a previous issue of this Journal.[1] The video and audio inputs to the modulators are taken via a U-link panel, which forms an interface with the studio equipment. Each modulator is followed by a channel filter, the output of which is fed into a resistive combining unit, which has a 26·5 dB loss. The vision-carrier level at the rack output is 8 mV for each vision carrier. The 140 MHz pilot signal is injected via the combining unit and gives a level which is also 8 mV at the rack output. The individual modulators are mains-operated, from the same supply as the studio equipment, but the pilot oscillator is operated from the telephone-exchange battery supply that is available from the distribution system. This arrangement is adopted so that the pilot signal used to regulate the line system and to operate the supervisory system is not vulnerable to a failure of the mains supply.

A more detailed diagram of a channel modulator and filter is shown in Fig. 6. The video input signal, 1 volt across a 75-ohm load, is amplified before having its d.c. component restored by a simple diode-type d.c. restorer. The low-pass filter cuts off video information above 5·5 MHz, and the signal passes into a Cowan-bridge modulator. One of the outputs from the crystal-controlled vision-carrier oscillator is fed into the vision modulator, and a modulated output is produced. The depth of modulation is determined by the amount of d.c. bias applied, which controls the level of carrier passed through the Cowan-bridge modulator. Fig. 7 is a circuit diagram of the

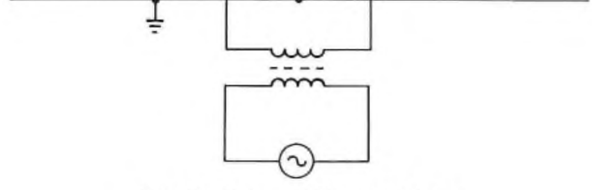


FIG. 7—Cowan-bridge modulator

modulator, which was first used for this type of application by the B.B.C. The carrier performs a chopping action on the video signal by making the diodes conduct on one half-cycle of the carrier. Without the d.c. bias there would, ideally at least, only be sideband information and no carrier at the output. The d.c. bias controls the voltage at which the carrier switches the diodes and, as a consequence, the carrier level appearing at the output. The modulated output-signal goes through the high-pass filter, which serves to stop any of the unwanted video signal from breaking through. The modulated

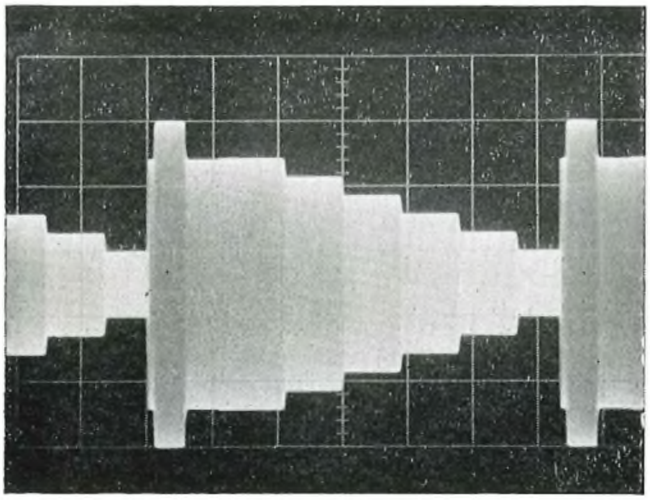


FIG. 8—Vision carrier modulated by a staircase waveform

signal is then amplified so that the carrier level is 400 mV at the output of the panel.

A modulated waveform is shown in Fig. 8, peak white corresponding to 20 per cent of the line synchronizing-pulse peaks. The vision band-pass filter attenuates the unwanted part of the lower sideband as well as unwanted spurious outputs from the modulator. The vision path is then combined with the sound path via a hybrid transformer.

The audio input is a balanced 600-ohm circuit, which is converted to an unbalanced signal in the input amplifier. The pre-emphasis network has a time-constant of $50\mu s$, which increases the level of the higher audio frequencies. This is a conventional circuit-element employed with audio frequency-modulation systems, and has the effect of improving the signal-to-noise ratio. The receivers employ a compensating de-emphasis network in their respective audio paths.

The audio signal passes from the pre-emphasis network to a 6 MHz frequency-modulated oscillator, where it produces a maximum deviation of $\pm$ 50 kHz, corresponding to a +8 dBm audio input signal level. This simple circuit has a disadvantage in that, on its own, the centre frequency tends to drift too far from its nominal value. This drift is considerably reduced by using a feedback loop; the 6·2 MHz crystal oscillator is used to produce a difference frequency of 200 kHz that passes into a discriminator to produce zero output voltage when the mean oscillator frequency is 6 MHz. A frequency error causes a proportional error voltage to be produced by the discriminator. The error voltage is then fed back to the oscillator to reduce the frequency drift. The arrangement has a sufficiently-long response time so as not to affect the wanted frequency variation produced by the audio signals. The frequency-modulated 6 MHz carrier is then translated to a higher frequency by a second Cowan-bridge modulator, using the second output from the vision-carrier oscillator. The output is filtered, amplified and then passed to the sound-channel filter, which rejects the unwanted sound-channel sideband that falls 6 MHz below the vision carrier, as well as other spurious harmonic responses. The sound channel is then combined with the vision signal via the hybrid output transformer.

The 140 MHz pilot-signal oscillator is crystal-controlled, and has an output-level meter with $\pm$ 0·25 dB scale markings. The rack has alarm circuits to indicate a pilot-signal failure, power failure or blown fuses. A mains-operated demodulator unit (Fig. 9) is provided to enable channel-performance to be checked. The same demodulator unit can be fitted into a portable carrying case and used at any point in a network. The demodulator introduces significant distortion, since the design is based on the use of commercially-available items used in television receivers. The combination of a modulator and demodulator has a typical *k*-rating* of 3–4 per cent.

TELEVISION RECEIVERS

The channel-tuning requirements have already been mentioned. Another important feature of the tuner unit concerns improvements to its immunity to external interference, mainly from broadcast and nearby mobile transmitters. Interference results from inadequate screening of the signal-path circuits, and this applies particularly to the inputs of tuner units. Isolating networks, generally fitted in broadcast receivers, are the most common cause of trouble, particularly where wire-ended capacitors are placed in series with each conductor of the coaxial input cable. An interfering signal picked up by this simple isolating arrangement would typically be 30 dB below the level of the same signal picked up by a half-wave dipole at the same point, i.e. an immunity of 30 dB. An input cable with a double-braided screen, combined with good terminating methods which do not expose the centre conductor, will give an immunity of at least 70 dB. Isolating networks have therefore been omitted from the v.h.f. inputs of receivers. For the present, each television receiver must be isolated from the mains supply by a double-wound mains transformer, and the chassis should be earthed. It is necessary, where valve tuner-units are employed, to ensure that the h.t. supply is adequately isolated from the centre conductor of the input coaxial lead.

References

1 Haworth, J. E. Schools-Television Distribution Network *P.O.E.E.J.*, Vol. 61, p. 234, Jan. 1969.
2 Lines, P. W. A 9-Channel V.H.F. Coaxial-Cable Closed-Circuit Television Distribution System. *P.O.E.E.J.*, Vol. 62, p. 93, July 1969.

* *K*-rating—linear waveform distortion assessment.

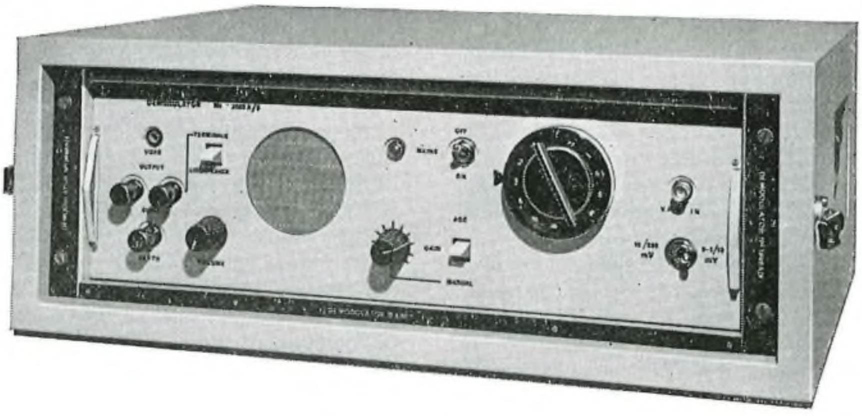


FIG. 9—Demodulator

Metal-Oxide-Semiconductor (MOS) Integrated Circuits
Part 1—The MOS Transistor

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The fundamental features and mode of operation of the metal-oxide-semiconductor transistor are described without recourse to complex solid-state physics. The various forms of the transistor are differentiated and, after a simple theoretical analysis, the characteristics of the p-channel enhancement type are examined. Attention is drawn to the unique properties of the MOST and finally its technology is outlined.

INTRODUCTION

The metal-oxide-semiconductor transistor (MOST) has characteristics analogous to those of the receiving-type pentode thermionic valve and may be regarded as its solid-state equivalent. As an individual device, however, the MOST appears to have a rather limited future; its real merit emerges when integrated into a microcircuit, thereby opening up a whole new field of electronic capability.

Although MOS integrated circuits may be used and even designed with negligible knowledge of the device itself, the telecommunications engineer will be in a better position to exploit this new technique if he has an appreciation of the mode of operation of the MOST and its associated technology. As a preliminary, some basic solid-state concepts are reviewed in a simplified manner.

MATERIALS

Semiconducting materials are essentially support media for electric charges. The charges may be positive or negative (of equal magnitude) and may be mobile or fixed. Mobile charges, often called carriers, travel in a random manner and have a wide range of speeds, but the bulk of them move slowly rather like fine particles in a viscous liquid. The fixed charges are simply distributed in a regular, though not necessarily uniform, manner throughout the material.

An n-type semiconductor may now be identified by its high spatial density of positive fixed charges. The vast majority of its carriers are negative, and together with a minority population of positive carriers, the material is normally electrically neutral throughout. In p-type material conversely, a high density of negative fixed charges and a minority-distribution of negative carriers, electrically balance the majority distribution of positive carriers.

Now a minority carrier, wandering through the material, is very likely to be attracted to, and meet, a carrier from the multitude of those of opposite sign and thus suffer neutralization. On its own this *recombination* process would gradually annihilate the minority carriers, but the neutral pairs are unstable and a fraction of these pairs is continuously breaking up into the constituent charges. This *regeneration* process maintains an equilibrium density of minority carriers.

The density of majority carriers in a semiconductor is a major factor determining the conductivity of the material. Terms such as "strongly n-type" may be used to indicate material of high carrier density and high conductivity. It will suffice on this model to think of a metal as an extremely n-type semiconductor.

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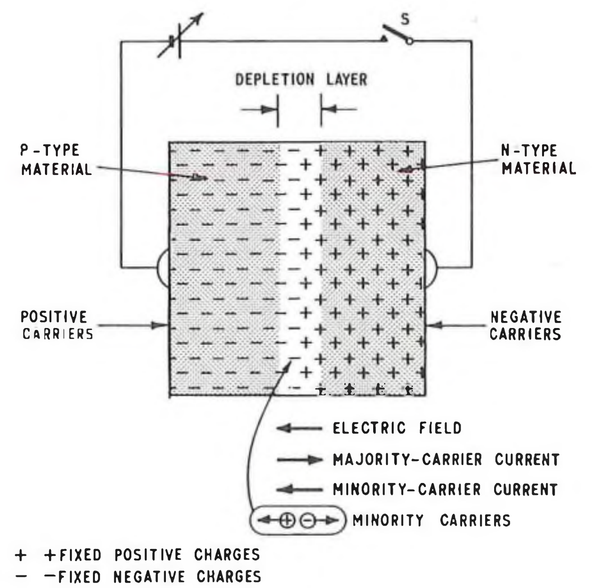
The p-n Junction

Suppose that in a single specimen of semiconductor material, p-type and n-type regions of equal fixed-charge density adjoin as shown in Fig. 1. Electrical connexions are



The fine dot pattern overlying the fixed positive or negative charges represents majority carriers

FIG. 1—The p-n junction showing depletion-layer formation

made to each side, but initially the switch S is assumed to be open. In this diagram and others which follow, neutral material is represented by a fine dot pattern of majority carriers covering the fixed charges of opposite sign.

At the junction, some of the carriers will, by virtue of their random motion, cross over to the other side. In doing so they will destroy the neutrality of the material on both sides of the boundary, because the fixed charges are then no longer perfectly balanced by carriers of opposite sign; the fixed charges adjacent to the boundary are thus "uncovered." Furthermore, due to their opposite signs, both the carrier movements will correspond to a flow of electric current from the p-type side to the n-type side, which cannot be maintained as the switch S is open. For every uncovered positive fixed charge there then exists a negative fixed charge on the other side of the junction, and these together contribute to an electric field acting from the n-type side to the p-type side. This field holds back nearly all the carriers on either side of the junction, but some will be moving fast enough to overcome it and would apparently constitute a residual current. The regeneration process is, however, going on all the time; a minority carrier appearing in the region of electric field, shown magnified in Fig. 1, will actually be accelerated across the junction, providing a balancing current component from the n-type side to the p-type side. The holding back of the majority carriers by the junction field is thus a stable condition which produces a paucity of mobile charge in a region straddling the junction, appropriately called a *depletion layer*.

In general, adjoining p-type and n-type regions do not contain equal densities of fixed charge, but similar arguments lead to the existence of an internal electric field made up from the contribution of pairs, positive and negative, of the fixed charges. If the density of the fixed charges is less on one side of the junction, the majority carriers must edge back further on that side in order to expose the same number of charges as on the other side. Hence, in a junction having, say, a stronger n-type side, the depletion layer will penetrate further into the p-type material.

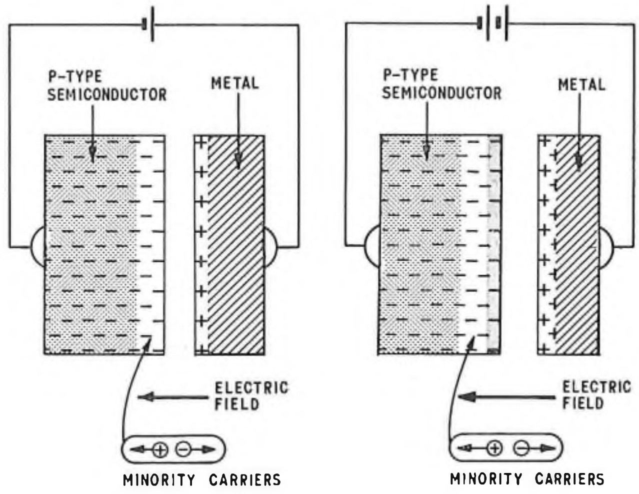
If the switch S in Fig. 1 is now closed, no current would flow at zero battery voltage as there is no source of energy, and conditions at the junction would remain unaltered. Raising the battery voltage however, applies a positive potential to the n-type side relative to the p-type side causing the junction to be reverse biased. The electric field thus appearing between the terminals augments the internal field, drawing back the majority carriers still further from the junction region, exposing even more fixed charges, and increasing the junction field to eliminate effectively the residual current component due to majority carriers. There is now a net flow of current across the junction from the n-type side to the p-type side due to regenerated carriers, but the current is so low that virtually all the applied voltage is impressed across the junction. The application of reverse bias thus produces a near-constant leakage current, and widens the depletion layer, which grows further into the side of lesser fixed-charge density.

Apart from the equilibrium charge movements just discussed, the majority carriers drawn back by the applied voltage will produce a transitory transfer of charge round the external circuit. Viewed from its terminals the junction thus behaves as a leaky capacitor which has a decreasing capacitance as the applied voltage is raised.

Finally, the steady rate of regeneration of minority carriers in the depletion layer is subject to two influences. First, the rate of regeneration, and therefore the leakage current, increase rapidly with temperature. Second, some of the minority carriers in transit will inevitably collide with other neutral pairs in their paths. If the applied voltage is above a certain critical value, these pairs may also divide and augment the natural regeneration process. The effect is cumulative, producing a large increase in current. For a given applied voltage the electric field across the junction varies inversely with the width of the depletion layer, so that this critical voltage, or breakdown voltage, falls with increasing conductivity of the material. This type of breakdown is quite reversible.

The Field Effect

Suppose that a metal plate is brought up close to a specimen of p-type semiconductor with potentials applied to the plate as shown in Fig. 2. The field appearing between the terminals of the capacitor thus formed tends to draw the majority carriers in both the semiconductor and the metal away from the surfaces, thereby exposing pairs of fixed charges which produce an electric field across the capacitor gap. In the metal, the fixed-charge density is so high that a very small movement of the majority carriers uncovers a large amount of charge; the charge may thus be considered as purely super-



(*a*) Depletion-layer formation (*b*) Inversion-layer formation

FIG. 2—Field effect

ficial (consistent with classical electrostatics). In the semiconductor however, the lower density of fixed charges requires that they be uncovered to a relatively substantial depth; the electric field thus penetrates significantly into the semiconductor, demonstrating *field effect*.

As in the p-n junction, regeneration takes place in the "uncovered" region of the semiconductor, yielding positive carriers which are swept immediately into the bulk material, and negative carriers which are now accelerated to the semiconductor surface. If the applied voltage has a fairly low value, the negative carriers will be neutralized by those majority carriers in the bulk material which are able to penetrate the electric field, thus yielding a depletion layer located at the semiconductor surface as in Fig. 2(*a*). If however the applied voltage is high enough, the number of arriving positive carriers will be reduced, allowing the accumulation of negative charge at the semiconductor surface as shown in Fig. 2(*b*), the surface then being described as inverted. As before, each positive charge on the plate is paired with a negative charge in the semiconductor (mobile or fixed) to form the electric field across the gap.

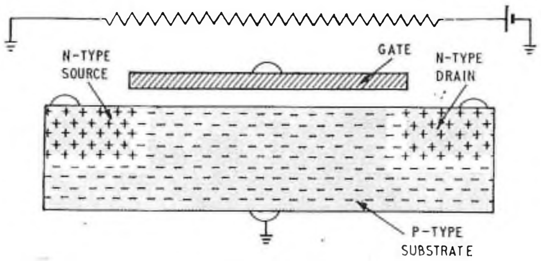
If the majority-carrier density in the semiconductor material is high, a relatively high voltage will evidently be required to produce inversion.

TRANSISTOR ACTION

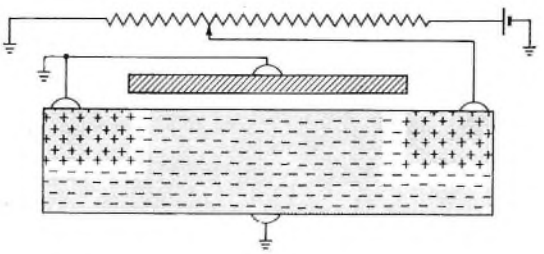
Suppose that two parallel bars of strongly n-type semiconductor material are located in the surface of a specimen of p-type material as shown by the sections of Fig. 3. A flat metal plate, parallel to the bars, is located between them and above the semiconductor surface. The plate is hereafter described as the gate electrode, whilst the n-type regions to which contacts are made are known as the source and drain. A further electrical contact is made to the p-type substrate and connected to earth potential. A potentiometer wire is shown above each section of Fig. 3.

With no potentials applied to the device, depletion layers will form round the source and drain as in Fig. 3(*a*), but because the fixed-charge and carrier densities in these regions are very high, the layer will exist almost entirely in the p-type substrate.

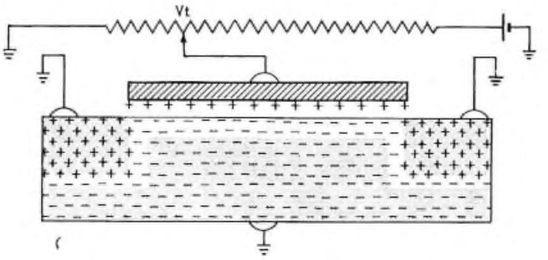
If the source and gate are earthed whilst the drain is made positive, as shown in Fig. 3(*b*), the source regions will remain unaltered but at the drain the depletion layer will penetrate further into the p-type region. The flow of drain current will be extremely small, arising from minority carriers generated in or near the depletion region. If the drain potential is now restored to zero, and the gate potential is raised progressively, field effect will gradually reduce the majority-carrier density



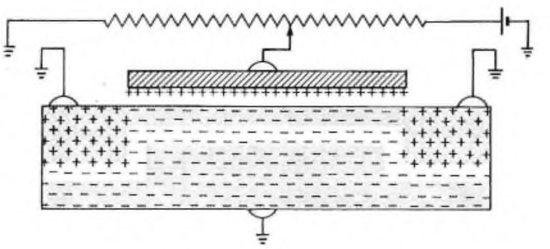
(*a*) Disconnected



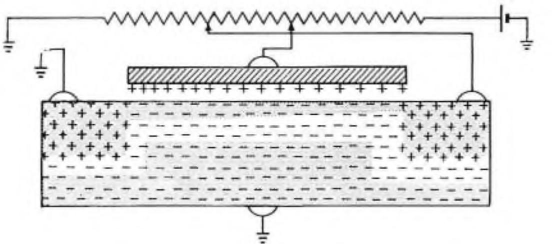
(*b*) Source and gate earthed, drain at positive potential



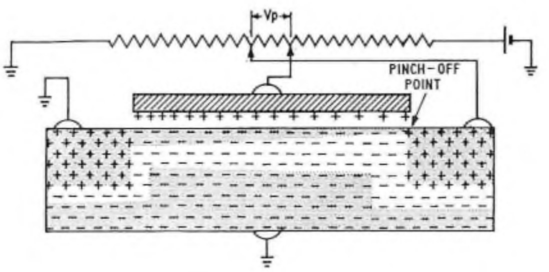
(c) Gate potential at threshold value, drain earthed



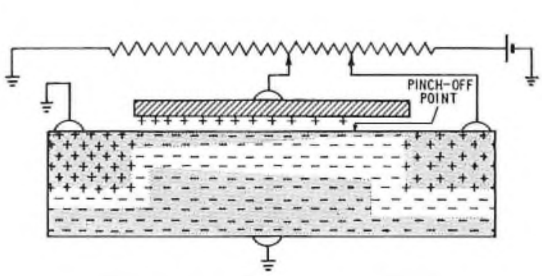
(*d*) Channel formation



(*e*) Channel taper due to drain potential



(*f*) Channel pinch-off point at drain



(*g*) Pinch-off point between source and drain

FIG. 3—Section of idealized MOS transistor showing effect of applied potentials

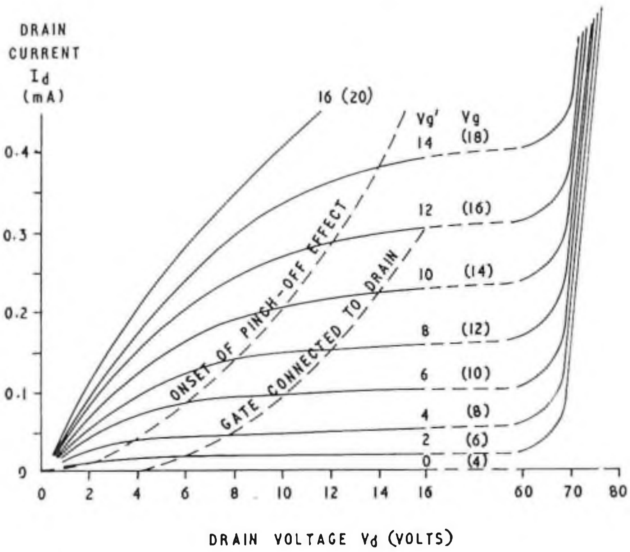
under the gate until complete depletion occurs as shown in Fig. 3(*c*). Further increases of gate potential will cause negative charge to accumulate at the silicon surface as indicated in Fig. 3(*d*). The carriers on both sides of each junction at the surface are now of similar sign (negative) so that they can cross over the junctions without producing additive current components. The path from source terminal to drain terminal now comprises a continuous distribution of mobile charge, similar to the material of a conductor (or more accurately, a resistor), and is called the *channel*. The critical gate voltage at the transition from complete depletion to the formation of a conducting path, is called the *threshold voltage*, marked as V_t on Fig. 3(*c*).

At gate voltages above the threshold value, raising the drain voltage would, from the resistor analogy, be expected to yield a proportionate drain current. Initially this is true, but the flow of current inevitably produces a voltage drop along the channel from drain to source, causing the attractive force holding the negative charge against the semiconductor surface to become progressively weaker towards the drain. The channel thus acquires the characteristic wedge shape of Fig. 3(*e*), this effect causing the drain current to increase less than in proportion to the drain voltage. If the drain voltage is increased until it is less than the gate voltage by just the threshold voltage, the wedge should taper down to zero thickness at the drain end, as in Fig. 3(*f*), predicting wrongly the interruption of the drain current. The threshold voltage, originally defined as the critical gate voltage for the flow of drain current (regardless of drain voltage), is thus the same as the potential difference between gate and channel, V_p on Fig. 3(*f*), necessary to "pinch off" the mobile charge. From this alternative definition, the threshold voltage is also known as the *pinch-off voltage*. The failure of this simple model stems from the assumption that the charge density in the channel is due simply to regeneration. In fact the pinch-off point can still be defined, but the condition implied is a hypothetical one, wherein there is a voltage drop along the channel without the flow of current. When channel current flows, the equilibrium density of charge in the channel up to the pinch-off point is still determined by the holding action of the gate voltage, but the charge due to regeneration is now negligible in comparison with that supplied from the source. At the pinch-off point, the current is sustained by the longitudinal electric field produced by the drain voltage.

At still higher drain voltages the pinch-off point moves away from the drain as in Fig. 3(*g*). This point remains however, by definition, a point of constant potential (for constant gate voltage) and now divides the channel into two distinctive regions. The source region, from the source to the pinch-off point resembles a resistor with a constant voltage across it, so that the current which flows will change only by virtue of alterations in its length. The drain region, from the pinch-off point to the drain, is similar to the depletion region of a p-n junction, and negative charge injected from the source region is simply swept by the electric field into the drain. The extent to which the drain current changes with further increases of drain voltage thus depends on the amount by which the source region shortens. For a p-n junction however, the voltage dependence of the depletion-layer thickness is a function only of the properties of the semiconductor material, so that if the channel is made long enough, expansion of the drain region will produce only a small fractional contraction in the length of the source region. The drain current thus rises slowly with the drain voltage, the dynamic resistance increasing with the distance from source to drain. Raising the drain voltage applies an increasing potential difference across the p-n junction between drain and substrate until breakdown occurs, with a consequent large increase in drain current.

It has been assumed hitherto that the source and substrate of an MOS transistor are at the same potential. The action of the transistor is not however destroyed if the substrate is biased negatively with respect to the source. The repercussions of substrate bias on the drain characteristics are not obvious even qualitatively. At first sight, a negative bias on the substrate would appear equivalent to a standing positive voltage on the gate, thus decreasing the threshold voltage. In fact however, substrate bias causes the depletion region under the channel to widen, thus exposing more negative fixed charge. As each negative charge in the substrate (mobile and fixed) must be paired with a positive charge on the gate to form the electric field across the gate-substrate gap, the ability of the gate charge to hold mobile charge against the substrate surface is reduced, and hence the threshold voltage is increased.

Typical drain characteristics derived from practical measurements, are shown by Fig. 4. The threshold voltage can be



(The signs used are those of the *n*-channel device but the magnitudes refer to a p-channel transistor)

FIG. 4—Drain characteristics for unit MOST with zero substrate bias

determined from the characteristic which just coincides with the voltage axis. No direct observation of the occurrence of pinch-off is possible, but its onset can be estimated by drawing the locus of points for which the gate voltage exceeds the drain voltage by the threshold voltage. A further and quantitative consideration of the characteristics is reserved for a later section.

Finally, Fig. 3 shows that the MOS transistor is always completely isolated from the substrate, due to the depletion layer surrounding both the electrodes and the channel.

Transistor Types

The transistor just described is a hypothetical device because the gate electrode has been represented as physically isolated. A useful degree of field effect is however only obtained if the gap between the gate and the semiconductor surface is very small, so that in practice a solid dielectric must be interposed; its presence leaves the general form of the characteristics unaltered, yet has a profound quantitative influence upon them. In particular, the dielectric changes the threshold voltage because, during preparation positive charge is unavoidably introduced both in the bulk of the dielectric and at its interface with the silicon. The total charge is shown schematically in Fig. 5. This charge repels the positive

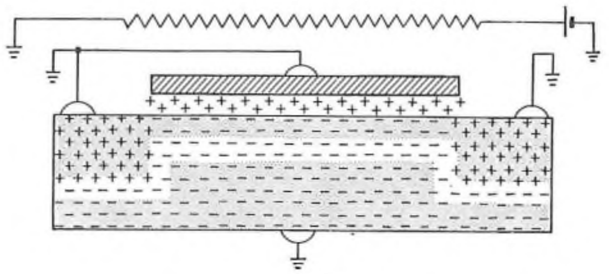


FIG. 5—Section of idealized MOS transistor showing effect of dielectric charge.

carriers in the substrate and acts like a standing positive voltage applied to the gate. Its effect is most easily demonstrated by plotting mutual characteristics (at constant drain voltage) as shown in Fig. 6(*a*). If the dielectric charge is sufficiently dense, as is often the case, it can on its own produce an inversion layer in the channel, allowing drain current to flow at zero gate voltage. Noting that conduction is by negative charge flow, it now becomes possible to distinguish between *n-channel enhancement* and *n-channel depletion* transistors according, respectively, to the absence or flow of drain current at zero gate voltage with the threshold voltage correspondingly positive and negative.

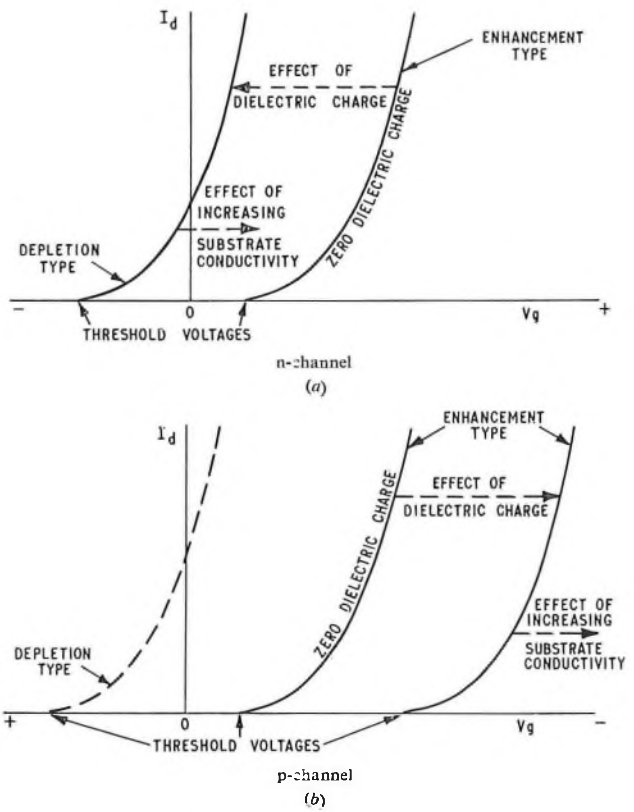


FIG. 6—Mutual characteristics for various transistor types

The curves of Fig. 6(*a*) depict transistors of low substrate conductivity, but the effect of increased conductivities is also shown. By using substrate material of a sufficiently high conductivity, the effect of dielectric charge can thus be offset to yield a practical n-channel enhancement device.

The corresponding p-channel device is readily conceived utilizing p-type electrodes in n-type substrate material.

Negative drain and gate voltages are now required and the direction of the drain current is reversed, but the mode of operation is exactly the same. The n-channel and p-channel transistors are not however perfect duals of each other. One reason is that the positive charge incorporated in the gate oxide now acts in opposition to the gate voltage and hence accentuates the enhancement-type characteristics of the hypothetical device. The influence of dielectric charge and substrate resistivity on the p-channel device is shown by Fig. 6(*b*). The natural forms of the MOS transistor are thus the n-channel depletion and p-channel enhancement types.* Another difference between n-channel and p-channel devices arises from the higher mobility of negative carriers compared to positive carriers which, as an analysis will later show, leads to a device of higher performance. Discrete transistors, particularly for use as amplifiers, therefore tend to be of the n-channel depletion type, but in integrated circuits serious isolation problems are avoided by using enhancement-type devices which in the quiescent condition conduct no current, and from which simpler circuit configurations are obtainable. In further analysis therefore, only the characteristics of p-channel enhancement transistors will be recorded.

Considerable confusion can arise in describing p-channel transistors due to the need for negative voltage supplies. For descriptive simplicity therefore, the signs of measured and analytical quantities will continue to be those of the n-channel device, until a later part of this series when actual circuits are discussed.

ANALYSIS

A truly comprehensive mathematical treatment of the MOS transistor has yet to emerge. For many practical purposes however, a very simple analysis is possible which despite many approximations yields results in remarkable agreement with experiment. This analysis is valid only for zero substrate bias and treats the threshold voltage as an independent variable. The theory also neglects movement of the pinch-off point after its formation at the drain, which implies perfect saturation of the drain current.†

The principal results of this simple analysis, valid for drain potentials below that required for pinch-off, and the outcome of its application when the current saturates are summarized below.

Before pinch-off, the drain current, I_d, depends on the gate voltage, V_g, and the drain voltage, V_d, according to

$$I_d = \beta\left(V_d V'_g - \frac{V_d^2}{2}\right) \quad \ldots\ldots \quad (1),$$

where $V_d \leqslant V'_g$ and

V'_g is the gate voltage margin above threshold,

i.e. $$V'_g = V_g - V_t \quad \ldots\ldots \quad (2),$$

and V_t is the threshold voltage.

The factor β is given by

$$\beta = C_0 \mu \frac{w}{l} \quad \ldots\ldots \quad (3),$$

where C_0 is the capacitance per unit area between the gate and the substrate,

μ is the carrier mobility (the velocity per unit applied electric field, assumed to be constant),

and $\frac{w}{l}$ is the channel width/channel length, or aspect ratio, the length being measured from source to drain.

* The p-channel depletion transistor is only realizable by the use of a physical channel, as opposed to an induced channel, between source and drain.

† As now used saturation refers to the constancy of the drain current. In sharp contrast, bipolar transistors are often said to be saturated when operated near the origin of the output characteristics.

The value of C_0 is

$$C_0 = \frac{\epsilon\epsilon_0}{t} \quad \ldots\ldots \quad (4),$$

where t is the thickness of the gate dielectric, ϵ is its dielectric constant and ϵ_0 is a fundamental constant.

As noted earlier, pinch-off at the drain occurs when

$$V_d = V_g - V_t = V'_g \quad \ldots\ldots \quad (5),$$

from equation 2. The drain current then reaches its nominal saturation value which by substitution in equation 1 is,

$$I_{d_{sat}} = \frac{\beta V'^2_g}{2} \quad \ldots\ldots \quad (6),$$

where $V_d \geqslant V'_g$.

The slope resistance of the drain characteristics at the origin, r, is obtained by differentiating eqn. 1 with respect to V_d, and putting $V_d = O$, which gives,

$$r = \frac{1}{\beta V'_g} \quad \ldots\ldots \quad (7).$$

The slope of the mutual characteristics, g_m, at all drain voltages above the onset of pinch-off, may be derived from equation 6 giving

$$g_m = \beta V'_g = \frac{1}{r} = \sqrt{(2\beta I_{d_{sat}})} \quad \ldots\ldots \quad (8).$$

An MOS transistor is often operated with the gate and drain strapped. As then $V_d > V'_g$, the drain characteristic obtained follows from equation 6,

$$I_d = \frac{\beta}{2}(V_d - V_t)^2 \quad \ldots\ldots \quad (9),$$

where $V_g = V_d > V_t$,

and the slope resistance,

$$r' = \frac{1}{\sqrt{(2\beta I_d)}} \quad \ldots\ldots \quad (10).$$

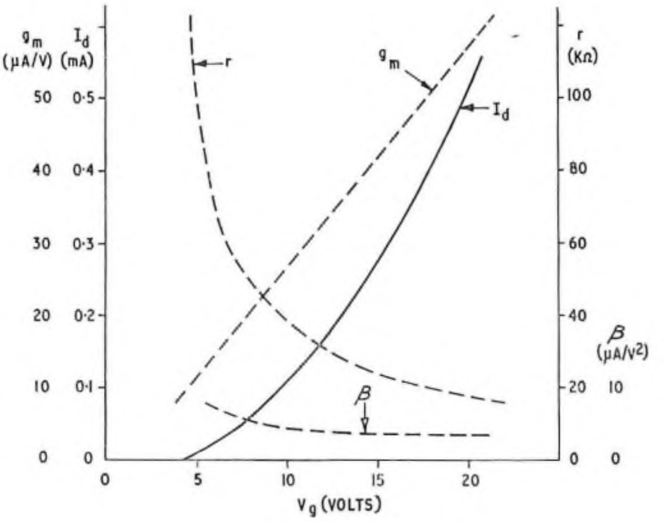
It follows immediately from the above equations that β and all the currents and conductances have a simple proportionate dependence on the aspect ratio, the carrier mobility and the reciprocal of the gate dielectric thickness.

All the independent variables are known or are determinable with reasonable accuracy, except for the carrier mobility which is always much less than that of bulk semiconductor material.

CHARACTERISTICS

An attractive feature of the MOS transistor is the simplicity of its characteristics. The device has, for example, no input characteristics because the gate current is insignificant. From the foregoing analysis, differences between the characteristics of practical transistors are seen to arise only from variations of threshold voltage, V_t, and the gain parameter, β. For comparison purposes however, once V_t is measured, it can be eliminated by presenting the characteristics in terms of V'_g. Furthermore, β can be expressed per unit aspect ratio, and for the optimized technology of present-day fabrication methods, its value does not differ widely from one manufacturer to another. The drain characteristics can thus be normalized with respect to aspect ratio and threshold voltage, and then be used to determine the characteristics of any other transistor. The curves of Fig. 4 have been prepared in this way for unity aspect ratio. The actual measured gate voltages are also shown in brackets; a threshold voltage of 4 volts is a very typical value.

The characteristics of Fig. 4 could be compared directly with the theoretical results. Due however to uncertainties, particularly of the carrier mobility, it is better to prepare a mutual characteristic for a drain voltage of, say, 20 volts, as shown in Fig. 7, and differentiate it graphically to obtain a curve of the transconductance, g_m. Taking V_t as 4 volts, V_g' can then be found from equation 2 and β from equation 8. When plotted on Fig. 7, β is seen to fall as the gate voltage is increased, but



For I_d, g_m, β, drain potential is 20 volts
for r, drain potential is zero

FIG. 7—Characteristics of unit MOST

soon steadies off to a value of about 4 μA/volt^2, which is typical of a transistor of unity aspect ratio or a "unit MOST".

At drain voltages above the pinch-off condition, the saturation is seen on Fig. 4 to be imperfect, as predicted by the earlier qualitative discussion. Furthermore, the current under saturation conditions is not a simple function of w/l. In consequence it is strictly only permissible to use the aspect ratio to scale the characteristics within the saturation region if the channel length remains constant in value, about 8 μm being applicable to Fig. 4. At the higher gate voltages on Fig. 4, the slope resistance at drain voltages 5 volts above the pinch-off locus is about 500 kohm.

Two other features of the drain characteristics are that they exhibit no offset, meaning that the curves all pass through the origin, and that the curves ultimately turn sharply upwards due to breakdown of the drain-substrate junction. The voltage at which this breakdown occurs depends, as noted earlier, on the substrate conductivity, but often lies in the range 50–80 volts.

The effect of substrate bias on threshold voltage cannot be so easily generalized, because such technological variations as exist between manufacturers can still produce fairly large differences. Typically however, the magnitude of the threshold voltage can increase by 2 volts for 20 volts of substrate bias.

Resistor Properties

If the gate potential of an MOS transistor is above the threshold value, a small positive drain voltage will draw a proportionate drain current corresponding to a resistance, r, of value anticipated by equation 7. A curve of r, derived from Fig. 4 and added to Fig. 7, exhibits the expected reciprocal relationship with the transconductance as determined at the same gate potential from the saturated region of the characteristics. If in Fig. 4 the gate voltage is sufficiently positive, the drain characteristic maintains an approximate linearity even up to fairly high drain voltages. The resistance of a unit MOST at a gate voltage of 20 volts is about 20 kohm for small drain voltages, rising to 25–35 kohm at high drain voltages.

The gate voltage of an MOS transistor may alternatively be specified by connecting it permanently to the drain to yield the characteristic also shown on Fig. 4, which is a plot of equation 9. The current is now highly non-ohmic and the curve does not even pass through the origin, because the device ceases to conduct when the gate voltage falls below the threshold value. The transistor is now a true two-terminal device, if the substrate is ignored, and can be used as a resistor for at least unidirectional current flow. The resistance is about 40 kohm at 20 volts rising to an extremely high value as the applied voltage is reduced.

At gate voltages below the threshold value, the drain current for any applied drain voltage (below breakdown) is merely the leakage current across the drain junction. The value will be temperature-dependent but will often correspond to a resistance between source and drain as high as 10^{10} ohms. Between "on" and "off" conditions therefore, the MOS transistor will exhibit a resistance change of the order of 10^6, a value independent of aspect ratio.

All previous references to the resistive properties of the MOS transistor have implied the unidirectional flow of current. The construction of the device is however symmetrical, so that the designation of the electrodes as source and drain is arbitrary, and current may flow in either direction between them as in an ordinary resistor. The utilization of this bilateral property of the MOS transistor implies, of course, appropriate circuit arrangements to ensure that the p-n junctions at the source and drain can at no time become forward biased.

Capacitances

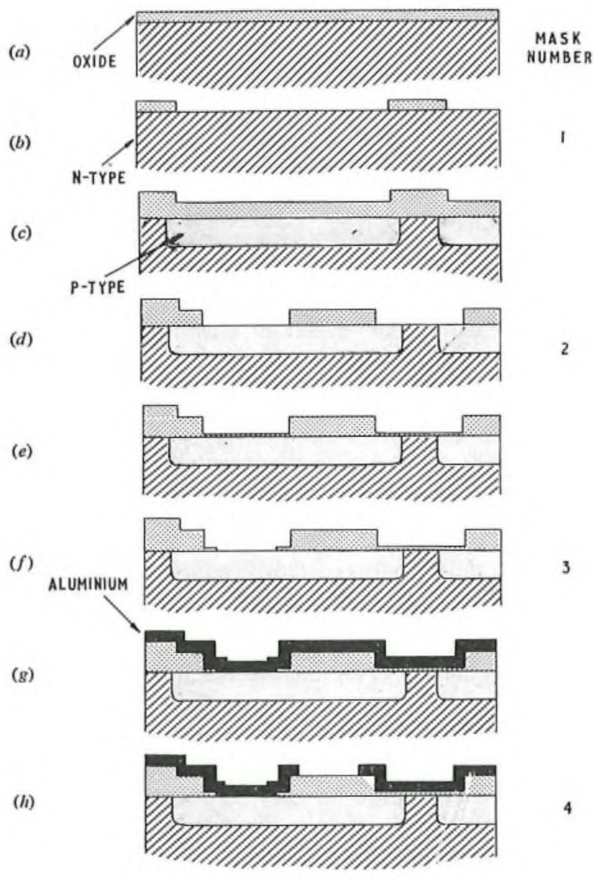
During the analysis of the MOS transistor, it was shown that the gate and substrate constitute a capacitor with a value C_o per unit area of gate. For a typical gate dielectric thickness of 0·12 μm and a dielectric constant of, say, 4, the value of C_0 from equation 4 is 300 pF/mm^2 of gate area. For a gate area of 8 μm × 8 μm the actual capacitance, C, is thus very small, amounting to approximately 0·02 pF. The insulation resistance of the gate dielectric is however likely to be about 10^{14} ohms, indicating a time constant of several seconds; this endows the MOS transistor with the ability to retain a potential applied to its gate when the gate is subsequently isolated. In practice the isolation cannot be effected perfectly, but it is usually possible for the gate to store charge for a least several tens of milliseconds, which is adequate for practical exploitation. In Fig. 3 the extremities of the gate electrode are shown coinciding with the ends of the source and drain areas, so that the other plate of the gate capacitor appears to be the channel. For reasons discussed in the next section however, the gate must partially overlap the source and drain electrodes, giving a direct gate-source and gate-drain capacitance; each would amount to about 0·01 pF for the square device mentioned above.

As noted earlier, the p-n junction behaves as a voltage-dependent capacitor, so that the MOS transistor also has capacitances from its source and drain to the substrate, typically of about 100 pF/mm^2 of junction area at zero bias, falling to 20 pF/mm^2 with a reverse voltage of 25 volts applied. For shallow electrode depths the junction area may be equated to the electrode area. The capacitance for a typical shallow area measuring 25 μm × 25 μm is likely to be about 0·02 pF at a reverse bias of 25 volts.

TECHNOLOGY

The MOS transistor owes its practical realization to the silicon planar technique, wherein the surface region of a very flat specimen of single-crystal silicon is treated selectively by thermal and deposition processes in accordance with patterns generated by micro-photography. The essential steps of the process, as applied to an MOS transistor, are summarized below with the aid of Fig. 8.

In order to prepare silicon with the desired n-type and p-type characteristics, controlled amounts of suitable impurities must be introduced into the crystal. Each foreign



(*a*) Wafer Oxidised—Thin Oxide
(*b*) Source and Drain Windows Photo-Engraved
(*c*) Boron Diffusion and Re-Oxidation—Thick Oxide
(*d*) Gate and Contact Windows Photo-Engraved
(*e*) Gate Oxide Growth—Very Thin Oxide
(*f*) Contact Windows Photo-Engraved
(*g*) Aluminium Metallization
(*h*) Metallization Pattern Photo-Engraved

FIG. 8—Processing sequence

atom becomes one of the desired fixed charges and provides a mobile charge of opposite sign. Accordingly, for a p-channel transistor, the starting material is a thin plate or wafer cut from an n-type ingot containing arsenic or phosphorus as the impurity at a concentration of about 1 atom per 50 million atoms of silicon, and having a resistivity of approximately 10 ohm cm. After polishing one side of the wafer by mechanical and chemical methods to obtain a flat and virtually damage-free surface, the wafer is oxidized in a furnace to a depth of about 0·2 μm as shown in Fig. 8(*a*). This silicon-dioxide layer is then covered with a thin film of a photo-sensitive emulsion, known as a resist, and exposed to ultra-violet light through a photographic plate (mask) upon which the desired pattern of the source and drain electrodes appear as clear areas on an otherwise opaque background. The wafer is then treated with a solvent which only attacks the irradiated areas of the resist. The pattern thus created in the resist is then reproduced in the oxide by immersion in an etchant, which removes the oxide except where protected by the resist. After removal of the remaining resist with another solvent, source and drain windows are left in the oxide as shown in Fig. 8(*b*).

For p-type characteristics in silicon, the preferred impurity is boron. The wafer is therefore heated, first in an atmosphere containing boron which reacts with exposed silicon to form a glassy boron-rich layer in the windows, and then in an oxidizing atmosphere which produces a layer of oxide about 1·5 μm thick over the whole surface. During this treatment the boron also diffuses into the silicon to yield a very high concentration of about 0·1 per cent just under the window. This concentration naturally declines with distance from the window, eventually reaching equality with that of the original n-type impurity, thus defining the electrode boundary as represented in Fig. 8(*c*). The depth of the boundary and its lateral penetration under the oxide is typically 1·5 μm, but can be as high as 6 μm, whilst the sheet resistance of the p-type material is usually in the range 10–100 ohms per square.

A further photo-engraving step then follows, using a second mask to cut windows for the gate area and for contacts to the electrodes, as shown in Fig. 8(*d*). A further stage of oxidation in a furnace then prepares the gate dielectric, growth being stopped at a thickness in the range 0·1–0·14 μm as in Fig. 8(*e*). As this process inevitably oxidizes the contact areas, a third masking step is required to re-expose the silicon surface as shown in Fig. 8(*f*).

A layer of aluminium about 1 μm thick is next deposited over the wafer by sublimation in a vacuum chamber. The film, shown in Fig. 8(*g*), is then photo-engraved to delineate the desired connexion pattern as in Fig. 8(*h*).* A final heat treatment is required to effect a good, alloyed, contact between the aluminium and the silicon, the surface resistivity of the metallization being typically 0·05 ohms per square. In practice there are many variants of the foregoing sequence. The gate oxide, for example, may be prepared by etching down the existing oxide layer to the desired thickness. Extra processes may also be introduced to control the amount and stability of the positive charge, earlier noted as an unavoidable constituent of the gate dielectric, the introduction of phosphorus into the oxide often being favoured. Silicon dioxide is not the only possible material for the gate dielectric, other insulators such as the nitride of silicon may be incorporated by deposition to form multi-layer dielectrics.

It should be observed, finally, that the geometry of the practical device differs from that of the idealized transistor (Fig. 5) in that the gate electrode extends over the source and drain regions. This overlap is undesirable, but it stems from the problem of accommodating errors in the successive alignment of the photographic masks such that no channel end can ever be uncovered by gate metal, which would render the transistor inoperable.

CONCLUSION

It has been demonstrated that the MOS transistor is a versatile circuit element, usable actively to provide gain or passively resembling a resistor. It is also a symmetrical device admitting the flow of current in either direction with no voltage offset at zero current. The control electrode is almost perfectly isolated, allowing the temporary storage of an input signal. Of the four different forms of the transistor, the p-channel enhancement type is one of the more easily realizable. It has input and output voltages of the same (negative) polarity and no current flows at zero input voltage. These features in combination with a particularly simple dependence of the characteristics on the constructional geometry, and a natural isolation from the material in which it is fabricated, make this type of MOS transistor a useful element for integrated circuits.

* In Fig. 8(*h*) the connexion to the other electrode is assumed to be off the diagram.

Value Analysis and the New Directory Holder

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U.D.C. 658.511

The technique of value analysis is being used in the Post Office to reduce costs by simplifying design. The basic principles of the technique are outlined and work recently carried out on the new directory holder is described by way of example. It is estimated that savings from this item alone could be as much as £100,000 per annum over the next 5 years.

INTRODUCTION

Value analysis is a systematic approach to cost reduction and has the same relationship to design as work study has to a production process. It originated and has been applied widely in the U.S.A. and is a requirement for most defence contracts in that country. There is a growing interest in its application in the U.K. and it is appropriate that the Post Office as a large purchaser should be actively engaged in value analysis and should encourage its suppliers in the use of this management technique. Cost reduction is not new to the Post Office, but value analysis represents a formal means of relating design, function and cost. As an example of possible achievements with this technique a value analysis exercise has been carried out on the telephone directory holder at present used in London kiosks and from this evolved two alternative designs which are now to be the subject of a development contract. The estimated savings with either design, coupled with economies which also become possible in the design of the associated wallboard, are expected to result in savings for the next five years in excess of £100,000 per annum.

DEFINITION OF VALUE ANALYSIS

Value analysis, can be defined as the systematic and functional study of an existing item, with a view to the elimination of unnecessary total costs whilst preserving essential performance requirements. The total costs referred to include, where appropriate, installation, maintenance, repair and power costs as well as the initial purchase price of the article. If this definition is adhered to strictly, value analysis can only be applied to items already in production and service when it is possible to quantify the savings resulting from the implementation of the value analysis recommendations.

If the same techniques are used before an article is first produced, i.e. at the initial design stage on a new item, this is referred to as value engineering and results in cost prevention rather than cost reduction. The distinction between value analysis and value engineering is somewhat arbitrary and in the Post Office value analysis is used as the generic term to cover both aspects of the work.

Value analysis calls for a logical and systematic approach to cost reduction thus ensuring that each design feature of the article under analysis is dealt with at the appropriate time during the exercise and given the appropriate weighting. Its application calls for an analysis of all the functions of the article and the assessment of the real cost of these functions. Its overall aim is to achieve the same performance at lower cost without affecting the reliability of the item. Its success stems largely from the creation of conditions which are conducive to original thought and by the use of a team rather than an individual, thus ensuring a cross-fertilization of ideas at the speculation stage.

THE JOB PLAN

The application of value analysis should follow a carefully planned program, referred to as the JOB PLAN, which has the following six stages:

Stage 1—Information

In the first instance as much reliable information as possible, including the latest purchase price, present and future annual demand, current stores position, assembly and detail drawings, specifications and the design history of the present item, is gathered together. The emphasis at this stage is on function and the cost of providing functions and a cost breakdown on the existing item including material, labour and overhead charges and, where appropriate, the tooling costs, together with a functional breakdown must be obtained. An item or component part invariably performs a number of functions, one of these can usually be identified as the basic function and the remainder are referred to as secondary functions, many of which are essential to the satisfactory performance of the item or part. In listing these functions it is important that they should be expressed as true functions. For example, the function "protect transmitter" is met in the design of a telephone by the mouthpiece, but to have written "provide mouthpiece" would have restricted the approaches to the concept of a mouthpiece.

Stage 2—Speculation

Having determined which functions are performed wholly or in part by each component part of the item, the cost of performing each of these functions can be estimated from the cost breakdown figures. Each function should be scrutinized to see if it is essential or can be eliminated, or if it can be transferred elsewhere to be performed in a simpler and less costly manner by another part. This might lead to the elimination of a part of the item under analysis. Although parts can often be removed for this and other reasons, their elimination must never reduce the reliability, no matter how large a saving might result from such action.

In addition to the functional breakdown there may be also a list of specifications and these must be scrutinized to establish whether or not they are realistic and whether a modification to any specification would simplify the design and manufacture of the item. The materials specified may be costly, in short supply, or difficult to process and alternative materials might need to be considered.

This speculative thinking process continues at the "brain storming" sessions of a small value analysis (V.A.) team, including one or two Value Analysis Branch members, a technical costs officer from the Contracts Division of Purchasing and Supply Department, representatives of the Development and User Branches and possibly an outside manufacturer, called together for this purpose. After sifting and analyzing the information presented to them, the team put forward their ideas and these are listed, no matter how outrageous they might at first appear. The objective is that, no matter how inept an idea or suggestion might seem on first hearing, it can trigger off creative thinking in the minds of others present which may, and often does, lead to the evolution of really worthwhile proposals. It is essential that the ideas and suggestions that are made during these "brain storming" sessions should be accepted without criticism; their evaluation comes later. Time is never wasted speculating and this stage should continue until no further ideas are forthcoming.

Stage 3—Evaluation

The V.A. team must now follow up the ideas and suggestions made at the speculation stage. The cost of every idea is evaluated and the cost of using alternative methods, materials and processes, thoroughly investigated. This evaluation on the basis of cost rather than feasibility will indicate the least expensive solutions and these must be explored first. Invariably there will be a number of bad points associated with any such proposal and when this happens every effort is made to eliminate or overcome these objections. A cost comparison between a number of economical and, on the face of it, practical solutions can then be made and a decision taken as to the line of action to be pursued with the object of developing still further those ideas which show real promise.

Stage 4—Planning

Firstly, the V.A. team must consider again those ideas and suggestions involving the elimination of unnecessary parts and manufacturing and finishing processes and, having established which of these can be eliminated, must consider the remaining component parts. Proposals may involve, on the one hand, an alternative method of meeting the functions associated with a part which is so much at variance with the original approach that the new part takes on an entirely different form and is often unrecognisable when compared with its predecessor. On the other hand, the proposals may involve consideration of the use of alternative materials, finishes and manufacturing processes, the use of wider tolerances and design simplification by reducing the number of details required in the construction of the existing part, and hence the assembly time involved. Either way it will be necessary, during this stage, to obtain the closest co-operation from specialist manufacturers and suppliers.

Before making firm proposals the V.A. team must be absolutely sure that their recommendations are feasible, that the proposed design meets all the functional requirements and that it does not represent a reduction in acceptable standards of quality and reliability. As the investigation progresses it will often become apparent that changes of installation, maintenance or operational procedures are involved and the need for consultation with staff associations will then arise; this will be through the normal channels such as, for example, the Experimental Changes of Practice Committee.

Once a final selection of the proposed changes has been made, the V.A. team must plan the development and introduction of the new design taking into account the time and cost of development, the need or otherwise for laboratory models and field trials, and any other costs involved in putting their final recommendations into practice.

Stage 5—Report

This, the penultimate stage of the job plan, demands the collection of all relevant data on materials, specifications and drawings from which manufacturer's information for the new item can be derived. The report must include all this information in a condensed and easily understood form, together with a simple description of the functions to be performed by each part, a before and after analysis sketch of each part where a change is being proposed, and the estimated cost of each part in terms of materials, labour and overheads.

The report is presented to management for final acceptance or otherwise and, assuming that its recommendations are accepted, there remains the question of implementation.

Stage 6—Implementation

In the Post Office this stage and indeed a number of activities in the planning stage are the direct responsibilities of other branches and the V.A. team is not authorized to commit any of the branches to particular actions. The V.A. team, therefore, takes the analysis to the stage of an agreed report. Thereafter, assuming that the recommendations in the report are accepted by management, it is the responsibility of the User and Development Branches concerned to implement the V.A. design changes.

THE DIRECTORY HOLDER NO. 5

This holder was intended for use in London, and was designed to accommodate nine directories in order to cover fringe area requirements. A simpler and cheaper shelf-type directory holder was designed for provincial use. The London-type holder, especially its swinging directory carriers, proved exceedingly popular and it was decided to extend its use to the provinces. This program would have entailed the provision of some 50,000 units over the next five years.

The original holder was designed with little background experience of any similar item and it was felt that the design could be improved in the light of the subsequent experience. Also, since the original design there had been changes in usage, e.g. introduction of the steel cash compartment to the coinbox, abolition of cigarette holders, proposals for new London directories.

The design and construction of the present Directory Holder, details of which are shown in Figs. 1 and 2, was based extensively on the use of aluminium alloy castings. These included the two side supports, the bottom shelf, and each of the five directory carriers which are mounted on a horizontal stainless-steel axle across the top of the holder between the two side castings. This design, which also made use of $\frac{1}{4}$ in mild steel upper and lower back plates and sheet metal inside linings, led to the production of an item weighing over 30 lb and stronger than was necessary to meet its basic function of holding securely a number of telephone directories whose total weight was unlikely to exceed 10 lb. The possibility of misuse and vandalism could not be ignored in the consideration of any alternative designs.

A cost breakdown on the existing item as given in Table 1 showed that the side castings and bottom shelf accounted for 35 per cent of the total cost of the holder and the five assembled carriers for approximately 40 per cent. The side linings and inner partition accounted for a further 9 per cent, the rear fixings for some 7 per cent and the axle and associated parts for approximately 3 per cent. The basic function of holding the directories involves the carriers (less the phosphor bronze springs and associated parts), the axle, the side castings, in part, and the rear fixings. These together represent approximately 50 per cent of the total cost.

A breakdown of functions on the existing item is given in Table 2.

The construction of the present holder and its method of attachment to the wallboard rule out any proposal to cater for holders of varying width in order to accommodate different numbers of directories. Since in the provinces it is likely that on average two carriers will suffice it was decided that any alternative design should avoid this limitation.

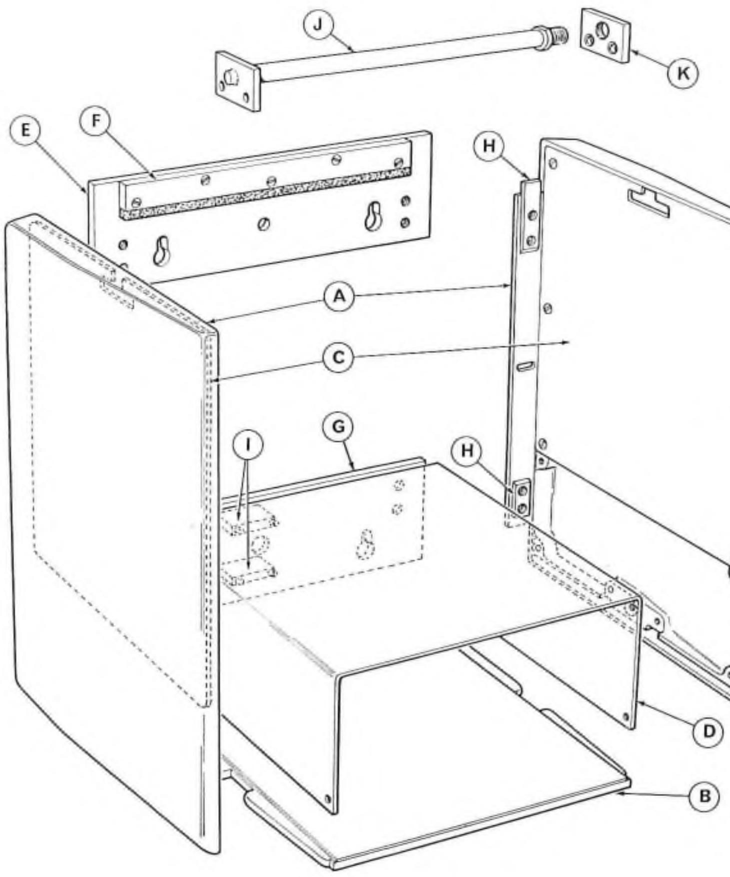

FIG. 1—Constructional details of the existing design of directory holder

TABLE 1

Percentage Cost Breakdown Directory Holder No. 5

Detail	Description	percentage Breakdown
A	Side Castings (2)	25·3
B	Shelf	9·7
C	Upper-side linings (2)	4·9
D	Partition & lower-side linings	4·2
E	Upper back-plate	1·6
F	Stop-plate and buffer	1·9
G	Lower back-plate	1·5
H	Fixing plates (4)	1·1
I	Locking fixing-brackets (2)	0·6
J	Axle	2·0
K	End plate (and washers)	0·6
L	Carrier, main castings (5)	22·5
M	Phosphor-Bronze spring clips (5)	4·2
N	Plates and rubber seatings (5)	4·7
O	Spring clamps (10)	1·7
	Assembly	8·8
	Screws, paints, adhesive etc.	4·7
	together with:	
P	Directory retaining bar (single)	—
Q	Directory retaining bar (double) purchased separately at 2s 6d. and 4s 3d each, respectively	—

TABLE 2

Breakdown of Functions Directory Holder No. 5

1. Holds main directories (basic function).
2. Provides shelf (for additional directories).
3. Secures directories (vandal-proof).
4. Protects directories.
5. Supports weight of directories.
6. Facilitates reading of directories.
7. Is safe in use.
8. Fixes to wallboard.
9. Locks to wallboard.
10. Is readily detached from wallboard.
11. Instructs in use ("LIFT").
12. Accommodates labels.
13. Looks good.

2–13 are all secondary functions

The shelf was provided for fringe area use to accommodate those local directories which could not be contained within the main carriers. This requirement does not arise in the provinces or for that matter in central London. The cost of the shelf with the part cost of the sides is roughly 20 per cent of the whole and it was therefore decided that the facility could be omitted. Omission of the shelf thus reduces the functions of the side castings to basically that of supporting the directory carrier axle only, and for this purpose, fixing to the wallboard and direct support of the carrier axle are all that is required. This can be achieved by a roughly triangular end bracket about a quarter of the size of the present side support. The inside surfaces of the end brackets are now concealed by the directories and it was agreed that the metal lining could be dispensed with. The reduction in size of the side supports reduces the protection previously afforded to the directories but it was felt that the continuing use of press-pahn (or alternatively a transparent plastic) cover would afford sufficient protection.

The present side castings are fixed to the two back plates which are in turn fixed to the wallboard. In addition, the

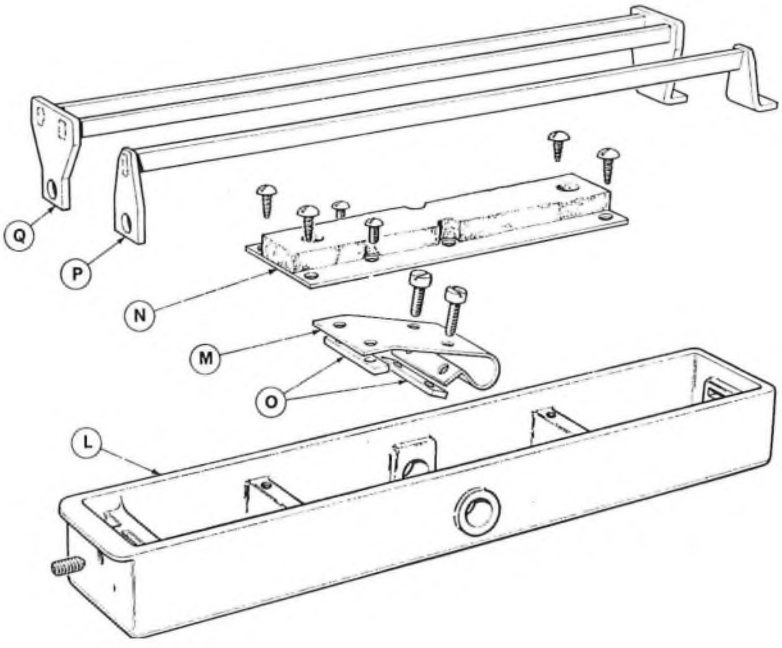

FIG. 2—The carrier of the existing directory holder

upper back-plate provides a directory-carrier stop-function whilst the lower back-plate forms part of a lock housing. The lock was provided to enable the maintenance officer to remove the directory holder completely when necessary to provide increased access to the coin box for maintenance purposes. However, with the advent of a steel cash compartment the coinbox was reorientated to give a more secure fixing; a byproduct of the change is improved maintenance access and ready removal of the directory holder is not now essential. As far as the top back plate is concerned it was agreed that the stop function was not essential and could be abandoned. By fixing the two end brackets directly to the wallboard, the two back plates and stop plate and the lock fixing brackets were eliminated.

Examination of the individual carriers revealed that about one third of the cost resulted from the elaborate arrangements for clamping around the central stainless-steel axle. These arrangements were provided to meet the function "Is safe in use," i.e. to provide damping and thus prevent fingers from being pinched on restoring directories. However, experience showed the arrangement to be ineffective since many directories were either so stiff that they were never fully returned, or were completely free. It was agreed that a cheaper and more effective solution would be to make the carrier in two halves in plastic and to clamp the two halves around the stainless steel axle as required. At the same time the edges of the carrier should be more fully radiused. Possibilities for reducing the cost of the stainless steel axle are the use of tube in lieu of rod, a less expensive material, and a simpler end fixing arrangement (circlips, suitably concealed).

Approximately 60 per cent of the cost of the present design is aluminium die and sand castings for the sides, shelf and directory carriers, and a considerable proportion of this cost is due to the finishing operations required. Redesign on the lines suggested should permit use of plastic material—structural foam, glass-loaded nylon, ABS, or PVC are suggested, with additional savings. The disadvantages of plastics would be flammability or marring due to cigarette burns. The former can be overcome by the use of a material not supporting combustion e.g. PVC, or some flame retardant grade of plastic. This still leaves the problem of marring but it was felt that this could be reduced by so shaping the top surfaces of the brackets and carriers as to cause a cigarette to roll off and by the use of suitably pigmented material, in any case it would probably be no worse than the present stove epoxy resin finish which deteriorates rapidly. It was agreed that a field trial would be necessary to determine final acceptability. The design of the plastic directory carrier would also permit the use of much simpler and cheaper directory retaining bars. Sketches of the complete holder and the carrier details are shown in Fig. 3 and 4.

An alternative approach would be to eliminate the carrier completely by providing a centrally located $\frac{1}{4}$ in diameter hole close to the spine of each directory and threading the directories onto the axle. Tests on simple models show that despite the presence of the hole in the directory no entries are obliterated and no difficulty is experienced in reading any entry. A sketch of this simplified design of holder is shown in Fig. 5; with transparent plastic covers replacing the present presspahn covers the need for labels is also avoided.

With the new design of holder screwed to the wallboard the secondary function "locks to wallboard" is eliminated, thereby saving the cost of the lock and lock fixing brackets and the need for a hole in the wallboard for this purpose. The design of the wallboard is also simplified, the four supporting studs and associated tapped-metal securing-strips at present used to fix the wallboard being eliminated. With the coinbox fitted square onto the wall there is insufficient space for the cigarette holder and this will no longer be provided in future—in any case it is official policy to discourage smoking in kiosks. As a result, the metal securing strip associated with the fixing of this shelf is also eliminated. The opportunity can also be taken to eliminate other features of the wallboard which, although essential when introduced, have become redundant over the years.

In its report the V.A. team recommended that a small contract be placed for the development of both V.A. designs of holder with priority being accorded to the simplified V.A. design in view of its expected cost advantage. Before selecting either design for large scale field trial some confirmation of durability would be required, this is particularly true of the simplified V.A. design, and to this end it was also recommended that the development should include the production of working models of both designs for trial in a busy locality. The simplified design of directory holder is estimated to cost not more than 25s, the alternative design, assuming an average of two carriers, not more than 50s and the estimated cost of the simplified wallboard is 48s. These figures coupled

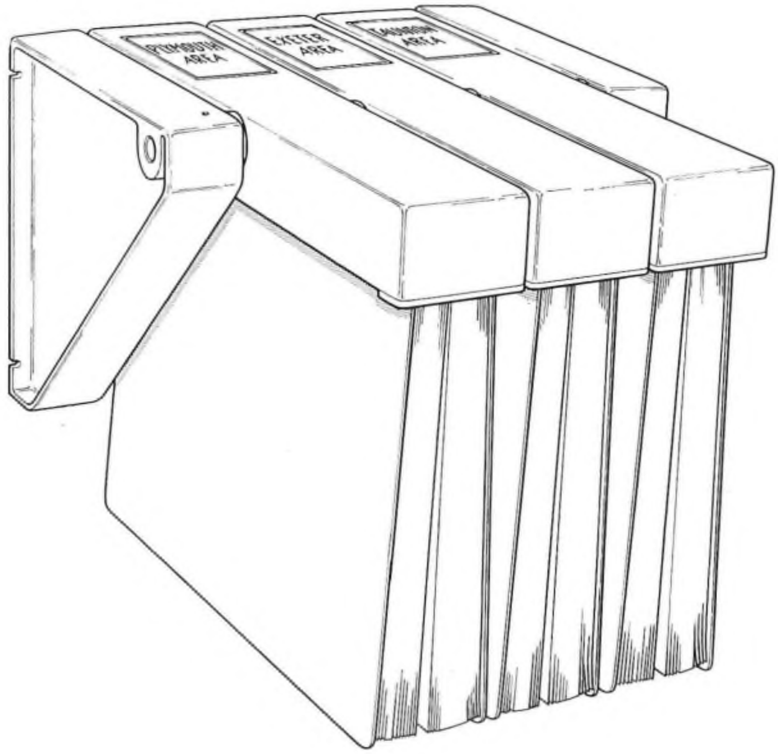

FIG. 3—Value Analysis design of directory holder

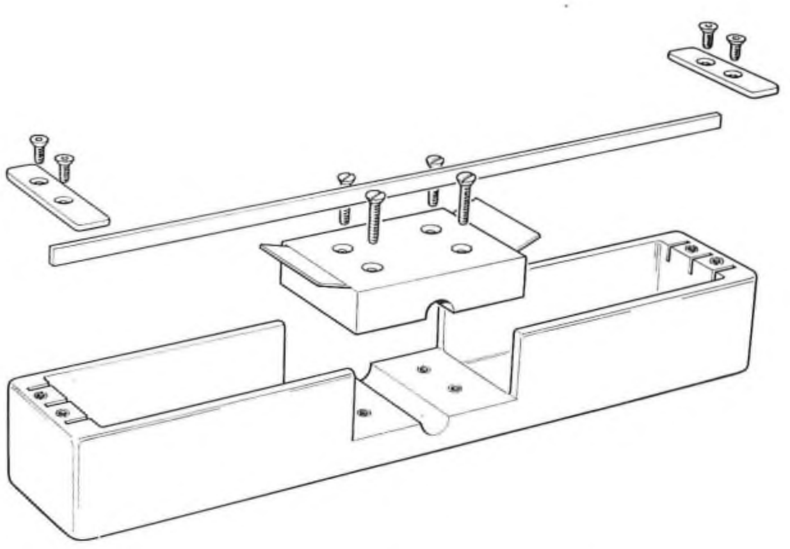

FIG. 4—The carrier of the value analysis design of the directory holder

with minor savings as a result of reduced packing costs, a simplified design of directory retaining bar, the omission of the lock and the avoidance of the need for labels, represent, on the basis of 10,000 installations a year, savings in excess of £100,000 per annum, whichever design of directory holder is finally adopted.

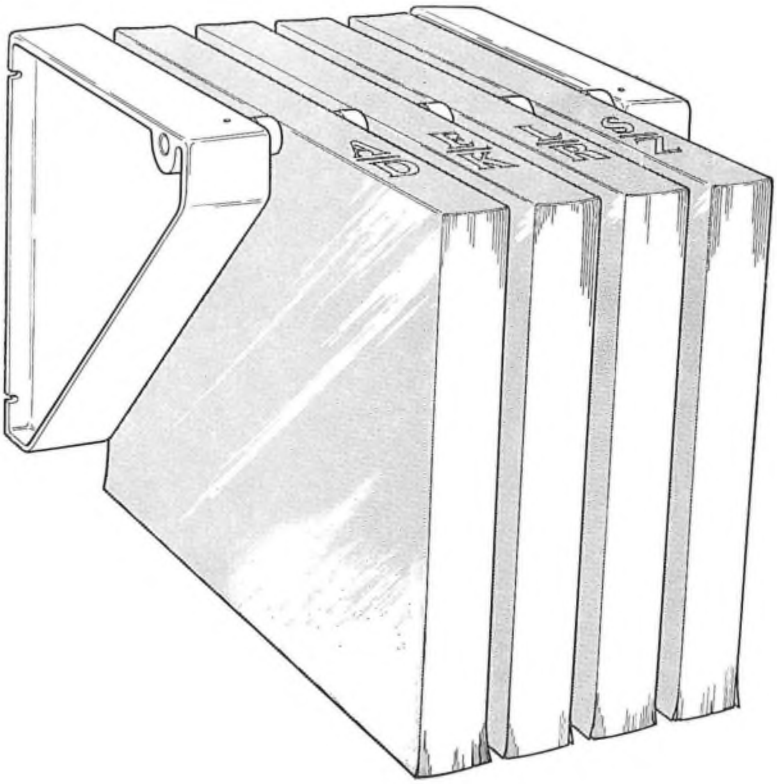

FIG. 5—Simplified value analysis design of directory holder

CONCLUSIONS

Value analysis is a relatively simple and proven common sense approach to cost reduction and represents a modern management technique that can be used to extremely good effect by an organization as large as the Post Office. Post Office management has recognized this in establishing a Value Analysis Branch organization in the Purchasing and Supply Department and with full co-operation between V.A. Branch and the Development and User Branches on the one hand, and between the Post Office and its suppliers on the other, tremendous savings can be achieved to the mutual benefit of all concerned.

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Overload Instability of Submarine-Cable Repeater Systems

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U.D.C. 621.315.28: 621.395.64: 621.3.016.35

Study of the instability observed on a submarine-cable repeater system shows that any bi-directional repeater system employing common amplifiers for the two directions of transmission is potentially unstable. The instability results from inter-band power transfer in two or more repeaters which are temporarily overloaded. Methods are described for measuring the overload performance of repeaters and for using a computer to calculate the margins against instability before a system is installed. Results are given of measurements made to check the accuracy of the calculations.

INTRODUCTION

For many years submarine-cable repeater systems have provided both directions of transmission over a single cable by using different frequency bands for the two directions. In each repeater the two bands are separated by a ring of directional filters across which is connected the common amplifier (Fig. 1). Systems of this type had been laid satisfactorily in many parts of the world, but in 1965, when the American Telephone and Telegraph Company were laying a cable in the Pacific, they encountered the phenomenon of overload instability, which makes any system of the above type potentially unstable. The instability results from power transfer between the bands by overload of the common amplifiers of two or more repeaters. Oscillation does not take place at a single frequency but involves a broad band of noise-type power in each band. It is more likely in a system with excess gain in one or more repeater sections, and it was under exceptional circumstances of this nature that the phenomenon was first observed.

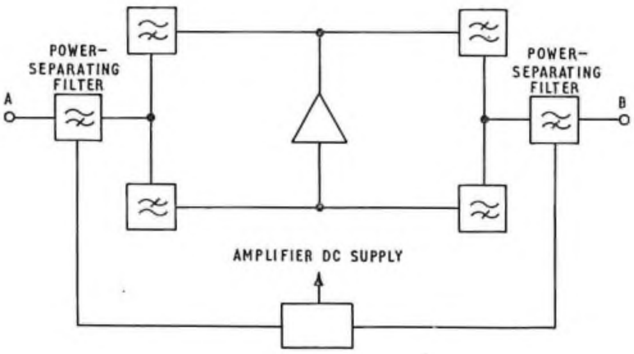

FIG. 1—Bi-directional repeater

As, at the time the phenomenon became known to the British Post Office, several systems were in production, an urgent program of work was carried out to enable these systems to be assessed before laying. The overload performance of most current types of British repeater was measured, and a computer program was written to use the measured repeater data for calculating the margins against oscillation on laid systems. Measurements on systems have been made to check the accuracy of the calculations.

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INSTABILITY MECHANISM

As was mentioned in the introduction, the phenomenon of overload instability was first encountered by the American Telephone and Telegraph Company when they were laying a system in the Pacific. It is normal practice to insert equalizers in a submarine repeater system, after every block of 10–15 repeaters, to correct for mismatches between repeater gain and cable loss, and in the American system such an equalizer was positioned at an intermediate station on an island. During the lay, because of a suspected d.c. fault, the island equalizer was by-passed. At this time the cable ship was 22 repeaters beyond this point, and when power was re-applied to the cable the system occasionally became noisy and unworkable. If power was removed and then re-applied, the noise condition disappeared. However, after another 12 repeaters had been laid the system was permanently noisy, and it remained in this condition until a spare equalizer was inserted at the island station, when the system became normal.

After some considerable thought, Bell Telephone Laboratories propounded the following explanation.

The equalizer had a loss equal to that of approximately half a cable section, and when it was by-passed there was a large amount of excess gain in that section. Thus, a burst of noise in the low-frequency (l.f.) band before this point would receive excess amplification and could overload amplifiers beyond this point. The overloaded amplifiers would produce harmonics and intermodulation products, some of which would fall into the high-frequency (h.f.) band and would be propagated in the reverse direction. These harmonic signals would receive excess amplification in the section without the equalizer and could thus overload amplifiers in the h.f. band beyond the equalizer section. These repeaters would produce intermodulation products which could fall back into the l.f. band at the original frequencies, and thus a feedback loop could be set up (Fig. 2).

The oscillation did not take place at a single frequency,

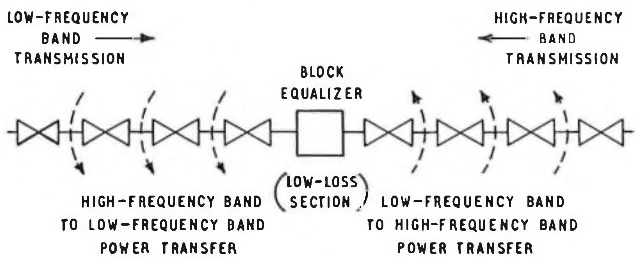

FIG. 2—Intermodulation power transfer on a system with low loss in one section

but produced a broad band of noise-type power covering both frequency bands, giving power transfer between the bands by a large number of intermodulation products. At first the oscillation was triggered by a high-level signal and could be cured by switching off for a short time. With more repeaters laid, and a greater inter-band power transfer, the basic system noise was sufficient to start the oscillation.

URGENCY OF THE PROBLEM

The attention of the Research Department was drawn to this phenomenon by representatives of the Bell Telephone Laboratories and the American Telephone and Telegraph Company, who visited the British Post Office in May 1967 for discussions on a proposed 5 MHz system between Canada and Bermuda.

At this time the British Post Office were, directly or indirectly, involved in several major submarine-cable projects. These were: a 3 MHz system, using valve repeaters similar to the Post Office type P repeater, being manufactured by Standard Telephones and Cables, Limited (S.T.C.) and to be installed by them between Portugal and South Africa; a 5 MHz system, designed by S.T.C. and with manufacture just starting, was due to be laid between the United Kingdom and Portugal in 1969; three 5 MHz systems, designed by Submarine Cables Limited (S.C.L.), and with manufacture nearly complete, were to be laid between the United Kingdom and Norway, the United Kingdom and Holland, and the United Kingdom mainland and the Channel Islands; a further 5 MHz system was under development by S.C.L. for Cable and Wireless, Limited; and the P.O. were at an advanced stage in the development of a 12 MHz repeater for use on North Sea routes.

The American system was unstable only when set in an abnormal condition, but it would be possible for a system to be unstable in its normal line-up condition, especially if there were a large increase in gain along the system due to temperature change, such as occurs in the North Sea. It also appeared probable that wider bandwidth systems were more prone to this form of instability. As it would be very expensive, if not impossible, to modify a system after it had been laid, figures for the stability margins of the above systems were required urgently.

CALCULATION OF SYSTEM STABILITY

The Bell Telephone Laboratories had outlined the work that they had carried out to determine whether their 6 MHz S.F. system would be satisfactory when laid. As this method appeared to be the best approach, the Research Department started an urgent program of work to develop similar facilities for calculating the stability margins of systems.

There were two main problems to be solved: firstly, data were required to characterize the repeater performance when in severe overload; and secondly, a method of calculation was needed to determine whether a number of such repeaters, when connected in a system with various misalignments, would recover from a temporary overload or maintain an oscillating condition. An empirical method of measurement was used to determine the repeater performance, and the calculations were performed by simulating the system on the Post Office Elliott 503 computer.

Repeater Characterization

Considerable care is taken in the design of repeaters to ensure that a system will meet specified intermodulation limits when fully loaded with normal-level signals. Traffic levels are chosen to make distortion due to overload negligible, i.e. the signal peaks overload the repeater for not more than 1 per cent of the busy hour. Thus, the performance below overload, where second and third order products predominate, has always been examined carefully, but the effects of very severe overload have received much less attention.

For normal signal levels it is possible to calculate the magnitude and frequency distribution of the repeater intermodulation from a fairly simple power-series approximation. Once overload is reached, however, higher-order products increase rapidly and the power series becomes so unwieldy that another approach must be considered. No mathematical method seemed suitable, so recourse was made to an empirical method.

The basic information required was the magnitude of the power transfer, from one band to the other, for various levels of loading, up to and above the overload point. As the system oscillation produced a noise-type signal it seemed reasonable to use white noise as the signal input.

The method used was to load the repeater with white noise in both bands and measure the difference between the actual output in each band and the ideal output of a linear repeater. An actual output in one band greater than the ideal output, called an expansion, is caused by intermodulation power transfer into the measured band. Similarly, an actual output less than the ideal output, called a compression, is caused by intermodulation power-transfer out of the measured band. By making measurements of the expansion or compression, first in the l.f. band and then in the h.f. band, with a range of input levels increasing in 1 dB steps in each band, two matrices are obtained describing the intermodulation power transfer into or out of each band for any combination of l.f. band and h.f. band loading.

Each matrix will comprise some 1,000 figures, and may be plotted as a 3-dimensional graph. Typical plots for a 3 MHz repeater type P are shown in Fig. 3 and 4. From these two matrices the actual l.f. band and h.f. band output may be obtained for any combination of l.f. band and h.f. band input. Fig. 4, for example, shows that with a h.f. band input giving an ideal output of +2 dBm and a l.f. band input giving an ideal output of +19 dBm, the expansion is 4·8 dB, producing a true h.f. band output of +6·8 dBm. Thus, the high-level signal in the l.f. band is overloading the repeater and producing intermodulation products whose frequencies lie in the h.f. band. The power of these adds to the low-level signals in the h.f. band to give an actual output greater than the ideal. It is this increase in signal occurring at many repeaters along the system which gives rise to the instability.

Computer Calculation

The computer program employs an iterative method to calculate the output signal levels of each repeater in the system and to check whether these signals return to their normal values after the system has been temporarily overloaded.

Assume that the repeaters are numbered from 1 to N in the l.f. direction of transmission and that, in the following discussion, when a signal passes from the output of one repeater to the output of the next repeater, the level is adjusted for any excess loss or gain of that section compared with an ideal section. The steps of the calculation are then as follows:

(*a*) Apply normal-level signals at each terminal and calculate the output levels of all repeaters on a linear basis. These levels are called the initial levels.

(*b*) Apply a high-level signal in one band, say the l.f. band, sufficient to overload some amplifiers along the system, and calculate the output level of each repeater in this band on a linear basis.

(*c*) With the high-level signal calculated in (*b*) as ideal output in the l.f. band, and the normal signal as ideal output in the h.f. band, the true h.f. band output of the Nth repeater is obtained from the h.f. band expansion matrix.

(*d*) For repeater $N-1$, the l.f. band high-level ideal output calculated in (*b*), and the true h.f. band output of repeater N, calculated in (*c*), allow the true h.f. band output

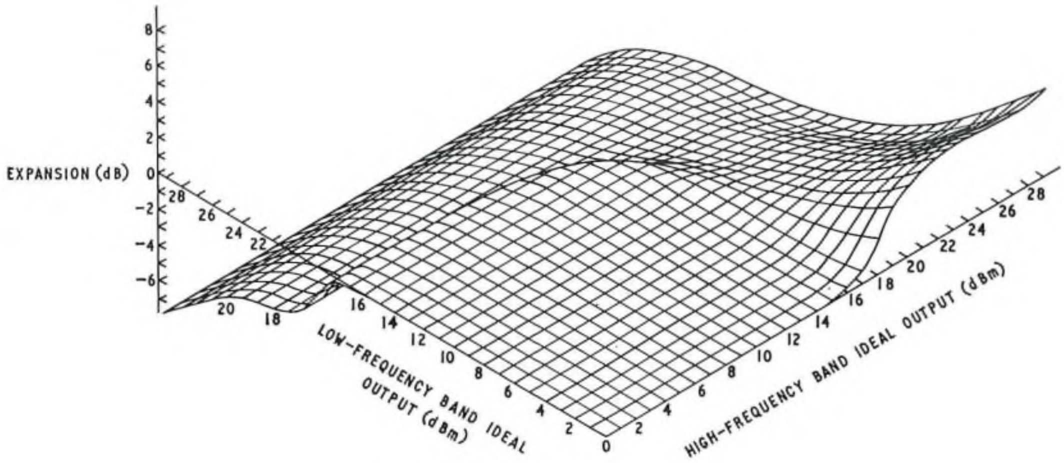

FIG. 3—Low-frequency band expansion matrix for Post Office 3 MHz type P repeater

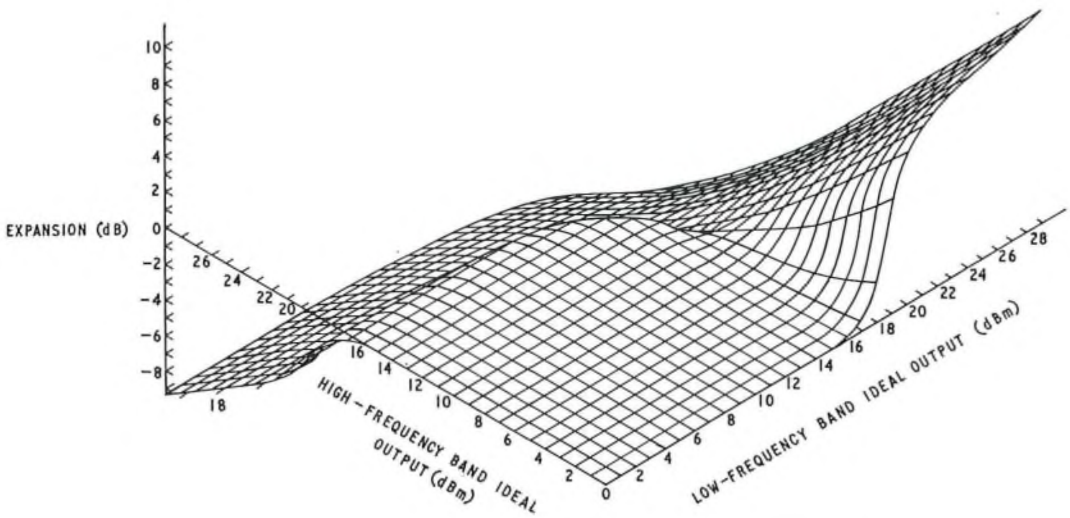

FIG. 4—High-frequency band expansion matrix for Post Office 3 MHz type P repeater

to be determined. This process is repeated until repeater 1 is reached.

(*e*) The high-level l.f. band input to repeater 1 is replaced by the normal-level signal. Then, by using this signal and the h.f. band output of repeater 2, as calculated in (*d*), the new l.f. band output of repeater 1 is determined from the l.f. band expansion matrix.

(*f*) For repeater 2, the l.f. band output of repeater 1, as calculated in (*e*), and the h.f. band output of repeater 3, as calculated in (*d*), allow the new l.f. band output to be calculated. This is repeated until repeater N is reached.

(*g*) The calculation is then repeated in the h.f. band direction starting from repeater N, whose l.f. band ideal output is as calculated in (*f*), and whose h.f. band ideal output is the normal level signal.

The iterations then proceed in h.f.-band and l.f.-band directions, alternately, until a steady state has been reached. For signal levels between the 1 dB measured steps of the matrices the computer linearly interpolates and, if values are called for outside a matrix, extrapolation is used from the last two figures of the row or column.

Referring to Fig. 5 the calculation may be expressed mathematically as follows:

$P_H(n, k)$ = h.f.-band output power of repeater n on kth iteration,

$P_L(n, k)$ = l.f.-band output power of repeater n on kth iteration,

$G_L(n)$ = excess l.f.-band gain from the output of repeater $(n - 1)$ to the output of repeater n.

$G_H(n)$ = excess h.f.-band gain from the output of repeater $(n + 1)$ to the output of repeater n,

$F_H[P_L, P_H]$ = repeater h.f.-band expansion with ideal output powers of P_L and P_H in l.f. and h.f. bands, respectively,

$F_L[P_L, P_H]$ = repeater l.f.-band expansion with ideal output powers of P_L and P_H in l.f. and h.f. bands, respectively,

$$P_H(n, k) = P_H(n + 1, k) + G_H(n) + F_H[P_L(n - 1, k - 1) + G_L(n), P_H(n + 1, k) + G_H(n)],$$ and

$$P_L(n, k + 1) = P_L(n - 1, k + 1) + G_L(n) + F_L[P_L(n - 1, k + 1) + G_L(n), P_H(n + 1, k) + G_H(n)]$$

In practice, it is assumed that a steady state has been reached in the calculation when the change in output level does not exceed 0·25 dB on any repeater, on two successive iterations in each direction. If all output levels are then the same as the initial levels, the system has recovered from the temporary overload and is stable. If the levels on any repeater are higher than the initial levels, the system is oscillating.

Facilities are incorporated in the program for specifying the details of the system. Thus, gain or loss misalignments, due either to repeater-gain error or to temperature effects, may be specified in each band independently, and different values may be given to different sections. Equalizers may be inserted at any position in the system to correct for the misalignments.

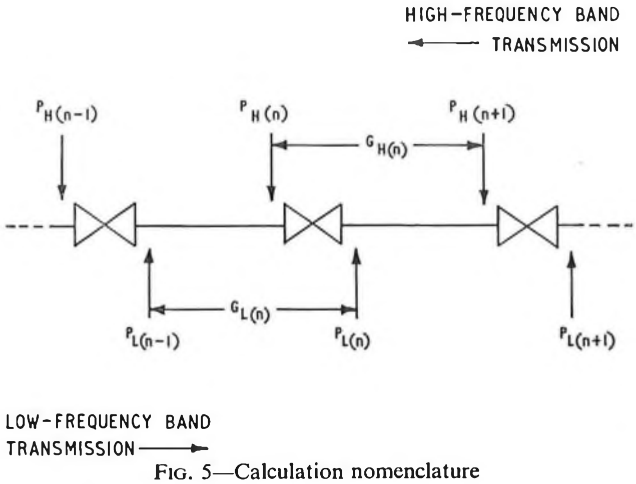

FIG. 5—Calculation nomenclature

If some repeaters or equalizers contain limiters, a second pair of matrices is required to specify their overload performance, and these limited units may then be called in by the computer at any position in the system.

Each computer run only determines whether the particular set of conditions specified results in a stable or unstable system. To determine the critical values of misalignments successive runs must be made with different values of misalignment. Before one can be certain that a specified condition is stable, the calculation must be performed with various values of the temporary overload signal, since the method of calculation allows a system to appear stable when it is subjected to a too-severe initial overload.

OVERLOAD STABILITY MARGINS

Margins Calculated

In order to assess and compare the various cable schemes four tests were established. All of the data derived from these tests are not always directly applicable, but are useful as a comparison. Various combinations of the tests are possible, to assess particular systems accurately.

The four tests are:

(*i*) *Gain Test*. The gain test calculates the maximum gain per repeater section which can be added to the planned system-shaping and temperature misalignments. The same value of extra gain is added to each repeater section and is assumed to be completely equalized at each ocean block-equalizer. This gives the maximum ocean block-gain misalignment.

(*ii*) *Loss Test*. The loss test is similar to (*i*) except that the maximum extra loss per section, equalized at each ocean block-equalizer, is calculated. This gives the maximum ocean block-loss misalignment.

(*iii*) *Step Test*. The system is assumed to have no block misalignments, only planned system-shaping and temperature misalignments. A lumped-gain step is inserted near the middle of the system, at a point where an ocean block-equalizer is proposed, and the maximum permissible value is calculated. It is necessary to carry out this test for several ocean block-equalizer positions to ensure that the worst position has been found.

(*iv*) *Slope Test*. A small amount of excess gain is added in each repeater section, but not equalized at the ocean block-equalizers, and the overall extra gain slope of the system calculated.

The gain test and loss test determine the maximum block-misalignment which can be allowed during the lay. Both tests assume that the misalignments are uniform over both bands and are the same value for every repeater. They also assume perfect equalization in the block-equalizers, whereas in practice some residual misalignment is inevitable. The step test is mainly of academic interest, since its conditions are unlikely to occur in a normal system, but it provides a useful comparison between systems. The slope test gives a measure of the temperature and aging effects which can be accommodated by a system.

In each test different values of gain or loss may be applied in the h.f. and l.f. bands. The tests may be carried out for any presumed cable temperatuie, the worst condition usually being the lowest temperature, but care must be taken to ensure that some other temperature does not show smaller margins.

Margins Required

At the present stage it is impossible to specify accurately the required margins. If excessive margins are specified considerable expense may be involved obtaining them, and the methods employed may worsen other system parameters. Needless to say, specifying margins which are too small could be courting disaster. To clarify the position the four tests were carried out on well-established existing systems on which no indication of this noise oscillation has been observed. Typical margins for a 1 MHz, 160-circuit systems are as follows:

(*i*) Gain test: 1·7 dB/section, 17 dB/ocean block,
(*ii*) Loss test: 1·7 dB/section, 17 dB/ocean block,
(*iii*) Step test: 15 dB
(*iv*) Slope test: 0·23 dB/section: 22·8 dB for complete system.

Since this system has shown no indication of the noise phenomenon, it is reasonable to assume that if all future systems were designed to have the above margins they would be satisfactory.

Tests on systems of greater bandwidths have revealed that the above margins cannot easily be obtained, and it is necessary to considered how far they may be reduced with safety.

Generous margins are desirable for the following reasons:

(*a*) The analysis is based on measurements on one repeater, usually a very early model, so allowance must be made for later production repeaters having slightly different transfer characteristics.

(*b*) The repeater transfer characteristics and the method of calculation are based on white-noise loading, and it is known that other spectral distributions can occur in an oscillating system and may give different margins.

(*c*) The system conditions are calculated using power addition; no allowance is made for possible voltage addition over some parts of the frequency spectrum.

(*d*) During switch-on, system conditions may pass through, and lock into, an unstable condition.

(*e*) Additional temperature misalignment in an unusually severe winter can considerably reduce the stability margins.

(*f*) A system with a small margin may exhibit a form of ringing, in which a momentary peak produces a longer burst of intermodulation noise.

A revised set of target margins, based on calculations on several 3 MHz and 5 MHz systems, is as follows:

(*i*) Gain test: 1 dB/section,
(*ii*) Loss test: 1 dB/section,
(*iii*) Step test: 10 dB,
(*iv*) Slope test: 20 dB for complete system.

It may be that even these margins are more than are necessary, but until more practical experience is gained it is essential that future systems should have overload stability margins approaching the above.

PRACTICAL TESTS

In order to make the calculations manageable several simplifications have been made, both in the measurement of the repeater characteristics and in the computer calculations. Since some system calculations indicated that modifications were required to obtain satisfactory margins, inevitably involving expense, and, possibly, delay to the system installation, it was essential to check the computer calculations with practical tests.

The simplest practical test is to connect two repeaters in tandem and to reduce the attenuation between them until an oscillatory condition is set up. An extension is to take a block of repeaters, i.e. during the loading of the cable ship, and to arrange for a gain step to be inserted at various points to produce oscillation.

It is not possible to reduce the attenuation between sections of a laid system, so other means must be employed to bring the system into oscillation, in order that a check may be made between calculation and measurement. The method used was to increase power transfer between bands via the terminal equipment until oscillation could be sustained.

Two-Repeater Tests

Comparison between computed and measured overload stability-margins was obtained in the laboratory by arranging two repeaters from a 3 MHz system to be joined together in such a way that noise oscillation occurred. To keep the correct cable-shape attenuation characteristic, and yet allow a controlled amount of flat excess gain in each band, the arrangement shown in Fig. 6 was used. Initially, the attenuator

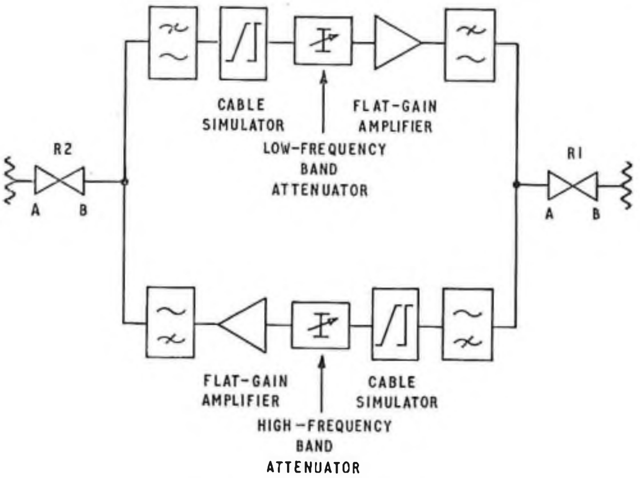

FIG. 6—Two-repeater test

completely cancelled out the gains of the flat amplifiers and, as the attenuator settings were reduced, each 1 dB step produced 1 dB of excess gain. The range of measured and computed excess gains shown in Table 1 demonstrates that

TABLE 1
Two-Repeater Test for Oscillation

System Condition	Measured Excess Gain (dB)		Computed Excess Gain (dB)		Error of Computed Gain (dB)
	Low-Frequency Band	High-Frequency Band	Low-Frequency Band	High-Frequency Band	
Stable	16	18	16	18	0
Unstable	16	19	16	19	
Stable	14	20	14	20	0
Unstable	14	21	14	21	
Stable	12	22	12	21	−1
Unstable	12	23	12	22	
Stable	10	24	10	23	−1
Unstable	10	25	10	24	

under laboratory conditions very close agreement exists between measured and computed stability conditions.

Terminal Transfer Tests

Tests were conducted by the Post Office Research Department, using a simulated cable system consisting of two terminals, two repeaters, and one length of simulated cable. With the co-operation of the manufacturers and overseas administrations, similar tests were conducted on much longer systems.

The tests were arranged to transfer energy from the h.f. band to the l.f. band at the A terminal and from the l.f. band to the h.f. band at the B terminal. The transfer had to be on a non-linear basis to prevent sinusoidal oscillation occurring before the noise-oscillation conditions could be reached. This was achieved by causing the received signal to overload an amplifier so that some of its intermodulation products fell in the send band. The level of overload was controlled by an attenuator, referred to as the transfer attenuator, and a series of attenuator settings giving stable and unstable system conditions was obtained. A transfer matrix was measured for each terminal, giving the transferred energy in the same

TABLE 2
Terminal Transfer Test: Laboratory System

System Condition	Measured Attenuation (dB)		Computed Attenuation (dB)		Error of Computed Attenuation (dB)
	A Terminal Z1	B Terminal Z2	A Terminal Z1	B Terminal Z2	
Stable	18	40	21	40	−3
Unstable	17	40	20	40	
Stable	21	29	21	29	0
Unstable	21	28	21	28	
Stable	22	29	22	28	1
Unstable	22	28	22	27	
Stable	23	28	23	27	1
Unstable	23	27	23	26	
Stable	24	27	24	26	1
Unstable	24	26	24	25	
Stable	25	27	25	26	1
Unstable	25	26	25	25	
Stable	26	25	26	26	−1
Unstable	26	24	26	25	
Stable	27	24	27	25	−1
Unstable	27	23	27	24	
Stable	28	23	28	22	1
Unstable	28	22	28	21	
Stable	29	22	29	21	1
Unstable	29	21	29	20	

TABLE 3
Actual System with 53 Repeaters

System Condition	Measured Attenuation (dB)		Computed Attenuation (dB)		Error of Computed Attenuation (dB)
	A Terminal Z1	B Terminal Z2	A Terminal Z1	B Terminal Z2	
Stable	11	∞	13	∞	2
Unstable	10	∞	12	∞	
Stable	11	16	13	16	2
Unstable	10	16	12	16	
Stable	14	13	14	13	0
Unstable	14	12	14	12	
Stable	16	12	16	13	1
Unstable	16	11	16	12	
Stable	∞	11	∞	12	1
Unstable	∞	10	∞	11	

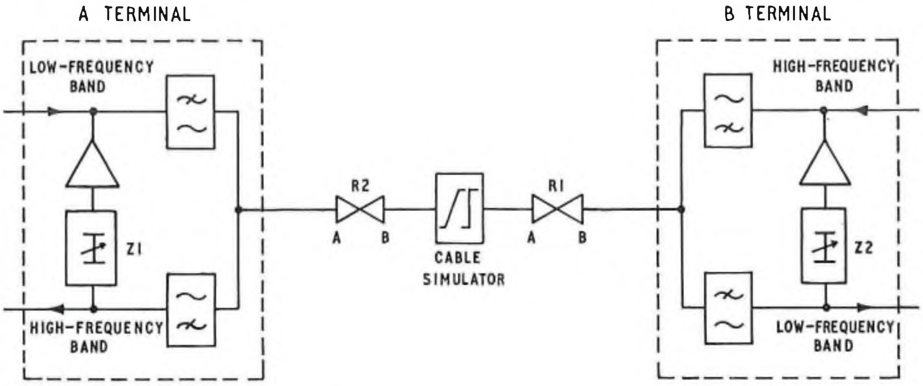

FIG. 7—Terminal transfer test

form as a repeater expansion matrix. Calculations were made to obtain a range of settings of Z1 and Z2 (the transfer attenuators, Fig. 7) which caused the system to be stable and unstable as in the practical test. Table 2 shows the small difference between computed and measured values obtained in the laboratory tests, and Table 3 illustrates that a similar correlation can be obtained from field tests.

METHODS OF INCREASING STABILITY MARGINS

Some of the systems investigated showed margins less than the limits set, and various methods of increasing the margins were examined.

One obvious method for new designs would be to rearrange the positions of the directional filters and then to use separate amplifiers for each direction of transmission. The filters would reduce the inter-band power transfer to a negligible amount. This arrangement makes the repeater more expensive, but it will be necessary for long-distance wideband systems.

For oscillation to take place, high-level signals must be present in both bands, thus any method of preventing the build-up of signals along the system will increase the stability margins. As level pre-emphasis is normally used the margin from traffic load to overload point is greater than necessary in the low-frequency band, and it would be possible to provide limiters operating in this band without worsening the normal system performance. The limiters will be most effective if incorporated in each repeater, but sufficient improvement can sometimes be obtained by inserting limiters in the ocean block-equalizers. On systems with large changes in gain along the system due to temperature variations, it is difficult to set the limiter level so that improved stability margins are obtained without worsening the normal system performance. As the traffic signal-to-noise ratio is usually good in the l.f. band it is possible to add excess loss along the system in the l.f. direction, either in each section, or by steps in the block equalizers. This will reduce the build up of signals along the system and thus give increased stability margins. The improvement obtained by this method is often as great as that obtained by the use of limiters, and it has the advantage that the effect on normal system performance can be calculated easily, and much larger errors in the equalization during the lay can be tolerated.

Modifications of the amplifier to improve the margins are difficult to design, as the amplifier is working in a markedly non-linear region. Cut-and-try methods have sometimes given improvements, and even quite small changes in the transistor-operating conditions and d.c. stabilization have produced considerable changes in the matrices and thus in the calculated margins.

SYSTEM CALCULATIONS

Submarine Cables, Limited (S.C.L.), Standard Telephones and Cables, Limited (S.T.C.), Cable and Wireless, Limited, and the Post Office co-operated in making tests on several types of repeater; some have already been manufactured and installed and others are in the course of manufacture or development.

(*a*) The 160-circuit valve repeater, type U, designed by S.T.C. and used on part of SEACOM, provides 160 3 kHz circuits in the frequency bands 60–552 kHz and 672–1,164 kHz. Matrices were measured on a production repeater at S.T.C., and calculations made on a 99-repeater system with no temperature misalignment. Very good margins were obtained, as shown in a previous section. Several systems of this type have been working satisfactorily for up to 3 years.

(*b*) A P.O.-designed 3 MHz valve repeater, type P, was modified by S.T.C. for use on the South Africa–Portugal system. The repeater provides 360 3 kHz circuits in the bands 312–1,428 kHz and 1,848–2,964 kHz. Matrices measured by S.T.C. were used for the system calculations; tests on a P.O. model repeater gave very similar matrices. Calculations for a link with 300 repeaters gave margins greater than the minimum requirements. This system is in deep water over its whole length and thus it has a negligible gain slope due to temperature change. Calculations made on a 600-repeater link showed no significant reduction in margins.

As this repeater provides redundancy by using an amplifier with twin forward paths and a common feedback path, tests were made of the effect of having one repeater working with a single forward path. The faulty repeater was placed, in turn, either side of the gain step and gave a reduction of 1 dB in the step test margin.

This system is now installed and working, and the longest link contains 275 repeaters.

(*c*) Designed by S.C.L., for North Sea systems, the 5 MHz type T transistor repeater provides 480 4 kHz circuits in the bands 312–2,292 kHz and 2,792–4,772 kHz. Early calculations showed that, of the three routes planned, the United Kingdom–Holland system with 14 repeaters and the Bournemouth–Jersey system with 18 repeaters were satisfactory, but that the United Kingdom–Norway system, with 53 repeaters and a possible gain slope of 15 dB at 4,772 kHz due to temperature change, would have insufficient margins as originally planned.

As manufacture of these systems was almost complete, it was decided to change the program and lay the Bournemouth–Jersey system first instead of the United Kingdom–Norway system. This allowed tests to be made on an installed system, by transferring power via the terminals, to confirm that the practical margins were not worse than the calculated values. Various methods of increasing the margins on the United Kingdom–Norway system were then examined. The use of limiters in the l.f. path of each equalizer only gave a small improvement, and the method finally adopted was to insert 1·8 dB of loss in the l.f. band in each of the four block-equalizers. The system is now installed and working. The results given in Table 3 show that good agreement is obtained between calculated and measured figures when the system is made to oscillate by power transfer via the shore terminals. There is thus confidence that the calculated margins have been obtained.

(*d*) The 5 MHz type Y repeater was designed by S.T.C. for use on the United Kingdom–Portugal system and provides 640 3 kHz circuits in the bands 312–2,292 kHz and 2,792–4,772 kHz. The system, due to be installed mid-1969, will contain 128 repeaters with equalizers after every 12 repeaters. Initial measurements on a model repeater showed that the system would have insufficient margins, and, as production was due to commence, S.T.C. carried out an urgent program of modification of the amplifier to improve the conversion matrices.

The system has a large seasonal temperature change over 24 repeater sections at the United Kingdom end, but a negligible change over the remainder of the system. In a case like this, the best system signal-to-noise ratio in the h.f. band is obtained by arranging for the major part of the system to operate at the maximum allowable level for all temperature conditions. This can be achieved by using non-standard cable-section lengths for the 24 sections. If the United Kingdom is the B station (h.f. transmit) the sections are shorter than normal, and if the United Kingdom is the A station (l.f. transmit) the sections are longer than normal. Although these two arrangements give the same system signal-to-noise ratio, the margins against overload instability are much better if the United Kingdom is the A station; an improvement of 10 dB is obtained in some margins.

With the improved matrices, and with the United Kingdom as the A terminal, satisfactory margins were obtained.

(*e*) The 5 MHz type Z repeater is a development by S.C.L. of their type T repeater. For the Canada–Bermuda (CANBER) system 80 repeaters will be used with five equalizers, the first after repeater 16 from Canada and then after every 13 repeaters.

As only a small part of this system is subjected to temperature change (13 repeaters at the Canadian end) improved margins are obtained if Canada is the A station. Calculation shows that the system stability margins are governed, almost entirely, by the long first block of 16 repeaters, which includes the sections subjected to the temperature change. For use on CANBER, the type T amplifier circuit was modified to increase the output power and improve the system signal-to-noise ratio. As these modifications worsened the conversion matrices and gave inadequate stability margins, S.C.L. further modified the amplifier to improve the matrices. Satisfactory margins have now been obtained.

(*f*) In 1967 and 1968 the Research Department was examining the design of a 12 MHz repeater to carry 1,140 circuits for possible use on North Sea systems or for long-distance systems, and preliminary studies were made of overload instability for such systems.

A North Sea system, such as a United Kingdom–Germany system, would have about 45 repeaters, and the worst problem would be the very large change of temperature, which would give an attenuation swing of $\pm$ 17 dB at the top frequency. Initial calculations showed that modifications to the repeater would be required to give satisfactory margins. Two methods were considered: (*i*) the use of separate amplifiers for each direction of transmission; and (*ii*) the connexion of a limiter at the mid-point of the l.f. band output directional filter to prevent the input level to the next repeater from reaching a value which would cause overload. Additional sections were needed in the l.f. filter to prevent distortion from the limiter entering the h.f. band. Calculations from matrices measured on a laboratory model showed that satisfactory margins could be obtained if a shore-controlled switchable equalizer was inserted at the mid-point of the system to compensate for half of the temperature variation of attenuation. This equalizer would be necessary, in any case, to obtain a satisfactory signal-to-noise ratio for the system.

For a long system, up to 4,000 nautical miles, temperature variation is usually small and the main problem is the large number of repeaters. Calculation showed that the repeater with a limiter would not give satisfactory margins and, as an improvement in the system signal-to-noise ratio was also required, it was decided to use separate l.f. and h.f. amplifiers.

The manufacturer awarded the contract for the North Sea systems has also decided to use this form of repeater.

SOURCES OF ERROR IN MEASUREMENTS AND CALCULATIONS

Measurement of the repeater matrices has generally been made by loading the repeater with white noise at its input. It is known, however, that when a system is oscillating the noise spectrum does not always resemble white noise, as a squegging condition has been observed, and the peak-to-r.m.s. ratio appears, from oscilloscope observation, to be greater than for white noise.

Matrices must be measured over a very wide range of loadings to prevent errors occurring when the computer extrapolates beyond the edges of the matrix.

On some repeaters the supervisory arrangements operate by transferring a narrow band of signals from one band to the other, to allow loop measurements to be made to each repeater in the system. Care must be taken to ensure that such methods do not worsen the matrices, either actually, or apparently, by false operation of the supervisory system when measuring the matrices.

The noise loading and the power transferred are measured as the r.m.s. power over the whole l.f. or h.f. band. In practice, the levels are not uniform with frequency, and it is known that all parts of the band are not equally important in maintaining the oscillation.

The computer calculation is a step-by-step process looking at each repeater in turn, and it is possible for the calculation to pass through the unstable condition and give an apparently stable system if the initial overload signal is too large. Thus, calculations must be made with a range of overload signals.

CONCLUSIONS

The phenomenon of overload instability poses a further problem to be examined during the development of a system using repeaters with common amplifiers for the two directions of transmission. The method of calculation described has given reasonable agreement between measured and calculated results on the check tests which have been possible. However, it is not normally possible to measure the actual system margins in the form calculated. The method relies on measurements made on a model repeater, and, therefore, the calculations cannot be made until the repeater development has reached an advanced stage. At this time it is usually difficult to carry out modifications if the margins are inadequate. Because of the various uncertainties the suggested design margins are fairly generous compared with the misalignments which normally occur during the system equalization.

Although overload instability caused great anxiety and involved those concerned in considerable work, in only one instance was the completion of a system delayed. For wider bandwidth systems of the future it is probable that separate amplifiers for each direction of transmission will be the normal arrangement.

ACKNOWLEDGEMENTS

This work has involved many people, and the authors would like to thank the Bell Telephone Laboratories for indicating the mechanism of oscillation and their method of calculation, Standard Telephones and Cables, Limited, Submarine Cables, Limited, and Cable and Wireless, Limited, for help in measurements on repeaters and systems. Particular thanks are due to Mr. B. J. Woods for writing the computer program and helping with the calculations.

Repertory Diallers

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U.D.C. 621.395.636:621.326.544.9

Repertory diallers enable an individually selected variety of national or international calls to be set up automatically by a simple operation, such as the pressing of a button. Three types are described which use three fundamentally different methods of information storage. All give a considerable time and effort saving over the conventional dial.

INTRODUCTION

A repertory dialler is a device which can be programmed with a repertoire of telephone numbers, so that by a simple operation the user can cause a selected number to be automatically dialled.

About thirty-years ago the Post Office introduced the Autodials No. 1 and No. 2, which were mechanical repertory diallers, the digits of the telephone number being represented by teeth on a brass disc. To dial a number, pulsing contacts were positioned so that they were operated by the teeth when the disc rotated. For various reasons the production of autodials was discontinued.

In recent years there has been a revival of interest in repertory diallers and the Post Office has been studying the market requirements of three categories of dialler. For marketing purposes these three types are known as the Key Callmaker, Tape Callmaker and Card Callmaker. Engineering titles are Autodial 100 series, Autodial 200 series and Autodial 300 series, respectively. The Post Office has sponsored the development of the key and card callmakers and purchased a quantity of tape callmakers for market trials. The three autodials are described briefly below.

KEY CALLMAKER

The Autodial No. 101A is an executive-style instrument, giving access to any one of 32 telephone numbers at the press of a button. A simple amplifier and loudspeaker are provided to monitor the progress of a call, so that the handset of the associated telephone instrument need only be lifted for conversation when the call has matured. The dialler, shown in Fig. 1, comprises a desk tablet, the Key Unit No. 1A, which measures 9 in × 7½ in × 3½ in high, and a wall-mounted unit, the Translator No. 1A, with an associated mains-driven power unit.

The Key Unit No. 1A houses the 32 address buttons, arranged in four columns of eight, and a further button for cancelling calls. The buttons have a face area of 1·25 in × 0·3 in and each is provided with a paper designation label protected by a transparent-plastic cap. Each button has a single sealed make contact which is operated by the movement of a permanent magnet. Once depressed, an address button is locked down by a solenoid to hold the contact made for as long as the autodial is controlling the call. Located in front of the address buttons, beside the cancel button, is a miniature loudspeaker for the monitor facility. On the other side of the cancel button are two warning lamps. One is lit when the autodial is operational, the other when a call is being dialled or held.

The Translator No. 1A, which should be mounted in a discrete but accessible position, contains the telephone-

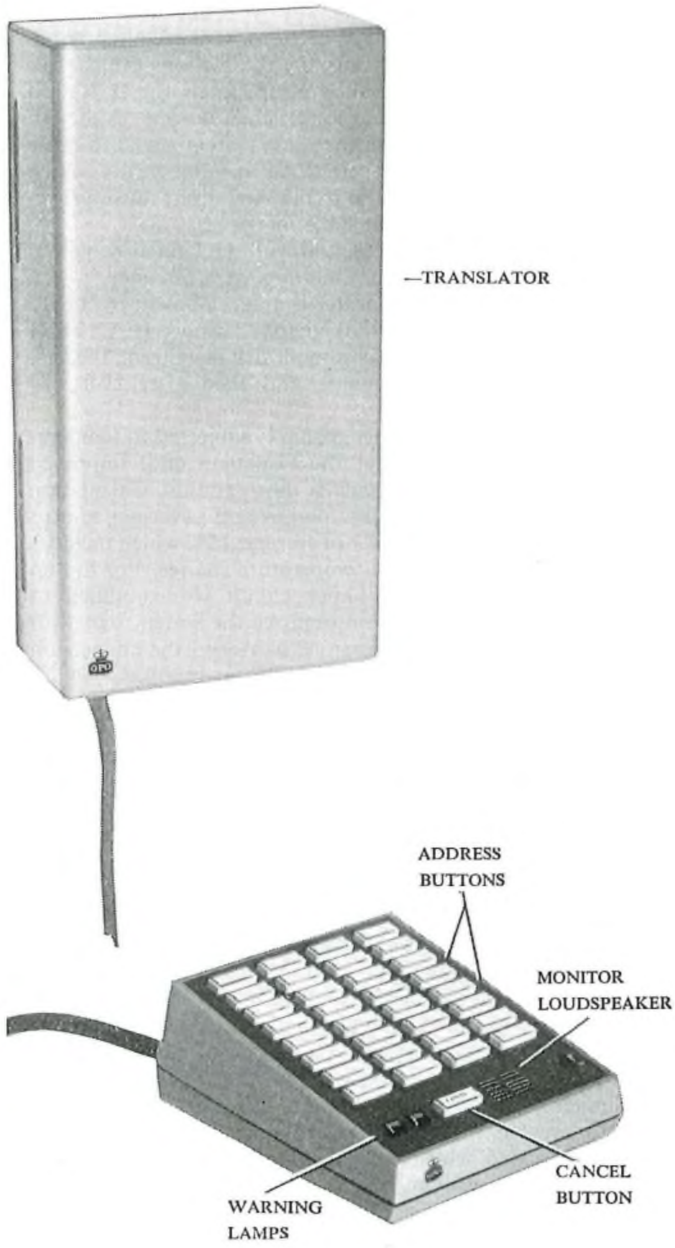

FIG. 1—Autodial No. 101A

address translation field and all the electronic circuitry. The translation field (Fig. 2) has 32 groups of 13 tags, one group associated with each address button. The first tag of each group is labelled ACCESS and the other tags are labelled 1–12.

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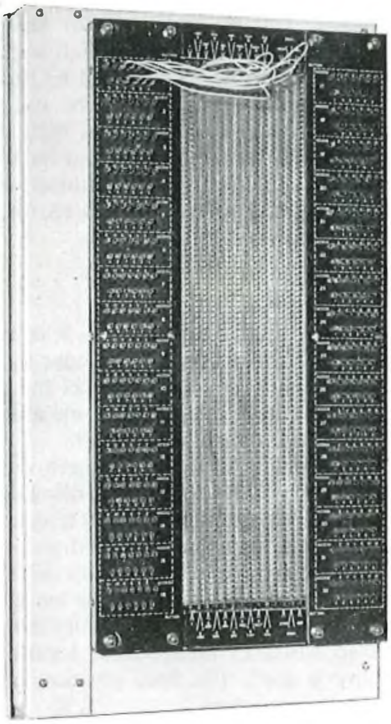


FIG. 2—Translator No. 1A

Between the two columns of tag groups are 14 slotted bars representing digit values 1–0, EXCHANGE, ISD, STOP, and a spare bar which can be cross connected to any other bar to give extra connexion capacity. Wire jumpers, 4½ in long, with crimped connectors, are used to connect the tags to the bars. The jumpers are supplied in four colours, red, white, blue and black, to assist identification if number changes are required.

Address Translation

To programme a telephone number, tag 1 of the chosen address group is jumpered to the digit bar corresponding to the first digit of the telephone number, tag 2 to the bar corresponding to the second digit, and similarly for the other digits. After the last digit has been connected, the next free tag is jumpered to the STOP bar, to provide an end-of-number signal.

Public-network calls from p.a.b.x. extensions are normally obtained by dialling 9 to gain access to the public exchange. On receipt of dial tone the remainder of the number is dialled. By jumpering the ACCESS tag of an address to the EXCHANGE bar, the autodial can be programmed to dial 9, pause for two seconds and then transmit the telephone number.

When an international number is required, the international access code 010 (or 9010 from a p.a.b.x. extension) is set up by jumpering the appropriate ACCESS tag to the ISD bar, the remainder of the number being connected as before.

Exchange-Line Connexion

The autodial is designed to be connected between the incoming line and the telephone installation, and is therefore provided with independent pulsing and line-hold circuits (Fig. 3). Because the autodial is connected to a line rather than a telephone instrument, it is not suitable for connexion to certain installations, such as p.b.x. switchboards.

The pulsing-relay contact is a mercury-wetted reed with a standard spark quench. During dialling the telephone line is short-circuited behind the pulsing contact by the mask-relay contact. At the end of dialling this releases and allows the monitor amplifiers and loudspeaker to reproduce supervisory tones and called-subscriber answer. The monitor amplifier is provided with automatic gain control so that tones in the level range −30 dBm +6 dBm can be reproduced.

Outline Circuit Operation

As an example, assume address No. 4 has been programmed with the local director number 246 8071. To call this number the user presses button 4 which triggers the control circuit and selects the address (Fig. 4). Immediately, the control circuit returns a potential to the key unit which energizes a

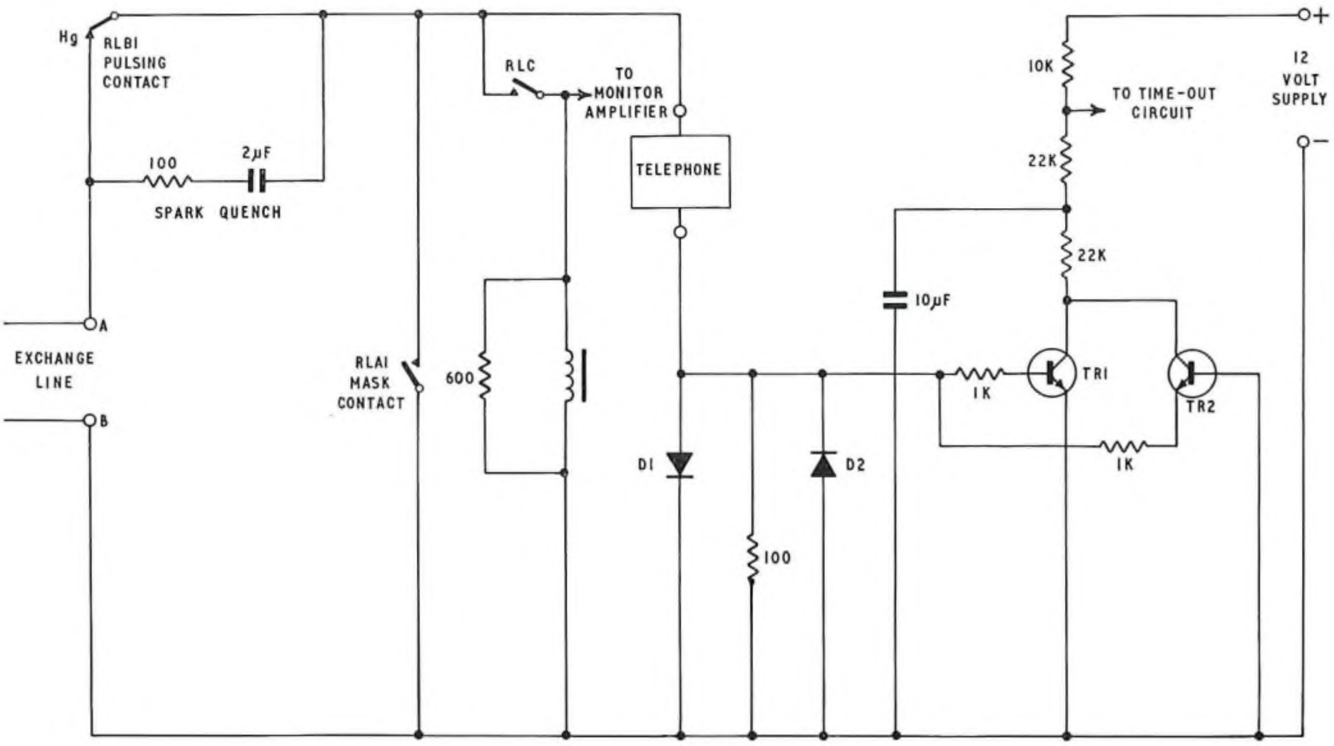


FIG. 3—Line circuit of Autodial No. 101A

solenoid and locks the button down. Further signals from the control circuit operate the mask relay which loops the line ready for pulsing, and connect the monitor amplifier behind the dialling loop.

After a two-second pause to allow for the seizure of the exchange equipment, the pulse generator is allowed to free run at 10 p.p.s. As each pulse is sent to line the pulse counter is stepped on until coincidence occurs with the value programmed for the first digit; a signal is then forwarded from the coincidence circuit to the inter-digital pause (i.d.p.) generator to give an 800 ms pause and to clamp the pulse generator. In the example, the value of the first digit is 2. A further signal steps on the address-code selector so that the second digit, 4 in the example, is presented to the coincidence circuit. At the end of the 800 ms pause the pulse generator again free runs at 10 p.p.s. until the pulse counter has counted four pulses, when coincidence again occurs. The process is repeated until the address-code selector steps to the eighth digit. The eighth digit tag has been jumpered to the STOP bar. The pulse generator is therefore clamped and the mask relay is released, removing the short-circuit from the input to the monitor amplifier so that supervisory tones and the called subscriber's answer can be heard. When the handset of the associated telephone instrument is lifted, the line current through the telephone circuit is detected, and the monitor amplifier is released from the line, leaving the call under the control of the telephone. If the telephone handset is not lifted within one minute after the end of dialling, the time-out circuit releases the call and restores the autodial to the standby state.

International Calls

When a call to an international number is initiated, the ISD-code selector is activated to cause the prefix-code 010 to be transmitted. The ISD-code selector has a two-stage binary counter which controls the prefix digit-sequence.

The values of the digits are determined by the coincidence circuit as for national-number digits. The use of a special ISD-code selector reduces the number of digit tags by three for each address, and associated components by 3 resistors and 1 diode per tag. Elements in the address-code selector which would be required to select digits 13, 14, and 15 are also not required.

TAPE CALLMAKER

The Autodial No. 201A, shown in Fig. 5, is manufactured in the USA by the DASA Corporation under the trade name of Magicall. The Plessey Co., Ltd., market the device in the United Kingdom, but have carried out some modifications to enable Post Office requirements to be met.

The complete device is made up of three units, the desk unit, the power-supply unit and the recording-dial unit. The magnetic-tape store has a capacity of 400 telephone numbers each of which can have a maximum of 18 digits.

The magnetic tape is cassette loaded with one side prepared as a writing surface and divided along its length into alphabetical sections. A red line runs diagonally from the A-end to the Z-end to assist in alphabetical location when the fast-wind facility is used. The final position of the tape is adjusted by the selector wheel.

The power-supply unit provides four voltages: −20 volts d.c. for the pulsing circuit, −10 volts d.c. for the amplifier and timing circuits, +20 volts d.c. for the Schmitt-trigger bias and 28 volts a.c. for the scan and tape-head motors. These supplies and an earth are connected to the main unit by a five-way cord.

The recording-dial unit consists of a modified Dial Automatic No. 21 LA in a Mounting Dial Automatic No. 22A. This is connected to the desk unit by a nine-way cord, plug and

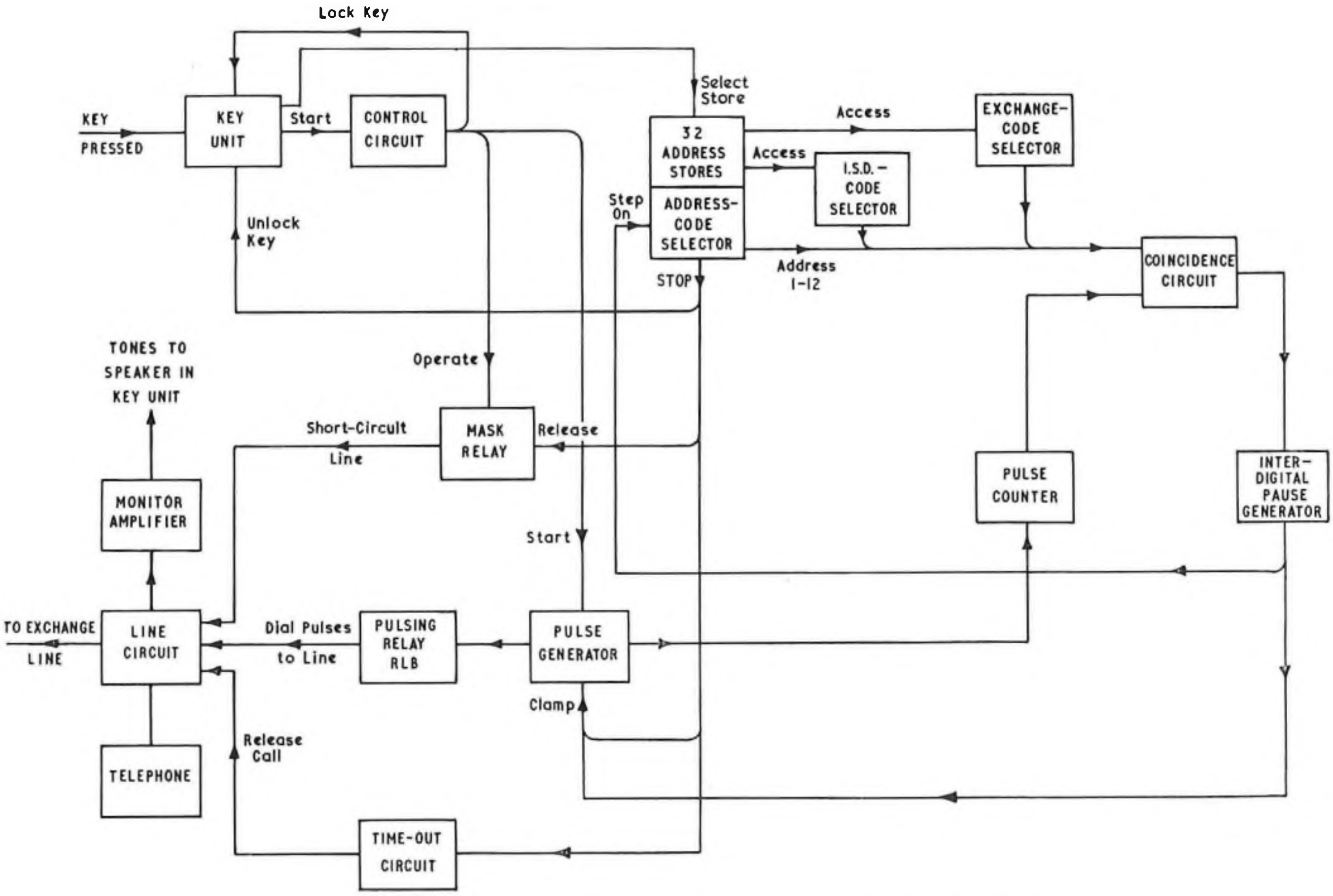


FIG. 4—Simplified block schematic showing operation of Autodial No. 101A

FIG. 5—Autodial No. 201A excluding power unit

This is connected to the desk unit by a nine-way plug and socket. The dial has been modified to include a motor start contact in series with the off-normal contact. This extra contact breaks when the dial is taken off normal, and makes while the dial is restoring. The tape head is thus driven across the tape by the tape-head motor only during pulsing.

Connexion

The autodial is connected to a telephone installation by a six-way cord. The line circuit consists of a dry-reed pulsing contact and two make contacts. The autodial must be connected to the installation such that the existing spark quench can be used. The connexion arrangement must also ensure that the pulsing contacts are isolated from the line during the recording of new numbers.

Operation

To record a telephone number, the recording-dial unit is plugged into the socket provided at the rear of the desk unit. The flap on the front of the autodial is lifted and the name or number is written in pencil on the chosen position on the tape. The tape is then moved to locate the entry between the black lines on the window. The CALL button is depressed and the lamp on the recording-dial unit glows. When the lamp darkens the first digit of the telephone number can be dialled. As soon as the dial starts to restore the lamp glows again. It will remain glowing for a period after the dial has returned to normal, when it darkens again the next digit can be dialled. The period between the dial restoring to normal and the lamp darkening corresponds to a pre-determined inter-digital pause. Using this procedure the entire telephone number can be recorded. After the last digit has been recorded the STAR button is pressed which causes the lamp to glow again. This provides a sufficient length of blank tape after the final digit to ensure correct switch off when playing back. When it darkens again the recording is complete and the recording-dial unit can be disconnected.

Should an access digit from a p.a.b.x. installation be required to precede the national or international number, then the STAR button is pressed after the access digit has been dialled, again to provide an extra-long pause. When the lamp darkens the remainder of the number can be recorded as previously described.

While a recording is being made the telephone handset must be left on the rest to prevent the number being transmitted to line.

To call a number which has been recorded, the appropriate position on the tape is selected and the telephone handset lifted. When dial tone is obtained, the CALL button is pressed, this causes the number to be automatically transmitted to line, and after pulsing leaves the call held by the telephone loop. If an access digit has been transmitted, the dialler will stop. When main-exchange dial tone is obtained the STAR button is pressed and the remainder of the number is automatically sent to line.

Outline Circuit Operation

Fig. 6 shows a simplified block schematic of the operation of the Autodial 201A. The tape is moved to the selected number, and when the CALL button is pressed, the head-motor control switches to the ON state and the tape head is driven

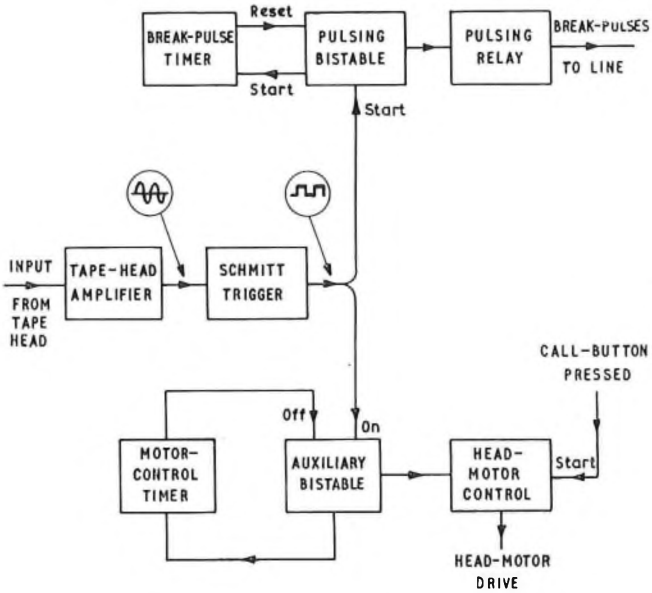


FIG. 6—Simplified block schematic showing operation of Autodial No. 201A

across the tape in search of a pulse. When the head detects a pulse the Schmitt trigger switches and restores, and by restoring sets the auxiliary bistable and the pulsing bistable to the ON state. The auxiliary bistable prepares the circuit for the i.d.p., and the pulsing bistable releases the pulsing relay sending a break to line. The pulse-correction circuit in the break-pulse timer resets the pulsing bistable to the OFF state after 61 ms, re-operating the pulsing relay and hence making the pulsing contacts. The head continues travelling across the tape and when another pulse is detected the Schmitt trigger switches and restores, causing the same sequence of operations to be repeated. After the final pulse of the digit a period of one second can elapse before the motor-control timer restores, but if a further series of pulses are detected within this time pulses from the Schmitt trigger maintain the auxiliary bistable in the ON state and set the pulsing bistable successively into the ON state.

If an access digit has been recorded the motor will stop one second after the access digit has been sent. The remainder of the number is sent by depressing the STAR button as soon as the second dial tone is heard.

CARD CALLMAKER

The Autodial No. 301A stores its dialling information on plastic cards, each card being programmed for one telephone number by having holes punched out in accordance with a simple code. Any telephone number consisting of up to 16 digits can be recorded in this way.

This autodial, shown in Fig. 7, is a self-contained unit

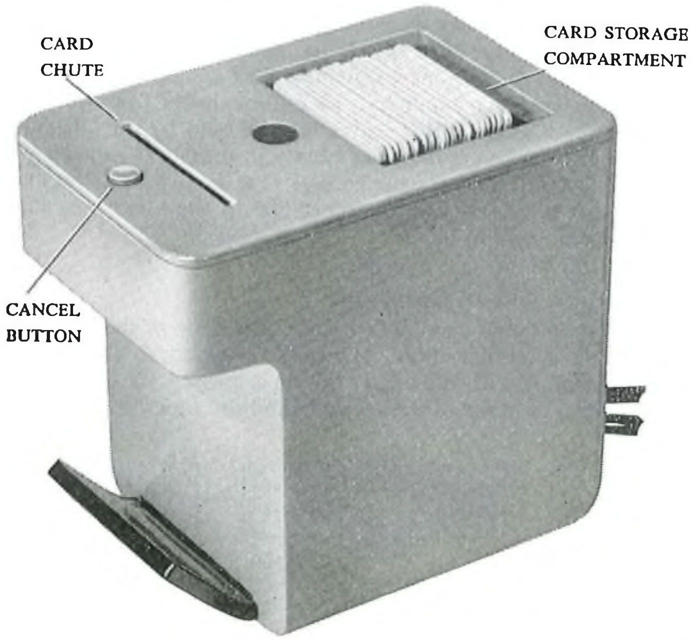


FIG. 7—Autodial No. 301A

with an internal mains-driven power unit, measures approximately 6 in × 4 in × 6 in and weighs $3\frac{1}{2}$ lb. In the top of the unit is a card chute through which the card falls during automatic dialling. The card is arrested at each row of punched-out holes by a solenoid latch pin, until on completion of dialling the card drops out into a translucent tray. A storage compartment for thirty cards is provided behind the card chute. A call may be cancelled at any time during the dialling process by pressing the button which is situated in front of the card slot, and replacing the telephone handset.

The cards, which measure $3\frac{1}{2}$ in × $2\frac{1}{4}$ in, are moulded in A.B.S. Copolymer with 16 rows of potential holes, each hole covered with a thin web which can be removed as required with a suitable pointed instrument. Writing surfaces are provided along the top and down the left-hand side for the

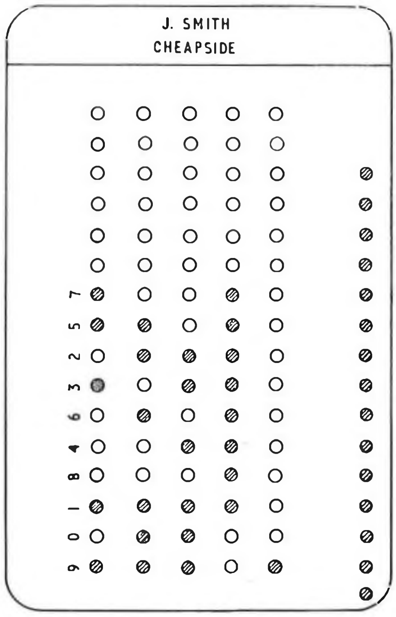


FIG. 8—Punched card

name and telephone number, respectively, of the called subscriber.

A typical card is shown in Fig. 8, each row of holes corresponds to one digit of the telephone number. The code is derived by deducting the number required from 16, and punching out holes corresponding to the result, where the first column on the left represents the value 1, the second column the value 2, the third column the value 4 and the fourth column the value 8. Therefore, for the digit 7, code-digit 9 must be recorded, i.e. holes punched out in column 1 and column 8. The digit 0 must be considered as 10, hence holes to the value 6 would be punched out. A jig is provided to assist the user in programming cards correctly.

Connexion

The line circuit of the autodial consists only of the pulsing contact, a mercury-wetted reed with a standard spark quench, and two mask contacts performing a similar function to the dial off-normal contacts. Dry-reed inserts are utilized for the mask-relay functions.

The autodial is normally connected between the incoming exchange-line pair and the telephone instrument, the pulsing contacts being inserted in the B-leg of the line, and one set of the mask contacts being connected across the line. On multiple telephone installations it is necessary to connect the autodial into one of the telephone instruments in series/parallel with the telephone dial. Both mask contacts are required for this type of connexion, but the autodial spark quench must be disconnected.

Operation

A simplified block schematic of the Autodial 301A circuit is shown in Fig. 9. To make a call the user lifts the telephone handset, obtains dial tone and inserts a selected card in the chute. The card comes to rest against a latch pin, with the bottom row of holes aligned between the light source and the photo-conductive cells which detect the digit value. The presence of the card operates the card-detect circuit, which in turn operates the mask relay, to short-circuit the line in preparation for pulsing, and triggers the i.d.p. generator. The latter enables the pulsing control circuitry to be used for the control of the first digit in the same manner as for subsequent digits, but without operating the latch control.

The dial-pulse generator is clamped by the output from the i.d.p. generator. The termination of this output triggers a 5 ms timer which provides a setting potential for the

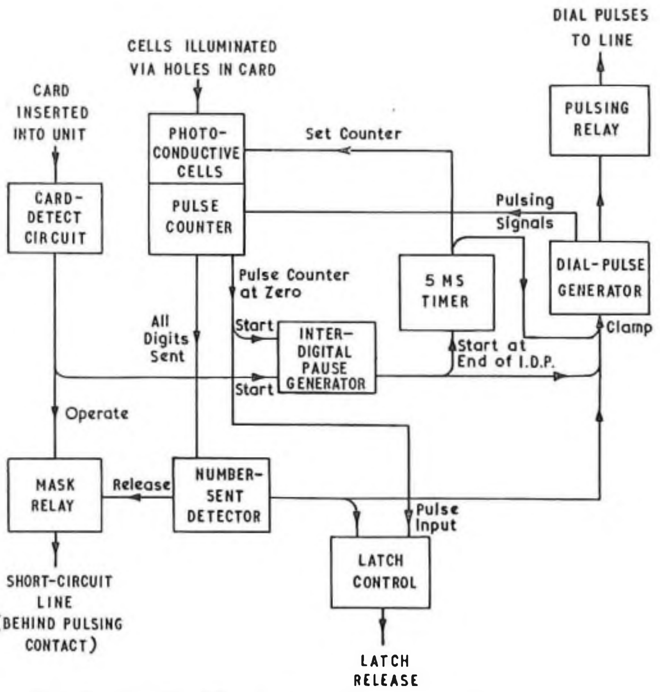


FIG. 9—Simplified block schematic showing operation of Autodial No. 301A

photocells, and maintains the clamp on the dial-pulse generator. The low resistance of the photocells which are illuminated through the holes punched out in the card, allow the associated binary pulse counter to be set.

When the 5 ms timer restores, the dial-pulse generator, a free running multivibrator, starts sending impulses to line and stepping the pulse counter. When the counter reaches its home state (binary 0.0.0.0.) it triggers the i.d.p. generator which clamps the dial-pulse generator, and causes the latch to release for 35 ms. This allows the card to fall and be caught by the latch pin locating in the first feed hole in the card. In this position the second row of holes is aligned between the photo-conductive cells and the light source. This process continues until no punched holes are presented to the photo-conductive cells. The number-sent detector then operates, releasing the latch until the card has fallen from the chute, and releasing the mask relay to enable conversation to take place.

If a public-exchange access digit from a p.a.b.x. is required to precede a national or an international telephone number, the access digit is recorded in the normal manner using the first row of holes, but the fifth hole is also punched out. The detection of this fifth hole causes the following i.d.p. to be increased to two seconds. This allows time for public-exchange dial tone to be connected before the remainder of the telephone number is transmitted.

CONCLUSION

The three repertory diallers described are currently undergoing various phases of product and market trials. The product trials check that each design gives a satisfactory performance under actual working conditions. The market trials establish that the facilities offered by the diallers meet the requirements of the majority of customers and enable an assessment to be made of the demand for these or similar devices. The future of the repertory dialler will be decided from the results of the trials.

Notes and Comments

Birthday Honours

The Board of Editors offers congratulations to the following engineers honoured by Her Majesty the Queen in the Birthday Honours List:

Telecommunication Headquarters	Prof. J. H. H. Merriman	Senior Director Development	Companion of the most Honourable Order of the Bath
North Western Telecommunications Region	H. Cheetham	Senior Executive Engineer	Member of the Most Excellent Order of the British Empire
Scotland	C. J. MacPherson, B.E.M.	Assistant Executive Engineer	Member of the Most Excellent Order of the British Empire
London Postal Region	C. F. Barnes	Executive Engineer	Member of the Most Excellent Order of the British Empire
Midland Telecommunication Region	J. A. Sheldon	Technical Officer	British Empire Medal
External Telecommunication Executive	J. T. Lutener	Technical Officer	British Empire Medal
N.W. Telecommunications Region	C. Marooth	Technical Officer	British Empire Medal
London Telecommunications Region	S. G. C. Hardy	Technical Officer	British Empire Medal

Board of Editors

Mr. C. R. M. Heath has resigned as an Assistant Editor on his resignation from the Post Office.

Letters to the Editor

Dear Reader,

Like so many other Post Office engineers I have always looked to the Journal of the Institution to keep me abreast of progress in our profession. In doing so the contributions have set a standard which has earned the Journal both national and international prestige of a high order. The Board of Editors and the editorial staff pay a lot of attention to the changes necessary to keep up the standard. Naturally, these changes have been more frequent in recent years and I hope that the new style and presentation adopted have been noticed and approved. But we cannot be sure of this, or of readers' opinions about the contents. I have at times over the years felt the urge to send a comment in praise or criticism to the Editor, but in the absence of a correspondence column the letters never got written.

As Chairman of the Board of Editors, I am able to offer you the opportunity which I have missed, and give myself the pleasure of making the first contribution.

I shall watch with interest to see whether my expectations are realized.

Yours sincerely,

N. C. C. de JONG

Postal Mechanization Dept.,
Postal Headquarters.
30 July.

Publication of Correspondence

The Board of Editors would like to publish correspondence on engineering or technical aspects of articles published in the *Journal*.

Letters of sufficient interest will be published under "Notes and Comments". However, correspondents should note that, as it is necessary to send copy to the printer well before publication date, it will only be possible to consider letters for publication in the January issue if they are received before 15 November 1969.

Letters intended for publication should be sent to the Managing Editor, P.O.E.E. Journal, London, W.C.2. and must show the correspondent's name and address.

Notes for Authors

Authors are reminded that some notes are available to help them prepare the manuscripts of the Journal articles in a way that will assist in securing uniformity of presentation, simplify the work of the Journal's printer and draughtsmen, and help ensure that authors' wishes are easily interpreted. Any author preparing an article for the Journal who is not already in possession of the notes is asked to write to the Managing Editor to obtain a copy.

It is emphasized that all contributions to the Journal, including those for Regional Notes and Associate Section Notes, must be typed, with double spacing between lines, on one side only of each sheet of paper.

Each circuit diagram or sketch should be drawn on a separate sheet of paper; neat sketches are all that are required. Photographs should be clear and sharply focused. Prints should preferably be glossy and should be unmounted, any notes or captions being written on a separate sheet of paper. Negatives or plates are not needed and should not be supplied.

Syllabuses and Copies of Question Papers for the Telecommunication Technicians' Course

The syllabuses and copies of question papers set for examinations of the Telecommunication Technicians' Course of the City and Guilds of London Institute are not sold by *The Post Office Electrical Engineers' Journal*. They should be purchased from the Department of Technology, City and Guilds of London Institute, 76 Portland Place, London, W.1.

Staff Changes

A number of letters have been received expressing disappointment that staff changes are no longer published in the *Journal*. The Board also regrets that this is no longer possible. The reorganization within the Post Office to prepare it for Corporation status and the disbanding of the old Engineering Department has meant that it is no longer convenient for Staff Units to present the required information.

Press Notices

Post Office Tries Carpets

The Post Office is experimenting with the use of carpet instead of traditional floor coverings in a few selected centres.

Although the carpet costs more, initially, than other floor coverings, the Post Office hopes it will work out cheaper in the long run because of reduced cleaning costs and a saving in the amount of acoustic treatment required.

Biggest of the experiments, due to start shortly, are at two new buildings—Eastern Region Headquarters in Colchester and the Telephone Manager's Office in Liverpool—in which carpeting will be laid in all rooms. For the experiment, only two types of carpet are being used—one all-nylon and the other 80 per cent wool 20 per cent nylon.

Carpet will also be laid in a number of sales bureaux and telephone switch rooms during the next few months. One of the switch rooms at Tipton, Birmingham, has already been completed.

Electric shocks experienced by some people walking on nylon carpet are not expected to prove a serious problem. It can be overcome by the use of an anti-static spray and this has already been done successfully at Tipton.

New Rod Pushing Machine for Underground Cables

The task of "hand-rodding" underground ducts as a preliminary to pulling telephone cables into them has been rendered obsolete by a new mechanized rodding and cabling system developed by the Post Office.

A continuous rod is power-driven from one end of a duct route to the other. The cable, which is attached to the end of the rod, is drawn into the duct by the subsequent retraction of the rod to its original position. The separate operation of winching the cable into position as at present is eliminated: the new technique enables the whole procedure to be carried out in one completely mechanized operation.

Adoption of the system is expected by the Post Office to result in a considerable increase in cable-laying productivity.

In technical terms, the rod is gripped by transverse pressure exerted between two caterpillar tracks which are driven through a worm drive by a pneumatic or hydraulic motor. The pushing machine is mounted at the rear end of a vehicle and power to operate the unit is derived from the vehicle's engine through a power take-off.

The rod is led to the duct by means of a flexible guide tube, then driven smoothly through the duct at speeds up to 160 ft per minute with a thrust of up to 900 lbf. In addition to the machine, the system comprises a live centre reel holding 200 yards of PVC tube, and an oscillator to indicate the location of any blockage in the duct. The full 200 yards of rod can be driven through ducts even when the ducts are partly occupied by other cables.

Two complete units are at present in operation, in Coventry and Sheffield. A further six will come into service shortly.

Large-scale adoption of the system is expected to take place in 1970.

GPO's World First in Aluminium

The Post Office has scored another world "first", in collaboration with British industry.

In its campaign to reduce costs and hold down charges, the GPO is now using aluminium instead of copper in cables linking the customer's telephone with the local exchange. This is expected to save about £500,000 a year.

The changeover began about eight months ago. By the end of this year all cable laid for subscribers' lines in local network extensions is likely to be in aluminium.

Although aluminium has been used experimentally before, Britain is the first country in the world to lay it for telephone lines in everyday use.

Prompted by increases in the price of copper, the Post Office began experiments in the 1950s—and ran into difficulties with jointing methods and corrosion. Patient research continued, in close co-operation with manufacturers, until the breakthrough came in the mid-1960s.

The jointing problem was solved by using a new crimping tool to compress the wire ends inside an insulated connector without stripping off the plastic insulation. A new method was developed of preventing corrosion in underground cables by packing them with petroleum jelly, greatly reducing the likelihood of faults.*

Further experiments established the most suitable grade and tensile strength for the aluminium conductor, while factory and field tests proved that aluminium cable could be made and laid using normal methods. The first bulk-produced aluminium telephone cable was laid in South-East England and further quantities are now ready for installation in the Midlands, the East and the South-West. Northern Ireland and Scotland will be next.

Aluminium cable costs about 10 per cent less than copper cable. Aluminium is not such a good conductor as copper but, since the metal is much lighter, this has been easily overcome by making the wire thicker. At Coventry, the Post Office is carrying out trials with aluminium wires thinner than previously thought possible: this may lead to a further reduction of costs. Bulk is a major factor in designing the larger cables that run between exchanges and distribution points and the possibility of using the thinner aluminium wires in these cables is also being examined.

A pneumatic machine for making better joints faster, developed by GPO research staff and a British manufacturer is now undergoing field trials which include tests on its suitability for aluminium cables.†

Ten Thousand More Telex Machines in Four Years

Britain's fully-automatic telex system has continued to grow by more than 15 per cent over the past year. The number of telex machines in use on 31 May is estimated at 26,350, compared with 22,852 a year earlier.

This represents an increase of 15·3 per cent which is comparable with the increase over the previous year; and it shows an increase of more than 10,000 since 1965, when the total telex machines in use was 15,052.

Local Radio—PO Confirms Policy on Wavelengths

The Postmaster General, the Rt. Hon. John Stonehouse, M.P., has rejected Mr. Hughie Green's view that 100 local radio stations could be provided on medium wavelengths. A team of Post Office experts has just completed a detailed examination of his proposals and their conclusions were sent to Mr. Hughie Green today.

Mr. Green submitted two feasibility studies to the Post Office. Both would have involved the use of directional aerials for some stations, including those for London and Manchester. They would also have involved the use of medium wave frequencies allocated to other countries, under the terms of Article 8 of the 1948 Copenhagen Plan. The Post Office conclusion is that, even by day, not all the stations Mr. Green proposed would give satisfactory reception; and, that for the remainder service areas would in general be so reduced after dark as to be completely unsatisfactory. For example, the station proposed for London would cover only 10 per cent of the Greater London Area after dark.

Post Office studies reaffirm the conclusions set out in the Government's White Paper on Broadcasting (Cmnd. 3169 para. 32 December 1966) that "no general service of local sound broadcasting, which would be available during the hours of darkness as well as in daylight, can be provided only on medium wavelengths allotted to the United Kingdom."

"At Midnight, Speak . . ."

Big savings in the small hours for people who make heavy use of the telephone are now possible with the new Midnight Line telephone service. Announced by the Postmaster General, the Rt. Hon. John Stonehouse, M.P., last September, the service is now in operation.

For £200 a year a Midnight Line customer will be able to make unlimited free dialled telephone calls within the United

* Developed by British Insulated Callender's Cables Ltd; process now used by all British telephone cable makers.

† The Plessey Co. Ltd.

Kingdom between midnight and 6 a.m., a period when the public telephone system has ample idle capacity.

By comparison, it would cost £500 for two hours' con-continuous traffic each night for 250 nights making dialled calls of over 35 miles in the cheapest rate period.

The service can be provided on most exchange lines with subscriber trunk dialling facilities and these lines can be used for ordinary chargeable calls outside the Midnight Line period.

The service is likely to be used mainly for transmission of data but can be used for ordinary dialled calls.

There is a connection charge of £50 for the special equipment needed at the exchange as well as the usual connexion and rental charges for the line and other apparatus such as modems (modulator/demodulator units) employed in Datel data transmission services.

New equipment which the Post Office plans to market about the end of the year will enable data calls to be made and answered automatically.

The Midnight Line service is operated by equipment at the exchange which disconnects the customers' line from the meter recording dialled calls, except when an international number is dialled. International Subscriber Dialling calls, and calls through an operator, can be made but are charged at normal rates.

If the service is required by a customer who is not served from an exchange on which it is provided, he may be able to have the service from the nearest suitable exchange. In such cases normal out-of-area charges and conditions will apply to the exchange line but there will be no additional charge for the service.

New GPO Information Service

Share Index by 'Phone

Rt. Hon. John Stonehouse, M.P., the Postmaster General, has decided to inaugurate a new GPO information service on the London Stock market on 21 July, by making the Financial Times Industrial Ordinary Share Index available as a public Telephone Information Service.

The new GPO service will enable enquirers anywhere throughout Britain and from overseas to hear a recorded message, which will be updated four times a day, Monday to Friday, giving the Index based on London Stock Exchange prices in mid-morning, at lunchtime, in mid-afternoon and late afternoon. A caller to 01–246 8026 will hear the latest Index and change—for example, "The Financial Times Industrial Ordinary Share Index at 10.30 was 412·6, up from yesterday's closing Index by 1·5."

In London this will be charged as a local call: elsewhere, where customers can dial direct, it will be at STD rates so that it can cost as little as 2d to hear the announcement and, even for subscribers in the remotest parts of the STD network, only 4d.

Customers not yet on STD can ring for the Index at normal operator rates—as can overseas investors interested in the London Stock Market. From the countries with which Britain has subscriber-dialling links, calls for the FT Index can be dialled at the cheaper ISD rates.

The FT Index, based on 30 leading shares, has been calculated continuously by the Financial Times for 34 years. It is widely reported throughout the world and is the accepted indication of the mood of the London Stock Exchange. Currently about 2,000 people a day are telephoning for the figure.

The FT Index will be the eighth of the Post Office's information services. The others, listed in local directories where available, are the Speaking Clock, Dial-a-Disc, Test Match, Weather, Motoring Information, Recipe and Teletourist services.

The Financial Times Industrial Ordinary Share Index is a price index of the equities of leading industrial and commercial companies covering a wide range of industry and distribution in Britain.

It is based upon the price movements of thirty shares. This number is sufficiently large to ensure that an abnormal price movement of a particular share does not have a disproportionate effect upon the movement of the Index. The constituents cover the whole range of British industry and represent a large segment of it in terms of market capitalization. Each constituent is a leader in its own industry and its share a leader in its own market.

The FT Index is calculated by taking the geometric mean of the price-relatives of the individual constituents. This is not as complicated or involved as it sounds. The price-relative of a share is the value of the current price divided by the price at the base date. The geometric mean of a set of thirty values is obtained by multiplying the thirty values together and taking the thirtieth root of the result. In practice, this calculation is made by taking the logarithms of the values, adding them together, dividing the total by thirty and taking the antilogarithm of the result. The value of the Index at the base date was taken as 100. This is a generally accepted convention for almost all indices.

The reasons for using the geometric mean instead of the better known arithmetic mean are many. Some of them are highly technical, but two of the most important are that the Index does not have to be restarted at periodic intervals and that it does not give undue weight to extreme values. A simple example will illustrate the latter point. Consider an index consisting of two shares A and B. A doubles in value whilst B halves. Under a geometric mean the index is unchanged at 100, but under an arithmetic mean the index rises to 125.

Provision is made in the method of calculation so that capital changes (such as capitalization or right issues) do not affect the continuity of the Index series. Changes in constituents are made periodically but not frequently. The overriding consideration in choosing a new constituent is that the principle of the FT Index constituents being representative of British industry and the market is maintained.

Data Transmission Services Expand Still Further, Postmaster General announces new Developments

New Datel services, to widen further the scope of the Post Office's fast-growing range of data transmission facilities, are planned for introduction in the next two years.

Announcing this in a written Parliamentary answer today, the Postmaster Genereral, the Rt. Hon. John Stonehouse, M.P., said: "We are planning two new services in the Datel range:

"Datel 48K which is a high speed service for which modems will be available on rental from the Post Office. These modems can be used on private leased circuits. We are also planning an experimental high speed network between London, Manchester and Birmingham on which customers will be able to book time in a similar manner to the ordinary telephone network. This network is planned to be operational in 1970.

"Datel 400 which is being designed for the collection of both digital and analogue data from remote points. This service should be available during 1971 or possibly 1970.

"We are also developing 'Dataplex' services involving multiplexing techniques. A typical application will enable computer bureaux to have telephone numbers on an exchange in distant towns enabling the customers of a bureau to call it more cheaply."

Datel 48K was forecast by the Postmaster General last September when he said there was clearly a need for a data transmission service operating at 48 kilobits per second that customers could use as they required.

The Post Office aims to introduce this service in early 1970 using new modems (modulators/demodulators) designed for very high speed transmission. Representative users are being invited to experiment with the service in its early stages and invitations are going out to a number of computer manufacturers and to organizations who have fairly frequent need for high speed data transmission.

Datel 400 will provide telemetry facilities for organizations collecting information from a number of remote points. It could have particular value for measuring liquid levels in reservoirs, rivers and storage tanks or for transmitting recorded weather information. Datel 400 will transmit digital data at speeds up to 600 bits per second. Sealed cases designed to permit use of modems in any kind of situation or environment will be available.

For computer bureaux customers located at a distance from the bureau the communication costs are sufficiently high, compared with the processing costs, to inhibit the use made of bureaux. The first of the Dataplex services will enable bureau operators to rent telephone numbers in towns remote from their processors to which their customers can make cheap, probably 'local,' telephone calls. Cost of Dataplex service will be met by the bureau operator but as the lines can be used very efficiently the overall effect will be to reduce costs. One of these Dataplex circuits will carry the equivalent of 12 data channels.

In addition to the direct advantage to customers Dataplex will enable computer bureaux to offer service at standard rates irrespective of the distance of the customer from the processor. The Post Office will benefit because Dataplex will take some calls from the heavily-loaded telephone trunk network.

New Cable to Portugal Comes into Service

A new submarine telephone cable, the first to join Britain and Portugal, came into service on July 28. The cable was provided for the British Post Office and Companhia Portuguesa Radio Marconi at a cost of over £4 million by Standard Telephones and Cables Limited.

The new cable contains 128 transistor operated repeaters and is 949 nautical miles in length running between Goonhilly, Cornwall and Sesimbra near Lisbon.

It will have a capacity for up to 640 telephone circuits which will be used not only for communications with Portugal and Spain but also to give access to other cables beyond Portugal—to the recently opened Portugal-South Africa cable, and next year to the USA via the new transatlantic cable (TAT 5) to be laid from Spain, and to Italy via a new cable (MAT 1) to be provided in the Mediterranean.

New Telephone System for Whitehall

A new network of private automatic branch telephone exchanges is to link government offices in the Whitehall area with one another, with government offices elsewhere and with the Houses of Parliament. Work has already started on the scheme which will replace the present largely manually-operated system. It will take several years to complete.

The new exchanges will be connected through a central automatic exchange enabling any telephone extension in the system to be connected to any other by "dialling" or "keying" not more than seven digits. Similarly a caller from any telephone outside the network, if he knows the extension number, will be able to dial it directly without having to contact a switchboard operator.

The Government's telephone bill will be less than it would be if the present largely manually-operated system were continued, while the users will have a much faster and more reliable service.

The total cost of the scheme will be split between two stages of which the first, covering about 30,000 telephone extensions, will be completed by about 1973 and will cost between £2 million and £3 million. The second stage will not be completed until after 1975.

The first four exchanges, serving 10,000 extensions, will use modern but conventional electro-mechanical equipment with dial telephones. Subsequent exchanges in the first stage will be of the recently-developed cross-bar type (a system connecting calls by electrical cross-points) with push-button telephones (keyphones).

The cross-bar exchanges have been developed by Plessey Telecommunications Group in co-operation with the Post Office and they will be supplying the first units. This system will give a high class service and offer complex ancillary features. It will, nevertheless, need less space and less maintenance work than the conventional system and keyphone callers will be able to make calls to other Whitehall numbers more quickly and all calls with less risk of error than by dialling.

It is appropriate that the first of these installations, which make the most efficient use of man-power, will serve 1,600 extensions in the Department of Employment and Productivity and other government buildings in St. James's. The Post Office expects this to be in operation in 1971. A few months later a similar installation serving up to 2,000 extensions in the Houses of Parliament will be brought into service, to give improved service to Members and others.

Some keyphones are already used in this country in association with private branch exchanges belonging to large firms. The Whitehall system, however, will introduce for the first time the 12-button keyphone. In addition to the ten push buttons for numerals this has two in reserve for additional facilities (such as data transmission) should they be needed later

Heathrow Leads World with Real-time Air-Cargo Control

Britain is to be the first nation in the world to clear incoming air cargo by computer.

The Postmaster General, Rt Hon. John Stonehouse, MP, announced today that the Post Office National Data Processing Service (NDPS) had decided to place a £3 million contract with International Computers Ltd. (ICL) to set up a round-the-clock real-time system at Heathrow Airport to speed air cargo by accelerating control and documentation.

Mr. Stonehouse said that this decision followed consultation between the customers who would use the system. The Steering Committee of the airlines' EDP Cargo Working Group had agreed subject to satisfactory conclusion of current discussions on contractual arrangements, to recommend acceptance of the ICL tender to next month's Working Group meeting. HM Customs and the shipping and forwarding agents had also agreed to support acceptance of the ICL tender. NDPS looked forward with confidence to all parties agreeing the choice of manufacturer and had decided to place the contract now to ensure timely implementation of the project.

Known as LACES (London Airport Cargo Electronic-data-processing Scheme) the system will be ready for service in 1971. It will be operated by NDPS on behalf of the airlines, shipping and forwarding agents, and HM Customs. It is capable of extension to other air- and seaports; and is expected to be extended later to handle exports. Other countries are planning similar systems and it is hoped that the Heathrow scheme will be the basis for an international airfreight data-processing network. Mr. Stonehouse said that he was delighted to be able to place the contract for such an advanced system with the British computer industry. The order would put ICL in a strong position to tender for future contracts at overseas airports.

LACES will drastically reduce paper work and virtually eliminate manual calculation of complex sums. It will make goods available to customers faster, reducing the need for storage space. All users will have instant information on the stages reached by every consignment passing through and it will be easier to deal with discrepancies at once.

In terms of value landed Heathrow is the world's largest international air terminal. As a British port of entry it ranks third (after London and Liverpool seaports). Cargo arrivals are expected to rise by 12 per cent annually, to reach a million tons a year by 1973.

To cope with the growth of trade a new 160-acre cargo area has been developed at Heathrow at a cost of £23 million. The LACES real-time computer system is being introduced to make the most efficient use of the new cargo terminal facilities by transforming documentation and control of the swelling tide of cargo. It will keep a constant check on imports, calculate Customs duty and other taxes, select documents and goods for inspection and provide daily accounts and updated statistics for all its users.

The LACES computers—on duty day and night seven days a week—will be housed in a new building near the airport. To communicate with them, at first there will be over 200 cathode-ray-tube sets with keyboards, giving visual display on television-type screens in agents', airlines' and Customs offices and cargo sheds. By 1978 there will be twice as many.

From airline offices information about consignments expected will be keyed into the computer. And airlines will be able to link their own communication and computer networks to LACES and transmit information direct from their oversea stations. As consignments arrive an operator in the cargo terminal will key-in details and any differences between goods expected and goods received will be printed-out by the computer.

For Customs Entry the agent or airline will key-in details of a consignment; the computer will calculate duty and purchase tax and flash the result on display screens within seconds. It will be programmed to show whether the consignment needs to be examined by Customs.

In addition to serving Heathrow the new LACES building will be a centre for other NDPS activities in West London.

Institution of Post Office Electrical Engineers

Essay Competition 1968–69

The Council of the Institution is indebted to Mr. T. J. Morgan, Chairman of the Judging Committee, for the following report on the essay winning the first prize in the 1968–69 Essay Competition. This essay entitled "The Valuable Effect of Work Study Upon the Provision of Urgent Private Wires" was written by Mr. D. E. G. Coles, Technical Officer, Birmingham.

The author explains how the growth of the Central Electricity Generating Board (C.E.G.B.) national grid has increased the complexity of its control system, consequently the Post Office has an increasing responsibility in the provision of private wires to the protective devices used. As a technical officer in a circuit provision control group he was frequently concerned with the provision of private wires for the C.E.G.B. An important protective system known as intertripping, which uses voice frequency (v.f.) tones for control, usually requires the provision of private wires at short notice. The growing importance of this work led him to analyse the present line-up methods with a view to improving efficiency of provision.

The provision, by traditional methods, of a 4-wire circuit was observed during 1968. Separate go and return pairs were provided between a generating station and a distant sub-station via two Post Office repeater stations, and the line-up took 12 hours. Some 27·3 per cent of the time was non-productive and 33·3 per cent was involved in travelling and setting up test equipment. The remaining 39·4 per cent was used for the actual line-up, and included 12·6 per cent of the total time (1·52 hours) for setting up equalizers, etc., at the repeater stations. Four journeys to the subscriber's premises were required, as a visit was necessary on the second day to complete only two hours work. The author suggests that tea breaks should be foregone on work of this nature unless they can be phased into a natural break. He considers that an alternative method of communication is required to avoid inconvenience to the subscriber and ineffective time.

The provision of a second private wire was then observed but efforts were made to avoid the delays in the first example. This time the maximum preparatory work was completed at the repeater stations whilst the engineer travelled to the renter's premises. To avoid use of the subscriber's line, a field telephone was utilized on one leg of the four-wire line. The connexion between the repeater stations was made with an exchange line and a repeater panel. The total time taken in this case was 4·4 hours.

Analysis showed that the percentage of effective time was increased from 26·8 per cent to 52·4 per cent. By avoiding use of the subscriber's line 2·2 hours were saved, and as a second visit was avoided, travelling time was reduced by 2·05 hours. The preparatory "part lining up" of the repeater station equipment, during the "engineer travelling" period saved 1·5 hours overall. The line-up time was reduced by 0·9 hours and 1 hour was saved by having no special tea breaks.

The author concludes that the considerable reduction of time spent at the customer's premises and the absence of interruption to service, together with the obvious efficiency with which the task was completed, greatly improved the departmental image.

Essay Competition 1969–70

To further interest in the performance of engineering duties and to encourage the expression of thought given to day-to-day departmental activities, the Council of the Institution of Post Office Electrical Engineers offers five prizes, a first prize of six guineas and four prizes of three guineas, for the five most meritorious essays submitted by Post Office engineers below the rank of Inspector. In addition to the five prizes, the Council awards five certificates of merit. Awards of prizes and certificates made by the Institution are recorded on the staff dockets of the recipients.

An essay submitted for consideration of an award in the essay competition and also submitted in connexion with the Associate Section I.P.O.E.E. prizes will not be eligible to receive both awards.

In judging the merits of an essay, consideration will be given to clearness of expression, correct use of words, neatness and arrangement, and although technical accuracy is essential, a high technical standard is not absolutely necessary to qualify for an award. The Council hopes that this assurance will encourage a larger number to enter. Marks will be awarded for originality of essays submitted.

Copies of previous prize-winning essays have been bound and placed in the Institution Central Library. Members of the Associate Section can borrow these copies from the Librarian, I.P.O.E.E., 2–12 Gresham Street, London, E.C.2.

Competitors may choose any subject relevant to engineering activities in the Post Office. Foolscap or quarto paper should be used, and the essay should be between 2,000 and 5,000 words. An inch margin should be left on each page. A certificate is required to be given by each competitor, at the end of the essay, in the following terms:

"*In forwarding the foregoing essay of . . . . . words, I certify that the work is my own unaided effort both in regard to composition and drawing*"

Name (in Block Capitals)..

Signature ....

Official Address..

The essays must reach:

The Secretary,
The Institution of Post Office Electrical Engineers,
G.P.O.,
2–12 Gresham Street,
London, E.C.2.

by 15th January, 1970

The Council reserves the right to refrain from awarding the full number of prizes and certificates if in its opinion the essays submitted do not attain a sufficiently high standard.

Institution Field Medal Awards 1967–68 Session

Details of the medals awarded for the best papers read at meetings of the Institution in field subjects primarily of regional interest were published in the July 1969 issue of the Journal.

The Council of the Institution is indebted to Mr. E. C. Swain, Chairman of the Papers Selection Committee of Council, for the following precis of the medal winning papers:

"*The Recruitment, Training and Education of Engineering Technician Apprentices*", *by R. C. Morris*

This paper presents a commentary on the methods of the day for the recruitment, training and education of Trainee Technician (Apprentices), mentioning the immediate problems and some of the ways in which they are being met in the Cambridge Telephone Area.

The author bases his annual Apprentice intake number calculation upon the premise that recruitment at this level is intended primarily for the eventual staffing of the Technical Officer grade, necessitating a forecast of Technical Officer strength and wastage 5 years after recruitment. When the size of the intake has been determined, Area publicity is arranged in such a way as to attract the optimum number of boys of appropriate qualifications to apply for employment at the right time of the year. Personal contact with schools and the Youth Employment Service, and the use of factual up-to-date literature, are stressed by the author as important factors in recruitment publicity, and the positive results of one local press campaign are shown. Selection of recruits by written examination and interview are fully covered in the paper, and the improved academic level of boys recruited by written examination is demonstrated.

The author mentions the importance of an induction course for apprentices. He goes on to outline the preparation of a field training program which ensures the full curriculum for each boy but avoids a build-up of trainees on any duty despite the large numbers of boys currently recruited. The organisation and principles of field control of apprentices are then dealt with, stressing the importance of keeping notebooks. The paper deals with the 3-stage training curriculum current at the time of writing, and gives a typical break-down of the specialization of an intake in its final stage. Regional Training School courses for apprentices form the backbone of the training scheme. The paper illustrates how these and Central Training School courses later are integrated into the general scheme.

The compilation of comprehensive records by the Area Training Officer is mentioned as an important facet of an efficient training scheme, and the aspects of wastage by resignation or upgrading.

The education section of the paper deals principally with the Area interpretation of the 1961 White Paper "Better Opportunities in Technical Education", and gives an appraisment of the block release system of technical college instruction.

As regards the future, the author sees programmed learning as the most significant single advance, but mentions also the comparatively rapid general improvement in engineering training outside the Post Office, since the introduction of the Industrial Training Act, 1964.

"*Steps Toward Exchange Maintenance By Direction*", *by A. Scott*

The author considers that the problem of providing a satisfactory service at an acceptable cost has not been solved by the Fault Card History Scheme. His paper discusses this, and also the report and the review of the Working Party on Exchange Maintenance which was set up in Scotland and concludes that the "deterioration spiral" which had developed in many exchanges was due to:

(*a*) The premature reduction in work unit values, during the period of grace following the old overhaul scheme,
(*b*) the dilemma of the Technical Officer subsequently faced with the decision whether or not to overhaul and hence possibly add to his arrears of preventive maintenance routines,
(*c*) the poor standard of supervision, particularly at the inception of the scheme.

The paper describes a scheme where, as a first step, the preventive maintenance staff and the functional maintenance staff (i.e. those dealing with faults arising from functional tests) are separated. To justify a team large enough to have the benefit of a T.O. (A) for on-the-floor supervision, ten director exchanges in one maintenance control area were dealt with as a group.

The second step was the use of punched cards, dockets or analysis of the fault history cards in such a way that any selector, part of a selector, category of fault and clear could be seen easily.

Since the functional maintenance staff in exchanges is small, it was considered essential to have some form of continuous monitor, and the use of the Automatic Traffic Monitoring Equipment ("Scotsmonitor") for this purpose is described in the third step.

In the fourth step a description of the various criteria to be considered before deciding to embark on preventive maintenance is given. The author points out, however, that the list is not exhaustive and other criteria could also be considered. The failure to find a satisfactory means of determining when to clean banks is a problem and unsuccessful attempts to solve this by the use of a noise tester with an amplifier and by the measurement of bank-wiper contact resistance are described. Better lubricants with longer periods between lubrications are called for.

A report of the scheme in action at several exchanges is given showing the results achieved and the cost.

The author concludes that by a continuous appraisal of the various criteria, the supervising officer should be able to direct, at a reasonable cost, his preventive maintenance team to avoid the onset of deterioration.

"*Birmingham Radio Tower—Planning, Construction and Commissioning*", *by J. R. Tipple and L. F. Williams*

The purpose of this paper is to explain the need for, and siting of, the Birmingham Tower together with its construction and commissioning. Those aspects of maintenance affected by the design of the tower and its services are also mentioned.

The authors commence by explaining the need for the tower, against the background of trunk traffic growth since 1939 and that foreseen to meet the needs of the expanding television and trunk traffic networks.

The types of structure approved by the Post Office and acceptable to local planning authorities are then detailed. The change in design from a round "Chilterns" type tower to that finally adopted (i.e. a ruptured cruciform) is also explained.

Having explained the need for, and the planning of the tower the authors go on to describe its actual construction, starting with the truncated pyramid foundation and continuing with the main structure and circular aerial galleries. Various incidents, some amusing and some potentially dangerous which occurred during the period of construction are mentioned.

Services necessary for efficient operation of the tower are then described in detail. The authors describe such requirements as the control desk, alarm systems, internal communications systems, water and power supplies.

Commencing at the top of the tower and working downwards, the authors explain the utilization of each floor of the building, which ensures that the relative allocation is in accordance with the technical requirements.

The methods whereby the existing radio systems were transferred, with a minimum of interruption to traffic, from the radio terminal on the roof of Telephone House, Birmingham, to the tower are discussed.

Illustrations and photographs showing the salient points in the construction and in the equipment installed are included in the paper; additional information on economic comparisons of circuit provision, the planning and description of a radio terminal, and typical performance specifications of the radio systems are covered in appendices.

A. B. Wherry
General Secretary

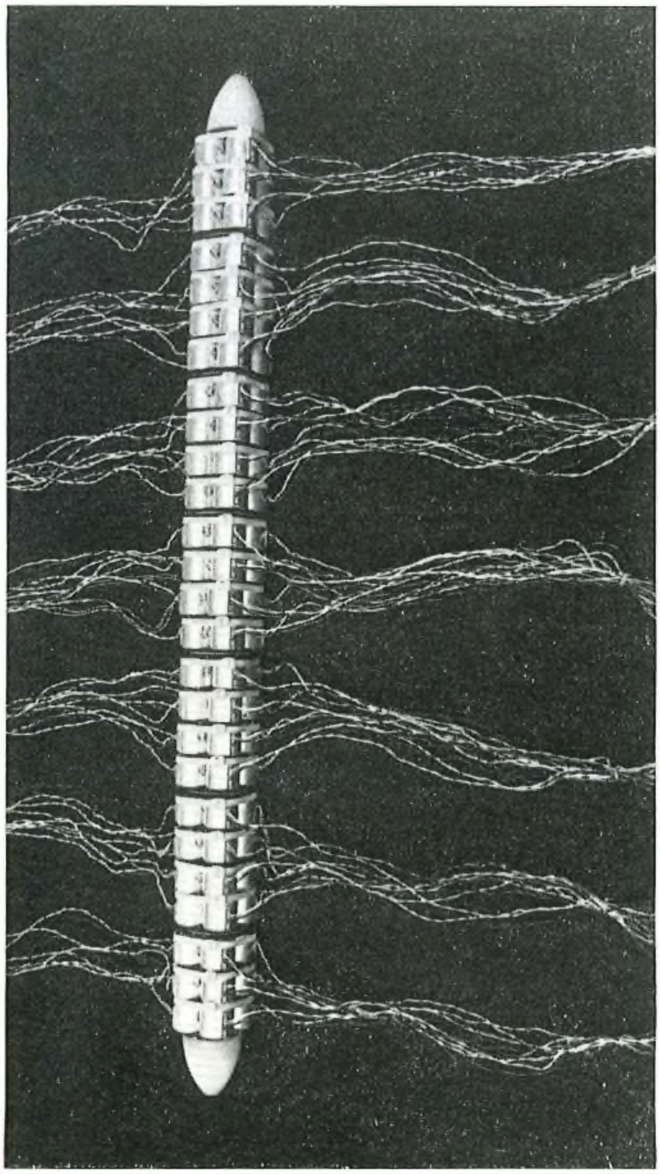
Regional Notes

South Eastern Region

Portsmouth-Ryde Submarine Cable

Work has recently been completed by the Network Planning and Programming Department in laying a new 104 pair 20lb/mile cable in the five miles of water separating the mainland from the Isle of Wight. The submarine link will form part of a new Portsmouth–Ryde CJ cable. This cable is unique in that it is fitted with loading coils in the joints at a nominal 2,000 yards spacing, giving a standard 20/88/1·136 cable.

A problem previously existed in providing local audio circuits between Portsmouth and Ryde, due to the high attenuation of unloaded submarine cables which necessitated four-wire circuits with amplifiers at both ends to give the required quality of transmission.



104–Pairs Unicoil Assembly

The greatly reduced attenuation of the new cable will permit circuits to work between Ryde and Portsmouth Central on a two-wire unamplified basis and between Ryde and Portsmouth Trunk as two-wire circuits, using a single negative-impedance type amplifier.

The new type of submarine cable joint containing 104 unicoils has been specially developed by the Telecommunications Development Department, and the armoured lengths were pre-jointed at the cable contractor's works.

M. W. Neville

Scotland

Removal of a Mobile Exchange at Lanark

Lanark exchange was recently converted from a CB 10 exchange to a group switching centre—a fairly routine operation these days, but one which had associated with it several unusual events.

Some years ago, a mobile telephone exchange (m.t.x.) was installed to provide relief to the exhausted manual exchange and the arrangements made for the provision and recovery of the m.t.x. were somewhat unusual.

The manual exchange was situated above a bank in Lanark's main street and the only suitable location for the m.t.x. was in a narrow vacant space between the bank and adjacent buildings. Mainly for security reasons, a wall had been built along the street frontage between the buildings, and it carried a stone plaque which was inscribed:

> "Here stood the house of William Wallace who, in Lanark in 1297, first drew sword to free his native land."

Lanark is the county town and justly proud of its associations with the Scottish patriot, so that when the wall was demolished, special arrangements were made with the Borough Architect for the safe preservation of the plaque. After the m.t.x. was moved into position, the wall was rebuilt—including the reinstatement of the plaque. The whole operation took about a week.

After the main exchange transfer, the m.t.x. was urgently required elsewhere. From the outset, it was decided to avoid demolition of the comparatively new wall, so quotations were sought from a number of crane-hire firms and, in the event, that of a Glasgow firm was accepted. Their quotation was £95, which included insurance cover for £14,000. The lifting beam used was specially manufactured by the firm and tested by the insurance company.

Crane lifting m.t.x.

The crane used was an Allen Grove telescopic crane, capable of lifting forty tons, the weight of the m.t.x. being about seven tons. Sufficient space was available in the street for the crane to be positioned, but, due to the very restricted manoeuvring space between the buildings, a very high lift was required. Hence, early one wet and windy Sunday morning, and with the statue of William Wallace watching us from the nearby church, the m.t.x. was lifted some twenty-five feet into the air and over the wall. The actual lifting time was about twenty minutes, the whole operation from start to finish taking less than two hours. Apart from a few very minor paint scratches, the m.t.x. was undamaged—and the plaque remained undisturbed.

F. A. L. and G. C. D.

North East Region

Restoration of microwave links to the Emley Moor Television Transmitter

During the afternoon of Wednesday 19 March 1969 the ITA channel between the Leeds Network Switching Centre (N.S.C.) and Emley Moor became noisy. Waveguide pressure had been lost at Emley Moor and there was every indication that the waveguide had been damaged, that moisture had penetrated and possibly that the aerial had been damaged. The receiving aerials for the Post Office microwave link were mounted on the main transmitting mast at Emley Moor.

Late in the afternoon the regional mast and aerial A.E.E. examined the main transmitting mast, which was heavily iced, and decided that ascent would be dangerous. This officer was still on site with the local radio maintenance T.O. when the 1,250 feet tall mast collapsed with an explosive roar at 1703 hours.

Destruction of the mast was complete and various buildings on the site were damaged, some of them quite severely. Much of the mast fell outside the site area completely blocking a main road and the stay wires sliced through the roof of a nearby methodist chapel. It was quite astonishing that there was no loss of life or serious injury. The post office personnel were in the microwave equipment room some twenty-five yards from the base of the mast at the time of the failure. One snapping stay-wire lashed over the snow covered roof of the room, cracking it, and allowing water to seep in. As the temperature rose during the evening this became a serious hazard to the terminal equipment.

Clearly no restoration of services was going to be possible during the evening since the ITA and BBC 2 transmitter aerials and the PO microwave aerials had been lost. The Post Office staff turned their efforts to safeguarding the radio equipment and protecting it from the ingress of water. All the equipment was sheeted over and the roof was cleared of snow. The building formed part of the BBC complex and the following morning they provided an external tarpaulin covering.

Next day various methods of restoration were discussed by Telecommunication Headquarters and Regional staff. It was decided that it would be impossible to use the original routing from Heaton Park via Windy Hill to Emley Moor, because this path needed very high dish aerials at Emley Moor and the proposed temporary broadcast masts could not accommodate these.

An alternative route was devised, exploiting the telephony traffic protection channels on the London–Leeds system, by intercepting these at Upton radio station and extending them to Emley Moor by means of Outside Broadcast (O.B.) temporary equipment. Thus, the ITA program from Heaton Park was extended, first to Tinshill (on the London–Leeds system) on a recently completed broadband channel which had not yet been taken into service, thence to Upton and Emley Moor. The BBC 2 program was teed off the East Anglia feed at Morborne Hill, farther south on the London–Leeds system, then routed northward to Upton and Emley Moor.

Loss of the telephony protection channels was made good by providing a manually-switched channel from London, via Oxford, Birmingham and Manchester to Tinshill.

Demodulation equipment was acquired from Copt Oak radio station in the Leicester Area and installed to feed the television channels to the O.B. links. Extra-long feeder-cables to cope with the height to which the aerials had necessarily to be fitted were supplied by the Midland Telecommunications

Erection of the scaffold platform with temporary BBC aerial in the foreground

Wreckage of the main mast

Region. Panning was carried out in darkness and the first link, providing a BBC 2 signal to an O.B. vehicle roof at Emley, was offered and accepted by the BBC at 2130 hours. The BBC commenced transmission on Friday 21 March at 1430 hours, from a temporary transmission aerial.

The second O.B. link was brought into service on the Friday at 1430 hours and this supplied the ITA signal to the roof of a building on the site at Emley. ITA started transmissions at 1550 hours on the Sunday from a temporary transmission aerial.

The initial O.B. aerial provision was only satisfactory as an emergency expedient since it provided only marginal clearance of trees on the Emley site. To provide a more satisfactory link a 60 ft scaffold platform was erected at Emley for the aerials. This was completed on the Sunday and the O.B. aerials transferred to it.

Meanwhile, arrangements were being made for a more permanent service to normal standards. This was achieved by 27 March with the provision of a transportable mast, aerial dishes and flexwell feeders, connected to the original rack equipment at Emley Moor.

J. D. Thomas

Red Deer Antlers at Norwich

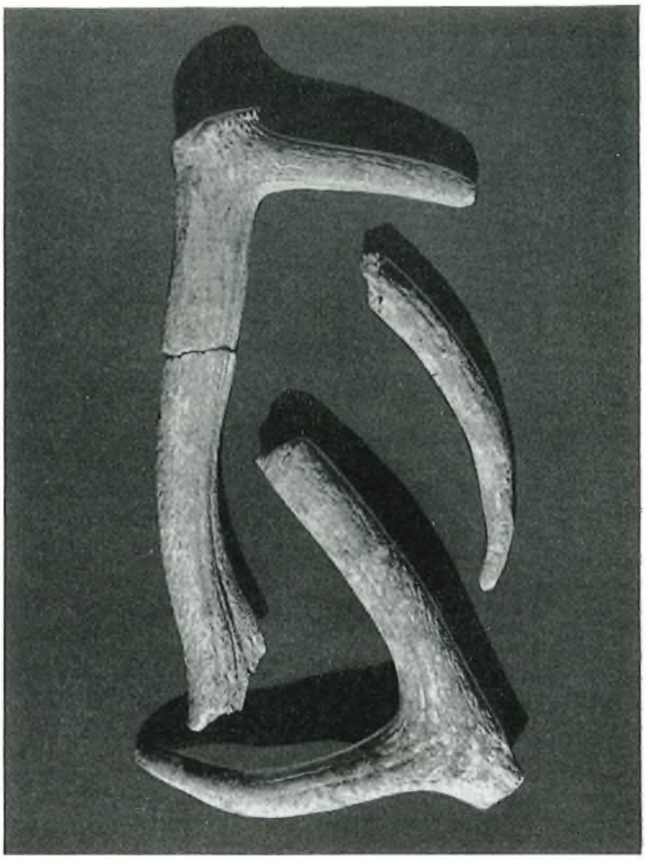
During recent duct laying operations between Norwich A.T.E. and the Repeater Station, an interesting find was made during excavation in an old part of the city, running parallel and adjacent to the river Wensum.

A tunnel was discovered, crossing the line of the excavation, in virgin chalk strata, approximately 8 feet down. This tunnel, four feet in diameter, was crossed by another short section of tunnel in which had been cut a shelf and on this picks made from Red Deer Antlers were found. The floor of this tunnel, which was at river level, was coated with signs of alluvial mud; giving rise to the opinion that the tidal water was used to soften the chalk for easier removal.

The object of the tunnel was for mining the hard black flints which lie in 12–15 inch layers. Some flints weigh up to 1 cwt. The flints were required for the manufacture of hunting and domestic tools in the Neolithic and Palaeolithic ages.

The Norwich museum identified the picks as being from Red Deer Antlers, but accurate dates can only be approximated, in the absence of radio-carbon tests.

A. E. R. B.



Associate Section Notes

Aberdeen Centre

On Friday, 2 May, the annual general meeting was held in the Imperial Hotel. After a few remarks by the chairman and the secretary, and the acceptance of the annual balance sheet, the following office bearers and committee members were elected:

President: Mr. J. W. H. Sharp; *Vice-President:* Mr. H. A. McFarlane; *Chairman:* Mr. R. T. Ross; *Vice-Chairman:* Mr. J. Davidson; *Secretary* and *Treasurer:* Mr. R. Mathewson; *Asst. Secretary:* Mr. R. Kemp; *Librarian:* Mr. W. Williamson.

After the meeting the company enjoyed an excellent dinner and were entertained by a local folk group called "The Crofters".

Edinburgh Centre

On Tuesday, 4 February, twenty-five members visited Melrose TXE 2 Exchange, the first electronic exchange in the Edinburgh Area. The P.O. Clerk of Works, Mr. S. Dodds, explained the TXE 2 System with the aid of trunking diagrams, then showed the actual equipment in situ, and answered the many questions which were put to him. This visit was throughly enjoyed by all present.

On Thursday, 3 April, a visit was made to British Rail Marshalling Yard at Millerhill by eleven members. We were shown the control tower which houses a computer. The computer receives information from the track of the weight, speed and position each wagon has to take in the appropriate siding.

We then saw the signal cabin for the section of main line which passes through the yard. The control systems used were similar to those we are accustomed to in the Post Office.

The annual general meeting and dinner was held in the Iona Hotel on Wednesday, 9 April, thirty-one members being present. The following office bearers were elected for 1969–70.

Chairman: Mr. J. A. Coghill; *Secretary:* Mr. M. K. Finland; *Asst. Secretary:* Mr. L. J. McQuatt; *Treasurer;* Mr. R. W. Elder; *Librarian:* Mr. T. A. Woolard; *Committee:* Messrs L. Young, J. King, S. Barr, J. L. M. Alexander, R. N. Cockburn, W. Crilly, R. S. Elder, J. Edwardson and W. Pearson.

Glasgow Centre

The annual general meeting, held in May, brought to an end a successful 1968/69 session which included talks ranging from cable pressurization to micro-electronics. There were also visits of great interest to S.T.V. Glasgow and to B.M.C. Bathgate.

Due to promotion, Mr. Marsh was unable to continue as chairman, an office he has held most sucessfully for the past six years. We thank him for the support he has given and wish him every success in his new post. The new chairman is Mr. J. McCullum and the following office bearers were also elected.

Vice-Chairman: W. Fotheringham; *Secretary:* J. S. Mitchell; *Asst. Secretary:* M. Cochrane; *Treasurer:* K. Gordon.

The 1969/70 program was discussed and for the forthcoming session proposed talks are: "Transit Networks", "Weather Forecasting", "Hospital Engineering", "Transistor Battles". A selection which the committee feel is wide enough to provide something of interest for everyone.

W. F.

Inverness Centre

The annual general meeting was held in the Tower Hotel on Thurdsay, 10 April 1969. The following office-bearers were elected:

President: Mr. J. J. Loughlin; *Vice-President:* Mr. R. I. Thompson; *Chairman:* Mr. J. Fraser; *Secretary:* Mr. W. A. Allan; *Treasurer:* Mr. A. Ross; *Librarian:* Mr. B. W. Fieldsend; *Committee:* Messrs R. H. Inglis, D. C. Bell, L. G. Nuttall, C. Wilson, E. J. MacLeay, I. C. MacLeod and G. Gordon.

After tea, four speakers gave their views on means of increasing productivity, which were as follows: "organization", "persuasion", "attitudes", "incentives".

Forty-one members of the Associate and Senior Sections attended the meeting, including two who had travelled all the way from Kyle. Discussion and comment continued until 11.15 p.m.

Oxford Centre

The annual general meeting of the Oxford Centre was held at the Kings Arms, Gosford, on 16 April when we were pleased to welcome Mr. S. H. Sheppard, Regional Liaison Officer, and Mr. P. Buck Telephone Manager.

The following officers were elected or re-elected:

Chairman: N. McCollin; *Vice-Chairman:* D. Cotterill; *Secretary:* D. Green; *Treasurer:* A. Shepherd.

Our summer program began on 14 May when a party of our members visited the Pressed-Steel Fisher factory at Cowley.

The future programme includes the following:

20 June:	Visit to the R.A.F. Station at Brize Norton.
12 August:	Visit to Newspaper House, home of the Oxford Mail and Oxford Times.
23 October:	Visit to Didcot Power Station.

D. A. G.

Exeter Centre

The 1968/69 winter program has drawn to a relatively successful conclusion with average attendance much higher than was at first expected.

The quiz which was held at the Drive Inn, Newton Abbot, on Friday, 11 April was attended by over 40 members and visitors. Torquay won this third round by 82 points to 78 and, having won the second of the two previous events, were declared winners of the series. The evening, like previous quizes, was very rewarding to all those who took part in the preparation, and the presentation.

The question master and adjudicator was Mr. E. H. K. Brown, scorekeepers, Messrs W. J. Foster, and J. Petherick, timekeeper Mr. N. H. B. West. Questions for this event were prepared by the Treasurer Mr. C. Chandler. The teams were: *Torquay*: J. J. Anning Capt., K. Border, B. Manuel, and L. E. Perryman; *Exeter*: L. J. Squires Capt., F. W. Beer, P. Henley, and B. Turner. Following the quiz the audience took part in recognizing a series of slides which were arranged by Messrs C. Millman and S. G. Page, who, together with Mr. L. C. Darch, helped with the final arrangements.

At the annual general meeting held in April the following officers and committee were elected: *President*: W. J. Foster; *Chairman:* G. S. Steer; *Vice-Chairman:* L. E. Hines; *Hon. Secretary:* T. F. Kinnaird; *Hon. Asst. Secretary*: J. J. F. Anning; *Hon. Treasurer:* W. F. Lambert; *Hon. Librarian:* N. H. B. West; *Committee:* Messrs M. W. Durrant, D. E. Elford, S. G. Page, J. L. Petherick and M. J. Saunders; *Hon. Auditors:* Messrs B. Adams and P. J. Hartnell.

After serving 7 years as Hon. Treasurer Mr. C. Chandler decided not to stand for re-election. The Centre is indebted to him for the work he has done, and for the active interest he has taken in all its activities.

Following the A.G.M., we were addressed by Mr. T. Taylor, Chief Instructor of Crypton Triangle Ltd, Bridgewater. As was hoped his talk on "Engine Tuning" attracted a good attendance. The event was so well received that the Committee consider that Mr. Taylor should be invited back before the end of the year to tell us more on this popular subject.

As instructed by the A.G.M., the committee have considered the introduction of a points system for the summer programs. and have decided that, in future, priority in the allotment of places on summer visits, for which there are limited seats, will be given to persons who have attended at least one meeting during previous winter's program. The committee consider that the system should be applied to the 69/70 program and its view will be put to the next A.G.M. for ratification.

The first event of the summer program this year was a visit to the Bristol Engine Division of Rolls Royce Ltd. Over one hundred applications were received, and the first 40 attended a tour arranged in April. The visit was thought to be by far the most interesting in the history of the Centre, and the hospitality of Rolls Royce was equally outstanding. Our party saw a mock-up of Concorde, the presentation of which was breathtaking, a close look at another Concorde under construction was followed by an excellent lunch. During the afternoon the party saw the many skills involved in building jet engines, the Avro Vulcan that formed the test bed for the Olympus engine, and the Hawker Harrier, followed by a film on jet engine testing. The Centre greatly appreciates all that Rolls Royce have done for us, and many members look forward to the repeat visit that has been arranged for July.

T. F. K.

Gloucester Centre

The annual general meeting was held at the Royal Hotel, Gloucester on 16 April 1969. There was a very good attendance and the following officers were duly elected:

President: Mr. R. Procter; *Vice-President:* Mr. R. T. Hoare; *Chairman:* Mr. A. K. Franklin; *Secretary:* Mr. P. G. White; *Treasurer:* Mr. W. E. Hewlett; *Librarian:* Mr. G. Wager; *Auditors:* Messrs F. E. Beard and G. Hale; *Committee:* Messrs A. C. Amos, R. Alder, C. T. Baldwin, J. H. Bowen, T. E. Cole, C. A. Gurney, C. R. Johns, N. Jones, J. S. Metherall and R. Smith.

It was reported that the Gloucester Section was very active and that membership had now increased to 258.

Following the annual general meeting, G. H. Adams Esq., gave a lecture on Cine Photography dealing with its history, sizes of films available, the advent of Super 8 and Single 8 (advantages and disadvantages) and equipment available. To conclude the evening Mr. Adams presented three amateur cine films including one of the opening of the Stroud Automatic Exchange, making some of our members film stars!

The summer visits began in June when a party of 25 spent a pleasant day at London Airport as guests of B.O.A.C. At the time of writing the July visit is to the Stuart Crystal Glass Works and future visits this year include the B.B.C. Studios at Shepherd's Bush and Bristol, John Harvey and Son (Bristol) for a film and appreciation of wine, the new signal box at Gloucester Station and finally the cigar factory of W. D. and H. O. Wills (Bristol).

Ideas for future visits and lectures are always welcomed, and should be given to the Secretary.

P. G. W.

Bournemouth Centre

On the evening of 15 May, 15 of our members visited the Eastern Divisional Police H.Q. at Bournemouth.

Our tour included visits and explanations of the Photography, Fingerprinting, Control Room, and the Criminal Investigation Departments. Identikit Pictures and their uses were explained to us. It was all most interesting and we finished up in the Cells, happily only for a short time.

Ten of our members visited the B.B.C. television studios in London on the 12 June, as on previous visits it was very a worth while tour.

On Thursday 26 June, a party of our members visited the B.A.C. Factory at Hurn Airport and on the 24 July we visited the Control Room at London Airport.

On Saturday 13 September, a visit was made to the Police Driving School at Devizes. Finally, on 2 October, there is a further visit of ten members to B.B.C. T.V. London.

This concludes our summer program.

H. J. G.

Ipswich Centre

We had a rather disappointing start to our winter session when the first of our talks entitled, "Motocross 1968", by John Banks, had to be cancelled owing to the speaker's indisposition. In November we were given a talk on the work of the C.I.D. by the Crime Prevention Officer of the local Police Force which, supplemented by a film, proved most interesting. Our next meeting was to hear Mr. B. Pearce, (R.H.Q.), read his Paper, "The TXE 2 Exchange", which attracted a very large audience all thirsty for information on the new system.

The first meeting of the new year took the form of a quiz by land line with the Oxford Centre. Although we were beaten by Oxford we all found the evening most entertaining and having issued a challenge for the next session we went home much wiser for our experience. At our February meeting we heard a talk on Bee-Keeping given by a local expert. This proved very interesting and we were all amazed at how involved the subject was.

The Annual Dinner and Dance was held the first week in March and a record number of members and their friends were catered for. We were also privileged to have Mr. S. H. Sheppard, our R.L.O., and his wife as our honoured guests and it was generally agreed that this was one of the most successful functions ever organized.

Our March meeting took the form of a film show, which is a popular annual event in our program. The annual general meeting was held in April. After the formal business of the meeting was over, a photographic competition was held. It was judged by the Manager of a local photography shop, and the Chairman's Cup was presented for the best overall entry.

R. L. B.

Bedford Centre

The 1968/69 winter session has been quite a successful one for this Centre. Some very interesting lectures on contemporary subjects were included in the program, such as "Basic Principles of Electronic Exchanges," "Pulse Code Modulation," and Computers. The last lecture, given on 28 May, dealt with "Lasers and their Applications." The lecturer brought with him and demonstrated a Helium-Neon laser.

Thanks are due to members of the Main Institution in Bedford for their support.

Centres in the Eastern Region are very fortunate in having Mr. S. H. Sheppard (Reginal Engineer) as Regional Liaison Officer. He actively supports and encourages our Associate Section and in his quiet, diplomatic way, has chaired two Conferences of Officers of the 12 Centres within the Region. These have stimulated an effort to produce an Eastern Region Associate Section Magazine, the first issue of which will be published in the Autumn.

If anyone has an article or any form of contribution which could be included in this publication, even if it is only a letter or a question of a controverisal nature, please contact the editor: Mr. E. W. H. Philcox, Telephone House, E1/6, Harpur Street, Bedford. Tel: Bedford 61561.

E. W. H. P.

Manchester Centre

The program for the 1968/69 session began later than usual, due to uncertanties caused by the splitting of the old Manchester area into three independent areas. Once under way, however, the session proved to be highly successful, with good attendances at meetings, and an ever-increasing membership, currently standing at 260.

In an attempt to promote interest in the younger staff, the centre held an essay competition open to TTAs and TTIs only. Despite the fact that the subject matter was left entirely to the entrants to decide upon, the response was poor. The winning entries were, however, excellent, and in no way reflected on the quantity of entries. The prizes were presented to the winners by the Vice-President Mr. A. C. Stollard, at a meeting attended by about 60 TTAs. Mr. Stollard gave a short talk about the centre, and it is hoped that the interest showed by the TTAs will result in a larger entry for the next competition, to be held this session.

The following lectures were held during the session:

November, "Computer Programming Techniques."
January, "The TXE 2 System."
March, "Engineering Promotion Proceedure."

The following visits took place:

December, Daily Express Newspaper.

February, General Electric Information Systems. (Data link computer system)
April, Thwaites Brewery.

The session concluded in April, with the annual general meeting, combined with an interesting film show. The following officers, and committee were elected for the next session: *President:* Mr. H. J. Wood; *Vice-President:* Mr. J. Gaukroger, Mr. A. C. Stollard; *Chairman:* Mr. C. F. Driver; *Secretary:* Mr. L. R. Hopwood; *Treasurer:* Mr. D. W. Roughley; *North Area Liaison Officer:* Mr. B. Hampson; *South Area Liaison Officer:* Mr. A. F. Turner; *Committee:* P. C. Hicks, I. D. Dick, G. Hardman, R. J. Edwards, A. F. Macallister.

The committee have quickly settled down to the task of preparing the program for the next session, and this should be available to the members by the end of July, in plenty of time for the next session. Arrangements have so far been made for talks on P.C.M., Crossbar exchanges, Postal Mechanization and Computer Programming. Visits have been arranged to Rolls Royce, British Rail.

It is hoped that this program will attract further members and, of course, be of interest to the existing membership.

L. R.

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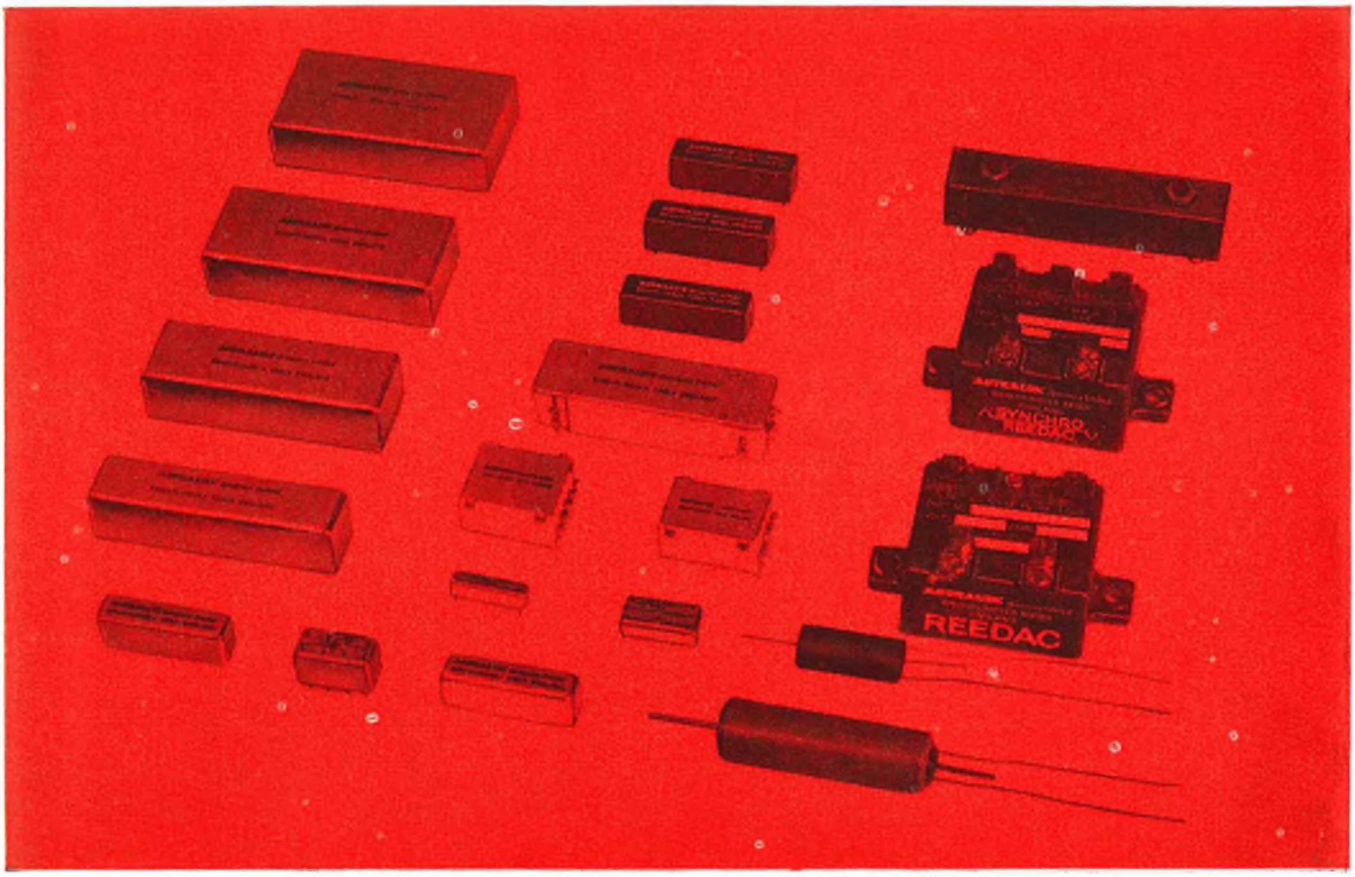

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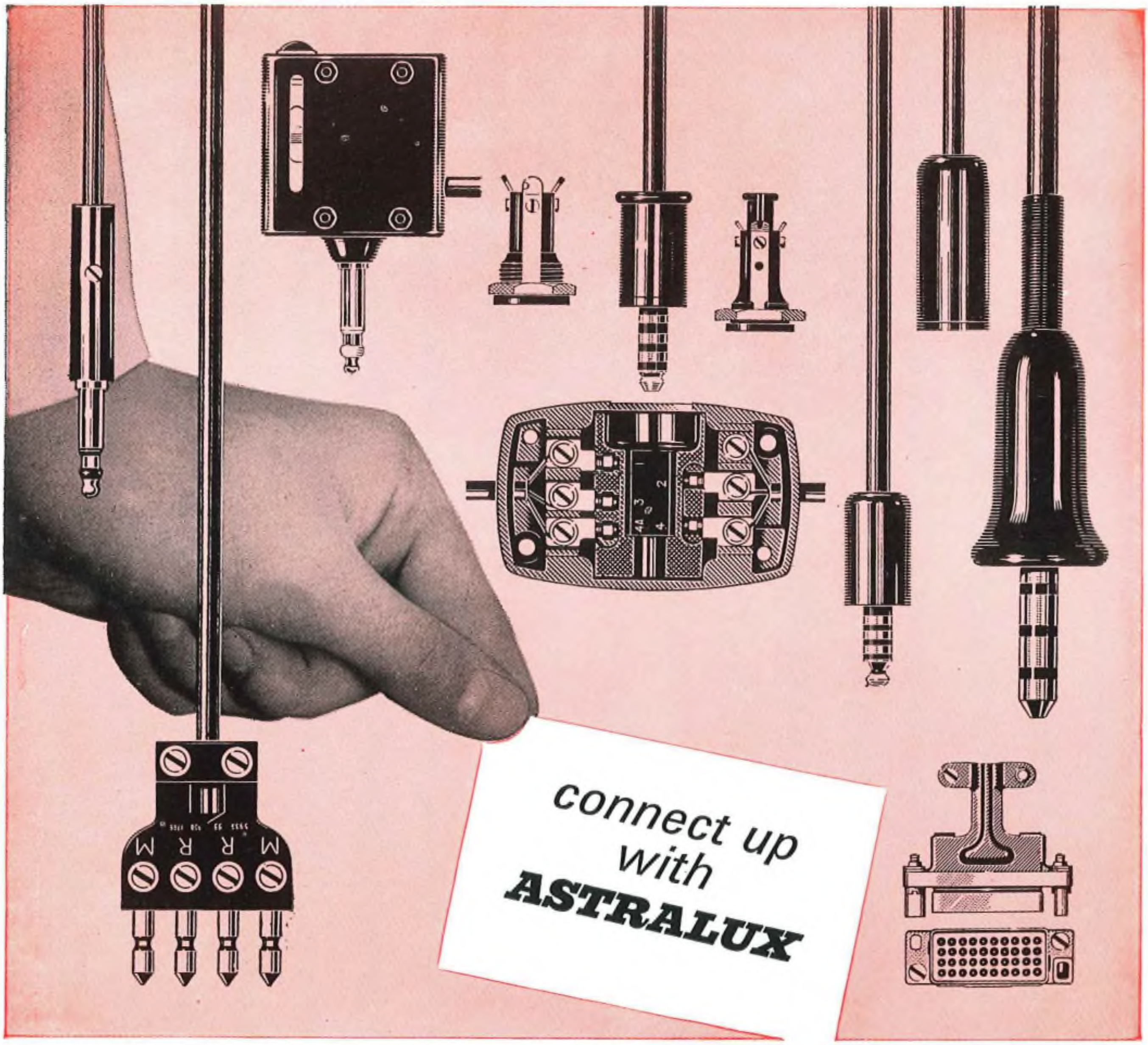
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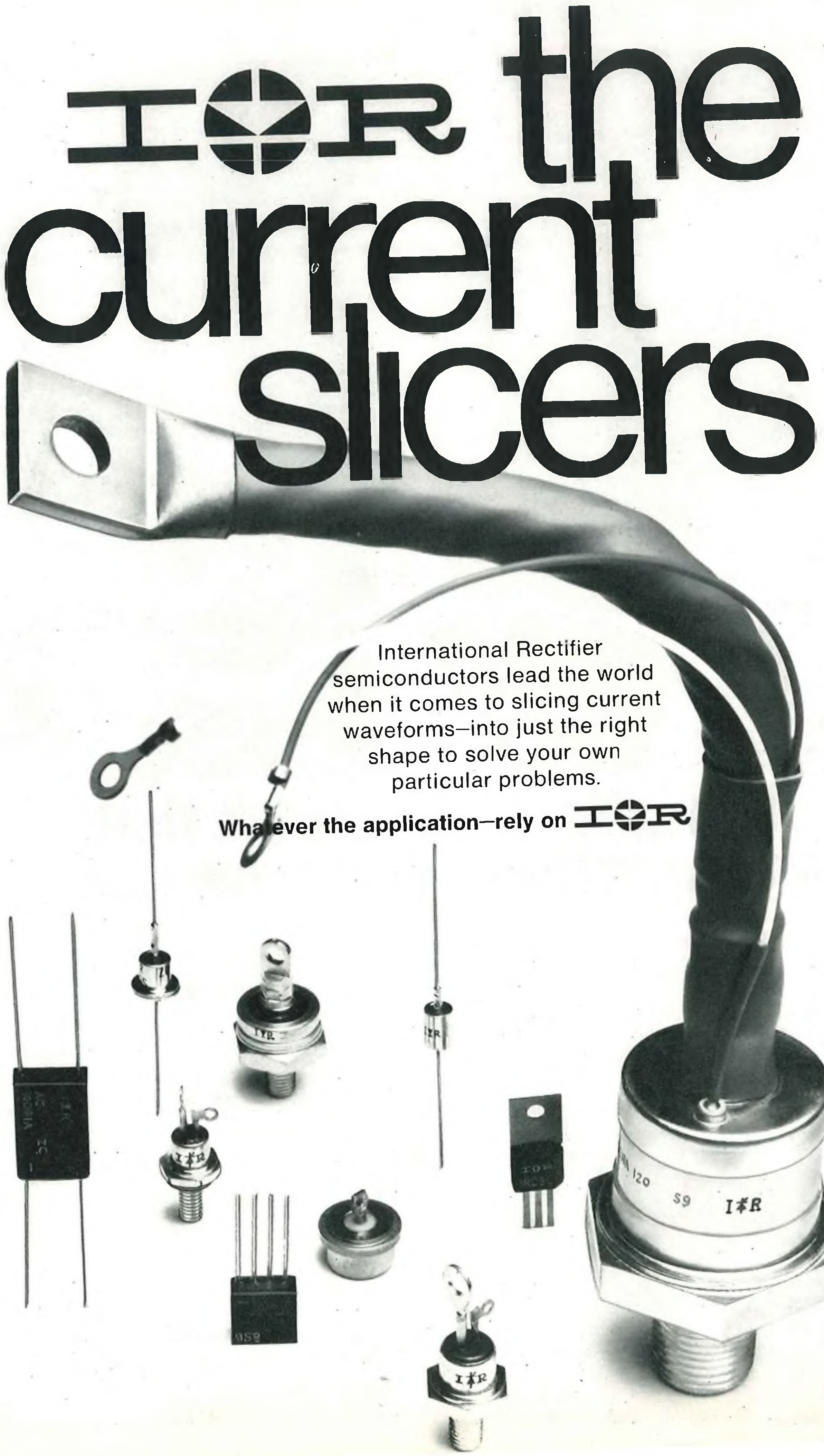
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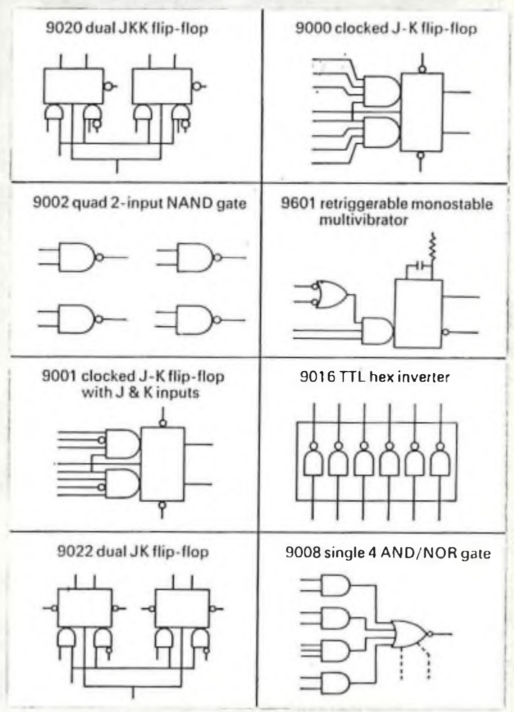

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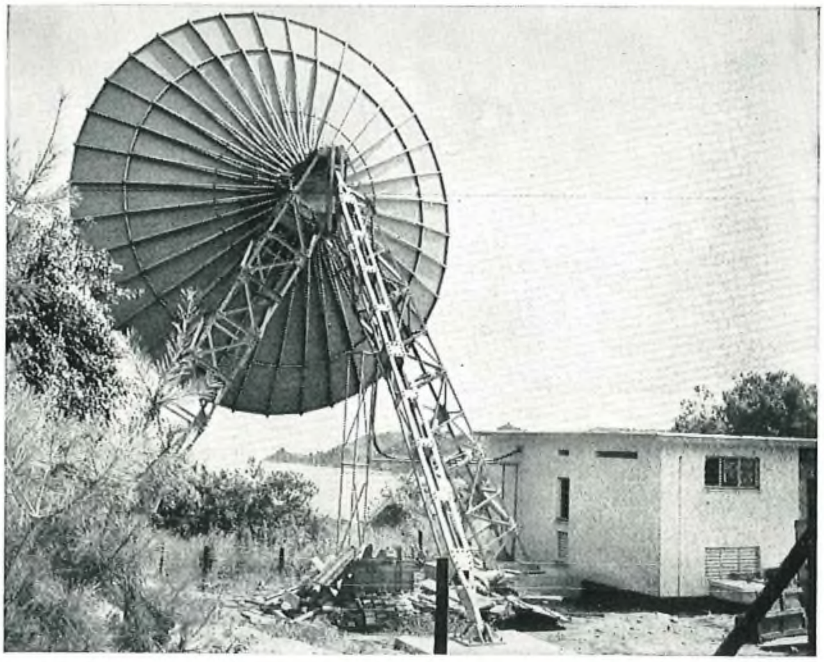

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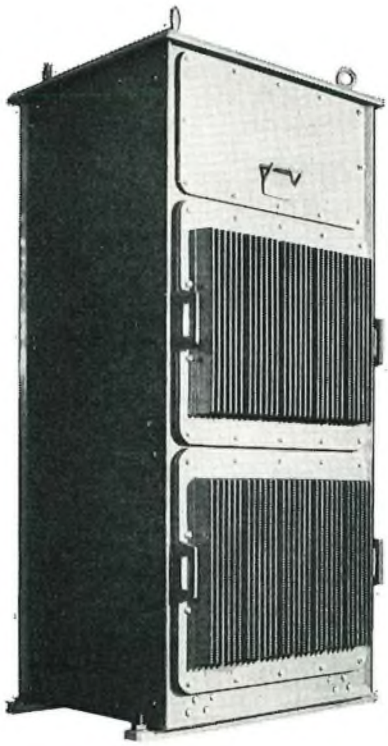

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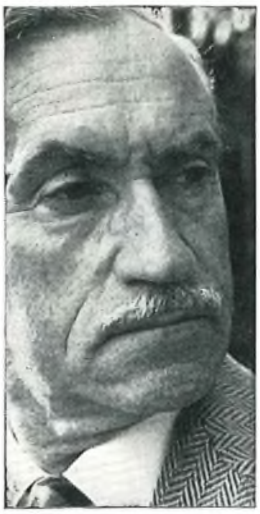

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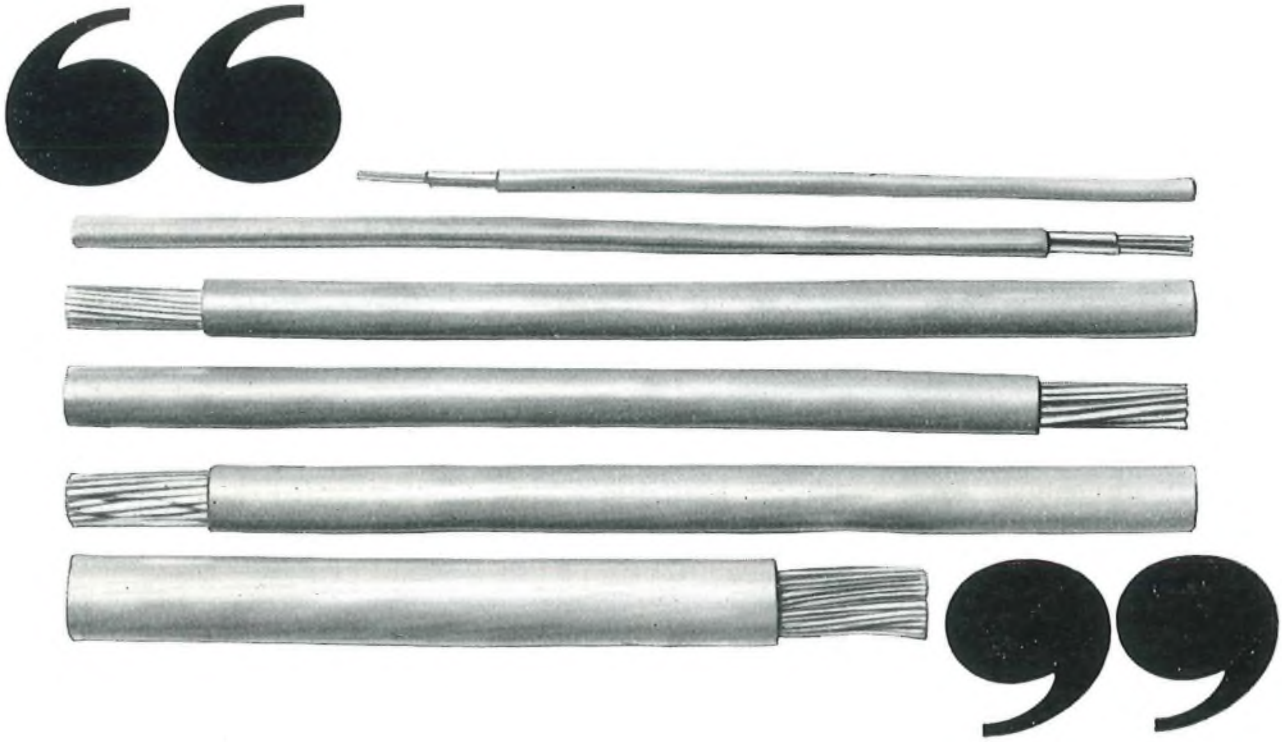

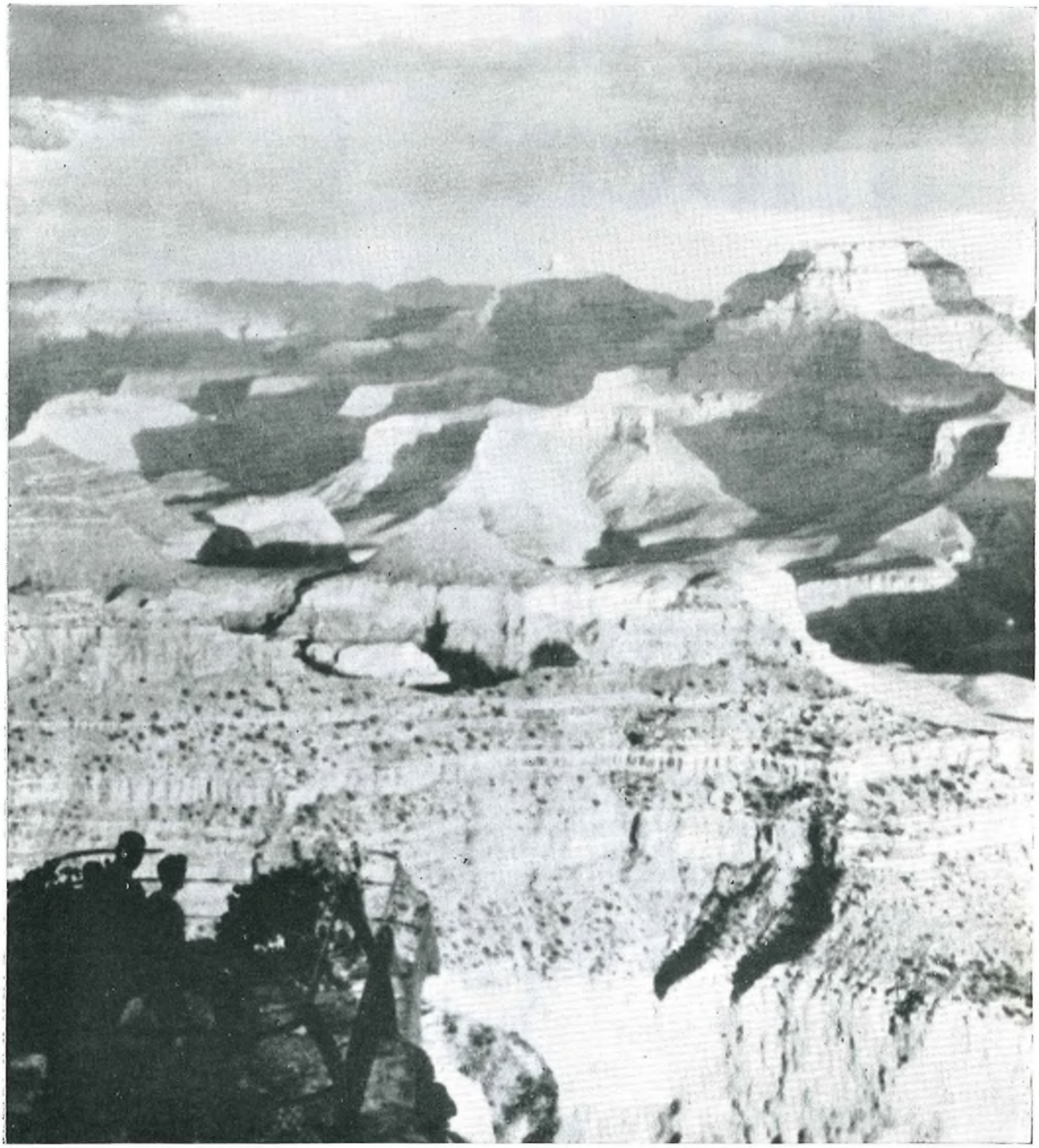

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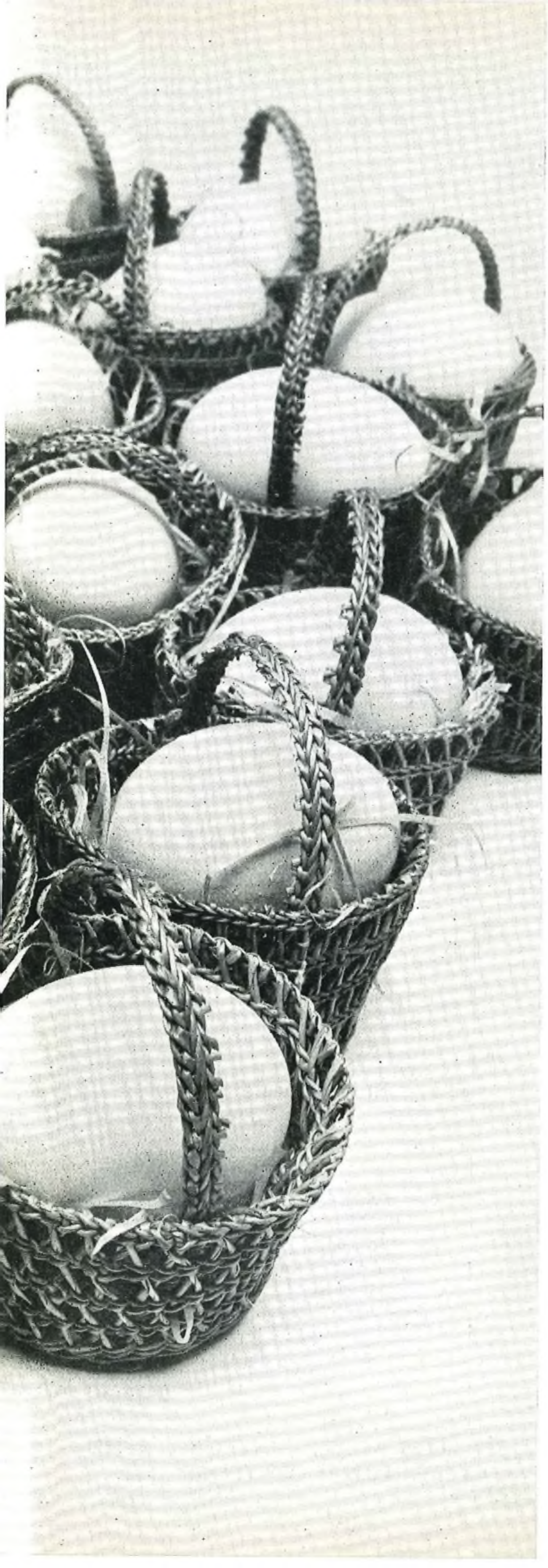

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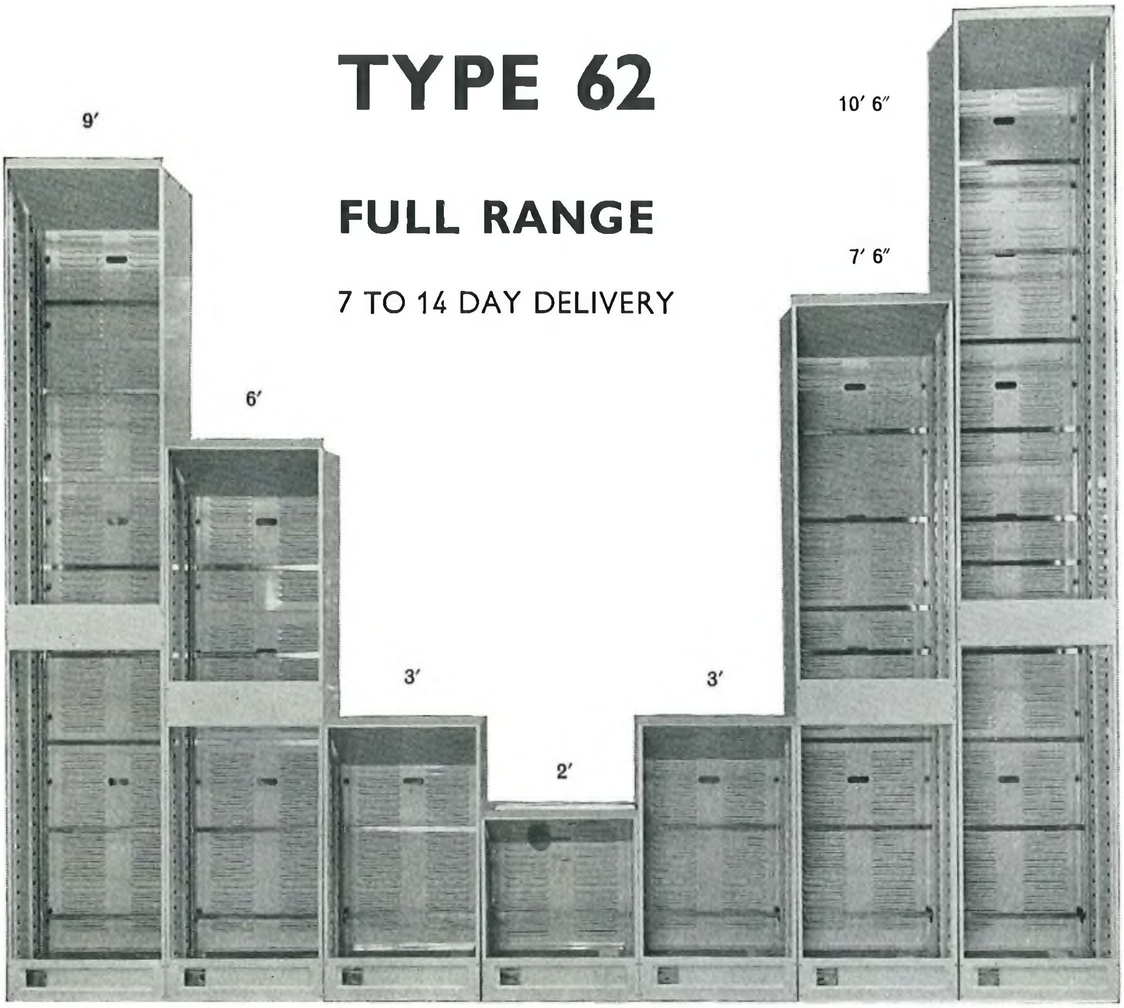

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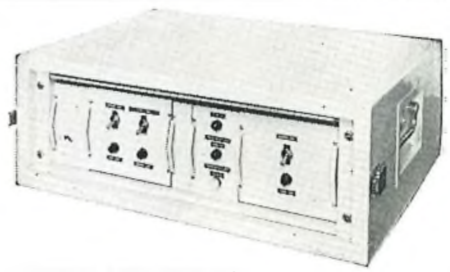

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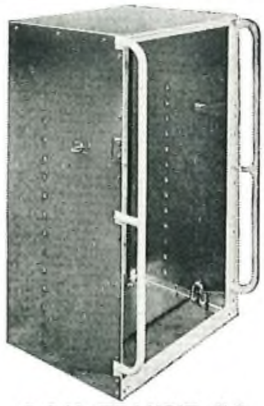

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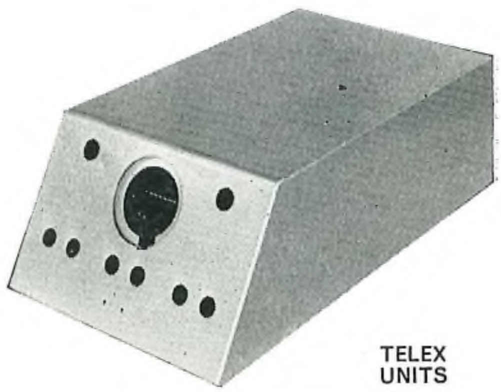

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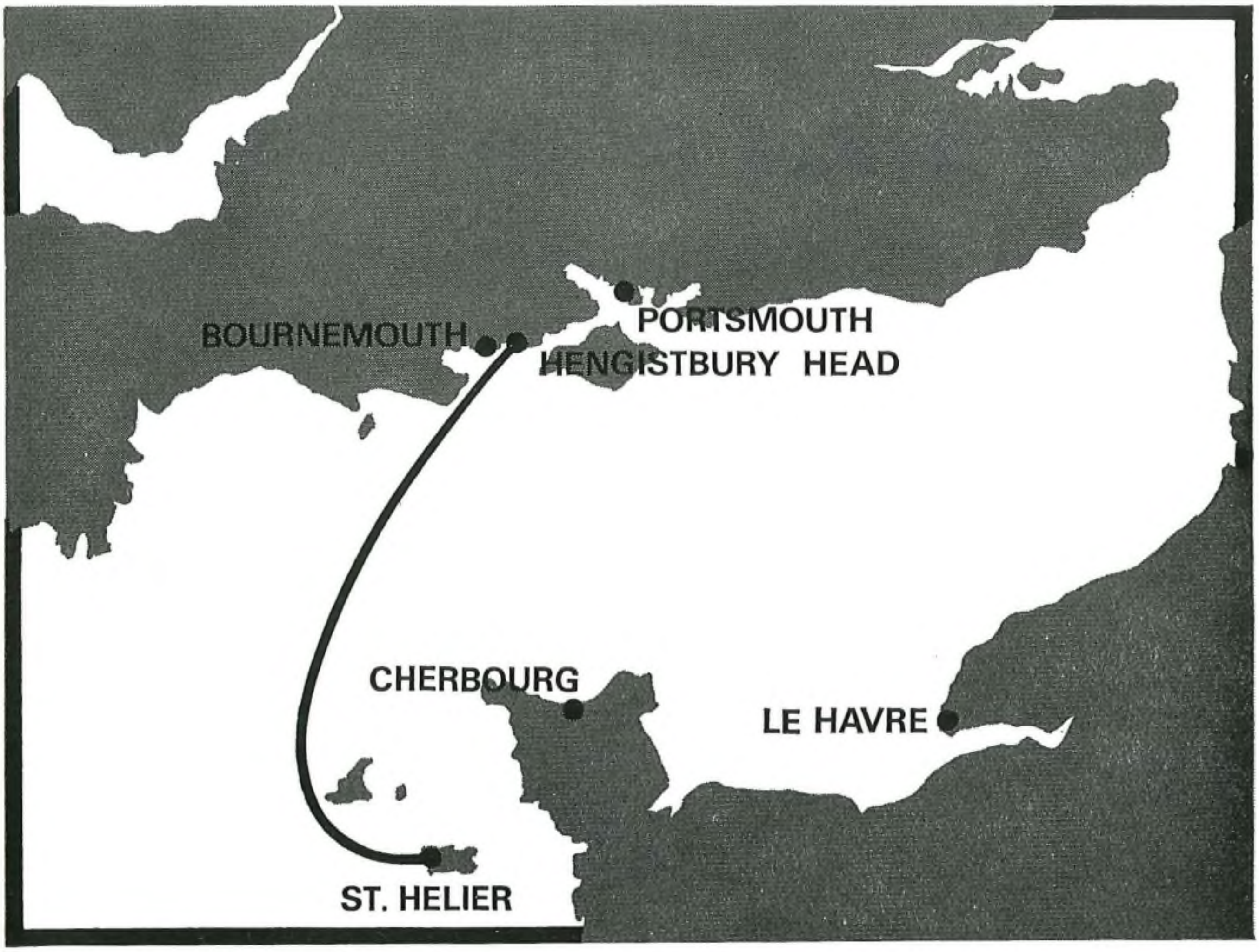

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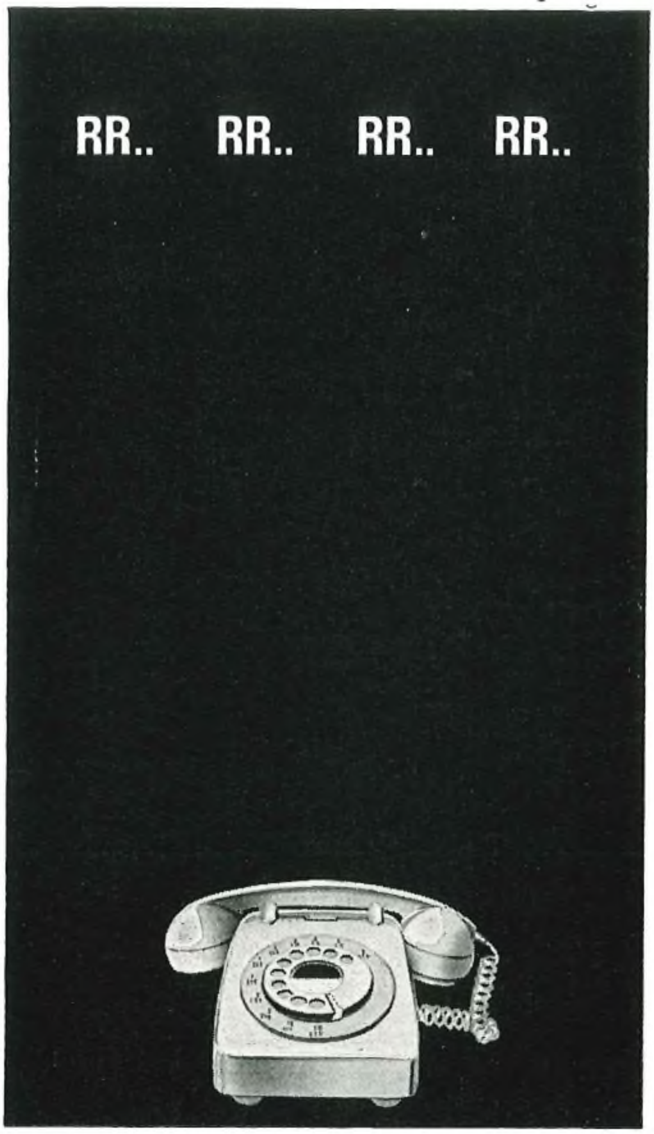

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