JOURNAL OF

The British Institution of Radio Engineers

(FOUNDED IN 1925–INCORPORATED IN 1932)

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

Vol. VII (New Series) No. 4 JULY-AUGUST 1947

NOTICE OF THE TWENTY-SECOND ANNUAL GENERAL MEETING

NOTICE IS HEREBY GIVEN that the TWENTY-SECOND ANNUAL GENERAL MEETING (the Fourteenth since the Incorporation) of the Institution will be held on THURSDAY, OCTOBER 9th, 1947, at 6 p.m., at the London School of Hygiene and Tropical Medicine, Keppel Street (Gower Street), London, W.C.1.

AGENDA

1. **To confirm the Minutes of the Annual General Meeting held on September 25th, 1946.** (Reported on pages 169-171 of Volume VI (New Series) of the Journal dated September-November, 1946).
2. **To receive the Annual Report of the General Council** (presented on pages 126-135 of this Journal).
3. **To elect the President.**

   The Council is unanimous in recommending the re-election of Admiral the Viscount Mountbatten of Burma, K.G., G.C.V.O., K.C.B., D.S.O., A.D.C., LL.D., P.C., as President of the Institution for the year 1947/48.
4. **To elect the Vice-Presidents of the Institution.**

   The Council unanimously recommends the re-election of:

   Air Vice-Marshal R. S. Aitken, C.B., C.B.E., M.C., A.F.C.
   Leslie H. Bedford, O.B.E., M.A., B.Sc.
   James Robinson, M.B.E., Ph.D., D.Sc.
   Paul Adorian.
5. **To elect the General Council.**

   The retiring members of the Council are:

   Sir Ernest Fisk (Honorary Member).
   Colonel J. D. Parker, M.B.E., B.Sc. (Hons.) (Member)
   G. A. V. Sowter, Ph.D. (Member).
   E. Cattanes (Member).
   W. W. Smith, B.Sc.(Hons.) (Member).
   G. A. Taylor (Associate Member).

   Air Commodore W. C. Cooper, C.B.E., M.A. (Member), has retired for business reasons.

   In accordance with Article 32, the Council has nominated:

   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)

   Hons. Treasurer: S. R. Chapman, M.Sc. (Member).

   Any member who wishes to nominate a member or members for election to the Council must deliver such nomination in writing to the Secretary, together with the written consent of such person or persons, to accept office, if elected, not later than September 15th, 1947. Such nomination must be supported by not less than 10 corporate members.
6. **To receive the Auditors' Report, Accounts and Balance Sheets for the year ended March 31st, 1947.**

   The Accounts for the General and other Funds of the Institution are given on pages 136 to 139 of this Journal.
7. **To appoint Auditors.**

   Council recommends the re-appointment of Messrs. Gladstone, Titley & Co., 74, Victoria Street, S.W.1.
8. **To appoint Solicitors.**

   Messrs. Braund & Hill, 6, Grays Inn Square, London, W.C,1., are recommended for re-election as Solicitors.
9. **Awards to prize winners.**
10. **Any other business.** (*Notice of any other business must reach the Secretary 40 days before the meeting.*)

Members unable to attend the Annual General Meeting are urged to appoint a proxy.

The British Institution of Radio Engineers

(FOUNDED IN 1925 – INCORPORATED IN 1932)

21st ANNUAL REPORT OF THE COUNCIL OF THE INSTITUTION

This report covers the twelve months ended March 31st, 1947. As announced on page 125, the Annual General Meeting will be held on October 9th, 1947.

INTRODUCTION

The report covers the first full year of activity since the end of World War II. The year has been one of intense and increasing activity along the broad lines of policy on which the Council has been working for some years. Members will notice in this report sections which appear for the first time and which mark an addition to the Institution's previous work. The degree to which the Council has been able to carry out the post-war programme has been very much hindered by external difficulties, but the Council is satisfied that very substantial progress has been made towards the immediate objectives of the Institution.

Among the problems during the past year have been difficulties of securing adequate staff for the Institution, extending Section activities, and a considerable all-round increase in costs. The extra work resulting from developments undertaken by the Council has outstripped the size of the staff and it has been almost impossible to secure the additional personnel thought necessary.

It is pleasing, therefore, to note the continued growth of the membership, side by side with the widening of the Institution's activities. The most outstanding event of the year was, of course, the honour conferred on the Institution by the Patronage of His Majesty the King, and appropriately announced on the occasion of the 21st Anniversary of the foundation of the Institution. The anniversary was celebrated by a dinner in London in October 1946, attended by many distinguished men of science and the Government, including the President of the Royal Society. A full report of the proceedings was given in the December 1946 Journal.

During the year, Admiral the Viscount Mountbatten of Burma was installed as President of the Institution and the Council takes this opportunity of expressing thanks and appreciation for the way in which the President has given counsel in the affairs of the Institution. Prior to his appointment as Viceroy of India, the President attended several meetings of the Council and many of the constructive suggestions made at those meetings will be developed during the ensuing 12 months.

Not covered by this report is the very successful Radio Convention held in Bournemouth in May 1947, which will be reviewed in the next annual report. Obviously, however, the work of planning and arranging the Convention had to be done during the year under review and the success of the Convention gives every promise that the larger Convention to be organized by the Institution in 1950 should be even more successful in a year when world conditions should be more settled.

Once again, the Council wishes to thank those members of the Standing and Section Committees without whose diligent work it would have been impossible to have achieved so much. The Council also expresses appreciation for the guidance of Air Vice-Marshal R. S. Aitken, C.B., who, during the absence abroad of Admiral The Viscount Mountbatten of Burma, has undertaken the duties of Acting-President.

The practice of dividing the annual report into the sections covered by the activities of the Standing Committees has the general approval of the membership, and is retained this year.

Professional Purposes Committee

In order to avoid repetition, reference is made to the last annual report which gave the terms of reference of this Committee. Much of the Committee's work during the past twelve months has been concerned with examining the activities of the other Standing and Local Section Committees, and otherwise co-operating with the Charter Committee, comprising Sir Louis Sterling (Chairman), Mr. Leslie McMichael (Immediate Past President), Dr. James Robinson (Vice-President) and Mr. W. E. Miller (Chairman of Council).

In the last annual report, a suggestion was made that the number of members serving on Council might be extended to include also the Chairmen of Local Sections. A conference of the Chairmen and Secretaries of Local Sections was, therefore, held on November 1st, 1946; plans were then discussed for revising the present constitution of Section Committees and in particular, arranging to cover the whole of Great Britain by forming sub-sections, where appropriate, to cover those areas which do not, for geographical reasons, come within the activity of a main Section.

If this is done, then representation on the General Council will be afforded by the automatic election to the Council of the Chairmen of the main Sections, and by agreement between the main and sub-sections, representation arranged on other Committees, in particular, the Papers Committee. Obviously, the selection of programmes is not merely a local, but a national matter of concern to the Institution and greater variety and interchange of papers in the Sections could be afforded by an extension of the personnel of the Papers Committee along the lines recommended.

The conference also served the very useful purpose of enabling those responsible for the local administration of the Institution's affairs to interchange ideas with the officers and staff of the Institution. The day's deliberations covered a wide range of subjects, from the administration and effects of the new rules of election and examinations, to the matter of a Royal Charter and the type and standard of lectures the Institution should provide. Not the least of the valuable aspects of the meeting was the constructive criticism the Local Secretaries were able to make of the general working of the Membership and Papers Committees.

In accordance with the points discussed at the Section conference, the Professional Purposes Committee is now drafting recommendations to be contained in a pamphlet of "Rules governing the formation and working of Local Sections." This will be reviewed at a further conference of Sections to be held this autumn.

The development of all Sections will finally entail a financial arrangement and this is the subject of comment in the report of the Finance Committee. In general, it is the aim of the Council to give all Section Committees complete responsibility for the programme of meetings arranged in each area, to provide for the representation of the Sections on Council, and on some Committees, and later, to enable those Committees to take a greater part in the general work of the main Membership Committee.

World Engineering Conference

During the year, the Institution was invited to attend the International Technical Congress held in Paris in September 1946 which was convened by the World Engineering Conference. The Congress has now been established as a permanent body under the title "The World Engineering Conference" with a small permanent secretariat and offices in Paris.. This body has world-wide support as indicated by the countries represented by national delegations: Great Britain, U.S.A., France, China, Canada, India, Switzerland, Belgium, Norway, Sweden, Denmark, Czechoslovakia, Poland, Greece and Egypt. National sections are being set up in each participating country and the British Section is already at work. As the Council of the Institution has always encouraged the principle of securing international co-operation, it has been decided to assist in the work of the Conference. The Institution is therefore subscribing to the British Committee and will also appoint Brit.I.R.E. members, where required, to the Committees of the Conference.

It was interesting to note that at the recent Paris conference, the presence of an official observer from the United Nations Educational Scientific and Cultural Organization foreshadowed the direct relationships which the Congress, or some organization arising from it, will have with this body. This is a matter of great interest to all professional Institutions. One of the main purposes of existence of such bodies is to institute and maintain qualifications which shall be the recognized standards in their own sphere of activity. The very considerable differences which exist in this respect in various countries cause difficulties in equating the services of technicians and professional men. It is becoming increasingly important to the smooth economic running of the world that such differences should be eliminated as far as possible. Standards and methods of training in other countries stimulate our own thoughts and ensure our capability to be in the vanguard of progress.

Coming within the sphere of international relationship, although not primarily concerned with the work of the World Engineering Conference, has been the strengthening of the connections established in previous years with the Société des Radioélectriciens. A regular interchange of Journals and other technical information has been arranged and officers and the secretary of the Société have visited the Institution during the year. The Council wishes to thank the officers of the Société for their great help in contributing to the arrangements made for the 1947 Convention held in Bournemouth.

Institution membership overseas

International relationship is obviously strengthened by the increase of the Institution's membership overseas.

Coupled with the complete coverage of Great Britain by Sections or Sub-Sections, is the consideration which must be given to the formation of Sections overseas, and particularly throughout the British Commonwealth, where the Institution's membership is growing. The Committee had correspondence with a number of active members in New Zealand, and as a result of the recommendation made, Council has approved the formation of Sections in New Zealand, one centred in Wellington and the other in Auckland. The arrangements now made should ensure that during 1948 these two overseas Sections will be functioning on the same lines as the Sections in Great Britain. With the experience gained by the willing co-operation of New Zealand members it is hoped to be able to extend the scheme of forming overseas Sections, and in this connection the Committee is already discussing proposals with members in South Africa.

It is of importance to note that in making these arrangements overseas, considerable work has to be done through the Education and Membership Committees, for the qualifications required for membership are, of course, precisely the same abroad as they are at home, and the Institution's regulations governing membership apply to all applicants irrespective of their location. In these matters, it is of the greatest importance to develop even further the excellent understanding which has already been made with the Australian Institution of Radio Engineers, whose scheme of examination now corresponds to the Brit.I.R.E. Graduateship examination syllabus, although there are certain differences in the qualifications required for election to the various grades of membership. During the year, the Committee has had many opportunities of meeting Australian I.R.E. members visiting this country and, through them, suggestions have been made to the Council of the Aust.I.R.E. upon which the Committee hopes to comment further in the next annual report.

Co-operation with other Institutions

Finally, it must be recognized that although primarily qualified and interested in one or even two branches of applied science, the average engineer has a more than passing interest in the development of other branches of applied science. This emphasizes the need for co-operation between engineering bodies, which has been stressed in previous annual reports. By co-operating in the matter of arranging meetings which do not clash, and issuing a programme covering all activities of interest to the engineer, excellent work has been done by such organizations as the Manchester Federation of Scientific Societies and the Scottish Association of Technical Secretaries, and the Institution is represented on and subscribes to both these organizations.

Membership Committee

The year under review has been crucial for industry and the many complexities encountered have not been conducive to that normal condition which encourages membership; moreover, this has been the first full year in which the Committee has operated under the revised Articles governing membership. As stated in the last annual report, it is the Council's opinion that at this stage of the science, it is undesirable to increase further the standard or conditions of membership. Notwithstanding the increased requirements for election however, the figures for the year under review show that increases in membership have been as high as ever before—a demonstration of development which is most gratifying, having regard to unsettled conditions.

Membership has always been confined to those who have qualified either by passing the Institution's Graduateship Examination, or certain exempting examinations, or who, by virtue of their research or other qualifications are worthy of membership. Before attaining corporate membership, an applicant must also give evidence that he is regularly engaged in a *responsible* technical capacity in the radio and electronic field.

With the exception of candidates who have secured transfers from Studentship to a higher grade of membership because of examination success, the table of proposals for transfer shows a decrease in applications accepted. As forecast in the last annual report, there is a reduction in the number of Studentship proposals and due, no doubt, to the further requirements specified in the revised Articles, there is an increase in the number of proposals for all grades of membership which the Committee has refused.

Overseas Membership

The enquiries received from applicants throughout the Commonwealth and foreign countries have been greater than ever before in the Institution's history. Overseas membership is gradually being increased, but there is no doubt a great desire overseas for autonomy. In almost every foreign country there is a society or institution which, in a broad way, operates for its nationals in much the same way as the Brit.I.R.E. does in England, and to a

PROPOSALS FOR ELECTION 1946-47

	Members	Associate Members	Associates	Companions	Graduates	Students	TOTAL
Received	18	119	155	2	10	251	555
Accepted	7	52	135	2	4	249	449

PROPOSALS FOR TRANSFER 1946-47

	A.M. to M.	Assoc. to A.M.	Grad. to A.M.	Grad. to Assoc.	Student to A.M.	Student to Assoc.	Student to Comp.	Comp. to M.	Student to Grad.	TOTAL
Received	7	36	1	2	15	46	1	2	11	121
Accepted	5	10	1	1	1	41	Nil	1	11	71

REMOVALS DUE TO RESIGNATIONS, EXPULSIONS OR DEATHS 1946-47

Member	Associate Members	Associates	Graduates	Students	TOTAL
1	8	10	2	130	151

lesser degree throughout the Commonwealth. As membership develops throughout the Empire, therefore, it is the Council's aim to establish Sections of the Institution in the countries concerned. Within the framework of having the same membership qualifications, it is hoped to see those Sections develop that freedom and power of action in the best interests of the local membership, whilst at all times acting in accord with the Institution proper.

Membership increase

In connection with the table published on page 129, it will be seen that it is now proposed to publish each year, not only a summary of proposals for election and transfer, but also a summary of removals from the membership registers. Some of these are due to resignations and deaths, but a large number of cases have been caused by members failing to keep in touch with the Institution, due, no doubt, to unnotified changes of address. In order to obtain an effective membership, however, the Council has agreed with the Committee that Article 60 must be rigidly enforced, otherwise the table of membership cannot be regarded as a proper and effective membership figure. Undoubtedly, many of the members removed from the registers will in time apply for reinstatement, and in future a separate table will be included to show the number of reinstatements in any one year.

Year Book

It is regretted that, owing to the scarcity of paper and other difficulties, it has not been possible to publish a year book during the last twelve months. Every effort is being made towards publication in 1948, since enquiries show that the Year Book is not only of great reference value to members at home and overseas, but also to Government and public bodies.

Education and Examinations Committee

Once again the year's work has centred on the Graduateship Examination. During 1946, the number of candidates who sat for the examination was 223. In all, only 71 candidates or 32 per cent. of the total, qualified for graduateship or higher grade membership. Of the candidates who wrote part only of the examination 48 per cent. were successful in all the papers they attempted, whilst 29 per cent. of the total number of candidates did not satisfy the examiners on any paper.

The prizes for the year 1946/47 have been awarded as follows :—

President's Prize :

Henry HIPPLE, of Liverpool.

Mountbatten Medal :

Henry HIPPLE, of Liverpool.

S. R. Walker Prize :

Alfred Walter WOODS, of Cape Town, South Africa.

Measurements Prize :

Edward Hall HIGHAM, of Sale, Cheshire.

With continued first-hand experience of seeing the work of students, the Committee again emphasizes the great lack of proper facilities available for those who wish to make a thorough study of radio engineering. That opinion does not dispute the fact that because of necessary economy in national manpower, early engineering training has to be of a general character. This and the claims of National Service delay specialized training which should nevertheless commence not later than the third year of a national certificate course. This report does not permit of more detailed comment, but the Council feels that the Committee's efforts to co-operate in general schemes of engineering training should have been utilized to a far greater extent. Members are aware of the meeting arranged by the Ministry of Education some two years ago and of the views which have been exchanged with other institutions who have similar interests to the expressed aims and objects of the Brit.I.R.E.

The Council is still anxious to co-operate in any scheme which will be in the best interests of advancing radio science, provided that such schemes do not disregard the importance of radio engineering as a distinct profession. Common ground has been established in the preliminary stage of an engineer's training by the Institution's co-operation in the work of the Engineering Joint Examination Board ; success in the Board's preliminary examination, or exemption therefrom on the various grounds recognized by the Board, has now been adopted *in toto* as a necessary requirement for registration as a student member of the Institution.

Examination Centres

Once again, thanks are due to many universities, technical colleges and education authorities throughout the world and also to the Admiralty, the War Office and the Air Ministry for continuing to provide invigilation and accommodation facilities for students sitting the Institution's examinations.

Examination Exemption

The number of applicants who on special grounds* claimed whole or part exemption from the Graduateship Examination totalled 97 and the Committee granted exemption as follows :—

Complete Exemption	Exemption from Parts 1, 2 and 3	Exemption from Parts 1 and 2	Exemption from Part 1	Exemption Wholly Refused
12	16	33	21	15

The above summary is given as an indication that, especially from overseas candidates, the Committee will give every consideration to a proposal which has reasonable grounds for exemption, even though the candidate may not be able wholly to comply with the list of exemptions published in the regulations. Indeed, the Committee now feels that the overall list of examinations recognized for exemption should be revised, having regard to the availability, especially overseas, of specialized training schemes for radio engineers.

Studentship Registration

Since the end of hostilities, Council has felt that some form of preliminary examination should be reintroduced which would more specifically govern the registration of student members than is at present implied in the Articles. In November 1946, it was therefore resolved to advise The Engineering Joint Examination Board that the Council would accept success in the examination of the Board as constituting the necessary technical evidence for the registration of student members. Moreover, it is obviously necessary to recognize the implication of the new Education Act which makes it unlikely that a student could commence specialized technical education before 17 years of age and in the opinion of the Council this should now be the minimum age for registration of student members. It is proposed, therefore, to convene an extraordinary general meeting and to ask the membership to approve the revision of Article 12 which governs the registration of student members.

*That is, on grounds not specified in the Regulations governing exemption.

City and Guilds of London Institute

The Institution continues to be represented on the City and Guilds of London Institute Advisory Committees for Telecommunications and Radio Service Work.

In the last annual report, reference was made to the new scheme of City and Guilds Examination in Telecommunications and this arrangement has now been approved and fuller details are available in City and Guilds pamphlet No. 50. In its effect on the Graduateship Examination, the Committee feels that exemption from the Institution's graduateship examination, based on the new telecommunications examination scheme, should be granted to candidates successful in Radio 2 and 3, plus Telecommunications Principles 2, 3 and 4, provided always that first-class passes are obtained in Radio 3 and Telecommunications Principles 4.

New examination scheme

These changes have come at a time when the Committee has been carefully considering a new graduateship examination syllabus, which it is hoped will be brought into operation with the November 1948 sitting. Among proposals before the Committee are the inclusion of mathematics as a compulsory subject, and the combination of the two sections of the existing Part 1 into a single physics paper. Minor changes have been made in the present syllabus to make the examination more searching and more extensive in scope and the names of papers in Parts 2 and 3 brought more into line with the subject matter. These minor changes will be published in full in the 11th edition of the membership and examination regulations, now in course of preparation.

Radio Trades Examination Board

In addition to being represented on the Board and on all the various committees, the Institution has continued to provide secretarial and other facilities for the Board.

In the period under review, new regulations and a revised syllabus were drawn up by the Board in consultation with the City and Guilds of London Institute Advisory Committee on Radio Service Work. This followed an agreement made in March 1946 whereby the written part of the Servicing examination would in future be conducted by the City and Guilds of London Institute (Department of Technology) and the practical tests arranged and conducted by the Board.

Under this new joint scheme, there are two types of certificate; the first is awarded to those candidates who succeed in the examination and whose practical training has been approved by the Board. The second certificate is awarded to candidates who, in addition to passing the examination, have regularly attended an approved technical course as well as having had experience in radio service work. Considerable time had to be devoted to preparing the way for this new joint scheme and in this connection, there were during the year some 14 meetings. The result has been an increase in the number of applications, and the examination was held in five centres in Great Britain.

The Board continues to be composed of representatives of the Radio and Television Retailers' Association, the Scottish Radio Retailers' Association, the Radio Industry Council and the Institution.

Programme and Papers Committee

The twelve months ended March 31st, 1947, have demanded more than usual activity from those members serving on the Papers Committee. In addition to the responsibility of arranging and co-ordinating details of the London and Provincial Section meetings, almost every meeting of the Committee was dominated by the preliminaries necessary for the 1947 Radio Convention.

The Committee is indebted to the London School of Hygiene and Tropical Medicine for providing accommodation for the London Section meetings, and to the authorities of Neville Hall, Newcastle, the University of Birmingham and the Birmingham Chamber of Commerce, to the Technical College, Coventry, the College of Technology, Manchester, the University College, Southampton, the Institution of Engineers, Glasgow, and the Heriot Watt College, Edinburgh, for placing premises at the disposal of the Institution for the provincial Section meetings.

There were thirty-six meetings held in Great Britain during the period April 1946 to March 1947—nine in London, six in the Midlands, six in Newcastle, seven in Manchester, six divided between Edinburgh and Glasgow, and one each in Southampton and Liverpool. The attendances have continued to keep up to standard with an average of over 100 members at London meetings and well over 60 at provincial Sections. Many of the local Section meetings were attended by the Secretary and during these visits, Section committee meetings were held giving full opportunity to discuss broad issues affecting the development and activity of the Institution.

The projected extension of the Institution's activities by the inauguration of other provincial Sections in the near future, e.g. Merseyside and Yorkshire, will, of course, place added reponsibilities on the Committee, but with the help and co-operation of all members in these areas, there is no doubt that these new ventures will be successful.

During the twelve months under review the proceedings of the Institution's meetings have been reported freely in the technical, trade and lay press and the Council gave permission for reproduction and translation of papers to be published in French and Russian technical journals. Reciprocal exchange of papers has also been maintained between the Institution and the Australian Institution of Radio Engineers; extracts from and comments on the papers of the Institution have also been published in technical journals in Australia and Canada. More than ever before, therefore, the activities of the Institution and the papers presented before the various sections have had a very wide circulation outside the Institution's Journal, as well as inclusion in world scientific abstracts. Subscriptions to the Journal from non-members throughout the world are now higher than ever before and but for paper restrictions the circulation of the Journal would be some fifty per cent. above the membership figure.

The restrictions on paper for the Journal and other publications have militated against regular production of preprints; the Journal and other publications were further hampered by the fuel crisis which came at what was probably the most vital stage of the Convention preliminaries when all printing and block making came to a standstill for some weeks. Despite these severe handicaps, the Committee was successful in having all but one of the Convention papers preprinted.

Shortage of materials, coupled with the rising circulation, has proved a major obstacle in the enlargement of the Journal, and whilst the Council is anxious that the proceedings should be published monthy, it is regretted that until the Paper Controller permits an increased allocation of paper, the Journal must of necessity remain austere.

Papers

The papers presented during this twelve-month period have been very well received. The field covered has been wide and many of the papers were completely original both in conception and presentation. The examination of manuscripts involves a considerable amount of time and discussion and the Committee's decisions on whether a particular paper should be read and/or published are not lightly made. Criticisms involving the modification of original manuscripts have, in the main, been well received by contributors and the Committee again wishes to thank the many members and others who have contributed to the Institution's proceedings and thereby made possible continuation of section meetings.

A noticeable trend in recent months has been the submission of theses by younger members. These are especially welcome since often they present the young idea in new and interesting ways and the Committee, in consultation with a panel of readers, welcomes the opportunity to assist, where possible, the young author who is able to make a valuable contribution to the proceedings.

The growth of the Institution creates an increasing need for papers suitable for reading before sections and/or publication in the Journal. As evidenced by the reports of other institutions at home and overseas, the continuous problem of securing papers is not peculiar to any one institution. The Committee emphasizes the great need for everyone to honour his membership and further the objects of the Institution by submitting, whenever possible, a contribution which would be of benefit to all radio engineers. This co-operation is obviously essential in order to secure dissemination of knowledge, and as a result of this appeal it is hoped that sufficient papers will be forthcoming to cater for further sections of the Institution.

1950 *Convention*

The Committee especially appeals for assistance from the entire membership to help with arranging the next convention, which will be even more international in character than the one just held. Arrangements are already in hand for participation in the Convention and contributions from engineers all over the world; in order that the British contribution may be creditable, suggestions from members are welcomed as to possible subjects and authors, visits and other arrangements and particularly, actual offers of papers.

Technical Committee

The Committee has been mainly concerned with the drafting of a report on " The development and utilization of miniature radio equipment." Mr. J. L. Thompson succeeded Mr. P. Adorian as Chairman of the Committee and during the year members of the Committee visited, by arrangement with the Chief Superintendent, the Ministry of Supply Establishments at Malvern and Christchurch.

Visits to these establishments have been most helpful to the Committee in incorporating a large volume of information in the report which it is hoped to publish during the next few months.

The Committee has also discussed the subject matter of further reports which might be considered as suitable topics for general discussion meetings of the Institution. In particular, the Committee has discussed the installation of television receivers (on which standards might be established), the development of radio diathermy equipment, power rectification and improved methods of electronic control. The preparation of the reports published by the Institution would be considerably helped by the appointment of additional Institution staff and, in particular, the Committee has recommended the appointment of a Technical Officer.

During the year, the Committee was consulted by the British Gliding Association regarding the work of that Association's Research Committee on radio aids. The Institution also continues to be represented on the following technical committees of the British Standards Institution :

EL/23, Wireless Apparatus ; EL/32 Radio Interference ; EL/49 Electronic Valves and EL/95 Radio Nomenclature.

There is obviously a real need for greater co-ordination in the profession in the publication of reports dealing with the development of radio science. Possibly, that stage may not be reached until complete agreement on other matters has been obtained, but the Committee continues to give co-operation wherever possible.

Finance Committee

As the accounts show, considerably higher expenditure in a number of directions has been necessitated during the year by further progress of the Council's post-war policy for expanding the work and raising the status of the Institution. The expansion of section activities and the greater cost of last year's special meetings, caused a considerable increase in expenses of members' meetings. A comparison of the expenditure account of previous years with the accounts published on page 137 clearly indicates the difficulty of keeping pace with rising costs, against which the margin of excess income carried forward from last year has been unavailing.

On the other side, revenue has been more than maintained and, in particular, the subscriptions from members once more show an increase. The growth in membership of the Institution which accounts for this increase has not, however, been sufficient to meet rising costs. There has also been a considerable decrease in other revenue, particularly in industrial donations.

During the year, the Committee was faced with the need for examining the question of not only maintaining but increasing the services to members—afforded by the employment of additional staff—and the fact that such costs were not being entirely met by the present rate of subscriptions. In December, the Committee urged that, in common with other professional institutions, the Council should examine afresh the subscriptions paid by the various classes of members and the Committee provided figures to show the revenue required if the Institution was to continue to increase membership facilities.

The Council has been most reluctant to place before the membership any proposal to increase subscriptions, but it is obviously essential that such a measure is required. Appreciating that such a step has been dictated by present conditions, the Council has decided to recommend that the increase in subscriptions shall be ***decreased*** by order of the Council, if such a step is found possible in the future. For the moment, however, it is essential that subscriptions be increased and it is hoped that the proposals to be circulated to the membership will be approved at the forthcoming Extraordinary General Meeting.

Should these proposals be accepted, they will not, of course, be effective until the 1st April 1948. Meanwhile, a proposal has been made that there should be a Capital Fund to which members of all grades will be invited to subscribe. If a sufficient sum was raised, the Institution would be able to overcome one of its greatest handicaps—that of lack of capital. In the era of the Institution, taxation has prevented the generosity which enabled many of the older Institutions to build up their reserves and finance many schemes which are so necessary to a professional body and for which a financial return cannot be expected for a few years.

The Finance Committee hopes to be able to place details of such a scheme before the membership at the Annual General Meeting.

Library Committee

The development of library facilities has been greatly assisted during the year by the appointment of a librarian. Book buying remains very difficult, but substantial additions have nevertheless been made. With the appointment of a librarian it will, as soon as paper supply permits, be possible to issue an up-to-date library catalogue. The postal system of borrowing for members has been widely used and several supplementary schemes have been adopted whereby books may be borrowed from other libraries.

The cost of the library has, of course, been maintained by the Louis Sterling Library Fund.

Benevolent Fund

As will be shown from the accounts, requests have been made of the Benevolent Fund. Such grants have not been of the magnitude which the Trustees would have liked owing to the need for conserving the assets. It will be recalled that the Fund was only started a few years ago. Nevertheless, the Trustees have been able to be of great assistance to all the applicants, apart from the actual grants made from the Fund.

It will be seen that there has again been an increase in the subscriptions and donations received from members, but if every member of the Institution subscribed, the Fund would soon be built up to the level which, in the opinion of the Trustees, will be essential in order to administer the Fund in an adequate manner.

It is possible that many members put this matter on one side, intending to deal with it in a less busy moment, and, as so often happens, forget it. The Trustees are anxious to build up a good Fund as soon as possible and, whilst they thank all those members who have subscribed, it is hoped that all other members will become associated with this aspect of the Institution's personal services.

The Trustees especially thank Firms in the Industry who have subscribed to the Fund ; in one case a substantial annual contribution has been made which will enable the Trustees to add to the investments purchased on behalf of the Fund.

Parliamentary Committee

The only work of this Committee has been in connection with representation of the Institution on the Parliamentary and Scientific Committee. That Committee has not been concerned with matters directly affecting the Institution and its members, although during the year the Institution's representatives served on a committee which is drafting a report on present facilities for technical education in Great Britain.

The Parliamentary and Scientific Committee has grown very much in importance and, as previously stated, nearly all the major engineering institutions of Great Britain now subscribe to the work of that Committee. Members of both Houses of Parliament also serve on the Committee.

During the past year, the Parliamentary and Scientific Committee has held receptions in the House of Commons to greet distinguished scientists from overseas and the Institution has always been represented on those occasions.

General

Although every endeavour is made in a report of this kind to acquaint the membership with the work done by Council during the year, it is quite impossible to detail each matter which has been dealt with by Council and the various Committees. The year has been a difficult one and the progress made has been due to the wholehearted co-operation of those members who have so willingly given their time to serving on Committees.

Some indication of the work which has been done is shown by the fact that the Council and Committees of the Institution had a total of 86 meetings during the year—evidence that the status and future progress of the Institution rests confidently upon the work and enthusiasm of the membership.

GENERAL ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1947

EXPENDITURE

	£	s.	d.	£	s.	d.
To Examination Expenses, including Printing of Examination Papers				256	2	1
,, Printing and Publishing of Proceedings, Reports, Regulations and Year Book, *less* Advertising Receipts				538	12	0
,, Salaries and State Insurance ..				3,647	7	0
,, Postage and Telephone				476	5	5
,, Rent, Rates, Light, Heat and Insurance				673	15	4
,, Printing, Stationery and Certificates				409	19	11
,, Secretary's Delegates, and Members' Meetings' Expenses				1,885	1	10
,, To Legal Fees				79	9	2
,, Audit and Accountancy Fees ..				26	5	0
,, Bank Charges and Cheque Books ..				25	3	0
,, Subscriptions to Outside Institutions				50	9	1
,, Repairs to Premises				98	18	3
,, Sundry Expenses				129	3	1
,, Prizes and Awards				16	7	6
,, Depreciation :—						
Office Furniture and Fittings ..	131	17	0			
Library	36	13	7			
				168	10	7
				£8,481	9	3

INCOME

	£	s.	d.
By Subscriptions, including arrears	5,109	19	3
,, Sundry Donations	406	9	6
,, Examination and Exemption Fees	448	1	1
,, Entrance and Transfer Fees	551	10	3
,, Sale of Examination Papers, Reprints and Journal	557	9	2
,, Interest on Investments	10	18	5
,, Radio Trades Examination Board—Secretarial Charges and Expenses Chargeable	76	4	6
,, Balance, being Excess of Expenditure over Income carried to Reserve Account	1,320	17	1
	£8,481	9	3

BALANCE SHEET AS AT 31st MARCH, 1947.

LIABILITIES

	£	s.	d.	£	s.	d.
Sundry Creditors				1,703	1	9
Subscriptions and Examination Fees in Advance				354	10	3
Prize Fund :—						
Balance at 1st April, 1946 ..	9	3	0			
Less Awards during year ..	5	4	0			
				3	19	0
Library Reserve Account				500	0	0
Convention Fund				192	5	0
Bank Overdraft				1,302	3	4
Reserve Account :—						
Balance as at 1st April, 1946 ..	861	15	6			
Less Excess of Expenditure over Income for the Year	1,320	17	1			
Balance per Contra ..	459	1	7			
				£4,055	19	4

ASSETS

	£	s.	d.	£	s.	d.
Office Furniture and Fittings as at 1st April, 1946	958	13	0			
Additions during year	358	4	0			
	1,316	17	0			
Less Depreciation for year ..	131	17	0			
				1,185	0	0
The Louis Sterling Library as at 1st April, 1946	291	2	0			
Additions during year	69	11	7			
	360	13	7			
Less Depreciation for year ..	36	13	7			
				324	0	0
Investments at Cost—£400 3 per cent. Defence Bonds				400	0	0
Stock of Stationery, Journals and Examination Papers at cost				1,002	13	5
Sundry Debtors, including Subscriptions in arrears				672	14	6
Cash in Hand				4	4	2
Cash at Bank, No. 3 Account				8	5	8
Reserve Account as per Contra				459	1	7
				£4,055	19	4

We have audited the above written Balance Sheet dated 31st March, 1947. We have received all the information and explanations which we have required and have satisfied ourselves as to their accuracy. In our opinion the Balance Sheet referred to herein is properly drawn up and contains a full, true and accurate statement of the Institution's affairs according to the best of our judgment on the information and explanations given to us and the facts shown by the books of the Institution.

5th August, 1947.
74 Victoria Street, Westminster, S.W.1.

GLADSTONE TITLEY & CO.,
Chartered Accountants.

Signed { R. STANLEY AITKEN (*Acting President*).
S. R. CHAPMAN (*Treasurer*).
G. D. CLIFFORD (*General Secretary*).

BENEVOLENT FUND

INCOME ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1947

	£	s.	d.		£	s.	d.
To Grants..	60	7	0	By Subscriptions and Donations	366	6	0
,, Balance, being Surplus carried to Reserve Account	342	19	1	,, Interest Received	33	5	1
				,, Income Tax Repayment on Savings Bond Interest	3	15	0
	£403	6	1		£403	6	1

BALANCE SHEET AS AT 31st MARCH, 1947

LIABILITIES	£	s.	d.	£	s.	d.	*ASSETS*	£	s.	d.	£	s.	d.
Reserve Account :—							*Investments at Cost :—*						
Balance as at 1st April, 1946.. ..	1,078	11	8				£100 2½ per cent. Defence Bonds ..	100	0	0			
Add Surplus for Year	342	19	1				£900 3 per cent. Defence Bonds ..	900	0	0			
				1,421	10	9	£100 3 per cent. Savings Bonds ..	100	0	0			
Due to President's Prize Funds				4	16	0	£100 3½ per cent. War Loan	104	0	0			
Due to Dr. Norman Partridge Memorial Fund				3	6	5					1,204	0	0
							Taxation Repayment Claim on Savings Bond Interest, 1946/47					13	6
							Due from General Account				162	0	1
							Cash at Bank				62	19	7
				£1,429	13	2					£1,429	13	2

We have audited the above written Balance Sheet dated 31st March, 1947, in respect of the Benevolent Fund. We have received all the information and explanations we have required, and in our opinion the Balance Sheet represents the true and accurate state of the Benevolent Fund.

5th August, 1947

74 Victoria Street, Westminster, S.W.1.

Signed LESLIE McMICHAEL, LOUIS STERLING *For Trustees*
G. D. CLIFFORD (*Hon. Secretary*)

GLADSTONE TITLEY & CO.,
Chartered Accountants.

THE PRESIDENT'S PRIZE FUND

INCOME ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1947

		£ s. d.			£ s. d.
1947 Mar. 31st	To Balance being Surplus for the Year carried to Reserve Account ..	4 11 5	1947 Mar. 31st	By Interest Received	4 11 5
		£4 11 5			£4 11 5

BALANCE SHEET AS AT 31st MARCH, 1947

LIABILITIES	£ s. d.	£ s. d.	*ASSETS*	£ s. d.	£ s. d.
Reserve Account :—			*Investments* at Cost :—		
As at 1st April, 1946 ..	237 0 6		£200 3 per cent. Savings Bonds	200 0 0	
Add Surplus for Year ..	4 11 5		£50 3 per cent. Defence Bonds	50 0 0	
		241 11 11			250 0 0
Due to General Account ..		13 4 1	*Due from Benevolent Fund* ..		4 16 0
		£254 16 0			£254 16 0

DR. NORMAN PARTRIDGE MEMORIAL FUND

INCOME ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1947

		£ s. d.			£ s. d.
1946 Mar. 31st	To Balance being Surplus for Year carried to Reserve Account	5 10 10	1947 Mar. 31st	By Interest Received	5 10 10
		£5 10 10			£5 10 10

BALANCE SHEET AS AT 31st MARCH, 1947

LIABILITIES	£ s. d.	£ s. d.	*ASSETS*	£ s. d.
Reserve Account as at 1st April, 1946	201 15 7		*Investments* at Cost :—	
Add Surplus for Year ..	5 10 10		£200 3 per cent. Defence Bonds ..	200 0 0
		207 6 5	*Due from Benevolent Fund*	3 6 5
			Due from General Account	4 0 0
		£207 6 5		£207 6 5

We have audited the foregoing Balance Sheets dated 31st March, 1947, in respect of the President's Prize Fund and the Dr. Norman Partridge Memorial Fund. We have received all the information and explanations we have required, and in our opinion the Balance Sheets represent the true and accurate state of the funds.

GLADSTONE TITLEY & CO.,
Chartered Accountants.

5th August, 1947.
74 Victoria Street, Westminster, S.W.1.

Signed { J. W. RIDGEWAY (*Chairman, Finance Committee*)
G. D. CLIFFORD (*General Secretary*)

THE BROADCAST ANTENNA*

by

H. Paul Williams, Ph.D., B.Sc.†

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

Introduction

In the design of transmitters whose operating frequency lies within the broadcasting band of 200-550 kc/s the main aim is to transmit as much of the radiated energy as possible along the ground. The problem is complicated, however, by the existence of reflecting layers in the upper atmosphere—at night-time these layers reflect much of the skywards radiation and thereby cause the amplitude of the received signal to fluctuate greatly at distances between about 100 and 200 km. from the transmitter. These signal strength variations are due to the fact that the rays reflected from the ionosphere are subject to rapid fluctuations in both amplitude and phase, with the result that the signal given by the combined sky wave and ground wave may have any instantaneous value from zero to several times that of the ground wave component only.

For stations having a radiated power of less than, say, 5 kW. the limitations caused by fading are not important since, in any case, the ground wave is too weak to give first-class reception at the distances where fading normally occurs ; but for stations of greater power the minimising of this fading is of considerable importance. The first part of this paper discusses the considerations involved in the design of anti-fade antennae and reviews the present-day position in this respect.

The typical broadcast antenna is too large a structure to permit much use of " cut and try " methods so that it is important that characteristics such as the input impedance and over-all efficiency should be capable of accurate prediction. In this respect the present-day situation still leaves something to be desired, although it can be claimed that reasonable engineering accuracy has been attained. The methods by which these characteristics may be calculated are discussed in the second part of this paper.

Apart from more refined calculations and small improvements in the design of masts, it would appear that the design of broadcast antennae has reached a position of stalemate. However, there is a radically new type of antenna which may find application at broadcast frequencies, namely, the slot antenna. The manner in which this type might be applied to broadcasting purposes is considered in the final part of this paper.

PART 1

CONSIDERATIONS GOVERNING THE FADE-FREE RADIUS

1. Calculation of Field Strength due to the Ground Wave

Before the field strength from a vertical radiator can be calculated it is necessary to know the current distribution or, if it is not known (which is usually the case) to assume some law for the distribution. A fair approximation to the actual current distribution is given by a sine law since the radiator carries a standing wave ; such a distribution law is shown in Fig. 1 for three different antenna heights. The true current distribution depends on the thickness of the antenna and in practice takes the form shown by the dotted line in Fig. 1. The most significant difference is that the current minimum is not zero but some 10 to 30 per cent. of the value at the current maximum. In fact, the thicker the antenna the more is this minimum obscured—this point is of importance when considering the anti-fading properties of an antenna and will be discussed again later in the paper. From the point of view of the field strength in the horizontal direction these departures from the " idealized " distribution make little difference so that the assumption of a sinusoidal distribution gives adequate accuracy.

With the idealized current distribution mentioned above, the relative field strengths in the horizontal plane for different antenna heights are given by

* *U.D.C. No.* 621.396.67.
Manuscript received, March, 1947.
† *Standard Telephones and Cables Ltd.*

the curve in Fig. 2, from which we see that the maximum radiation along the ground is obtained when the height of the antenna is $0{\cdot}64\lambda$. This fact was first pointed out by Ballantine[1] in 1924.

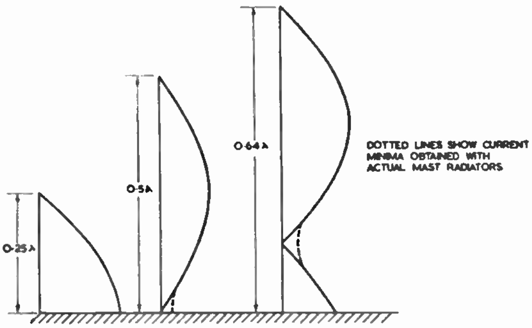

Fig. 1.—Current distribution of simple vertical radiators. (Idealized sinusoidal distribution.)

It can readily be shown from the theory of radiation that the field strength of a short vertical radiator above a perfectly conducting earth is 300 mV/m at a distance of 1 km. if the radiated energy is 1 kW. This value corresponds to unity on the relative field strength scale in Fig. 2.

In practice the horizontal field strength as given in Fig. 2 will be reduced by joulean losses in the antenna system. These are due to such causes as earth resistance, dielectric and conductor losses, corona discharge, etc. In a well-designed antenna only the earth losses are of importance. The radiation loss and the joulean losses of an antenna can be conveniently expressed in terms of the loop radiation resistance R_{1r}, and the loop dead loss resistance R_{1d}, where by the term "loop" we mean that we are taking a current antinode as the reference point. When these two values are known the efficiency η of the antenna system is given by

$$\eta = \frac{R_{1r}}{R_{1r} + R_{1d}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The propagation losses over a plane earth may be calculated by means of Sommerfeld's[18] attenuation constant, which we shall call A_1, while the additional attenuation introduced by a spherical earth can be allowed for by a shadow factor which we shall call A_2. The latter factor does not depart appreciably from unity within the ground wave service areas of medium wave stations and may therefore be excluded to a first approximation.

With these two factors we can express the field strength of the ground wave by the following formula :

$$E_g = \frac{300\sqrt{\eta P}}{D} F(h)\, A_1 A_2 \text{ mV/m} \quad \ldots(2)$$

where P = input power in kW.,

D = distance in km,

η = efficiency of antenna system,

$F(h)$ = field strength relative to a short antenna (Fig. 2),

A_1 = attenuation factor allowing for propagation losses (Fig. 3),

A_2 = shadow factor allowing for the curvature of the earth (Fig. 4).

The attenuation factor may be obtained from the curves in Fig. 3 in which the abscissae are ex-

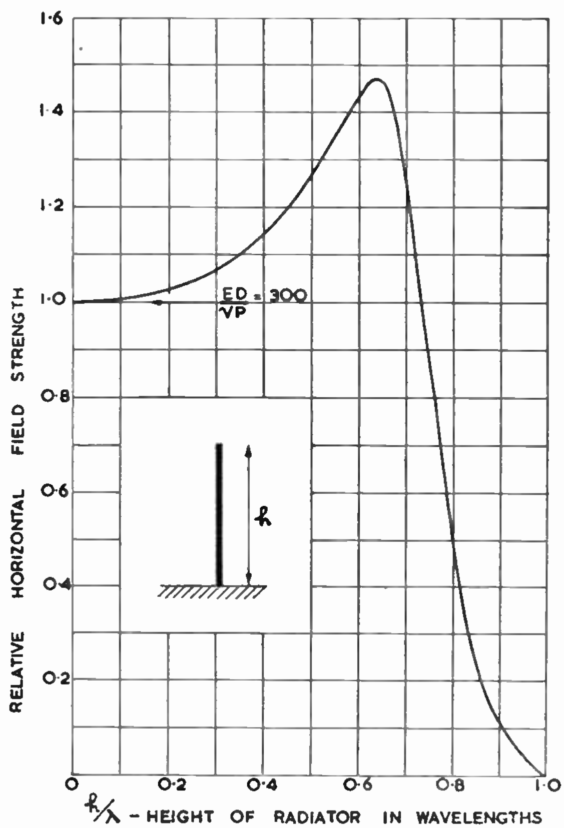

Fig. 2.—Relative horizontal field strengths for vertical radiators.

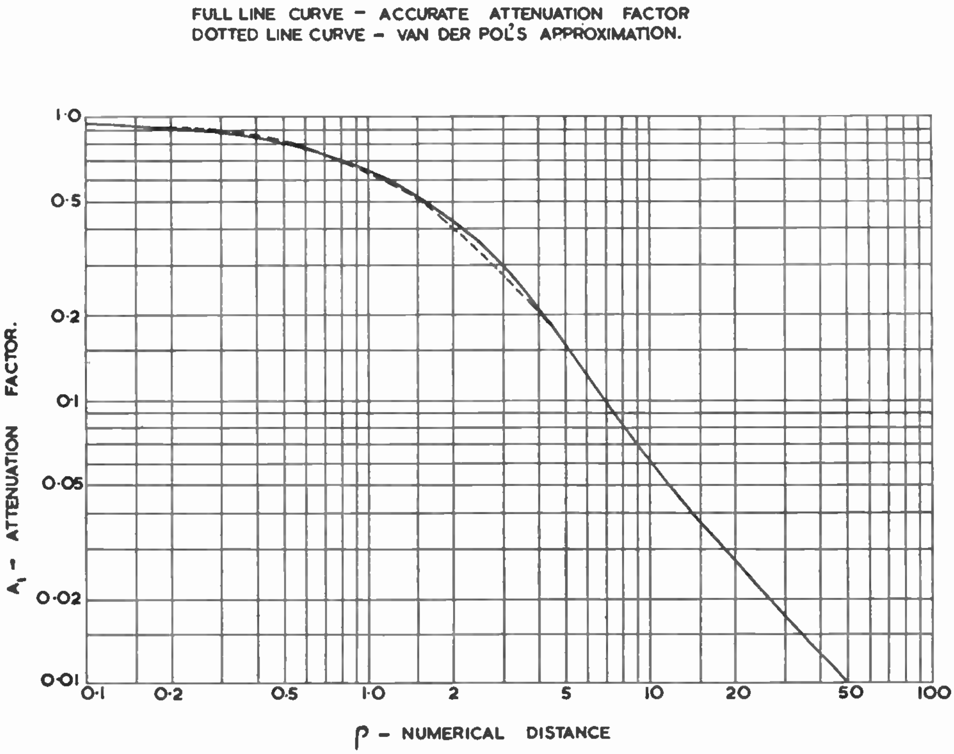

Fig. 3 Attenuation factor for long and medium wave transmissions.

pressed in terms of ρ, the numerical distance. For medium wavelengths and normal soil conductivities the value of ρ is given fairly accurately by

$$\rho = \frac{\pi}{60\,\lambda g} \cdot \frac{D}{\lambda} \cdot 10^3 \quad \ldots\ldots\ldots\ldots(3)$$

where λ = wavelength in metres,

g = soil conductivity in mhos/metre.

Van der Pol has given a simple approximate formula for the attenuation factor which is as follows :

$$A_1 = \frac{2 + 0{\cdot}3\rho}{2 + \rho + 0{\cdot}6\rho^2} \quad \ldots\ldots\ldots\ldots(4)$$

The curve given by this formula is shown dotted in Fig. 3.

A table of typical soil constants is given opposite.

The shadow factor varies with frequency and soil conductivity, but as a reasonable approximation we may take the curve given by Burrows[8] for a perfectly conducting earth—this curve is shown in Fig. 4.

Type of Ground	Relative Dielectric Constant, ϵ_r	Conductivity, g	
		Mhos/ metre	E.M.U.
Exceptionally well-watered pastoral land with rich soil.	20	0·03	3×10^{-13}
Pastoral land with good soil.	15	0·01	10^{-13}
Pastoral land with low hills.	10	0·005	5×10^{-14}
Hilly country with moderate vegetation.	5	0·002	2×10^{-14}
Built-up urban districts.	5	0·001	10^{-14}

The above equations and figures give all the relevant data for calculating the field strength of the ground when the height of the antenna, the wavelength, and soil conductivity are all known.

In many cases it is convenient to have a direct comparison of antenna performance which is independent of the input powei, the distance and the attenuation factors. In this way we are led to the definition of the figure of merit described below.

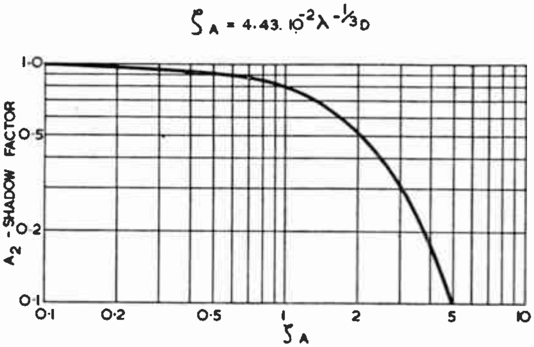

Fig. 4.—Shadow factor for a perfectly conducting earth.

Figure of Merit

From the point of view of comparing the performance of antennae in as far as their field strength along the ground is concerned, we must take into account the losses in the oscillatory circuit formed by the mast and the earth in the induction field but *not* the subsequent earth losses in propagation. That is, in equation 2, we take η into account but put A_1 and A_2 equal to unity—then rearranging the terms gives

$$\frac{ED}{\sqrt{P}} = 300\sqrt{\eta}\,F(h) \qquad \ldots\ldots\ldots\ldots(5)$$

The expression $ED/\sqrt{P}$ is called the *figure of merit* and gives the field strength at 1 km. for 1kW. input. It will be noticed that this figure is proportional to the square root of efficiency and directly proportional to the horizontal field strength factor F(*h*).

For a very short antenna $F(h) = 1$ and if the efficiency is 100 per cent then $\eta = 1$ also, whereupon

$$\frac{ED}{\sqrt{P}} = 300.$$

For an antenna giving a maximum field strength along the ground $h = 0{\cdot}64\lambda$ and $F(h) = 1{\cdot}467\lambda$, so that with 100 per cent efficiency

$$\frac{ED}{\sqrt{P}} = 440.$$

In both cases the field strength E will be in mV/m. It should be noted that it would not be dimensionally correct to say that $ED/\sqrt{P} = 300$ *mV/m* since the dimensions of $ED/\sqrt{P}$ are actually those of the square root of a resistance. It is therefore better practice to quote the figure of merit simply as a numeric.

Typical figures for an anti-fade antenna working on a wavelength of 500 metres would be $\eta = 0{\cdot}95$ and $F(h) = 1{\cdot}33$, which gives

$$\frac{ED}{\sqrt{P}} = 390.$$

When the exact height of the anti-fade antenna has not yet been decided upon, or when the *relative* anti-fade properties of such an antenna are being considered, it is convenient to assume tentatively a round figure of 400 for the figure of merit. This has been done in the calculations given in this paper—it will be appreciated that the anti-fade radius is not influenced thereby, it is only the absolute scales which are a few per cent. out for some of the antenna heights.

In order to measure the figure of merit it is usual to take the field strength measurement at some distance between 1 and 5 km. and to make a correction for the earth losses in propagation. These measurements are taken at about 12 different directions around the antenna. If, for example, $\lambda = 500$ metres and $g = 0{\cdot}01$ mhos/metre the correction at 1 km. would be negligible, but at 5 km. the correction would be an increase of 4 per cent. on the measured field strength.

2. Calculation of Field Strength due to the Sky Wave

The geometry of the sky wave is shown in Fig. 5a, while Fig. 5b is a diagram showing the effect of local earth reflections at the point of reception.

The value of E_s is determined by the vertical polar diagram of the transmitting antenna, the figure of merit, and the input power. In order to take the most unfavourable conditions from the point of view of interference we assume a reflection coefficient of unity and that reflection takes place from the E layer, which is at a height of 100 km. then the field strength of the downcoming wave is given by

$$E_s = \frac{300\sqrt{\eta P}}{D} F(h)\,F(\theta)\sin\theta \quad \text{mV/m} \ldots(6)$$

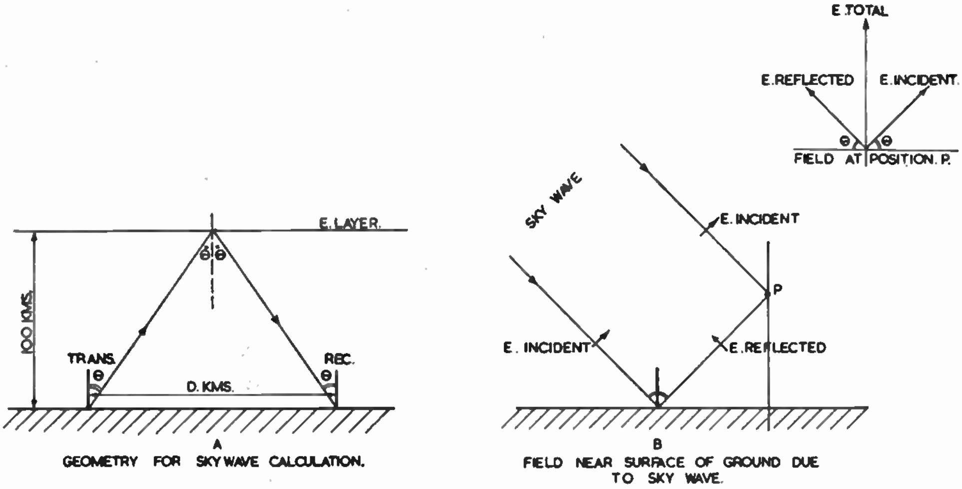

Fig. 5.—Diagrams for sky wave calculations.

where $F(\theta)$ = standardized polar coefficient (i.e. the vertical polar pattern with a scale such that $F(\theta) = 1$ at $\theta = 90°$)

The worst possible conditions will arise when the electric vector at the point of reflection is vertically polarized in which case, since the ground approximates to a perfect conductor at medium wavelengths, the field strength near the ground will be given by

$$E'_s = 2 E_s \sin\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where E'_s = maximum effective field strength due to sky wave.

On combining equations (6) and (7) we obtain the effective maximum sky wave field strength as follows :

$$E'_s = \frac{600\sqrt{\eta P}}{D} F(h)\, F(\theta) \sin^2\theta \ \ \text{m}V/\text{m} \ldots (8)$$

The function $F(\theta)$ depends on the current distribution along the antenna and in the case of a sinusoidal distribution this function is given by

$$F(\theta) = \frac{\cos(\beta h \cos\theta) - \cos\beta h}{\sin\theta\,(1 - \cos\beta h)} \quad \ldots\ldots (9)$$

where $\beta = 2\pi/\lambda$

i.e. βh = height of antenna in radians.

Curves of the above formula are shown in Fig. 6 where they are plotted on a logarithmic scale. Figure 7 shows three cases (corresponding to those shown in Fig. 1) which are plotted in the normal polar fashion.

3. Calculation of the Fade-free Radius

It is apparent from Fig. 5 that if the field strength due to sky wave and ground wave are comparable at distances between 100 and 200 km. then the radiation from an antenna should be reduced as far as possible at angles of about 30° to 40° from the vertical if the fading is to be kept to a minimum. Examination of the curves in Fig. 6 shows that a radiator which is $0{\cdot}64\lambda$ high would be quite unsuitable in this respect ; in fact, it is found that the optimum lies somewhere between 0·52 and $0{\cdot}57\lambda$, the exact value depending on the wavelength and ground conductivity.

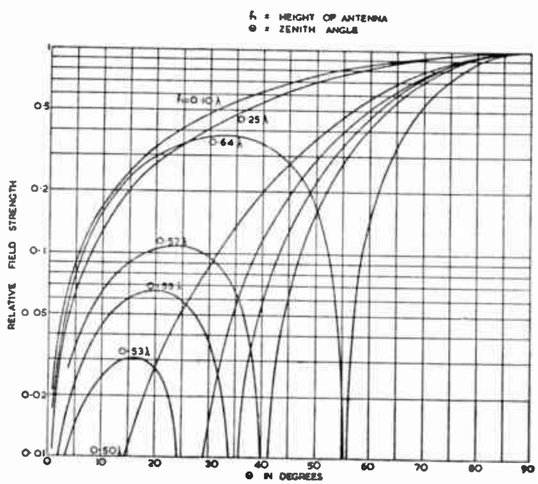

Fig. 6.—Vertical polar diagrams of a vertical radiator.

The ratio of the ground wave field strength to the maximum sky wave field strength can be obtained from equations (2) and (8) with the following result :

$$E_g/E_s' = \frac{F(\theta)\sin^2\theta}{2A_1 A_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

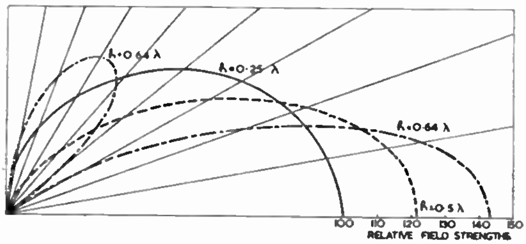

Fig. 7.—Vertical polar diagrams of radiators shown in Fig. 2.

In practice we are also interested in the absolute values of field strength, consequently it is preferable to work out both equations (2) and (8) and to plot them together, using a logarithmic scale for the ordinates. If we wish to find the distance for which the ratio $\frac{E_g}{E_s'} = 3$, we multiply the E_s' curve by 3 and note where it intersects the ground wave curve. This multiplication can be performed on logarithmic paper by simply moving the whole curve upwards by the required amount. In Figs. 8 and 9 some typical examples of ground wave and sky wave field strength curves are given. The first figure shows the effect of varying ground conductivity for a constant wavelength, while the second shows the variation with wavelength for a fixed ground conductivity. It will be noticed that whereas an antenna height of 0·57λ gives the greatest fade-free radius with good soil conductivity, when the soil conductivity is poor or average the optimum antenna height will lie somewhere between 0·52 and 0·55λ. These lower antenna heights also have the advantage of more rapid reduction in the strength of the sky wave as one moves inwards from a distance corresponding to the fade-free radius. The antenna height 0·57λ should therefore only be employed if practically the whole of the area to be served is of high conductivity.

With a sinusoidal distribution of antenna current the sky wave field would be as shown by the dotted lines. In practice the finite thickness of the antenna modifies the current distribution so that the minimum in the sky wave curves is filled in as shown by the full curves of Figs. 8 and 9. This " filling-in " causes a deterioration in the fade-free properties of the antenna so that it is important to keep the antenna current distribution as sinusoidal as possible. This may be done either by making the antenna extremely thin or by feeding at a current antinode (a method which is mechanically undesirable) or, if the antenna cannot be made thin, it should at least be of uniform cross section.

This modification to the idealized sky wave curves is one of the major problems in broadcast antenna design and every effort should be made on major installations to obtain results as near to the idealized case as possible. (The sky wave curves shown in Figs. 8 and 9 represent the case of a thin

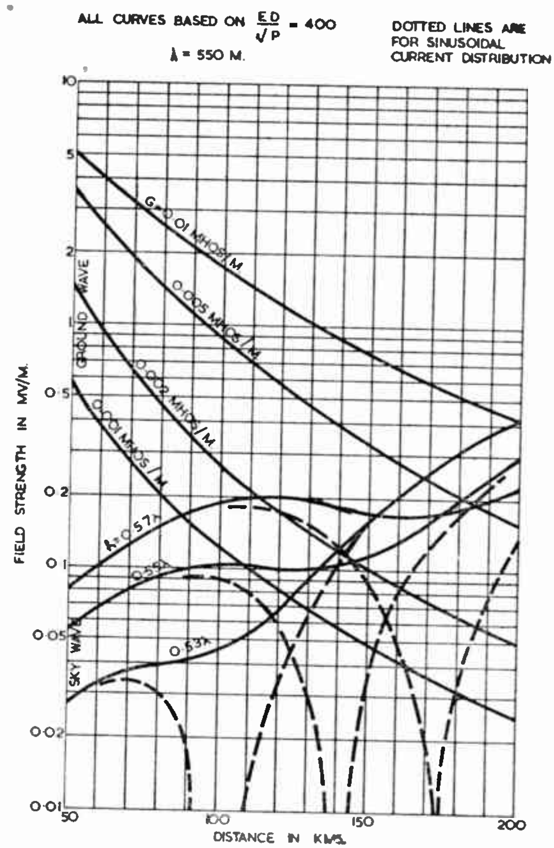

Fig. 8.—Variation of anti-fade radius with ground conductivity and height of antenna.

radiator of uniform cross section whose ratio of length-to-radius is at least 100.)

The improvement obtained by the use of the anti fade type of antenna will be appreciated by com-

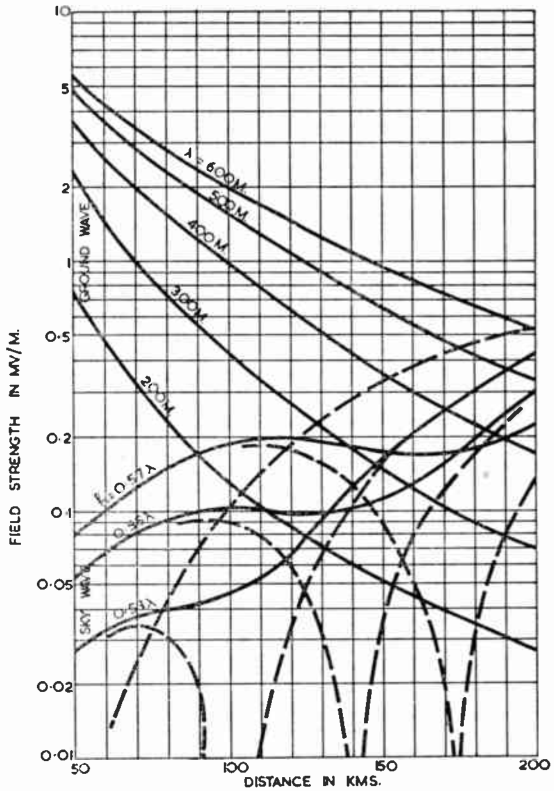

Fig. 9.—Variation of anti-fade radius with wavelength and height of antenna. (All curves, based on $\frac{ED}{\sqrt{P}} = 400$ *and g = 0·01 mhos/m. Dotted lines are for sinusoidal current distribution.)*

paring the two service areas shown in Fig. 10 (p. 147). The dotted boundary line in this figure encloses the fade-free region given by an anti-fade antenna of height 0·56λ, while the full line encloses the region covered by a T-type antenna of height 0·27λ and length of top 0·44λ. The increase in service area is as much as 130 per cent.

4. Factors Governing the Choice of Type of Antenna

Broadcast antennae of the anti-fade variety exist in quite a number of mechanical and electrical variations, a number of which are illustrated in Fig. 11.

In order to discuss their properties we may consider in particular the three types shown in Fig. 12, together with their corresponding current distribution. Two main facts are brought out by this figure : they are

1. Increasing the cross section of the conductor increases the current in the region of current minimum.
2. With a non-uniform characteristic impedance the current maximum is displaced towards the sections of lower characteristic impedance and also the current minimum is less sharply defined.

The above features have the following influence on the vertical polar pattern and the corresponding sky wave field strengths :

1. The increase of the current minimum increases the sky wave radiation at angles of about 30° to 40° from the vertical. With a perfectly sinusoidal distribution (an impossibility in practice since it is contrary to the laws of radiation), the sky wave would be as shown by the dotted lines in Figs. 8 and 9. The greater the current minimum the more the sky wave is increased at such angles and this is detrimental to the fade-free properties. The degree of deterioration due to the filling in of the current minimum depends on the ground conductivity and the height of the antenna. For instance, with good ground conductivity and a relatively low antenna the increase in the sky wave field strength in the region where the minimum should occur is of no consequence. In practice, however, we always aim at attaining as great an anti-fade radius as possible, and this invariably involves working in, or near, the region influenced by the current minimum. Consequently the current minimum should be kept as small as possible, i.e. the radiator should be as thin as is practicable.
2. The movement of the current maximum towards the sections of lower characteristic impedance invariably means that this maximum is brought nearer to the base of the antenna. This is because in order to obtain a *uniform* characteristic impedance the antenna would have to be in the shape of a cone whose apex is on the ground and whose base is in the air, whereas practical antennae do not increase in cross section towards the top.

The diamond type of antenna shown in Fig. 11 is an exception to this over the first half of its elevation, but the tapering of the top half causes an even greater non-uniformity section, the importance of which has been stressed in previous paragraphs, and straightforward mechanical construction. For major installations the series-fed method is to be preferred since the

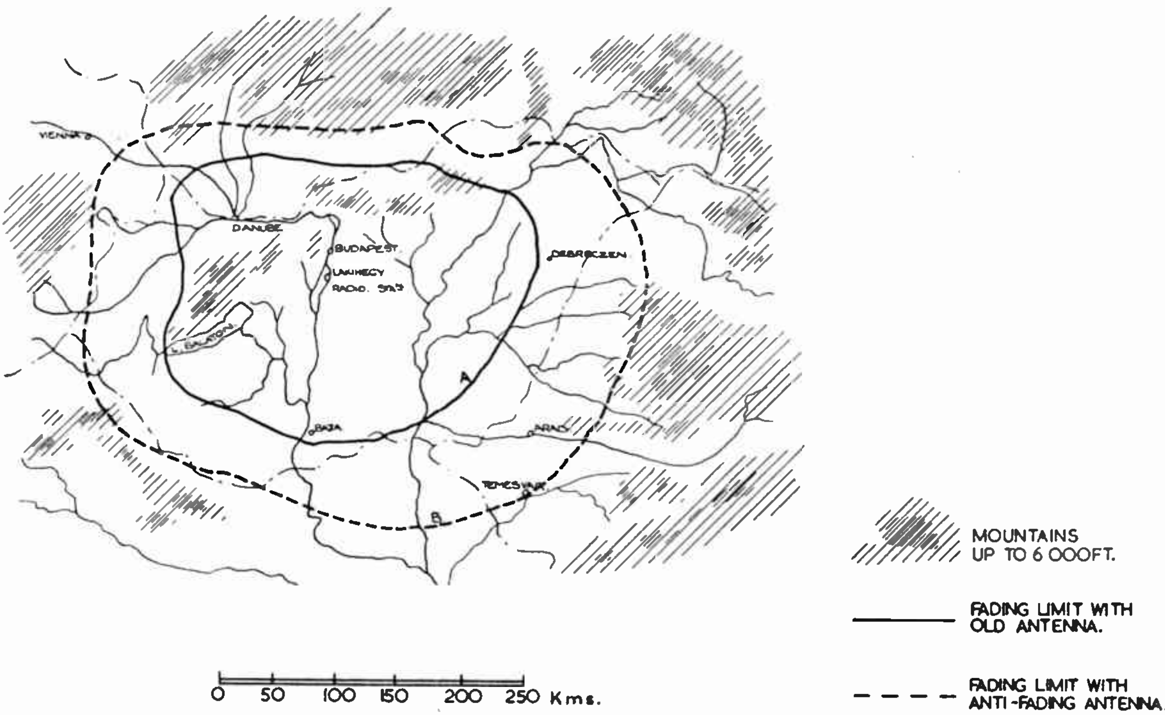

Fig. 10.—Map showing improvement in fade free radius obtained with anti-fade antenna (from reference 11).

in the characteristic impedance as a whole. This lowering of the current maximum is accompanied by an increase in the current minimum near the base of the antenna, and both features are detrimental to the fade-free properties of the antenna. Nevertheless, it is to be noted that with a uniform antenna of narrow cross section any improvement that may still be achieved can only be obtained by employing a still narrower cross section.

The Uniform Guyed Radiator

Figure 11A shows a guyed radiator of uniform cross section. In order to allow for errors in the assumption of ground conductivity, it is usual to fit an adjustable extension (commonly called a " flag pole ") at the top of the antenna. This type of antenna has the merit of having a small cross vertical polar pattern deteriorates with shunt feeding due to higher currents near the base. Series feeding involves the use of a large base insulator, but this presents no difficulties, neither is it difficult to equip the tower with lightning protection and static discharge circuits.

The Top-Capacitor Antenna

By fitting a crown of some 10 to 15 metres diameter at the top of an antenna as shown in Fig. 11B a reduction in height of about 20 per cent. may be achieved without appreciable deterioration in the fade-free properties. The size of the top capacitor depends on the thickness of the mast—the thicker the mast the greater the size needed for a given percentage reduction of the height of the radiator.

The Self-supporting Mast Radiator

Self-supporting towers of the type shown in Fig. 11C have a distinctly non-uniform characteristic impedance since they taper from the base upwards. Recent designs have succeeded in making the cross section at the base remarkably small for masts whose heights do not exceed 100 metres, but for greater heights the bending moments due to wind pressure at the top become so great that a broader base is needed. Antennae of this type therefore find their main application at the shorter wavelengths or when antennae of a height of about $0{\cdot}25\lambda$ are required for smaller installations.

The Diamond-shaped Antenna

The type of antenna known as the diamond, or "cigar," type of radiator is shown in Fig. 11D. At the time when this type of antenna was devised it represented an advance in antenna design since guying arrangements were thereby simplified. Later, it was found that there was some deterioration in the anti-fade radius due to the non-uniformity of the characteristic impedance. The present-day tendency is to sacrifice as little as possible of the desired electric properties of a radiator, and, since narrow uniform towers are mechanically feasible, it is now considered better practice to use the uniform type of radiator.

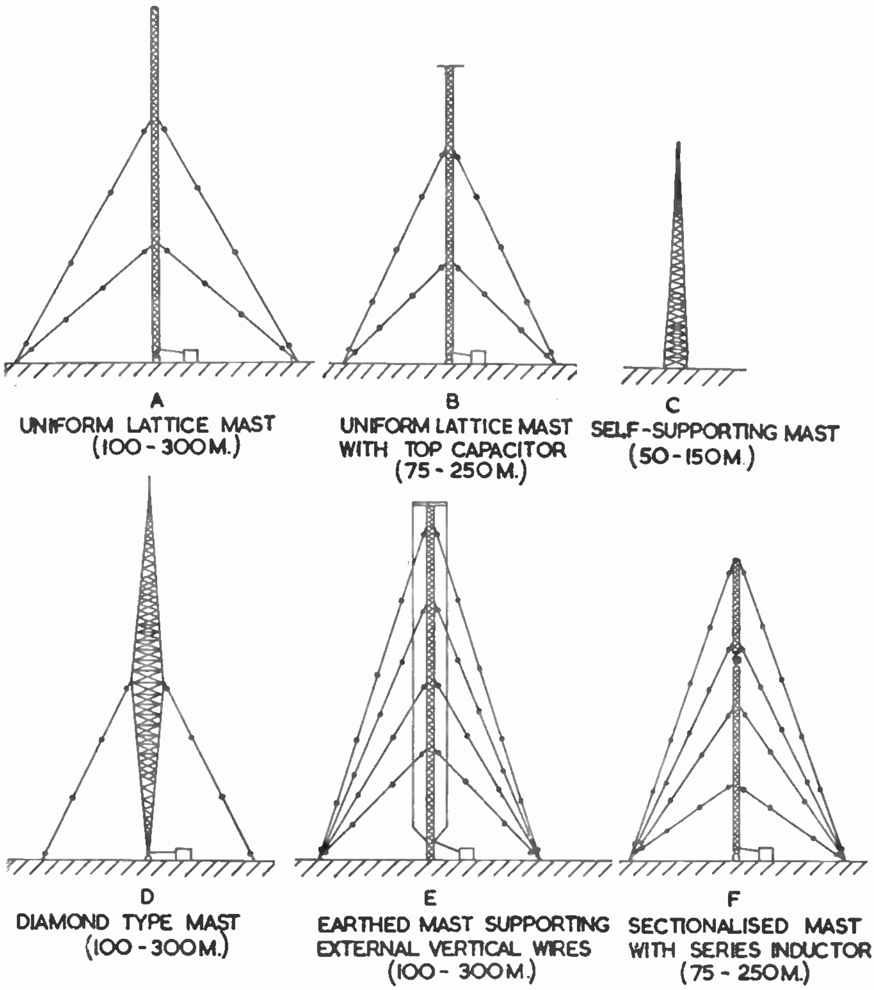

Fig. 11.—Six different types of broadcast antennae.

The Outrigger Type of Antenna

Figure 11E shows a variation in which the mast structure acts as a support for three or more wires which are suspended symmetrically from the top of the mast on outriggers. In this manner it is possible to earth the mast itself and yet to series feed the radiating elements.

Unfortunately such an arrangement has a lower characteristic impedance than that obtained by using the mast itself as the radiator, and hence there will be a slight deterioration in the fade-free properties.

From a mechanical point of view the simplicity of earthing the mast must be weighed against the extra wind load due to cross arms at the top (it should be remembered that these do not cause any saving in height as in the case of capacitance loaded antennae). This increased wind loading necessitates the use of more guys than would otherwise be needed.

The Sectionalized Antenna

Yet another way of reducing the over all height of a radiator is to insert an inductor some two-thirds of the way up the mast, as illustrated in Fig. 11F. With a sectionalized antenna of this nature care must be taken that not only is the insulation adequate, but that the break in the mast structure is mechanically strong. For this reason this type requires more guys than usual.

If a combined sectionalized and top-capacitor antenna is used then a wide range of tuning adjustments is possible. Even so, the over all height cannot be reduced below about 0·4λ without detriment to the fade-free radius. An antenna of this type has recently been installed at the Brookmans Park Station of the B.B.C., on which site it was essential to keep the height as low as possible in view of the proximity of Hatfield Aerodrome.

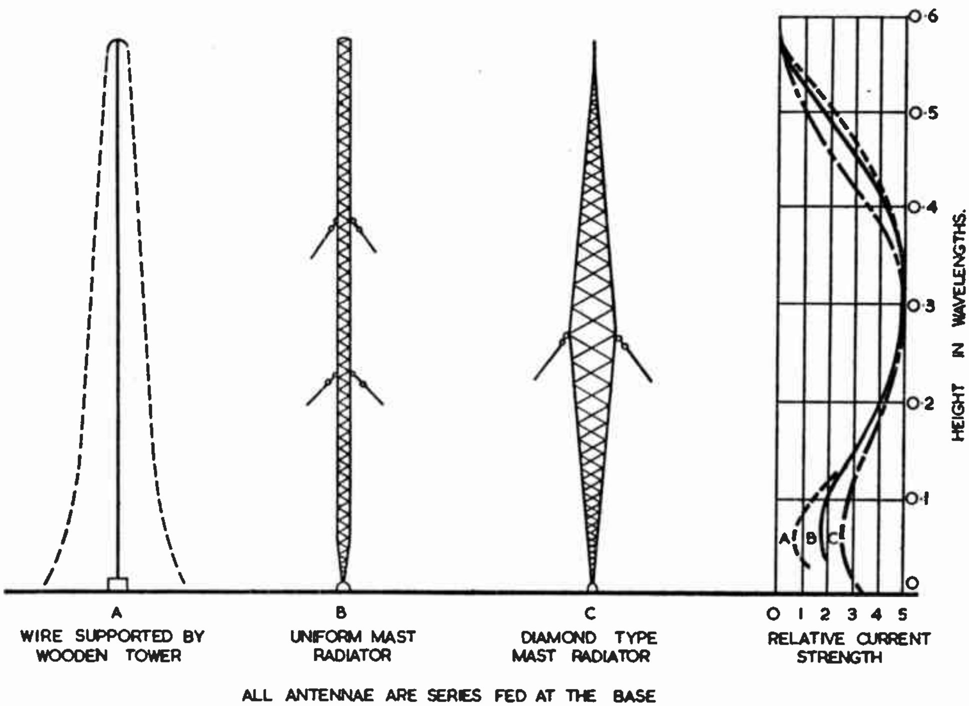

Fig. 12.—Three types of broadcast antennae with corresponding current distributions.

Other Types of Anti-Fade Antennae

Among the types of anti-fade antennae not mentioned in the above list are the following:

(*a*) Thin wire antenna supported by wooden tower (usually fitted with a top capacitor).

(*b*) Elevated dipole type (the dipole is loaded to shorten its length and the whole is supported by a wooden structure).

(*c*) A ring of six antennae with or without a centre antenna.

All three of the above variations can give satisfactory results electrically, but they suffer from the disadvantage of being mechanically complicated. In particular wooden structures are no longer favoured, for their upkeep is costly and they are too liable to catch fire.

General Conclusions

If we restrict ourselves to a single radiator whose height is not to exceed about half a wavelength (e.g. a Franklin antenna one wavelength high is ruled out), then the thin uniform tower cannot be improved upon. Various methods have been devised for slightly shortening the height of the radiator, but in no case can a reduction in height of more than 20 per cent. be obtained without at the same time causing an undesirable deterioration in the fade-free properties of the antenna.

There is really nothing very remarkable about such a conclusion. The fade-free properties are obtained by space phasing at angles between 30° and 40° from the vertical; hence the shortening of the radiator by means of a lumped reactance is contrary to the basic needs of the situation. All that can be said is that practically the same result can be obtained by loading *provided* the height of the antenna is not reduced by more than 15 to 20 per cent.

PART 2

DETERMINATION OF ANTENNA CHARACTERISTICS

1. Base Radiation Resistance and Reactance

During the last decade it was customary to calculate the impedance of a vertical radiator on the assumption that it was equivalent to a uniformly loaded transmission line. The loading could be determined by the loop radiation resistance which could be based, in the first place, on the assumption of a sinusoidal current distribution. If greater accuracy were required, then a re-calculation could be made using the current distribution appropriate to the uniformly distributed loss resistance. This process has been described in articles by Labus[13] and McPherson[14]. In using the equivalent transmission line technique mentioned above, the characteristic impedance assumed for the antenna was usually based on Howe's[12] methods, whose formula for the case of a cylindrical antenna gives the results shown in Fig. 13.

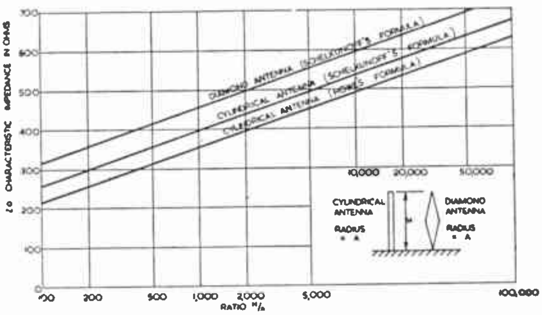

Fig. 13.—Characteristic impedance of vertical radiators.

When using this method one soon notices that the values in the neighbourhood of the second resonance (i.e. when the antenna is half a wavelength long) are appreciably in error, since the shortening effect given by the equivalent transmission line formula is distinctly less than that obtained in practice. For example, with a uniform vertical radiator whose height is 50 times the diameter, the equivalent transmission line method indicates a resonant length of $0{\cdot}485\lambda$, whereas experimental investigations indicate a resonant length of $0{\cdot}425\lambda$.

In order to account for such differences, it was customary to include some arbitrary capacitance in shunt with the base input impedance. It is to be noted that this capacitance was additional to whatever might be attributed to the base insulator, and was assumed to represent the extra capacitance between the lower part of the tower and the ground.

This unsatisfactory state of affairs was improved to a considerable extent when Schelkunoff[17] introduced his "biconical antenna" method of calculation. The results based on the biconical antenna method agree far better with experimental values without the need for including some arbitrary extra capacitance across the base.

Figure 14 shows the experimental curves obtained by Morrison and Smith[15] on a uniform radiator, while the dotted lines in this figure are theoretical values obtained by Schelkunoff's[17] method. The agreement is still not *very* good, but the method represents a remarkable improvement over the previous techniques. In the theoretical curve of Fig. 14 no account has been taken of the shunt capacitance of the base insulator, but such refinement would cause only minor modifications in the curve.

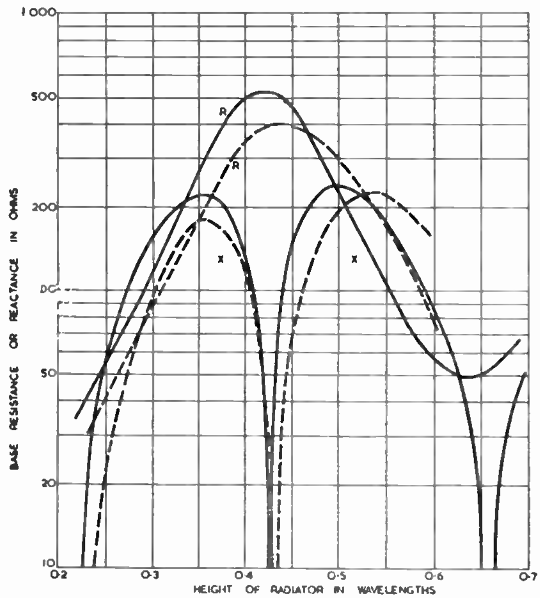

Fig. 14.—Impedance curves of a uniform vertical radiator. Full curves: experimental values (Morrison and Smith—ref. 15). Dotted curves; theoretical values, Schelkunoff's biconical antenna method.

The biconical antenna method takes as its basis an antenna of conical shape fed at the apex and other shapes are regarded as non-uniform conical antennae whose characteristic impedance is expressed in the form of an average value. For a cylindrical antenna, the average characteristic impedance is given by

$$Z_0 = 60 \left(\log_e \frac{2h}{a} - 1\right) \quad \text{.............(11)}$$

where a = the radius of the antenna in the same units as h.

The above formula is shown plotted in Fig. 13 (in addition Schelkunoff's curve for a diamond-shaped antenna has been included). It is apparent from the curves that the characteristic impedance of the cylindrical antenna depends on the manner in which the calculation is made. These difficulties originate from the fact that the characteristic impedance of an antenna is not uniform unless it happens to be in the form of an inverted cone.

When the cross section of the antenna is triangular or square, some equivalent radius has to be taken. For this purpose the author would suggest the following values:

$$a = 0{\cdot}50\, b \text{ (triangular cross section)} \quad ..(12)$$

$$a = 0{\cdot}63\, b \text{ (square cross section)}$$

where a = equivalent radius

b = width of one side

Figure 15 gives the input impedance and reactance of a cylindrical antenna, using the biconical antenna method over the range of heights normally used for anti-fade antennae; these curves are extensions of those given by Schelkunoff. A number of further extensions such as the input impedance of diamond-shaped

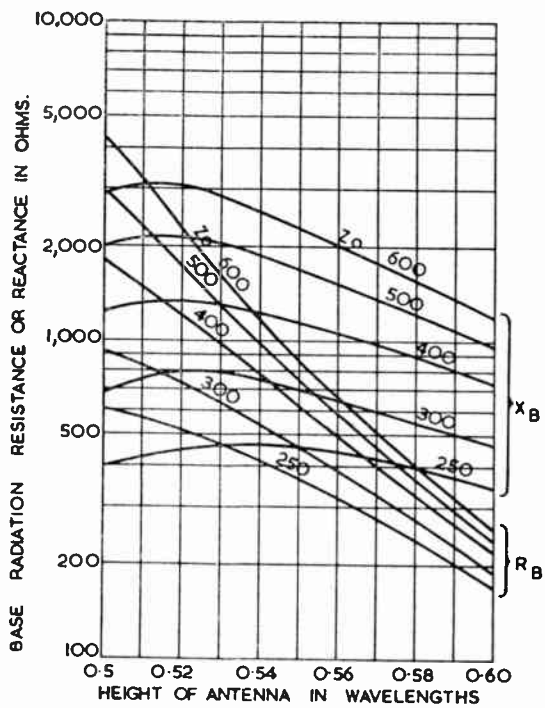

Fig. 15.—Input impedance of unloaded vertical radiators of uniform cross-section.

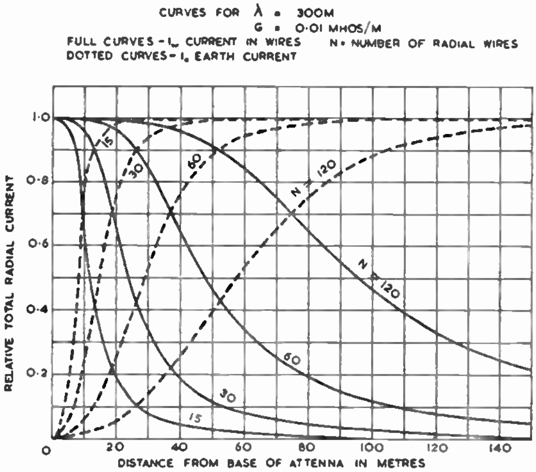

Fig. 16.—Distribution of earth and wire currents in a radial earth system.

antennae, or of loaded antennae could all be made from the information given by Schelkunoff, but the author has not had the time to do this himself, neither does he know of any such extensions having been published as yet. It is therefore still customary to fall back on the equivalent transmission line method where sectionalized or loaded antennae are concerned.

2. Joulean Losses in the Antenna System

The losses in an antenna system may be classified into conductor losses, dielectric losses and earth losses. Of these various forms the first can be shown to be entirely negligible. Although tower radiators are often fitted with thick copper wires running along their entire length, this is more by way of an additional precaution in the event of an appreciable resistance developing between the joins of the girder structure, for under normal conditions the structure itself takes most of the current.

Dielectric losses are also negligible if the guys are sufficiently sectionalized. A detailed investigation of this problem has been made by Brown[4] who showed that the breaking of the guys into sections whose lengths were not more than, say, one quarter of the height of the antenna, was quite sufficient to keep the voltages across guy insulators to a reasonable value. The losses across the base insulator are also only a fraction of one per cent., particularly if the precaution is taken of placing an earth mat under the insulator (such a mat prevents excessive dielectric currents in the neighbouring earth).

We are therefore left with the earth losses as the only significant losses in the antenna system. These may be reduced to a few per cent. by providing a sufficient number of radials over a radius of about half a wavelength. The problem of earth losses received considerable attention by Brown[2] who, together with Lewis and Epstein[6], has also provided experimental verification of his formulae. These formulae give the ratio of the current in a radial wire system to that in the earth in the following form :

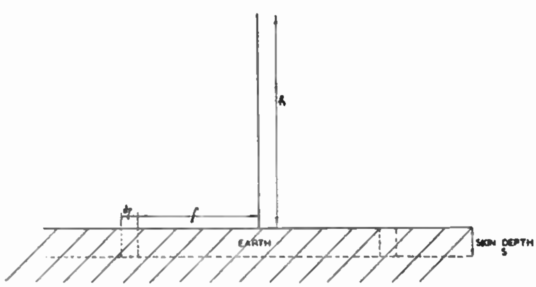

Fig. 17A—Diagram for earth loss formulae.

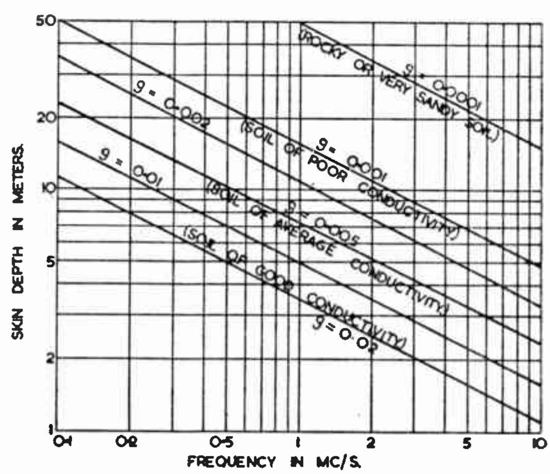

Fig. 17B—Skin depth for various ground conductivities.

$$\frac{I_e}{I_w} = j\left(\frac{\pi\rho}{sn}\right)^2 \left[\log_e\left(\frac{\pi\rho}{an}\right) - 0{\cdot}5\right] \ldots (13)$$

where ρ = radial distance from the base,
s = skin depth in metres,
a = radius of earth wire in metres,
n = number of earth wires.

The curves based on this formula are shown in Fig. 16, assuming a wire gauge of No. 10 S.W.G.—the wire diameter has actually little effect within quite wide limits. These curves show that when 120 radial wires are used, the amount of current still travelling through the earth has become quite small. If we neglect the losses in the wire, then the power loss in the soil is given by (see Fig. 17)

$$\int_{\rho_1}^{\rho_2} dW = \int_{\rho_1}^{\rho_2} \frac{I_e^2}{2\pi\rho\, sg}\, d\rho \ldots\ldots\ldots\ldots (14)$$

$$= \frac{I^2\rho}{2\pi\rho\, sg} \log_e \rho_2/\rho_1$$

The integral is taken between the limits of ρ_1 and ρ_2, and since these limits should cover the induction field of the system, the outer limit, ρ_2, should be about 0·4 or 0·5λ; unless a large number of wires are used, the integral is insensitive to the upper limit. When the number of radials is large, say 120, the result *is* sensitive to the upper limit chosen, but then the percentage loss is quite small and the exact value is in any case in doubt on account of the initial assumptions made. In any case, it is easiest to evaluate the integral graphically, using the curves of Figs. 16 and 18.

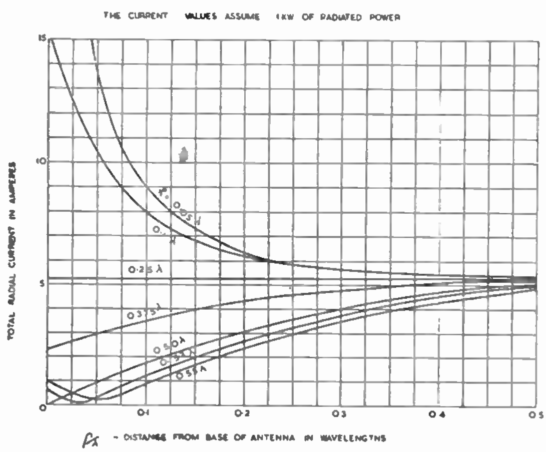

Fig. 18.—Current distribution in the earth for vertical radiators

The use of the foregoing formulae requires a knowledge of the total earth current at a given radius from the base of the antenna. A fair approximation of this value may be obtained by making the usual assumptions of the sinusoidal distribution for the antenna; this leads to the following formula for the radial current at a distance ρ from the base of the antenna:

$$I\rho = \frac{I_b}{\sin\beta h}\left(e^{-j\beta r_1} - e^{-j\beta\rho}\cos\beta h\right) \ldots (15)$$

where I_b = current at base of antenna,
r_1 = distance from top of antenna to the ground at radius ρ.

Figure 18 shows some curves based on this formula.

The influence of earth losses on an antenna system may be appreciated from the table on page 154, in which the suffix b refers to the base and l to the current loop:

It is apparent from the table on page 154 that an antenna whose height is of the order of half a wavelength is inherently more efficient than a short antenna. This is due to two reasons, (1) that the radiation resistance is greater, (2) because the maximum radial current is at some distance from the base where the circumference of the earth system is much greater. There is therefore little difficulty in obtaining an efficiency of some 95 per cent. with anti-fade antennae if a large earth system is employed. This efficiency refers, of course, to the antenna system only and excludes losses due to the coupling circuits or transmission lines.

PART 3

FUTURE POSSIBILITIES IN BROADCAST ANTENNA DESIGN

From the foregoing discussion it will be realized that there is apparently no alternative in broadcast antenna design to the use of a tower some 0·4 to 0·6 wavelengths high. In certain cases arrays of antennae have been used for the purpose of reducing or augmenting the radiation in a given direction (a recent example of a directive system is the array at Pittsburgh's KQV station which consists of five self-supporting masts, each 350 ft. high). When designing an array it is a great help to have some form of calculating machine so that alternative solutions and also the tolerances in any given solution can readily be examined. A machine of this nature was designed by the author[20] during the war, while recently Brown and Harrison[7] have described one which shows the polar pattern directly on a cathode ray tube.

By searching for a suitable combination of antennae it is possible to obtain a distinct increase in the fade-free radius in certain directions, but always at the expense of a deterioration in other directions. Nevertheless, a solution of this nature may be appropriate in some cases due to the particular distribution of populations and ground conditions.

A radically different line of attack would be to use the slot antenna principle. On the face of it this would require the use of deep trenches in the ground about a tenth of a wavelength deep and half a wavelength long. An obvious way of reducing the depth would be to fill the trenches with water, in which case the depth could be reduced by a factor of 9. On the other hand, the water would need to be kept reasonably pure and this might make the scheme uneconomical.

There is, however, no need to build the slot into the ground, it might equally well be built *above* the ground by means of a system of wires suspended on poles some 30 metres high. Thus we could visualize an antenna working on a wavelength of 300 metres consisting virtually of a raised earth system built round a channel made by two rows of 30 metre poles. The channel could be some 20 metres wide and 150 metres long so that a total of eight poles would probably suffice to support the wires terminating at the " slot." Farther out the wire system (which might have a mesh of, say, 20 metres) could be brought down gradually to earth. A buried earth system would also be required and the transmitter could be housed between the two wire systems.

The slot system as described so far would be directional in a horizontal plane, but this could be avoided by having two slots at right angles. Even then the system would not be comparable with the normal anti-fade antenna since the skywards radiation would be excessive. If, however, an array of such slots were constructed the vertical polar pattern could be controlled to reduce the skywards radiation, particularly if this were only required in certain directions.

What are the advantages to be gained by such slot arrays? From the expense point of view they would show no advantage over the single tall radiator—except perhaps where the ground contours happened to be exceedingly favourable. On the other hand, the continual increase in flying activities has made it more and more essential to

TABLE OF EARTH LOSSES

$\lambda = 300$ metres

$g = 0{\cdot}01$ mhos/metre

Height of simple vertical antenna	λ/20 (15 metres)		λ/4 (75 metres)		λ/2 (150 metres)	
Base (or loop) Radiation Resistance ..	1		36·6		99·5 (loop)	
Ground loss Resistance and Efficiency	R_{bd}	η	R_{bd}	η	R_{ld}	η
(*a*) With 10 cm. diameter earth rod ..	14·5	6·5%	25·2	63·3%	6·4	94·0%*
(*b*) With 15 radial wires each 25 m. long	0·96	51·0%	8·7	80·7%	6·3	94·1%*
(*c*) With 120 radial wires each 150 m. long	0·072	93·3%	2·13	94·4%	3·5	96·7%

* *These values are optimistic, since the current at the base is not zero in practice. More likely values are* 80% *and* 90% *for* (*a*) *and* (*b*) *respectively.*

keep the heights of obstructions as low as possible, and in this respect the slot array would be a great improvement.

List of References

1. Ballantine, Stuart. " On the optimum transmitting wavelength for a vertical antenna over perfect earth." *Proc. I.R.E.*, Vol. 12, p. 833. Dec. 1924.
2. Brown, G. H. " The phase and magnitude of earth currents near radio transmitting antennas." *Proc. I.R.E.*, Vol. 23, p. 168, Feb. 1935.
3. Brown, G. H. " A critical study of the characteristics of broadcast antennas as affected by antenna current distribution." *Proc. I.R.E.*, Vol. 24, p. 48, Jan. 1936.
4. Brown, G. H. " A consideration on the radio-frequency voltages encountered by the insulating material of broadcast tower antennas." *Proc. I.R.E.*, Vol. 27, p. 566, Sept. 1939.
5. Brown, G. H., and Leitch, John G. " The fading characteristics of the top-loaded WCAU antenna." *Proc. I.R.E.*, Vol. 25, p. 583, May, 1937.
6. Brown, G. H., Lewis, R. F., and Epstein, J. " Ground systems as a factor in antenna efficiency." *Proc. I.R.E.*, Vol. 25, p. 753, June 1937.
7. Brown, G. H., and Morrison, Wendell C. " The RCA antennalyzer—an instrument useful in the design of directional antenna systems." *Proc. I.R.E.*, Vol. 34, p. 992, Dec. 1946.
8. Burrows, Charles R., and Gray, Marion C. "The effect of the earth's curvature on ground-wave propagation." *Proc. I.R.E.*, Vol. 29, p. 16, Jan. 1941.
9. Chamberlain, A. B. and Lodge, W. B. " The broadcast antenna." *Proc. I.R.E.* Vol. 24, p. 11, Jan. 1936.
10. Gihring, H. E. and Brown, G. H. " General considerations of tower antennas for broadcast use." *Proc. I.R.E.*, Vol. 23, p. 311, April 1935.
11. Holland, F., Strong, C. E., and McLean, F. C. " The Budapest anti-fading antenna." *Elect. Comm.*, Vol. 12, p. 289, April 1934.
12. Howe, G. W. O. " On the capacity of radio-telegraphic antennae." *Electrician*, Vol. 73, p. 829, Aug. 1914.
13. Labus, J. " Rechnerische Ermittlung der Impedanz von Antennen." *Hoch. u. Elecktro*, Vol. 41, p. 17, Jan. 1933.
14. McPherson, W. L. " Electrical properties of aerials for medium and long-wave broadcasting." *Elect. Comm.*, Vol. 16, p. 306, April 1938 ; Vol. 17, p. 44, July 1938.
15. Morrison, J. F., and Smith, P. H. " The shunt-excited antenna." *Proc. I.R.E.*, Vol. 25, p. 673, June 1937.
16. Norton, K. A. " The calculation of ground-wave field intensity over a finitely conducting spherical earth." *Proc. I.R.E.*, Vol. 29, p. 623, Dec. 1941.
17. Schelkunoff, S. A. " Theory of antennas of arbitrary size and shape." *Proc. I.R.E.*, Vol. 29, p. 493, Sept. 1941.
18. Sommerfeld, A. " Uber die Ausbreitung der Wellen in der drahtlosen Telegraphie." *Ann. der Phys.*, Vol. 28, p. 665, Mar. 1909.
19. Wells, N. " A new type of anti-fading aerial." *Marconi Rev.*, Vol. 6, p. 12, July-Sept. 1938.
20. Williams, H. Paul. " A machine for calculating the polar diagram of an antenna system." *Elect. Comm.*, Vol. 21, p. 103, 1942-44.

CONVENTION DISCUSSION

Mr. P. Adorian (Member) opening the discussion said that he would like to know the basis on which the fade-free radius was obtained in the case of Fig. 10. While he appreciated the fact that the areas enclosed by the full line and dotted line, respectively, showed the relative effect of the anti-fade type aerials, the fade-free radius shown seemed somewhat higher than would be expected. The definition of fade-free radius depended on the ratio of direct and indirect ray strength that was tolerated. In this connection, he drew attention once more to the graph published in the January/February, 1946, issue of the Journal of the Institution, Fig. 2, page 36.

Mr. D. A. Bell : I am familiar with the idea of a slot aerial having one side enclosed by a cylinder of about $\frac{1}{4}$-λ radius, but I was surprised that Dr. Williams suggested a trench only the same width as the slot and $\frac{1}{8}$-λ deep. Surely this will have a considerable effect on the feed-point impedance of the slot, if no other effect ?

Mr. W. M. Dalton (Associate Member) : With the slot aerial, design seems to have completed the circle back to Marconi's aerials at Clifden and Glace Bay. Why is it that half-wave horizontal aerials are not used to a greater extent ? Does ground absorption have much effect on horizontally polarized transmissions ?

REPLY TO THE DISCUSSION

Dr. Williams : In speculating on further developments in the design of broadcast antennae I have used a certain amount of licence in regard to the engineering problems to be overcome. It was in this spirit that I suggested that slot type of antenna might be only $\frac{1}{8}$-λ high. Mr. Bell is quite right in pointing out that this would have a considerable effect on the feed-point impedance of the slot. I mentioned this figure because it seemed to me to represent, roughly, the lowest height for which it might be possible to tune the system whilst still maintaining a reasonable efficiency.

On the other hand, I am not suggesting that one could restrict the width of the cavity below the slot to the same dimension. Perhaps in my sketches on the blackboard I did not make this quite clear. The supporting poles around the perimeter are not a part of the oscillatory system, in fact, I had in mind wooden poles, and it was with this idea that I suggested heights of only 30 to 35 metres. The width of the " cavity " should be about $\frac{1}{2}$-λ which means that underneath the slot we would have effectively a square box of side $\frac{1}{2}$-λ and depth $\frac{1}{8}$-λ.

I agree with Mr. Adorian that the fade-free radii shown in Fig. 10 seem greater than one might expect. These results were obtained by Hungarian engineers in the course of their investigations on the relative performances of an old T type and of a new diamond type of antenna. I heard verbally from one of the engineers concerned that the ratio of direct to indirect field strength was taken as 5 to 1, but it would appear that some averaging of the results must have been made since, under the worst possible conditions, the fade-free radii could certainly not have been so great.

Mr. Dalton has raised the question of radiation from horizontal conductors. Where such conductors form the top of a " T " or inverted " L " antenna, their fundamental purpose is to provide a reactive end impedance to the vertical portion of the antenna so that the vertical portion has a higher average current. The horizontally polarized radiation from these tops is of no service in broadcasting since the surface wave with this form of polarization is very weak.

To maintain a substantial field in the vicinity of the ground it is essential that vertical polarization be used. This is only to be expected since the ground is quite a good conductor at broadcast frequencies so that fields whose electric vector is parallel to the ground are appreciably attenuated.

The case of the slot antenna is different. Although we have a horizontal current distribution this is of such a nature that vertically polarized waves are generated. The actual current distribution at any part of a cycle may be determined by considering the electric field distribution in a meridian plane through the complementary dipole. This field distribution is identical with the magnetic field distribution around the plane of the slot, and to find the current distribution curves are drawn which are orthogonal to the lines of magnetic field strength. The electric lines of force which result from this current distribution around the slot are identical in form with the magnetic lines around a complementary dipole, i.e., they form semi-circles around the slot and are therefore vertically polarized at ground level.

In view of my remarks on the relative merits of vertical and horizontal polarization, some of you may be wondering why both forms appear to be almost equally useful as far as television and F.M. broadcasting is concerned. The answer lies in the fact that for transmissions on ultra-short waves we no longer rely on the surface wave (since this becomes quite weak even with vertical polarization) but instead we depend on the space wave component of the radiation field. The latter component consists of the sum of the direct ray and the ray reflected off the ground. The reflection coefficients are such that, except for heights of less than about one wavelength, the field strengths are substantially the same for either form of polarization. We therefore see that with transmissions on wavelengths of a few metres we are working on the underside of the first lobe of the vertical polar diagram, and because of this it is desirable to mount the transmitting antenna as many wavelengths as possible above the ground—a quite different state of affairs from those prevailing on medium wave transmissions.

THE PROBLEMS OF RADIO COMMUNICATION WITH MOVING TRAINS*

by

G. H. Leversedge, M.I.R.S.E.†

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

Early Experiments.

Attempts to convey intelligence directly into the cabs of locomotives and guards' brakes of trains in motion have been made from quite early days in railway history. Apart from innumerable cab signalling and automatic train control devices which are outside the scope of this paper, the possibility of transmitting telegraph messages and, later, speech, has exercised the brains of many inventors, who, often with very limited knowledge of railway conditions, have suggested all kinds of schemes, some of which were tried out under working conditions from time to time.

The main difficulty in the past was the high attenuation of any practical form of transmission link for bridging the gap between the track equipment and the moving train. Diverse methods have been tried such as earth loop currents produced by injecting energy into a section of rail under the train and magnetic and capacitative couplings, using coils or plates fixed to the train to induce currents in the rails and wires along the track. A suggestion was made recently to employ supersonic vibrations in the rails as a carrier for audio signals but no practical tests appear to have been made. Transmission link losses made it very difficult to design sufficiently sensitive receiving apparatus to operate reliably with reasonable transmitted power.

A system of telegraph transmission using steel wires along the track and plates fixed to the roof of the guard's van was developed by Edison and Phelps and installed in America as early as 1886. It is on record that this was used by a train held up in a snowdrift to maintain communication with railway officials and relief trains when all normal telegraph circuits were out of action.

* *U.D.C. No.* 621.396.931. *MSS. received March*, 1947.

† *London and North Eastern Railway.*

Applications of "Wired Wireless" and Radio to Railway Working.

This paper is limited to consideration of speech transmission on moving trains; its applications, problems, and the results of experimental work carried out in recent years. Telegraphy has obviously a more limited field of application than telephony, although uses may be found for the printing telegraph, and facsimile apparatus; in fact, a demonstration of the latter has already been given on one American railway.

At the present time, two workable forms of speech transmission link have emerged; the inductive system and space radio. Both have their own advantages and disadvantages which will be discussed later. Both systems have been dependent on developments in electronic engineering, and employ similar methods, the only fundamental difference between them being the method of transferring energy across the gap between the line side equipment and the train. These two types have been developed side-by-side and many experimental installations have been tested in the last few years chiefly in America where no doubt the great distances and long block sections create an urgent need for such facilities.

Particulars of the applications under consideration by British railways at the present time and the conditions under which the apparatus would require to be operated should prove of interest to those engaged in the design of mobile communications equipment. The chief of these applications are as follows:

(1) *Hump Marshalling Yards.*

In these shunting yards, trains of goods wagons for many different destinations are re-grouped and made up into trains for the same locality. The mixed trains are uncoupled in sections, each destined for a particular station, and the whole train of wagons pushed over the hump by a shunting engine. The separate "cuts" then run down by gravity, and, after being suitably spaced by retarders, enter the appropriate siding. The points leading into the sidings are sometimes controlled automatically by machines in the control tower in which information as to the correct position the points should take up in readiness for each approaching cut can be stored before the operation commences. The driver of the shunting engine at the rear of a long line of trucks cannot, of course, see what is happening on the other side of the hump, and it is therefore important that rapid means of communication should be provided from the shunter on the ground especially in the case of a mishap. Radio appears to be the ideal solution in this case, and it is considered that the work of these yards could be speeded up by its use.

Equipment in control towers could be of the fixed or semi-portable type, but portable equipment might be required for ground shunting staff. The shunting engine apparatus should be capable of easy changing for maintenance purposes.

(2) *Communication with Sites of Mishaps.*

Portable radio equipment carried on breakdown trains would be invaluable in enabling instructions and information to be transmitted between headquarters and the scene of the accident, probably via the nearest signal box which could either retransmit messages over the ordinary telephone lines or switch the radio link to them Such equipment would undoubtedly have been useful for directing the work of clearing snow drifts during the serious blockage of the railways last winter.

(3) *Portable Equipment for Engineering Works.*

Portable equipment of the "walkie-talkie" type could be used, for example, when a large signalling installation was brought into use. Rapid means of communication between various locations and a central point, e.g., the signal box, would speed up the work, reduce dislocation to traffic, and simplify the checking of functions and controls.

(4) *Communication between Driver and Guard.*

This would be particularly useful in the case of long goods trains which may be nearly half a mile long. Delays may be minimized when, for example, a train is stopped in abnormal circumstances, as it would avoid the present necessity for the fireman and guard to walk the length of the train to confer regarding the action to be taken to obtain assistance and protect other traffic.

It is impracticable to provide wires along the train and communication must therefore be provided by similar means to those necessary for speaking between fixed points and trains. Recently the use of radio has been suggested for co-ordinating road and rail traffic particularly in cases of emergency when, for example, a gap in the rail service is temporarily bridged by the use of road vehicles. The maximum effective range required for this purpose would be 10-15 miles.

These are the main applications at present under serious consideration in this country, but other possible uses can be foreseen and may be required in the future. Communication between traffic control centres, signal boxes, and trains should enable any abnormal circumstance arising during the journey to be more quickly and efficiently dealt with, and if the practice of equipping trains with loudspeakers for the purpose of making announcements to passengers while travelling is extended, early notification of changes of connections could be given when normal timings are upset for any reason. Facility for passengers to make public telephone calls during the journey was tried out in Germany in 1926, and a little later in Canada, but, at the time, this service did not appear to have met with much response from the public. Another application, which, is, however, not directly connected with the subject at present under discussion, is the provision of emergency radio equipment for use as junction links between railway trunk exchanges during breakdown of normal circuits or to provide additional emergency junctions to cover abnormal traffic.

Operating and Technical Requirements.

When considering the design of apparatus to cover these various requirements, the desirability of using one standard method and type for as many purposes as possible should be borne in mind, as this would tend to simplify maintenance and operating instructions to the staff.

As has previously been stated, both inductive and radio systems have been found capable of giving a satisfactory service on railways. The inductive system has the advantage that Post Office authority is not required for its use and any frequency technically suitable can be employed. As in radio, a carrier is modulated by the audio input and modulation may be of any kind ; both amplitude and frequency modulation having been tried in tests on railways in the U.S.A. It is therefore possible to use the existing open line wires along the track to carry the transmission a considerable distance without interfering with their normal functions, but the increasing use which is being made of multi-channel open line carrier circuits makes it necessary to ensure that the inductive system does not cause interference to these. From this point of view, F.M. may be preferable for the inductive equipment. Power consumption of earlier types of inductive systems was high compared with radio, but the two methods are now about equal in this respect. There is the possibility of inductive communication proving useless, when perhaps the need for its use was greatest, owing to damage to the pole route by snow or gales.

Technical details of systems of this kind developed in America differ considerably. Frequencies between 7·5 kc/s and 250 kc/s have been employed and the transmitting and receiving coils on the train vary from small coils fixed in close proximity to the rails to large loops completely surrounding the engine or brake. The fixed stations are usually connected to the line wires through some form of impedance coupling which matches the transmitter and receiver to the lines. Practical ranges of 25 to 40 miles more under favourable conditions, have been achieved, signal/noise ratio being, as with radio, the main governing factor.

Coming now to consideration of space radio, many trials have been carried out in this country and abroad with various types of apparatus. Frequencies as wide apart as 1,675 kc/s and 2,660 Mc/s have been tried, and comparison made of the relative advantages of amplitude and frequency modulation. Frequencies much under 100 Mc/s appear, however, unsuitable on account of the limited space available for aerials.

Although British railways have for many years endeavoured to obtain authority for operating regular radio services, this has not yet been granted by the Post Office, although it is hoped permission will be given in the near future when international frequency allocations have been agreed.

As members of this Institution will be aware, the United States Federal Communications Commission has recently allocated 60 channels 60 kc/s wide between 158·4 and 162 Mc/s for exclusive use of railways, together with further channels for short distance shunting yard communication in the 44-108 and 186-216 Mc/s bands, shared with television and other services, while other bands are also available for experimental purposes. There is no definite information yet as to the frequencies likely to be allotted to British railways.

Another question of importance is that of the regulations which may be imposed as regards operating procedure. These must be as simple as possible, and any examination of railway staff which may be considered necessary before permitting them to operate, radio equipment should be reduced to the bare essentials. The design of the equipment should be such as to require the minimum number of controls, the ideal to be aimed at being the simplicity of an ordinary telephone. For simplex working, the send/receive switch should be incorporated in the microphone or hand set. For most railway purposes, simplex operation appears better than duplex, as the latter would reduce the number of channels in a specified band and necessitate means for changing frequencies, being provided when any two of a group of stations required to communicate with each other, e.g., driver, guard, and a signal box. Duplex operation would, of course, be practically essential for a public telephone service for passengers and for an emergency radio link between railway switchboards. The choice of frequencies to be used will, of course, depend on Post Office allocations, but should experimental work indicate that a particular band is technically more suitable to meet the peculiar conditions inherent in train communication, it is hoped that this point will receive due consideration when definite allocations are made. Ranges of five miles or so would be ample to cover the applications being considered here at the moment, and future possible uses would not be likely to require a range exceeding about 25 miles.

Details and Results of Tests.

Trials to date indicate that the above requirements can easily be covered by comparatively simple apparatus operating at frequencies of 80 to 160 Mc/s in normal country, but difficulties arise in mountainous terrain with deep cuttings and tunnels. The problem of communication between guards and drivers of long goods trains in tunnels and from trains in tunnels to points outside, particularly when the tunnel is not straight, requires investigation. It is reported from the United States that very promising results have been obtained by the use of apparatus operating on 2,660 Mc/s. This was manufactured by the Sperry Gyroscope Company, and was tried out on the Chicago Rock Island and Pacific Railroad over 160 miles of track in difficult country in the

Rockies, including a number of tunnels, one of which, Moffat tunnel, is over six miles long. This equipment operated with a power of 10 watts, frequency modulation transmitting a band 150 kc/s wide and used velocity modulated klystron valves. The aerial on the engine consisted of six units mounted one above the other, each unit consisting of three horizontal dipoles and a bi-conal reflector. This arrangement gave 360° coverage in the horizontal plane, but limited vertical spread to that sufficient to cover tilting when on gradients. Aerial gain was about 10. Fixed stations had eight units in the aerial stack.

It is reported that, except for short interruptions of 15 to 20 seconds in unusually difficult country with hills and deep cuttings, signals were consistently strong round curves, through gorges and even in the six-mile Moffat tunnel. The good results obtained in tunnels are considered to be due to the tunnel acting as a wave guide at this frequency.

Another method of overcoming the difficulty of absorption of radiated energy by the tunnel walls has been tried out on the Baltimore and Ohio railroad in a 2,760 ft. tunnel at Mount Airy by the Bendex Aviation Corporation, using 158·19 Mc/s.

A screen of six copper wires 3 ft. wide was run near the crown of the tunnel with a single insulated conductor 10-in. below. This system of wires was connected to aerials located on hills at each entrance to the tunnel. It is reported that when the transmitter was operated a mile from the tunnel mouth, signal strength within the tunnel compared favourably with free space transmission and there was no noticeable variation at different positions in the tunnel.

Experiments have been carried out to test the relative advantages of amplitude and frequency modulation, but here the specialists seem to have wide differences of opinion. After listening carefully to their arguments, one gains the impression that, so far as the type of communication under review is concerned, the choice of a standard method will mainly depend on details of design of the apparatus.

As with all mobile installations, a very important consideration is the effectiveness of A.V.C. to keep a steady output volume when signals vary over a wide range. Signal-to-noise ratio, is, of course, a problem common to all radio communication. It is understood that considerable improvements have been made in amplitude modulated mobile equipment as regards A.V.C. and noise suppression, and it would seem that either kind of modulation can be made to give good results in normal circumstances. More experimental work is, however, required to decide the best method and most suitable frequency band for reliable communication under all conditions likely to arise, including the case of a long curved tunnel. Much improvement may also be possible in the design of aerials suitable for mounting in the limited space available on locomotives and necessarily close to large masses of metal. Other features to be considered are power consumption, bulk, weight, ease of operation and maintenance, reliability, and cost.

The London and North Eastern Railway, with which the author is associated, has taken advantage of every opportunity to demonstrate the advantages of radio for railway operation, and tests have also been carried out on other lines in this country. As an indication of the work done here in recent years, particulars will be given in the following of apparatus tried out and results obtained in tests made on the L.N.E.R. during the last three years or so.

The first three demonstrations to be described were given during the war, mainly for the purpose of showing the possibilities of the use of radio to non-technical officers. Very strict conditions were imposed by the Post Office for security reasons including a very limited time period for the trials, and it was therefore not possible to make much detailed investigation.

The first of these tests was made in September, 1943, to demonstrate driver-to-guard communication on a train of 50 wagons travelling from London to Hitchin via Hertford. This route passes through Ponsbourne and Molewood tunnels, the former being 1½ miles long.

The radio telephones used were Redifon R.G.3 type, manufactured for British Overseas Airways by Messrs. Rediffusion, working on 77·15 Mc/s, amplitude modulated with a power of 0·6 watt in the aerial. Frequency stability better than ± 0·1 per cent. was obtained by means of a temperature compensated master oscillator. A voice frequency band of 50-5,000 cycles was transmitted and quality and intelligibility of speech were very good. Visual and audible calling indications were incorporated, operated by modulating the carrier at 7 kc/s. Lifting the hand-set automatically brought the transmitter into action and send/

receive switching was operated by a switch in the hand-set via a Bowden wire incorporated in the hand-set cord. Power consumption was about 50 watts from a 24-volt battery.

For convenience, the equipment at the front of the train was installed in a guard's van and not on the engine. The aerials were horizontal di-poles mounted about 6 in. above the roofs of the guard's vans at each end of the train. Communication throughout the journey was very good, except in tunnels where signals faded out completely. When the train was partly in the tunnel and partly in the open, it was found that communication was possible with the receiving end considerably farther in the tunnel than the transmitting end.

In March, 1944, a trial was made with the same type of apparatus and the same frequency between a local passenger train and Gordon Hill signal box on the same line as the previous test. The same type of aerial was used, that at the signal box being fixed at a height of about 20 ft. Communication was established with the signal box for a distance of about two to three miles on each side.

In April, 1944, a demonstration designed to show the possibility of connecting a radio link with a train to the Company's trunk telephone network was given to the chief officers of the Company. Peterborough, at which a railway trunk switching exchange is situated, was chosen as the point for making the connection. The only set available at the time for installing in the train was a Marconi T.P.6, and the frequency used, 1,675 kc/s, can hardly be considered ideal for the purpose. The aerial on the roof of the saloon used for the test was a loop of insulated wire supported a few inches above on bobbin insulators, both ends of the loop being connected to the aerial terminal of the set, and the earth terminal connected to the under frame of the saloon. Other arrangements were tried, but time was too limited to do much in this direction. The audio input and output of the fixed radio station was connected through a manual " send/receive " switching unit to a jack on the trunk exchange. It may here be remarked that the operator who had to listen in at Peterborough to the conversation and switch the direction of transmission of the radio channel performed this arduous duty very creditably, especially as some of the speakers were not much accustomed to " Over to you " procedure.

Communication between the train travelling northwards was established at Biggleswade, about 33 miles from Peterborough, and no difficulty was experienced in holding conversations with offices in London, in some cases through two railway switchboards, in addition to that at Peterborough.

Tests of a more extended and technical nature have been carried out during the last two years by the General Electric Company, in the Bradford area of the L.N.E.R. This area, on the backbone of the Pennines, was chosen because the terrain is as difficult from a radio transmission point of view as any likely to be encountered in this country. Owing to the gradients, tests on long trains have have not been possible. A demonstration of engine-to-rear guard's brake communication was given in December, 1945, on a short passenger train of three coaches. Tests were also made from the train to the General Electric Company's station at Wibsey. A frequency of about 80 Mc/s was used with a power of 7 watts in the aerial. Both frequency and amplitude modulation were employed, the engine transmitter being F.M. and the brake A.M., but there was no provision for comparing the two methods under similar conditions of external noise level during the demonstration. Aerials were ¼ wave vertical rods. The trial was made over the route Bradford-Halifax, Halifax-Keighley, Keighley-Bradford. Communication between engine and rear brake was satisfactory under all conditions, including tunnels. Noise level on the tank engine was very high, particularly in tunnels on up grades. Under such conditions, loudspeaker reception was not sufficient, but, using an ear-piece in addition to the loudspeaker, speech was quite intelligible. Communication between the train and Wibsey was very variable and quite impossible in tunnels and deep cuttings.

A further demonstration was given in September, 1946, between a train and the signal boxes at Cullingworth and Ingrow in the same area as the previous test. This section of line passes through Lees Moor tunnel, 1,527 yds. long, which has two bends in the form of a letter " S." The equipment used on this occasion was designed for police and similar mobile services, and operated on about 81 Mc/s frequency modulation, being used with a maximum deviation of 12·5 kc/s. Aerial power was about 10 watts. Power consumption from a 12-volt battery was 4 amps., receiving and 16 amps., transmitting. Aerials were ¼ wave vertical rods as the previous tests, these being mounted on short poles 15 ft. high at the signal boxes.

The trial was mainly staged to demonstrate train-to-signal box communication under the most difficult conditions that could be imagined, and owing to the bends it was necessary to instal three relay stations in the tunnel, two being 360 ft. and 1,320 ft. respectively from the Cullingworth end and the third 350 ft. from the Ingrow end. These relays were operated manually, but in practice they would, of course, be automatic and unattended and would have to work on staggered frequencies.

The tunnel sets and aerials were similar to those on the engine and in the signal boxes, the aerials being mounted on spikes driven into the ballast midway between the " Up " and " Down " tracks. With this arrangement, communication could be obtained with one or other of the relay stations from all positions in the tunnel and, in the open, there was no difficulty in speaking to one or other of the signal boxes. Transmission between the two signal boxes was also quite satisfactory. Direct transmission round bends in the tunnel was not found to be possible.

Although the demonstration proved that communication can be effected, by the use of relay stations, on frequencies of the order of 100 Mc/s under the most onerous conditions likely to arise, a simpler and cheaper solution to the problem is obviously desirable. Possibly the answer will be found in the use of much higher frequencies on the lines of the American experiments referred to earlier.

The application of radio to marshalling yard working was demonstrated in August, 1946, by Messrs. Pye Telecommunications, Ltd., using their standard mobile equipment, in Whitemoor Yard near March. The frequency used was in the 70-100 Mc band amplitude modulated and aerial power 12 watts. The carrier frequency was crystal controlled, crystal frequency being multiplied nine times in two stages, A.V.C. and a form of partial squelch to reduce background noise in the absence of a signal were incorporated. Power consumption from a 12-volt battery was 5·7 amps. receiving and 12·7 amps transmitting. The A.F. amplifier (10-12 watt) could be used for feeding either the transmitter or a public address type speaker. Normal reception was on a small cabinet speaker. One set of equipment was installed on a diesel-electric shunting engine and a similar set in the shunter's cabin. Clearances between diesel locos and the loading gauge are very limited and the fixing of aerials presents some difficulty; the aerials used in the test were horizontal di-poles mounted across the loco just in front of the cab on the metal roof of the engine housing, clearance being only about three or four inches. Under these conditions, the aerials were directional, but the angle of coverage was found sufficient. A similar aerial was fixed to the top of one of the hump shunting signal posts.

Shunts were carried out with the three-position semaphore signals, normally used to control the rate of shunting, out of action to demonstrate the greater flexibility of radio.

The apparatus covered the requirements very satisfactorily, very good transmission being obtained when the engine was three miles away from the shunter's cabin. Three miles did not represent the maximum range of the equipment, even with the inefficient aerial used on the loco, but there was no opportunity to test at greater range. For practical purposes, less powerful equipment giving a much smaller range, say about one mile, would be adequate.

The latest application of radio to moving train communication is the equipment on the train specially built in this country for the Royal tour of South Africa.

In addition to provision of broadcast reception, a Marconi short wave transmitter and receiver were provided in the pilot train for high speed telegraph transmission of Press reports and general communications while the train was moving or stationary. The main transmitter was automatically keyed by a high speed wheatstone transmitter fed by tape prepared by a keyboard perforator.

From the point of view of this paper, however, perhaps the most interesting part of the equipment is the frequency modulated V.H.F. radio telephones provided by the General Electric Co. Ltd. These were for the purpose of enabling the pilot and Royal trains to be in constant communication with each other. The apparatus was of the type widely used in the United Kingdom for police cars and the fire services but this is the first time it has been put to practical use in a train built in this country.

It is hoped that details of the performance of this apparatus in different kinds of country encountered during the tour will be made available for the guidance of those interested here.

Conclusion

Apart from communications, developments in electronics open wide fields for possible improvements in railway operation. Television may have uses in signal boxes which control level-crossing gates out of sight of the signalman. Radar safety devices may be developed to prevent collisions. The possibility of adapting radar to cover the peculiar requirements of traffic confined to definite tracks and the necessity of ensuring that, so far as possible, any failure will not lead to lessening of the safety factor is now being examined. Economies may be effected in the number of conductors required for signalling functions and indications by the use of selective frequency control. It will be apparent that British railways are fully alive to the advantages of making use of many modern developments in electronic engineering.

Acknowledgments

The author desires to express his thanks to Mr. J. C. L. Train, M.C., M.Inst.C.E., Chief Engineer, London and North Eastern Railway for permission to read this paper and to Mr. A. E. Tattersall, M.I.E.E., F.Inst.P., for his kind collaboration and advice during its preparation. He also wishes to acknowledge his indebtedness to Messrs. Rediffusion Ltd., the General Electric Company, and Pye Telecommunications, Ltd., for much useful information with regard to the apparatus used for the demonstrations, and advice on the subject generally.

CONVENTION DISCUSSION

Mr. P. Adorian (Member): It is a great pity that the development of railway communications has been considerably hampered owing to difficulty in obtaining wavelengths for this purpose. It is hoped that after the coming international discussion on wavelength allocations the Post Office will see its way to make available certain suitable wavebands for railway communications for operational and experimental purposes, so that railway communication in this country should have the same facilities for free and unrestricted development as in America.

In my opinion, the most useful purpose that radio communication can serve on trains in Great Britain is to act as a link between the engine driver and the brake van, particularly in the case of long goods trains. It would seem that the eventual solution for this purpose will be a radio link using wavelengths which are small compared with the distance between the train and tunnels, that is, wavelengths of the order of 3-10 cms. Using such wavelengths, a radio transmitter with a carrier power of not more than 0·5 W. should be able to give 100 per cent. communication facilities between engine driver and brake van, even with the longest trains and under all conditions.

Later on, the Chairman asked whether anybody in the room had had practical experience of radio communication on trains and Mr. Adorian made a second contribution as follows:

I took part in the experiments in March, 1944, which were mentioned by Mr. Leversedge, and I also had the experience, about 20 years ago, of talking on a railway telephone available to the travelling public between Berlin and Hamburg.

May I take this opportunity to refer to another speaker's comments on using radio I.F.F. systems on trains as an anti-collision device. While from the radio engineer's point of view this is an interesting proposition, I would have thought that for British railways, a system similar to that adopted by the G.W.R. which even stops a train if it goes past a stop signal, would be quite foolproof on account of its simplicity, reliability and lower cost, and thus preferable to a radio system.

Mr. McMichael (Member) referred to the earlier work of pioneering of L.N.E.R.—notably in 1924, when special tests were made by R.S.G.B. transmitting and receiving on " Flying Scotsman " when C.W. morse sitnals were transmitted and received to many radio stations between Kings Cross and Newcastle. Range of 100 miles 2-way and 175 miles transmission. Twenty amateur stations took part.

Mr. Hayhoe (Associate): There appears to be a field open for exploration incorporating a transmitter and visual receiving equipment on the train, triggering off a transponder/s at fixed point/s ahead.

This would be a form of I.F.F. as used during the war and would appear to have possibilities in conditions of bad visibility by indicating to the train driver that the track ahead was clear for a known distance. Intelligence could be transmitted to a limited extent by coded responses.

REPLY TO THE DISCUSSION

Mr. G. H. Leversedge : The opinion expressed by Mr. Adorian that the eventual solution of the problem of maintaining radio communication in tunnels will be the use of wavelengths which are small compared with the distance between trains and tunnel walls, i.e., of the order 3-10 cms. is very interesting.

As has been stated, experiments have been carried out in America on these lines, and the railways in this country have asked for permission to experiment with similar equipment.

Such short wavelengths would involve the use of types of equipment of which many of us have as yet no practical experience, but if it is found possible by these means to solve outstanding problems, the design of compact reliable apparatus which would be simple to operate and maintain, and produce at a reasonable price would appear to be well worth investigation.

With regard to train control, the G.W.R. system certainly has the advantages of simplicity and comparatively low cost.

It is always best to use the simplest means practicable to achieve any result, particularly in signalling where failures may cause delays to traffic or possibly a lessening of the safety element.

There are, however, cases where use of more complicated equipment can be justified by economies which can be effected; e.g., in line wires, by its use.

Mr. McMichael's reminder of the experimental work carried out by him on the L.N.E.R. in 1924 is very interesting especially when one considers that the results obtained compare favourably with the range of modern inductive telephone equipment now in use in America.

Mr. Hayhoe's suggestion to use a form of I.F.F. to indicate that the section of line ahead of a train was clear, could no doubt be made to work, although there appear to be some interesting problems to be solved before a practical system could be evolved.

Suggestions to use radar for the prevention of collisions on railways have been made frequently since the war, but any method depending on reflections from the train ahead would appear to be applicable only to single lines. Where more than one pair of rails existed, coding would be necessary to distinguish between trains on different tracks involving transponder equipment which would be subject to failure and loss of safety element. Mr. Hayhoe's suggestion, however, would be an adjunct or alternative to the fixed signals. A considerable amount of intelligence would have to be transmitted by the use of different codes or carrier frequencies to provide for four or possibly more signal aspects and to distinguish between signals applying to different lines. The aspects commonly displayed by modern colour light signals are (1) red, (2) single yellow, (3) double yellow, and (4) green, and these may be increased in the future. Apart from these, there are signals with special functions which might require to be included in the coding scheme. One of the most difficult practicable problems would appear to be that of automatically modifying the response of the receiver when the train was switched from one line to another.

The present method of increasing safety and reducing delay due to fog is the use of electrically lighted colour light signals with efficient optical systems concentrating the light into powerful beams, and the relative cost, effectiveness and reliability of any alternative system would have to be carefully compared before its adoption could be justified.