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"To promote the general advancement of and to facilitate the exchange of information and ideas on Radio Science."

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ANNUAL GENERAL MEETING OF THE INSTITUTION

The TWENTY-SECOND ANNUAL GENERAL MEETING of the Institution (the fourteenth since incorporation) was held at the London School of Hygiene and Tropical Medicine, London, W.C.1, on October, 9th, 1947, commencing at 6.5 p.m.

Mr. W. E. Miller (Chairman of Council) presided and was supported by other officers of the Institution and members of the Council. Thirty-two corporate members were present at the commencement of the meeting and the Chairman held twenty-four proxy votes.

The Secretary read the notice convening the meeting, which had been published in the July/August 1947 Journal, and repeated in a letter circulated to all corporate members of the Institution on the 16th August, 1947.

1. To confirm the Minutes of the Annual General Meeting held on September 25th, 1946.

In accordance with the Institution's custom, the minutes of the last Annual General Meeting were recorded on pages 169–171 of the September/November 1946 Journal. The Chairman (Mr. W. E. Miller) moved that this record should be adopted as the correct minutes; this proposal was unanimously approved and the minutes signed accordingly.

2. To receive the Annual Report of the General Council.

The Chairman referred to publication of the Annual Report for 1946/47 on pages 126–135 in the July/August 1947 Journal and continued :—

"I do not consider it necessary to elaborate the very detailed report which the Council has already submitted to the membership, since this not only covers every phase of the Institution's activities for the year in question, but also, I think, admirably indicates "the shape of things to come."

From my own contact with the membership, I know the feeling of appreciation held by us all in having the honour of the Patronage of His Majesty The King. Notice of this honour was a notable landmark in the history of the Institution, coming as it did, to mark also the 21st anniversary of our foundation.

The report of the Professional Purposes Committee shows that in many directions the Council has been at work to promote the status of the membership and to enable the Institution to carry out the objects specified at the time of its incorporation. Outside Great Britain, the past 18 months have seen great developments in our international connections which we all hope will be of the greatest possible advantage to engineers of whatever nationality.

This aspect of a professional society's work cannot be over-emphasized because we know and must appreciate more than ever that science knows no national boundaries. Our own efforts are exemplified in particular by the attendance of French engineers at our Convention, which, although not within the purview of the year in question, necessitated a great deal of work during the year 1946/47.

The Council has done everything possible in furthering wherever appropriate, co-operation with other engineering institutions, both at home and overseas, and our increasing membership overseas is indicative of the status which the Institution enjoys throughout the world.

The membership figure has increased in very similar proportions to the figures presented to you in the 1945/46 report. The value of those figures can only be appreciated when it is borne in mind that during the year, conditions were by no means normal and that it was the first full year in which the Council enforced yet higher conditions of election. These conditions will lead also to a more widespread interest in the examinations of the Institution and it may be rightly felt that after many years of difficulties and perhaps, prejudice, the Institution's long standing views on education and training in radio engineering are now reaping at least part reward. Certainly, it is now possible for intending members of our profession to obtain the training that is necessary.

The Institution has also played a not inconsiderable part in attending to the needs of a branch of the industry which, whilst not meeting our membership requirements, needs the assistance of professional radio engineers—I refer to the training schemes for service mechanics now being covered by the Radio Trades Examination Board which has reached most useful agreement with the City and Guilds of London Institute.

The attendance here tonight and throughout the whole of last year's session is in itself adequate comment upon the work of the Papers and Technical Committees. It must not be forgotten that the Papers Committee works very closely with the provincial section Committees, of which there are now six, making it possible for all members throughout the country to attend regular meetings and to benefit by association with fellow members.

Both these Committees co-operated to a very great extent in making arrangements possible for our first post-war Convention and here I would like to thank not only those Committees, but the members of all Committees of the Institution for the considerable amount of work which they have devoted, in an honorary capacity, to furthering the Institution's objects.

I propose, as previous Chairmen of Annual General Meetings of this Institution have recommended, to move the adoption of the Council's report, reserving comment on the finance section of the report until a little later in this meeting."

Seconding the Chairman's motion for the adoption of the Annual Report, Dr. Hilary Moss referred to the considerable amount of work done by Council and the various Committees which had of necessity to be abbreviated in a report of this character. Members had seen, during the past year, some of the results achieved by Council in furthering the status of the Institution as well as developing all activities. The unanimous adoption of the Report would convey the appreciation of members for the work of Council and the Committees.

The report was then unanimously approved.

3. To elect the President.

The Chairman referred to the Agenda which gave the Council's unanimous recommendation and Mr. Miller stated that during the past year members of Council had an unforgettable experience in having had with them, until his departure for India, the attendance of Admiral Mountbatten at Council meetings. His immediate grasp of the Institution's problems had never failed to astound those who attended Council meetings, and it would be obvious that much of the new work undertaken by the Institution during the year had been largely the result of the foresight and great personal interest which the President had shown in being responsible for finally directing the policy of the Institution.

Mr. Miller then formally moved that Admiral the Earl Mountbatten of Burma be re-elected as President of the Institution.

In seconding the proposal that Earl Mountbatten be re-elected as President of the Institution, Mr. E. A. W. Spreadbury also suggested that a message of good wishes from the meeting be conveyed to the President.

The resolution and suggestion was carried unanimously.

4. To elect the Vice-Presidents of the Institution.

The Chairman stated that from the notice already sent to corporate members of the Institution it was apparent that Council's decision to recommend the re-election of the four Vice-Presidents was a popular one.

Mr. Miller continued:

"We much regret the absence of Air Vice-Marshal R. S. Aitken tonight, but he has had a breakdown in health, and for that reason only is not in this Chair. During the last six months, he had had a most strenuous time at the Institution, since, at the personal request of our President, Air Vice-Marshal Aitken has been acting in Admiral Mountbatten's absence.

It is of great help to the Council that they have had throughout the year the frequent attendance of Vice-Presidents at their Council meetings—it is so very essential that every officer of the Institution takes an active part in the Institution's work and it is with such feeling that I recommend we now elect the following as Vice-Presidents of the Institution for the ensuing 12 months:

Mr. Paul Adorian.
Air Vice-Marshal R. S. Aitken, C.B., C.B.E., M.C., A.F.C.
Mr. Leslie H. Bedford, O.B.E., M.A., B.Sc.
James Robinson, M.B.E., Ph.D., D.Sc.

Mr. H. Tibbenham seconded the proposal and the four members mentioned were then unanimously elected Vice-Presidents of the Institution for the year 1947/48.

5. To elect the General Council.

The Secretary reported that for the second successive year corporate members had not made any additional nominations to those circularised by the Council on August 20th, 1947. Many members had, however, commented most favourably upon Council's nominations and in accordance with the constitution of the Institution therefore, the following were elected to the General Council for the year 1947/48:

Sir Louis Sterling (Honorary Member); E. Cattanes

(Member); H. Moss, Ph.D., B.Sc. (Hons.) (Member); L. Grinstead (Member); W. W. Smith, B.Sc. (Hons.) (Member); G. A. Taylor (Associate Member); J. L. Thompson (Member); Honorary Treasurer, S. R. Chapman, M.Sc. (Member).

Mr. W. E. Miller then welcomed the new members of the Council.

6. To receive the Auditors' Report, Accounts and Balance Sheets for the year ended March 31st, 1947.

Mr. S. R. Chapman (Honorary Treasurer) stated that the Institution's accounts for the year ended March 31st, 1947, together with the auditors' statements thereon were published on pages 136/7 of the July-August 1947 Journal.

In commenting upon the meetings of the Finance Committee during the past twelve months, the Treasurer pointed out that in addition to the special activities of the financial year under review, the Finance Committee was also much concerned with the financial arrangements for the Convention, the figures for which would be laid before the members at the end of the current financial year, i.e. after 31st March, 1948.

So far as the year ended 31st March, 1947 was concerned, the report of the Finance Committee had been included in the Annual Report of the General Council. It was to be expected that as the Institution's general activities increased, there would also be a proportionate increase in expenditure. This fact alone accounted for the rise in the expenditure side of the accounts. The Council and Committee had closely watched this curve.

The main problem which had constantly been before the Finance Committee was the one of meeting the increased expenses involved in administering the affairs of the Institution. No one could disagree with the fact that everything today was very much more expensive than ever before in the Institution's history. It was not only necessary to watch this increasing curve, which was so often beyond the control of the Committee, but it was necessary to plan, as stated in the Annual Report, for increasing still further the activities of the Institution and continuing to add to its prestige and status.

All this unfortunately required money. The Committee was most reluctant to recommend to Council any increase in membership subscriptions, but since it was imperative *not* to lower the standards of admission to the Institution, it was necessary to call upon the membership to consider the advisability of slightly increasing the annual subscriptions. The Treasurer stated that the increases would not be of a major kind but would be very comparable, and indeed, lower than most other professional engineering bodies. The proposed increases would mostly affect Full Members whose subscriptions would be increased from £4 4s. 0d. to £5 5s. 0d., Associate Members' subscriptions would be increased from £2 12s. 6d. to £3 13s. 6d. and Associates from £2 2s. 0d. to £2 12s. 6d. The Finance Committee had urged that the matter of increasing subscriptions should be discussed if possible at the Annual General Meeting and the Treasurer emphasized that the Council had agreed that at the forthcoming Extraordinary General Meeting the proposed alterations to the appropriate Articles would be so phrased as to enable the Council to decrease subscriptions back to their present level should economic conditions ever permit of such a course. This fact alone fairly showed that the Council was loth to advocate increases in subscriptions, but it was a necessity forced upon them.

Notwithstanding the heavy expenses met during the year under review, it should be possible, by the economies exercised during the past few months, to report a substantial improvement toward continuing to build up the reserves so necessary for sound financing of the Institution.

Mr. Chapman then moved the adoption of the General Account and Balance Sheet, coupled with the Statements and Accounts for the Benevolent Fund, President's Prize Fund and the Dr. Norman Partridge Memorial Fund, stressing that the Council hoped members would discuss at this Annual General Meeting any points arising out of the proposed increases in the subscription rates.

Mr. J. R. Hughes (Member): "I feel the Finance Committee is to be congratulated upon the clear way it has set out the financial position of our Institution which enables us all to face clearly the situation in which we now find ourselves. Our task as an Institution is academic, but we must nevertheless make an effort to keep our feet firmly upon the ground. We must try to realise that any Institution, to achieve its objects, must be properly financed and must be able to proceed on its way, on a proper scale and on a proper standard unrestrained by financial stringencies. My own experience of Committee work in this Institution has been of the Membership Committee and that, perhaps, as well as any other Committee, gives opportunities for realising how great the Institution's scope can become."

"Our Treasurer has had a difficult task but he has given us a clear analysis of the accounts. I feel that we should now give him our fullest support and I have pleasure in both seconding the proposal to adopt all the accounts and also the proposal to call an Extraordinary General Meeting as soon as possible to put into effect the small adjustments to the subscription rates, as proposed by the Council."

Mr. Basil Wardman (Member) suggested that senior members should not be unduly penalised because their numbers were necessarily small. The proposed increases in subscription rates should be very carefully reviewed before the Extraordinary General Meeting in order to avoid hardship at a time when everyone had to consider expenditure. Mr. Wardman did not oppose Council's proposal if they had carefully examined every aspect of the proposal, but felt that no step should be taken unless the Council was assured that it would not result in any loss of members.

Mr. L. W. Meyer (Member) urged that there should be a general breaking down in the accounts to give a more itemised explanation of expenditure, thereby making it possible to estimate how the expenses and income proportionately benefited the individual grades of membership and also how annual subscriptions were made up from the various classes of member. Mr. Meyer also suggested that every Annual Report should contain advice of the effective membership in each grade.

The Chairman, Mr. W. E. Miller, stated that note would be taken of Mr. Meyer's suggestions, many of which could well be incorporated in the Annual Report, although it would be difficult to break down the costs falling upon each particular grade of membership.

Messrs. J. L. Thompson and J. A. Sargrove (Members) spoke in support of the accounts and in particular the proposal to make the small increases in subscriptions and both advocated that in spite of present day difficulties, it was inadvisable to exercise economies and indeed, membership facilities had to be extended which, in turn, demanded financing such schemes in advance of their actual operation.

Before inviting the meeting to vote on the proposal of the Treasurer, seconded by Mr. J. R. Hughes, the Chairman put to the meeting a resolution proposed by Mr. Meyer, seconded by Dr. H. Moss, that "The Finance Committee should prepare itemised accounts on expenditure and income for the previous year (ending 31st March, 1947) and the present year for presentation to the corporate members prior to voting, at the proposed Extraordinary General Meeting, on the matter of increasing subscriptions." The resolution was defeated on a show of hands without invoking the use of the proxies, and the resolution of Mr. S. R. Chapman, seconded by Mr. J. R. Hughes, was then approved *nem con.*

The Chairman thanked members for contributing to this discussion from which it appeared that members agreed with the necessity for increasing subscriptions; in order to obtain a formal resolution on this matter, an Extraordinary General Meeting would be held on the 11th December, 1947.

7 & 8. To appoint Auditors and Solicitors.

The Chairman, Mr. W. E. Miller, in recommending the re-appointment of Messrs. Gladstone, Titley & Company as Auditors to the Institution, said he would like to pay tribute to their unfailing assistance in helping the Institution in all its accountancy matters and particularly for the able way in which they had advised and guided the Institution in the very delicate negotiations during the past few years with the Commissioners of Inland Revenue.

Many members of the Institution needing legal advice had had personal experience of the help and courtesy of Mr. Charles Hill, who had for so long guided the Institution in the many matters requiring legal advice. It would be apparent that as the Institution grew in status and obtained wider recognition, legal advice would be very necessary and correct legal procedure very essential. Mr. Miller therefore moved that Messrs. Gladstone, Titley & Company be re-appointed Auditors to the Institution and that Messrs. Braund and Hill be re-elected Solicitors to the Institution. The proposal was carried unanimously.

9. Awards to Prize Winners.

The Chairman referred to page 130 of the Annual Report quoting the examination prize winners during 1946/47. All these candidates were outside London, and it was only possible to award the President's Prize and the Mountbatten Medal to Henry Hipple (Associate). Mr. Hipple made suitable acknowledgement on receiving these two awards from the Chairman of Council.

10. Any Other Business.

There being no other business, Mr. W. E. Miller thanked members for their attendance and suggested that in addition to the message of good wishes to the President, already approved by the meeting, a message of goodwill might also be sent to Mr. Leslie McMichael, who, for the first time since he become a member of the Institution, was unable to be present at the Annual General Meeting. Mr. McMichael was recuperating from a serious illness and it was agreed with acclamation that a message of goodwill be sent to the Immediate Past President.

NOTICES

New Sections of the Institution

In addition to the Merseyside Section, which held its inaugural meeting on November 12th, 1947, it is hoped to form yet another new Section to cover the Yorkshire area.

This Section will be centred on Leeds and all members who may be interested in contributing to the success of this venture should communicate with Mr. W. H. Clayton (Associate Member), 24, Oakwell Oval, Leeds, 8.

The formation of this Yorkshire Section will take place just as soon as the necessary arrangements can be made, always providing that there are the requisite indications from local members that such a Section will be adequately supported.

Scottish Section

Members are requested to note that at the Annual General Meeting of the Scottish Section held on October 15th, 1947, Mr. H. G. Henderson (Associate Member) was elected Chairman (vice Mr. A. Redpath) and Mr. A. M. Turnbull (Associate Member) was appointed Honorary Local Secretary.

All communications for the attention of the Scottish Section Committee should be addressed to Mr. Turnbull, 68, Lauderdale Gardens, Glasgow, W.2 (Telephone: West 4983).

The Institution's Library

The pamphlets listed below are now included in the Institution's Library and are available on loan to members:

The Magnetophone Sound Recording and Reproducing System. B.I.O.S. Final Report, No. 951.

Survey of Existing Information and Data on Radio Noise over the Frequency Range 1–30 Mc/s. D.S.I.R. Radio Research Special Report, No. 15.

Electronic Valve Bases, Caps and Holders. British Standard 448: 1947.

The following is not available on loan, but may be seen in the Library:

Interservice Radio Glossary. I.R.C.S.C. Paper, No. 38.

R.C.M.F. Exhibition

The Fifth Annual Private Exhibition of British Radio Television and Electronic Components and Test Gear, organised by the Radio Component Manufacturers Association, will be held in the Great Room at Grosvenor House, Park Lane, London, W.1, from Tuesday, 2nd March to Thursday, 4th March, 1948 inclusive.

As in former years, the exhibition is promoted to acquaint Radio and Electronic manufacturers and engineers with the most recent advances in the design and development of British Radio, Television and Electronic Components and Accessories, Radio and Television Gear and Instruments, and in the materials employed in their manufacture.

Special facilities will be created to emphasize the importance of export, and improved amenities will exist for the reception and information of manufacturers and agents from abroad.

The Exhibition will be open to visitors, *by invitation only*, from 10 a.m. to 6 p.m. daily. Applications for invitation cards should be made to the Secretary, Mr. W. T. Ash, 22, Surrey Street, London, W.C.2, and not to the Institution.

Premium Awards 1946–47

It is with pleasure that the Council announce the awards of Premiums for Papers published in the Journal for the year ending 31st March, 1947.

The Clerk-Maxwell Premium: Mr. J. A. Sargrove (Member) for his Paper "New Methods of Radio Production," published in the January-February 1947 issue.

The Hernrich Hertz Premium: Mr. M. M. Levy (Member) for his Papers "Pulse Modulation and Demodulation" and "Pulse Technique," published in the March-April and May-June issues respectively.

The Marconi Premium: Mr. A. J. Tyrrell (Associate Member) for his Paper "The Design and Application of Modern Permanent Magnets," published in the September-November Journal.

The Dr. Norman Partridge Memorial Award is withheld since this is applicable to Papers on improvements in sound reproduction, a subject which was not dealt with by any published author during the year.

Appointments Register

As is well known the Institution maintains registers of employers and employees' requirements. In the past, members have made free use of this service, but in certain cases they have failed to notify the Appointments Registrar when an appointment has been accepted.

It would be of considerable help, in future, if employers and prospective employees would inform the Registrar of any appointment made or accepted, and so help to keep the registers free of redundant matter.

INTERNATIONAL AUTOMATIC TELEGRAPH NETWORKS* (Part 1)

by

Commander (L) J. D. M. Robinson, R.N.

A Paper read before the Institution's Radio Convention held at Bournemouth in May, 1947.

(This paper expresses the author's personal opinions and is not necessarily a statement of official policy.)

Recent developments in the long-distance telegraph techniques of the fighting services of the British Commonwealth and the U.S.A. are of a revolutionary nature. They constitute possibly the most far-reaching development in telegraph communication technique since the introduction of radio.

They open up new possibilities in respect of international telegraph communications, and it appears probable that the fighting services, by virtue of their developments for defence communication, may now be in a position to offer a major contribution to the everyday communications of the world.

There is good reason to believe that these developments, with the further investigations which the fighting services have initiated in this country, and which are now being conducted with the co-operation of the G.P.O. and civil telegraph organisations, will lead to the creation of an international telegraph network of greatly enhanced scope and efficiency.

Whilst these new developments cover the whole field of telegraph communication, radio engineers will be required to play one of the most important and difficult roles. For it is in the provision of radio channels of adequate performance, particularly with mobile units such as ships and aircraft, that some of the most difficult problems are waiting to be solved.

This Paper outlines the possibilities and presents and analyses the problem. The project is of such dimensions and importance that it is clearly impracticable for any one service or department to work on it in splendid isolation. The British aspect of the project must clearly be a national one, wherein all available resources of the Nation are mobilised in the closest possible harmony with the Dominions.

With this object in view this Paper has been prepared, to place the project and its problems squarely before this Institution with the conviction that the assistance which the Institution membership (at Home and in the Empire) can render in effecting a satisfactory solution to the various problems will be considerable.

This Paper therefore differs somewhat from the normal type of paper presented to an institution inasmuch as, if I may borrow phraseology used by Viscount Mountbatten in his address to the Institution at the 21st Anniversary dinner, it is not so much the solution of the problem which is being presented but rather the problem itself.

The problem with which we are concerned is essentially that of providing Automatic Telegraph Networks on the widest possible basis. There are clearly various scales on which an Automatic Telegraph Network can be provided and, in general, the greater the scale and scope of the network the greater and more difficult are the associated problems, particularly in regard to securing the necessary agreement by all users of the network as to the various techniques which shall be adopted.

An example of the smallest end of the scale would be the Defence Teleprinter Network established in Great Britain during the war. This was set up by a single authority who could design the network as a whole and employ any desired techniques. The problems for this type and scale of network are comparatively simple.

Rising in the scale to an intermediate example there is the project for a single long-distance automatic telegraph network serving all the fighting services of the U.K. in which it is clearly desirable that the Dominions should be included. It was this proposed network to which Viscount Mountbatten referred in his address to the Institution on the occasion of the 21st Anniversary dinner last October. It must be emphasized that this plan is still under consideration and has in no way proceeded beyond the investigation stage.

A network on this scale introduces the problem of securing agreement among the different service departments of the United Kingdom, and also of the Dominions if they join in the scheme, as to the technical standards to be adopted for the network as a whole. The fact that this network would clearly have to provide communication with civil networks, and might in some circumstances have to be integrated therewith, complicates the problem still further.

* U.D.C. No. 621.394.74: 621.396.65 (100) *Manuscript received April, 1947.*

At the top of the scale there is the concept of an "International Automatic Telegraph Network." This involves even greater problems owing to the greater divergence of existing telegraph techniques and the requirements of the various nations, and the greater difficulty of securing international agreement on the various technical and traffic standards.

The proposal for the establishment of an International Automatic Telegraph Network which resulted directly in the current investigations now being conducted in Great Britain under the aegis of the Radio and Cable Board was made at the Bermuda Telecommunication Conference, November, 1945, by Major-General Frank D. Stoner, then Assistant Chief Signal Officer of the U.S. Army Signal Corps, and accepted in principle by the conference.

At this Conference, General Stoner gave a demonstration illustrating the capabilities of the U.S. Army Command and Administrative network (Fig. 1) which had been built up during the war. He accompanied this demonstration by an address to the conference which, in view of its fundamental importance and interest, is reproduced as Appendix "A" to this Paper.

using the "message storage" inter-circuit technique developed by the U.S. Army, to set up an international telegraph network of considerably greater scope and efficiency than is possible with existing international communication techniques."

A simple sentence with a world of implication behind it.

The force of General Stoner's argument and the interest of the British Commonwealth therein is greatly accentuated by the fact that the United Kingdom fighting services have already agreed on the adoption of the same message storage technique for similar purposes largely if not entirely due to the pioneering work of the U.S. fighting services during the last war. Moreover, this technique constitutes an essential part of the technical plan for the joint service strategic network which is now under consideration.

In this Paper considerable space has been devoted to the part played by the U.S. fighting services. This has been done because a realistic examination of the subject makes it quite apparent that they have made a notable contribution to the technique of long-distance Automatic Telegraph Networks. It is doubtful if the full extent and implications of this contribution are generally realised. Moreover, an accurate knowledge of the general

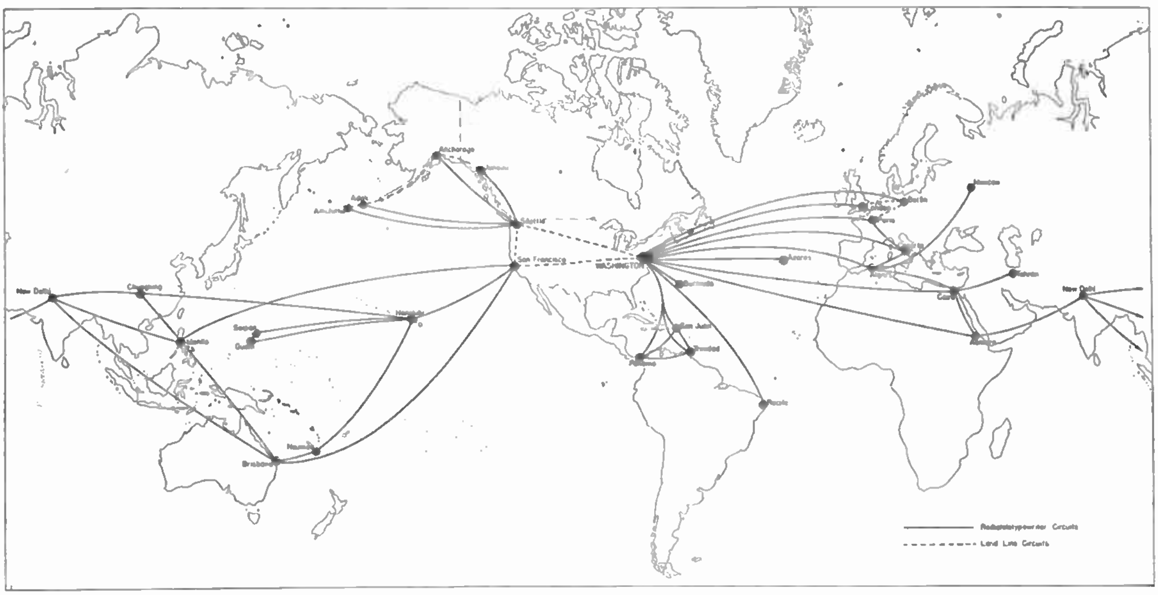

Fig. 1.—U.S. Army Command and Administrative Network.

What General Stoner proposed in effect was this:

"The U.S. Army has demonstrated on a very large scale that, subject to universal agreement on one particular telegraph technique, namely the telegraph code and alphabet, it is now possible and practicable by

background of the subject is a pre-requisite to a proper understanding of the problem as a whole, particularly as the underlying theme is "International co-operation." The validity of these arguments will no doubt be more apparent after a careful and objective study of the Paper.

So much for the general background to the situation which may be summarised as follows :—

(*a*) The United States have proposed that by utilising the " message storage " technique developed by the U.S. Army, an International Automatic Telegraph Network offering considerably higher performance than existing international communication systems can and should be set up.

(*b*) This proposal was accepted in principle by the Bermuda Conference, 1945, and is now under technical investigation by the Radio and Cable Board.

(*c*) The United Kingdom fighting services have already adopted in principle and in much detail the message storage technique developed by the U.S. fighting services.

(*d*) A technical plan for a Joint Service (long-distance) Automatic Telegraph Network for the United Kingdom is under consideration. The same message storage technique forms an essential part of this plan.

(*e*) The general introduction of automatic telegraph networks necessitates much greater agreement among all users in respect of technical standards than has been necessary hitherto.

Before the situation can be portrayed in any greater detail it is necessary next to define and analyse the terms " Automatic Telegraphy " and " Automatic Telegraph Networks."

The following definition for Automatic Telegraphy has recently been agreed by a joint service/civil committee of the Radio and Cable Boards :—

" Any method of telegraph operation in which, by the utilisation of automatic apparatus, the manual operations involved are effectively reduced."

In other words it is not a particular technique but rather the general art of replacing man-power and human skill by machines.

From this we can reasonably coin a definition for an " Automatic Telegraph Network." Having regard to the B.S.I. definition of a " Network," namely " A plurality of inter-related links," we may define an Automatic Telegraph Network as " A telegraph network in which, by the utilisation of automatic apparatus, the manual operations necessary for the transmission of messages between any points of the network are effectively reduced."

It should be noted that this suggested definition does not say that manual operation must be avoided completely.

This would be impossible because there must always remain the manual operation of feeding a message into the network.

For reasons which will be apparent later, the two following sub-definitions for Automatic Telegraph networks may be deduced and will be necessary to discriminate between the two types of network :

(*a*) " *Automatic Routing Network.*"

A telegraph network in which the manual operations involved in transmitting a message between any points of the network are *limited* to the operations of feeding a message into the network and removing a message from the network."

(*b*) " *Manual Routing Network.*"

A telegraph network in which manual routing operations are involved but telegraph operation and manual transcription of messages is *eliminated,* after the initial operation of feeding a message into the network."

It should be particularly noted that with these two sub-definitions the essential feature of *any* form of automatic telegraph network is the elimination of manual telegraph operation *and also manual transcription* throughout the network, apart from the initial operation of feeding the message into the network. In other words, if a telegraph network does not dispense with *both* these methods of operation it should not, in the light of the developments now under consideration, be classed as an " Automatic Telegraph Network."

This point is neither a fact nor—as yet—an accepted opinion. It is a proposal made as part of this Paper, and an assumption on which this Paper generally is based.

Attempts by many authorities to operate special high-speed radio circuits have often resulted in a traffic bottleneck at each terminal. Messages could be cleared over the circuit considerably faster than they could be " manually transcribed " at the terminal office. Instances can be quoted where special high-speed radio circuits were found to be worse than normal manual telegraph circuits for the transmission of urgent messages and were consequently used mainly or entirely for non-priority traffic. A " high-speed " circuit may save circuit time, but is not in itself always of much assistance in saving overall message transmission time from origin to destination ; reduction to a minimum of manual transcription is equally if not more important.

An analysis of the techniques employed in the U.S. Army Command and Administrative Telegraph Network and in the United States Naval Trunk Exchange Network indicates that, whilst efficient automatic transmission and reception on each radio and land line circuit is a *sine quâ non*, the essential new feature of these networks which more than any other factor is responsible for their high overall efficiency in comparison with other existing communication " systems " is the abolition of manual transcription between all radio and landline circuits of the respective networks. A number of special techniques and refinements are necessary to achieve this, but this is the outstanding feature.

The foregoing arguments can be summarised in two simple, but important statements :

(*a*) It is of only partial value to provide automatic working on individual circuits of a telegraph network unless automatic or semi-automatic means of transferring messages from circuit to circuit is also provided. In modern communications it is not merely a requirement to save circuit time ; it is equally or more important to minimise the time spent in transmitting messages from the office of origin to the office of destination.

(*b*) It is not in conformity with modern ideas and developments to regard a telegraph network as an " Automatic Telegraph Network " unless manual telegraph operation *and* manual transcription of messages are both dispensed with throughout the network.

Having clarified the interpretation of the term "Automatic Telegraph Network" the basic object of any such network may be deduced as follows :

> " To provide telegraph communication between all telegraph offices served directly by the network, which will be effected by fully automatic or semi-automatic methods which involve neither manual telegraph operation nor manual transcription of messages at any point of the network, apart from the initial operation of feeding a message into the network."

Now there is a snag in this definition which affects the whole conception of an international network, and that is the interpretation of the term " Telegraph offices served directly by the network."

In this respect there are two fundamentally different conceptions. The first conception is that the Telegraph Offices served directly by the network (i.e., without manual transcription) shall be limited in each nation to a few " Head Offices " in which special telegraph equipment may, if necessary, be installed which conforms to the technical standards of the main international network, in the event of these being different from those used on the normal telegraph networks of the nation concerned.

The second conception is that all, or any desired, telegraph offices of each nation, including mobile units, shall be served directly by the main network through the medium of the normal automatic telegraph network of the nation concerned, or possibly a special network conforming to the technical standards of that nation.

The first conception makes it possible to design the international network irrespective of any existing or projected national techniques. On the other hand, the scope of the network would be severely limited as each nation as a whole could be served only through the medium of manual transcription. Such a scheme would offer little advantage over existing international communication systems.

The second conception provides very much greater scope wherein the advantages of a large automatic telegraph network can be achieved. It implies, however, one or other of two fundamental conditions : either the various nations concerned must agree to conform to certain basic standards on their national automatic telegraph networks or alternatively the international network, must be so designed that it will "embrace" the various different national automatic telegraph networks, both existing and projected. The choice of these alternatives is clearly a matter of high policy. For the purpose of the remainder of this Paper, however, in so far as it may be necessary to assume the scope and requirement of an international automatic telegraph network, the assumption will be made that this must in general serve directly the normal telegraph offices, including mobile units, of various nations, through the medium of existing or likely future national automatic telegraph networks. Not only does this conception appear the most likely, but it also raises the most interesting problems.

It is this question as to the possible scope of automatic telegraph networks and the extent to which agreement on the various technical standards adopted thereon must be agreed by all participating departments or nations—which in turn depends on the form of the network—that will form the background to an analysis of the component techniques of Automatic Telegraph Networks, which can now be undertaken.

To avoid making this Paper unduly complicated the predominant technique known as " Printing Telegraphy," i.e., " any method of telegraph operation in which the received signals are automatically recorded in printed characters," will be considered first. The possible application and limitations of Facsimile Telegraphy and Mosaic Telegraphy to Automatic Telegraph Networks will be discussed later.

Referring to Table I, it will be seen that the general scheme of techniques constituting any Automatic (printing) Telegraph Network may be divided for analysis and planning purposes into three main divisions :

(*a*) *Universal Techniques*, i.e., those which must be standardised throughout the network irrespective of its form.

(*b*) *Inter-Circuit Techniques*, i.e., those by which the transfer of messages from circuit to circuit is effected, and which must be standardised at each inter-circuit relay station of the network.

(c) *On-Circuit Techniques*, i.e., those which are employed for the transmission of messages *on* each circuit, and which must be standardised for each circuit or group of circuits such as a mobile network.

codes, for an automatic telegraph network can be settled mainly on traffic considerations, taking into account the *general* performance of the circuits of the network as a whole and the degree of accuracy and error indication required. At the same time, any special requirements

TABLE I.—AUTOMATIC TELEGRAPH NETWORK TECHNIQUES

A

UNIVERSAL TECHNIQUES

(i.e. those which must be agreed by all participants irrespective of the form of the network).

1. Telegraph alphabet.
2. Terminal Telegraph Code, or " Scheme of Codes " with converters.
3. Procedure.

" INTER-CIRCUIT " TECHNIQUES

- 1. "Direct Connection "*
  - Switching
    - Auto.
    - Manual
  - "Patching"
- 2. "Message Storage "
  - Auto-routing
  - Manual-routing ("Tape-relay ")

B

" ON-CIRCUIT " TECHNIQUES

1. Telegraph Signalling Speed.*
2. Telegraph Transmission Technique (e.g. Synchronous or Arhythmic).
3. Radio Transmission Technique.
4. Landline Transmission Technique.
5. Submarine Cable Transmission Technique.
6. Special " on-circuit " telegraph codes, with on-circuit code conversion equipment, for special engineering purposes, e.g. " Error detection," Automatic Error Correction, etc.

* NOTE :—In general, the "on-circuit" techniques can be agreed or standardised independently for each link, circuit or group of circuits, *except* that in networks employing " Direct connection " inter-circuit techniques, the Telegraph Signalling Speed must also be standardised throughout.

These three divisions of techniques are largely, but not entirely independent. The degree to which they can be considered independently depends mainly on the inter-circuit technique as will be apparent shortly.

Universal Techniques.

It is evident that the basic procedure must be standardised throughout any automatic telegraph network, whatever the form of the network. As this is a non-technical matter which requires only an organisation to effect the necessary standardisation it will not be referred to again in this Paper.

Before considering the question of telegraph codes, it is necessary to explain why the adjectives " Terminal " and " On-Circuit " have been introduced. It is an attempt to simplify an otherwise extremely complex and apparently almost insoluble problem by dividing it into two sections which, it is hoped, can be considered separately. It appears probable that the choice of the terminal telegraph code, or scheme of terminal telegraph

for low-grade or extra-important circuits, e.g., for full error-detection with or without automatic error correction, which apply only to certain circuits or certain classes of circuit, and which should not be allowed to hamper the whole network, can be met by employing a special error-detecting or other form of telegraph code, complete with one-circuit code conversion equipment, to each circuit or class of circuits that requires these aids.

It will be clear that to enable a message to be sent over an automatic telegraph network, either the terminal telegraph code must be agreed throughout the network, or, if this ideal is unobtainable, a scheme of inter-related terminal telegraph codes may be used, provided code-converters are employed at all points of the network where it is necessary to change the coded form of the message from one telegraph code to another.

In either case the telegraph alphabet, that is to say, the characters and symbols which can be telegraphed, must be standardised for the network as a whole.

If the network incorporates a scheme of two or more different terminal telegraph codes, the telegraph alphabet for general use over the whole network will be limited to those characters and symbols which are common to all the terminal telegraph codes employed in the network.

Space does not permit any detailed consideration in this Paper of the various telegraph codes which might be used as terminal telegraph codes of an automatic telegraph network. They could well form the subject of a completely separate Paper.

TABLE II.—COMMON TELEGRAPH CODES

Code	Possible Combination	Comparative Economy in Circuit Time	Degree of "Error-Indication"	Positive "Error-Detection"	General Remarks
Morse	Unlimited	Poor—bad on figures	Poor	—	Unequal number of elements in each character involves complication in printing equipment. Absence of case-shift is an advantage on low-grade circuit (e.g. mobiles).
Cable (Ordinary)	Unlimited	Best of all but requires 3 signalling conditions (e.g. +, —, o)	Good	—	Ditto
Cable (Double-current)	Unlimited	Moderate	Good	—	Ditto
5-unit	Limited* 32 i.e. 2^5	Good	Slight	—	Alphabet is already fully loaded and in some respects is inadequate for present needs.
6-unit	Limited** 64 i.e. 2^6	Usually worse than 5-unit depending on type of traffic	Slight	—	The possible abolition of case-shift would be an advantage on low-grade circuits.
7-unit (Error-detecting)	Limited* 35	Moderate	High	Yes	
8-unit (Error-detecting)	Depending on method of use	Poor	High	Yes	Conversion between 5-unit and 8-unit codes (using the latter for error-detection purposes) is comparatively simple (Von Duuren process).

NOTE: *The use of double or triple " cases " on keyboards and printers enables approximately two or three times as many effective combinations to be obtained.

**With 6-unit code single case, more effective combinations are available than in the 5-unit code with double case.

GENERAL NOTES:
1. The higher the number of elements in each character, the higher the percentage of errors to be expected on a given circuit.
2. This table is not intended to serve as anything more than a general outline to illustrate the chief codes and their salient features.

TABLE III.—COMPARISON OF INTER-CIRCUIT TECHNIQUES

A DIRECT CONNECTION	B MESSAGE STORAGE
Switching and Patching :— Telegraph signalling speed must be standardised throughout the network or such portion(s) of the network as may be required to employ this technique.	This method must be used if telegraph networks of different telegraph signalling speeds are to be linked together.
Can be used to provide teleprinter " direct-working " or " conference facilities."	Can be used to provide teleprinter " direct-working " or " conference facilities " only in certain circumstances and with the introduction of some transmission delay. The telegraph signalling speed must be the same throughout.
Provides the most rapid transmission of messages provided the essential network conditions are fulfilled.	An appreciable, though comparatively small, delay is introduced at each relay point. This should be reduced considerably by automatic routing systems if developed satisfactorily.
Comparatively economical in operating personnel.	Comparatively extravagant in operating personnel. This should be reduced considerably by automatic routing systems if developed satisfactorily.
Effective only on a network containing a relatively large number of lightly loaded circuits.	Effective and particularly advantageous on a network of heavily loaded circuits.
Relatively inefficient in employment of available circuits.	Makes the most efficient possible use of all available circuits.
Relatively sensitive to fluctuations in performance and availability of circuits.	Flexibility shows up to marked advantage in a network wherein performance and availability of circuits fluctuate.

For the immediate convenience of those who may not hitherto have studied the problem, however, the more common codes which might be employed for such purpose are listed in Table II, together with their more outstanding features.

The question of terminal telegraph codes will also be mentioned again later in this Paper in connection with the design of the International Automatic Telegraph Network as a whole.

Inter-Circuit Techniques.

Referring to Table I, it will be seen that inter-circuit techniques, that is to say, the techniques which are used to transfer messages from circuit to circuit, can be divided into two basic forms, namely those in which messages are stored for a significant time between the circuits concerned and those in which messages are transferred either by direct connection or through a form of repeater in which any time delay introduced will be limited to an insignificantly small amount.

" Direct connection " inter-circuit systems (with or without repeaters) are commonly known as " Patching " and " Switching." " Patching " is the term normally used for the operation of setting up through circuits semi-permanently in accordance with prior notice or standing instructions ; " Switching " denotes the operation of establishing through circuits by means of route instructions signalled prior to each message or group of messages. Switching may be effected manually or automatically.

The most effective form of message storage technique in general use today is that achieved by the use of printed and perforated tape and is known in the fighting services as " Tape Relay." This involves manual handling of tapes, but there is also a message storage system in use in America wherein the tapes are operated automatically (see Appendix " B ").

The basic features of the " Direct Connection " and " Message storage " principles are shewn in Table III.

From this table the following salient points may be deduced :

(*a*) Only by a message storage inter-circuit technique can telegraph networks using different telegraph signalling speeds be linked together.

(*b*) Teleprinter conference facilities can be provided only by direct connection which in turn cannot be achieved unless the telegraph signalling speed is standardised over the whole network or over such portions of the network as are required to provide conference facilities.

(*c*) Switching provides the most rapid communication service but will work satisfactorily only over a network containing a comparatively large number of high grade lightly loaded circuits of substantially constant performance and availability.

(*d*) Message storage introduces a small delay in the overall transmission time of messages but is eminently suited to networks of a limited number of heavily loaded circuits and can compete better than switching when the circuits are of fluctuating performance and availability.

(*e*) Message storage makes the most efficient use of limited circuit availability.

It will now be expedient to consider the relative merits of these two basic inter-circuit techniques in relation to the conception already defined for an international automatic telegraph network.

Such a network will consist of two distinct divisions—the " National " or " Feeder " networks and the " Inter-nation " network of long-distance radio and submarine cable circuits, which will link together the various " National " or " Feeder " networks.

A comparison of the salient features of these two divisions is given in Table IV.

If Tables III and IV be now examined in conjunction, it would appear that the following general conclusions can be drawn :

(*a*) The conditions pertaining to the Long-distance " Inter-nation " network—particularly the radio portion—are such as to indicate under present conditions a balance strongly in favour of using a form of message-storage inter-circuit technique. The arguments are less strong in the case of the submarine cable network.

TABLE IV.—COMPARISON OF "NATIONAL" AND "INTER-NATION" NETWORKS

" NATIONAL " or " FEEDER " NETWORKS	LONG-DISTANCE " INTER-NATION " NETWORK	
	(*a*)	(*b*)
Predominantly land-line, or V.H.F. or U.H.F. radio circuits :	Long-distance H.F. radio circuits :	Long-distance submarine cable circuits :
Relatively constant high grade circuits.	Fluctuating performance of circuits.	Circuits of medium grade and constancy of performance.
Relatively constant availability of circuits.	Fluctuating availability of circuits.	Constant availability of circuits (except during magnetic storms).
Usually practicable to provide plenty of circuits ; relatively low emphasis on making maximum possible use of available circuits. (This is normally due to the relatively short length of circuit.)	Availability of circuits severely restricted ; strong emphasis on making the maximum possible use of available circuits.	Availability of circuits most severely restricted ; strong emphasis on making the maximum possible use of available circuits. (This is mainly due to length and expense of cables.)
Owing to relatively large number of circuits, economy in ratio of operators to circuits is of comparatively great importance.	Owing to relatively small number of circuits and the relatively high installation and operating costs of each, economy in ratio of operators to circuits is of comparatively low importance.	Owing to relatively small number of circuits and the relatively high installation and operating costs of each, economy in ratio of operators to circuits is of comparatively low importance.

(*b*) The conditions pertaining to the "National" or "Feeder" networks are much more inclined to a form of switching technique; the balance between arguments for switching and message-storage techniques are fairly evenly balanced and local circumstances and requirements may well sway the balance. One might well have considered the balance to be apparently in favour of switching techniques were it not for the evidently successful performance of the United States Naval Trunk Exchange Network—which is predominantly a land-line network using manually-controlled message-storage inter-circuit techniques ("Tape Relay") and the automatic routing message-storage system designed by Bell Laboratories for the Republic Steel Corporation, Cleveland, Ohio, which is entirely a land-line network.

It is important to note that there is no basic technical necessity for the inter-circuit technique to be standardised throughout the network. It may well be, and indeed it appears very likely, that certain of the national networks will develop or retain automatic switching, whilst the long-distance "Inter-nation" portion of the network may employ predominantly message-storage inter-circuit techniques with perhaps a limited scale of provision for direct inter-circuit connection to cover essential requirements for conference facilities and very high priority messages.

Having considered in general terms the two basic forms of inter-circuit technique, some thought should be devoted to the main features and recent developments in message-storage techniques. It is not thought necessary to consider switching techniques in this Paper as these have not, so far as is known, been subject to any special developments in connection with possible applications to a long-distance International network. Moreover, all available information on this subject can readily be obtained elsewhere. It is of interest to note, however, that the C.C.I.T. has recently set up a commission to study this problem.

Message-storage technique can be in two forms: Manual Routing and Automatic Routing. In both forms, as so far developed, messages are handled inter-circuit in a form of perforated tape. In the "manual routing" system (known in the British and U.S. fighting services as "Tape Relay") the tapes are handled manually, the necessary handling being governed by routing and other instructions appearing on the tape at the beginning of each message. In the "Automatic Routing" systems so far known to have been developed the necessary tape-handling operations are effected mechanically, such operations being governed by special groups signalled at the beginning of each message.

Consideration will first be given to the Manual routing technique. Mention was made earlier in this Paper of the pioneering work carried out by the U.S. fighting services in the development of an efficient manual routing message-storage technique. If one can imagine a large signal centre, such as the U.S. War Department Signal Centre at Washington, D.C., where in one large room there are scores of two-way automatic circuits, and where a message received on any one circuit may be required to be re-transmitted on any one or more outgoing circuits or be printed for local distribution, it becomes apparent that such an organisation to be efficient must be "streamlined." This is precisely what the U.S. fighting services did during the last war and which the United Kingdom fighting services are endeavouring to improve still further.

The "Tape relay" principle had been used for many years to a limited extent by civil and commercial telegraph organisations. The recent war-time experience of the fighting services, however, has clearly indicated that some essential "streamlining" and co-relation of the component technique must be achieved before a large-scale automatic telegraph network based on the "Tape relay" principle can be made to render the high performance which it has now been shown can be obtained from a properly designed network of this type. Moreover, it is open to considerable doubt whether the performance obtainable from a large scale tape-relay network without such "streamlining" would be sufficient to justify such wide and basic employment of "Tape relay."

Such streamlining can be focussed on to three principal operations:—

(*a*) The handling of tapes received in the tape-relay room.

(*b*) The transmission of tapes on outward circuits.

(*c*) The duplication of tapes for multiple-address messages.

Closely associated with these operations is the all-important question of procedure, which, however, is outside the scope of this Paper.

Handling of Tapes.

When a tape is received in a tape-relay room, the operator concerned has to determine what are the routing instructions at the beginning of each message and also that the message has, to all appearances, been correctly received. With morse or cable code, it is possible for an expert operator to read the route instructions moderately quickly, but it would take him considerably longer to check the whole message. With the widely standardised 5-unit code, however, reading the perforations is a much slower and more difficult process. The U.S. fighting services therefore developed the *Printing Reperforator*, which prints the characters on the tape in addition to the perforations. This may be achieved either by using a wider tape and printing the characters down one side or by using so-called "Chadless" tape (see Fig. 2), in which the perforations are only partially made leaving a comparatively solid tape over which the printed characters may be super-imposed.

The introduction of this technique saved both time and operators and was a major contribution towards the employment of relatively unskilled operators.

Transmission of Tapes.

If at a tape-relay centre, only a single automatic tape transmitter is provided on each circuit an inefficient transmission technique must result.

the transmission of the message tape in transmitter "A" automatically carries on. Meanwhile, a second message may be inserted in transmitter "B." Nothing happens until the transmission of the first message is complete whereupon, without any further action by the operator, the circuit series number for the second message is automatically signalled and, when this is complete, transmission of the second message begins.

Thus, all that is required of the operator is to insert a message tape in whichever transmitter happens to be vacant without waiting for the transmission from the other transmitter to finish.

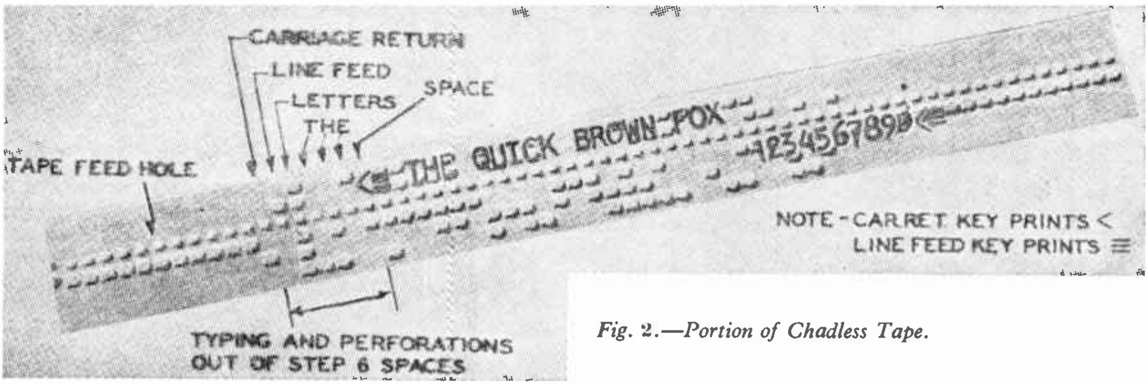

Fig. 2.—Portion of Chadless Tape.

Firstly, if wastage of circuit time is to be avoided an operator must be allocated permanently to each circuit to watch the outgoing tape and insert the next tape immediately the first tape has run through. Alternatively, if this inefficient use of operators is avoided and one operator is allocated to a number of circuits, circuit time is certain to be wasted because the operator cannot be at each circuit ready with the next tape precisely as each transmission finishes.

Secondly, as some check that each message is received at the distant end is essential, either it is necessary to waste circuit and operators' time by acknowledging the receipt of each message, or alternatively to waste operators' time and inevitably a little circuit time by transmitting pre-perforated "series number" slips prior to each message. This in turn leads to complications in respect of logging messages which have been transmitted and re-transmitting messages which are not correctly received in the first place at the distant end. To overcome these deficiencies the U.S. fighting services developed a "dual-headed automatic tape transmitter with incorporated automatic series number transmitter."

The functioning of this equipment is briefly as follows. The operator inserts a tape in transmitter "A." This causes the auto-numbering device to signal the circuit series number for that message. When this is completed,

This equipment enables one operator to control a number of circuits and prevents any wastage of circuit time so long as messages are available for transmission.

Associated with this equipment as part of the overall transmission technique, a printing reperforator is used to record all transmissions on each circuit. As this record tape contains not only each message transmitted but also the series number thereof, it forms a convenient means not only of logging messages, but also of re-transmitting any messages not correctly received at the distant end on the first occasion.

Duplication of Tapes.

A considerable proportion of fighting service traffic consists of multiple-address messages, that is, messages which have to be transmitted to a number of different authorities. The tape-relay technique lends itself to this requirement owing to the ease with which tapes may be duplicated. All that is necessary is to provide at each tape-relay station a bank of printing reperforators operated from a single automatic tape transmitter. A few minor refinements will be necessary, depending on the procedure.

Before leaving this subject of manual routing tape-relay techniques, there are two matters of interest.

The first is that the printing reperforator and the dual-headed tape transmitter with automatic numbering device have both been adopted in principle as standard equipment by the United Kingdom fighting services, though equipment of British design and manufacture will naturally be used.

The second matter is to provide an answer to the question known to have been raised frequently in Great Britain :—

> " What is there about the American Tape-relay technique which is so novel and for which such great claims are made ? There is nothing particularly novel about their frequency shift signalling or Single Side-Band techniques and our own commercial organisations have used ' Tape relay ' for years."

The suggested answer to this question is as follows :—

> " It is agreed that there is no new basic principle which has not been known in Great Britain for many years. But, firstly, the Americans have *refined* their on-circuit techniques, particularly the frequency shift signalling technique, and have thereby secured the first pre-requisite for an efficient automatic telegraph network, namely, links and circuits of an adequate standard of performance. Secondly, they have introduced *essential* refinements into the tape-relay technique, the more important of which have just been described. They have also developed a procedure and message handling organisation specially suited to an automatic telegraph network and have so designed the network as a whole that it readily embraces existing landline systems and techniques. It is the *summation* of these and other refinements that has made possible the provision of an overall network technique of such evidently high efficiency. Moreover, the U.S. fighting services have demonstrated the efficiency of their networks, under full-scale operational conditions, to the evident satisfaction of the fighting services of the British Commonwealth."

A description of message storage inter-circuit techniques would not be complete without a reference to the automatic routing tape-relay technique of which an excellent example is provided in the system used by the Republic Steel Corporation, Cleveland, Ohio. A brief description of this system is given in Appendix " B."

That concludes the subject of " Inter-Circuit Techniques."

On-Circuit Techniques.

It is intended here only to touch very briefly on the subject of on-circuit techniques, partly because full information on each of the techniques can, with a few exceptions, be found elsewhere, and partly because the question of radio and landline transmission techniques is covered by part II of this Paper.

Referring to Table I, it will be observed that there are a number of on-circuit techniques. Some or all of these techniques must be agreed as a " scheme of on-circuit techniques " for each inter-service, inter-departmental or international circuit. In this respect, circuits between mobile units and between such units and station of the fixed network(s) should be grouped as a class for which the minimum number of different schemes of on-circuit techniques should be agreed.

It will normally be possible, though not necessarily desirable, for a separate scheme of on-circuit techniques to be used on each circuit, all mobile units counting ideally as a single circuit for this purpose.

Telegraph Signalling Speed.

To make the most efficient use of a circuit or radio frequency allocation, either the telegraph signalling speed must be raised to the limit which the bandwidth of the circuit or frequency allocation, or other practical limitations such as multi-path effects, will allow, or alternatively the circuit must be " channelled " into a number of relatively low speed circuits.

It is generally agreed that the latter course is the best from many points of view, particularly ease of handling traffic, though there may be cases such as mobile units where the additional equipment required for channelling is impracticable and where, therefore, a high telegraph signalling speed may be necessary to meet traffic requirements.

What is not universally agreed, however, is the actual telegraph signalling speed which should be standardised for telegraph circuits generally. The C.C.I.T. standard is 50 bauds. The speeds in current use in the U.S.A. vary from 45½ bauds to 75 bauds.

A parallel and relative factor is the bandwidth of standard telegraph channels which in frequency division systems is dependent on the frequency spacing of channels. The C.C.I.T. standard telegraph channel spacing is 120 c/s, whereas the telegraph channel spacing used on the American continent is 150 or 170 c/s. There is, therefore, the possibility that the current American trend towards higher telegraph signalling speeds may be based on a logical and reasonable desire to make the fullest use of the comparatively wide telegraph channels.

One reason why the C.C.I.T. standard of 50 bauds was selected was because at that time the techniques were such that this speed was the maximum that an operator could control on a fully loaded circuit without wastage of circuit time. The introduction of the printing reperforator and the dual-headed tape transmitter which have been described earlier in this paper and which enable an operator to control two or more circuits simultaneously, clearly renders this assumption not necessarily applicable to the main circuits of a message-storage network, though it will normally still apply to "tails" or "feeder" networks.

It would appear that these arguments emphasize the difficulties in the way of securing world-wide agreement to a standard telegraph signalling speed, and the consequent necessity for the inter-nation portion of an international network to employ message storage inter-circuit techniques.

Telegraph Transmission Techniques.

The main issues under this heading are whether the telegraph signals shall be transmitted by synchronous systems or by "Arhythmic" systems which involve start and stop signals for each character.

The arhythmic system is the most widely used, though there are minor differences in the schemes for start and stop signals—particularly in respect of the duration of the stop signals—which might well be abolished by general agreement. Generally speaking, these discrepancies are not sufficient to prevent inter-communication though their existence has to be taken into account in the design of telegraph instruments.

The chief advantages of synchronisation are slightly greater accuracy and, with certain systems, a saving of circuit time through not having to transmit the start and stop signals.

Special On-Circuit Telegraph Codes.

Mention was made earlier in this paper of the attempt to separate for purposes of investigation and planning, the Terminal Telegraph Code, or scheme of codes, and any special codes used for on-circuit engineering purposes on certain circuits or classes of circuits.

This suggested method of approach to the problem depends on two factors. Firstly, that such special "on-circuit" requirements will be needed only on certain circuits or classes of circuits and not throughout the entire international network (including the component national networks); and secondly, that on-circuit conversion from the standard terminal telegraph code to the special on-circuit code required can be effected satisfactorily and comparatively simply. Space does not permit a full discussion of this problem and the various possible alternatives being given here. A single example shewing what appears at first sight to be a practicable and likely solution must suffice.

The chief special on-circuit requirement is likely to be for "Error-detection," by which is meant that if a character becomes corrupt during the course of transmission the receiving telegraph instrument will not print or perforate the corrupt character but will provide a positive indication of the error. Once this facility has been provided it becomes possible to extend it to provide a system which automatically asks for and obtains repetitions of corrupt characters.

The essential principle of error-detection in its present state of development is that the code used for the transmission of the messages on the circuits concerned must be such that all characters contain the same number of "marks" and also the same number of "spaces." The theory is that an atmospheric or other momentary circuit fault will, by changing a unit from a mark to a space or vice versa, upset the constant proportion between the marks and spaces and this situation can then be employed to cause the indication of an error.

The two error-detection codes at present used or known are the 7-unit and 8-unit. Morse code and more particularly cable code provide some indication of the existence of an error, but do not provide a positive indication such as a special symbol or operation of a special circuit. Moreover, some experience on behalf of operators may be necessary to obtain full advantage of the error indication provided.

In regard to the 7-unit code, conversion between this and the most common terminal telegraph codes is at best a complicated process in which there may also be certain limitations.

The 8-unit code, on the other hand, used in the manner suggested by Van Duuren appears to offer a considerably more satisfactory and simple solution, which would probably justify the extra circuit time occasioned by the eight units. With this system conversion from 5-unit to 8-unit is effected simply by adding three impulses to each character in such a manner that there are always four "mark" and four "space" elements in each character. Conversion between the 8-unit code and any common form of terminal telegraph code is likely to be practicable, though less simple than in the case of 5-unit code.

The fact that, so far as is known, full error detection cannot be achieved without the employment of a code containing a comparatively large number of units which will consequently be extravagant in circuit time, lends force to the policy suggested in this Paper that such a facility should not be provided universally throughout a combined radio and landline network, but should be applied individually to such circuits or classes of circuits as may be found—probably only as a result of experience—to need this facility. It is possible that all mobile circuits might need it; it is conceivable that the entire long-distance radio portion of the network might need it; on the other hand it may be found necessary only in a few isolated circumstances.

Facsimile Telegraphy.

Facsimile Telegraphy in its normal application for transmitting pictures and diagrams usually makes use of telephone channels, and as such is outside the scope of this Paper. It may also be used, however, as an alternative to "Printing Telegraphy" for the transmission of written messages. Used for this purpose it offers the following advantages over printing telegraphy:—

(a) Easier and quicker operation.

(b) Simpler equipment which is easier to maintain.

(c) In special circumstances where a very wide channel band-width can be provided, considerably higher effective signalling speeds than are normally attainable in printing telegraphy can be achieved.

As an alternative to printing telegraphy, facsimile telegraphy suffers from the following disadvantages:

(a) It is very approximately ten times (at least) as extravagant in circuit band-width for a given signalling speed.

(b) Duplication of received messages is at present a longer and more difficult process.

(c) Regenerative repeaters cannot be used as in printing telegraphy to avoid cumulative distortion over a series of circuits in tandem.

The extravagant use of channel band-width is a fundamental principle which is unlikely to be reduced appreciably by further development. This rules out the possibility of facsimile telegraphy replacing printing telegraphy generally on long distance channels—particularly channels on high-frequency radio links.

The use of facsimile telegraphy for the transmission of written messages appears therefore to be limited to short and inexpensive channels where economy in band-width is not a prime requirement.

Facsimile telegraphy may therefore be developed as a local feeder or distribution system for use in certain circumstances in connection with a printing telegraph network. It may also be used in special circumstances where the need for exceptionally rapid transmission of intelligence outweighs the need for economy in channel band-width. Facsimile transmission offers this special facility which is not obtainable by normal printing telegraphy.

Mosaic Telegraphy.

This term has been agreed by the Radio and Cable Board to denote such systems as the "Hellschreiber" system, wherein printed characters are built up on a facsimile basis by means of signals which are transmitted automatically from a keyboard or perforated tape. The main advantages of this system compared with normal printing telegraphy are:—

(a) As the characters are comprised of many more elements than in printing telegraphy, it is often possible to obtain readable results on a channel that is too poor to work printing telegraphy.

(b) The receiving equipment can be much lighter and simpler.

Like facsimile, however, its disadvantages are:—

(a) Approximately ten times as extravagant in the use of channel band-width.

(b) Duplication of received messages would be a longer and more difficult process.

(c) Page printing is impracticable.

(d) Re-transmission is impracticable except by manual transcription.

It appears, therefore, that whilst this system has its attractions, it cannot be regarded as a likely alternative to printing telegraphy on any main network. It might well have application, however, for local telegraph communication particularly where small mobile units are concerned.

Conclusion.

From what has been said, it is now possible to express the four main design requirements of the future international automatic telegraph network, on the assumption that the requirement is for an inter-nation network to inter-connect existing and likely future national telegraph networks.

The first requirement is to provide long distance radio links of adequate performance, and in particular to provide the minimum number of different schemes of on-circuit technique of adequate performance for use between mobile units and between these units and stations of the main network. The problem thus presented is primarily one for radio engineers.

The second requirement is to allow for the retention of different telegraph signalling speeds by the various national networks unless and until a standard speed can be agreed and adopted by all participating nations. It has been made clear in this Paper that this can be achieved only by the adoption of a form of message storage inter-circuit technique.

The third requirement is, by suitable geographical layout of the network and by suitable design of the scheme of inter-circuit techniques over the network as a whole, to provide the best possible continuity of communication in all circumstances between all points of the network. This implies abandonment of a "point-to-point" communication outlook and its replacement by a comprehensive network technique. The U.S. Army have demonstrated that with an efficient world-wide network it may be regarded as perfectly normal to route traffic between Europe and America via the Orient when the vulnerable North Atlantic circuits are out of action.

The fourth requirement, which is probably the most important, difficult and far-reaching of all, is for the inter-nation portion of the network to be able to handle traffic originated in any national network either in any one of an agreed scheme of existing telegraph codes or *in any code which may be found necessary in the future.* For example, 5-unit code may be accepted generally today as being satisfactory on most national networks. While, however, there exists such a strong undercurrent of opinion that the 6-unit code, or possibly a form of cable code, would be more satisfactory as a standard terminal telegraph code for future universal communication, it would be as foolish and short-sighted to standardise universally and irrevocably on the limited 5-unit code as it was of our forefathers to standardise on the narrow railway gauge. Like the 5-unit code, it was adequate for requirements at the time it was introduced; but requirements expanded and eventually outstripped the capabilities of the narrow gauge, even as international telegraph requirements may outstrip the limited facilities offered by the 5-unit code, as indeed has begun to happen already.

It is clearly impossible to persuade all the nations concerned to change from 5-unit to 6-unit or cable code overnight. It should not be impossible so to design the framework of the international telegraph network of the future that any users or nations can develop 6-unit or cable code systems on a step-by-step basis and be able to work with these systems at any time over the international network. There are several possible ways in which this might be achieved: to determine the best way is a problem; it might well be said that it is *the* problem.

It is upon the degree of co-operation by all concerned and all who can help in any way that the speed with which these problems can effectively be solved depends.

It is upon the rapid and effective solution of these problems that depends the ability of the British Commonwealth of Nations to seize the unique opportunity which is now presented—but which may soon retract—to offer a major contribution towards the smooth and rapid exchange of information between the nations. May this not prove to be a contribution to the future peace of the world?

APPENDIX "A"

STANDARDIZATION OF THE FIVE-UNIT CODE

Address by Major-General Frank D. Stonor, U.S. Army Signal Corps, to Bermuda Telecommunications Conference, 1945.

19th November, 1945.

We are now entering what we all hope will be a long-enduring period of world peace. The maintenance of that peace will obviously require the closest and most constant co-operation of the major world powers. In the swift current of modern history, however, events pile up too suddenly and with too rapid an international effect to permit effective co-operation unless we have communications that can link our countries with the requisite high speed of service and accuracy of transmission.

The speed and accuracy which we need in our communications are not going to be possible if we fail to standardize our transmission code. Only through such standardization will we be able to send messages from the equipment of one country into the equipment of another for relay into still a third without drastically impairing the speed of service and the accuracy of transmission. The failure to adopt a standard code involves the same complications for communications that the construction of different gauge railroads involves for common transportation. Messages can no more move from one gauge track to another than can locomotives. Uniformity and standardization are absolutely essential.

For the sake of the peace, we cannot afford to forget the communications lesson we have learned in the war. The expansion, flexibility and efficiency that resulted from adopting the standard five-unit teletype code during the war furnished the U.S. Army (and through it the armies of the Allied Powers themselves) a communications system without precedent in its history.

Before the war practically all radio telegraph circuits were operated in the International Morse Code, using either manual transmission and aural reception or high-speed transmission and reception. The method was inadequate to the needs of a mobile, global war. This was true whether the type of operation was high-speed Boehme or Creed radio-telegraphy, high-speed I.B.M. radiotype or ordinary manual radio. The highly skilled operators needed were difficult to secure and train. Service was slowed by having to repeat the manual sending of every message every time it was relayed.

The possibilities of error in re-transmission were multiplied many times and service messages increased proportionately. Delays and possibilities of error could not be tolerated. Mechanical means had to replace human skill.

The Communications Service of the U.S. Army Signal Corps, with the aid of our commercial carriers and electronic equipment manufacturers, accordingly developed a radioteletype system that solved the pressing problem of adequate war-time communications. It was, and still is used by the U.S. Army in a globe-encircling network based on a belt-line system.

This network showing principal routes is outlined on the map illustrated on page 267. Over 822,000 miles of radio and wire channels were established and this consolidated network has handled more than 50,000,000 words per day since the summer of 1943. Uniform procedures and directional routing indicators were developed permitting traffic to flow from any station on the network to any other station on the network by means of relaying perforated tape. This system permitted station WAR to handle a 900 per cent. increase in traffic work load with an increase of only 28 per cent. in authorised personnel. Average work load per operator increased from 100 messages per operator in the case of high-speed radiotelegraph circuits to 600 messages per operator on radioteletype circuits.

The use of this standard five-unit perforating code has made the same tape completely interchangeable between land-line, radioteletype and cable facilities. For example, from New York a message can be tape-relayed by land-line to Seattle, speeded on its way to Anchorage by cable, then via radioteletype to an island in the Aleutians, all without the slightest change in the appearance or character of the tape.

This teletype code, also known as the Baudot Code, is already in general use on the commercial and government wire lines in North America and in several transoceanic submarine telegraph cables. It is identical with the code used in teletypewriters made by the Creed Manufacturing Company in the United Kingdom and generally employed in British wire communications. It has been estimated that 80 per cent. of our communications equipment today is employing this code.

The code employs only five elements or pulses as against the six, seven or eight in other codes. Since the essential bandwidth required to transmit signals at a given speed is directly proportionate to the number of elements in the code employed, the five-unit code makes the most economical use of the radio frequency spectrum.

The employment of this code on radio channels utilises a new radio technique variously known as carrier shift, frequency shift or two-tone operation. It is in reality a special case of frequency modulation in which two radio frequencies differing by a few hundred cycles are transmitted alternately. The higher frequency is normally designated as the "marking" or "working" signal and the lower as the "spacing" or "idling" signal. While the difference between the two frequencies is usually 850 cycles, this difference has no theoretical significance and can be reduced considerably without detrimental effects, provided, of course, that the equipment is appropriately adjusted to such changed operation.

The use of a continuously transmitted carrier, with frequency shift modulation, permits the use of F.M. technique in the receiving apparatus, in addition to normal space diversity reception thereby greatly reducing the effects of radio fading and of certain types of radio noise and interference. Additional distortion measuring tests, made continuously at the operating terminal, provide adequate insurance against any normal transmission errors that might otherwise occur. Errorless printer operation is obtained.

The adoption of this code as the international standard would produce results challenging the liveliest imagination. With radioteletype, cable and land-lines linking all United States areas with all areas of the British Commonwealth of Nations, our globe would immediately be interlaced by a network which could carry a message in a few minutes from Singapore through Brisbane, Hawaii and San Francisco to Chicago, or from a little hamlet in Kansas to a city in Yorkshire without any reprocessing of the message. The originator would punch out the tape at the start of its global journey. Whether relayed by land-line in the United States or England or India, by radio or cable across the various seas, that message would speed on automatically from point to point, jumping from wire to radio and back again, finally emerging, after only a few minutes, in printed form on a teletypewriter at its ultimate destination. It could follow any of the radio, cable or land-line channels without ever being retyped.

It is within this framework that we must plan and paint our picture of the future, a future already partly realized and actually working during the war. Its flexibility, and instant adaptability to the needs of emergencies, was demonstrated again and again throughout the war. Perhaps as illustrative and dramatic as any was the incident during the second Quebec Conference in 1944, when the Combined Chiefs of Staff were trying to decide whether, in view of a suddenly altered strategic situation in the Pacific, General MacArthur should be instructed to advance his attack on Leyte one month from the planned date of November 20th to October 20th. The meeting was being held late at night in Quebec. General Marshall and General Handy went into our Army Signal Centre a short distance away and asked to speak to General MacArthur in Hollandia. The belt-line went into immediate operation. Through classified automatic encipherment the question was typed out on a machine in Quebec, electrically cut through by land-line from

Dominion and United States territory to Washington and from there on out over the belt-line by land-line and radio to the receiving printer at Hollandia in the Pacific. The reply came back instantly, typed out by General MacArthur's operator in Hollandia, travelling over the same belt-line, printed on our machine at Quebec. A globe-encircling discussion—yet the Generals were not out of the Combined Chiefs of Staff meeting altogether more than five minutes.

These are the terms in which we thought of communications during the war, the belt-line method by which we achieved such wonderful results. These are the terms, the only terms, in which we can think of and plan our commercial communications for the post-war world.

It is not merely that this semi-automatic, tape-relay, five-unit teletype code system makes for immediate and great material benefits through conservation of equipment, personnel, labour, space and cost. It is not merely that the system easily adjusts itself to vastly increased traffic loads, and that war-time engineers have developed successful application of the code to radio circuits. It is not merely these advantages that suggest the system's post-war use.

The coming years are going to witness a tremendous expansion in international communications. Weather information from points scattered in every corner of the world, collected by centralized organizations to be disseminated to vitally interested aviation, shipping and other industries; world-wide agricultural reports; international trading; the United Nations Organization and its numerous subordinate governmental agencies interlocking with offices all over the world—all these and the innumerable other sources of international communications are going to create an urgent need for a modern, streamlined global communications system.

Such a system will not be possible unless communications can be interchanged between all the plant structures of all countries speedily, accurately and efficiently. That interchangeability calls for a fully integrated, unified, belt-line system, based on uniformity and standardization of procedures, equipment and facilities. Our commercial carriers and electronic equipment manufacturers have demonstrated their great ability and capacity to meet the needs of war. They can and should assume the initiative in carrying out any post-war plan of standardization of equipment and methods.

The following proposal is therefore submitted to this committee for consideration:—

> That the five-unit Baudot Teletype Code be adopted as a Telecommunications standard for all radio printer channels between the U.S. and the British Commonwealth of Nations.

APPENDIX "B"

REPORT ON AUTOMATIC ROUTING MESSAGE-STORAGE A/T SYSTEM FITTED BY BELL LABORATORIES FOR REPUBLIC STEEL CORPORATION, CLEVELAND, OHIO.

Fully Automatic Tape Relay System—known as 81B1—installed at the various Offices and Works of the Republic Steel Corporation.

General Description of the System.

1. This is a fully automatic tape relay system developed by the Bell Laboratories in conjunction with the Western Electric and the Teletype Corporation. It is the latest automatic telegraph system to be developed in the U.S.A. and was only completed early in 1944, incorporating all the experience gained with the similar but earlier system installed at Schenectady.

2. The Republic Steel Corporation have a number of factories and offices connected on a network, the centre of which is at their Head Office at Cleveland, Ohio. Outstations are mostly connected on a number of party lines, each connecting two of seven outstations. There are also a number of direct lines. Six of the major circuits are duplex and the remainder, including direct lines, are all simplex. Four normally work at 75 w.p.m. and the remainder at 60 w.p.m. There are no radio links and the system is in operation for only eight hours a day.

3. The reasons for adopting the particular grouping of outstations and the different speeds of working is mainly to suit their pre-determined traffic, the considerable distance between stations and the class of work that the outstations are engaged on, e.g., sales of manufacturing. It is interesting to note, however, that the 75 w.p.m. circuits can and do operate at a slower speed under certain circumstances and it is believed that the slower circuits can be operated at 75 w.p.m. Moreover, distant stations can be isolated, or alternatively, traffic can be concentrated to one or more stations as desired, in fact the system is extraordinarily versatile.

Outstation Apparatus.

4. The apparatus fitted at an outstation on a duplex party line consists of an automatic transmitting and receiving teleprinter on one side and a receiver only on the other. Stations on simplex party lines have the automatic transmitter-receiver only while outstations on direct lines have manually operated teleprinters. Certain

stations act as relay stations and have typing re-perforator transmitters fitted in addition, to re-transmit messages over direct lines to further outlying stations. Each outstation has a small control unit and all that the operator has to do to transmit a message, having prepared the tape on a keyboard perforator, is to insert it into the transmitter.

Head Office Apparatus.

5. The apparatus at Head Office consists of the following :—

(1) Associated with each duplex circuit is :

(*a*) A typing re-perforator-transmitter normally to receive messages from outstations and re-transmit them across the office to one of the transmitters associated with the outgoing circuits, and

(*b*) *Two* sets of equipment as above, arranged to receive messages from across the office and transmit them to the outstations.

(2) Associated with each simplex circuit is :

One typing re-perforator-transmitter to receive from and a similar set to transmit to the outstations.

(3) Control Board.

(4) A bank of monitoring page printers, one associated with each circuit.

(5) Two intercept typing re-perforators and one auto-transmitter situated on the supervisor's desk.

(6) Automatic line finder and director apparatus, relays, power supplies, etc. In addition there is a repair bench with the usual testing facilities.

6. The apparatus detailed under 1, 2, 4 and 5 is of Teletype manufacture specially designed for the speeds mentioned. The transmitters and receivers directly associated with each circuit are housed in neat pressed steel dust-proof cases about five feet high arranged in a workmanlike console form with the control panel in the centre. The control panel takes the form of a desk with a mimic diagram of the system incorporating switches for control of the circuits. The monitoring printers are mounted to form a separate console and the apparatus detailed under 6 is built into two sets of panels about 8 feet high by 20 feet long by 3 feet deep.

Method of Working.

7. The automatic switching apparatus associated with each circuit performs several functions. Firstly, the director effects a connection and tests each outstation in turn. If there is a tape waiting in the transmitter of an outstation, it completes the connection to the associated re-perforator-transmitter mentioned in para. 5 (1a) and starts the outstation's transmitter. The message is pre-fixed by a code and directional call which denotes priority and destination. Assuming that the priority is normal and the destination is an outstation, on another circuit, an automatic line finder completes the circuit across the office to whichever of the two re-perforator-transmitters (para. 5 1b) associated with the wanted station's circuit that is free. If neither is free the message is received and stored by the first re-perforator-transmitter until one of them can receive the message when the connection is automatically completed. The second re-perforator-transmitter (para. 5 1b) can also store the message if the transmitter is operating on another station, but the message is again automatically relayed as soon as the director completes the connection.

8. The message having been received from the outstation, the director effects a connection to the next station and so on in turn, allowing a 10-second interval at those stations having empty transmitters. If no station has any traffic, the director will continue testing each station in sequence until it has completed the circuit twice, it will then rest for a period which can be adjusted. If any station has a priority message to transmit, the Supervisor receives a warning signal and by means of a switch on the control panel can cause the director to effect an immediate connection to the calling station.

9. Should messages be stored for more than a pre-determined time owing to abnormal traffic on one circuit, the apparatus will automatically slow down the receiver associated with that circuit to 50 w.p.m. until the traffic has been cleared.

10. It will be appreciated, however, that normally messages are received, transmitted across the office and re-transmitted out almost simultaneously. That is, re-transmission commences after a few inches of tape have been received. However, messages can be stored either by the incoming or outgoing apparatus. This permits all cross-office traffic to be operated at a fixed speed while the line traffic is operated at various speeds as required. It also permits lines to be operated continuously even if cross-office connections are engaged. However, since the receiver-transmitters on duplex circuits are duplicated, cross-office traffic is rarely held up.

11. Storage is effected in the following manner. If the apparatus on a receiving circuit is receiving faster than it can transmit across the office, a loop is formed between the re-perforator and the transmitter which are mounted alongside each other. Arrangements are made under the apparatus for the loop to be neatly coiled. If the re-perforator stops owing to the cessation of incoming messages the transmitter continues to operate until the tape becomes taut between the two, an arm then moves up the tape towards the re-perforator until the last character has been transmitted, when it stops. By this means blank spaces in the tape are avoided, thus effecting saving in circuit time.

Interception of Messages.

12. Two types of intercept circuits are provided :—

(a) *Wilful Intercept*.—This is used for intercepting and recording on the re-perforator any message which may require special handling or which cannot be transmitted to its destination due to the receiving station being closed, or due to a circuit fault. In the latter case, the message is re-routed by the supervisor or held until the restoration of the circuit. For this purpose the supervisor has an auto-transmitter.

(b) *Miscellaneous Intercept*.—This is completely automatic and serves to intercept and record all messages having an incorrect code or call sign. In this case, the line finder immediately switches the message on to the intercept machine, at the same time causing a red light to glow on the control panel and sounds an alarm gong. The Supervisor then inspects the tape in the intercept machine to find out the reason for rejection, and either makes the necessary corrections or refers the message back to the originator.

Staff.

13. The total staff required to operate the traffic at Headquarters consists of one female supervisor and one maintenance mechanic. In addition, at each outstation and at Head Office there are a number of keyboard perforator operators, depending on the traffic being handled.

Traffic.

14. As mentioned above, the system only operates during normal office hours, i.e., eight hours a day. During that period it handles 3,800 messages amounting to over 152,000 groups without any assistance or interference by human element whatsoever, other than the initial preparation of the original tapes and their insertion in the transmitters.

15. In addition to messages, orders are handled over the system, reaching a figure slightly over 100 a day and averaging 180 groups per order, thus the full total of traffic handled in eight working hours is 170,000 groups.

16. On a 24-hour basis, therefore, this small fully automatic system is capable of handling without any undue strain over half a million groups and without, virtually speaking, any supervision when compared with the U.S. Navy Department's huge staff of some hundreds engaged to handle only eight times as many groups by semi-automatic methods.

Maintenance.

17. The Teletype machines on this system are specially designed to operate at 75 w.p.m. and the only maintenance required is routine oiling, replacement of springs, etc., which is carried out by the maintenance mechanic. A number of spare machines are kept available to replace the working machines in rotation. These plug into the console and do not require any connections being made. It was stated that over a period of four years not one major breakdown had ever occurred and that simple preventative maintenance was found desirable only once every six weeks, i.e., once every 264 working hours which on a 24-hours basis is once every 10–11 days.

Advantages and Disadvantages of the System.

18. (a) Circuits and machines are used to as near the theoretical maximum capacity as practicable.

(b) Staff requirements are insignificant.

(c) Messages are handled more expeditiously than by the manual tape relay system.

(d) No message once initiated can get mislaid whilst in the system.

(e) Maintenance of the automatic equipment requires more skill though no greater than that possessed by auto-telephone switchboard mechanics.

(f) The system is not so flexible as a manual system and the grading of messages may prove a complication.

19. Discussing this type of equipment with the U.S. Navy and Army officials at Washington, it was stated that had this equipment been developed before the war, it would have undoubtedly been used in place of the manual tape relay.

Conclusion.

20. The writers of this report consider that this type of equipment has such important advantages, particularly in the saving of man-power, that some such system of automatic relaying or switching must eventually be introduced within the service organisation.

21. Consideration has, therefore, been given to the possible adoption of this system for Naval or other Service purposes. Firstly, there is a very limited use for party lines so that the director system would rarely be required, which is a considerable simplification. Secondly, there are questions of priorities routing and broadcasting to be considered. Thirdly, consideration must be given to automatic switching as distinct from automatic tape relay.

22. Investigations on these lines are being pursued. Other than remarking that it is known that similar systems are under development and that the difficulties or priorities routing and broadcasting can be overcome, the writers are not at the moment in a position to give a considered report on this aspect of the matter.

23. In the meantime, the writers consider that very early development of the typing re-perforator-transmitter should be progressed in this country as considerable use for such a machine can be foreseen.

International Automatic Telegraph Networks (Part I) (*continued*).

CONVENTION DISCUSSION

Mr. H. R. A. Wood : In view of the generous praise which has been given to the U.S. Services for the development of their Radio Teleprinting and Tape Relay working, in which I wholeheartedly share, I would like to take this opportunity of making a few observations. With what I trust is pardonable national pride it can be truthfully stated that one of the fields in which this country has indisputably led the world is international telecommunications and automatic telegraphy. British engineers, backed by British capital, pioneered the submarine cable and, undeterred by early misfortunes, built up a world-wide network. Marconi developed radio as a means of communication from this country, supported by a team of British engineers, and in the early 1920's, when the rest of the world was thinking in terms of long-wave, low-speed wireless circuits, British engineers came forward with proposals for very high speed short wave circuits which seemed then so fantastic that they were received with utmost scepticism and even derision. I need not dwell on the subsequent results of the Beam Wireless Services, since it is a matter which is now history.

Late in the year 1944, after the R.A.F. had established the first all-British multi-channel long distance radio teleprinter circuits, I was sent to the U.S.A. to investigate the progress made there. Like Commander Robinson, I cannot speak too highly of the friendly, courteous and extremely helpful reception I was given. I was allowed to spend several weeks investigating the system as an unaccompanied observer, but at the same time I was immediately given any explanations or assistance I sought. The U.S. Services tape relay system was, in my opinion, highly to be recommended and in many respects copied, but it must be pointed out, in fairness to this country, that twenty years earlier the Eastern Telegraph Company and their associates, whose world-wide network stretched from Buenos Aires to Shanghai, London to Capetown, Sydney to Bombay, had abandoned a tape relay system even more highly developed, replacing it by an automatic relay system by means of which messages passed between terminal stations, through as many as ten relay stations, entirely electrically and without the reproduction of messages in the form of perforated tape at the intermediate stations.

I would not impose further on your time in commenting on the Paper so ably presented by Commander Robinson which, all will agree, is a most valuable survey of a highly specialised field, but I would like to point out that this country has possessed for a long time a great international telegraph network, which has been the envy of all, particularly the U.S.A. When communications are made International, therefore, as we believe and hope they should be, let us not forget that this country will be making the largest contribution to the common cause.

Mr. G. T. Dain : The equipment on the stage has been set up to demonstrate the saving of operator and circuit time which results from the use of an automatic message-numbering system in a telegraph office. Although some of the individual machines used in this demonstration are of American manufacture, we have in fact gone a stage further than the Americans in our system of automatic control of message numbering. Whereas the American system requires that each message should be on a separate length of tape, and each piece of tape has to be manually inserted in one of the two transmitter heads by the operator, our equipment is arranged to detect an " end of message " code punched in the tape and transmit a serial number for each of a chain of messages on a continuous tape. As a result, the operator is only required to re-load tape into the transmitter at the completion of a complete run of traffic to a particular destination, instead of having to insert a tape for each message. The serial numbers are at present transmitted from a punched tape. The disadvantages of this are that it must be typed out by the operator in the first place, and that it can only be used a limited number of times. Eventually this number type will be replaced by an electrical device which automatically generates the teleprinter code pulses representing each number as required.

W/Cdr. E. A. D. Hutton : In this branch of the communication art perhaps more than in any other, the interests of the military and of the civil are interlocking and interdependent. Any soundly conceived strategic communication system must be developed on the proposition that, in time of emergency, it may be expanded by integration of available military and civil communications. Thus, the technical standards for military radio and/or wire teletype systems are similar to, and in many respects identical with, those of civil teletype systems. This conception has by no means gained universal recognition and much remains to be done to bring military and civil engineering thinking closer together, both within and between Europe and America. With this in mind, there are a few comments I should like to make on Commander Robinson's Paper.

With regard to signalling speeds, I would suggest that more emphasis should have been placed on the 75 baud/170 c/s channel spacing standard. American practice has shown conclusively that 100 g.p.m. can be handled with that standard and tele-typewriters will shortly become available generally which are capable of sustained operation at that speed. The 75 baud standard is to be recommended if for no other reason than that speed of service is thereby increased.

On the vexed question of teletype codes, the importance of economic factors should not be overlooked. The U.S.A. has, to date, manufactured equipment for, and operated, the majority of radio teletype systems. In the process, U.S.A. agencies have demonstrated the suitability of the 5-unit code beyond all possible doubt. Other countries, in building up their teletype systems, must bear in mind the need for integration with U.S.A. systems in order to achieve international, world-wide nets. While the 7-unit code offers a certain advantage in error detection, this is heavily discounted by inability to integrate with U.S.A. systems. I have found no strong support in America for the 6-unit code; its chief advantage is the possibility of eliminating case shift, which is not a real advantage if a suitable keyboard (such as the International No. 2) is used with a signals procedure which minimises the need for case shift. It should be borne in mind that the U.S.A. is heavily committed to 5-unit code systems and will not change in the foreseeable future. It would be unwise for other countries to install systems incapable of direct connection with U.S.A. systems, and this applies to both the military and civil carriers.

Commander Robinson compares facsimile communication unfavourably with printing telegraphy. I agree, in general, with this section of the Paper. However, the development of micro-wave communications has opened the way for more equal competition between facsimile and printing telegraphy on short haul, internal nets, since the necessity for economy in bandwidth is not paramount at super-high frequencies. A recent American development, still in the experimental stage, offers the possibility of 1,000,000 g.p.m. signalling speed with 6 Mc/s bandwidth. The system employs television scanning of microfilm copy and is planned to operate with carrier frequencies on the order of 5,000 Mc/s, or on coaxial cable circuits.

Space and time limitations have enabled Commander Robinson to deal only briefly in his Paper with the important aspects of radio transmitting and receiving equipment to be used on long haul nets, such as an Empire system. It is generally agreed that the two principal systems available are those employing single sideband and frequency shift techniques. Both systems have advantages and disadvantages in comparison with the other. In my opinion, the greater simplicity, lower cost and smaller size of frequency shift equipment commend it for all services except possibly those where voice and/or facsimile signals are required to be transmitted simultaneously with teletype signals. The final decision on equipment to be used must again depend, not only on technical considerations, but also on economic factors, having regard to the type of equipment already used or planned in the internal radio teletype systems of the various countries concerned.

In closing I should like to state that the views expressed herein are solely those of the writer and do not represent or reflect the official policy of the Royal Canadian Air Force.

REPLY TO THE DISCUSSION

I most fully support Mr. H. R. A. Wood's remarks concerning the services rendered in the past by this country in the field of long distance communication. There is, however, always the danger that the undisputed champion may become over-confident and allow complacency to lend to his defeat. I suggest with all humility that the Paper shows what a golden opportunity is today afforded the British Commonwealth, who, by the mobilisation of its military and civil resources, may well perform a fresh service to the world, compared to which its past efforts would seem small indeed. But progress waits for more; if organised leadership is not forthcoming from one quarter it will be found in another or events will shape their own haphazard destiny.

If the Fighting Services and Civil Telecommunication organisations of the British Commonwealth do not act together now as one body, this unique opportunity may soon pass away.

Mr. Dain's observations, which I am in a position to endorse, indicate that at least one British firm is beginning to grapple in a very satisfactory manner with some of the more immediate problems of detail. If this instance could be made typical of the British radio and landline telecommunication engineering industry, a marked step forward would have been made towards effecting a satisfactory solution of the general problem I have outlined.

In reply to Wing Commander Hutton, there is no occasion for me to comment further except for two minor points. Firstly, it is not necessarily true to say that the 7-unit code cannot be integrated with U.S.A. systems; this would appear to depend on the method of application. Only when the 7-unit code is employed as a " terminal Telegraph code " is the statement strictly accurate.

Secondly, with regard to the 6-unit code, I do not agree that abolition of case-shift is necessarily the chief advantage of this code. For international communication I regard the facilities for a greater number of characters than are available with the 5-unit code as of probable greater importance.

INTERNATIONAL AUTOMATIC TELEGRAPH NETWORKS*—Part II.

THE DESIGN PROBLEMS OF RADIO LINKS FOR AUTOMATIC TELEGRAPHIC NETWORKS*

by

E. V. D. Glazier, B.Sc., Ph.D.

A Paper read before the Institution's Radio Convention held at Bournemouth, in May, 1947.

(1) Introduction.

In the design of radio links for successful automatic telegraphy suitable for networks of the type described by Commander Robinson in this issue (pages 266–285), the radio engineer is confronted with the problem of providing higher grade transmission systems than heretofore. Automatic telegraphy places far more exacting requirements on the transmission link than is the case with systems involving a manual element, such as reading Morse signals by ear or visual reading of undulator tape. When reading telegraph signals the ear is capable of adapting itself to receiving conditions over a much wider range than is so far possible with any mechanical or electrical system. It is well known that almost any automatic system requires a signal-to-noise ratio of at least 10 dB better than a manual system, such as Morse, of approximately the same word speed. Other features besides signal-to-noise have also to be improved before an automatic telegraph is reliable, and these will be discussed in detail.

To avoid undue increases in transmitter power the radio engineer has to pay very great attention to detail in the design of his aerials and equipment in order to achieve the necessary improvement. The magnitude of the problem depends upon the type of installation; for example, whether fixed or mobile, or whether short or long range. For fixed stations it is possible to use considerably more elaborate aerials and equipment than is the case with installations of the mobile type such as ship, vehicle or aircraft. The mobile installation does, therefore, present the more difficult problem.

Although most of the considerations discussed in this Paper apply in some form or other to all automatic telegraph systems, they can best be understood by assuming the normal two-condition (i.e., mark or space) type of transmission link.

The merits and demerits of the various automatic telegraph systems and codes will not be discussed, but a code of the 5-unit type will be assumed by way of illustration. It is generally agreed that this code is not necessarily the best for radio transmission, but it serves very well to demonstrate the problems that are encountered.

(2) Fundamental Principles of Automatic Telegraphy.

Many systems fall within the category of automatic telegraphy, but for the present purpose it is sufficient to consider those systems wherein a character (letter or figure) is automatically converted to a suitable code of mark and space elements which can be transmitted over a two condition type of transmission link. Such instruments may be keyboard or tape, the former producing the code immediately on depression of a key, the latter forming a paper tape with code punchings which subsequently generate the electrical code in another instrument known as the automatic transmitter. At the receiving end the code elements operate electromagnets or other devices to cause the character to be printed on paper or alternatively to punch code holes in paper so that the message can be passed into the automatic transmitter of another link.

It is clear that in such a system the sending and receiving mechanisms must be synchronised so that a succession of received elements is delivered in the correct order and at the correct time to the receiving mechanism. This may be effected by complete synchronism or by a start-stop method. In the former case the distributor at the sending instrument which distributes the code signals to the link and the distributor at the receiving instrument which distributes the received signals to the printing mechanism, may be driven by synchronous motors which are dependent upon tuning forks, crystals, or other sources of high stability. Special synchronising pulses may be used to ensure correct phase relationship. To avoid this accurate synchronising of sending mechanism and receiving mechanism, the start-stop system is used. In this system the motors of the sending and receiving machines run with a speed tolerance of, say, $\pm\frac{1}{2}\%$ about the correct value. When a telegraph

* U.D.C. No. 621. 396. 65 : 621. 394. 74 : 621. 394. 3.
Manuscript received April, 1947.

character is to be sent, the transmitting mechanism is coupled to its motor for one character. The first impulse known as the start signal causes the receiving mechanism to be coupled to its motor for one character. The slight speed difference over the short duration of one character causes no trouble.

The 5-unit start-stop code is the most widely used system of automatic telegraphy and is usually known as teleprinter code, since it is used for teleprinters. The same code and system of operation is employed for tape relay equipment of the 5-unit code type. This system is assumed from hereon since it serves so admirably to illustrate the problem.

(2.1) *Type of Signal.*

The signals for each character consist of a positive polarity " start signal " of 20 milliseconds (m/s) duration, followed by five positive or negative code signal elements, each element being of 20 m/s duration, followed by a negative polarity "stop signal" of 30 m/s. Thus, all characters are of constant duration, namely 150 m/s. When no signals are being transmitted the teleprinter continues to transmit negative polarity. This has been arbitrarily called the " marking " condition. The positive impulses during signalling are called " spaces." A typical teleprinter signal is shown in Fig. 1.

The object of the start signal is to prepare the distant teleprinter for the reception of the five units or elements of the character which follow. This start signal causes the receiving mechanism to be coupled to the driving motor for 130 m/s, after which it is uncoupled until the next start signal is received. This feature removes the necessity of having accurate synchronisation between the sending and receiving mechanisms. So long as all the teleprinter motors in a network are within the prescribed speed tolerances of ± 0.5%, complete interworking is possible.

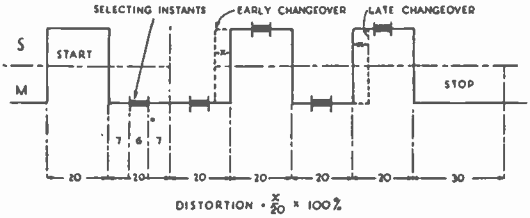

Fig. 1.—Teleprinter signal for letter " J " showing " selection instants " and distortion.

The process of setting the receiving mechanism to print the desired character is carried out during a short instant at the middle of each 20 m/s code element. These instants are known as " selecting instants " and are also shown diagrammatically in Fig. 1.

It should be noted that the mean current of this signal is not zero. This remark applies to all characters some of which will have a high predominance of positive or negative. This means that teleprinter signals have a D.C. component and it is important that this should be transmitted, or at least restored, otherwise distortion will result.

(2.2) *Signalling Speed.*

The length of the shortest element in a telegraph system is an important characteristic, since it is related to the bandwidth required in a radio transmission system.

The number of the shortest elements which can be transmitted in one second is the telegraph speed and is expressed in " bauds." Thus, a channel of 50 bauds is one in which the shortest telegraph element, i.e., mark or space, is 20 m/s long. If the elements are transmitted by amplitude modulation of a carrier wave a certain bandwidth is required. The conditions which determine this bandwidth will be discussed later, but it is sufficient for the moment to say that the total bandwidth required for a double side-band amplitude modulated carrier, which is modulated with a signal of " n " bauds is of the order of $fb = 1.6n$ to $fb = 2n$ c/s. If only one side band of the amplitude modulated carrier is used the bandwidth is one-half of these figures and this is the minimum bandwidth that can be used. Practical systems of modulation will in general use a greater bandwidth than given above. Roughly speaking it can be assumed that telegraph signals of 50 bauds contain frequencies up to 50 c/s.

(2.3) *Telegraph and Teleprinter Distortion.*

If the impulses are generated accurately by the sending teleprinter and they are transmitted so that they are faithfully reproduced at the receiving teleprinter, then, provided the latter is in correct adjustment, the desired character will be printed. Transmission systems can, for reasons which will be explained later, produce telegraph distortion at the receiving end of the system ; if the change-overs from positive to negative and vice versa do not occur accurately at the 20 m/s intervals with respect to the first part of the start signal then there is telegraph distortion present. In the case of teleprinters the definition of distortion is as follows :

> The distortion of a received teleprinter signal is the time by which any change-over is early or late with respect to its correct position (as measured from the first instant of the received start signal), expressed as a percentage of the unit signal element length.

It will be observed from this definition that if the first change-over of the start signal is early or late with respect to the true starting instant, then all subsequent change-overs are liable to be distorted even though they may occur at the true instant.

In Fig. 1 if the change-overs had occurred at the instants shown by dotted lines (x) m/s away from the correct instant with relation to the start, then the distortion would be $\frac{(x)}{20} \times 100\%$.

Distortion may in general be of three kinds; fortuitous, bias and characteristic. Fortuitous distortion is distortion of a random nature due to some variable feature of the transmission link. Bias distortion may be caused by some asymmetry of the equipment or link. Characteristic distortion is generally a function of the equipment and occurs consistently with any given combination of signal elements.

From Fig. 1 it will be seen that so long as the intended change-over occurs between two selection instants the correct character will still be printed. It follows that with a teleprinter having selection instants at approximately the middle 6 m/s of each element, the distortion which that teleprinter will handle is approximately 35%. If change-overs occur outside these tolerances or if spurious change-overs are introduced by the transmission system, then incorrect printing may ensue.

If the selection instants were reduced so as to be of extremely short duration it is evident that the theoretical maximum distortion which a teleprinter could handle would approach 50%.

(3) Integration of Line and Wireless Techniques.

Automatic telegraphy has been used on line networks for many years. The teleprinter system using 5-unit start-stop code is the most widely used system. Interworking or switching of teleprinters is often used. That is, teleprinter lines are connected to manual or automatic exchange switchboards, and messages are transmitted between any two teleprinters by setting up a connection as in telephone practice. This method of operation is only possible when the lines provide telegraph channels of very low distortion, since the distortion of links in tandem is additive.

Where teleprinter channels are derived from V.H.F. or U.H.F. radio circuits of the fixed type they are usually sufficiently good to be terminated on switchboards and interworked with line circuits. Technically there is no reason why circuits derived from H.F. radio links should not be terminated on switchboards and world-wide interworking obtained. Economic considerations intervene here, however, and make it necessary to use systems such as the tape relay with message storage, so that the more expensive links can work at greater efficiency.

The teleprinter system has already been applied to radio links and is becoming increasingly popular, in spite of the fact that radio performance must be improved beyond that required for manual systems. There is much to be said for standardising with line practice in this respect although, as stated earlier, the code developed for line use is by no means ideal for radio use.

When two telegraph channels are connected in tandem the overall telegraph distortion of the circuit can approach the sum of the separate distortions of the two links. If a link has a distortion of 15% it can be seen that the interworking of more than two such links in tandem is not likely to be satisfactory. This problem can be overcome by regeneration, that is the use of a regenerator which accepts signals up to, say, 40% distorted and delivers them free from distortion.

In the tape relay system this regeneration is carried out at each receiving reperforator. The latter instrument perforates the tape in accordance with the correct received message so long as the distortion is less than a certain figure, say, 40%. When this tape is passed to the next link the automatic transmitter passes it on again free from distortion. It is clear, however, that when a character is received incorrectly it will be passed on as such and the number of errors is thus cumulative. Moreover, any error in the address or in the routing instructions may cause a message to be sent to the wrong place.

The aim of the radio engineer must be to provide circuits equal to or better than line performance. He should aim at systems producing not more than one error in 10,000. In this connection it should be stated that many of the line telegraph systems are in need of improvement. Systems of radio transmission that can be easily repeated over land-line to terminal stations should be aimed at.

With this general statement of the problem, consideration will now be given to the causes of distortion in radio links and a brief resumé will be given of current practice used to reduce distortion.

(4) Causes of Telegraph Distortion and Misprinting in Radio Links.

It is important to know the causes of telegraph distortion and misprinting on radio links, and to take all possible steps to reduce such effects.

Telegraph distortion can be produced during transmission through a radio link, by one or more of the following causes:

(1) *Noise.*

Noise (atmospheric or man-made) appearing at various points in the radio link can produce voltages which interfere with the receive relay.

(2) *Fading.*

Fading of the radio signal, either slow or rapid, can cause telegraph distortion. If the radio equipment is designed to handle such fades then, in the limit, during deep fades the noise will cause distortion.

(3) *Transmission time.*

Variations of transmission time of the radio signal, due to varying reflection paths (also known as multi-path effects) will cause telegraph distortion.

(4) *Radio equipment.*

Various parts of the transmitting and receiving equipment can cause distortion, e.g., oscillators having frequency drifts, relays, filters, etc. Noise can also be introduced by the equipment.

In general, (1), (2) and (3) will cause fortuitous distortion and (4) will cause characteristic distortion. The manner in which some of these features of radio links cause distortion will now be considered. The term distortion will be used somewhat loosely to include true telegraph distortion together with omitted and spurious characters.

(4.1) *Distortion due to Noise.*

Consider first of all a simple continuous wave (C.W.) system in which a pulse of radio carrier conveys a mark signal, and no carrier a space signal, the receive relay being biased to half the signal strength. Such a pulse envelope received with no noise interference is shown dotted in Fig. 2A. Suppose the pulse originates at the transmitter with square flanks (although this is not essential) then a very wide bandwidth would be required at the receiver to preserve the square pulse. Such a wide bandwidth would admit noise during the space periods and the probability

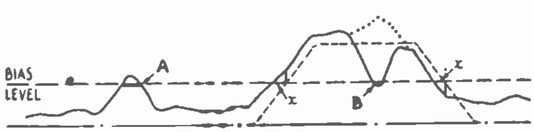

Fig. 2A.—Distortion of single current signal by noise.

of noise causing misprinting, as at A, would be high. Restriction of bandwidth at the receiver reduces the probability of this, but at the same time it causes sloping flanks on the received envelope. If the bandwidth is too narrow, misprinting caused by interference of type A will be small, but the flanks of the pulse will be so slow in rising that the time displacements (x) will be large, causing distortion. Considerations such as this set the limit to minimum bandwidth given in para. 2.2. If the receiving system is correctly biased, signals free from noise can still be accurately received even if the envelope is trapezoidal. However, the noise combines with the signal and produces a received signal as shown by the full line. The noise will have a frequency and phase random with respect to the signal. The combined envelope of signal plus noise may be above or below the true signal envelope, according to whether the noise is nearly in phase or out of phase with the signal.

The relay or receive element will change from mark to space or vice versa whenever the combined envelope crosses the bias level. Thus, the noise produces distortion corresponding to the time displacements (x) besides causing possible misprinting as at A and B.

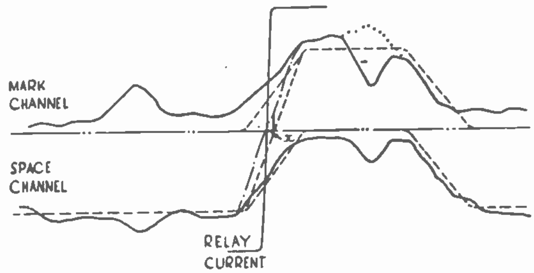

Fig. 2B.—Distortion of double current signal by noise.

In the case of a double current signal in which one tone or carrier represents a mark and another a space, as in Fig. 2B, similar remarks apply. Noise interference can still cause spurious change-overs and distortion, although it is evident from this diagram that the effect of noise will be reduced, because in the space condition noise often reinforces the signal, whereas in the single carrier case it inevitably causes a misprint.

The degree of interference produced by noise will depend upon the level and character of the noise. In the case of steady random noise the interference will be less severe than with noise due to, say, local lightning, if the average levels of the two types of noise are identical.

(4.2) *Distortion due to Fading.*

Having accepted the principle that the received signal at the narrowest bandwidth will be trapezoidal in shape, then from Fig. 2A, if the signal amplitude varies and the bias level does not, distortion of the element length will occur. Even with the best known means of controlling the bias point such distortion is inevitable. The double current or two-frequency system again has advantages in this respect since the receive element (relay or otherwise) is operated unbiased. However, a large disparity between mark and space signal amplitudes will produce distortion in the double current system.

If all known automatic gain control devices are used, then during very deep fades, the signal-to-noise ratio will deteriorate, and distortion may be caused by the noise.

(4.3) *Distortion due to Multi-Path Effects.*

On many types of radio link the signals reaching the receiver aerial may have travelled over widely differing paths. Those signals which have suffered many reflections will generally have travelled longer distances and will arrive after signals having the minimum reflections. Thus, a particular carrier pulse in the C.W. system will appear at the receiving aerial as the sum of a number of pulses starting at different instants of time, of different amplitudes and differing sinusoidal phases. The leading edge of the carrier pulse can thus be very erratic. According to some authorities (1) on links of three or four thousand miles the time between the first arrival of a steep fronted pulse and its last arrival can be 2 m/s or even 3 m/s. Similar effects occur with other systems besides C.W. So far as the telegraph equipment is concerned this erratic build-up of the signal element produced telegraph distortion of the fortuitous type.

(4.4) *Distortion due to Equipment.*

Distortion may be caused in the equipment at many points of the circuits, and it is important to keep this kind of distortion at the absolute minimum, so that the unavoidable fortuitous distortions (which add to the equipment distortion) produce as few errors as possible.

Transmitting and receiving relays can cause bias distortion if they are incorrectly adjusted. In the case of double current signals it is important to see that signals are generated symmetrically. In other respects the transmitting equipment is generally free from distortion.

The receiving equipment is somewhat more difficult to deal with. Imperfections of the automatic gain control circuits are very difficult to correct especially with single current systems.

Frequency drifts can cause bias distortion in some systems, as can mistuning of receivers. Careful design of the final teleprinter D.C. signal circuits is essential to avoid distortion.

(5) The Reduction of Misprinting on Radio Teleprinter Systems.

A radio link with a consistently good signal-to-noise ratio, for example, 25 dB measured at the output of a 100 c/s wide filter, can in general be used for successful radio teleprinter operation, using normal line voice-frequency telegraph practice. Radio links using U.H.F. and some links of the V.H.F. type fall within this class.

Radio links of the H.F. type do not always have such a good signal-to-noise ratio and they are subject to fading. Such links form a very important section of communications, and it is therefore necessary to use methods of modulation and other devices to minimise the effect of noise. The methods of modulation developed for greater reliability on the H.F. band are also applicable to V.H.F. and U.H.F. radio links. Consideration of these problems is therefore applicable in large measure to most types of radio channel. With mobile installations such as ship, vehicle or aircraft stations, restrictions on aerial systems necessitate the use of equipment of the utmost efficiency and detailed consideration of all methods of reducing distortion and misprinting are well worth while. The noise level with mobile stations is often high; for example, on board ship there are many devices which cause interference and which are difficult or uneconomical to suppress.

(5.1) *Choice of system of modulation.*

Several methods of modulating the radio frequency are available. These will be broadly divided into:

(1) Direct methods in which the positive and negative teleprinter pulses control the R.F. directly.

(2) Indirect methods in which the pulses are converted into one or more tones which then modulate the R.F. by any one of the several known methods, e.g., A.M. or F.M.

Either of these methods may be further sub-divided into single-current working or double-current working. With single-current working one polarity of pulse or one frequency is used to transmit a mark and no pulse to indicate a space. This method requires the application of a bias, either electrical or mechanical, at the receiving end to change the relay, or other receiving element, to space on removal of the signal.

With double-current working, one polarity or one frequency represents a mark, and opposite polarity or a different frequency represents a space.

(5.1.1) *Direct methods of modulation.*

(1) Single-current working.

In this system the carrier is transmitted at maximum level for a negative polarity or mark, and suppressed for a positive polarity or space. This is also known as continuous wave (C.W.) working or simply "on-off" keying.

The idle condition of a teleprinter is transmission of the "mark" or negative polarity. It is necessary for the carrier to be transmitted in this condition in order that the receiver A.G.C. shall be held to the level of the signal. If the reverse condition were used the receiving teleprinter would operate on noise during the idle condition.

The C.W. method of transmission has been very commonly used especially in conjunction with high-speed morse equipment. It has been used for teleprinter operation but has not always been successful on links operating near the limit of noise.

The method of modulation and detection is generally very simple. At the transmitter a relay is usually employed to switch the R.F. on and off at an appropriate stage. At the receiver the principle of detection is simple rectification. This rectification is carried out either at the I.F. or at a beat frequency. In either case the signal is passed through a filter to reduce the effect of noise components at other frequencies. The resulting D.C. from rectification is caused to operate a polarised relay. A bias must be applied to this relay to enable it to change over when the carrier is removed. Preferably this bias should be automatically set to half the signal current and should vary with it.

It will be seen, however, that in conditions of variable noise and rapid fading the setting of the bias is no easy matter. This method is similar to single-current line telegraphy. Methods of improving this system of signalling involve steps to maintain the carrier at a fairly steady level at the receiver. That is reduction of the fading ratio, and is usually effected by wobbling the carrier a few hundred cycles at a low rate. Improvements of up to 10 dB in fading ratio have been claimed for this device.

(2) Double-current working.

In this system the carrier is transmitted at maximum level for a negative polarity or mark, and at maximum level but 850 c/s (or any other suitable value) lower in frequency for a positive polarity or space. This method is also known as Frequency Shift (F.S.) or double-frequency keying.

In this method it will be seen that the transmitter works at full power continuously. The advantages of this method will be touched upon briefly. Firstly, it will be seen that the receive relay need not be operated in the biased condition. It will be less susceptible to variations of signal level and noise. The received signal may be passed through a limiter as in F.M. practice. This has the effect of reducing the disturbance caused by noise, provided the noise is not too large in voltage. The method is similar to double-current line telegraphy. It is also akin to the F.M. method of radio.

Both these methods of direct modulation place somewhat rigid requirements on the transmitter and receiver oscillators. The drift of these oscillators must be held to the very tightest limits. Some form of frequency drift alarm or automatic frequency control is desirable if transmitter and receiver crystals are not used.

(5.1.2) *Indirect methods of modulation.*

There are three main methods in current use:

(1) Single-tone.
(2) Two-tone.
(3) Four or Six-tone.

(1) Single-tone.

In this method, transmission of negative polarity or mark is effected by sending a tone (usually audible) into the transmission system. For positive polarity or space the tone is suppressed.

The tone is used to modulate the R.F. either by amplitude or frequency modulation. In the former case the tone should cause 100% modulation to secure the maximum gain over noise. Even so it should be noted that the power in one sideband (which is all that is effective in overcoming noise) is only one-quarter of the steady carrier power. In a single-tone system the receiving relay has to be biased to half the amplitude of the signal, and it is therefore analogous to single-current telegraphy.

With single-tone working applied to ordinary A.M. or F.M. links, there are no special frequency stability requirements on the radio links. However, it should be noted that where single-tone working is applied to a single sideband radio system the result is analogous to C.W. transmission, except that with single side-band there is a continuous signal transmitted for frequency and level control purposes.

(2) Two-tone.

In this method a mark is transmitted by sending one tone over the radio system, and a space by sending a different tone. Each of the two tones can be transmitted over the radio system by A.M. or F.M. Each tone should modulate 100% to secure the maximum gain over noise.

The relay in this method may be operated unbiased and the system is thus analogous to double-current working. Frequency stability of the radio equipment is not so important excepting where the system is single side-band. In the latter case it should be noted that two-tone transmission over a single side-band system is equivalent to the frequency shift method of working except that vestigial carrier is transmitted for level and frequency control purposes.

The two-tone system has been very widely used, but with A.M. radio links only one-quarter of the steady carrier power is available for discrimination against noise.

(3) Four-tone and Six-tone.

In the four-tone system, two tones represent a mark and two different tones a space. The six-tone system is similar except that there are three mark tones and three space tones. These systems have been used to give greater reliability on radio links subject to selective fading, and are discussed in more detail later.

These systems are applicable to A.M. or single side-band links. In the four-tone case, each tone must modulate the transmitter 50%. This represents a loss of signal strength, but if four-tone working overcomes selective fading, such a loss must be tolerated, and increased power used if necessary.

In the six-tone case the modulation per tone must be reduced to about 33% unless the tones are phased when it can be increased to about 45%.

(5.1.3) *Summary of methods of modulation.*

The actual choice from the many possible systems for a particular application depends upon the characteristics of the radio link (noise, fading, etc.), whether fixed or mobile, the amount of traffic to be handled and so on. The aim in the choice of a system is to obtain the best possible signal-to-noise ratio and maximum stability of level of signal. It is only possible to make recommendations in the most general terms as developments in a particular system may change the situation. Broadly speaking, single-current systems are to be avoided. The double-current systems are preferable for most applications and should be used where possible.

TABLE I.

Type of Link.	H.F.	V.H.F.	U.H.F.
(1)	(2)	(3)	(4)
Over 1,000 miles. (Fixed).	(*a*) Single side band with two-tone multi-channel. (*b*) Frequency shift.		
100 to 1,000 miles. (Fixed and mobile.)	(*a*) Frequency shift. (*b*) Two, Four or Six-tone on A.M.		
Less than 100 miles. (Mobile.)	(*a*) Frequency shift. (*b*) Two, Four or Six-tone on A.M.	(*a*) Two-tone A.M. or F.M. (*b*) Tone multi-channel on A.M. or F.M.	(*a*) Single-tone. (*b*) Two-tone (*c*) Tone multi-channel.

For long distance fixed services, tone systems of multi-channel on single side-band links seem to be preferable. With the SSB system the phase of the carrier is unimportant, and correct demodulation of tones can proceed at the receiver when the carrier is changing in phase or indeed fading completely. With normal A.M. (double side-band) a phase shift of the carrier with regard to the side-bands can reduce the tone output to a low level although the carrier and side-band amplitudes are normal.

Accepting the above general principles as a guide, the choice of systems is given in Table I, although every case must be considered on its merits. Systems (*a*) and (*b*) represent possible first and second choices.

(6) Design of the Transmitter System.

The method of transmitting the outgoing radio telegraph signals depends upon the type of modulation adopted. C.W. systems are well known and will not be discussed. Frequency shift transmitter systems will be briefly touched upon. The tone systems will also be briefly described.

Considerations governing choice of power are not proper to this Paper but it should be remarked that with mobile installations the minimum power necessary should always be used to avoid interference with adjacent receivers.

(6.1) *Frequency Shift Systems.*

The simplest system is that in which the master oscillator of the radio transmitter is of the coil and capacitor type. The frequency shift signal may then be obtained by keying a suitable value of capacitance across the master oscillator tuned circuit. This capacitance will have to be adjusted to produce the correct frequency shift at various transmitted frequencies. If the master oscillator is followed by frequency multiplication stages, the shift produced by the capacitor must be the appropriate sub-multiple of the shift.

The keying of the trimmer capacitor may be effected by a telegraph relay or by means of an electronic switch; for example, a diode whose bias can be controlled by the telegraph signals. The main limitation of this method is the transmitter frequency stability which must be achieved with receiving systems incorporating narrow filters. To improve frequency stability, keying of a capacitor across a crystal master oscillator has been attempted. This method is not to be recommended, however, because it is difficult to achieve stability of the amount of the frequency shift; special crystal cuts are also necessary.

A more usual type of frequency shift master oscillator is that using the principle of interpolation oscillators. The transmitted radio frequency is derived by subtracting a frequency of, say, 465 kc/s from a frequency derived from a crystal oscillator. The 465 kc/s oscillator can be of a high stability coil and capacitor type, the frequency of which can be shifted the desired 850 c/s by using a capacitor keyed by the telegraph signals. Thus, something like 95% of the outgoing frequency is of crystal oscillator stability, the remaining 5% being of good coil and capacitor standard. The 465 kc/s is subtracted by producing upper and lower sidebands on the crystal oscillator output with a balanced modulator. Suppression of the unwanted side-band and any residual crystal oscillator leak is carried out by simple tuned circuits. With the choice of 465 kc/s for the interpolation oscillator the transmitter crystal is standard with the crystal in the receiver if used.

The shift of 850 c/s, which has been mentioned in describing these systems, is fast becoming standard in the U.S.A. and in the United Kingdom. In Germany, a shift of 360 c/s was used. The smaller shift would enable the use of a narrower I.F. filter, and would give a slight improvement under noise conditions especially with the F.M. method of reception. The smaller shift would, however, aggravate the frequency drift problem, and a very careful assessment of all the factors is indicated as being necessary in the near future.

With a relay method of keying the transmitter, the change from mark to space frequency is very rapid and the transmitted signal is almost a square telegraph signal, frequency modulating a radio frequency which is the mean of the mark and space frequencies. This type of transmitter signal is satisfactory when the method of reception employs an F.M. type of discriminator. Where the method of reception employs narrow mark and space filters, this type of transmission is liable to produce distortion. If mark and space filters are used for reception, the change from mark to space frequency at the transmitter should be more gradual. This can be achieved by filtering the D.C. telegraph signals and using a reactance modulator type of frequency shifter.

(6.2) *Tone Systems.*

The transmitter should be capable of transmitting a band of 300 c/s to approximately 2,500 c/s with small frequency and harmonic distortion. The additional equipment necessary at the transmitting end is a source of tones and a means of modulating or keying them with the telegraph signals.

For two-tone systems, a tone oscillator with a tuned circuit may be employed. A capacitor may be keyed by a relay across the tuned circuit to change from one tone to the other. In compact installations care must be taken to ensure that the means of keying does not cause radio interference. If a relay is employed it must be radio suppressed and as capacitors must be employed for suppression, their effect on the tuned circuit must be taken into account. An alternative scheme is the use of separate tone oscillators, one for each frequency, with keying between oscillators carried out by means of metal rectifier modulators.

For multi-channel or frequency diversity systems a multiplicity of such oscillators may be used. If phasing between tones is aimed at in order to secure maximum efficiency then rotary tone generators or phased oscillators locked to a master must be employed.

Where two tones are used it is desirable to pass them through transmitting filters before modulating the radio equipment. For multi-channel systems or systems of more than two tones, the use of transmitting filters is essential. If such filters were not used the transmitted signals would be tones of, for example, 900 c/s, with a square wave modulation of say 50 bauds. Such signals have side-bands of $\pm$ 25, $\pm$ 75, $\pm$ 125 c/s, etc., of gradually diminishing amplitude. These side-bands would cause serious cross channel interference. Even in the single channel, two-tone case they can cause telegraph distortion, so that transmitting filters are again desirable.

(7) The Design of the Receiving System.

The radio frequency circuits of the receiving system usually follow conventional practice. They are invariably of the superheterodyne type. The signal from the intermediate frequency filter may, however, be detected in several ways which depend broadly upon whether they are frequency shift signals or multi-channel tone signals. Before passing to a detailed consideration of these detection systems, reference will be made to a few points which must be observed when selecting or designing a receiver for radio teleprinting.

The first point concerns selectivity. The desirability of passing the signals through narrow filters has already been stressed. Ideally these filters should be at the radio frequency, but this is not possible because of the narrowness and sharpness required. The filtering has, therefore, to be carried out at intermediate or audio frequency. Nevertheless, the radio circuits should be as selective as possible before frequency changing is carried out and before too much radio frequency gain is introduced. This is necessary to prevent blocking of the receiver by interfering signals. Furthermore, to prevent interfering signals from mixing with one another during frequency changing and then penetrating subsequent filters, the centre frequency of each filter should preferably be greater than the bandwidth of previous filters.

The I.F. filter should have a uniform loss in the pass band and the signals should pass symmetrically with respect to the centre frequency of the filter. This is desirable in order to preserve the symmetry of signals, especially those of the two-tone or frequency shift type.

A further point concerns the stability of the receiver oscillators. This stability cannot be too high, especially with frequency shift systems. In the case of single side-band systems some form of automatic frequency control is essential.

(7.1) *Detection Systems.*

The signals from the I.F filter of the radio receiver can be rectified directly to D.C. teleprinter signals in the case of interrupted C.W. and frequency shift systems. In the latter case a frequency discriminator is required. This system will be described after reference to the general principles of tone detection systems.

The tones may be demodulated from the I.F. output by the usual methods of detection in the case of A.M. and F.M. systems. In the case of interrupted C.W. and frequency shift systems, a B.F.O. is necessary to reduce the I.F. output frequency to the correct tone frequencies. In either case the tones are then passed through selecting filters to minimise noise interference and then passed on to the tone detector.

(7.2) *Single-tone Detectors.*

A single-tone detector will, in general, include a filter for selecting the desired tone, an amplifier, and a tone rectifier followed by an output stage driving the receive relay. A means must be provided to operate the relay to space on the cessation of the tone. This may be an electrical bias on the relay equivalent to half the amplitude of the received signal. This bias must be adjusted during setting-up a circuit. Automatic bias circuits have been evolved which provide this half amplitude bias automatically. These bias circuits must have a long time constant compared with the element length, to preserve the bias during a succession of spaces. In the case of radio circuits subject to fast fading, it is clear that such detectors are not likely to be highly satisfactory. This is one of the inherent difficulties of single-tone detection.

On radio circuits using V.H.F. or U.H.F. frequencies, where the performance approaches line, these difficulties do not arise. The type of single-tone detector used in line practice can be applied with success to such circuits.

(7.3) *Two-tone Detectors.*

Several types of two-tone detector have been employed. The most usual type is that in which the two tones are passed through two filters, one for each tone. Having thus separated the mark and space tones, they are amplified, rectified, smoothed and applied to the output stage which has two valves in push-pull with a polarised relay.

A further type is that in which the two tones are passed to a frequency discriminator. If the mid-frequency of the mark and space tones coincides with the mid-frequency of the discriminator, the teleprinter D.C. signals will be produced without bias. If there is a drift of the two tones, bias will be produced.

(7.4) *Four-tone and Six-tone Detectors.*

To combat selective fading on long sky wave circuits, two tones can be used for mark, followed by two other tones for a space. In German practice, six tones were used, three for mark and three for space. This constitutes frequency diversity which may be used as an alternative to space diversity. This system is applicable to mobile installations where space diversity aerials are impossible. So long as, at least, one tone is satisfactorily received signalling is maintained. Either one or two receivers may be used. A separate mark/space detector is required for each pair of mark/space tones. These detectors may be combined such that the largest mark voltage and the largest space voltage are applied to the final output stage. Thus, if one mark tone is subjected to a fade the remaining mark tone preserves signalling. This may be called " peak combination." An alternative point of combination is at the anodes of the output stage of each detector. With this connection the average of the two tones is selected rather than the larger of the two. This may be called " average combination." In general the former connection is to be preferred because the weaker signal, which would tend to have the worst signal-to-noise ratio, is rejected. A further method of diversity combination or switching is to select the diversity channel having the best signal-to-noise ratio. This switching is best achieved by an electronic switching system which must be capable of operating at a speed which does not influence the receive relay or element.

(7.5) *Frequency Shift Detecting Systems.*

One method of detecting frequency shift signals is that of reducing the I.F. output by a B.F.O. down to two-tone signals and then detecting by one of the methods outlined in Section (7.3). It will be realised that any frequency drift at the transmitter, receiver first oscillator, or B.F.O. will cause a drift of tones. If narrow selecting filters, e.g. 100 c/s wide, are used the frequency stability requirements are very high. Automatic frequency control circuits may be used. Such circuits need very careful design owing to the narrow limits of drift and the fact that the control tone, e.g. the mark tone, is interrupted with telegraph signals and is subject to fading.

To overcome the frequency drift problem considerable thought has been given to a system in which the I.F. output is limited and passed directly to a discriminator, thus producing the negative and positive teleprinter signals directly if the frequencies are correct. As stated previously frequency drift now produces signal bias which must be reduced if distortion is to be kept down. A drift exceeding 425 c/s (with U.S. and British equipment 850 c/s shift) would cause relay change-overs to cease unless other steps were taken. To preserve signalling during frequency drifts the teleprinter signals may be passed through capacitors. These capacitor circuits may have a long time constant compared with signal elements, or a short time constant. In the first case, during periods of no traffic, the capacitors will discharge leaving the output relay or circuit with no holding current. In this condition the output circuit is prone to disturbance by noise. Efforts to apply D.C. restoration have been made to overcome this difficulty and further development here is indicated.

The case of the series capacitor with short time constant compared with an element length, corresponds to differentiation of the teleprinter signals. A short negative pulse will be produced by a positive to negative change-over, and a short positive pulse by a negative to positive change-over. These pulses are passed on to a side-stable circuit or relay. This scheme has one possible advantage in that it continues to signal if either mark or space frequencies are subject to a complete fade.

It is, however, prone to disturbance by noise because during idle periods the signal is not effectively employed. Considered as an F.M. signal, the 850 c/s frequency shift system with 50 baud telegraph signals has a deviation ratio of about 17 : 1 for the fundamental telegraph component and a much lower ratio for the higher frequency telegraph components which provide a steep change-over. These signals pass satisfactorily through a 1,200 c/s filter, ignoring the frequency drift problems. Although chosen originally to fit in with certain tone filters the figure of 850 c/s does not seem unreasonable although it is somewhat higher than is usual in F.M. practice. Any reduction of the shift may aggravate the frequency drift problem.

These systems are still largely in the experimental stage. There is evidence that for fixed services the problems are solved as completely as possible by the use of temperature controlled crystal transmitters and receivers, with conventional two-tone detectors. The study of less elaborate schemes of frequency shift transmission is, however, well worth while. Developments in the future will no doubt provide simple systems, independent of small frequency drifts, capable of transmitting the D.C. component and thus of low distortion.

(7.6) *Diversity Reception.*

On long distance radio links using sky-wave transmission, selective fading can occur. Two radio frequencies of equal transmitted amplitude and only 100 c/s apart can be received with momentary amplitude differences of at least 15 dB[2]. Due to interference between waves arriving at the receiving aerial after having travelled over different paths, one of the frequencies may be received strongly while the other is subject to a deep fade. A second or so later the strong signal may fade while the weak signal rises to a strong one. The phenomenon occurs together with multi-path pulse distortion effects. With two-frequency transmission on a link subject to this phenomenon, misprinting is very liable to occur during a selective fade.

There are several precautions to be observed in order to minimise this trouble. The time constant of the two-frequency detector A.G.C. must be short compared with a telegraph element; limiters in the two-frequency path may be employed. The most satisfactory method is, no doubt, the use of space diversity, that is the use of two or three receiving aerials with independent receivers and detectors. It is, in general, only suitable for fixed stations. The signals may be combined by the peak method or by the average method. Where the receiving layout must be compact, as on board ship or other mobile installation, the use of four- or six-tone working with a single aerial gives frequency diversity which can give satisfactory results. Further elaborations that may be adopted at fixed stations are aerials directional in bearing and elevation, and steerable aerial systems. In a triple diversity aerial scheme two of the aerials may be used for the dominant form of polarisation, say horizontal, whilst the third is designed for vertical polarisation.

(7.7) *Reception Element.*

When the received radio signals are reduced to D.C. signals they may be passed on to the teleprinter in two ways. They may be used to operate a sensitive polar telegraph relay which repeats local power on to the teleprinter, or they may operate mark and space valves which feed current to the teleprinter receiving magnet directly.

Up to the present time, the relay method had been used almost exclusively. It is, in general, very satisfactory but precautions must be taken to ensure that radio interference generated by the relay contacts does not reach the radio receiver input. This may be ensured by a screened aerial lead-in, or by physical separation of the relay and radio equipment. These methods are often inconvenient especially for ship and field equipments, and it is necessary to suppress all telegraph relays with capacitors and chokes. Suppression of relays for a wide band of radio frequencies is extremely difficult.

The valve output method is free from radio interference and has much to recommend it. There seems no doubt that this method should be further developed, although it involves power packs of considerable output.

(8) Multi-Channel Systems.

The maximum operating speed of a teleprinter is 66 words per minute. Some teleprinter tape systems are capable of 100 words per minute. This represents a severe reduction when compared with the 100 to 200 words per minute that has been used successfully with Morse tape systems. To increase the traffic handling capacity of teleprinter links, it is necessary to use multi-channel working so that two or more separate teleprinter channels can be derived from one radio link. It is obvious that a radio link for multi-channel teleprinter working must be of higher signal-to-noise ratio than for a single teleprinter channel. Similarly, a channel for high-speed Morse must be superior to one for low-speed Morse. For this reason it has been common practice to reduce the speed during deteriorating radio conditions.

It is very desirable that a multi-channel radio teleprinter link should be flexible in order that the number of channels can be varied to suit the radio conditions. With deteriorating conditions the number of channels can be reduced, thus maintaining a good standard of accuracy per channel.

There are two methods of achieving multi-channel telegraph operation:

(1) Time division.

(2) Frequency division.

Each system has its merits and these will now be considered in detail.

(8.1) *Time Division Multi-Channel Systems.*

For an N-channel system operating on this time division principle the common transmission system is used for $\frac{1}{N}$th of a signal element by each channel. The early Baudot system is an example of this type. Fig. 3A shows the principle of this system. Some means of synchronisation is necessary to keep the channel selecting wiper arms in synchronism. Actually a mechanical wiper is not essential and electronic distributors have been devised. Some form of signal storage element is also necessary so that the teleprinter keyboard can be operated independently of the wiper arm.

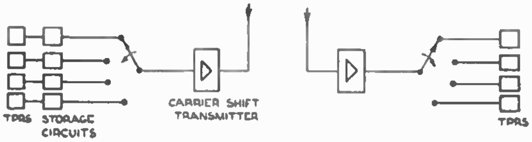

Fig. 3A.—Simple time division multi-channel system.

The transmission link has to be capable of handling N times the telegraph speed of one channel. Thus, filter widths have to be greater and for the same signal-to-noise ratio the signals have to be correspondingly stronger.

Difficulties with this system are liable to arise on long radio links subject to multi-path effects (see Sec. 4.3). Consider, for example, a four-channel teleprinter multiplex system, the element length will be $\frac{20}{4} = 5$ m/s. That is, the radio link must transmit elements of 5 m/s with a distortion maximum of about 2 m/s. When multi-path effects producing random delay differences of 2 or 3 m/s (1) have to be contended with, it is easy to see that a time division system may be unsatisfactory on such links.

The advantages of time division are that the equipment can be relatively simple and it need not be bulky. The equipment for a two-channel time division system (diplex) can be very simple and it is, therefore, applicable to mobile stations.

Flexibility of the number of channels can usually be provided with this system. To obtain the maximum gain over noise, the filter width should be reduced as the speed is reduced; this involves supplying a range of filters. A disadvantage of the system is that the distributer usually ties each channel to a definite speed of signalling.

(8.2) *Frequency Division Multi-Channel Systems.*

In the frequency division system a separate tone frequency is allotted for each channel, or if the system is two-tone, then there are two tones per channel. Figure 3B shows a block schematic of a two-tone multi-channel system. Such a system can only operate over a link capable of transmitting a band of audio frequencies. Such links are normal A.M. or F.M. links or single side-band (S.S.B.) links. Whether the system is single- or two-tone, the radio equipment has to be capable of transmitting N tones simultaneously. The tones selected are usually those employed in line telegraphy, namely 420 c/s, 540 c/s, 660 c/s and so on with 120 c/s spacing.

These frequencies are odd harmonics of 60 c/s and are so chosen that the even harmonics of the lower channel tones, which may be produced during passage through the transmission link, fall between higher chanńels and thus do not cause interchannel interference. Odd harmonics of tones, especially the third harmonics, do coincide with higher channels and can cause interchannel interference.

It is evident that with a frequency division multi-channel system the percentage modulation of the radio carrier per channel must be much lower than for a single channel link. If the telegraph tones are generated by free running oscillators, then it is possible for the instantaneous voltages of all channels to reach their positive peaks at the same instant. If the radio equipment is not to be overloaded, then it is clear that the modulation per channel must be $\frac{1}{N}$th of the maximum permissible modulation.

If phasing of the tones is not used then the signal-to-noise ratio of the radio link for 100% modulation must be 20 log N dB better than for a similar type of single-channel link. Actually, a concession of 3 to 6 dB can be allowed on this figure for six to twelve channels respectively, to allow for the fact that all channels peaking simultaneously is not a serious factor.

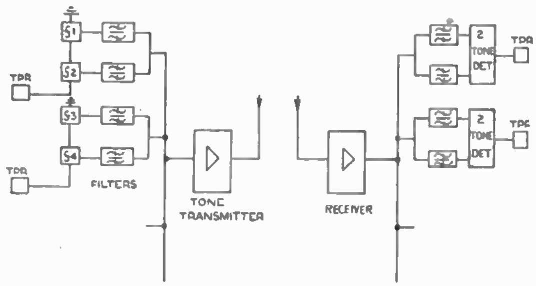

Fig. 3B.—Simple frequency division multi-channel system.

From the point of view of distortion due to noise, there is little to choose between time division and frequency division multi-channel working, provided the radio system is of the frequency shift type in the former case and the single side-band type in the latter case. Where multi-path effects and fading have to be contended with, as on long distance radio, there seems no doubt that frequency division is most satisfactory, since with this system the teleprinter elements are still 20 m/s long and 2 or 3 m/s distortion can be well tolerated.

(9) Telegraph Distortion Measurements.

With the greater use of teleprinters for line and radio systems, there is a growing need for adequate telegraph distortion measuring equipment. There is a possible need for equipment providing the following facilities:

(*a*) Measurement of teleprinter transmitting distortion.

(*b*) Measurement of teleprinter receiving margin.

(*c*) Measurement of the overall telegraph distortion of a transmission link.

(*d*) Continuous monitoring and measurement of the distortion of received traffic teleprinter signals.

An instrument of the type (*c*) is essential for checking newly developed radio links. It cannot be stressed too strongly that the telegraph distortion produced by the equipment and by radio transmission conditions must be accurately known.

The last equipment is also of especial interest in connection with radio teleprinter systems. When a radio teleprinter system is carrying traffic and the radio channel is deteriorating due to atmospheric conditions or transmission path changes, the only warning of the oncoming conditions is incorrect printing. If, however, a distortion monitor is connected across the receiving end of the circuit, adequate warning of deterioration is given and consideration can be given to changes of radio frequency, aerial, etc. Indeed, automatic switching over to transmitters and receivers on alternative frequencies is a possibility.

(10) Conclusion.

The design and provision of radio links for automatic telegraphy is still in a very early stage. The advantages of automatic systems have been proved in the line communication field, and they seem to be gaining ground in the radio field. Much remains to be done to provide a completely reliable system. In a short paper, such as this, it is not possible to describe all the transmission systems that have been developed up to date, but it is generally agreed that considerably more work on this subject is necessary. It is hoped that this paper will stimulate thought and work on the subject.

The author wishes to acknowledge the permission of the Director of Telecommunications Research and Development (Defence), Ministry of Supply, to publish this paper.

Bibliography.

(1) " High Speed Recording of Radio Telegraph Signals " by R. B. Armstrong and J. A. Smale. *J.I.E.E.*, Vol. 91, Part III, No. 16, of December, 1944.

(2) " Radio Section—Chairman's Address " by A. H. Mumford. *J.I.E.E.*, Vol. 93, Part I, No. 61, of January, 1946.

TRANSFERS AND ELECTIONS TO MEMBERSHIP

Since publication of the last list of Elections, Transfers and Registrations (see Page 212 of the Journal) the Membership Committee met on October 23rd and November 25th 1947, to consider 48 proposals for election to Graduateship or higher grade of membership, and 47 proposals for transfer to Graduate of higher grade of membership.

The following Elections and Transfers have now been approved by General Council: 37 for direct election, and 26 for transfer.

The following reinstatements were also agreed to by the Membership Committee: 2 to Associate Membership, and 1 Student.

Direct Election to Full Member

CADELL, Colin Simpson, C.B.E., M.A.	London, W.1
HEFTMAN, Stephen Tadensz	Harrow Weald
HELMORE, William, C.B.E., Ph.D., M.Sc., F.C.S.	Kingston Hill, Surrey.
FRENCH, Henry William, B.Sc.	London, N.W.8
RENWICK, Sir Robert	London, E.C.
SAY, Maurice George, Professor Ph.D., M.Sc., A.C.G.I., D.I.C.	Edinburgh
WASSEF, Yousef	Cairo

Direct Election to Associate Member

*ALEXANDER, Hector James	Dunedin, N.Z.
ATKINSON, George Herbert B.Sc. (Hons).	Halifax
BALICKI, Stanislaw	Stanmore, Middx.
CHRZANOWSKI, Jerzy	London, N.W.7
DANILEWICZ, Leonard Stanislaw	Harrow Weald
DANILEWICZ, Ludomir	Wembley, Middx.
EXWOOD, Maurice	Nottingham
FOSTER, Wm. Douglas, B.Sc.	Wellington, N.Z.
GALLOWAY, Anthony Lennox	Northam, Devon
GARNER, Raymond Hubert B.Sc. (Eng).	Blackpool
GLENDINNING, William	London, S.E.23
HAMPTON, George, M.A.	Cairo
LAZECKI, Stanislaw	London, S.W.6
*MANSELL, Lionel Henry	Leicester
PEGRUME, Sydney Arthur	Nairobi, Kenya
ROBERTSON, Angus James Eric	Coogee, Australia
SEYMOUR-HAYDON, Alan Arthur Torquil	Iver, Bucks .
TAYLER, Geoffrey George Sidney	Cowley, Oxford
TRIGG, Reginald Douglas	Welwyn Gdn. City
WAHBA, Abdel Monem	Cairo

Direct Election to Associate

BAILEY, Douglas John	Westcliff-on-Sea
BALLS, Leslie Robert	Great Yarmouth
BARKER, P. Hall	Wellington, N.Z.
BOWER, John Bingham de Courcy	London, S.E.6
BURTON, Dennis Stanley	Boston, Lincs.
CLITHEROE, Frederick Henry	Newhaven, Sussex
EAVES, Norman	Stoke-on-Trent
KWISSA, Witold	Harrow Weald
SABOTKA, Kazimierz	Stanmore
WLODARCZYK, Stefan	Stanmore
WYMAN, Kenneth Henry	Stonehouse, Glos.

Transfer from Companion to Full Member

DEUCHARS, George Dalginross, O.B.E.	Cairo

Transfer from Companion to Associate Member

HANDBY, John Edmund	Victoria, Australia

Transfer from Associate Member to Member

DULEMBA, Boleslaw	Rio de Janeiro
TYRRELL, Arthur James	Bexley, Kent

Transfer from Associate to Associate Member

AHL, Edwin Sidney	Wrexham
ATKINS, John Percival	Daventry
BLANCHARD, Allan Robin Wood	Salford
COGHLAN, Arnold Edward	South Shields
CADE, Cecil Maxwell	London, S.W.
ELLIS, Norman William	Hockley, Essex
FORSTER, John Ions	Newcastle-on-Tyne

Transfer from Student to Associate

COLLIER, Geoffrey Louis	Nottingham
CROW, Stanley George	London, N.9
DIX, Gordon Sidney	Cranford, Middx.
EAST, Alexander Maurice	Grays, Essex
HARRIS, John	London, N.W.8
IMRIE, Thomas Colin, Fl/Lt.	RAF, Debden, Essex
KENDALL, James Samuel	Birmingham
RITCHIE, Roy	Rutherglen
ROBINSON, Raymond Gray Rippon, B.Sc.	Cambridge
SIMMONDS, Percy William	London, W.5
WALE, Edward Frederick	Ilford, Essex
JARDINE, William	Chislehurst

Transfer from Student to Graduate

NORMAN, Geoffrey Percy	Epsom
SARIN, Jagdish Chandra, B.Sc.	New Delhi
WILLIAMS, Keiran Francis	Dublin

* Reinstatements.

STUDENTSHIP REGISTRATIONS

Since the list published in the October issue of the Journal, the Membership Committee have considered a further 73 proposals for Studentship, and Council have approved the registration of all these, as follows:

BEECROFT, William Douglas	Bradford
BRISTER, John Arthur	Leigh-on-Sea
BROWN, Alfred Dixon	Norwich
BRYANS, William Orvle	London, N.5
BUNDY, Douglas Ernest	Winchester
BELL, Ronald	London, N.16
CHALLENOR, Alan Keith	Ashfield, N.S.W.
CLIFTON, Frank Ronald	Doncaster
CONLON, James	London, S.W.12
COOK, Robert Rae	Hull, Yorks
COPESTICK, Leslie Bennett	New Malden, Surrey
DHARKAR, Krishnarao Ramrao	Burhanpur, India
DORMEHL, William John	South Africa
DUNN, John Harvey	Glasgow
ETTER, Alwyn Charles	Dartford
EVE, Godfrey Arnold	London, N.8
FERREIRA, Tobie Muller	Port Elizabeth
FISHER, Walter Augustus	London, W.9
FLUSKEY, Richard Daniel	Eire
FARRAR, George Henry	Bradford
GRIGGS, John Edward	Wallington, Surrey
GRIFFITHS, Noel Arthur	London, N.6
GRISS, Arthur Augustus	St. Helens, Lancs.
GOULDSTONE, Paul	Northampton
HENDERSON, Norman	Bishop Auckland
HODGSON, John	Middlesbrough
HOLMES, Peter William	Seven Kings, Essex
HORNER, William Beswick	Whatton, Notts.
HOUSDEN, John Richard George	London, W.9
HOWARD, John Henry, B.Sc.	Great Yarmouth
JAYATILAKE, Cyril	Ceylon
KERSLAND, Norman Olan	Auckland
LAURISTON, Harold Graham	Cardiff
LEES, Andrew Christie	Chester
LENNOK, Stanley Conyers, B.Sc.	Gateshead
LE ROY, Jaques Cyril	Mauritius
MAIN, John Robb	Maidstone
MATHEWS, Vincent Victor	Singapore
McDONNELL, William	Dublin
MELLOR, Jim	Dover
MOORE, Bernard	Bristol
NEVE, Arthur Rupert	Devonport
NEVILL, Francis William	St. Albans
NISSIM, Moshe	Palestine
PANJACHARAM, Thampoo	Singapore
PANTON, Victor Alphonso	London, W.1
PERT, Eric, Flt./Lt.	Southsea
PEARSON, James Frank	Brigg, Lincs.
PHILLIPS, Maurice Marcus	Ashford, Middlesex
POWER, John Desmond O'Neill	Cardiff
PRYCE, Francois Devlin	Stratford-on-Avon
RAMAGE, Frank Archibald	London, E.11
RAMAN, S., M.A., B.Sc.	Madras
RAWLE, Frank	Bishop Auckland
ROGERS, David Walter William	Birmingham
RUNDELL, John Trethowan	Orpington
RUSHALL, Stanley John	Rugby
RUSHTON, Arthur	Manchester
RUSSELL, Alexander	Glasgow
SIAL, Jagdish Parshad, B.A.	New Delhi
SIMPSON, John Wilson	Glasgow
SPINK, Charles Herbert	London, W.5
SPINK, Joseph Albert	Accrington, Lancs.
SKIRROW, James Adam	Sydney, N.S.W.
STEWART, Edward Samuel	New Zealand
TELFER, James C. W.	Glasgow
VADGAMA, Gulab Maganlal	London
VAN-HORNE, Peter Morrison	St. Albans
WIFFEN, Montagu Arthur	Opapa, N.Z.
WILSON, Edmund Thomas Patrick	Dublin
WRIGHT, Kenneth	Hoylake, Cheshire
XAVIER, Basilio Eugenio Alvares	Hong Kong
YOUNG, Lester Harold	London, N.10

ADDITIONAL NOTICES

Graduateship Examination, May 1947

This is the last list of Overseas Candidates and completes the results of the Graduateship Examination held in May 1947.

Twenty-five candidates appeared for examination throughout all Overseas Centres.

The following candidate has passed Parts 1, 2 and 3

MEDBURY, Robert Colin — Perth, Western Australia

The following candidate has passed Part 1 only

PEATFIELD, John Albert (S) — Sydney, N.S.W.

The following candidate has passed Parts 2 and 3

COOK, John Arthur (S) — Perth, Western Australia

The first Pass-list of the November Examination will be published as soon as available.

E.C.M.E. Broadcast

Elsewhere in this issue there is news of Council's award to Mr. J. A. Sargrove (Member) for his Paper "New Methods of Radio Production," which was first read before the London Section in February of this year.

This new conception of receiver manufacture, E.C.M.E. as it is called, has aroused a good deal of interest in many countries, and subsequent to the London presentation of the Paper, Mr. Sargrove was honoured by an invitation to read the Paper before the Société des Radioélectriciens in Paris.

More recently, the B.B.C. engineers visited the Sargrove laboratories at Walton-on-Thames and made recorded impressions of E.C.M.E. in action. These recordings were included in the B.B.C.'s " Science Magazine " programme on December 4th, 1947, and broadcast on the 1,796 and 267 metre wavelengths, as well as on the shortwave programmes to Western Europe, Scandinavia and Finland.

Programme of Section Meetings

Details of all Section Meeting arrangements are almost complete and will shortly be published in booklet form.

This programme will be circulated to all grades of the Institution's membership and anyone who does not receive a copy during the next week or two, should notify the Publications Officer.

The task of obtaining and selecting suitable Papers for reading before the various Sections is by no means a light one and the Programmes and Papers Committee, enthusiastic though its members are, cannot make progress without the help and co-operation from all members.

The Committee, which is now engaged in arranging details for the 1948–49 Session, make an earnest appeal for contributions of Papers so that *before* the commencement of the new Session details of all Section meetings can be circulated.

Graduateship Examination, May 1948

The next Graduateship Examination will be held on May 20th and 21st, 1948, at the usual centres. The latest date for receipt of entry forms from candidates who wish to appear at centres in the British Isles is March 31st, and the latest date for receipt of entries from candidates overseas has now passed.

A certain number of past examination papers are available from the offices of the Institution at 2s. 6d. per set or 3s. 0d. for two sets, post free. All papers from 1942 to 1947 inclusive are available, except November 1943 and November 1946, which are now out of print.

Membership and Examination Regulations

The 11th edition of the Membership and Examination Regulations of the Institution has now been published. This edition, which conforms in size with the Journal, contains much up-to-date information, including the revised scale of examination fees and the provision that Students shall in future have passed the Engineering Joint Examination Board's Common Preliminary Examination before registration as Student Members.

Copies of the Regulations may be obtained on application to the London Office of the Institution.

Graduateship Examination, November 1947.

The examination was held at nine centres in the British Isles and at 17 overseas. At the time of going to press, complete attendance returns are not available, but it is expected that 150 candidates attended. This figure shows an increase on previous examinations.

Apprenticeship Schemes

The Institution has received an increasing number of enquiries from Students who wish to obtain employment in Radio Engineering under a trainee scheme with opportunity for study. These requests come largely from overseas and ex-service men who feel that they are too old to start a normal apprenticeship.

The Institution hopes shortly to contact many firms and companies, both small and large, with the object of placing these Students. Meanwhile, the General Secretary will be pleased to receive details of any existing trainee or apprenticeship schemes.

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The British Institution of Radio Engineers

(Founded in 1925. Incorporated in 1932.)

REGULATIONS GOVERNING EXAMINATIONS.

(Revised June, 1947)

Candidates are requested to note carefully the following instructions.

1. Answer books, ink, blotting paper and log tables will be supplied at the examination, but each Candidate should provide himself with a pen and a ruler. Slide rules may be brought to the examination.

2. Candidates must keep a note of their number, which **must** be on the front page of each answer book used.

The Name of the Candidate must NOT appear anywhere on the Examination Papers, either on the headings or in the answers to the questions.

3. The Presiding Officer shall have power to discontinue the examination of any Candidate who may misconduct himself.

4. No Candidate will be allowed to communicate with, receive assistance from or copy from the paper of another. If this rule is infringed, the name of the person will be struck off the list of Candidates.

5. Candidates must **not** retain **any printed or manuscript paper or book** during the examination and must leave same with Presiding Officer before the hour of commencement of the examination. Any Candidate infringing this rule or consulting any printed or manuscript paper or book during his examination will be disqualified.

6. Each Candidate must write his answers legibly and must commence **each answer on a fresh page headed by his examination number and the number of the question.** Rough calculations (if any) should be carefully crossed out. No part of any paper is to be torn off. Scrap paper will **not** be allowed.

7. **Candidates' examination work must show evidence of a good general education. Marks may be deducted for defective writing, spelling, composition or grammar.**

8. After the examination has commenced no Candidate is to leave the room (without permission) until he has handed in his answers to the Presiding Officer. Any Candidate who leaves the room without permission will not be allowed to return.

9. When the Presiding Officer has declared the period allowed for examination over, Candidates must immediately cease writing.

10. Candidates may retain the question papers, except when requested to return them by the Presiding Officer.

11. The cost of the examination at all centres is defrayed by the British Institution of Radio Engineers.

12. Each Candidate will be informed by post, usually within two months of the date of the examination, whether he has passed or failed. No other information will be given.

13. Terms and symbols in examination answers should comply with the British Standard 204 : 1943 and British Standard 530 : 1937. The latter is out of print, but there is a copy in the Institution's Library.

14. Smoking will not be permitted in the Examination Room.

The British Institution of Radio Engineers

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GRADUATESHIP EXAMINATION—15th MAY, 1947

FIRST SESSION

Heat, Light and Sound

10 a.m.—11.30 a.m.

Examiner—W. T. PRATT, B.Sc., A.C.G.I., D.I.C., A.M.I.E.E.

Candidates are required to answer TWO Questions ONLY from each of Sections A, B and C, making six in all.

SECTION A (Heat)

1.

Find the volume of the bulb of a thermometer tube such that a rise in temperature of 1°C. causes the mercury to rise 2 mm. up the stem, the diameter of the latter being 0.2 mm. Coefficient of real expansion=0.000181 per °C.; Coefficient of linear expansion of glass=0.000009 per °C.

2.

A piece of metal is heated to 40°C. and placed in a dry cavity in a large block of ice at 0°C and covered with a second block of ice. It is found that 60 g. of water are formed. The metal is then quickly dried and transferred, without gaining heat in the process, to a calorimeter of water equivalent 9.5 g. containing 200 g. of water at 50°C. The final temperature of the mixture is 32°C. Determine the latent heat of fusion of ice and the water equivalent of the metal.

3.

A vessel containing liquid at its boiling point, and suitably jacketed to prevent heat losses, is stirred by a motor-driven stirrer using 0.1 h.p. If 250 g. are evaporated in 1 hour, what is the latent heat of vaporisation of the liquid ?

(1 h.p.$=7.5\times10^9$ ergs per sec.; $J=4.2\times10^7$ ergs per calorie.)

SECTION B (Light)

4.

A small glowing electric lamp is set up in two positions in turn on the axis of a spherical concave mirror whose radius of curvature is 12 in. The first position is 4 in. and the second is 20 in. from the mirror. Find the magnification in each case and describe the characteristics of the image.

5.

A converging lens of focal length 15 cm. is placed 25 cm. from an object 3 cm. high. What is the size of the image and what is its nature and position ? If the lens is replaced by a diverging one of 15 cm. focal length, where will the image be and what will be its size ?

Heat, Light and Sound—*continued*

6.

Enumerate the apparatus required to obtain a pure spectrum, and show how it should be arranged. Describe very briefly the spectra obtained when the source of light used is (*a*) an electric lamp, (*b*) daylight, (*c*) a bunsen burner with salt in it.

SECTION C (Sound)

7.

An observer standing by the side of a railway line watches the approach of a train as it leaves the tunnel. He hears the whistle (apparent frequency=576 c/s.). Immediately after he hears the echo from the hill through which the train has passed. The note seems to be considerably lower. Explain this and calculate the true frequency of the note, and also that of the echo, assuming the train moved at 60 m.p.h. and the velocity of sound is 1,100 feet per sec.

8.

What are the causes of " pitch " and " quality " of a musical note ? Two 4 ft. organ pipes. one closed at one end and the other open at both ends are sounded on a day when the speed of sound in air is 1,120 ft. per sec. Calculate the frequency of the fundamental note in each case,

9.

How are echoes produced ? An observer at a certain distance from a cliff notices that the interval between the sound he makes and its echo is 3 sec. He then walks 550 ft. nearer to the cliff and finds that the corresponding interval is 2 sec. Calculate (*a*) the velocity of sound, (*b*) the observer's original distance from the cliff.

The British Institution of Radio Engineers

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GRADUATESHIP EXAMINATION—15th MAY, 1947

FIRST SESSION

Electricity and Magnetism

11.30 a.m.—1 p.m.

Examiner—C. STOKES, B.Sc., A.M.I.E.E., A.M.Brit.I.R.E.

Candidates are required to answer FIVE questions only.

1.

The moving coil of a loudspeaker has 120 turns of $1\frac{1}{2}$ ins. mean diameter. The flux density of the magnetic field in the gap is 10,000 lines per sq. cm.

(*a*) Calculate the axial force produced by a current of 1 ampere in the moving coil.

(*b*) If the coil is moving with a velocity of 100 cm/sec., calculate the E.M.F. induced in it.

2.

State the laws of electrolysis and define the term "electrochemical equivalent."

An accumulator, although fully charged, is left connected to the charger and is gassing freely due to a current of 10 amperes passing through it. Calculate the weight of oxygen and hydrogen evolved in one hour.

Electrochemical equivalent of hydrogen = .00001045 g/coulomb.
Chemical equivalent of hydrogen = 1.008.
Chemical equivalent of oxygen = 8.

3.

Given that Joule's equivalent is 4.18 joules/calorie :—

(*a*) Calculate the amount of heat in Centigrade heat units produced by the dissipation of 1 kilowatt-hour.

(*b*) Calculate the flow of cooling water required, in gallons/minute, for a transmitting valve dissipating 50 kW if the water enters at 20°C. and leaves at 65°C.

1 lb. = 453.6g.

4.

Give a diagram of the Weston Standard Cell showing the construction, naming the materials used, stating the value of E.M.F. (with temperature correction, if possible) and indicating the polarity of its terminals.

5.

Explain the difference between E.M.F. and P.D. Calculate the internal resistance and E.M.F. of a source of electrical energy which gives 2 amperes at 6 volts or 10 amperes at 5.5 volts.

Electricity and Magnetism—continued

6.

Define the " inductance " of a coil.

A coil of 1,000 turns of negligible resistance produces a flux of 50,000 lines when a current of 2 amperes flows through it.

What is its inductance in henrys ?

If a steady p.d. of 10 volts is suddenly applied to this coil, what is the rate of rise of current?

7.

Compare briefly the magnetic properties of soft iron, high permeability alloy, and permanent magnet materials in relation to their uses in radio apparatus.

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GRADUATESHIP EXAMINATION—15th MAY, 1947

SECOND SESSION

Radio Technology

2.30 p.m.—5.30 p.m.

Examiner—G. A. TAYLOR, A.M.I.E.E., A.M.Brit.I.R.E.

Candidates are required to answer SIX questions only.

1.

A potential of 100 volts alternating at a frequency of 10 kc/s is applied to a circuit containing an inductance of 200 μH and a resistance of 10 ohms. Calculate—

(*a*) the current flowing in the circuit,

(*b*) the angle of lag.

Vectors and curves (not necessarily to scale) should be used in illustration.

2.

Explain what is meant by the term "depth of modulation." Show, by diagrams, how the carrier wave of a valve generator can be modulated by speech currents. How can the depth of modulation be measured?

3.

What is the difference between constant-K and m-derived filters? Discuss the main features of each, and, in the case of the latter, show that "m" can not exceed unity.

4.

Describe, with sketches, the meaning of "secondary emission" in a valve. Discuss any advantages or disadvantages of this characteristic.

5.

A triode valve has an anode characteristic resistance of 18,000 ohms and an amplification factor of 16. A non-inductive resistance of 50,000 ohms is connected in the anode circuit. If a p.d. of 1 volt is applied between the grid and the cathode, calculate the value of the p.d. developed across the resistance.

6.

Draw a diagram of a cathode ray tube and describe how the brilliance and focus of the tube may be controlled. What forms of distortion are likely to occur and how are these caused?

7.

Describe with circuit diagrams a Moullin voltmeter. If such an instrument is required to be calibrated to read say 0 to 1 volt at a frequency of approximately 500 kc/s, describe a satisfactory method of calibration.

Radio Technology—continued

8.

A circuit has inductance of 2,200 μH, and is tuned to resonance by a capacitance of 220 pF. The series resistance of the circuit is 2.5 ohms, and a resistance of 0.5 Megohm is connected across it. Calculate the effective " Q " and dynamic resistance of the circuit.

9.

Draw curves showing the growth and decay of current in a circuit containing inductance and resistance only when a steady voltage is applied. Discuss the term " time constant " as applied to such a circuit and state any general deductions which may be made.

In a circuit for which $L=1$ henry and $R=200$ ohms, what percentage of the final value of current is reached when a steady voltage has been applied for a period of 0.01 second ?

The British Institution of Radio Engineers

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GRADUATESHIP EXAMINATION—16th MAY, 1947

THIRD SESSION

Radio Engineering

10 a.m.—1 p.m.

Examiner—E. T. A. RAPSON, M.Sc., D.I.C., A.C.G.I., M.Brit.I.R.E., A.M.I.E.E.

Candidates are required to answer SIX questions.

1.

State the conditions for oscillation in a tuned-grid triode oscillator. In such a generator, the resistance and capacitance of the tuned circuit are 24 ohms and 0.8 microfarad respectively: if the mutual conductance of the triode is 3.5 mA per volt, calculate the mutual inductance necessary to maintain oscillations. Prove the formula used.

2.

Describe, with the aid of a circuit diagram, one system of amplitude modulation. The R.M.S. value of a radio-frequency voltage before modulation by an audio-frequency signal is 50 V and after modulation it is 57.5 V. Calculate from first principles the percentage modulation. Determine also the power in each side band expressed as a percentage of the carrier power.

3.

Explain the meaning of "skin effect" and "proximity effect" in conductors and show how they influence the distribution of current in the conductor of a radio-frequency coil. Discuss the significance of these effects in the design of coils (*a*) for receivers and (*b*) for transmitters.

4.

The distributed inductance of an open-wire transmission line is 14.4 mH per mile and its distributed capacitance is 0.04 microfarad per mile. Calculate the characteristic impedance of the line. Determine a suitable value for the ratio of conductor spacing to radius of a quarter-wave line to match this transmission line to a load of 400 ohms.

5.

A triode, employed as a cathode follower, has an amplification factor of 40 and a mutual conductance of 4 mA per volt. If the cathode resistance is 10 kilohms, calculate (*a*) the voltage amplification of the stage and (*b*) the output impedance.

Radio Engineering—*continued*

6.

Explain the theory of electronic mixing in a frequency-changing circuit. Describe the action of such a system as employed in a modern super-heterodyne receiver; draw a circuit diagram and explain the functions of all the components.

7.

Enumerate the advantages and disadvantages of negative feed-back amplification. The overall gain of a feed-back amplifier is 37.5 db; feed-back is provided by a potential divider of ratio 80 to 1. Calculate the gain of the amplifier without feed-back.

8.

Explain the purpose of automatic frequency control in a super-heterodyne receiver. Give a circuit diagram and explain the action of one such system.

9.

A rectangular frame aerial having 20 turns is 100 cm. high and 75 cm. wide. It is placed with its plane vertical and at an angle of 30° to the direction of a transmitter, the field strength of which is 10 mV per metre at 300 kc/s. If the resistance of the frame is 3 ohms and its inductance is 1 mH, calculate from first principles the P.D. across the terminals of the tuning capacitor at resonance.

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GRADUATESHIP EXAMINATION—16th MAY, 1947

FOURTH SESSION

Radio Reception (Receiver design and practice)

2.30 p.m.—5.30 p.m.

Examiner—E. E. ZEPLER, Ph.D., M.Brit.I.R.E.

Candidates are required to answer FIVE questions only.

1.

Sketch the circuit diagram of a grid leak detector with variable retroaction, working at 10 Mc/s, and explain all the functions of the valve. Give the approximate values of the components used and estimate roughly the audio frequency amplitude produced at the anode of the valve, if a 30% modulated signal of 1 millivolt amplitude is induced in the grid circuit.

2.

A power output stage with pentode in Class A is to be designed. The following data is available; the anode impedance R_a and the mutual conductance g_m of the valve, the H.T. E_a, the anode current i_a of the pentode with zero bias, and the speech coil impedance R_L. State which of the data given influences the choice of the output transformer.

If $E_a=300$ volts, $i_a(V_g=0)=80$ milliamperes, $R_a=50{,}000$ ohms, $g_m=5$ milliamperes per volt and $R_L=4$ ohms, estimate the optimum turns ratio of the output transformer and justify your conclusion.

3.

The transfer ratio of a signal from the aerial to the grid of the input valve of a receiver working with automatic gain control is found to decrease with increasing signal. The causes are stated to be mistuning of the first circuit and feedback. How do you explain the effect and how would you proceed to find and remove them ?

4.

Give design details for a Radio Frequency amplifying stage for a frequency of 45 Mc/s. If the bandwidth is to be 2 Mc/s give approximate values to all the essential components and plot stage gain against frequency for the relevant frequency range.

5.

Draw the circuit diagram and describe the action of a vibrator working (*a*) with an additional, (*b*) without an additional vacuum rectifier. Give values to the filter components and justify them.

Radio Reception (Receiver design and practice)—*continued.*

6.

State the fundamental principles involved in (*a*) electrostatic and (*b*) magnetic screening. Describe the methods used at audio and radio frequencies and give reasons for differences (if any). How would you expect intermittent contacts of the lids of screening cans to affect the screening ?

7.

What is understood by signal to noise ratio ? Two receivers are submitted to comparison tests and the following facts are found :—

(*a*) The signal to noise ratios are equal on an outdoor aerial, and independent of the strength of the signal.

(*b*) The signal to noise ratios differ, if a signal generator is used as a radio frequency source.

Explain the effects and comment on the possible designs of the receivers.

8.

What is understood by " tracking " in a superheterodyne receiver and how is it achieved in practice ? Illustrate your explanation by a numerical example. Perfect tracking is by no means expected and knowledge of any of the relevant formulae is therefore not required.

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GRADUATESHIP EXAMINATION—16th MAY, 1947

FOURTH SESSION

Radio Transmission

2.30 p.m.—5.30 p.m.

Examiner—J. W. WHITEHEAD, B.Sc., M.I.E.E., M.Brit.I.R.E., A.Inst.P.

Candidates are required to attempt SIX questions.

1.

Give an account of the principal errors to which a direction finder, using a loop aerial, is liable.

A loop aerial, consisting of 10 turns on a circular former of diameter 1 metre, is tuned by a variable condenser to a transmitter radiating on a wavelength of 500 metres. With the aerial oriented for maximum signal, the voltage developed across the tuning condenser at resonance is found to be 500 mV peak. If the resonance value of the tuning condenser is 300 pF and the r.f. resistance of the loop is 3 ohms, calculate the field strength at the loop.

2.

Derive an expression for the characteristic impedance of an open twin-wire radio transmission line in terms of inductance and capacitance per unit length of line.

Describe a method of matching such a line to the centre of a horizontal half-wave dipole.

3.

Describe any one type of frequency-stabilised master oscillator.

4.

Distinguish between the " phase " and " group " velocities of radio waves propagated through the ionosphere.

5.

Describe any method by which the degree of distortion generated within an audio frequency amplifier may be measured.

Radio Transmission—continued

6.

The equivalent electrical circuit of a quartz crystal (neglecting resistance) is shown in Figure 1.

Assuming that resonance occurs in this circuit when the impedance between X and Y is a maximum, deduce the resonant angular frequency when :—

$L = 169$ H, $C_1 = 0.1$ pF. $C_2 = 10$ pF.

If the crystal is connected between grid and filament of a certain valve, the effect on C_2 is an increase to 20 pF. Calculate the change in the resonant angular frequency.

What is the practical significance of the result ?

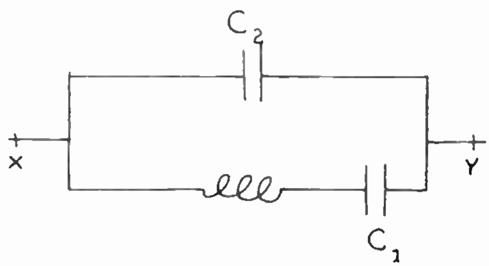

FIG. 1

7.

Design from first principles a single section T-type attenuator which will produce an attenuation of 15 db. The input and output impedances are to be 600 ohms.

8.

Give a reasoned account of the advantages at high frequencies of " inverted " (i.e., grounded grid) amplifiers as compared with conventional amplifiers.

9.

Explain, with the aid of a circuit diagram, a method of frequency modulating a carrier wave Enumerate the advantages of this method of frequency modulation.

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GRADUATESHIP EXAMINATION—16th MAY, 1947

FOURTH SESSION

Television

2.30 p.m.—5.30 p.m.

Examiner—T. B. TOMLINSON, B.Sc.(Hons.), Assoc.Brit.I.R.E.

Candidates are required to answer FOUR questions only.

1.

(*a*) The received image of an Alexandra Palace transmission takes the form of a linear gradation from black on the left-hand side of the picture to peak white on the right-hand side, with the exception of a narrow band or strip of peak white intensity in the centre. Describe, with the aid of diagrams, the waveform of the video signal in the region of two consecutive frame synchronising pulses.

(*b*) Explain fully what is meant by positive and negative modulation. What are the relative advantages and disadvantages of the two systems ?

2.

State the principles of electrostatic and electromagnetic deflection as applied to cathode ray tubes. A cathode ray tube using an anode voltage of 1,000 has its screen at a distance of 30 cm. from the anode. Evaluate from first principles the maximum deflection of the spot which may be caused by the earth's field if the tube is placed with its axis vertical ? ($H=0.18$, $e/m=1.77\times10^7$ e.m.u. per g.)

3.

Contrast and compare the following types of wide band amplifier circuits for use in the intermediate frequency stages of a superheterodyne type of receiver ; (*a*) Single tuned circuits, (*b*) "Stagger" tuned circuits, (*c*) Coupled circuits.

A pentode valve of mutual conductance g_m is used as a simple tuned anode amplifier. Derive an expression for the gain of the stage at the resonant frequency in terms of g_m, B, and C, where C is the total tuning capacity. The band width B is defined as the difference between the two frequencies at which the response is $\frac{1}{\sqrt{2}}$ times the response at the resonant frequency.

4.

Describe in detail any one complete synch. separator and subsequent pulse shaping circuits designed to synchronise both line and frame scanning oscillators in which thyratrons are used. Give a complete diagram including the scanning oscillator circuits, suggesting suitable values for all components.

What precautions are taken to prevent :—(*a*) Image signal modulation affecting the line synchronism ? (*b*) Incomplete interlace ? (*c*) Irregular destriking of the thyratron in the line scanning oscillator circuit ?

Television—*continued*

5.

Write **short notes** on :—

(*a*) Factors influencing the choice of the intermediate frequency of a superheterodyne receiver.

(*b*) The coupling of the aerial to the input tuned circuit of a vision receiver.

(*c*) Single and double sideband reception.

(*d*) D.C. restoration.

(*e*) Interference due to automobile ignition systems.

6.

Describe in principle and detail :—

(*a*) The photo-electric effect and its application to the " Emitron " camera.

(*b*) The super-sonic light valve.

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GRADUATESHIP EXAMINATION—16th MAY, 1947

FOURTH SESSION

Audio Frequency Engineering

2.30 p.m.—5.30 p.m.

Examiner—H. BRENNAN, B.Sc., M.Brit.I.R.E.

Candidates are required to answer FIVE questions.

1.

Give experimental illustrations to distinguish between the propagation of sound waves and actual motion of matter. Discuss the range and sensitivity of the human ear and explain why the ear is able to distinguish the character of a sound.

2.

Explain the terms :—Amplitude of Vibration, Oscillatory Velocity, Oscillatory Pressure. Explain how these measurements are related to one another and to the Intensity in energy units in the case of a sound wave in air.

State the relationship between the Intensity and Loudness of sound, explaining clearly how the loudness of a sound at any frequency and level is calculated.

3.

Calculate the maximum dimensions and discuss the most suitable shape and the most suitable surface structure of a room in which a person could just satisfactorily address a full audience without sound reinforcement. Base your calculations on the average level of speech, and a noise level of 40 db above the threshold of audibility. Deal fully with the dominant factor involved in enhancing the aural results.

4.

An auditorium has been fitted with a sound reinforcing system and is subject to undesirable echoes, reflections, and interference. State the tests necessary to determine the cause of these disturbances, and the measures to be adopted to reduce them ; (*a*) by modifications to the superficial structure, and (*b*) by the improved selection and disposition of the sound reinforcing apparatus.

5.

Discuss any three of the following:—Electro-acoustic Transducer, Attenuation Equalizer, Characteristic Impedance, Variable Density Recording, Class B Amplifier, Sensitometer.

6.

Describe the operation and design of high and low frequency exponential horn loudspeakers suitable for cinemas, with particular reference to the frequency range dividing network, and the matching of the mechanical impedance of the diaphragms with air loading.

Audio Frequency Engineering—continued

7.

The output stage of an audio-frequency amplifier is designed to work into an impedance of 150 Ohms. Show how to make the most efficient coupling between this amplifier and ten loudspeakers; the impedance of each speech coil is 7.5 Ohms and each is fitted with a transformer having ratios 15/1, 20/1, 25/1.

8.

Describe the method and the apparatus required to determine the intensity level of noise by an objective method.

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GRADUATESHIP EXAMINATION—16th MAY, 1947

FOURTH SESSION

Valve Manufacture and Technology

2.30 p.m.—5.30 p.m.

Examiner—J. TEMPLETON, B.Sc.(Hons.)

Candidates are expected to attempt THREE questions from Section "A" and TWO questions from Section "B."

SECTION "A"

1.

Describe briefly the process of thermionic emission and state Richardson's Law.

Describe (*a*) ... ... Schottky Effect
(*b*) ... ... "Shot" Effect
(*c*) ... ... Field Emission

2.

Describe what is meant by "secondary emission." Draw, with an appropriate explanation, characteristics of a screened-grid valve to illustrate the effect of secondary emission.

State two further examples where secondary emission occurs in vacuum tubes and describe briefly the effects produced.

3.

Define Peak Inverse Voltage of a rectifying valve. Give a typical characteristic of this voltage against condensed mercury temperature for a hot-cathode mercury vapour rectifier. Discuss other factors which affect this voltage and show how the Arc Voltage depends upon the condensed mercury temperature.

4.

Describe with the aid of diagrams, the construction and operation of :—

(*a*) A Mercury Vapour Diffusion Pump
(*b*) A Fractionating Two-Stage Oil Diffusion Pump.

Compare the characteristics of mercury and oil as pump fluids.

5.

Describe the meaning of the terms (*a*) a getter ; (*b*) dispersal gettering ; (*c*) contact gettering. What important characteristics must be considered when selecting the material for a getter ?

Give an example of a getter, and its performance, in one of the following (*a*) receiving valve ; (*b*) mercury vapour valve ; (*c*) high temperature transmitting valve.

Valve Manufacture and Technology—*continued*

6.

Define clearly the term "vapour pressure."

Describe briefly, and illustrate with one example for each, one advantage and one disadvantage of (*a*) High Vapour pressure and (*b*) Low Vapour pressure in vacuum work.

What is meant by a "virtual leak" in a vacuum system and state how it can be avoided?

SECTION "B"

7.

Describe briefly, with the aid of a diagram, the construction and operation of the short form of McLeod Gauge with square law scale.

What precautions must be observed when installing and using a McLeod Gauge, especially in order to obtain accurate results?

A McLeod Gauge has a bulb and closed capillary of volume 250 cc. The weight of 84 mm. length of mercury in the capillary is 0.52 g. Obtain the calibration, as distances from the end of the closed capillary, for pressures of 10^{-5}, 10^{-4}, 10^{-3} and 10^{-2} mm. Hg. Density of mercury—13.6 g. per cc.

8.

Describe, with the aid of diagrams, the operation of a rotary multi-head sealing machine for sealing assembled radio valve feet into glass bulbs.

Indicate the general principles of firesetting and the types of flame used.

9.

Specify all the important properties of metals that have to be considered when the metal is used in a vacuum tube.

Name three metals which are commonly used in vacuum tubes and describe the factory pre-treatment before assembly for each example. Also state clearly for what purpose each metal will be used in your examples.

10.

Define the terms "Fluorescence" and "Phosphorescence."

Describe fully one method for processing a clean cathode ray tube in preparation for sealing.

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GRADUATESHIP EXAMINATION—16th MAY, 1947

FOURTH SESSION

Radio Measurements

2.30 p.m.—5.30 p.m.

Examiner—S. R. WILKINS, M.Brit.I.R.E.

Candidates are required to answer FOUR questions.

1.

A tuning coil resonates at 1,000 kc/s with a capacitance of 250 pF whilst when the capacity is reduced to 50 pF its resonant frequency is 2,000 kc/s. With the injected signal held constant at 1,000 kc/s the voltage developed at resonance is 10V. r.m.s. and with the condenser retuned to 247 pF the voltage drops to 7V. r.m.s.

Determine (*a*) The self capacitance of the coil.
(*b*) The true inductance of the coil.
(*c*) The Q of the coil.

2.

Write a short essay on the design of radio frequency wavemeters for the range 150—1,000 Mc/s.

3.

Indicate by drawing a circuit diagram and quoting the balance condition in each case the relationship that exists between the Wien bridge and its equivalent parallel T circuit. Show how the latter can form the basis of a stable audio oscillator.

4.

Describe the method and apparatus necessary for obtaining the axial acoustic frequency response of a loudspeaker. What other tests will be necessary to give a complete picture of the acoustic performance of the loudspeaker ?

5.

Describe fully two of the following :—

(*a*) The magnetic crack detector.
(*b*) The " Bedford-Puckle " hard valve time base.
(*c*) The cathode ray tube as a bridge balance indicator.

6.

A beat-frequency oscillator has a true cathode follower output stage employing a valve with a mutual conductance of 5 mA/V. What is the output load into which the valve will deliver maximum power ?

Give design details for the insertion of a three stage T attenuator so that the power output into this load can be reduced by a maximum of 30 db.

GRADUATESHIP EXAMINATION.

Persons eligible for Examination. Only the following may enter for the Examination: –

(*a*) Candidates who are prospectively or actively engaged in radio or allied engineering and who can produce satisfactory evidence as to this and also as to general education and character.

(*b*) Students of the Institution whose subscriptions for the current year have been paid.

(*c*) Candidates who have lodged with the Secretary in London a duly completed proposal form P for election as Graduate, Associate, Associate Member or Member.

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The British Institution of Radio Engineers

(FOUNDED IN 1925 - INCORPORATED IN 1932)

The following details of the arrangements made for the 1947 Radio Convention are given for the general information of the Institution's members.

Programme Details

for

RADIO CONVENTION

to be held at the

Tollard Royal Hotel,

Bournemouth

May 19th to May 23rd, 1947

Further and detailed arrangements will be given to all members who are attending the Convention. Members who have not reserved accommodation through the Institution but who wish to attend any of the meetings, visits, luncheons or dinner, should notify the Institution as quickly as possible. Telephone enquiries during the period of the Convention should be made at Bournemouth 6671 (Information Room).

Owing to paper restrictions, it is regretted that only members who are actually attending the Convention meetings can be supplied with preprints.

(Supplement to the March-April, 1947, issue of the Institution's Journal)

Tuesday *May 20th,* 1947

Morning Session

A Paper by

A.M.
9.45

Professor H. M. BARLOW, Ph.D., B.Sc.(Eng).

"THE EXPLOITATION OF MICRO-WAVES FOR TRUNK WAVE-GUIDE MULTI-CHANNEL COMMUNICATIONS"

Summary :

The problem of employing a wave-guide to carry a modulated micro-wave as a vehicle for multi-channel communications is examined on the basis of technique now available. It is shown that by a suitable choice of frequency and wave mode in a cylindrical copper guide a scheme can be devised which should give some thousands of independent channels over a single tube. Moreover, there are possibilities of using the guide simultaneously for electric power transmission. Methods of construction to provide a flexible wave-guide, effects of ellipticity of the guide, elimination of unwanted modes of propagation, the generation and modulation of the ultra-high frequency carrier, are all considered as some of the more important specific problems. The conclusion is reached that exploitation of the wave-guide for this purpose is well worth pursuing.

A Paper by

11.30

H. GUTTON, D.Sc. and J. A. ORTUSI, D.Sc.

"ULTRA HIGH FREQUENCY MODULATION ON WAVE GUIDES"

Summary :

For the transmission of very short signals micro-waves are frequently used. They allow high definition television signals to be transmitted. The transmitters used are velocity modulated tubes ; their efficiency can be considerably improved when using very high Q cavity resonators, but then the modulation bandwidth is reduced.

The device permits the energy fed to the radiator to be modulated by inserting a variable impedance on the wave-guide. The transmitted wave varies with the impedance magnitude ; the reflected wave is absorbed into the output cavity resonators of the transmitter.

The variation of the anode voltage for a full anode or split anode magnetron, when operating with a magnetic field near the value which induces the resonance of the space charge, determines the variation of the impedance.

The modulation applied to the magnetron needs a power of 2 watts. The H.F. losses in the modulator are smaller than 3 watts, and the bandwidth is 12 megacycles.

Some experiments of modulation on 10 cm. wavelength will be presented at the Convention.

Tuesday *May 20th*, 1947

Afternoon Session

P.M.

2.15

A Paper by

D. A. BELL, M.A., B.Sc.

"TELEVISION RECEIVING AERIALS"

Summary :

The object of this paper is to present to the practical engineer methods for measuring and matching aerial impedances at television frequencies. It is usually necessary to have a length of feeder between aerial and impedance-measuring equipment, and the paper describes the practical use of two forms of circle-diagram, polar and cartesian, which facilitate the evaluation of the impedance at the far end of a transmission line in terms of the impedance measured at the near end. Various sources of error, and the relevant corrections and practical precautions, are discussed. Impedance transformers, balance to unbalance converters, and wide-band stub systems are also examined.

3.45

A Paper by

H. PAUL WILLIAMS Ph.D., B.Sc.

"THE DEVELOPMENT OF THE BROADCAST ANTENNA"

Summary :

The main requirements of a medium wave broadcast antenna are that its efficiency should be high, that most of the radiation should be directed along the ground and that radiation at a certain angle from the vertical should be a minimum. It is shown that an efficiency of over 90% can be obtained with a good earth system. A detailed discussion is given of the various factors which determine the fade-free radius. In some cases it is advantageous to use a directive system employing two or more radiators—it is convenient to use a calculating machine for determining such arrangements.

A future possibility is the use of deep trenches instead of the present high masts. These would have the advantage of presenting no obstruction to low-flying aircraft.

8.15

A Paper by

Commander (L) J. D. M. ROBINSON, R.N. and E. V. D. GLAZIER, Ph.D., B.Sc.

"INTERNATIONAL AUTOMATIC TELEGRAPH NETWORKS"

Summary :

The paper describes the developments in Automatic Telegraph Networks technique made by the fighting services of this country and of the U.S.A. It also analyses the problem raised by the United States proposal accepted in principle by the Bermuda Telecommunication Conference, 1945, for the establishment of an international automatic telegraph network. The extent to which various technical standards must be agreed by all participants is discussed, and consideration is given particularly to the message storage inter-circuit technique pioneered by the U.S. fighting services.

The section presented by Dr. Glazier deals with the integration of land-line and radio transmission techniques and discusses the problems presented by the requirements for radio channels—particularly in the case of mobile units such as ships, vehicles and aircraft.

The paper includes a demonstration of the apparatus.

Wednesday *May 21st*, 1947

Morning Session

A Paper by

A.M.
9.45

W. J. O'BRIEN

" RADIO NAVIGATOR AIDS "

(*including the Decca Navigator*).

Summary :

A general discussion of radio navigational aids is first given with an analysis of the geometry of plotting, and a review of the better known methods of generating directional patterns. The methods of determining system accuracy are given and the factors determining the choice of a navigational system are analysed. The latter part of the paper deals with the Decca Navigational System, giving the principles of operation, a detailed description of the construction and operation of the receiving and ground station equipment, a discussion of the instrumental accuracy and an analysis of the problems relating to interference, static, changing conditions of signal propagation and system ambiguities.

Supplementary to this paper is the demonstration on the Decca Radio Ship off Bournemouth (see visits, page 7).

A Paper by

11.30

CAPTAIN V. A. M. HUNT, B.A.(Cantab.), A.F.R.Ae.S.

"THE FUNCTIONAL REQUIREMENTS OF RADIO AIDS TO CIVIL AVIATION"

Summary :

This paper treats the subject of Radio Aids to Civil Aviation from the viewpoint of the crew and operator. For the sake of clarity, the subject has been divided into Communications, Long Distance Navigation, Short Distance Navigation, Auxiliary Navigation Aids, Landing Aids and Collision Avoidance. Each of these sections has been taken in turn through the procedure outlined below.

The paper first sets out the ideal Functional Requirements for a particular service. Secondly, it describes how these requirements have been modified for the benefit of designers. Thirdly, it demonstrates how the P.I.C.A.O. Special Radio Technical Division at Montreal tackled the question of international standardization. Finally, it concludes with some notes on possible trends for future development.

For details of visits to B.O.A.C., Hurn and Poole and S.R.D.E. (Christchurch), please see page seven,

Wednesday *May 21st, 1947*

Afternoon Session

P.M.
2.15

A Paper by

G. H. LEVERSEDGE, M.I.R.S.E.

" THE PROBLEMS OF RADIO COMMUNICATION WITH MOVING TRAINS "

Summary :

Some success in communication between moving trains and fixed points was obtained as early as 1886, but until the advent of electronic methods, the high attenuation of the transmission link did not admit of practical results.

Two methods of transmission have been successfully developed, one using inductive couplings to rails and wayside line wires, and the other space radio. The relative advantages and disadvantages of the two systems are discussed. Particulars of the applications at present under discussion by British Railways and possible future uses are given.

The conditions under which equipment will be used and the requirements it is desirable to incorporate in the design of the apparatus are covered from the Railway Engineer's point of view.

Some experiments carried out in this country and abroad are described and their implications discussed.

Applications of electronic engineering for other railway purposes are briefly stated.

3.45

A Paper by

J. B. LOVELL FOOT

" A ONE KW. V.H.F. FREQUENCY MODULATED TRANSMITTER "

Summary :

The Paper outlines the salient features of a V.H.F. transmitter for broadcast use.

After stating the requirements of the equipment a description of the mechanical arrangement is given. The transmitter is physically divided into three parts : (1) The Power Unit. (2) The Driver Unit. (3) The Power Amplifier Unit.

A description of the main electrical features is then given which include : Sections on : The automatic centre frequency control circuit, and a modulation monitor with provision for accurate calibration.

Finally, the Power Amplifier is outlined and details of a satisfactory dummy load included.

8.0

A Paper by

W. S. BARRELL and G. F. DUTTON Ph.D., D.I.C.

" HIGH FIDELITY RECORDING AND REPRODUCTION "

Summary :

The desiderata of high fidelity recording are discussed and the necessity for factors other than the simple extension of the frequency range considered. Dynamic range, signal-to-noise ratio and such-like factors are dealt with. The full audible frequency range and a possible " acceptable range " are considered from the point of view of practical considerations and limitations. The paper includes a summary of the apparatus.

Thursday *May 22nd,* 1947

Morning Session

A.M.

9.30

A Paper by

G. L. HAMBURGER
(Member)

"AN AUTOMATIC RESPONSE CURVE TRACER FOR AUDIO FREQUENCIES"

Summary :

The apparatus was designed for the specific purpose of the measurement of the audio frequency response between input and output of lines. The principle of the apparatus obviates the necessity of ganging between the automatic sweep—B.F.O. at the sending end and the Automatic Response Curve Tracer at the receiving end, so that no synchronism by means of a pilot line is necessary. Naturally, the apparatus is equally suitable for rapid response measurements in the laboratory of filters, amplifiers, loudspeakers, etc. It is entirely automatic in its operation, i.e., the pressing of a button produces the calibrated response within a few seconds.

The response is produced on a long afterglow screen of a cathode ray tube complete with a raster of rectangular co-ordinates. The vertical co-ordinates denote octaves of frequency, and the horizontal co-ordinates 3 db. steps ; both sets of co-ordinates are in themselves equally spaced. The response curve is this plotted against a double logarithmic raster covering a range of 40 to 10,000 c/s and 40db. The raster calibration of the response curve is inherently correct and not subject to otherwise inevitable drifts in the apparatus.

A Paper by

F. C. F. PHILLIPS

11.30 "A DIRECT-READING FREQUENCY MEASURING SET"

Summary :

The principle employed in this equipment is, in the first stage, to heterodyne the signal with a known frequency derived from a source of standard frequency and to indicate a digit which is the first figure in the value of the signal frequency. The beat frequency from the first stage is passed to the second stage where it is heterodyned again with a lower standard frequency and the second digit indicated. This process is continued until the final stage is reached. The final stage is a deflectional type of frequency meter which indicates the remaining figures in the signal frequency value.

The Paper will therefore describe the problems involved in devising a system of the above kind and their solution so that an unambiguous reading of the signal frequency is obtained without thought on the part of the operator.

SOCIAL ACTIVITIES

In addition to the technical programme, special social facilities for the ladies are being arranged by a Ladies Committee and Thursday evening will be set aside for the Convention Dinner and Dance.

Thursday **Afternoon Session** *May 22nd*, 1947

P.M.

2.15

A Paper by

R. KOMPFNER, Dipl. Ing.

"THE KLYSTRON AS R.F. AMPLIFIER AT CENTIMETRIC WAVELENGTHS"

Summary :

This paper will examine the mechanism of amplification in the Klystron, from the point of view of a sensitive amplifier at centimetric wavelengths. A detailed study is made of the sources of noise which contribute to the overall noise appearing at the output of the valve. A proposed method of reducing the noise by balancing two distinct sources of noise against each other is critically examined. Some experiments on the shot noise appearing in long electron beams are described.

3.45

A Paper by

A. H. ALDOUS, B.Sc., D.I.C.

"TRANSMITTING VALVES FOR COMMUNICATION ON SHORT WAVELENGTHS"

Summary :

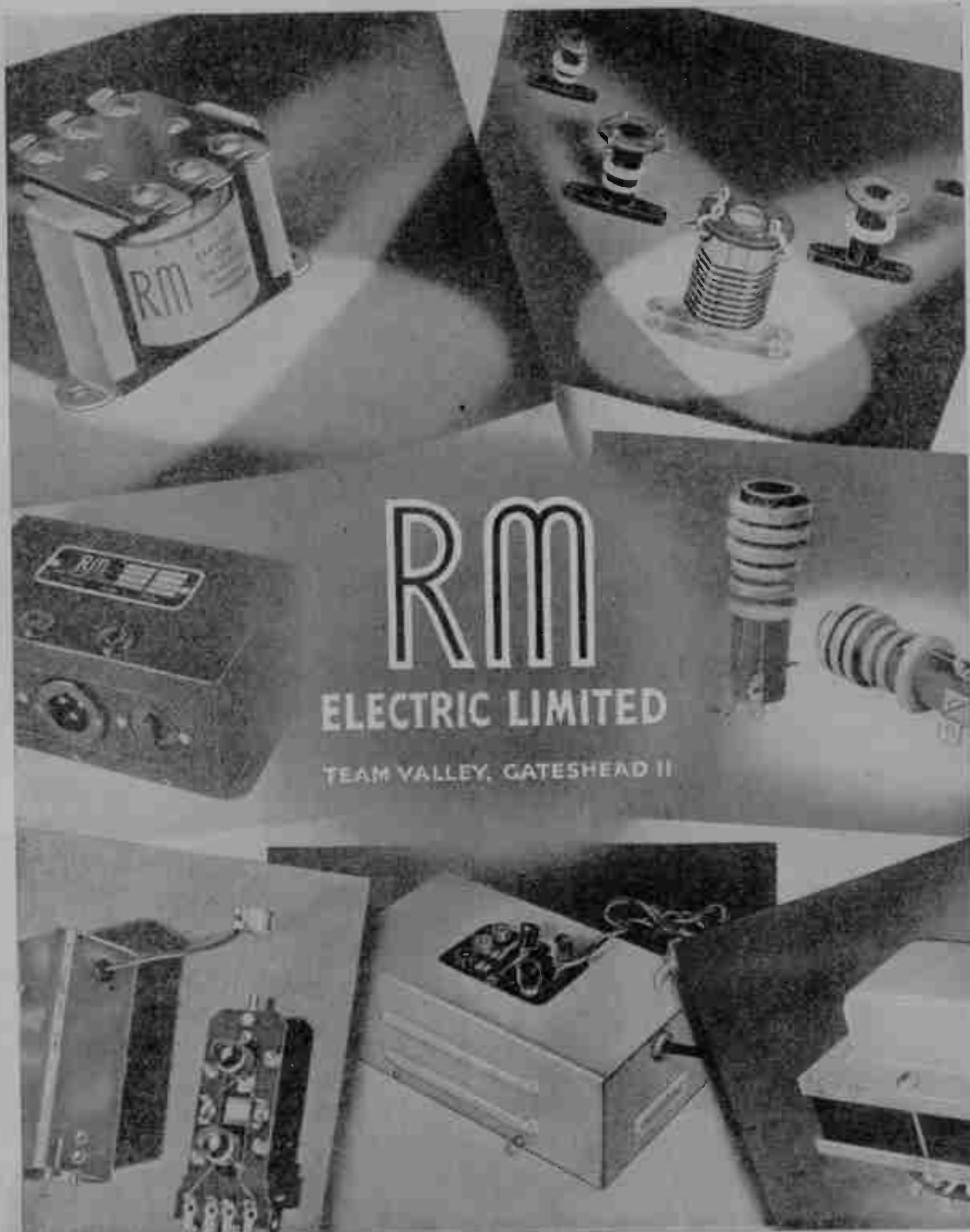
A review is made of the requirements and properties of communication systems as affecting the choice of valves to be used as oscillators and amplifiers. The various types of valve suitable for use on short wavelengths are discussed from the point of view of these requirements.

This is followed by a description of the constructional features and performance of some of the more recently developed C.W. triodes. Finally, a short dicussion is given of the requirements of valves to be used as modulators for the various types of modulation.

VISITS TO TECHNICAL ESTABLISHMENTS

The arrangements for visits to technical establishments include the following :

Leaving Hotel at		*Place of visit*
	TUESDAY, MAY 20th.	
10.30 a.m.	One party to	Decca Navigator Ship
2.15 p.m.	One party to	Decca Navigator Ship
2.15 p.m.	One party to	B.O.A.C., Hurn
4.00 p.m.	One party to	Decca Navigator Ship
	WEDNESDAY, MAY 21st.	
10.30 a.m.	One party to	Decca Navigator Ship
2.15 p.m.	One party to	Decca Navigator Ship
2.15 p.m.	One party to	H.M.S. *Collingwood*
2.15 p.m.	One party to	B.O.A.C., Hurn
4.00 p.m.	One party to	Decca Navigator Ship
	THURSDAY, MAY 22nd.	
10.00 a.m.	One party to	Decca Navigator Ship
2.15 p.m.	One party to	Decca Navigator Ship
2.15 p.m.	One party to	S.R.D.E.
2.15 p.m.	One party to	B.O.A.C., Poole
4.00 p.m.	One party to	Decca Navigator Ship



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