The Journal of

THE BRITISH INSTITUTION OF RADIO ENGINEERS

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"To promote the advancement of radio, electronics and kindred subjects by the exchange of information in these branches of engineering."

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34th ANNUAL REPORT OF THE COUNCIL OF THE INSTITUTION

The Council has pleasure in presenting the 34th Annual Report of the Institution which reviews the proceedings for the twelve months ended 31st March, 1960. The Annual General Meeting will be held on January 11th, 1961, at the London School of Hygiene and Tropical Medicine, Gower Street, London, W.C.1, commencing at 6 p.m. (The Agenda was published in the November Journal).

INTRODUCTION

THROUGHOUT this Report there is evidence of the Institution's continued expansion. Concurrently with increasing work in the education field was the number of members' meetings, a still further increase in *Journal* output, and increasing recognition of the value of the Institution's work.

Transcending those activities, however, was the work undertaken by the Council leading to the decision to recommend to members that the Institution should submit to Her Majesty's Privy Council a Petition for the grant of a Charter of Incorporation.

Such a recommendation could not lightly be undertaken; indeed, there had been a lapse of fourteen years since the 1947 Council first appointed a Committee to examine the possibilities of the Institution being able to justify the honour of a Charter. There is now considerable evidence of the Institution's status and of the continued expansion of its work. There is also proof that the declared objects of the Institution will continue to be implemented in such a way as to fulfil the obligations which would be imposed by the granting of a Charter.

Accordingly, the Council was unanimous in authorizing the Professional Purposes Committee, in consultation with Counsel and the Institution's Solicitors, to prepare a Petition. In the event, as related in the editorial to the March 1960 *Journal*, the approval of the corporate members was sought and unanimous approval given to the lodgement of the Petition.

Subsequent developments do not come within the purview of this Report and the final decision of Her Majesty's Privy Council will not be known until 1961.

This Report includes final comment on the last Convention. The success of this side of the Institution's activities has for long been evident. The Institution's Conventions are traditionally based on the disclosure of details of new work. Immediately after the 1959 Convention consideration was given to the desirability of making plans for 1961 and once again the initiative has been taken in planning the first Convention of its kind in Europe on "Radio Techniques and Space Research."

As the following pages reveal, therefore, the thirty-fifth year of the Institution has shown that every aspect of Institution activity has been further developed with, it is believed, satisfaction to the membership and considerable confidence in the ability of the Institution as a whole to fulfil its objects and to meet the challenge of the future.

PROFESSIONAL PURPOSES COMMITTEE

More meetings of the senior Committee of the Institution have been held during the twelve months under review than at any other time in the Institution's history. In particular this Committee has had responsibility for the work involved in the preparation of the Petition to Her Majesty The Queen's Privy Council for the grant of a Charter of Incorporation. For this purpose, the Committee has been assisted by several Past Presidents of the Institution. The Council also wishes to acknowledge the assistance given by Mr. C. Gray Hill, of Braund & Hill, Solicitors to the Institution, and by Sir Lynn Ungoed-Thomas, Q.C., M.P.

The following Officers constituted the Charter Committee and have acted as Petitioners on behalf of the Institution:—

Admiral of the Fleet The Earl Mountbatten of Burma, K.G., P.C., G.C.B., G.C.S.I., G.C.I.E., G.C.V.O., D.S.O., LL.D., D.C.L., D.Sc. (*Vice-Patron and a Past President*).

Leslie Herbert Bedford, C.B.E., M.A., B.Sc., F.C.G.I. (*Past President*).

William Edward Miller, M.A. (*Past President*).

Paul Adorian, F.C.G.I. (*Past President*).

Rear Admiral Sir Philip Clarke, K.B.E., C.B., D.S.O. (*Past President*).

George Armstrong Marriott, B.A. (*Past President*).

Professor Eric Ernest Zepler, Ph.D. (*President*).

John Leslie Thompson (*Vice-President*).

Colonel George William Raby, C.B.E. (*Vice-President*).

Air Vice-Marshal Colin Peter Brown, C.B., C.B.E., D.F.C. (*Vice-President*).

Professor Emrys Williams, Ph.D., B.Eng. (*Vice-President*).

Subsequent events will fall into the next year of the Institution and will be referred to in the 35th Annual Report.

History of the Brit.I.R.E.—The legal advisers to the Institution recommended that a history of the Institution should be prepared as a supplement to the Petition for a Charter. Accordingly a complete history of the Brit.I.R.E. since its foundation in 1925 was compiled under the direction of the Professional Purposes Committee. Under the title "A Twentieth Century Professional Institution" the book provides an objective and critical evaluation of the whole work of the Institution. It has now been made available to all members.*

Election of Officers and Council for 1961.—It is hoped that a decision on the Petition for the grant of a Charter to the Institution will be made known during the first few months of 1961. In the event of the Petition being successful, the Charter will nominate the Charter President, other Officers and members of the Council.

In view of this possible development, the Council feels that corporate members will not wish to vote at the Annual General Meeting on the election of new Officers and Council who may only take office for a matter of a few months. Accordingly, the President, Professor E. E. Zepler, the existing Vice-Presidents, members of Council and the Honorary Treasurer are prepared to continue in office until the result of the Petition is made known.

Institution Accommodation. — Previous Annual Reports have referred to the Institution's accommodation problem. Although alterations have been made to the present building to accommodate new staff, it is impossible to extend still further. During the year, therefore, there has been renewed activity in an endeavour to secure a suitable freehold site for the erection of a building, or to obtain a building which would lend itself to reconstruction.

An approach was also made to the Ministry of Works and in the latter part of the year the Ministry advised the Council that they would be prepared to help the Institution to acquire additional property adjacent to 9 Bedford Square. Negotiations are now in progress for permission to make the necessary structural alterations to the two buildings in order to provide a lecture theatre, adequate Library and Committee rooms, and sufficient accommodation for the Institution's administrative staff.

* "A Twentieth Century Professional Institution" is available from the Institution, price 30/-.

Parliamentary and Scientific Committee.—The Council welcomed the decision of the Parliamentary and Scientific Committee to hold its first Conversazione in December 1959. A representative of the Institution served on the organizing Committee and through the Institution a number of radio and electronic exhibits were shown.

The Conversazione was held at the Royal Society, London, and a report on this activity of the Parliamentary and Scientific Committee was given in the January 1960 *Journal* of the Institution.

Conference of Local Section Representatives.—Nearly all the Sections in Great Britain were represented at the meeting held in London on 23rd April, 1959 and useful discussions took place on the proposals for revision of the Bye-laws affecting the constitution of Local Section Committees. A number of suggestions for improving liaison with the main Programme and Papers Committee were made and during the past session these have been implemented, particularly in the contributions made to Section programmes under the sponsorship of the Specialized Group Committees.

The Conference terminated by the local Section delegates attending a dinner of the Council and its Committees, as reported in the May 1959 *Journal* (p. 288).

Research Scholarship Fund.—The Council has accepted a recommendation made by the Professional Purposes and Finance Committees that the Institution should establish a Research Scholarship Fund. A Committee has been appointed and recommendations on the purpose of the Committee and the endowment of Research Scholarships will be laid before members in due course.

Commonwealth Activity.—Further extension of Institution activities overseas is planned, and discussions are proceeding with a view to holding exploratory meetings in the near future in Kenya; members in the Federation of Malaya are also interested in the possibility of a Section being set up in that area.

The Professional Purposes Committee is also currently reporting to Council on the best means of meeting requests for the visit of an Institution representative to meet members in India, Pakistan, Australia and South Africa.

It has already been agreed by Council that, in order to review the whole of the Institution's work in Canada and to see how far it is possible to develop the activities of the Canadian Advisory Committee, an Officer of the Institution shall visit Canada during the next twelve months.

MEMBERSHIP COMMITTEE

The Eighth Edition of the List of Members was published in March 1960 and circulated to all members. This List emphasized that membership of the Institution is international in character.

In London alone 2,311 new enquiries about membership were received during the year and this number does not, of course, take into consideration enquiries received and answered by local section secretaries in the United Kingdom and overseas. The Committee takes this opportunity to acknowledge the work done by local secretaries in dealing with those enquiries.

During the year 1,450 proposals were considered by the Membership Committee for election or transfer to the various grades of membership. Table 1 gives details of the elections and transfers considered and approved by the Committee for the past year, excluding studentship registrations.

Comparison with the equivalent figures for the previous year shows that the rate of increase in the number of corporate members has been maintained whilst in the case of Graduates a record number of elections and transfers has been recorded. In past years the Committee has had to comment, as indeed have other engineering Institutions, on the apparent decline in the number of students registering with their appropriate professional Institution. It is therefore gratifying to report that the Brit.I.R.E. had an increase of students during the year. A total of 498 studentship registrations were approved during 1959-60 and losses amounted to 324 by resignation, removal and death, whilst an additional 134 qualified for transfer to a higher grade of membership.

Whilst the number of applicants for registration increased it was noticeable that the majority held academic qualifications in excess of the minimum qualifications laid down. This suggests that in future a greater percentage of students will qualify for transfer to Graduate than in previous years. The Common Preliminary Examination conducted by the Engineering Joint Examination Board which has been adopted as the basic education requirement for studentship registration has been discontinued. Candidates from the United Kingdom will now be required to submit passes at ordinary level in the appropriate subjects of the General Certificate of Education or an equivalent qualification. Overseas candidates applying for registration will be expected to offer similar qualifications, for example, either the General Certificate of Education conducted by the University of London or, alternatively, the Cambridge Overseas School Certificate. All candidates must have passed in the following subjects:—English Language, Mathematics, Physics and either a further Science subject or, alternatively, a foreign language.

Membership Growth.—On 31st March, 1960, the *effective* total membership of the Institution was 6,332. As shown in past Reports, there is a consistent growth in membership and the present figure compares with 5,392 five years ago (1956).

Honours.—Once again the Council has particular pleasure in referring to the fact that members of the Institution were included in Her Majesty's Birthday and New Year's Honours List. Notices have already appeared in the July 1959 and January 1960 *Journals*.

Honorary Member.—In recognition of his work in the field of television and medical electronics Dr. V. K. Zworykin was elected an Honorary Member. The members assembled at the 1959 Convention endorsed the Council's decision and the Convention provided an opportunity to present certificates not only to Dr. Zworykin but also to Mr. E. K. Cole whose election was reported last year.

Appointments Register.—There has not been any increase in the number of members seeking

Table 1

Elections and Transfers for the year ended 31st March, 1960
(Excluding Studentship Registrations)

	Total considered	Approved						
		Honorary Member	Member	Associate Member	Companion	Associate	Graduate	*Total*
Direct Elections	505	1	7	88	—	89	190	375
Proposals for Transfer	428	—	18	140	—	12	107	277
Proposals for Reinstatement	19	—	—	3	—	6	7	16
Totals	952	1	25	231	—	107	304	668
Losses during the year								
Resignation, Removal or Decease		1	5	35	1	38	66	146
Transfers to other grades		—	—	18	—	29	96	143
Totals		1	5	53	1	67	162	289
Net gain in membership		—	20	178	—1	40	142	379

assistance in finding new or alternative appointments. On the contrary, the number of applicants continues to decrease whilst the demand from industry and other employers still increases. Only 31 members applied for assistance in securing alternative employment and 199 introductions to prospective employers were afforded.

EDUCATION COMMITTEE

This is the first Annual Report of the Education Committee since it was established as a separate entity in 1959. The first meeting was held on 2nd June and a further nine meetings were held during the year under review.

Report on the Education and Training of the Professional Radio and Electronic Engineer.—One of the first tasks of the Education Committee was to prepare a report on the education and training of the professional radio and electronic engineer. Much of the Committee's future policy in terms of the various qualifications available has now been laid down in this report.*

The Graduateship Examination.—The Committee has also undertaken during the year under review a detailed study of the syllabus of the various parts of the Graduateship Examination with a view to recommending to Council various changes in content and standard for both Section A and Section B. The last substantial change in the syllabus was introduced in November, 1956. As far as Section A is concerned, it is intended to introduce one further three-hour examination paper in the subject of Physics in May, 1962. There will be a slight re-organisation of the syllabus content of the existing Parts 1 and 2 of the examination.

It is proposed that Section B shall also be extended and the Committee has in mind that Advanced Radio Engineering and Advanced Electronic Engineering, at present forming alternatives in Part 4, will become two separate compulsory subjects.

Two other suggestions that are at present being studied by the Committee are examinations in Industrial Administration and in English.

The Higher National Certificate.—Changes in the Graduateship Examination are bound to be reflected in the exempting qualifications accepted by the Institution and this is certainly true of the Higher National Certificate in Electrical Engineering. The Committee has already commented in the report that the H.N.C. is likely to remain as a widely used route to membership of the Institution and it is recommended that this route be allowed to remain open. There are disadvantages in the acceptance of the Higher National Certificate, particularly in regard to the wide variations in standard and content, despite assessment by the Institution. This is particularly noticeable in the treatment of Radio and Electronic Engineering, although in recent years many colleges have introduced syllabuses designed to meet the Institution's recommendations.

This variation has been offset by making grants of exemption dependent upon the college at which the National Certificate was taken. The Committee proposes to require in future that all courses be formally submitted for individual consideration.

After 1963 the minimum requirement for full exemption in terms of a Higher National Certificate in Electrical Engineering will be as follows:—

Ordinary National Certificate

1. Credits in all subjects in the S3 examinations.
2. Physics (heat, light and sound) endorsement (50 per cent.) to the Ordinary National Certificate.
3. The final year of the Ordinary National Certificate (S3) should contain a substantial proportion of Electronics (up to 40 per cent. is permitted by the existing regulations).

Higher National Certificate

1. Credits in all subjects in the A2 examinations.
2. Mathematics to be a subject in both years.

* *J. Brit.I.R.E.*, **20**, pp. 643-56, September 1960.

3. Radio or Electronic Engineering should comprise at least one complete subject in each year.
4. An A3 endorsement in a specialist Radio or Electronic subject the standard to be beyond A2.

This exemption will be dependent upon acceptance of the course by the Institution.

City and Guilds of London Institute.—In the previous Annual Report it was indicated that the new examination scheme for Telecommunications Technicians (subject No. 49) would not secure exemption from the Graduateship Examination on the same basis as that previously accorded to Telecommunications Engineering (subject No. 50). One of the early tasks assigned to the Education Committee was the consideration of this point and in particular the precise recommendations for exemption to be granted. Candidates who hold Telecommunications Technicians' Certificates will be granted exemption from Parts 2 and 3(i) of Section A. No further exemption will be granted to holders of supplementary subjects (No. 300) and candidates with individual subject certificates which do not form a group certificate will not be considered for exemption.

Co-operation with Technical Colleges.—The Committee is grateful to the colleges and universities who were so quick to provide information on their courses for the Committee's Education and Training Report. There was a 90 per cent. response to the Institution's questionnaire and this provided information not only for the immediate report but for future reference and in particular for the work on National Certificates.

Crowther Report.—Many of the recommendations of the Crowther Report, in particular those concerned with additional time for study, block release and sandwich courses, had been adopted wholeheartedly by the Education Committee and incorporated in the report on education and training.

It is likely to be many years before the number of candidates being trained by sandwich courses reaches anything like the number at present being trained to professional standards by part-time day and evening class courses. It is largely for this reason that the Education Committee's report emphasises the need to continue to accept persons trained by this part-time method.

Naturally the Education Committee is very anxious that everything should be done to increase the amount of time available for academic study. Syllabuses are constantly expanding and higher standards required.

Relations with the Defence Services.—Representative members from the Royal Navy, the Army and the Royal Air Force serve on both the Education and Examinations Committees thus implementing the policy of Council to foster co-operation between professional engineers whatever their sphere of employment.

As mentioned in the previous Annual Report, the Directorate of the Royal Electrical and Mechanical Engineers and the General Council of the Institution had agreed to appoint a joint "working party" which would examine common matters of technical education and qualification. The working party was also required to make comment on submitting success in the Institution's Graduateship examination as a qualification which would be approved for the purposes of obtaining a Commission in the Royal Electrical and Mechanical Engineers Corps. The working party, which included Mr. R. H. Garner (Chairman of the Institution's Education Committee), met on a number of occasions and included in their report are agreed views on the acceptance of the Graduateship Examination in respect of Officers specializing in radio and electronics.

The Royal Air Force has also approached the Institution with regard to the acceptance of various courses for exemption. The Electrical Engineering Cadet Course at Henlow is already accepted, as reported last year. The equivalent course, the Technical Service Entrant Course, designed for officers already serving in the R.A.F., has also been accepted on an equivalent basis. Two other courses, the Air Electronics Officers' Course and Air Signallers' Course, have been accepted for exemption from Part 2 of the Graduateship Examination. Since many officers accepted for training on these two courses already hold G.C.E. Advanced Level passes in Physics and Mathematics, this decision enables such officers to secure exemption from the whole of Section A of the Graduateship Examination.

Symposium on the Training of Radio Apprentices.—Another example of Service co-operation with the Institution is shown in the symposium which was jointly arranged by the South-Western Section of the Institution and the authorities at the R.A.F. Radio Apprentices' School at Locking, near Weston-super-Mare, on 7th October, 1959. Over one hundred members and guests attended this symposium, which proved extremely valuable. Summaries of the papers were published in the September 1960 *Journal*.

EXAMINATIONS COMMITTEE

The Examinations Committee is now responsible for all matters pertaining to the Graduateship Examination arrangements and for determining the acceptable exempting qualifications.

Graduateship Examination Entries and Results. The conditions for entry to the Graduateship Examination were revised in November, 1959, and it is not easy, therefore, to compare the results obtained in the May and November examinations except in respect of the number of candidates entering and qualifying for election or transfer to Graduate or Associate Membership.

Previously candidates could take one or more subjects at one sitting and were credited with a pass in the subjects in which they were successful. In November, 1959, however, the Examination was divided into two separate sections, Section A and Section B. Candidates are now required to complete Section A before entering for Section B and must sit all parts of a section at one sitting, other than those parts which they have previously passed or from which they have been exempted. Candidates unsuccessful in one or more parts are failed in the section as a whole unless, in the case of failure in one part, they reach a standard which the Examinations Committee considers adequate to allow them to sit that one subject again.

The results in the May and November, 1959, examinations are shown below; where available the comparative figures for 1958 are given in brackets.

Past Annual Reports have referred to the gradual decline in the number of candidates entering for the Graduateship Examination, since 1956, when the new syllabus and regulations were introduced. This decline now appears to have been arrested and the number of entries seems to have stabilized at approximately 800 each year.

Exemptions. The number of applications for exemption from the Graduateship Examination continues to rise with the increasing number of applications for membership of the Institution. The majority of the applications are based on University degrees and the Higher National Certificate and endorsement subjects and in accordance with the published regulations. The Committee however has to consider many applications which are based on qualifications not published in the schedule of exempting qualifications and these always require careful consideration of syllabuses.

During the year 497 applications were received and of these 159 were granted exemption from the entire Graduateship Examination, and 282 were granted exemption from part of the examination.

MAY 1959	
Entries received	435 (425)
Candidates appeared	346 (322)
Number of candidates who succeeded in part	118 (105)
Number of candidates who by their success completed the examination requirements	35 (58)

NOVEMBER 1959		
Entries received	342	(392)
Candidates appeared	252	(285)
Candidates who succeeded in Section A	52	(105) succeeded in part
Candidates who succeeded in Section B	38	
Number of candidates who by their success completed the examination requirements	40	(33)

Courses for Approval. A feature of the work of the Examinations Committee over the past four years has been the number of applications which have been received from technical colleges for the assessment of Higher National Certificate and other courses for exemption purposes. Owing to the wide variation in standard and content it is essential that each course be examined in detail. The majority of the applications are from colleges which include in the final two years of the Higher National Certificate (A1 and A2) one Radio or Electronic Engineering subject in each year. Thirteen such courses were considered and their exemption confirmed from parts 2, 3 and 4 of the Graduateship Examination with the proviso that a candidate must obtain credits in the final year.

There were in addition four Higher National Certificate courses submitted in which three radio and electronic engineering subjects were included in the final two years. One course was approved for exemption from parts 2, 3, 4 and 5, provided that a candidate obtained credits in all A2 subjects. The remaining three courses await a final ruling by the Education Committee.

The Committee has also been consulted by technical colleges on the possible recognition which would be granted to courses which are not yet in operation, e.g. the proposed sandwich course in Electronics and Control Technology submitted by the Leicester College of Technology and Commerce and several proposed Higher National Certificate schemes from other colleges. Such consultation at the draft stage has the advantage that any deficiencies in syllabus or practical work may be rectified before the course is in operation.

Assessment of Examination Papers. Many colleges instead of running a course for an endorsement to the Higher National Certificate to secure exemption from part 5 of the Graduateship Examination, have introduced post-Higher National Certificate courses assessed by the Institution. This is a fairly novel feature of the Examinations Committee's work and it first started three years ago with two colleges. It has now expanded to eleven colleges submitting between them sixteen question papers and a total of 185 candidates. The Examinations Committee feels that this method of examination should be encouraged since it permits the Institution a much greater control of examination syllabus and standard.

Examination Prize Winners. Since the last Annual Report a new prize has been announced for the most successful candidate in the specialist subject of Television. The prize has been endowed by Associated Television Ltd. and it is awarded for the first time to the most outstanding candidate in this specialist subject in the 1959 examinations.

The Committee takes this opportunity to congratulate the following examination prize winners:—

President's Prize: Sujan, Chandu Sobhray (*Graduate*).

S. R. Walker Prize: Smikt, Oded (*Graduate*).

Television Prize: Cridland, William Wyndham (*Graduate*).

With the end of National Service and the reduction in the Armed Services the number of applicants sitting the Graduateship Examination whilst serving has fallen to a very small figure. For this reason the Mountbatten Medal has been withheld. The Committee is now formulating new terms of reference for the award of this prize.

Examiners. The Institution's examiners for 1959 have had the additional burden of assessment of college examination papers, although in some cases where the number of papers has been heavy in one subject, for example Electronic Measurements, additional examiners have been engaged. Council takes this opportunity of expressing thanks to those members who have assisted in this way.

The arrangements for the holding of the Graduateship Examination would also not be possible without the help given by the authorities at the examination centres. The number of centres used was 67 and in 1959 there were centres as far apart as Tahiti and San Paulo. In many of the small centres the British Council was of the greatest possible assistance in arranging accommodation and invigilation for the Institution.

TECHNICAL COMMITTEE

The most tangible and visible results of the Committee's work have been the reports and recommendations which have been prepared and published in the Institution's *Journal*. The Committee particularly concentrated on the series "Recommended Methods of Expressing Electronic Measuring Instrument Characteristics." Five sections have already been published, and work has commenced on the sixth. The titles of these six reports and their publication dates are as follows:—

1. A.M. or F.M. Signal Generators. *January 1958.*

2. Cathode Ray Oscilloscopes. *January 1959.*

3. Low Frequency Generators. *March 1960.*

4. Valve Voltmeters. *April 1960.*

5. A.F. and R.F. Bridges. *August 1960.*

6. Stabilized Power Supplies. *February 1961.*

There is an international effort to secure standardization of instruments, in particular valve voltmeters and signal generators. An essential prerequisite in these international deliberations is agreement on the method of expressing characteristics to be measured. In this respect the Technical Committee's work has been of some value.

A particular example of the need for an accepted method of expressing instrument characteristics was given in the December 1959 issue of *British Communications and Electronics*. This included a comparison of the characteristics of l.f. generators taken from the published literature of the manufacturer. A glance at the different methods which manufacturers employ to describe the same characteristic is full justification, were that necessary, for all the work of the Technical Committee in this field.

Consideration is now being given to the subject of reliability. Although a great deal has been published on this subject, the Technical Committee considers that a useful service could be provided by collating the published data on design for reliability.

The absence of national facilities for the measurement of fundamental electrical quantities at radio frequencies above 5 Mc/s gives cause for concern. Although these facilities exist in the establishments of the Ministry of Aviation, Inspectorates and the armed services, there is no impartial national laboratory which can make these facilities available to manufacturers.

Standards. An important aspect of the work of the Technical Committee is ensuring that the Institution is properly represented on all the appropriate B.S.I. technical committees. Representatives have been appointed to three new committees and three other representatives have been replaced. The full list of Institution representatives is given as an appendix to the report together with an indication of the work in hand.

During the year, Mr. H. A. Binney, Director of the British Standards Institution, gave a paper on "The Work of the B.S.I. in Relation to the Radio and Electronics Industry" which was published in the July, 1960, issue of the *Journal*.

The Council is grateful to all those members of the Institution who give their time so freely to representing the Institution on the various B.S.I. committees. The preparation of standards and specifications acceptable to all sides of industry is a most valuable contribution to productivity, safety and quality.

Technical Lectures. The function of the Technical Committee in providing a forum for lectures on specialist subjects has largely been taken over by the specialist groups. The Technical Committee hopes to foster a development of more general lectures providing a background on important subjects for the member not professionally engaged in those subjects. Examples of this type of lecture have been the two student lectures which covered the broad subjects of transistors and servo-mechanisms. In addition there has been some consideration of the inauguration of an annual itinerant lecture as suggested at a meeting of local section representatives. The Committee has in mind the possibility of an eminent person giving a review paper with an appeal to a wide audience.

PROGRAMME AND PAPERS COMMITTEE

The activities of the Programme and Papers Committee cover a very wide field, including such items as consideration of papers for publication in the *Journal*, co-operation with all Sections in the arrangement of meetings and symposiums, recommendations on the award of Premiums, and assistance in Conventions. It is difficult, therefore, to give prominence to one particular aspect in a year in which increasing activity has been recorded in every direction. Pride of place must be given, however, to the Convention held in Cambridge in July 1959. The theme—*Television Engineering in Science, Industry and Broadcasting*—attracted well over three hundred scientists and engineers from all over the world, most of whom took advantage of the residential facilities afforded in Downing College and Peterhouse.

During the four days of the Convention, fifty papers, lectures, and short formal contributions were presented, and arrangements made for appropriate discussions. Whilst all meetings took place in the Clerk Maxwell Lecture Theatre of the Cavendish Laboratory, it was necessary throughout the Convention to use an overflow lecture theatre connected to the main theatre by closed circuit television.

Institution Conventions have always been notable for their international character and on this occasion no fewer than eleven papers originated from overseas—four from the United States, four from Soviet Russia, two from France and one from Bermuda. The attendance was similarly international.

Meetings in Great Britain.—With three Specialized Groups adding their quotas to the programme of Institution meetings in London, and eight Sections actively engaged in promoting meetings in other parts of Great Britain, the 1959-60 Session represented the most active year in the Institution's history. The total of meetings held in the United Kingdom was eighty-nine, of which thirty were held in London and fifty-nine in the Sections.

The practice, started during the 1958-59 Session, of holding half-day symposiums in London was continued during the past session, and the Programme and Papers Committee sponsored three—Electronic Digitizing Techniques; Magnetic Recording Techniques; and Stable Frequency Generation. The Computer Group arranged a similar symposium on Input and Output Devices for Computers. All these symposiums were well supported, nearly two hundred engineers taking part in that on Magnetic Recording Techniques. It is the Council's intention to promote a similar number of meetings of this type during the coming session.

Overseas Meetings.—As stated in the last Annual Report, Mr. George A. Marriott, Past President of the Institution, visited Canada and as a result of his meetings with members in Toronto and Montreal it was agreed to establish Sections in both those centres. Particular mention must be made of the enthusiasm which has attended the opening of the Section in Montreal. Several meetings and visits were arranged during the first year of activity and the Montreal Section Committee has planned an even more ambitious programme for the forthcoming session.

The Sections in India, New Zealand, Pakistan and South Africa are continuing their work and programmes of meetings are arranged to enable members to discuss technical matters of particular local interest, as well as to learn of the most recent work in the various fields of radio. In this connection the overseas Committees have been pleased to arrange meetings at short notice at which engineers from the United Kingdom visiting their countries have given formal and informal papers. Members who are visiting any of the overseas countries in which the Institution has a local Section are therefore invited to get in touch with the local Committee either directly or through the Institution in London. It is certain that mutual benefit will result from such meetings.

Consideration of Papers.—The refereeing of papers submitted for inclusion in the Convention was shared by the Convention Committee and the Programme and Papers Committee. Out of a total of over sixty papers considered, it was possible to accept, either as submitted or with comparatively minor amendments, some sixty-five per cent. Of the remaining papers over half were regarded as likely to be suitable for publication if revised and the number of papers judged to be completely unsuitable for publication was very small. This reaffirms the Committee's belief that the leaflet *Guidance for Authors of Journal Papers* has been of great assistance in enabling authors to cast their material in the form suitable for the *Journal*.

Papers by authors from overseas again featured frequently in the contents of the monthly *Journals*, and the countries of origin included Australia, Bermuda, Canada, France, India, Norway, the United States and the U.S.S.R.

The type of paper accepted for publication in the *Journal* has ranged from theoretical analyses of waveguides to engineering papers on instrumentation for rockets and guided missiles, while new developments in television, computers and components reflect the advance of electronics. The Committee is expecting that the direct contribution of the Specialized Groups will shortly begin to make its impact and with this in mind the panel of referees is being extended and the Council has been asked to increase the membership of the main Committee.

The Committee wishes to make it clear to prospective authors that the shorter paper is particularly welcomed. This type of contribution has been an important feature in the programmes of the half-day symposiums, but it is hoped that more members will consider the possibility of describing aspects of their work in the form of a short paper for publication only.

The Journal.—The 1959 volume of the *Journal* exceeded 800 pages and it is encouraging to record also that the circulation of the *Journal* increased appreciably during the year. The figure certified by the Audit Bureau of Circulation averaged 7,160 copies per month for the second half of 1959; the figure for the first half of 1960 shows a further substantial increase to 7,571. These figures do not include *Journals* circulated *after* A.B.C. audit; the sale of back copies materially increases the certified figures, and provides tangible demonstration of the value of the Institution's *Journal*.

In addition to keeping members abreast of new developments through the publication of papers, the *Journal* also serves to keep members in touch with more general Institution affairs. For example, "News from the Sections" is widely appreciated by many members who have the opportunity to participate in Section meetings both at home and overseas. News items on current technical and educational affairs, information on new Standards, and the Section dealing with papers published in overseas journals—"Radio Engineering Overseas" are other features which contribute to the value of the *Journal*.

It is impossible to discuss the Institution's *Journal* without making some reference to the support received from advertisers toward the heavy costs of printing. The Council must obviously restrict advertisements to those having an appeal to the engineer and research worker. Thus, although revenue from this source will never cover production costs, increased advertising is an essential to the maintenance of the standard and increasing content of the *Journal*. The Institution is grateful, therefore, to those members who have helped during the year by recommending to their Companies the use of the *Journal* as an advertising medium. A cumulative index to advertisements giving technical data was included in the December 1959 issue and showed the wide range of components and complete equipments featured in the advertising pages of the *Journal* throughout the year.

The increasing number of papers being submitted and accepted for publication influenced the Council's decision to enlarge the format of the *Journal* with effect from the January 1961 issue. This will allow an increase of about one-fifth in editorial content without increasing the number of pages in the year's Volume.

Institution Premiums. — Particular thanks must be expressed for the endowment of two further Premiums during the past year—the Associated Rediffusion Premium and the J. Langham Thompson Premium — which are intended to recognize outstanding papers in the fields of Television Broadcasting and of Medical and Biological Electronics respectively. For the year 1959, therefore, there have been fourteen Premiums and Awards available for outstanding papers, and the Council has approved the award of seven of these; full details are given in the September 1960 *Journal*.

Co-operation with the Australian I.R.E.—During the year the Committee was happy to take advantage of the mutual agreement with the Institution of Radio Engineers Australia for the reprinting of outstanding papers from each other's proceedings. Two papers were therefore reprinted in the *Journal* during the year: the first "Some Aspects of Permeability Tuning"* had been recommended by the Brit.I.R.E. Council for the award of the Australian Institution's Hayes Memorial Medal for 1957; the second, "The Problems of Reliability and Maintenance in Very Large Electronic Systems for Shipboard Use",† had been read by a Member of the Brit.I.R.E., Captain G. C. F. Whittaker, R.N., at the Australian I.R.E.'s Convention.

Acknowledgments.—Council expresses thanks to the authorities of Universities, Technical Colleges, etc., for their co-operation in providing facilities for Institution meetings in Great Britain and overseas. The Council also wishes to record thanks to authors who presented papers, particularly those who visited two or more Sections, and organizations who provided demonstrations and equipment, especially at the 1959 Convention. The contribution to the work of the Committee which has been made by the many members and outside specialists who have given reports on the suitability of manuscripts for publication is also gratefully acknowledged.

Finally, the Council wishes to thank the editors of many technical and scientific journals who have co-operated during the year by including in their publications notices and reports of Institution meetings and other activities.

LIBRARY COMMITTEE

Library Stock and Equipment. Since publication of "Library Services and Technical Information" in 1958, five supplements have been issued. These supplements have listed the acquisition of 124 new books and 45 bound volumes of periodicals. The Library Handbook now lists 2,300 books which are available in the Institution's Library. In addition, well over 200 periodicals are obtainable in the reference section.

More members and organizations have taken advantage of the Library facilities and nearly 1,500 books were loaned during the year, including 427 through the postal service.

It has been necessary to install a further extensive run of shelving to cope with the increased number of books in the lending and reference library. Periodical storage still remains a problem in view of the shortage of space in the Library for periodical racks.

Co-operation with other bodies. The Council was pleased to meet a request from the North Western Polytechnic Library School to provide study facilities for one of their students who was taking the Finals Course of the Library Association. He was making a special study of radio and electronics literature and the Librarian was able to give him all the assistance he required.

The National Foundation for Educational Research is to publish a bibliography of articles on technical and commercial education. The Institution has been consulted on this venture and the Librarian has undertaken to scan a selected number of periodicals for papers which should be abstracted for the bibliography.

Holborn Public Library has received a donation from Philips Electrical Ltd., for the purpose of establishing a special reference library—known as the Philips Foundation Library—in radio and electronic engineering. The Institution has advised on the first list of books to be purchased for this library and has donated a set of bound volumes of the *Journal* and other Institution publications.

During the year assistance was also given to members of other Institutions who wished to have access to a radio and electronic engineering library.

* *J.Brit.I.R.E.*, **19**, pp. 47-60, January 1959.
† *J.Brit.I.R.E.*, **19**, pp. 625-46, October 1959.

Technical Information. An important function of the Institution is to provide technical information to members and other enquirers. These range from a request for a full bibliography on a particular specialised subject, to definitions of terms.

Apart from members, requests are received from firms, ASLIB (of which the Institution is a member), Public Libraries, information bureaux, technical colleges, and occasionally members of the public.

Acknowledgments. The Institution in its turn is dependent on the librarians of other libraries for assistance, since it does not possess all the books and periodicals which are sometimes requested. The Science Library in particular is most helpful in this respect, and also provides photostats of periodical papers when required, at a very reasonable charge.

The Institution also wishes to thank members who have presented books and periodicals to the library, and publishers in this country and abroad who have supplied new technical books which have been reviewed in the *Journal* and placed in the Institution's Library.

FINANCE COMMITTEE

Arising out of the 33rd Annual Report of the Council there was agreement at the last Annual General Meeting* to there being an increase in subscription rates. In order to give effect to that agreement an Extraordinary General Meeting of the Institution would have been necessary. The Council agreed, however, that this step should be postponed for a year since, if the Institution's Petition for the grant of a Charter was successful, Bye-laws would have to be adopted which would then provide the opportunity to make the proposed amendments to subscription rates.

This temporary relief to members has not, unfortunately, been matched by any abatement in the increasing costs of services and materials. Thus, the Finance Committee has had the problem of meeting rising charges coupled with increased expenditure concomitant with the needs of a growing Institution. The accompanying Accounts indicate the fine margin to which the Committee has had to work.

Income and Expenditure.—Notwithstanding increased basic costs, the Accounts show that economy measures resulted in a very small percentage increase in overall expenditure.

On the other hand, revenue has been more than maintained; re-imbursement from the Radio Trades Examination Board is now more commensurate with the cost of operating this Institution service.

* *J. Brit.I.R.E.*, **19**, p. 739, December 1959.

Institution growth, shown in other sections of this report, has necessarily increased administration expenses. Against this item must be recorded the work involved in the establishment of new Sections, both at home and overseas, the organization of the 1959 Convention, and the continued increase in the number of meetings and in the production of the *Journal*. The latter continues to attract greater advertising revenue which has very largely offset the increased costs of production.

All this work was accomplished despite considerable difficulty in Institution accommodation. Whilst the cost will enter into the twelve months following this Report, it must be noted that toward the end of the year under review, new charges were being incurred consequent upon the necessity of using additional accommodation to that provided at 9 Bedford Square.

The excess of income over expenditure should therefore be regarded against the information provided in this Report. The Committee particularly expresses appreciation of the continuing support given by members and many companies in the radio industry to the Building Appeal. The co-operation of the Holborn Borough Council in providing rating relief for 9 Bedford Square is also appreciated.

Balance Sheet.—The Council continues to approve the practice of allocating donations to the Building Appeal to a special account and to investments. This long standing policy will enable the Institution to meet the costs which will be involved if present negotiations for an extension to 9 Bedford Square prove successful.

The item "Balances at Banks Overseas" will grow even more substantial in the next few years. As previously stated, however, such moneys may be recalled for reduction of the Institution's liabilities. These assets, coupled with the increase in investments (shown in Schedules 1 and 2) indicate a general strengthening of the Institution's financial background. It cannot, however, be improved to a satisfactory level without the increase in subscriptions to which this and the last Annual Report have referred.

CONCLUSION

One purpose of an Annual Report is to give every member an opportunity of noting the work done in pursuance of the Institution's objects. Each year, however, presents a problem in preparing a concise but adequate statement commensurate with increased achievement. The events of the past twelve months, which may well prove to be most notable in the history of the Institution, are no exception.

The foregoing pages will, however, remind members that progress in every sphere of the Institution's activities would not be possible without the help of members who serve on Committees, and of all concerned with the advancement of radio and electronic science and engineering, including industry, educational services and the three Services.

Implementation of all the work reported does, of course, depend upon the Institution's administrative staff. The Council believes that it voices the opinion of all members in recording appreciation of the way in which the staff has coped with a year of vigorous activity, notwithstanding the difficulties of accommodation.

Investments at Cost 31st March, 1960

Schedule (1) *INVESTMENTS—GENERAL FUND*

	£	s.	d.
£200 3% Savings Bonds 1960/70 ...	200	0	0
£800 4% Consolidated Stock	712	15	6
£600 4% British Transport Guaranteed Stock 1972/77	544	1	4
£200 Ether Langham Thompson (800 Ordinary Shares of 5s. each)	—	—	—
£1,000 5½% Commonwealth of Australia 1977/80	987	13	7
(Market Value at 31st March, 1960, £3,117 0s. 0d.)			
	£2,444	10	5

Schedule (2) *INVESTMENTS—BUILDING APPEAL*

	£	s.	d.
£1,400 4% Consolidated Stock	1,219	3	0
£2,000 3½% War Loan	1,464	4	3
£1,300 British Electricity Guaranteed 3% Stock 1968/73	990	10	6
£3,000 4% British Transport Guaranteed Stock 1972/77	2,754	9	5
£100 6% Associated Electrical Industries Debenture Stock 1978/83	98	10	0
£1,500 3% Exchequer Stock 1962/63 ...	1,428	10	7

Schedule (2) continued.

	£	s.	d.
£1,000 5% Conversion Stock 1971 ...	1,001	6	3
1,600 Units Orthodox Trust	1,032	8	6
250 Units A.E.G. Unit Trust	136	19	0
£1,000 6% Rhodesia and Nyasaland Stock 1978/81	988	0	1
200 Units Commonwealth Trust ...	100	0	0
2,000 Shares Falcon Trust	500	0	0
£500 5½% Commonwealth of Australia 1977/80	492	11	7
£500 Imperial Chemical Industries (2,000 5% Preference Shares of 5s. each) ...	452	19	6
£500 British Petroleum 6% Preference Shares of £1 each	684	12	9
£250 National Commercial Bank of Scotland (500 Ordinary Shares of 10s. each)	1,425	6	0
(Market Value at 31st March, 1960, £13,950 2s. 6d.)	14,769	11	5
Halifax Building Society	4,992	14	0
Balance at Bank	5,606	2	11
	£25,368	8	4

GENERAL ACCOUNT

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1960

1959 £	1959 £		£ s. d.	£ s. d.
		Administration Expenses:		
	11,120	*Salaries and State Insurance* ...	13,205 19 7	
	450	*Pension Scheme*	859 7 9	
	1,858	*Postage and Telephone*	1,834 3 9	
	1,133	*Printing and Stationery* ...	1,084 7 0	
	797	*Travelling and Entertaining Expenses*	1,136 0 7	
	387	*Delegates Expenses*	420 6 5	
	672	*Council & Committee Expenses*	827 3 9	
	150	*Audit Fees*	150 0 0	
	559	*Bank Interest and Charges* ...	463 16 4	
	52	*Legal Expenses*	219 12 4	
	174	*Sundry Expenses*	259 14 0	
17,352				20,460 11 6
		Institution Premises:		
	1,746	*Rent, Rates and Insurance (Net)*	1,504 1 2	
	472	*Lighting and Heating*	447 1 5	
	765	*Office Expenses and Cleaning* ...	843 7 6	
	512	*Repairs*	363 9 0	
3,495				3,157 19 1
		Institution's Journal, List of Members, Library and Reports:		
	9,812	*Printing and Publishing less Advertising Receipts*	9,807 15 7	
	1,865	*Postage*	1,920 2 4	
	125	*Envelopes and Wrappers* ...	96 16 0	
11,802				11,824 13 11
537		Convention Expenses (*Net*) ...		535 5 10
		Examination Expenses:		
	600	*Printing Papers and Regulations*	449 19 5	
	532	*Examiners' and Invigilators' Fees and Expenses*	589 0 11	
	88	*Hire of Accommodation* ...	142 14 9	
1,220				1,181 15 1
		Section Expenses:		
	414	*Printing, Stationery and Postage*	433 5 4	
	723	*Hire of Accommodation, etc.* ...	833 1 10	
	1,033	*Travelling Expenses and Subsistence*	1,006 0 11	
2,170				2,272 8 1
379		Grants to other Institutions ...		363 0 0
130		Premiums and Awards		170 4 6
		Depreciation		
	386	*Office Furniture and Fittings* ...	380 15 10	
	111	*Library*	156 10 2	
497				537 6 0
3,544		Excess of Income over Expenditure carried to Reserve Account		5,484 12 3
£41,126				£45,987 16 3

1959 £		£ s. d.
21,959	Subscriptions including Arrears received	24,587 18 11
4,931	Building Appeal Donations	5,379 10 7
1,773	Donation from Industry	2,068 1 3
2,252	Examination and Exemption Fees	2,540 3 10
1,805	Entrance and Transfer Fees	1,784 6 0
6,225	Sales of Publications, etc.	5,772 3 7
423	Interest on Investments (Gross)	563 18 9
1,758	Radio Trades Examination Board: Secretarial Charges	3,291 13 4
£41,126		£45,987 16 3

THE BRITISH INSTITUTION OF RADIO ENGINEERS

GENERAL ACCOUNT

BALANCE SHEET AS AT 31st MARCH, 1960

1959 £	1959 £		£ s. d.	£ s. d.
		RESERVE ACCOUNT:		
		Excess of Income over Expenditure: Balance at 1st April, 1959	8,379 4 3	
		Add Surplus for the Year ...	5,484 12 3	
8,379				13,863 16 6
		CURRENT LIABILITIES:		
	4,946	Sundry Creditors	8,297 16 10	
	5,159	Subscriptions and Examination Fees in Advance	6,419 13 11	
	17,749	Bank Overdraft	15,080 3 2	
27,854				29,797 13 11
£36,233				£43,661 10 5

Signed: E. E. ZEPLER (*President*).
J. L. THOMPSON (*Chairman of Finance Committee*).
G. A. MARRIOTT (*Immediate Past President*).
G. A. TAYLOR (*Honorary Treasurer*).
G. D. CLIFFORD (*General Secretary*).

1959 £	1959 £		£ s. d.	£ s. d.
		FIXED ASSETS:		
		Office Furniture and Fittings at cost	7,287 5 10	
		Less Depreciation to date ...	3,866 5 10	
3,465				3,421 0 0
		The Louis Sterling Library at cost	2,463 4 6	
		Less Depreciation to date ...	1,051 4 6	
1,011				1,412 0 0
		INVESTMENTS AT COST:		
1,457		See Schedule (1) on page 902 ...		2,444 10 5
		BUILDING APPEAL:		
20,867		See Schedule (2) on page 902 ...		25,368 8 4
26,800				32,645 18 9
		CURRENT ASSETS:		
	4,041	Stock of Stationery, Journals and Examination Papers at Valuation	4,440 11 4	
	499	Income Tax Repayment Claim	531 19 0	
	3,158	Sundry Debtors	3,418 8 3	
	317	Sections—Balance at Bank and in Hand	95 13 9	
	1,384	Balances at Banks Overseas ...	2,514 11 8	
	34	Cash in Hand	14 7 8	
9,433				11,015 11 8
£36,233				£43,661 10 5

REPORT OF THE AUDITORS TO THE MEMBERS OF THE BRITISH INSTITUTION OF RADIO ENGINEERS

We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit. In our opinion proper books of account have been kept by the Institution so far as appears from our examination of those books and proper Returns adequate for the purposes of our Audit have been received from the Sections Overseas. We have examined the above Balance Sheet and annexed Income and Expenditure Account which are in agreement with the books of account. In our opinion and to the best of our information and according to the explanations given to us, the said accounts give the information required by the Companies Act 1948, in the manner so required. The Balance Sheet gives a true and fair view of the state of the Institution's affairs as at 31st March, 1960, and the Income and Expenditure Account gives a true and fair view of the Excess of Income over Expenditure for the year ended on that date.

42, Bedford Avenue, London, W.C.1.

6th December 1960.

GLADSTONE, JENKINS & CO.

Chartered Accountants, Auditors.

Appendix 1

INSTITUTION REPRESENTATIVES ON B.S.I. COMMITTEES

COMMITTEE	WORK IN HAND
ELE/TLE/2 Graphical Symbols for Electrical Engineering and Telecommunications **F. G. Diver, M.B.E.** (*Member*)	Actively amalgamating and revising B.S.108 and B.S.530 and revising and extending graphical symbols for semi-conductor devices and for logic elements.
TLE/1 Terminology and Symbols for Telecommunications **F. G. Diver, M.B.E.** (*Member*) TLE/1/1 Nomenclature and Letter Symbols for Telecommunications **H. G. Foster, M.Sc.** (*Member*)	Completed revision of B.S.204 glossary of terms. At present concentrating on definitions of letter symbols for semi-conductor devices.
TLE/2 Radio (including Television) Receivers **F. T. Lett** (*Associate Member*) TLE/2/3 Receiving Aerials **A. Brown** (*Associate Member*)	Preparing standards on measuring and expressing the performance of a.f. amplifiers, television, a.m. and f.m. receivers. Methods of measurement for receiving aerials.
TLE/3 Radio (including Television) Transmitters *To be appointed*	Not currently revising standards.
TLE/4 Components for Telecommunications Equipment **M. H. Evans** (*Associate Member*)	Completed revision of B.S.2011 basic climatic and durability tests. Revised draft for standard for composition variable resistors. Preparing a draft B.S. for valve holders including information in B.S.448.
TLE/5 Electronic Tubes **G. R. Jessop** (*Associate Member*) TLE/5/2 Electrical Characteristics of Electronic Tubes and Valves **G. R. Jessop** (*Associate Member*)	Code of practice on use of electronic valves. Considerable international activity on measurement of electrical characteristics of valves.

Appendix 1 (continued)

COMMITTEE	WORK IN HAND
TLE/8 Instruments and Test Equipment for Telecommunication **S. R. Wilkins** (*Member*)	Microwave measuring instruments; bump test machine.
TLE/8/3 Signal Generators **R. A. H. Gooday** (*Associate Member*)	Mainly concerned at present with international standardization aspects.
TLE/8/4 Electronic Instruments for Voltage Measurement **D. L. A. Smith** (*Associate Member*)	New standards are being drafted.
TLE/9 Aircraft Radio Equipment **D. M. O'Hanlon** (*Associate Member*)	External connections of equipment intended for installation in civil aircraft.
TLE/11 Piezo-Electric Crystals **A. E. Crawford** (*Associate Member*)	The measurement of frequency and equivalent resistance of crystal units with international standardization particularly in mind.
TLE/12 Transistors **B. R. A. Bettridge** (*Member*)	Essential ratings and characteristics of transistors, and methods of measurement. Dimensional standards. Work started on a code of practice.
ELE/32 Radio Interference **O. E. Trivett** (*Member*)	Not currently revising standards.
ELE/66 R.F. Heating Equipment **R. E. Bazin** (*Member*)	Not currently revising standards.
ACM/8 Electro-Acoustic Transducers **H. J. Leak** (*Member*)	The method of measurement of loudspeaker performance with international standardization particularly in mind.
USM/2/6 Letter Symbols (Electronics, etc.) **H. G. Foster, M.Sc.** (*Member*)	Mainly concerned with the revision of Part 6 of B.S. 1991 Letter Symbols and Abbreviations. Also work on a draft standard on letter symbols for semi-conductor devices.

Brit.I.R.E. BENEVOLENT FUND

ANNUAL REPORT OF THE TRUSTEES FOR THE YEAR 1959-60

The Trustees of the Benevolent Fund have pleasure in reporting to subscribers on the work of the Fund for the twelve months ended 31st March 1960. The Account and Balance Sheet are published on page 910 of this Journal.

The Trustees have particularly welcomed the support of further members during the year which has resulted in an increase of nearly £400 in donations. The number of members who made donations was 1,304, compared with 1,100 for the previous year. Thanks are expressed to all members who have supported the Fund.

Inevitably, as the Institution grows older and larger, the number of claims on the Benevolent Fund must increase. The Trustees are therefore anxious to secure the support of *all* members of the Institution. Each year there is a gradual, but nevertheless slow, increase in the number of members of the Institution who contribute to the Fund, but the present position of nineteen per cent. of the membership giving help cannot be regarded as satisfactory. A plea is therefore made to all members to help, if only in a small way, to increase the resources. It is, in fact, the only Benevolent Fund exclusively devoted to the professional radio engineer and his dependants, and the history of its work shows how invaluable such a Fund can be in time of emergency.

It is insufficiently realized that however small an annual contribution, its value can be increased if each member completes a deed of covenant. For the information of new members, the following table gives a few examples of how the Fund benefits from a deed of covenant without involving the subscriber in any extra expense.

Income from Covenants

(Based on the Standard Rate of Income Tax at 7s. 9d. in the £)

Amount covenanted annually for 7 years	Tax reclaimed annually by the Trustees	Estimated gross amount received by the Trustees
£ s. d.	£ s. d.	£ s. d.
1 1 0	13 4	10 0 4
2 2 0	1 6 8	24 0 8
5 5 0	3 6 5	59 19 11

The Honorary Secretary will be very pleased to give further information to any member willing to subscribe in this way.

Industrial Support.—The Radio Industries Club of London and the Radio Industries Club of Manchester have for nearly twenty years given an annual donation to the Benevolent Fund. These contributions come from a cross section of the entire radio industry, and the Trustees are most grateful for this support. Since the last war Electric and Musical Industries Limited have also been most generous in their annual donations and recently Erie Resistor Ltd. have added their support. The Trustees of the Fund much appreciate the encouragement given to their voluntary work by these manufacturers.

Grants.—The assistance given during the year mainly involved continued help to those cases referred to in the last Report. Towards the end of the year, however, the Trustees were advised of the death of four members whose widows and children will need either or both financial aid and assistance in the education of children. Reference will be made to these cases in the next Report.

A great deal of assistance has been given in the form of advice. One family, for instance, previously receiving assistance is now able to manage on its own but the Trustees have given an assurance that they will help the widow in the event of any breakdown in her health which would preclude her present part-time employment.

Another member has developed multiple sclerosis and in this connection the Benevolent Fund has joined with the Professional Classes Aid Council in helping him to secure a pension and National Assistance and to furnish and convert the house in which his family is living.

Two long-standing cases are still the concern of the Trustees, one Associate Member, who has recovered from a severe attack of tuberculosis, has recently had a recurrence of lung trouble. The Trustees have been able to assist him and his family whilst he has been in hospital and during convalescence. His son is one of those children being educated at the Royal Wolverhampton School. In the other case the Benevolent Fund have been responsible for the education of three children of a deceased member, one of whom is still at the Royal Wolverhampton School.

Schools.—In general, the Trustees find that help is best given to a widow by assisting in the placing of children in suitable schools thus enabling the mother to be free to take up a business life and preserve a measure of independence. Subscribers have always signified their approval, therefore, of the way in which the Trustees have made donations to those Schools which have been able to accept children nominated by the Trustees. Since the inception of the Benevolent Fund, the governing body of Reed's School has always been most helpful and a further Bursary, for entry into this School has been purchased.

With the opening of new Boarding Houses, Reed's School is now able to accommodate more boys. The new houses were opened by Her Majesty Queen Elizabeth the Queen Mother in November 1959. On that occasion the Institution was pleased to advise on the installation of closed-circuit television for the ceremony and the Institution's President, Professor E. E. Zepler, had the honour of being presented to Her Majesty The Queen Mother.

The Royal Wolverhampton School is still responsible for the education and boarding of a boy and a girl sponsored by the Trustees. Here again the Governors have plans for extending the school buildings to cope with the increasing intake of children. It is pleasing to note that in the last report of the Governors of the Royal Wolverhampton School the results of the G.C.E. Examination at Ordinary Level were well above average for the country.

The Trustees have also continued their support of the Royal Wanstead School whose report also indicates increasingly good results in the "O" level of the G.C.E. examination.

The full reports of these three Schools can be seen in the Institution's Library, but the Honorary Secretary will be pleased to send a copy to any subscriber who wishes to learn more of the excellent work which is done by these independent boarding schools.

Balance Sheet.—Past Reports have indicated the wish of the Trustees to build up a healthy reserve for the Benevolent Fund in order always to have adequate resources to give the maximum help. The Fund's investments have again been increased by just over £1,000 and the Schedule of Investments is appended to this Report.

Acknowledgments.—Once again the Fund's Honorary Solicitor and Honorary Auditor, Mr. Charles Hill and Mr. R. H. Jenkins, have rendered valuable help to the Trustees. Thanks are also expressed to those members who advise the Trustees of any member or his family who need help and who, in many cases, willingly give voluntary assistance by visiting a home away from London to ensure that everything possible is being done.

Schedule of Investments at Cost

	£	s.	d.
£200 3% Savings Bonds 1960/77 ...	191	3	6
£200 3% Savings Bonds 1965/75 ...	182	15	9
£1,500 3½% War Loan	1,157	15	9
£200 3% British Electricity Guaranteed Stock 1968/73	155	19	6
£2,000 4% British Transport Guaranteed Stock 1972/77	1,863	14	10
£4,000 4% Consolidated Stock	3,526	16	0
£200 5½% Exchequer Stock 1966 ...	201	2	0
£800 Commonwealth of Australia 5½% Stock	788	2	7
£50 Associated Newspapers Limited—200 Deferred Shares of 5s. each	166	4	6
£100 6% L.C.C. Loan 1975/78	99	4	4
£200 6¼% Liverpool Corporation Mortgage	200	0	0
£300 5½% Middlesbrough Corporation Mortgage Loan	300	0	0
£100 6% Associated Electrical Industries Debenture Stock 1978/83	98	10	0
300 Units Commonwealth Trust ...	150	0	0
Falcon Trust Limited—500 Shares ...	125	0	0
Great Universal Stores 300 7½% Preference Shares and 200 4½% Preference Shares of £1 each ...	354	2	0
(Market Value as at 31st March, 1960, £8,560 0s. 0d.)	£9,560	10	9

Brit.I.R.E. BENEVOLENT FUND

NOTICE OF ANNUAL GENERAL MEETING OF SUBSCRIBERS

NOTICE IS HEREBY GIVEN that in accordance with the Rules the Annual General Meeting of Subscribers to the Institution's Benevolent Fund will be held on WEDNESDAY, 11th JANUARY, 1961, at the London School of Hygiene and Tropical Medicine, Keppel Street. Gower Street, London, W.C.1. The meeting will commence at 6.30 p.m. approximately (immediately after the Annual General Meeting of the Institution).

AGENDA

1. To confirm the Minutes of the Annual General Meeting of Subscribers held on 2nd December, 1959. (Reported on page 56, Volume 20 of the *Journal*, January, 1960.)

2. To receive the Annual Report of the Trustees. (Published on pages 907-8 of this *Journal.*)

3. To receive the Income and Expenditure Account and Balance Sheet of the Benevolent Fund for the year ended 31st March, 1960. (Published on page 910.)

4. To elect the Trustees for the year 1961.

   Rules 5 and 6 state :—

   5. The Trustees of the Fund shall consist of not more than five and not less than three members of the Institution who have been elected at an Annual General Meeting of Subscribers to the Benevolent Fund.

   6. The Trustees shall be elected at the Annual General Meeting by all members *who have subscribed to the Fund* during the preceding twelve months, ended March 31st in each year, and the Trustees shall hold office until successors are appointed.

   The retiring Trustees are :—

   G. A. Marriott, B.A. (Immediate Past President).
   Rear Admiral Sir Philip Clarke, K.B.E., C.B., D.S.O. (Past President).
   A. A. Dyson, O.B.E. (Member).
   A. H. Whiteley, M.B.E. (Companion).
   G. A. Taylor (Member) (*Honorary Treasurer*).

5. To appoint Honorary Solicitors.

   The Trustees recommend the re-appointment of :—

   Mr. Charles Hill, 6 Gray's Inn Square, London, W.C.1.

6. To appoint the Honorary Accountant.

   The Trustees recommend the re-appointment of :—

   Mr. R. H. Jenkins, F.C.A., 42 Bedford Avenue, London, W.C.1.

7. Any other business.

By Order of the Trustees,

(*Signed*) G. D. CLIFFORD

Honorary Secretary.

(The Rules governing the operation of the Benevolent Fund were published in the last (8th) edition of the List of Members.)

THE BRITISH INSTITUTION OF RADIO ENGINEERS
BENEVOLENT FUND

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1960

1959 £		£ s. d.
419	Grants	399 9 6
100	Purchase of Bursaries at Reed's School	100 0 0
10	Postage and Stationery	12 17 3
34	Sundry Expenses	20 6 0
747	Balance being surplus for the year carried to Reserve Account	1,207 6 2
£1,310		£1,739 18 11

1959 £		£ s. d.
982	Subscriptions and Donations	1,354 13 0
328	Interest Received (Gross)	385 5 11
£1,310		£1,739 18 11

BALANCE SHEET AS AT 31st MARCH, 1960

1959 £		£ s. d.	£ s. d.
	RESERVE ACCOUNT		
	Balance as at 1st April, 1959	8,601 14 7	
	Add Surplus for Year	1,207 6 2	
8,602			9,809 0 9
	CURRENT LIABILITIES		
88	Amount due to The British Institution of Radio Engineers		— — —
£8,690			£9,809 0 9

1959 £		£ s. d.	£ s. d.
	FIXED ASSETS		
8,497	Investments at Cost ... ... (See Schedule on page 908)		9,560 10 9
	CURRENT ASSETS		
110	Income Tax Repayment Claim	117 15 8	
83	Cash at Bank	38 12 6	
—	Amount due from The British Institution of Radio Engineers	92 1 10	
			248 10 0
£8,690			£9,809 0 9

For Trustees:—

Signed
G. A. MARRIOTT (*Chairman*)
A. A. DYSON
G. D. CLIFFORD (*Honorary Secretary*)
G. A. TAYLOR (*Honorary Treasurer*)

I have audited the above written Balance Sheet dated 31st March, 1960, in respect of the Benevolent Fund. I have received all the information and explanations I have required and in my opinion the Balance Sheet represents the true and accurate state of the Benevolent Fund.

42, Bedford Avenue, London, W.C.1.
6th December, 1960.

R. H. JENKINS, *Chartered Accountant,*
Honorary Auditor.

Electron Transmission of Mesh Lenses for Scan Magnification in Television Picture Tubes†

by

PAUL J. DOLON, M.SC. ‡ and WILFRID F. NIKLAS, PH.D., ASSOCIATE MEMBER ‡

Summary: Battery operated transistorized television receivers require low power consumption. The magnetic deflection system of a display tube absorbs considerable energy; thus, scan magnification as means for power saving gains increasing importance in modern display tube design. The principles of scan magnification and scan conservation are outlined. Magnetic and electrostatic lenses showing a diverging action and thus applicable to scan magnification, are discussed. Divergent electrostatic lenses employing mesh electrodes are presently being applied to scan magnification. The use of such beam-intercepting electrodes reduces the brightness obtainable even though the electron transmission of such a structure may be higher than its optical transmission. The question of the electron optical mesh transmission is investigated both theoretically and experimentally. Numerical integration of the paraxial ray equation and its analytic solution indicate that the electron optical transmission of these mesh electrodes increases with increasing strength of the interstitial lenses. However, appreciable increases are obtained only in very strong lenses. Methods of determining experimentally a possible change of mesh transmission with changing strength of the interstitial lenses are discussed. It is shown that the mesh transmission may increase with increasing lens strength, but the increase thus obtained is not a substantial one.

List of Symbols

ρ	relative electron transmission.
r	radial co-ordinate.
z	axial co-ordinate.
$r_{0\,(max)}$	maximal initial radius of transmitted electron beam.
R	aperture radius.
$V(z)$	axial potential.
E_1, E_2	external electric fields on the two sides of the aperture ($E_1 = -E_2 \equiv E$).
V_e	mesh potential.
V_c	axial potential at the mesh.
a, b, c, d	integration constants, subject to boundary conditions.
f	focal distance of aperture lens.
V_s	screen potential.
R^*	radius of mesh.
$J_{\frac{1}{4}}, J_{-\frac{1}{4}}$	Bessel functions.

These symbols are defined in more detail under the equations where they are used for the first time in the text.

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U.D.C. No. 621.385.832:621.397.62

1. Introduction

The electron beam in a television picture tube scans the phosphor screen point by point and thus writes a picture, whereby the brightness pattern of the televised scene is reproduced by modulating the electron beam. The deflection of the electron beam is due to time dependent magnetic fields in the deflection yoke. Considerable energy is required for the cyclic build-up and collapse of these fields. The energy necessary to deflect the electron beam over a certain angle depends on the electron velocity at the deflection centre and thus generally on the final high voltage applied to the tube, and increases with increasing deflection angle.

Battery-operated portable television receivers have been developed recently. The total power consumption of such receivers should be as low as possible in order to increase the operational time of the battery and to keep the weight of the unit low. On the other hand, portable receivers are used at high ambient illumination levels. Thus, high brightness values are required to achieve a reasonable contrast in the reproduced television picture. High brightness values require high screen voltages, which fact, as mentioned above, leads to increased deflection power requirements.

Portable television receivers should also be as compact as possible. Thus, the picture tube in such a receiver should have a large deflection angle. This requirement leads also to high deflection power consumption. For these reasons, methods are sought to allow conventional beam deflection over a smaller angle and thereafter to magnify the small angle scan by a divergent electron lens which does not appreciably add to the power consumption of the set. This action of the electron lens is called "scan magnification" and the lens a "scan-magnifier." Alternatively, power reduction may be achieved instead of, or in addition to, magnification of the scanning angle by deflecting the beam in a low potential field and utilizing post deflection acceleration *without* the usually resulting scan-convergence. This method is called "scan conservation."

In the following sections, the application of both magnetic and electrostatic lenses will be surveyed. The magnetic quadrupole lens, applicable to scan magnification, will be described briefly. Electrostatic lenses for the same purposes which necessarily employ beam intercepting meshes will also be discussed. The opinion has been expressed quite generally† that the transmission of such mesh lenses for electrons is substantially higher than the optical transmission of the mesh employed. Indeed, it has been stated publicly that "meshes with an optical transmission of, say, 50 per cent. show an electron transmission of 90 per cent. and higher in scan magnifier lenses." As a high electron transmission of scan magnifying mesh lenses is essential for the industrial applicability of these structures, it was deemed prudent to subject this question to a more rigorous investigation. Thus, both theoretical calculations and experimental measurement of the electron transmission of such mesh lenses will be considered; theoretical results obtained by numerical evaluation of the relevant trajectory equation will be verified empirically within the achievable error-margin. Scan conservation methods will also be considered.

† See, for instance, ref. 4.

2. Methods of Scan Power Saving

2.1. *Scan Magnification by Magnetic Lenses*

Any scan magnifier must comprise a divergent or over-convergent lens. In the case of an over-convergent lens, the electron beam leaves the centre of deflection at a small angle α but is made to converge subsequently and then crosses the axis of the tube at an angle larger than α. Over-converging scan magnifiers are impractical because of the required increase in the length of the tube.

The action of a quadrupole consisting of four properly shaped and positioned pole pieces, is divergent in one (say, the horizontal) direction and over-convergent in the perpendicular (vertical) plane[1, 2]. The necessity of exact positioning of the electron beam within the inhomogeneous field of the quadrupole lens leads to very stringent requirements in the high voltage power supply regulation. Furthermore, additional quadrupole or toroidal lenses are required to obtain anastigmatic focusing. The complexity of this method does not permit within the scope of this paper a detailed discussion of scan-magnification by quadrupole lenses.

2.2. *Scan Magnification and Scan Conservation by Electrostatic Lenses*

Electrostatic lenses with all the electrode structure outside the beam cross-section with the exception of certain immersion lenses of a type not suitable for scan power saving, are inherently convergent. This statement can be understood by recalling that a symmetrical two-tube lens consists of two "semi-lenses" (lens-halves) separated by an equipotential surface, at the mid-plane between the two electrodes, of a potential corresponding to the algebraic average of the constituent electrode potentials. The first of these semi-lenses (on the low voltage side) is a positive (convergent) lens, the second a negative (divergent) lens. It can be shown that the first semi-lens is always stronger; thus, the overall effect of both semi-lenses is convergent.

If a mesh is placed in the mid-plane of the two electrodes and the potential applied to the mesh is lower than the algebraic average of the input and output electrode potentials, the two semi-lenses become divergent[3]; such a structure is applicable to scan magnification[4]. As both lens halves act as divergent lenses, one semi-lens suffices, at least in principle, for obtaining scan power saving. For reasons of high brightness, an accelerating lens is then the preferred type. Thus, the first electrode can be connected to the mesh and the combination of these two electrodes is kept at a potential appreciably lower than the potential of the remaining elec-

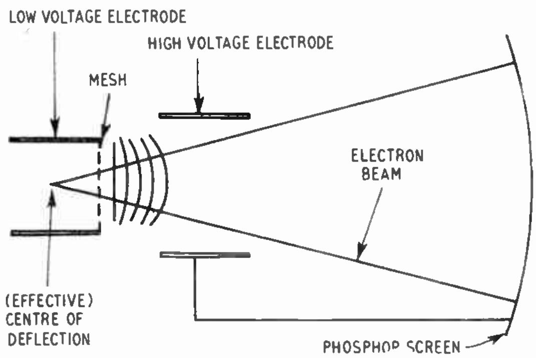

Fig. 1. Two-electrode mesh lens for scan magnification.

trode. While such a structure shows "scan conservation" and only little or no "scan magnification," this latter effect can be substantially increased by forming the mesh with a concave curvature in the direction of electron propagation. Utilizing these lenses, small angle scanning takes place always in the low voltage region before the mesh, seen in the direction of electron propagation.

Divergent lens structures of the two-electrode and three-electrode type, which are self-explanatory, are shown in Fig. 1 and Fig. 2. Such mesh lenses have the disadvantage of displaying a two-fold defocusing effect on the electron beam. Due to the finite beam diameter in the plane of the mesh, the beam is diverged; in addition, the interstitial lenses formed by the openings in the mesh converge the elementary electron bundles forming the beam. As the strength of these interstitial lenses is generally rather high (see later), this converging lens action will generally result in an over-convergence of the elementary electron bundles, in turn leading to effective defocusing of the electron beam on the target. The interstitial lenses themselves may project a shadow of the mesh. Furthermore, the mere presence of a beam-intercepting mesh may lead to a loss in electron beam intensity. As mentioned before, the investigation of this loss represents the main objective of this paper. On the other hand, the converging action of the interstitial mesh lenses (aperture lenses) may tend to increase the electron-optical transmission of a mesh beyond

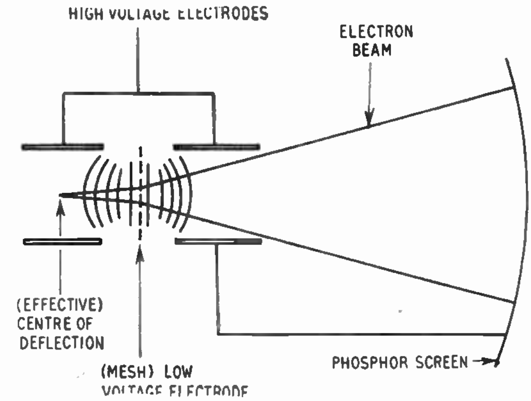

Fig. 2. Three-electrode mesh lens for scan magnification.

its optical transmission value. The ratio of these two values, ρ, to be termed "relative electron transmission," obviously increases with increasing strength of the interstitial lenses. We shall now investigate more closely the relationship between the relative electron-optical transmission of the mesh and the strength of the interstitial mesh lenses.

3. Mathematical Analysis of Electron Transmission of Mesh Lenses

The mathematical analysis of the electron transmission of mesh lenses requires a knowledge of the electron trajectories through a representative one of the interstitial lenses of which the mesh lens is constituted. For reasons of simplicity, the interstitial mesh openings will be assumed to be circular and aberrations of the interstitial lenses will be neglected. It will be assumed further that the interstitial lens considered is located in the paraxial region of the mesh-lens.

The electron trajectories can be obtained from the axial potential distribution by numerical integration of the paraxial ray equation, an approximating method, the accuracy of which can be improved on arbitrarily by simply increasing the number of intervals chosen. Thus, this method is inherently capable of yielding rather reliable numerical results; however, no insight can be obtained into the functional relationship between lens parameters and mesh transmission.

Such a functional correlation may be obtained by solving the paraxial ray equation in closed form. It will be shown that the paraxial ray equation, for the axial potential distribution in such an interstitial lens, can be solved, with certain simplifying assumptions, by Bessel functions of the $\frac{1}{4}$-order.

Thus, in the following sections we shall first discuss the axial potential of an interstitial lens and its derivatives. Then the solution of the paraxial ray equation by numerical integration will be outlined and, finally, an analytic solution for the ray equation will be developed.

3.1. *The Axial Potential Distribution for a Single Aperture*

In the following mathematical derivation the initially decelerating symmetrical saddle field lens of a circular mesh aperture of radius R will be considered (scan-magnifier lens as shown in Fig. 1). Since transmission values in general are measured by the ratio of the integral cross-sectional area of all transmitted beams to the total area of the surface in question, the relative electron transmission ρ for a single aperture is given by:

$$\rho = [r_{0\,(\max)}/R]^2 \qquad \text{.........(1)}$$

where $r_{0\,(\max)}$ is the maximal initial radius of the transmitted electron beam. The maximal radius of the transmitted light beam is, of course, identical with the aperture radius R.

$r_{0\,(\max)}$ may be determined from the electron-trajectory through the aperture. The trajectory, in turn, may be obtained by solving the paraxial ray equation in closed form or by numerical integration, provided the axial potential distribution is known. The analytical solution requires certain assumptions in addition to those used for the numerical solution, hence the latter is believed to be more accurate; the former results in a functional correlation of all parameters involved. For this reason, both methods of approach were carried out.

The axial potential $V(z)$ in the field of a circular aperture is given[5] as:

$$V(z) = V_0 - \tfrac{1}{2}(E_1+E_2)Z + \frac{R}{\pi}(E_1-E_2)\left(\frac{Z}{R}\tan^{-1}\frac{Z}{R}+1\right) \qquad \text{.........(2)}$$

where z is the axial co-ordinate, V_0 the mesh potential and E_1 and E_2 are the values which the field approaches in front and behind the aperture†. In the case considered of the symmetrical saddle field lens, we have $E_1 = -E_2 \equiv E$. Thus, we obtain for $z = 0$:

$$V(0) = V_c = V_0 + \frac{2ER}{\pi} \qquad \text{.........(3)}$$

as

$$\lim_{Z\to 0}\left[\frac{Z}{R}\cdot\tan^{-1}\frac{Z}{R}\right] = 0$$

Substituting eqn. (3) for V_0 in eqn. (2), leads to

$$V(Z) = V_c + \frac{2E}{\pi}Z\tan^{-1}\frac{Z}{R} \qquad \text{.........(4)}$$

The derivatives of the axial potential V with respect to z are:

$$V' = \frac{2E}{\pi}\left[\tan^{-1}\frac{Z}{R} + \frac{Z/R}{1+(Z/R)^2}\right] \qquad \text{......(4a)}$$

and

$$V'' = \frac{4E}{\pi R}\left[\frac{1}{(1+Z^2/R^2)}\right]^2$$

The knowledge of the axial potential and its derivatives permits the solution of the paraxial ray equation by numerical integration as well as in closed form.

3.2. *Numerical Integration of the Paraxial Ray Equation*

The paraxial ray equation in the cylindrical co-ordinates z and r is given[6] by:

$$Vr'' + \frac{V'}{2}r' + \frac{V''}{4}r = 0 \qquad \text{.......(5)}$$

This can be rewritten as

$$-\frac{V''}{4}r = \frac{V'}{2}r' + Vr'' = \sqrt{V}\frac{d}{dz}(r'\sqrt{V})$$

† As it is normally assumed, we postulate that E_1 and E_2 do not depend on z beyond a sufficiently large distance from the aperture.

or

$$\frac{d}{dz}(r' \sqrt{V}) = -\frac{rV''}{4\sqrt{V}} \quad \ldots\ldots\ldots(5a)$$

Integrating both sides between z_2 and z_1 leads to[7]:

$$\left[r'\sqrt{V}\right]_{Z_1}^{Z_2} = -\tfrac{1}{4}\int_{Z_1}^{Z_2} \frac{rV''}{\sqrt{V}}\,dz$$

or

$$r'_{z2} = r'_{z1}\sqrt{\frac{V_{z1}}{V_{z2}}} - \frac{1}{4\sqrt{V_{z2}}}\int_{Z_1}^{Z_2}\frac{rV''}{\sqrt{V}}dz \quad \ldots\ldots\ldots(6)$$

By assuming r, V and V'' under the integral sign to be constant within a sufficiently small interval $[Z_2, Z_1]$, we obtain:

$$r'_{z2} = r'_{z1}\sqrt{\frac{V_{z1}}{V_{z2}}} - \frac{\bar{r}\,\bar{V}''}{4\,\bar{V}}(Z_2 - Z_1) \quad \ldots(7)$$

where $\bar{r}$, $\bar{V}$, $\bar{V}''$ represent the constant (average) values of r, V, and V'' within the small interval under consideration.

This algebraic equation allows the calculation of the constant slope of the electron-trajectory within any interval. Thus, we can construct an arbitrarily good approximation to the trajectory, consisting of straight segments adjoining each other at the interval boundaries.

This procedure has to be carried out point by point from a value $z = z_0$ where the lens action is sufficiently weak and where $r = r_0$ and $r' = 0$, to $z = 0$ (location of the mesh) where $r = r(0)$. Since we tacitly assumed the validity of the paraxial ray equation over the entire lens diameter (thus excluding the influence of geometric lens-aberrations), the family of electron trajectories with different r_0 are geometrically similar curves. This means that:

$$r_0/r(0) = r_{0\,(\max)}/R \quad \ldots\ldots\ldots(8)$$

Thus, we obtain from eqn. (1):

$$\rho = [r_0/r(0)]^2 \quad \ldots\ldots\ldots(9)$$

Note that this result depends on the selection of the effective radius of the lens field z_0. We assumed $z_0 = R$, a restriction which decreases the value of ρ somewhat. Further, electron incidence normal to the plane of the mesh was assumed. As the strength of the aperture lens increases with increasing angle of incidence[8] and as z_0 increases with increasing lens-strength, the value of ρ thus obtained will be somewhat lower than the actual value. However, it can be shown that the error, introduced by these simplifications, is not a substantial one. Beyond these restrictions, the accuracy of the results is limited only by the number of intervals used in the trajectory integration.

3.3. *Analytic Solution of the Paraxial Ray Equation*

As mentioned above, we also tried to develop a single equation functionally correlating ρ to the other parameters. To solve the electron trajectory equation in analytic form, one more simplifying assumption was added to those already used. The arc tangent in the expression for axial potential (eqn. (4)) is replaced by the first term of its series-expansion. This approximation is valid only for small values of the argument z/R, hence, in the close vicinity of the mesh.

The axial potential distribution (eqn. (4)) thus becomes:

$$V(Z) = V_c\left(1 + \frac{2E}{\pi R V_c} Z^2\right) \quad \ldots\ldots\ldots(10)$$

and the first derivative

$$V' = \frac{4E}{\pi R} Z \quad \ldots\ldots\ldots(10a)$$

The paraxial ray equation (eqn. (5)) expressed in terms of a new variable

$$P = rV^{\frac{1}{4}} \quad \ldots\ldots\ldots(11)$$

is given by[6]

$$P'' = -\frac{3}{16}\left(\frac{V'}{V}\right)^2 P \quad \ldots\ldots\ldots(12)$$

or by substituting for V and V' from eqn. (10) and eqn. (10a):

$$P'' = -\frac{3}{16}\left[\frac{4EZ}{\pi R V_c\left(1 + \frac{2E}{\pi R V_c} Z^2\right)}\right]^2 P \quad \ldots\ldots(13)$$

Since $\frac{2EZ^2}{\pi R V_c} \ll 1$ is true even for the strongest lens practically possible, namely, the unipotential saddle field lens with 0 mesh potential, eqn. (13) reduces further to

$$P'' = -\frac{3E^2Z^2}{\pi^2 R^2 V_c^2} P \quad \ldots\ldots\ldots(14)$$

The solution of eqn. (14) is[9]

$$P = Z^{\frac{1}{2}}\left[c\, J_{\frac{1}{4}}\left(\frac{A}{2}Z^2\right) + d\, J_{-\frac{1}{4}}\left(\frac{A}{2}Z^2\right)\right] \qquad \ldots\ldots(15)$$

with

$$A = \frac{\sqrt{3}E}{\pi R V_c} \qquad \ldots\ldots\ldots(15a)$$

The Bessel functions $J_{\frac{1}{4}}$ and $J_{-\frac{1}{4}}$ reduce to relatively simple expressions for small arguments converting P into a linear function of z (see Appendix 1).†

We can now transform this solution of the modified paraxial ray equation into a form in the original variable r using the reduced Bessel functions and obtain

$$r = V^{-\frac{1}{4}}(a+bz) = V_c^{-\frac{1}{4}}\,\frac{a+bz}{1+\dfrac{EZ^2}{2\pi R V_c}} \qquad \ldots\ldots(16)$$

The constants a, b, can be determined from the boundary conditions $r' = 0$ and $r = r_0$ at $z = z_0 = R$.

Thus, we obtain

$$r = r_0\,\frac{1-\dfrac{ER}{2\pi V_c}+\dfrac{EZ}{\pi V_c}}{1+\dfrac{EZ^2}{2\pi R V_c}} \qquad \ldots\ldots\ldots(17)$$

This equation describes the trajectory through a symmetrical, initially decelerating saddle field lens formed by a (circular) mesh-aperture valid under the assumptions listed in the text.

Since the focal distance for a (circular) aperture lens is given[10] by $(E_2 = E_1 = E)$:

$$f = \frac{2V_c}{E} \qquad \ldots\ldots\ldots(18)$$

and using the same consideration of the geometrical similarity of trajectories as before (and which is also exhibited by eqn. (17)), we obtain:

$$\rho = \left(1-\frac{ER}{2\pi V_c}\right)^{-2} = \left(1-\frac{R}{\pi f}\right)^{-2} \qquad \ldots\ldots\ldots(19)$$

The relative electron transmission ρ as a function of the normalized lens power $\dfrac{R}{f} = \dfrac{RE}{2V_c}$ is depicted in Fig. 3. Curve A of this figure shows the results obtained by numerical integration of the ray equation (see previous Section) and curve B shows the results obtained from the analytic solution. It will be shown later on that only those parts of the curves correlated to small values of the (normalized) lens power are of practical importance.

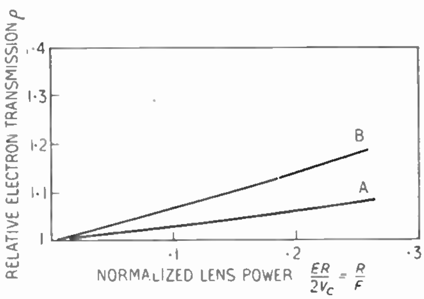

Fig. 3. Relative electron transmission as function of normalized mesh lens power (theoretical values).

Having obtained theoretical solutions for the electron transmission of meshes, measurement methods and experimental results will be discussed in the following sections, which will substantiate the essence of the theoretical findings.

4. Experimental Results

4.1. *Measurement Methods*

The seemingly simplest way of measuring the mesh transmission would be to determine the current intercepted by the mesh and then obtain the difference between cathode current and mesh intercepted current. The ratio of this value and the cathode current is the electron optical mesh transmission. This method is, however, hardly reliable because a current meter in the mesh lead does not measure the current intercepted by the mesh, but the difference between primary electrons intercepted by the mesh and secondary electrons emitted from the mesh. Both the direction and amount of the measured current will depend on the coefficient of secondary emission. The current read in this manner is very low for metal meshes and this approach cannot be used for determining the mesh transmission.

A second possible method is the comparison of tubes containing a scan magnifier lens with a mesh and tubes in which the lens contains no

† The assumption of a small argument was already used in the reduction of eqn. (13).

mesh. Even if these two groups of tubes are nominally identical, and even if the tubes are adjusted to equal cathode current values, differences in both screen structure and aluminizing might falsify the brightness reading. Comparing average brightness values determined on tubes with and without mesh would, of course, give an average value for the electron optical mesh transmission; however, large numbers of readings on different tubes are required to obtain reliable results. Thus, this method does not lend itself to individual comparison between two tubes.

We have attempted to determine the variation of the mesh transmission, in individual tubes containing scan magnifiers employing a mesh, as a function of the voltage ratio in the tube. The mesh electrode is brought out to a side contact on the neck of the tube; hence, it is possible to connect the mesh electrode with the screen of the tube and thus to operate with zero lens strengths for both the scan magnifying lens and the interstitial mesh lenses. For this condition the drive is adjusted to give a certain cathode current value. Care is taken that this current value is well below the critical current at which beam interception occurs in the apertures of the electrostatic main lens.

A line raster on the face of the tube is adjusted to a certain size and the tube is focused for minimum line width. Under this condition the mesh of the scan magnifier lens acts as a mere beam interceptor. The transmission of the mesh for electrons is the same as the transmission of the mesh for light rays, at least to a first approximation, neglecting a slight increase of transmission due to "skew electrons." The brightness of the line raster is now measured with an eye-corrected Weston photocell.

Next, the potential of the mesh is decreased in steps. In doing this we are creating an ever-increasing strength for the interstitial mesh lenses. Both the cathode current and the raster size are carefully controlled and kept constant. For each potential value of the mesh, the line raster is refocused for minimum line width and the brightness is measured. In decreasing the potential of the mesh and keeping the potential of the screen constant, the measured brightness should increase provided the electron optical transmission of the mesh increases with increasing strength of the interstitial mesh lenses beyond the value of the optical transmission.

It should be noted that secondary electrons reach the screen at a certain value of the ratio of screen and mesh potentials. These secondary electrons, while having a different velocity than the primary electrons and not carrying information, will nevertheless contribute to the brightness reading.

4.2. *Results*

The influence of the strength of the interstitial mesh lenses on the electron transmission of scan magnifiers employing the mesh, or on the brightness obtainable on the phosphor screen of television picture tubes, has been determined as outlined in the previous section for voltage ratios of four or less in the scan magnifier lens.

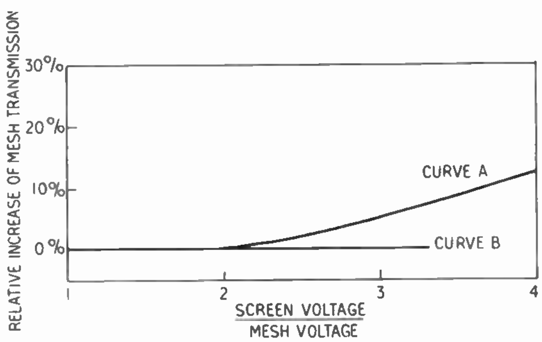

Fig. 4. Relative electron transmission as function of the ratio of screen voltage and mesh voltage (experimental values).
Curve "A": Relative increase of mesh transmission for a two-electrode scan magnifier as shown in Fig. 1.
Curve "B": Relative increase of mesh transmission for a three-electrode scan magnifier as shown in Fig. 2.

Substantially higher voltage ratios can hardly be used in practical television picture tubes as they lead to severe degradation of resolution. The results are depicted in Fig. 4.

Curve A of this figure shows the correlation of mesh transmission and voltage ratio determined for a two-electrode scan magnifier as shown in Fig. 1. It can be seen that the electron optical mesh transmission increases by approximately 10 per cent. for voltage ratios in the range of 1 to 4. Thus a mesh having an optical transmission of, say, 50 per cent. has an electron optical transmission of approximately 55 per cent. at the voltage ratio of 4.

Curve B of this Fig. 4 shows the correlation of mesh transmission and the ratio of screen and mesh voltage for a three-electrode mesh type scan magnifier as shown in Fig. 2. It can be seen that the mesh transmission does not change within the accuracy of the method used (± 3 per cent.).

The apparently greater increase of the mesh transmission with increasing voltage ratios for the two-electrode scan magnifier is not fully understood, but may possibly be explained by the fact that in this case the collection of secondary electrons occurs only in the forward direction and thus a considerable portion of the brightness increase is due to secondary electrons. Having available both theoretical and experimental results, it is now possible to compare both methods and assess the practicability of using electrostatic scan magnifiers employing meshes in television picture tubes for portable receivers.

4.3. *Comparison between Experimental and Theoretical Results and Discussion*

In correlating the experimental findings with the results of the previous theoretical section valid for a three-electrode scan magnifier, the field E at the mesh is expressed by[2]

$$E = 1{\cdot}32 \frac{V_s - V_0}{R^*} \qquad \text{.........(20)}$$

where

V_s = screen potential.

V_0 = mesh potential.

R^* = radius of the electron lens (in our case 0·5 in.).

Substituting eqn. (20) into eqn. (3) gives

$$V_c = V_0 + \frac{2{\cdot}64}{\pi} \cdot \frac{V_s - V_0}{R^*} R \qquad \text{.........(21)}$$

Using eqn. (20) and eqn. (21), the normalized lens power (in units of the mesh lens radius $R = 10^{-3}$), R/f may be expressed by

$$R/f = \frac{ER}{2V_c} = \frac{1{\cdot}32 \times 10^{-3}\,(V_s/V_0 - 1)}{1 + 1{\cdot}68\,(V_s/V_0 - 1)\,10^{-3}} \qquad \text{.........(22)}$$

The ratio V_s/V_0 ranged from 1 to 4 in the experiments, the ratio 4 corresponding to $R/f = 3{\cdot}98 \times 10^{-3}$. A lens with a focal length 252 (namely $1/3{\cdot}98 \times 10^{-3}$) times its radius is still a relatively weak lens and thus should not affect greatly the electron trajectories. According to eqn. (19) such a lens should give rise to about 0·25 per cent. increase of electron transmission. Thus, the correlation between this theoretical result and the experimental results depicted by Curve B of Fig. 4 is quite satisfactory.

The lens shown in Fig. 1 has not been investigated theoretically. However, it may be assumed that the change of mesh transmission as function of the voltage ratio applied follows approximately the correlation derived for the lens shown in Fig. 2.

The experimental results for such a two-electrode lens depicted in Curve A of Fig. 4 indicate that the mesh transmission changes more pronouncedly as a function of the voltage ratio than the extrapolated theoretical results indicate.

As mentioned previously, the two-electrode lens of Fig. 1 permits collection of secondary electrons emitted by the mesh only in one direction, namely, in the forward direction. Further, the specific geometry employed in the two lens structures being compared resulted in a weaker potential gradient in the forward direction for the two-electrode lens of Fig. 1. Both these conditions can be expected to result in more secondary electrons bombarding the phosphor screen of the tube at random. Thus, it seems probable that the brightness increase found experimentally is largely caused by secondary electrons.†

It should also be noted that the increase in mesh transmission found experimentally is only about 10 per cent. It was estimated previously that the accuracy of the experimental method employed amounts to about ± 3 per cent. Thus, the measured increase of 10 per cent. is hardly of any practical consequence.

† It should also be mentioned, that the increase in line-width, experienced with increasing scan-magnification, leading to decreasing current-densities at the phosphor-screen, might give cause to a slight increase in brightness, as phosphor-saturation decreases in importance.

Summarizing, it may be concluded that *practical* electrostatic scan magnifiers employing meshes cannot be designed to provide electron transmission substantially higher than the light optical transmission of the meshes employed.

5. Acknowledgments

The authors gratefully acknowledge their indebtedness to Dr. C. S. Szegho for his continued interest and helpful suggestions extended to us while working on this paper, and also to Mr. P. J. Reinhart for carrying out the measurements described above.

6. References

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7. Appendix 1 : Reduction of equation (15)

The Bessel functions $J_{\frac{1}{4}}$ and $J_{-\frac{1}{4}}$ may be expanded into series†

$$J_{\frac{1}{4}}\left(\frac{A}{2}Z^2\right) = \frac{Z^{\frac{1}{2}}\, A^{\frac{1}{4}}}{\frac{1}{4}!\,\sqrt{2}}\left(1 - \frac{A^2 Z^4}{20} + \ldots\right)$$

$$J_{-\frac{1}{4}}\left(\frac{A}{2}Z^2\right) = \frac{\sqrt{2}}{(-\frac{1}{4})!\, A^{\frac{1}{4}}\, Z^{\frac{1}{2}}}\left(1 - \frac{A^2 Z^4}{12} + \ldots\right)$$

Omission of all but the first terms in the series expansions is justified for $E/V_c \leq 10^8$, this value being well above any value encountered in practical aperture lenses of the type discussed here.

† See ref. 9, p. 128.

INSTITUTION NOTICES

A New Format for the January Journal

Reference is made in the Annual Report to the increasing number of papers which are being accepted for publication in the *Journal*. It has therefore been decided that, with effect from the January 1961 issue, the page size of the *Journal* will be increased to 11 in. by 8½ in. Opportunity has been taken at the same time to adopt a new, more striking design for the cover, to re-arrange the position and presentation of the "Contents" page and to make a number of changes to the layout of the first pages of papers. The type size and face and general layout of papers are not being altered but the increased page area will allow more effective presentation of diagrams and mathematical formulae; more important, however, is the fact that the change provides an increase in the word content of each page of approximately 20 per cent.

The editorial to the January issue has been written by the Vice-Patron, Admiral of the Fleet The Earl Mountbatten of Burma, K.G. The *Journal* includes a particularly wide range of papers covering nearly every aspect of radio and electronic engineering as may be seen from the following list:—

"Electro-Acoustics for Human Listeners," PROFESSOR COLIN CHERRY.

"The Problem of Frequency Synthesis," H. J. FINDEN.

"The Cathode Loading Limit in Circular Beam Electron Devices," HILARY MOSS.

"Variation of L.F. Noise Figure of a Junction Transistor," S. DEB AND A. N. DAW.

"System Engineering in Theory and Practice," M. JAMES AND G. S. EVANS.

"Radio Guidance Elements of the B.L.E.U. Automatic Landing System for Aircraft," J. S. SHAYLER.

"Reception of B.B.C. Television Sound Transmission on 41·5 Mc/s at Halley Bay, Antarctica," L. W. BARCLAY.

"Symmetrical Transistors," G. H. PARKS.

"Engineering Aspects of Missile Telemetry Equipment," W. M. RAE.

"455 Mc/s Telemetry Ground Equipment," F. F. THOMAS.

The issue will also contain news of the activities of the Institution's sections in Great Britain and the Commonwealth, articles on recent technical developments and abstracts from overseas journals.

East Midlands Section

The growth of the radio and electronics industry in the East Midlands combined with the increase in Institution membership in the area has lead to the suggestion of regular local meetings. An exploratory meeting of members will therefore be held on Wednesday, 25th January at the Leicester College of Technology.

The intention of this exploratory meeting is to determine the extent of this support and if sufficient the Council will no doubt be asked to authorize the formation of an East Midlands Section. All members in the area have been sent details, but other persons interested should get in touch with Mr. W. J. Stevenson, A.M.Brit.I.R.E., 77 Beacon Road, Loughborough, Leicestershire.

Completion of Volume

This issue completes Volume 20 of the *Journal* and an index is enclosed.

Members wishing to have their Journals bound by the Institution should send the 12 issues for the year together with the index to 9 Bedford Square, London, W.C.1. A remittance for 16s. 6d. plus the appropriate return postage (for Great Britain 3s.; Commonwealth and other countries 4s.) should accompany the Journals.

Physical Society's Exhibition

Members are reminded that, by courtesy of the Institute of Physics and the Physical Society, tickets may be obtained from the Institution enabling them to visit the Physical Society's Exhibition of Scientific Instruments and Apparatus at the Royal Horticultural Society's Halls, Victoria, London, S.W.1, on the morning of Monday, 16th January between 10.30 a.m. and 2 p.m. Tickets giving admission at the following times may also be obtained from the Institution:

Monday, 16th January, 2 p.m. to 7 p.m.
Tuesday, 17th January, 10 a.m. to 9 p.m.
Wednesday, 18th January, 10 a.m. to 7 p.m.
Thursday, 19th January, 10 a.m. to 7 p.m.
Friday, 20th January, 10 a.m. to 1 p.m.

As the number of tickets available, particularly for the "members' morning," is limited, early application is advisable.

Electronic Techniques in Oceanography †

by

M. J. TUCKER, B.SC. ‡

A paper read at a meeting of the Institution in London on 27th April, 1960.

In the Chair: Rear-Admiral Sir Philip Clarke, K.B.E., C.B., D.S.O. (*Past President*).

Summary: General factors governing the design of electronic equipment for oceanographic use, and the design of housings for withstanding high pressures are discussed briefly. Underwater acoustics is discussed in some detail. Electromagnetic waves do not travel far underwater, and acoustic waves are therefore used for many of the purposes for which electromagnetic waves are used in the atmosphere: echo-ranging and detection, telemetering, etc. Finally, two wave recorders are described: a shipborne wave recorder, and an f.m. pressure gauge which has a resolution of 1 part in 10^6 of full scale and which is suitable for digital recording and analysis.

1. Introduction

In common with all branches of science, Oceanography has benefited greatly in recent years from the introduction of electronic instruments. On a typical cruise of the Royal Research Ship *Discovery II* it is becoming difficult to find room for all the electronic equipment required. Permanently installed are the navigation instruments; radar, Decca, loran, gyro-compass and navigational echo-sounders. For survey work these may be supplemented by special devices such as course recorders and track plotters. Then, depending on the object of the particular cruise, the biologists may have photometers used for comparing photosynthesis in the sea with the incident illumination, or acoustic echo-detection devices for investigating the habits of marine animals. The chemists may have a conductivity meter for determining the salt content of the sea, or a photo-electric colorimeter used for analysing trace elements. The geologists may have a precision echo-sounder for measuring deep-sea topography, or a sonar for obtaining acoustic pictures of the sea bed. The physicist may have devices for measuring the height of sea waves, or for measuring deep ocean currents.

This is merely a selection from the sea-going electronic equipment. There are also shore-based recorders (for waves and tides for example), equipment for use in buoys, and special computing equipment for analysing results. The author has felt it best to start with a few general remarks about the special problems of using electronics in oceanography, and then to discuss a few particular and representative applications in some detail.

2. General Considerations in the Design of Electronic Equipment for Oceanography

Reliability is, of course, a universal requirement of all equipment. Though a failure in oceanographic equipment is not so expensive as one in a guided missile, for example, which might cause a million pound rocket to be wasted, it can still be quite expensive and might result in the loss of a unique opportunity to obtain certain observations. A ship costs perhaps £300 a day to run, and a few wasted days soon add up to a considerable sum. Similarly, it may cost £1,000 or more to re-lay a faulty shore-based wave recorder.

† Manuscript received 26th March 1960. (Paper No. 597.)

‡ National Institute of Oceanography, Wormley, Godalming, Surrey.

U.D.C. No. 621.37/9: 557.46.018

However, accepting the reality that faults may occur, it is important to design a system which cannot give false information without making it obvious that something has gone wrong. It sometimes happens that when a set of observations are analysed, the results are not quite what was expected and the scientist concerned asks "Are you quite sure the instrument was working properly at the sensitivity stated?" It is very embarrassing if one has to admit that a fault could have occurred without one's being aware of it. Similarly, to avoid any doubt as to the setting of a sensitivity control, a fixed sensitivity is desirable. This often means that high-resolution recording is necessary in order to record small outputs with sufficient accuracy. Anyone who has been at sea in rough weather will realise that even good sailors are not at their best under these conditions: intelligence is inversely proportional to wave-height. The ideal instrument for use at sea has therefore only one control: an on/off switch.

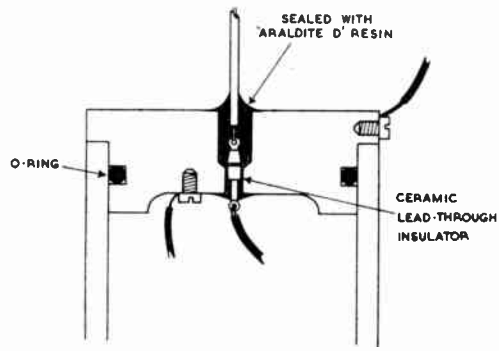

Fig. 1. The end-seal for a scaffold-tube used as a pressure case, showing a simple electrical lead-through suitable for use where high insulation is not required (tube diameter approx. 2 in.).

Though these desirable features cannot always be achieved, some instruments approach them fairly closely, and the shipborne wave recorder described in Section 5 is an example of such an instrument.

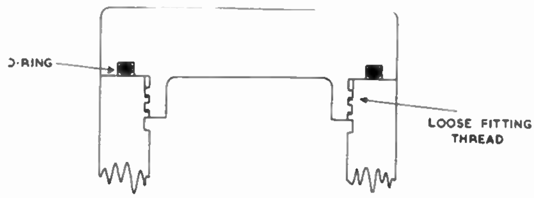

Fig. 2. The end-seal for the pressure case of the deep-sea camera. The material is anodized aluminium alloy.

3. Pressure Housings

The greatest depth in the ocean is about 10,000 metres, but the area exceeding 5,000 metres in depth is comparatively small. Thus, oceanographic instruments for lowering into the deep ocean are usually adequate if they will withstand a pressure corresponding to 5,000 metres (approx. 500 atmospheres, or 7,000 lb/in.^{2}). As so often happens, it has been found that extreme conditions can be met with apparatus of elegant simplicity if the correct principles are used.

The cheapest pressure housings consist of aluminium scaffold tubing, with ends sealed as shown in Fig. 1. This illustration also shows the simplest type of electrical lead-through which is adequate for low-impedance circuits; it can be used for connecting a magnetostriction transducer, for example. The mode of action is that the rubber "O" ring is trapped just tightly enough in its groove to form a seal at low pressure. Increasing pressure forces it into the corner of its groove, and at the same time tends to compress the tube and so reduce the gap between the inner wall of the tube and the plug. This end cap will seal at all pressures, and yet can be pulled out by hand when required.

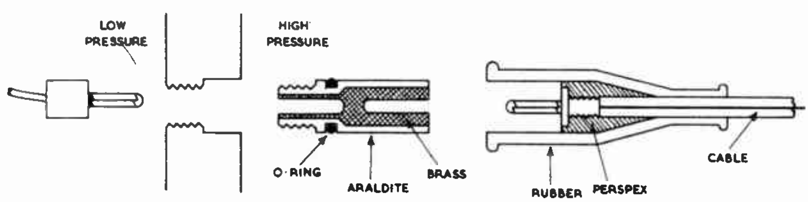

Fig. 3. Expanded diagram of the watertight plug and socket used on the deep-sea camera.

A variation of this principle is shown in Fig. 2 for a larger tube, where the simple type of plug shown in Fig. 1 may tend to jam. Here the square threads are made with a lot of clearance. The cap is screwed on hand-tight, and the pressure pushes the cap down on to the tube producing the same effect as before.

Where an external plug and socket is required, the arrangement shown in Fig. 3 is used, which is watertight at all pressures. It works on the principle of having no air spaces: before mating, it is filled with silicone grease which occupies any small cavities. (Figures 2 and 3 show arrangements used on the deep-sea camera described by Laughton[1].)

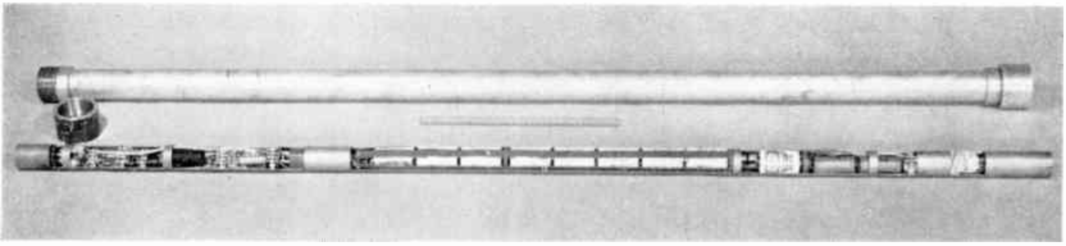

Fig. 4. An example of an electronic instrument housed in a scaffold tube (an irradiance meter).

Figure 4 shows an example of an electronic instrument using a scaffold-tube pressure housing. This is an integrating irradiance meter used for comparing photo-synthesis in the sea with the incident light. The instrument is suspended during the daylight hours at the required depth from a small buoy with the photocell (at the left in the figure) pointing upwards. The photocell current charges a capacitor: when the voltage of this reaches a predetermined level, the capacitor is discharged. The number of discharges is proportional to the integral of the incident illumination, and is recorded on a telephone message register visible through a window at the other end of the tube (instrument due to L. Draper).

4. Underwater Acoustics

Perhaps the field of greatest interest to a radio engineer is underwater acoustics. Here, many of the techniques familiar to him have their parallels, but in a strange world in which the waves travel 2×10^5 times slower than radio waves, and frequencies down to a few cycles per second are sometimes radiated.

The reason for the widespread use of sound underwater is that electromagnetic waves of all wavelengths are rapidly attenuated in the sea. This fact is of far-reaching importance. It confines the growth of green plants to about the top 100 metres of the ocean, means that the ocean is heated from the top, unlike the atmosphere which is heated from the bottom, restricts the use of underwater photography to small-scale features, and prevents the use of radio and radar under water. It is fortunate that sound travels comparatively well in the sea, though not as well as electromagnetic radiation in the atmosphere, and can be used instead of radio for many purposes.

4.1. *Underwater Echo-ranging*

The differences in the properties of radio and acoustic waves, and the differences in techniques are well illustrated by a comparison of a typical radar with its underwater acoustic equivalent, called A.S.D.I.C. in Britain and Sonar in America (Table 1). The author prefers the latter term since it seems to him to be so much more descriptive. The sets chosen for comparison are those fitted in the R.R.S. *Discovery II*, and are the Kelvin-Hughes Type 2C radar, and a sonar specially designed by N.I.O. for fishery and geological investigations.

The radar engineer's first reaction may well be that oceanographers are lucky to be able to deal with low frequencies and long-duration pulses. This is true, and whereas the radar engineer has to work hard to get pulse lengths much below the 60 m of the Type 2C radar, sound pulses 1 cm or less in length can be obtained for short-range work. However, a heavy price has to be paid in the slowness with which information can be gathered. If a sonar could be designed with the 50 mile range of the radar, only 30 pulses per *hour* could be transmitted. This limitation can be mitigated to some extent by rapid sector-scanning techniques, such as those described by D. G. Tucker and others[2], but is still serious.

The similarity in the carrier wavelengths of the two devices is largely coincidental, but results in transducers of similar aperture (Fig. 5).

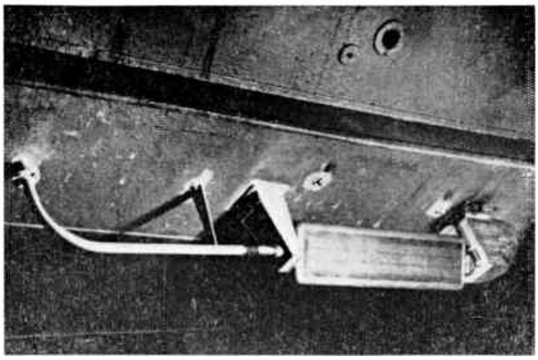

Fig. 5. The transducer of the 36 kc/s sonar.

Table 1

Comparison of Radar and Sonar Equipments

		Radar	Sonar
Velocity of propagation		3×10^{10} cm/sec	$1{\cdot}5 \times 10^5$ cm/sec
Carrier:	frequency	9420 Mc/s	36 kc/s
	wavelength	3·2 cm	4·2 cm
Pulse:	duration	0·2 μsec	1 msec
	length	60 m	1·5 m
	power	60 kW	250 W
	repetition frequency	1000 pulses/sec	1 pulse/sec
Maximum range		50 miles	750 m
Horizontal beam angle		1·3°	1·3°

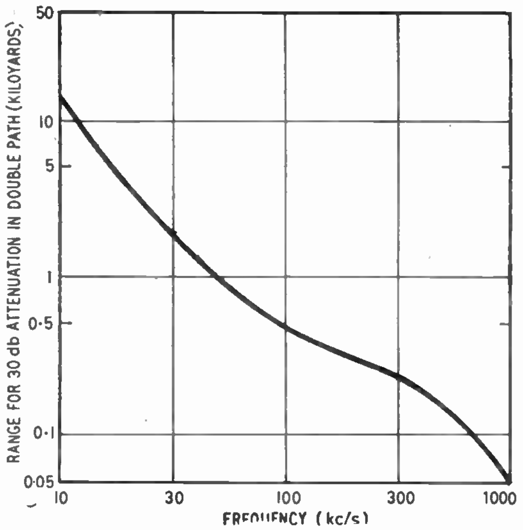

Fig. 6. Range at which there is a 30 db loss due to absorption of sound in the water (double path in clean, bubble-free sea water).

Two other effects, not usually serious in radar, also limit the range of a sonar: absorption and refraction. Figure 6 shows the range at which there is a 30 db absorption loss in the double path of a sonar. Though this is small compared with the losses due to the spreading out of the sound, which may be in the region of 100 db, it often turns out to be the limiting factor in the design of a sonar, and the ranges given are within a factor of two of those usually achieved in practice. If a given sonar just detects a certain target at this range it would require more than a 10,000-fold increase in power to double the range of detection.

The absorption increases quickly with frequency, and so for a given range there is a fairly definite upper limit of frequency that can be used. Apart from the effect of absorption, the higher the frequency the better, since the transducers are smaller and cheaper, the possible resolution is higher, and the background noise in the sea is lower. Thus, unless there are other special factors to be taken into account, the carrier frequency of an acoustic device in the sea is governed fairly closely by the range required.

The second fundamental limitation on the range obtainable with sonar is refraction. The velocity of sound in water increases with increasing temperature (and increasing salt content and increasing pressure, but these are usually unimportant). Since the sea tends to be stratified with warmer water near the surface, a beam of sound initially travelling horizontally gets bent away from the surface towards the sea bed. The effect varies from place to place and according to the season of the year, but typically will limit the useful range of a horizontal sonar in the North Atlantic to a few thousand yards.

Sonar, like radar, was originally developed for military purposes, but has proved of great importance in civilian applications. For example, a striking recent application of the set which has just been discussed is to investigate the surface geology of the sea bed. In shallow water (up to, say, 100 fathoms), a detailed acoustic picture of the sea bed can be obtained (Fig. 7). The acoustic beam points out sideways from the ship, is slightly depressed from the horizontal, and stabilized against roll. The echo pattern is recorded as an intensity modulation using a mechanical stylus moving across paper impregnated with chemicals. The echoes are amplified, rectified and passed through the stylus. One of the ions liberated reacts with iron from the stylus to cause a darkening of the paper. As the ship steams on a straight course, an acoustic picture of the sea bed is slowly built up on the chart. In the picture shown, the strata can clearly be seen, together with some small fractures in the rocks. Combined with mechanical sampling of the sea bed, this technique enables the geology to be determined in considerable detail.

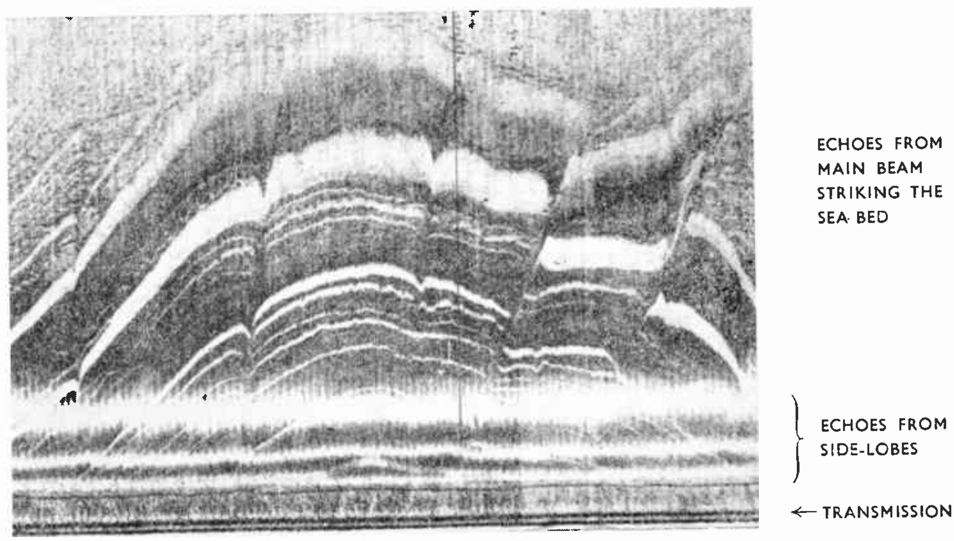

Fig. 7. An acoustic picture of the sea bed obtained using the sonar described in Table 1.

Only very brief mention can be made of the other applications of underwater echo-ranging. The one of greatest economic importance is the location of fish by fishermen, and as "echo-sounding" it is widely used for determining the depth of the sea for navigational purposes. For scientific purposes, precision echo-sounding can give much useful information about deep-sea geology and sedimentation processes, and special echo-sounders which can penetrate the sea bed can help elucidate the sub-bottom geology. Some of the work on echo-ranging being done at Birmingham University has recently been described to this Institution by Professor Tucker[3].

4.2. *Acoustic Telemetering*

There are two types of information which are required from instruments in the sea. The first is measurement of something to do with the sea, and the second is information about what is happening to a piece of equipment. Most measuring instruments at present in use are self-contained and the information is stored in the instrument till recovery, but in some cases it would be a great convenience if the measurement could be telemetered directly to the ship. In the second type of problem, the information required may be, for example, the depth at which a sampling net is being towed, or whether a corer or camera has reached the sea bed and has operated.

The obvious way of bringing the information back is over an electric cable, but this has many disadvantages. The first is that special weight-bearing cables nearly always have to be used, since it is impracticable to handle both a steel wire rope and a separate electric cable unless they are short. Such weight-bearing cables are used by oil companies for lowering instruments down oil wells, but do not stand up well to marine use which is in some ways more arduous than working from a stable platform ashore. Cables more suitable for marine use have been designed, but are still not satisfactory where lengths of more than a few hundred yards are required. It is, after all, difficult to design even a plain steel wire rope which will support much more than its own weight in the greatest depths of the ocean (about 10 km). The special winches with slip-rings are also expensive and take up valuable deck-space.

There is thus considerable incentive to develop acoustic telemetering devices, and the reason there are not more of them is probably mainly the lack of instrument engineers skilled in the somewhat specialized art of underwater acoustics. It may also be partly due to the fact that some early devices using thermionic valves were comparatively bulky and unreliable.

4.2.1. The pinger

It is remarkable how much use can be made of even the simplest telemeter. In fact, the only acoustic telemetering device used extensively to the present time is a very simple one called a "pinger." In its simplest form, shown in Fig. 8, a capacitor is charged from hearing-aid type batteries and discharged through a cold-cathode gas-filled tube (a strobotron, for example) in series with the winding of a "scroll" type magnetostriction transducer. This causes a momentary contraction of the scroll-ring, which then oscillates at its natural frequency and emits a damped train of waves. The transducer frequencies so far used have been in the region of 10 kc/s, which gives reasonable sized transducers without excessive absorption in the water at the ranges required.

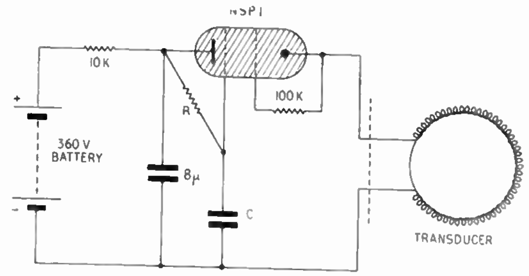

Fig. 8. The circuit of a "pinger," a simple acoustic pulse generator.

Swallow[4] has used this device in his neutrally buoyant floats for measuring deep ocean currents. These floats consist of aluminium alloy tubes which are less compressible than sea water, and which will therefore float at a fixed depth if suitably weighted. By following the floats, the path of the water current can be determined. In this application the pinger is self-running with a repetition frequency of one every few seconds. The pings are picked up by a directional hydrophone system on the ship, and by steaming the ship to a new position and again measuring the direction of the float relative to the ship, its position can be determined. The life of the floats can be extended by including a clock to switch them on for only a few hours a day, and the record so far achieved by Swallow is to follow the same float for nearly seven weeks.

A similar pinger is used by Laughton[1] in his deep-sea camera, to tell the operator when the camera, lowered from a cable, has reached the sea bed. A pinger attached to the camera emits pulses at a slow rate during the lowering, but when the trigger weight hits the sea bed the pulse rate is increased and a photograph is taken using an electronic flash. The operator then raises the camera a few metres, waits a minute during which the camera resets itself and the ship drifts a little, and then lowers the camera again to take another photograph. The camera can take up to 100 photos without recharging.

Though this pulse generator is very crude, with a power efficiency of only about 2 per cent., it has the major virtues of simplicity and low cost. The range of detection is two to four miles, depending on weather conditions. A similar device has been designed by Edgerton and Cousteau[5], who have included a clock to trigger the pulses at intervals of precisely 1 sec. The received pulses can thus be recorded on a precision echo-sounder recorder in such a way that successive pulses appear under one another on successive sweeps of the stylus. Such a pinger attached to a device lowered over the side of a ship gives all kinds of useful information. For example, the separation of the directly received pulse and its echo from the sea bed will give the height of the device above the sea bed to an accuracy of a few feet. In a deep-sea corer, part of the equipment is released and drives itself into the sea bed, and this can also be seen hapening by watching the echoes from the various parts of the device.

4.2.2. Depth-of-net Telemeters

There is increasing interest throughout the world in commercial fishing using mid-water trawls. A shoal of fish is located and its depth measured using an echo-sounder, and the ship then tows the trawl net through the shoal. However, without instruments it is difficult for the fisherman to know whether his net is at the correct depth, since many factors can affect this. Similarly, there are many occasions when the marine scientist would like to know the depth of his equipment. One of the more promising devices for this purpose is the acoustic-telemetering pressure gauge.

Such a device has been described by Stephens and Shea[6] of the U.S. Fish and Wildlife Service, who redesigned a similar device described by Dow[7]. In this instrument, the pressure varies the frequency of a supersonic carrier, and temperature is also measured and varies an audio frequency which is transmitted as an amplitude modulation on the carrier.

The arrangement of the system is shown in Fig. 9. The use of directional transmitters and receivers, even though they have to have wide beams, greatly improves the signal/noise ratio. Between 1 and 2 W is delivered to the transducer at a frequency varying between 21 and 36 kc/s, and this is modulated by the temperature signal varying between 200 and 800 c/s.

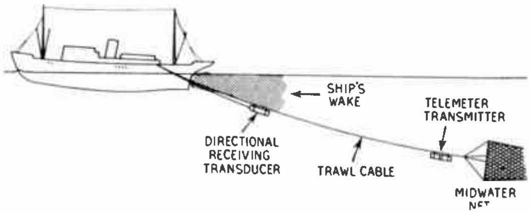

Fig. 9. The arrangement in use of an acoustic-telemetering depth-of-net meter.

The receiving transducer is slipped down the towing warp after this has been fully let out, and thus needs no extra men for its operation. After pre-amplification, the received signal is fed to an l.f. radio receiver whose dial reading is a measure of the depth. The output of the radio receiver is the audio-frequency temperature signal. A depth accuracy of 1 per cent. and a range of one mile is claimed for this instrument.

5. Wave Recording

Waves are perhaps the physical oceanographer's most important study from the economic point of view. Several tens of millions of pounds are spent each year protecting the coasts and harbours of Britain alone from the action of waves, and about 300 ships of one sort and another are lost each year, mainly due to wave damage in storms. The author has seen no figures for the value of time lost due to delays to ships having to slow down in rough seas, but it must be several millions of pounds a year. Recording of waves will tell the engineer what he is up against, and is an essential step in the deeper understanding of their properties and of their interaction with ship and shore.

In passing, it may be remarked that for most practical purposes, sea waves have the characteristics of filtered random noise, which is only too familiar to the radio engineer. When analysing sea waves, bandwidths in the region of 0·01 c/s are used, so it may be imagined that the incoming signal is rarely analysed directly, but is usually recorded and speeded up, or recorded and analysed digitally.

A wide variety of wave recorders have been made. One can record the movement of the sea-surface up and down a wire by capacitance or resistance methods, or use an echo-ranger looking upwards from the sea bed. One can record the variations in pressure on the sea bed as the waves pass overhead, or measure the vertical component of the acceleration of a small float on the sea surface. Two types of wave recorder will be described briefly here: one for use in ships at sea, and the other an f.m. pressure recorder which can be used with a radio telemeter, and which is suitable for high-precision digital recording.

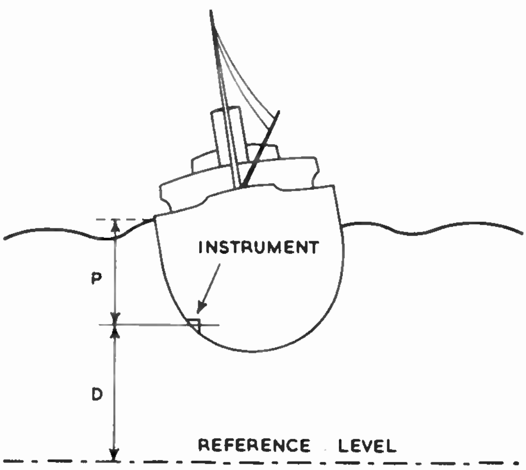

Fig. 10. The principle of the shipborne wave recorder.

5.1. *Shipborne Wave Recorder*

The recording of waves on the deep sea is difficult because there is no stable platform available on which to mount one's instruments. In the Shipborne Wave Recorder the problem has been overcome by measuring the height of the waves relative to the ship, and the vertical displacements of the ship itself, and adding these together (Fig. 10). The height of the waves relative to the ship is determined by measuring the pressure on the hull at a point sufficiently deep never to come out of the water.

The difficult measurement is the vertical displacement of the ship, which is performed by measuring the vertical component of acceleration and integrating this twice electronically. Electronic integrators of high quality are commonly used in analogue computers and two such integrators in series are required to convert a voltage proportional to acceleration into one proportional to displacement. Such a system is subject to serious drift, however, since an integrator has a voltage response inversely proportional to frequency. Any small d.c. or very low frequency spurious voltages that may be introduced into the input give rise to proportionately large outputs, and this effect is particularly important with two integrators in series. Unfortunately, there are several ways in which such spurious voltages can be generated. For example, non-linearity of the accelerometer or its associated circuitry can produce a rectification of the wave envelope, and good linearity here is thus essential. However, the most important source of low frequencies is unfortunately fundamental to the way the accelerometer is mounted. Ideally, it should be held truly vertical by mounting, for example, on a gyroscope, but to reduce complication and increase reliability, the accelerometer is actually hung in gimbals and forms a short period pendulum. This means that it is tilted by the sideways acceleration of the ship: in fact, if the period of the pendulum is short, it sets itself in the direction of the resultant acceleration whose magnitude $|G(t)|$ it thus measures.

But $$|G(t)|^2 = (g+\ddot{z})^2 + \ddot{x}^2 + \ddot{y}^2$$

where g is the acceleration due to gravity.

This gives to the second approximation

$$|G(t)| = g + \ddot{z} + (\ddot{x}^2 + \ddot{y}^2)/2g$$

The last term is non-linear and thus produces rectification and intermodulation between the component frequencies in the waves, resulting in d.c. and low-frequency components. If the accelerometer output were truly integrated, the ship would appear to be rising from the earth

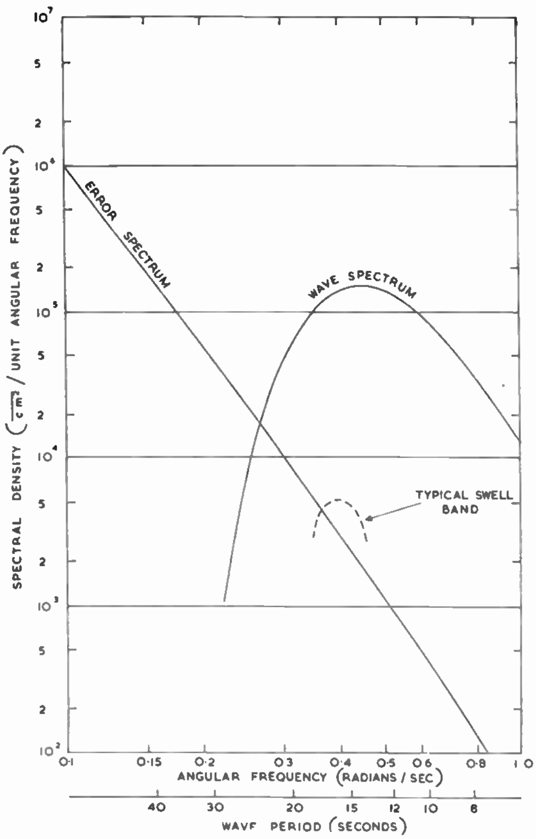

Fig. 11. The spectrum of the errors due to measuring waves with a vertical accelerometer hung in gimbals instead of being held truly vertical.

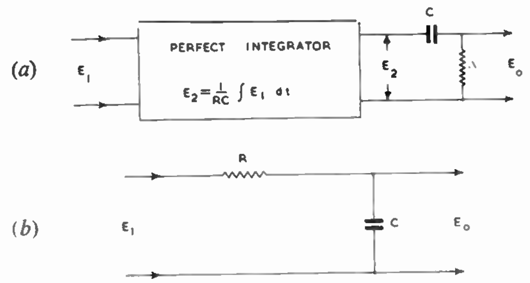

Fig. 12. (a) Integrator and high-pass coupling; (b) Simple circuit with identical response to that of the arrangement shown in (a).

with ever increasing velocity. Using one of the empirical formulae for the frequency spectrum of sea waves, this effect can be calculated[8] with the result shown in Fig. 11. (This is actually the result of calculation for an accelerometer in a small buoy, but is qualitatively similar to the result for a ship). It can be seen that a suitable high-pass filter would remove effectively all the error signal. One might think in terms of a simple RC coupling, as shown in Fig. 12(a). It turns out that this combination of integrator and RC coupling has precisely the same response as the RC smoothing circuit shown in Fig. 12(b). This is very fortunate, since an integrator with high-pass filter turns out to consist of two cheap and simple components. In practice, a further series-capacitor RC coupling has to be included to completely block the d.c. component. The cut-off characteristics of this arrangement are not very sharp, of course, but are adequate for the application (Fig. 13).

In order to measure waves approaching the ship from all directions, it is necessary to have recording heads on both sides of the ship and to average their outputs. The resulting circuit is shown in Fig. 14. (The rectifier circuits on the outputs of the measuring transducers, which are variable-coupling transformers, have been omitted for simplicity.) The second integrator also acts as an RC input coupling for the pressure signal. This also helps to match the phases of the two signals.

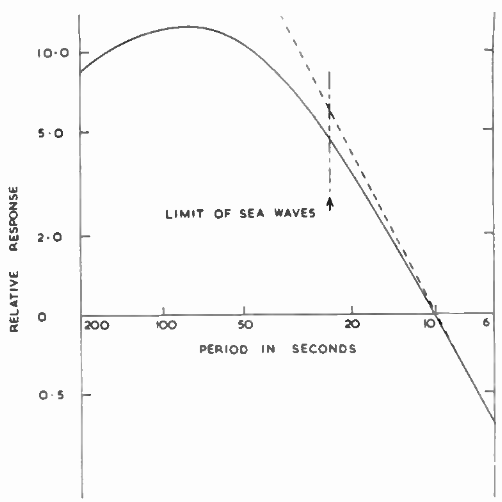

Fig. 13. The frequency response of the circuits following the accelerometer in the shipborne wave recorder.

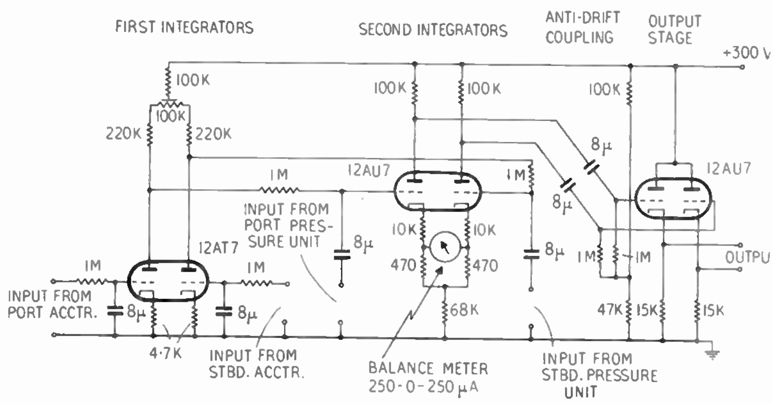

Fig. 14. The circuit of the shipborne wave recorder (with the rectifier circuits on the outputs of the measuring heads and some minor details omitted).

The majority of possible faults in this equipment produce one or more of the following indications.

(1) The balance meter on the front of the panel shows an abnormal deflection.

(2) The output zero shifts.

(3) The record shows long period fluctuations.

In most applications a resolution of 1 per cent. of full scale is adequate to give the required accuracy over the full range of wave-heights, and recording with fixed sensitivity is therefore possible if a good quality recorder is used.

Once installed, a record can be obtained at any time merely by switching on the main switch.

The instrument thus comes near to fulfilling the requirements set out in Section 2.

5.2. *The Vibrotron Pressure Gauge*

The final instrument to be described here is an absolute pressure-gauge capable of a resolution of 1 part in 10^6 of full-scale, and suitable for digital recording.† It consists of a very fine tungsten wire stretched between a diaphragm exposed to the pressure and a rigid support. The wire is in the field of a permanent magnet and is arranged in a bridge circuit roughly balanced for d.c. so that it can be maintained in oscillation at its resonant frequency by a transistor amplifier. The tension in the wire and hence its resonant frequency depend on the external pressure. The device with its amplifier and pressure housing is shown in Fig. 15.

The measuring head is connected to the recording station by a single coaxial cable which carries the d.c. power supply to the amplifier and the a.c. signal back to shore. The frequency varies in the range 10 to 17·5 kc/s and is measured on a counter-type frequency-meter connected to a print-out or tape-punch recording mechanism. By multiplying the frequency and counting for some seconds, a resolution of about 1 part in 10^6 can be obtained. The useful limit of accuracy is governed by the temperature

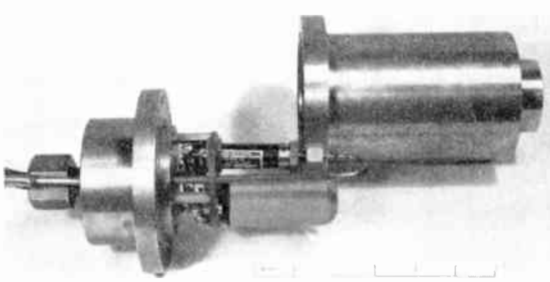

Fig. 15. The Vibrotron pressure gauge, maintaining amplifier and pressure case.

† "Vibrotron," manufactured by Borg-Warner Corporation, California.

coefficient, which is about 1 part in 10^3 per °C and is non-cyclic so that it cannot be corrected. This is overcome to a large extent by burying the recording head either in the sea bed or in a large box of sand with only a small tube connecting it to the sea. This prevents any rapid temperature fluctuations from reaching the measuring head, and is adequate in most circumstances for fluctuations with periods of up to one hour. Using an instrument with a full scale range of about 150 metres, waves of about 1 mm in amplitude with periods of a few minutes have been measured using digital filtering and analysis techniques[9]. A fuller description of this instrument and the recording techniques has been given by Snodgrass et al[10].

The output of the Vibrotron is in a form suitable for radio telemetering, and the Scripps Institute of Oceanography of the University of California has, in fact, such a telemeter operating between San Clemente Island and La Jolla in California, a distance of about 70 miles.

6. Conclusion

The author has attempted to show that electronic engineers have a field of considerable interest and importance in oceanographic instrumentation, and that though many techniques are borrowed or adapted from other fields, there is scope for considerable originality.

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OBITUARY

It is with very deep regret that the Council records the death of **Professor George William Osborn Howe, D.Sc., LL.D.,** on 7th November at the age of 84 years. Professor Howe, who was elected an Honorary Member of the Institution in 1956, was Emeritus Professor of Electrical Engineering at Glasgow University.

Born in Kent, Professor Howe was apprenticed at the age of 14 to the firm of Siemens at Woolwich and some years later spent a year with Siemens Schuckert in Berlin. His academic studies were undertaken at Armstrong College, Newcastle, where he graduated with honours in 1900. For six years he lectured at Hull Technical College and in 1909 he became assistant professor of electrical engineering at the City and Guilds Engineering College. From 1920 to 1921 he was head of the department of electrical standards and measurements at the National Physical Laboratory, but he then returned to the field of education: he was appointed first James Watt professor of electrical engineering at Glasgow University, a chair he was to occupy for a quarter of a century.

As one of the first professors of electrical engineering to teach and write about those applications of electro-magnetic theory which comprise radio engineering, Professor Howe was well known in educational and engineering circles. During his long tenure of the post of Technical Editor of *Wireless Engineer*—from 1926 to 1955 and for a further three years as a consultant editor—his Editorials dealt authoritatively and lucidly with an enormous range of subjects.

Members of the Brit.I.R.E. had opportunities to hear, and subsequently study, papers by Professor Howe in 1947, when he spoke on "Radio Waves and the Ionosphere" to the Scottish Section, and in 1951 when he delivered the Inaugural Clerk Maxwell Memorial Lecture at Cambridge during the 1951 Convention. In these, as in all his lectures and writings, clarity and perception were outstanding.

In addition to his Honorary Membership of the Institution, recognition of Professor Howe's work in engineering and education included Honorary Doctorates of Laws and of Science, Fellowship of the Institute of Radio Engineers of America and the award of the Faraday Medal of the Institution of Electrical Engineers.

Ill health had lead to Professor Howe's complete retirement from active life some three years ago. The Institution was represented at his funeral by Mr. H. G. Henderson, Treasurer and past Chairman of the Scottish Section.

The Council has also learned with regret of the deaths, during the past year, of the following members:—

Leslie Spurgeon Hall joined the Institution as an Associate Member in 1941 and was transferred to full Membership in 1944. His association with radio began in 1926 when he entered the Royal Australian Navy, subsequently gaining wide experience in shipborne and airborne communications. On his retirement from the R.A.N. in July 1939 he received an appointment with the Australian Department of Civil Aviation. After the war Mr. Hall was concerned for some years with the teaching of radio engineering and more recently he went to Brisbane to assist in the development of television in Queensland. He took an active part in the work of the Institution of Radio Engineers, Australia. Mr. Hall was 51 years of age when he died on 10th March following an operation.

Frederick Thomas Simpson (*Associate*) who died in March, aged 51 years, was in charge of the Communications Section of the London Electricity Board. He had been with the Board and its predecessors for over 25 years having obtained his early technical training with Siemens Bros. Limited. Mr. Simpson had represented the Central Electricity Authority at meetings of the Conférence Internationale des Grands Reseaux Electriques concerned with radio and telephone interference. He joined the Institution as a Student in 1948 and was transferred to Associate in 1955.

Frederick Cecil G. Stock was elected to full membership in 1931, shortly after his retirement from the Royal Marines with the rank of Captain. In the years before the war he worked on his own account in the manufacture of custom-built public address and domestic radio equipment. During the last war Captain Stock was with the Admiralty Signals Establishment and after the war he became a civilian technical officer at the R.E.M.E. Workshops. Before his retirement owing to ill-health in 1958 he was in the G.W. Trials Department of Vickers Armstrongs Ltd. He died on 11th May aged 65 years.

Francis R. Fallon (*Graduate, 1945*) of Glasgow.

Patrick Poey (*Graduate, 1957*) of London, S.E.16.

Norman H. Shepherd (*Student, 1945*) of Dunedin, New Zealand.

James P. Sherman (*Student, 1952*) of Nicosia.

M. S. Udyaver (*Graduate, 1956*) of Bombay.

Alfred S. Urbanski (*Student, 1956*) of Montreal.

A Method for Interpreting the Doppler Curves of Artificial Satellites†

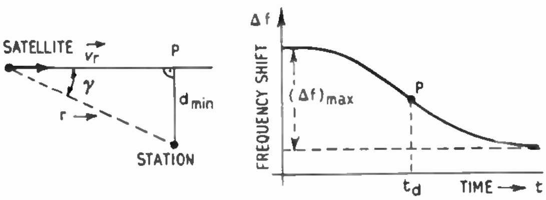
by

G. BOUDOURIS, D.SC., ASSOCIATE MEMBER‡

Summary: A graphical-analytical method designed for determining the point of inflexion and the maximum slope of experimental Doppler curves is explained in detail. The method appears to give adequate accuracy, and to be very easy in its practical application.

1. Introduction

It is well known that the frequency of radio signals emitted from an artificial satellite and received at a fixed ground station is subject to the Doppler effect. The measurement of the Doppler shift is of considerable interest: for calculations of the orbit of a satellite, study of the ionosphere, etc.



(*a*) (*b*)

Fig. 1. The motion of the satellite relative to a ground station and the resulting Doppler curve.

A Doppler curve has the appearance shown in Fig. 1(b). The experimental determination of the curve to the maximum accuracy is a problem with which we will not concern ourselves here.§ We shall discuss, however, the following question: once the curve has been traced, what will be the most accurate method for deducing from it the parameters which are to be made use of in the subsequent calculations. The principal parameters which it will be necessary to determine are (Fig. 1): the time t_d of passage of the satellite at the minimum approach distance and the maximum slope S_{max} of the Doppler curve at the corresponding point of inflection (P).

It is obvious that these parameters could be measured directly from the graph. However, in general, the important portion of the Doppler curve around the central point P is nearly a straight line and the accuracy would not be sufficient (it would be inferior to the precision of the experimental determination of the curve). We believe that it is useful, in view of the importance of Doppler measurements, to present details of a more accurate graphical-analytical method.

2. Basic Equations

If f_0 is the frequency transmitted from the satellite and f the frequency received by the ground station, the Doppler shift, $\Delta f = f - f_0$, is given by the expression:

$$\Delta f = \frac{v_r f_0}{c} \cos \gamma \qquad \text{.........(1)}$$

where $\cos \gamma = \dfrac{-v_r \ (t - t_d)}{\sqrt{\{v_r^2 \ (t - t_d)^2 + d^2_{min}\}}}$

v_r is the velocity of the satellite relative to the observing station,

c is the velocity of propagation of electromagnetic waves

and γ is the angle of incidence (Fig. 1(a)).

† Manuscript (in French) received 29th October, 1959. (Contribution No. 28.)

‡ Centre National de la Recherche Scientifique, Paris.

U.D.C. No. 513.615.2:521.6

§ The principle of this method is briefly discussed in a previous paper: G. Boudouris, J. Bournazel and E. Vassy, "Measurements of the Doppler-Fizeau effect of artificial satellites," *L'Onde Electrique*, 39, pp. 934-48, December 1959.

Hence $v_r = \frac{(\Delta f)_{max}}{2} \cdot \frac{c}{f_0}$, $d_{min} = \frac{v_r^2 f_0}{cS_{max}}$ ...(2)

$(\Delta f)_{max}$ being the total shift of frequency.

3. Considerations which affect the Principle of the Method

An obvious course would be to apply the theoretical expression (eqn. (1)) to the form of the measured Doppler curve, and to deduce from it analytically the parameters in which one is interested. However, the measured curve does not generally conform to a theoretical expression because the actual curve is more or less influenced by propagation anomalies. One therefore risks inaccurate experimental results in which the errors could not be assessed.

It was decided, therefore, to limit the recording of the measured curve to that covered by an analytical expression in the central part only of the curve. The parameters to be determined are, in effect, linked mainly with this central part for which the experimental determinations follow the calculated shape of the Doppler curve.

The limitation in the central part of the measured curve is equivalent, from the analytical point of view, to considering the development in a series obtained by expanding powers of t, from the theoretical expression and only retaining a certain number of the series terms. The central part may then be expressed by a polynomial. The degree of this polynomial will not be less than three, and hence the determination of the point of inflexion t_d of the Doppler curve by neglecting the second derivative of the polynomial then becomes impossible. One could not, moreover, retain a large number of terms since the practical application would become difficult.

It was decided, therefore, to express the central part of the measured curve by a polynomial of the third degree:

$$y = ax^3 + bx^2 + cx + d \qquad \text{.........(3)}$$

This gives:

$$x_{(y''=0)} = t_d = -\frac{b}{3a} \qquad \text{.........(4)}$$

$$y'_{max} = S_{max} = -\frac{b^2}{3a} + c \qquad \text{.........(5)}$$

The coefficients of the polynomial are determined by inspection of the measured curve.

4. Practical Application

The determination of the coefficients of the polynomial is not finally necessary. One can avoid it and obtain directly the parameters t_d and S_{max} by the aid of some observations of the experimental curves and a simple numerical calculation.

To arrive at this practical aspect of the method, let us fix the axes (x, y) in such a way as to cut off in the first quadrant $x0y$ the central part AB of the Doppler curve (Fig. 2). Next divide the sector 0B into three equal parts 01, 12, 23. Each of these parts will be considered

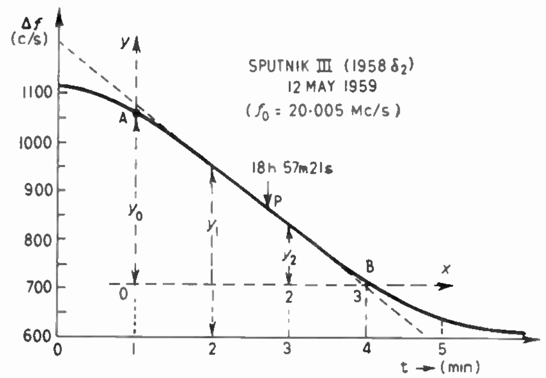


Fig. 2. An observed Doppler curve. (The origin of the time corresponds to 18h 54m 41s.)

in turn equal to a unit of time (one minute in the example). One will obviously seek in practice to fix the axes (x, y) in such a way that this unit of time will be equal to a half minute, a minute or two minutes. The co-ordinates y are always expressed in cycles per second.

One will find, in considering the axes which have thus been chosen:

$$\begin{aligned} &\text{for } x = 0: y_0 = d \\ &\text{for } x = 1: y_1 = a + b + c + d \\ &\text{for } x = 2: y_2 = 8a + 4b + 2c + d \\ &\text{for } x = 3: 0 = 27a + 9b + 3c + d \end{aligned}$$

and the solution of the system gives:

$$\left.\begin{aligned} a &= -\tfrac{1}{6} y_0 + \tfrac{1}{2} y_1 - \tfrac{1}{2} y_2 \\ b &= y_0 - \tfrac{5}{2} y_1 + 2 y_2 \\ c &= -\tfrac{11}{6} y_0 + 3y_1 - \tfrac{3}{2} y_2 \end{aligned}\right\} \qquad \text{.........(6)}$$

Equations (4) and (5) can finally be written

$$t_d = \frac{-2y_0 + 5y_1 - 4y_2}{-y_0 + 3y_1 - 3y_2} \qquad \text{.........(7a)}$$

$$S_{max} = -\tfrac{1}{2}\frac{(-2y_0 + 5y_1 - 4y_2)^2}{-y_0 + 3y_1 - 3y_2} -$$

$$-\tfrac{1}{6}(11y_0 - 18y_1 + 9y_2) \qquad \text{.........(7b)}$$

The procedure may be summarized under the following steps:

Fix convenient axes on the graph and note on it the provisional unit of time which has been adopted.

Read off the three ordinates y_0, y_1 and y_2 (in cycles per second).

Apply equations (7).

Correct the results obtained for the unit of time referred to the second.

The practical application of the graphical-analytical method is easy and rapid. To take an example reading from Fig. 2: y_0 = 345, y_1 = 238, y_2 = 115; and one finds t_d = 18h 57m 21s (U.T.), S_{max} = 2·07 cycles per second.

5. Accuracy

The proposed method assures an accuracy clearly superior to that which one obtains by reading directly from the graph. A slight displacement of the axes (x, y) about an initial position does not have any appreciable influence on the results. The convenience of the method permits moreover two determinations to be carried out rapidly for two different positions of the axes and the average to be taken.

The accuracy obtained, as far as it can be assessed, seems to be ±1 sec for the time t_d, and 0·5 per cent. for the maximum slope S_{max}. Since it may be assumed that in general the Doppler curves are determined experimentally with comparable precision, this proposed method is very suitable and can be used with profit in interpreting the results of the measurements.

APPLICANTS FOR ELECTION AND TRANSFER

As a result of its November meeting the Membership Committee recommended to the Council the following elections and transfers.

In accordance with a resolution of Council, and in the absence of any objections, the election and transfer of the candidates to the class indicated will be confirmed fourteen days after the date of circulation of this list. Any objections or communications concerning these elections should be addressed to the General Secretary for submission to the Council.

Transfer from Associate Member to Member

CAMERON, Hector Francis L., B.A.(Cantab). *Bourne End, Bucks.*
DUMMER, Geoffrey W. A., M.B.E. *Gt. Malvern, Worcs.*

Direct Election to Associate Member

BALMER, John. B.Sc. *Catterick Camp, Yorks.*
BARRALL, Edwin Arthur Leonard. *Colchester.*
BOOT, John *London, N.W.5.*
GRIFFITHS, Anthony Philip. *Gloucester.*
KHAN, Lt.-Cdr. Haroon Rashid, B.Sc., P.N. *Karachi.*
LEVIN, Zalman. *Givataim, Israel.*
LEWIS, Michael Edmund. *Stevenage, Herts.*
*LIDINGTON, Harold Lionel. *Bexleyheath, Kent.*
MacDERMOTT, Robert Terence. *Havant, Hants.*
*MARATHE, Daltalray Hari, B.Sc. *Bombay.*
PENDLEBURY, Norman Howarth. *Dartford, Kent.*
PERRY, Henry James, B.Sc. *Cambridge.*
SWALLOW, Reynold Frost, B.Sc. *Taiping, Malaya.*
SWEENEY, Robert Luke, B.Sc.(Eng.). *Knebworth, Hertfordshire.*

Transfer from Associate to Associate Member

ALLCOCK, Geoffrey Arnold. *Southampton.*
OKE, Domingo Michael T. M. *Lagos.*

Transfer from Graduate to Associate Member

ASHLEY, Edward Harold. *North Wembley, Middlesex.*
BISHOP, Donald Edwin. *Enfield.*
BOWLES, Eric. *Wallington, Surrey.*
CAWTHORNE, John. *London, E.9.*
EL-JADIRY, Fakhry Karim. *Basrah, Iraq.*
WHITESIDE, Thomas. *Thorpe Bay, Essex.*

Transfer from Student to Associate Member

CHENNEOUR, Capt. Kenneth, R.E.M.E. *Hong Kong.*

Direct Election to Associate

HALE, Leslie. *Stevenage, Hertfordshire.*
HASLEHUST, Lt. Col. Dennis Maitland, R.Sigs. *Surbiton, Surrey.*
KENNY, Ernest Moston. *Newcastle-on-Tyne.*
MOSELEY, Edward. *Port Talbot, Glamorganshire.*
POULTNEY, Jack Albert. *Dagenham, Essex.*
REGAN, Timothy. *Edinburgh, 9.*
SUBRAMANIAN, Peruvemb R., B.Sc., B.E. *Bombay*
TRACE, Robert James. *London, N.6.*
WILLINGHAM, Geoffrey Charles. *Southampton*

Direct Election to Graduate

BALLARD, Brian Arthur. *London, S.W.8.*
BARRETT, Michael John. *Eastbourne.*
BAYNES, William Robertson. *East Kilbride.*
BOAKES, Bernard Frederick. *London, E.11.*
BOTTOMLEY, Edward Annan. *Edinburgh.*
BOYCE, Peter William. *London, N.13.*
BULPETT, Maj. Edward. *Sunbury-on-Thames.*
BURGESS, David Albert. *Banstead.*
CHUNGYAN, Glenroy, B.Sc. *Nottingham.*
COLEMAN, David Anthony. *Devizes, Wilts.*
CONSTANTINE, Norman Joseph. *Liverpool, 13.*
COTTRELL, David Edward. *Hornchurch, Essex.*
CRAIG, John Henry Stewart. *Bracknell.*
DOWNHAM, Peter Sidney. *Enfield.*
EDWARDS, Kenneth. B.Sc.(Eng.). *Hatfield, Herts.*
FLYNN, Eric William. *Tunbridge Wells.*
FRITH, Richard. *Plymouth.*
GALLAGHER-DAGGITT, George Edward. *Chelmsford*
GATES, Robert Victor. *Letchworth, Herts.*
GODWIN, Brian Michael. *Newport, Mon.*
HANSON, Thomas William. *London, E.11.*
HARMAN, Malcolm William. *Worcestershire.*
HUGGETT, Dudley J., B.Sc.(Eng.). *Ewell, Surrey.*
ING, John. *Uxbridge, Middlesex.*
JACKSON, Alan Russell. *Ilford.*
KENNER, David John, B.Sc. *Fareham, Hampshire.*
KING, Walter Henry T. *Stevenage, Herts.*
LOCKE, Rodney Patrick C. *Whitton, Middlesex.*
LOVERING, Roy Thomas. *Maidenhead, Berkshire.*
MACHIN, John Willis. *Stoke-on-Trent.*
MACINTOSH, James Murdock. *Glasgow.*
MARSHALL, Keith John. *London, N.8.*
MARTIN, Michael Bryan. *Manningtree, Essex.*
MOLE, Lindsay Gerald Richard. *Lancing.*
MORGAN, Lewis Eifion. *Worcestershire.*
PENERY, Michael Thomas, B.Sc. *Shepton Mallet*
PERRY, Edward Adolphus. *Brighton.*
*RAMANATHAN, P. V. N. *Agra.*
RAYNER, Ralph William. *Gloucestershire.*
REED, Michael. *Chelmsford.*
SCUDDER, Eric John. *Rayleigh, Essex.*
SRIVASTAVA, Flt. Lt. Vishwanath Sohai, M.Sc., India Sigs. *Bangalore.*
STUDD, Peter John, M.A. *Kampala, Uganda.*
TRAISH, George Ernest. *Baughurst, Hampshire.*
VINCENT, Dudley Joseph. *London, W.7.*
WESTMORE, Roger. *Welling, Kent.*
WISE, Philip Noel. *Stevenage, Herts.*
WITTE, John Joseph. *Halstead, Essex.*

Transfer from Student to Graduate

ARYA, Mamohar Lal. *London, W.13.*
BAILEY, Kenneth Alan. *Bletchley, Bucks.*
GERRARD, George Alan. *Stanmore, Middlesex.*
HALLS, Ronald Stanley. *Ringwood, Hampshire.*
HANSCOTT, John. *Havant, Hampshire.*
HODGE, Alan Robert. *Bushey, Herts.*
KLIMEK, Georg s Eugene. *London, S.W.9.*
ODAMETEY, Alexander Kpanie. *London, S.E.15.*
OSBORNE, Peter David. *London, N.W.7.*
RADIA, Suryakant Kantilal. *Nairobi.*
SANDRASEGARAM, Sampanther, B.Sc. *London, W.2.*
SEXTON, Brian Leslie. *Leigh-on-Sea.*
WILKINSON, Charles Leslie. *Wirral, Cheshire.*

STUDENTSHIP REGISTRATIONS

The following 31 students were registered at the October meeting of the Committee. The names of a further 39 students registered at this meeting together with 85 students registered at the November meeting will be published later.

ADENIYI, Oladunjoye. *Lagos.*
AHMED, Adnan. *Harlow, Essex.*
BARCLAY, Robert. *Stockport, Cheshire.*
BATTY, Colin Edward. *Gosport.*
BREEZE, Alan G. *Lymington, Hampshire.*
BROWNBILL, Walter. *Kampala, Uganda.*
CHATFIELD, Kenneth R. *Hayes.*
CHEN MU CHENG. *Singapore.*
CHRISP, Clive Roy. *Basingstoke.*
COLE, Derek J. *Surbiton, Surrey.*
COLLINS, James A. *London, N.6.*
COPPOCK, Ronald G. *London, S.W.16.*
DOCTORS, Michael S. *London, E.17.*
DONALDSON, Colin. *Colchester.*
ELLARBY, Colin Leslie. *Hull.*
FERBRACHE, Eric. *Guernsey.*
FULTON, Eric. *Thurso, Caithness.*
*GENTRY, Maurice Dudley. *Elizabeth East, South Australia.*
GIBSON, George A. *Weston-Super-Mare.*
GOPAILLON, Peron, B.Sc. *London, N.1.*
HAKHAVERDIAN, Armik. *Tehran, Iran.*
HANIFF, Mohamed S. S. *London, S.W.12.*
HARNDEN, Frank Edward. *Ilford.*
HAWKINS, John Patrick. *Wokingham.*
HILL, Eric S. *Wells, Somerset.*
HOOKER, S. W. G. *Eastleigh, Hants.*
IVATT, Kenneth R. *London, N.6.*
JONES, Robert P. *Twyford, Berkshire.*
KHANNA, Kaluram K., M.Sc. *Bombay.*
KNIGHT, Ernest John. *Gosport.*
LANE, James F. *Greenford, Middlesex.*

* Reinstatements.

Scientific Manpower and Industrial Development

Report of a One-day Conference on 16th November 1960 organized by the Institute of Personnel Management.

It was hardly to be expected that a conference of industrial personnel and training officers, public servants, heads of departments from universities and colleges of technology, and a few others, should produce any really new ideas on the subject of scientific manpower and industrial development. It was therefore no surprise that none was produced. What was a surprise, however, was that after brilliant speeches from Lord Hailsham (Minister for Science), Sir Harold Roxbee Cox (a former member of the Scientific Manpower Committee of the Advisory Council on Scientific Policy, and the present Chairman of the National Council for Technological Awards) and Sir Owen Wansbrough-Jones (formerly Chief Scientist, Ministry of Supply), much of the morning's discussion should be concerned with no more constructive matters than complaints from the C.A.T.s about their salaries and the unsuitability of the name "Diploma" for their main award.

Lord Hailsham in his opening address emphasized that the form of intellectual snobbery which put Applied Science below Pure Science must be eliminated, that we must try to estimate the country's real needs in scientific manpower and not merely try to "keep up with the Joneses," that we must do something about getting women to enter science and technology, and that we must not overlook the need to train technicians.

Sir Harold emphasized the difficulties of comparisons with other countries and the importance of the non-graduate professionally-qualified engineer. He thought that the production processes of large quantities of simple items offered as interesting a field of work as the more glamorous fields of aircraft and electronics and that more young scientists and engineers should be attracted to production engineering. He, too, stressed the need for technicians as well as technologists.

Sir Owen thought that the teachers in universities and C.A.T.s would always readily adapt their courses to demonstrable needs, and that they were, in fact, in touch with the needs of industry. He thought that greater specialization and longer courses were needed, and underlined many of the points made by Sir Harold.

The floor during the rest of the morning was held by the C.A.T.s, in spite of pleas from the Chair. The continued emphasis by the C.A.T.s of their hardships—not very convincing to a University head who has experience of C.A.T. lecturers applying for university posts at very much lower salaries, and of the generous scale of equipment provided by the Ministry of Education—looked like an apology for failure. But are they failures? Surely they should have been talking with enthusiasm about their work, their plans, the growth of their research, and the quality of the people obtaining Dip. Tech.'s.

The afternoon session opened to another vigorous and stimulating speech by Dr. B. V. Bowden, Principal of the Manchester College of Science and Technology. He stressed the failings of the British nation, and pointed out that the same complaints of the lagging-behind of our industry and universities were made by people like Huxley a century ago. Our failure to come to grips with the educational problem is thus a very long-standing one. Dr. Bowden then pressed his case for an enormous development of technological education in Britain on the lines of the methods used on the Continent. He emphasized the advantages of large institutions and of a closer link (to the point of partial integration) with industry.

The discussion which followed this address got off on better lines than that of the morning. Professor W. R. Hawthorne of Cambridge University and Professor A. S. T. Thomson of Glasgow Royal College of Science and Technology spoke of steps the universities were actually taking to provide better facilities for engineering students to learn industrial engineering.

The final speech was by Mr. J. E. A. Stuart of the Staff Department of Imperial Chemical Industries. His theme was quite different from the others. He spoke of the importance of engineers and scientists in management and showed what I.C.I. were doing both in this regard and in the recruitment and subsequent encouragement of younger people. He discussed the necessity of making scientists and engineers more effective by studying closely the nature of their duties and removing unnecessary tasks. The employment of non-scientific people (e.g. Arts graduates) could help a great deal in some work.

On the whole, the conference was well worthwhile and it is to be hoped some positive advances will result from it.

D. G. TUCKER.

News from the Sections . . .

South Midlands Section

The opening meeting of the 1960-61 session was held on 7th October at Cheltenham when an audience of about sixty heard Mr. H. C. Nickels present a paper "The New B.B.C. Television Centre."

Mr. Nickels began by outlining the layout of the various buildings forming the Centre and with coloured slides illustrated some of the interesting architectural features. He then discussed the cameras used in the production studios and gave the reasons why the Corporation adopted the Image Orthicon. He also gave details of the development work on lenses, hoods, turrets and iris control.

The layout of the studio technical area was next considered and Mr. Nickels explained the new system whereby four cameras can be controlled by one man from a specially-designed desk. Adjacent to this is the lighting control position and details were given of this, the various lights used and the hoist motors. The production and sound control rooms were described and also the central technical area—the central apparatus room, the presentation studios, and central control room and telecine.

Lastly the power requirements were considered and details were given of how this power is brought into the Centre, controlled and distributed. Special mention must be made of the many excellent coloured slides which Mr. Nickels had personally produced to illustrate his lecture. The speaker ended by answering many questions amongst which were some on system standards, d.c. component, vision switches, colour television, fire precautions and problems of maintenance. G. W. M.

West Midlands Section

The 1960-61 session of the West Midlands Section opened on October 12th at Wolverhampton College of Technology with a lecture by Mr. Alan Douglas on "The Electrical Synthesis of Music."

Firstly, the object of synthesizing music was stated: this is not only to simulate the sounds of existing musical instruments, but also to produce sounds which cannot be produced by normal means. A synthesizer has the advantage that its power and frequency range are virtually unlimited; in addition, unlike a conventional instrument, the harmonic content does not vary with the pitch of the note being played.

Next, the speaker gave an account of some of the properties of musical sound. It was stressed that not only the harmonic content of a sound, but also the rate at which it builds up are important if the note is to be identified. This is especially important in connection with percussive sounds.

Mr. Douglas then described a type of keyboard by means of which the quality of the sound producer could be made to depend on the finger pressure exerted by the player, so that the instrument was much more versatile than conventional electronic organs. In addition, the intervals between successive notes were so small that a virtually continuous range of frequencies could be produced.

Another method was then referred to briefly—an American system in which sounds could be coded by means of punched tape, and subsequently reproduced. Mention was also made of the possibility of tape recording an existing sound, and then altering its character by manipulating the tape.

The lecture closed with recorded examples of synthesized music. The examples showed that musical instruments could be imitated almost perfectly, while music of a most futuristic character could also be produced. D. H. A.

Union of South Africa Section

The plans of the Section Committee for the coming session include a series of discussion evenings for student members. The intention is that students shall send in problems regarding their studies to the Committee who will arrange for Corporate Members familiar with the particular fields to prepare solutions. An evening meeting will then be held at which a selection of the problems can be fully discussed by students and the members concerned. Students having problems suitable for dealing with at these meetings are invited to write to the Honorary Local Secretary, Mr. G. V. Meij, P.O. Box 133, Johannesburg.

H.F. Propagation—its Present and Future Use for Communication Purposes †

by

A. F. WILKINS, O.B.E., M.SC. ‡

A paper read at a meeting of the Merseyside Section in Liverpool on 11th January 1960.

Summary: In the present congested conditions of the h.f. band the planning of frequency allocation demands improved accuracy of prediction of both maximum and minimum frequencies usable on any radio circuit. Such improvement involves greater accuracy in the prediction of ionospheric critical frequencies and m.u.f. factors. An extension of knowledge of the paths taken by the waves in travelling from transmitter to receiver is important both for prediction purposes and also for facilitating the design of aerials. Current work on these problems, especially that at the Radio Research Station, is reviewed. The effects of ionospheric irregularities, such as storms, in degrading the accuracy of predictions is noted, and new results on irregularities in trans-equatorial propagation are described. Recent work on the study of lateral deviation of h.f. signals and on the application of the back-scatter technique to the determination of optimum signalling frequencies and to the study of the distribution of sporadic-E ionization is summarized.

1. Introduction

The ability of waves in the h.f. band (3 to 30 Mc/s) to span large distances was first demonstrated in 1923 and it was soon realized that the potentialities of these waves for communications purposes was very great. It was found, for example, that, although the radiated power required to produce a given field strength at a distant point was comparable to that needed on the long waves then being used, the input power to the transmitter could be made much lower because of the greater radiation efficiency of h.f. aerials and the ability to concentrate the power in the required direction.

Some of the weaknesses of h.f. communication were quickly appreciated; amongst the more important of these may be mentioned the continuous fading of the received signal, the possibility of its serious weakening or disappearance for several days running, and the inability on most circuits to maintain a 24-hour service using a single operating frequency. The reasons for these propagational phenomena were not then properly understood and it is interesting to note that, although there was some evidence for thinking that the waves were propagated by reflection from ionized regions above the earth's surface, it was not until 1924 that Appleton and Barnett demonstrated conclusively the existence of an ionized layer (the Kennelly-Heaviside or E-layer) at a height of about 100 km. The existence of a higher, F-layer, which is of greater importance in h.f. propagation was discovered by Appleton in 1925.

After Appleton's discoveries the investigation of the ionosphere has been undertaken in many countries and, as a result, a large body of knowledge has been built up. Work has proceeded concurrently on the scientific study of h.f. propagation and the more important phenomena concerned can now be explained. There are still gaps in our knowledge which prevent our specifying the performance of circuits with the accuracy which engineers desire. In this paper it is proposed to indicate the nature of some of these gaps and to review the work being done in an attempt to fill them.

† Manuscript first received 12th October 1959 and in final form on 25th August 1960. (Paper No. 598.)

‡ Official communication from the D.S.I.R. Radio Research Station, Slough, England.

U.D.C. No. 621.396.11.029.55

2. The Use of Propagation Knowledge in Frequency Allocation

From 1923 the commercial application of the h.f. band has increased very rapidly until, at the present time, the bulk of international communications are carried out with its use. Perhaps some of the most serious current problems arise from this heavy usage of the band and from the continuing demand for more frequency allocations in it. The magnitude of the problem confronting the International Frequency Registration Board in allocating frequencies, a task which must be carried out so as to avoid undue interference between stations on similar frequencies, may be obtained from the fact that there are over 200,000 allocations for fixed stations only listed in the h.f. section of the Radio Frequency Record of the International Telecommunications Union. It would be impossible to accommodate this number of services without resorting to frequency sharing, and such a procedure is arranged on both a time and a geographical basis. In time-sharing two or more stations allotted the same frequency and transmitting in conditions which would result in mutual interference are made to work to different time schedules. In geographical sharing the same frequency is allotted to stations which are separated physically by such great distances that interference is normally improbable.

In order to apply sharing procedures effectively a considerable knowledge of the mechanism of propagation is necessary and, in particular, of the world distribution of ionization in the ionosphere. This knowledge must be applied in the production of predictions of the m.u.f. and l.u.f. which will exist for transmission between any two points on the earth's surface. Much attention has been devoted to this problem during and since the war but there is still scope for improvement in the accuracy of predictions for use both in day-to-day circuit operation and in the planning of frequency allocation.

The basic information from which the m.u.f. is derived is obtained from the results of measurements, made at vertical incidence, of the characteristics of the ionosphere; data from some 120 stations, distributed over the world, are currently being used at the Radio Research Station for this purpose. This information enables the daily variation of ionization in all the ionospheric layers to be obtained by interpolation for all geographical locations. Ionization levels have then to be predicted for some months ahead and this is usually done by using sunspot numbers as a measure of solar activity and estimating what the number is likely to be at the time concerned. This procedure is not ideal because the sunspot number may vary violently from month to month in a way unrelated to ionospheric changes, and its prediction is especially difficult near the maximum of the cycle.

If a sufficiently long period is considered, the mean error in predicting critical frequencies will be zero because the probability of making high and low estimates should be equal and the quality of predictions is therefore judged by the dispersion of errors about the mean. In some recent comparisons between critical frequencies measured at various observatories and the corresponding values predicted six months in advance and read from world contour charts, Minnis and Bazzard[2] have obtained values of standard deviation of 15 per cent. for the F2-layer critical frequencies (f_0F2) and 5 per cent. for the E-layer critical frequencies (f_0E) which vary in a much more straightforward fashion.

The m.u.f. for propagation by way of any layer is obtained by multiplying the critical frequency at the reflecting point by an m.u.f. factor which, in the case of the predictions produced at the Radio Research Station, is derived in terms of certain ionospheric parameters by the methods of Appleton and Beynon[3] and this procedure gives good results up to the limits of a single "hop" from any layer. The two control-point method is still in current use for m.u.f. estimation beyond single hop range; in its application the m.u.f.s for separate single hops terminating at each end of the path and of length 4000 km for F2-layer and 2000 km for E-layer propagation are considered. The path m.u.f. is thus determined in terms of the ionospheric characteristics at control points 2000 km and 1000 km from each end of the path with no reference to the state of the ionosphere over the remainder of the path. In spite of its empirical nature the method gives fairly satisfactory results and is simple to apply, but for more accurate determinations the modes of propagation obtaining over the whole path should be taken into account.

Comparisons have been made of ionospheric predictions with results of practical experience on a large number of circuits[4] and it has been found that the differences between the predicted and observed times of fade-in and fade-out on a given frequency are of the order of magnitude expected from consideration of prediction error sources the magnitude of which can be estimated. It was also concluded that, although on the average, agreement was good, discrepancies remain which require further examination. The fact that the accuracy of predicted fade-in and fade-out lines is reasonably good implies that communication over the long circuits considered started and failed by the establishment or cessation of propagation by waves reflected at the F2-layer distant about 2000 km from one or other end of the circuit. Although this appears to be a reasonable approximation to the truth at the times concerned, the m.u.f.s derived by the two control-point method may be inaccurate at other times because, as will be seen from Section 5, propagation may then be complex.

In considering frequency sharing and, indeed, the general planning of h.f. circuits, it is considered that the following improvements in m.u.f. predictions are necessary:

(a) more accurate predictions of f_0F2 and m.u.f. factors;

(b) the two control-point method should be abandoned and the actual modes of propagation considered;

(c) in addition to modes propagated by E-, F1- and F2-layers, account should be taken of sporadic-E modes.

2.1. *Possible Improvements in the Prediction of f_0F2 and M.U.F. Factor*

The shortcomings of the sunspot number as a measure of solar radiation have been mentioned. To avoid these difficulties Minnis[5] has proposed another index, I_{F2}, based on f_0F2 itself and has shown that, for a given observing station and time of day, f_0F2 and the m.u.f. factor for a given distance of transmission by way of the F2-layer, $M[D]$F2, may be represented by the regression equations

$$f_0\text{F2} = a + bI_{F2}$$
$$M[D]\,\text{F2} = c + dI_{F2}$$

where a, b, c and d are numbers.

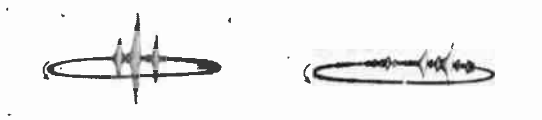
Having found the coefficients a, b, c and d, they may be plotted as world contour charts and future values of f_0F2 and $M[D]$ F2 for the time of day concerned may then be calculated after I_{F2} at the future date has been settled. Estimates have been made by Minnis and Bazzard[2] of the accuracy with which f_0F2 can be predicted using both the index I_{F2} and the sunspot number. They find that, for average conditions, the error due to imperfect correlation between f_0F2 and either I_{F2} or the sunspot number has a standard deviation of 4 per cent. and 6 per cent. respectively. If the additional errors due to erratic fluctuations in the indices are included, the standard deviations increase to 6 per cent. for I_{F2} and 9 per cent. for the sunspot number. These two figures may be compared with the actual figure of 15 per cent. quoted in Section 2. but it should be borne in mind that this figure includes a contribution arising in the plotting of contour charts.

In the process of predicting by the use of the ionospheric index it is proposed to feed the f_0F2 and $M[D]$ F2 data into an electronic computer instead of using contour charts as at present and, at the same time, to programme the computer to calculate the m.u.f.s for each possible mode of propagation by the method outlined in Section 2.2.

One advantage of the prediction procedure using the regression equations is that when the coefficients a, b, c and d have been determined for all available ionospheric observatories they may be used with any given predicted values of I_{F2} to give future values of f_0F2 and $M[D]$ F2 for any future time; it is not necessary to have a continuous supply of recent vertical incidence data from all ionospheric observatories. Only the f_0F2 data from the few observatories whose data are used to construct the I_{F2} index are needed.

2.2. *Computation of Modes of Propagation*

The elementary concept that h.f. waves travel over long distances by equal length hops between the ground and the ionosphere is a considerable over-simplification of the facts as may be seen from even a superficial examination of pulse echo patterns received from distant stations. Examples of the complexities which occur may be seen in Fig. 1 which refer to reception at Slough from two transmitters at Lawrenceville, New Jersey, used on the trans-atlantic telephone circuit.



(a) 1450 G.M.T., 21 March 1934. (c) 0155 G.M.T., 2 March 1934.

(b) 1920 G.M.T., 20 June 1934. (d) 0150 G.M.T., 25 May 1934.

Fig. 1. Pulse reception from Lawrenceville, N.J.

Figure 1(a) shows, on an elliptical time-base of total duration $16\frac{2}{3}$ millisec, an echo pattern typical of equinoctial propagation on the New York-London path in 1934 on 14 Mc/s. The three main echoes, reading from right to left, are 2-, 3- and 4-hop reflections from the F2-layer, but it will be noted that there are several other smaller echoes also present. In Fig. 1(b), showing a pattern obtained on the same frequency in June, there are at least three closely-spaced echoes in the main group with a small echo well separated from them; the strongest of the echoes in the main group is probably a three-hop F2-layer echo and the identification of the others is doubtful. The example of 5 Mc/s reception in Fig. 1(c) was typical of conditions on this night frequency; while the strong echoes are probably F2-layer multiple hops the weaker echoes were not identified. Figure 1(d). which shows echoes covering the whole time-base, was obtained at a time when f_0F2 at Slough exceeded the signal frequency. Such a frequency would not be used for communication over the North Atlantic path at the time concerned because of the multipath distortion which would arise but the record is included here to show the large number of paths by which the waves may travel.

Owing to the complex distribution of ionization over the earth's surface the mathematical analysis of the paths which can be taken by waves in travelling between any two points is intractable but, by introducing certain simplifications, Kift[6] has developed a method of determining these paths which gives results in close agreement with practice. This method takes into account the critical frequency and height variations of the ionosphere along the great-circle path and, to overcome the difficulties resulting from horizontal gradients in these parameters (layer-tilts), he assumes that the layers are horizontal at each area of reflection of the waves. He also assumes that the vertical gradient of ionization is parabolic and uses the Appleton and Beynon theory[3] to obtain the ground range of waves incident at various angles on the layer at the horizontal surfaces. This procedure involves the solution of the Appleton and Beynon equations by electronic computer for various values of height of maximum ionization and thickness of the layer, and of a factor equal to the ratio of the critical frequency to signal frequency. By such procedure it is possible to specify, for a given signal frequency and distance, the paths of the various received waves, their angles of elevation and their time of travel between transmitter and receiver. The m.u.f. at any time for a given distance and the corresponding mode may also be found and this m.u.f. is the parameter which will be determined by electronic computer in terms of data referred to in Section 2.1.

2.3. *M.U.F. Predictions and the Effect of the Sporadic-E Layer*

In recent years it has been established that sporadic-E ionization can increase the m.u.f. of a circuit above the value corresponding to E-, F1- and F2-layer transmission especially in the summer. Experimental evidence of the effect of sporadic-E on h.f. communication has been given by Shearman[7] and Wilkins and Kift[8]. It is known that sporadic-E ionization in temperate latitudes appears as clouds of up to a few hundreds of kilometers in extent and that the majority of them are fixed in position. The very nature of the phenomenon, the cause of which is at present unknown, makes the forecasting of its incidence difficult and no really accurate method of allowing for its effects in m.u.f. prediction is yet known. Investigation of sporadic-E was intensified during the International Geophysical Year and subsequently; this work may ultimately lead to an easing of the prediction problem.

The sporadic-E ionization which exists in a belt centred on the magnetic equator and ±15 degrees of latitude wide is of more regular occurrence and can therefore be taken into account in m.u.f. predictions. Its effect on trans-equatorial propagation is considerable (see Sections 3.2 and 5).

2.4. *Prediction of L.U.F.*

The prediction of the lowest usable high frequency (l.u.f.) of circuits is also important for the planning of frequency allocation as well as of general circuit operation. The accuracy of such predictions is, at present, less than that of the m.u.f. owing to the limited knowledge of the magnitude of the factors concerned. Basically the method employed consists in calculating the field strength produced at the receiver by the given transmitter; there is usually one frequency, the l.u.f., at which this field strength will be sufficient to give the necessary signal/noise ratio. The factors governing the field strength, apart from transmitter power and aerial directivity, are the amount by which the waves are weakened by passage through the ionosphere. Most of this weakening takes place in the D-layer (non-deviative absorption) but some takes place at reflection at the layer concerned in the propagation (deviative absorption).

Current methods of assessing l.u.f. involve the use of world charts depicting the variation of absorption as a certain function of the solar zenith angle. These charts were produced at a time when our knowledge of world absorption variations were very limited and revision is necessary in the light of more recent measurements, particularly those made during the I.G.Y. Piggott[9] has recently developed a method of computing field strengths for h.f. transmission in tropical areas using up-to-date knowledge; although this method may also be used for l.u.f. calculations its application for this purpose is laborious.

The world noise data charts required in this prediction have been drawn up largely as a result of the work of the Radio Research Station in the U.K. and of the National Bureau of Standards in the U.S.A., and the current charts have been issued by the C.C.I.R. Minor revisions of these charts are likely as a result of observations made during the I.G.Y.

To improve the accuracy of l.u.f. predictions is likely to involve a good deal of labour and it is therefore possible that electronic computers may be applied in the future.

3. Irregularities in H.F. Communication

The foregoing sections have considered the prediction of m.u.f. and l.u.f. for the undisturbed ionosphere; the average values of ionospheric parameters suitable for the period in question —usually one month—are used in their construction. There are natural disturbances which greatly affect the accuracy of such predictions; the most important of them is the ionospheric storm.

3.1. *Ionospheric Storms*

During ionospheric disturbances the m.u.f. may be reduced and the l.u.f. increased in such a way that the available working band is reduced to zero. This inability to work in storm conditions is, perhaps, the most serious drawback of h.f. communications. In a severe storm world-wide communications may be disrupted but, more usually, circuits in high latitudes are those most affected. No method of overcoming these disruptions is known other than resorting to alternative means of communication (e.g. cables) or by relaying through points in low latitudes which are little affected by storms. As an example of the extent of degradation which may be caused by storms, the case of the commercially very important U.K.-North American circuits may be cited. Jowett and Evans[10] have stated that commercial time is lost on these circuits mainly at sunspot minimum and that this loss during winter months may amount to as much as 50 per cent. and 40 per cent. of the scheduled time per month on the Montreal-London and New York-London telephone circuits respectively. By relaying through Barbados experience has shown that about half the lost time may be recovered.

The breakdown of communication due to storms has resulted in attention being given to the possibility of predicting their incidence. If it were possible accurately to predict the time of onset of a storm important traffic might be transmitted prior to that time, or arrangements made for diversion of traffic to other routes.

The accurate prediction of storms is difficult in that the solar events from which they arise are themselves difficult to predict. Thus, sudden commencement storms are due to particle emission from a solar flare, the ultra-violet radiation from which may have caused a sudden ionospheric disturbance (s.i.d.) some 30 hours before the commencement of the storm. But an s.i.d. is not necessarily followed by a storm; the particles emitted from the flare may not strike the earth's ionosphere. The M-region storm, which is common at sunspot minimum and tends to recur at 27-day intervals, is caused by particle emission from certain solar regions the nature of which is unknown and which have not been identified visually. Although, when such a series of storms has started, some success may be obtained in predicting further storms of the same series, it is possible to predict neither the onset of the series nor its end with any certainty. It seems unlikely that, with our present knowledge of solar processes, useful long-term storm warnings will be possible. Short-term warning services for North Atlantic and North Pacific do, however, exist and it is understood that they are found useful by communication engineers.

The incidence of s.i.d.s is random and there is no possibility of predicting them.

3.2. *Degradation of Trans-Equatorial Communications*

Communication engineers have known for some years that degradation of trans-equatorial h.f. circuits may occur at a time related to sunset at the equatorial part of the circuit and that the effect is worst during equinox months at sunspot maximum. Humby[11] has given examples of this degradation on circuits between the U.K. and Colombo and Singapore. It is also very pronounced on circuits between the U.K. and Africa with the result that broadcast reception may become scarcely intelligible on all frequency bands and telegraphy may be either hindered or made impossible.

Osborne[12] has pointed out the connection between this phenomenon and that of the apparent disintegration of the F2-layer into clouds at sunset observed by him at Singapore. While there is now good evidence that this "spread-F" effect is one cause of the signal degradation, work at the Radio Research Station during recent years has suggested that there is another factor to be considered.

Continuous recordings during 1958 of the signal strength of the telegraph station VQG 237 (23·741 Mc/s) at Nairobi have shown that some degradation near sunset always occurs and that, on the average, the delay between the onset of the effect and the maximum deterioration of strength is about 25 minutes. The time of onset appears to be predictable to within ±30 minutes, but has no regular seasonal changes such as might be expected if the time of onset on a normal ionospheric layer is the principal factor. It is now considered that the onset of weakening in this case results from the decrease in ionization and break-up into a cloudy structure of the equatorial sporadic-E layer which shows no marked seasonal ionization variation; the clouds give rise to a scattering of the energy incident on them and a fluttering signal results at the receiver; if the main mode of propagation involves reflection from equatorial sporadic-E, as may well be the case, there will be a decrease in signal strength as a result of the scattering.

Further evidence of the sporadic-E effect has been provided recently by Mr. E. W. Hayes of the B.B.C. who, while listening in Sarawak to m.f. broadcast transmissions from Manila and Okinawa, has noticed that the decrease of strength and distortion around sunset is sufficient to render the programme unintelligible. Both paths concerned cross the sporadic-E belt and, in the m.f. band, only E-layer reflections would be involved at the time concerned. Observations made at the D.S.I.R. station at Singapore on m.f. signals which do not cross the sporadic-E belt show that no such sunset effect occurs.

Some of the Nairobi records (Fig. 2) show that, after recovering from sporadic-E effect, the signal is later depressed by spread-F and then fades out prematurely. The predicted fade-out time for the case shown in Fig. 2 was 2030

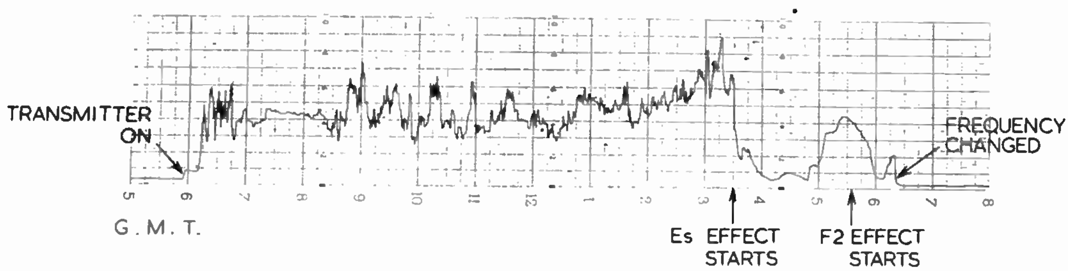


Fig. 2. Field strength variations of Nairobi, VQG237, 23·7 Mc/s, 11th November, 1959.

G.M.T. Rapid, shallow, fading is present from 1530 G.M.T. onwards but this is smoothed on the record due to the long time-constant in the equipment.

It does not appear to be possible to overcome these effects by any method other than by relaying the signals from a point such that the signal paths are clear of the disturbed area of the ionosphere.

4. H.F. Propagation Phenomena and their Effect on Aerial Design

The use of directional aerials in h.f. communication is important not only because they enable the required field strength to be produced at the receiver with less transmitter output, but also because they help to reduce interference to and from stations working on adjacent channels, or, in the case of distant stations, the same channel.

Economic factors usually limit the size of aerials because highly directive arrays are large structures and occupy a good deal of land. Technical limitations to their size arise from the fact that, in the case of receiving arrays, the field will be incoherent over the aperture of the array and a worth-while increase in gain may therefore not be obtained with very large arrays. An array with a very narrow beam would also be undesirable if lateral deviation of the waves from the great-circle path is a possibility.

In the interests of obtaining the greatest efficiency in communication and especially to obtain the greatest wanted signal pick-up in the presence of interference it is desirable to match the aerial characteristics to the propagation conditions as advocated by Hitchcock.[17] This involves the design of the aerial so that its major vertical lobe embraces, in angle of elevation, the main downcoming energy in the wanted signal. Such a matching process is performed in the MUSA array but its expense and azimuthal inflexibility have militated against its widespread use. The MEDUSA system of Morris and Mitchell[14] is a much more flexible system which permits lobe steering in azimuth and elevation; as it also permits the simultaneous reception of several stations it is, potentially, a very important receiving system.

In the case of aerials which cannot be steered, matching to the propagation conditions must be done by design based on a knowledge of the angles of elevation of the main modes of propagation and how they vary with time. These angles may be estimated using Kift's technique (Section 2.2) or they may be measured. Much information on angle of elevation has been obtained in recent years at the Radio Research Station during investigations into the mode of propagation of h.f. signals.

These investigations have shown the importance in communication over long distances of energy propagated at low angles of elevation. During daytime measurements on signals from south-east Asia, for example, it has been found[8] that the strongest rays are received in the United Kingdom at an angle of elevation of 7 deg during autumn and winter in the 16 Mc/s to 18 Mc/s band, and at 5 deg in the summer. While no information has been published on corresponding measurements for night frequencies, there is evidence that similar values of angle obtain and there are, in fact, theoretical grounds for this expectation[6]. The view that angles of elevation of the received energy are higher at night is unlikely to be true and it will almost certainly be necessary, in the interests of obtaining maximum signal/noise ratios at night, to increase the height of aerials for both transmission and reception.

By designing aerials to be used in long distance communication for maximum efficiency at low angles of elevation and reduced response at higher angles, reduction in multipath effects should result with improvement in the operation of high-speed telegraph circuits. As the low-angle rays require less ionization for their propagation, there should be an extension of the operating time on a given frequency.

5. Experimental Study of Modes of Propagation

Two main methods are used at the Radio Research Station for this investigation. One of them involves the transmission of pulses at a fixed frequency and the measurement of the angles of elevation and relative time delays of the received echoes. Angles of elevation may be measured on any type of signal but only pulses may be used to give the time delay. Identification of the modes of propagation is fairly straightforward for short and medium distance transmission over areas for which good ionospheric data are available, but for long distances the observations must be interpreted with the aid of procedure such as that described in Section 2.2. The angles of elevation may be measured either by comparison of the amplitude of the signal e.m.f. produced in two horizontal aerials installed one above the other on a flat site[15] or by measuring the phase difference between the e.m.f. in two horizontally spaced aerials.[16]

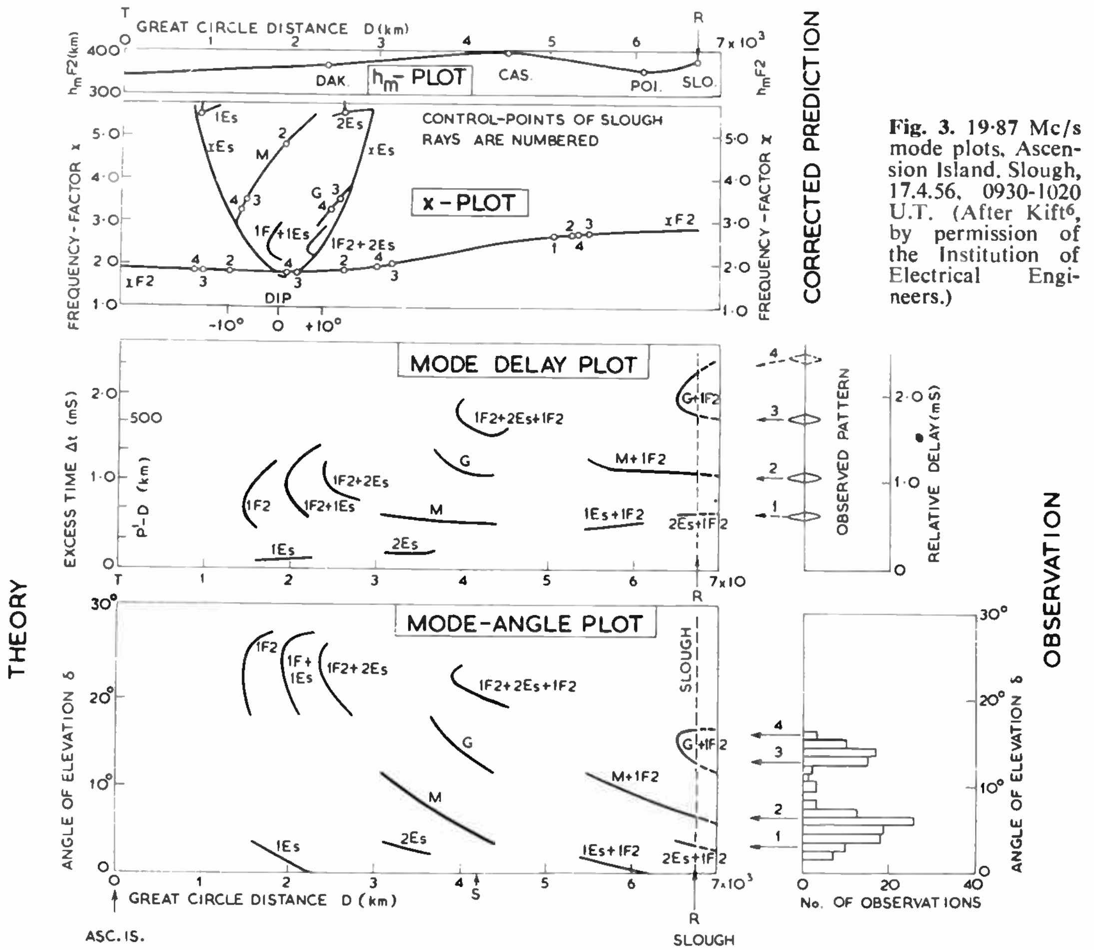


Fig. 3. 19·87 Mc/s mode plots, Ascension Island. Slough, 17.4.56, 0930-1020 U.T. (After Kift[6], by permission of the Institution of Electrical Engineers.)

An example of the application of such measurements is shown in Fig. 3 for pulse signals received at Slough from Ascension Island on 19·87 Mc/s. This figure also indicates the expected modes of propagation calculated, using Kift's method, in terms of forecast values of ionospheric critical frequencies and heights along the path corrected by measurements made at Slough, Poitiers, Casablanca and Dakar. It will be noted that all modes are complex with the exception of the one-hop F2 and one- and two-hop sporadic-E modes receivable at various distances from Ascension Island. The measured values of angle of elevation (δ) and time separation (Δt) will be seen to agree well with those calculated.

Figure 4 is an example of measurements of angle of elevation on a telegraph station made for the purpose of obtaining information for receiving aerial design purposes. The measurements are plotted as histograms for ten-minute periods. The frequency of measurement in any small angular range is a rough measure of the strength of the corresponding echo. Thus, between 1435 G.M.T. and 1445 G.M.T. there are two main echoes present at angles of elevation of 8·5 deg and 19 deg, the former being the stronger. The arrows shown in three of the plots indicate that the angles below them were seen to be varying in the direction indicated.

The other method involves pulse transmission on a frequency which is continuously varied over a wide band and the recording of the echoes with a receiver the tuning of which automatically follows that of the transmitter. The records show the variation with frequency of the time separation of the echoes. Such technique is being exploited in Germany[17], Canada[18, 19] and the U.S.A.[20, 21, 22] in addition to the U.K. Similar technique but with manual adjustment of the receiver was used over ten years ago by Beynon[23] for investigating propagation between Burghead (Scotland) and Slough a distance of 715 km; these experiments showed that the F2-layer m.u.f. agreed (to within 3·8 per cent.) with the value calculated using Appleton-Beynon theory.

The experiments with automatic equipment quoted have covered transmission over distances of to about 2400 km; the results have, in

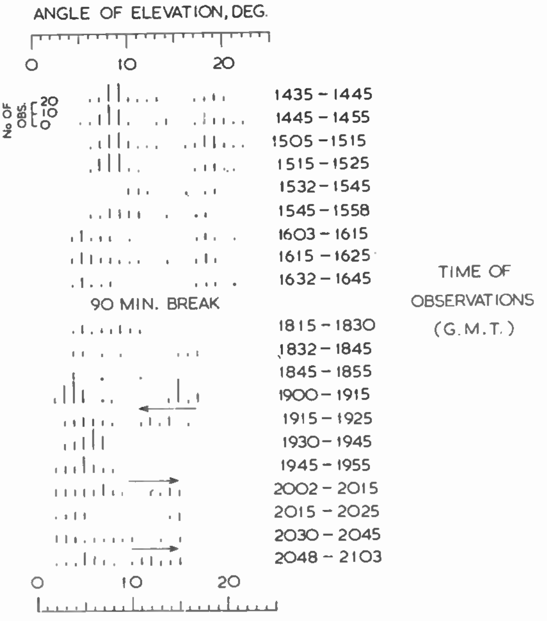


Fig. 4. Angles of elevation of Bombay 18·420 Mc/s, 7th October, 1956.

some cases, been compared with theoretical expectations based on vertical incidence ionospheric data measured mid-way between the ends of the path and in all cases good agreement has been obtained.

During the I.G.Y. sweep-frequency transmissions have been made by Warren and Hagg[24] between Ottawa and Slough (5300 km). One result of this work has been the confirmation of the possibility of a single-hop mode (a Pedersen ray) over the path and this phenomenon has been shown by Kift[25] to be in accordance with calculations based on Appleton-Beynon theory.

5.1. *Sweep Frequency Work at the Radio Research Station*

The sweep-frequency apparatus in use at the Radio Research Station transmits in 10 kc/s steps over the band 5·5 Mc/s to 45 Mc/s. Control of all processes in both transmitter and receiver is effected by crystal clocks the stability of which is such that synchronization of the whole system may be maintained for several days without adjustment. Simultaneity in the starting of transmitter and receiver is obtained by adjusting the timing of certain switching operations at the receiver in accordance with instructions sent by simple code from the transmitter while working on a fixed frequency.

Preliminary tests were made between Slough and Inverness (704 km); a typical record is shown in Fig. 5. Comparisons were made of the characteristics of propagation as measured from the records with those calculated on the basis of Appleton-Beynon theory using vertical incidence ionospheric characteristics measured at Slough and Inverness. Close agreement was obtained between the observed and calculated records; in particular the observed and calculated m.u.f.s for F2-layer transmission agreed within 3 per cent.

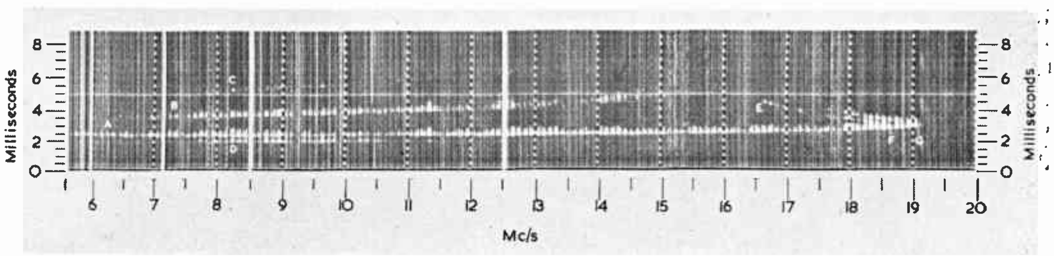


Fig. 5. Record of time separation with frequency of echoes received at Slough from Inverness.

Further tests have been made between October 1957 and November 1958 with the transmitter in Malta and the receiver at Slough (2100 km). It was expected that propagation over this path would be straightforward during normal ionospheric conditions and such proved to be the case as shown in Figs. 6(a) and (b) for winter and Fig. 6(c) for summer conditions. Observed values of the m.u.f.s of the several modes of propagation have again been compared with theoretical expectations based on ionospheric data measured at Genoa, Rome and Schwarzenberg (Switzerland) and differences of about 3 per cent. obtained.

The apparatus is now being used to investigate propagation over the Ascension Island—Slough path (6800 km) for which daytime conditions are complex as shown in Section 5.

Sweep-frequency technique, in addition to its assistance in identifying the modes of propagation, enables direct measurements to be made of the m.u.f. and l.u.f. for comparison with predictions. It also indicates the stable modes of propagation, i.e. those for which aerials should be designed both to transmit and receive most effectively, and it gives a display of the multipath delay at any usable frequency so that a circuit may be operated on the most appropriate of its assigned frequencies to minimize multipath effects.

6. Lateral Deviation in H.F. Communication

In the prediction of m.u.f.s by the methods outlined earlier it is assumed that the waves are propagated along the great-circle between transmitter and receiver and experience has shown that when a circuit is operated below the m.u.f. the signals are confined closely to the great-circle. In assessing the accuracy of predictions in terms of the times of fade-in and fade-out of a signal at any frequency it is important, in cases where the signal is received outside the predicted period, to know whether any gross discrepancies between predicted and observed times are due to reception off the great-circle.

It is known that departures from great-circle propagation may occur during ionospheric storms; it has been noted, for example, that in moderate storms over the North Atlantic, signals transmitted from the U.K. may be received in North America from directions south of the great-circle. Such lateral deviation of h.f. waves has been reported by Miya and Kawai[26] for signals received in Japan from Europe under quiet ionospheric conditions. These workers found that, although great-circle propagation obtained while the path m.u.f. exceeds the signal frequency, deviations of as much as 140 deg may be obtained after the failure of the great-circle path and these devia-

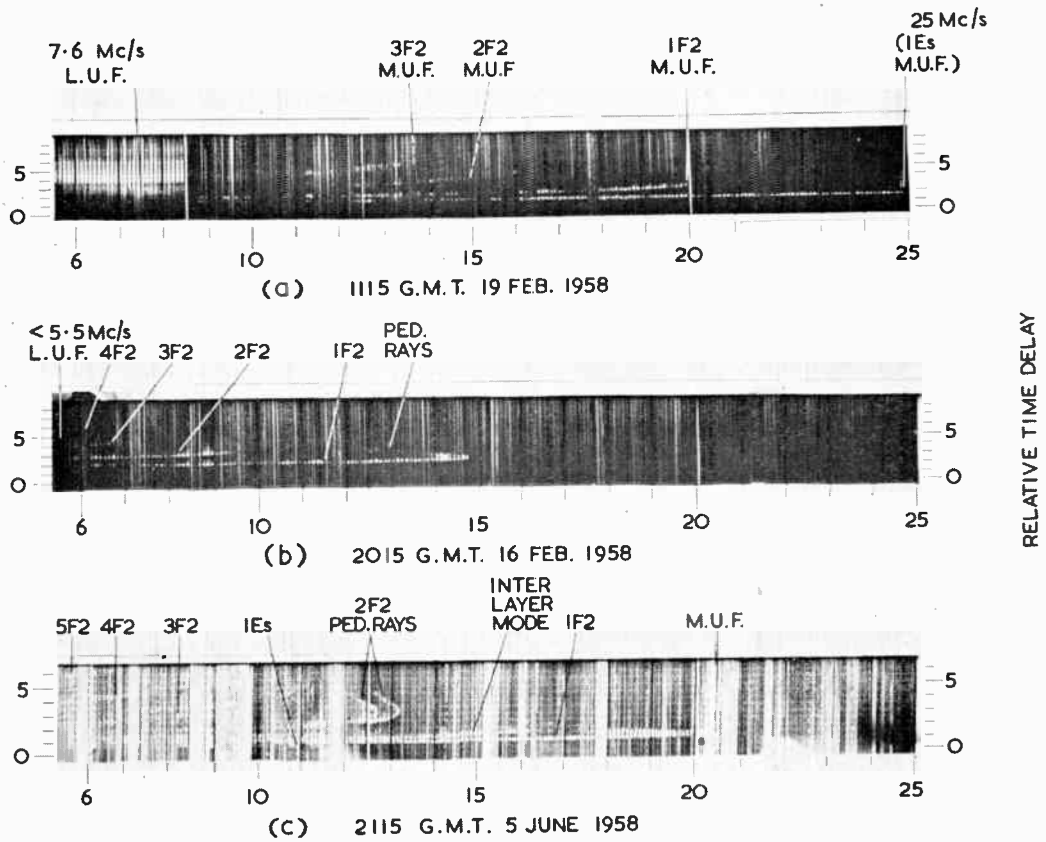


Fig. 6. Record of time separation with frequency of echoes received at Slough from Malta (2100 km).

tions are explained as the result of scattering of the waves from the land to the south of the normal great-circle path.

Similar experiments have been made on Japanese h.f. signals received at the Radio Research Station and it was found in January 1959 that, after fade-out on the great-circle path of the signals in question (32° E of N) the bearing of the signal changes to about 60°–70°, at which it remains for about ½–1 hour, and then jumps to about 110° for a similar period before the signal disappears. These southerly deviations may be explained thus. Great-circle propagation fails because of inadequacy of F2-layer ionization density at the Japanese end of the path. When this occurs there is still adequate ionization to permit transmission south of Japan; the waves will be focused at the ground at the edge of the skip zone and there will be other focusing zones after two and more hops. Ground scattering from the first focusing zone will, on considerations of distance from the transmitter, be stronger than that from subsequent focusing zones; the signals from the first zone are those received at 60°–70° bearing and they ultimately fail because of the F2-layer electron limitation at the European end of the path. Subsequently the weaker signals from the second zone become audible at a bearing of about 110° and ultimately fail for similar reasons to those from the first zone. Scattering from other focusing zones are too weak to be received.

Northerly deviations have also been recorded during these tests. They appear in the late evening well after the end of the phenomena referred to above; the bearings vary from about 350° to 15° and the signal is very strong with flutter fading. It is likely that this reception is taking place by way of reflection from auroral curtains.

7. Use of Back-scatter Technique

The use of back-scatter technique for investigating h.f. propagation phenomena has already been discussed by Wilkins and Shearman[27] and it is likely that the technique will play an increasing part in facilitating the commercial operation of h.f. systems by providing instantaneous observations as to whether the signals are arriving at their destination.

The technique can also be of value in h.f. broadcasting where no immediate report on reception conditions is possible.

7.1. *Application of Back-scatter Techniques to Civil Aviation Communications*

With a view to testing the utility of back-scatter technique for determining the optimum frequency for use in ground-to-air working, tests are being performed in co-operation with the Ministry of Aviation and B.O.A.C. with aircraft flying on the North Atlantic routes. For these tests a commercial transmitter at the Birdlip station of the Ministry is pulse modulated and the received back-scatter displayed on a linear time-base produced on a cathode-ray oscillograph and graduated in miles. The transmitter is capable of rapid tuning to any of the allocated frequencies and it is thus possible to assess the "illumination" on each frequency over the air traffic lanes. Although the experiments have not yet been concluded it has been found that the back-scatter patterns, together with a knowledge of the distance of the aircraft, have enabled the highest frequency capable of covering the distance to be determined and the use of this frequency in communications has resulted in an improvement of signal/noise ratios. A tendency for aircraft transmission on the route to be crowded into frequency bands well below the m.u.f. for the distance to be covered was also noted and the application of the back-scatter observations in such cases has enabled a more suitable (higher) frequency to be selected for the test aircraft with corresponding reduction of interference.

7.2. *Use of Back-scatter Technique for Investigating Sporadic-E Ionization*

Reference has already been made to the fact that the mode of production of sporadic-E ionization is obscure and that no satisfactory method of predicting its incidence exists. Considerable attention has been given to this phenomenon during the I.G.Y. and, at the Radio Research Station, the growth and movement of sporadic-E clouds has been studied with the aid of a back-scatter sounder with plan position indicator[28]. Analysis of the results has shown the main features of the diurnal, seasonal and geographical distribution of the ionization within a radius of 3,000 km from Slough. A tendency was noted for sporadic-E to occur more frequently before noon with a maximum in summer daytime and in a preferred direction to the south of Slough. Occasionally the clouds have been observed to move with velocities of 200 to 300 km per hour. The mean horizontal dimension of the clouds was 150 km.

8. Conclusion

For some years past the width of the commercially exploitable frequency spectrum has increased by a factor of ten every decade due to technical progress; the exploitation of the h.f. band itself is an example of about a decade of progress. Another example of this trend has led to the rapid expansion of the commercial use of the v.h.f. and u.h.f. bands since the war; while such developments may have relieved the pressure in the h.f. band to some extent, the use of these frequencies with conventional technique for long-distance work is usually precluded on economic and political grounds. The application of even higher frequencies in the future is likely to be restricted to short distance working because of the high propagation losses.

The next decade may, however, see world-wide communications being carried out using earth satellites as relays of v.h.f. and u.h.f. signals. One such proposal involves the use of a series of satellites carrying powered repeaters while another would use a large metallized sphere placed in orbit at a distance of 26,500 miles from the centre of the earth; at this position the sphere would appear, from the ground, to be stationary since its time of orbiting the earth would be 24 hours, and signals directed to it would be scattered to the distant terrestrial receiving point. It is also possible that the relaying of signals by scattering at the moon may be used commercially in the future.

Extensions of the use of the submarine, wide-band, repeatered cable are also planned and the Commonwealth telephone cable will revolutionize communication with countries such as Australia and New Zealand with which direct h.f. communication is frequently difficult.

But whatever novel methods of long-distance communication are developed in the future, h.f. propagation will remain of prime importance for the transmission of the world's telecommunications and the application of knowledge gained from the study of the ionosphere to the practical ends of improving these communications will be necessary for some time to come.

9. Acknowledgment

This paper is published by permission of the Director of Radio Research, Department of Scientific and Industrial Research.

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Radio Engineering Overseas . . .

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SPEECH QUANTIZATION

The transmission path bandwidth for speech quantized in amplitude depends on the number of quantization thresholds and only the logatom intelligibility can be used as a criterion of the suitability of equipment with low number thresholds. The results of logatom intelligibility measurements for a low number of thresholds are reported in a recent German paper and it is shown that the intelligibility can be improved for an even number of thresholds when noise is mixed with the speech before quantization. This makes possible a speech transmission of acceptable quality with a quantization using only two thresholds.

'The quantization of speech with a small number of steps," W. Andrich. *Nachrichtentechnische Zeitschrift,* **13,** pp. 379-83, August 1960.

IONOSPHERIC SOUNDING

Developing the sounding-equipments normally used for ionospheric research the German Post Office has constructed an ionosonde which combines the advantages of the fast (American) ionosonde—i.e. the high speed of recording sequence without mechanical limitations—and those of the slow (English-German) ionosonde—i.e. the possibility of tuned circuits in transmitter and receiver over a wide frequency range. The use of the principle of the device is not confined to ionospheric research.

By using supplementary recorders it is possible to transform the ionosonde into a real "active h.f. spectrometer." Time is introduced again as a natural variable in the records of the ionospheric characteristics. There are two fundamental possibilities: firstly, the record of the virtual heights against time, where the minimum heights of the ionospheric layers are clearly visible. Because some frequencies are missed due to interference from continuous strong transmitters, curves of constant plasma frequencies (i.e. constant electron densities) are also shown. On the other hand the minimum and critical frequencies in the E-region and—with some restrictions—also in the F-region can be recorded as functions of time by gates in the height ranges.

Combining the records of heights as a function of time, with the frequency as a parameter, and the frequency records as function of time for different ranges in height, the direct record of the F(3000) m.u.f., the "maximum usable frequency," can be written. The m.u.f. can be used physically as an excellent measure for the profile form of the F2-ionization. The universal use of the directly recorded ionospheric characteristics is discussed. The possibility is mentioned of comparison with the record of other geophysical measurements, which are always recorded against time.

In the second part of the paper it is pointed out that the *a priori* knowledge concerning the echo pulses has only partially been used in the past. Possible applications are discussed for four criteria, namely: periodicity, signal shape, r.f. phase, direction of arrival. With better use of such distinctive criteria it is suggested that it should be possible to obtain improvements.

"An active high-frequency spectrometer for ionospheric sounding. I. Direct recording of ionospheric characteristics. II. Selection of echoes from disturbances." K. Bibl and K. Rawer. *Archiv der Elektrischen Ubertragung,* **14,** pp. 341-47, 373-79, August and September 1960.

AIRBORNE ELECTRONIC EQUIPMENT

Some of the particular problems which are encountered by radio and electronics engineers in Australia in installing the equipment in Service aircraft are discussed in a paper presented at last year's I.R.E. Convention in Melbourne. It is pointed out that Service requirements, both in number and type of equipments per aircraft are almost invariably complex and that available space for installation is often severely limited. Environmental conditions under which the equipment must function are described and the effects of these on equipment installation are discussed. The procedures involved in testing equipment and components from the design stage onwards are elaborate and necessitate very extensive test facilities which are briefly described. The authors conclude that although the integration of electronic equipment design with that of the aircraft itself is highly desirable, it is not yet economically practicable in Australia. Thus it is often found that quite extensive installation problems result.

"The design, installation and operation of electronic equipment in service aircraft," N. R. Bennett and W. M. Rice. *Proceedings of Institution of Radio Engineers, Australia,* **21,** pp. 323-31, May 1960.

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