29th ANNUAL REPORT OF THE COUNCIL OF THE INSTITUTION

*The Council has pleasure in presenting the 29th Annual Report of the Institution which
reviews the proceedings for the twelve months ended 31st March, 1955. The Annual General
Meeting will be held on Wednesday, October 26th, 1955, at the London School of Hygiene
and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.*

INTRODUCTION

Conventions are becoming an accepted part of the activities of most professional institutions,
and the 1954 Convention at Oxford was the most important of the Institution's meetings which
took place during the year under review.

Each of the Institution's post-war Conventions has been divided into sessions which generally
reflect the specialized activities of members. One of the most difficult problems in planning a
Convention is to decide upon a theme which will cover a range of subjects to suit the wide interests
of all members, and the arrangements of the 1954 Convention gained much approval and support.
It seems certain that most members prefer Conventions to be based on one of the universities.

Outside such activities were the equally important, but perhaps not so well known, problems
which confronted the standing committees. The work done in recent years by the Education
Committee in redrafting the syllabus of the Institution's Graduateship Examination formed the
basis for further attempts by the Professional Purposes Committee to obtain agreement from
outside bodies on acceptance of the Institution's examination as a recognized qualification.
Efforts were also made to secure wider understanding of the Institution's purpose in holding the
examination; nothing has happened in the last twelve months to alter the opinion expressed by
Council in the introduction to the last annual report, namely, that continued development in
scientific and technical fields inevitably demands specialization if the necessary man-power is to be
found to cope with the needs of industry.

Particular reference must also be made to the increasing usefulness of the work of the Technical
Committee. By publishing specialized reports, the Committee has endeavoured to achieve the
twofold purpose of supporting the work of such bodies as the British Standards Institution,
whilst at the same time preparing the necessary groundwork for common discussion by all who
are interested in the work of the professional radio engineer.

Other standing committees have also made a notable contribution in not only maintaining, but
in extending the influence of the Institution's work. The local committees overseas particularly
have done much toward ensuring that their work upholds, and indeed enhances, the status and
tradition which is enjoyed by the Institution.

A further commitment of the Institution is the nomination of members to serve on outside
advisory bodies and similar organizations; the Council welcomes these further opportunities to
be of service to the profession.

All this work would be impossible of achievement were it not for those engineers who so
freely and voluntarily give their services to the Institution. During the year the Council and
Committees held 51 meetings and the President and Officers renew with great warmth their
thanks to those who have served.

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PROFESSIONAL PURPOSES COMMITTEE

In the last Annual Report the Committee expressed the view that the attendance at the 1954 Convention would show whether there would be sufficient support for the formation of a specialized group of the Institution devoted entirely to securing papers and arranging meetings on Industrial Electronics.

Some members have, however, suggested that, as the Institution's activities cover the whole field of radio and electronic engineering, the setting up of a specialized group may tend to give undue prominence to only one section. Others feel that there is also need for specialized groups in the subjects of television and communications. Such an extension of the Institution's activities will inevitably demand more staff work and the services of members prepared to serve on the various Committees.

The Committee is still examining the whole question of setting up specialized groups or sections and is to give a further report to Council during the next few months.

External relationship.—Elsewhere in this report reference is made to the continuing representation of the Institution on various bodies. In this way, the Council has implemented the policy stated in nearly every Annual Report that it wishes to co-operate with any organization whose activities directly or indirectly affect the work of the Institution and the status of the professional radio and electronics engineer.

The Committee wishes to record appreciation for the way in which successive Presidents and other Officers of the Institution have worked towards the principle of securing professional unity among engineers. It is regretted that these efforts have not secured the desired result in regard to the work of the Advisory Committee appointed by the Minister of Labour and National Service on the operation of the Technical and Scientific Register.

Whereas the Civil and Mechanical Engineering Sections of the Technical and Scientific Register operate under the guidance of Advisory Committees representing three or more bodies, the interests of the radio and electronics engineer are the concern of an Advisory Committee comprising representatives of only *one* Institution.

As stated in the report of the Education Committee, the need to provide more facilities for the training of radio engineers is recognized by the fact that a greater number of technical colleges have started courses to cover the requirements of the Institution's Graduateship Examination, or alternative examinations. This development encourages the view that the Council should continue negotiations with the Minister of Labour.

Safeguarding membership. — Under this heading in the last Annual Report reference was made to the Council's intention to institute legal action to restrain unauthorized persons from describing themselves as members of the Institution. In one case it was necessary to take such action and the case was heard in the Queen's Bench Division of the High Court of Justice. In consequence, an injunction was granted to restrain the defendant from describing himself as a member of the Institution or from using any colourable imitation which might lead to the impression that he was a member of the Institution.

It is hoped that any member who learns of an unauthorized person describing himself as a member of the Institution will advise the Secretary so that similar action may be taken.

Coat of Arms.—During the year the Council petitioned the College of Arms for the Grant of Armorial Bearings and Supporters to be borne and used by the Institution. The Council wishes to record thanks for the subsequent help given by Mr. Anthony R. Wagner, C.V.O., the Richmond Herald, in the design of an appropriate Coat of Arms.

The Institution overseas.—In an endeavour to secure for members overseas the same advantages as are enjoyed by members in Great Britain, the Council re-examined the operation of local Sections in the Commonwealth. At various centres in India, Pakistan, South Africa and New Zealand regular meetings of members are held and during the year the Committee and the Council have had the advantage of meeting several members who take a prominent part in overseas activities.

The emigration of members to Canada has raised the problem of acceptance of the Institution's membership by the Association of Professional Engineers of Canada. Registration with the Association is compulsory for practising professional engineers in Canada. The main difficulty has been the insistence of the Associa-

tion that all registered engineers should have passed a suitable examination in Chemistry. Engineering Economics, Specifications. Ethics, Fluid Mechanics. and Strength of Materials.

The Council expresses appreciation for the services given by Mr. L. H. Paddle (Vice-President) who is resident in Canada and in direct negotiation with the Association on behalf of the General Council.

The Association does not operate a separate section or activities for radio and electronics engineers, but it is hoped that the present negotiations may be a further step toward securing co-operation with them on matters affecting the professional radio engineer.

Social activities.—Last year the Committee reported that it had under consideration a proposal that the Institution might hold a Ball in aid of its Benevolent Fund. It is felt, however, that the number of similar functions held within the industry would not justify a further addition to the social calendar. Moreover, as stated under the report of the Trustees of the Benevolent Fund. financial support for the Institution's Benevolent Fund is now received from both the Radio Industries Club of London, and of Manchester.

The Institution will, however, continue to hold occasional social functions to mark specific occasions, such as Conventions, etc. In this latter connection, the Committee has already discussed plans for the holding of a Convention during 1956 which, apart from its technical value, will also provide a further opportunity of social contact between members.

MEMBERSHIP COMMITTEE

A comparison with the statement published in the last Annual Report will show that whilst direct elections to the various grades of membership were a little below the 1953-54 figure, the number of transfers to higher grades of membership increased considerably. This last point is a particularly pleasing feature in view of the opinion of the Committee, expressed in the last report, that a number of members appeared not to be in their appropriate grades.

The table which follows gives an analysis of the increase in elections and transfers, as well as the loss which has occurred in the membership.

Table 1

Statement of Elections and Transfers for the Year Ended March 31st, 1955

	Total considered	Elections and transfers approved						
		Member	Associate Member	Com-panion	Associate	Graduate	Student	Total
Direct elections	703	7	43	3	53	58	497	661
Proposals for transfer	258	6	75	—	30	81	—	192
Proposals for reinstatement	9	—	1	—	2	—	6	9
Totals	970	13	119	3	85	139	503	862

Losses During the Year

Loss by resignation. removal and decease	8	23	2	36	16	253	338
Loss by transfer to other grades	—	6	—	27	41	118	192
Totals	8	29	2	63	57	371	530
Net gain in membership	5	90	1	22	82	132	332

It will be noted that the increase in this last figure is almost entirely due to the larger number of Students who had to relinquish their association with the Institution through inability to complete the Graduateship Examination requirements within the stipulated five years. The loss incurred in the higher grades of membership is again very small and is lower than the corresponding figure for the previous year. Apart from the loss caused by the death of 18 members, the bulk of the loss from higher grades was mainly due to the Institution's inability to contact members, and the Committee takes this opportunity of reminding all members that it is most important to keep the Institution informed of their whereabouts.

Table 2 gives the growth of membership over the last five years; although this shows a reduction in the net annual increase, due to the loss of Students and the smaller number of direct elections, the Committee is pleased to report that the total membership now exceeds 5,000.

Table 2

Membership Growth over the Last Five Years

As at March 31st		Total Membership		Annual Increase		Enquiries Received
1951	...	3,634	...	285	...	1,866
1952	...	4,018	...	384	...	1,703
1953	...	4,383	...	365	...	1,964
1954	...	4,750	...	367	...	1,711
1955	...	5,082	...	332	...	1,813

Enquiries.—Enquiries regarding membership totalled 1,813, which is a slight increase on the previous year's figure. This number only represents enquiries handled by head office and excludes those dealt with by the local Section Secretaries. Thanks are expressed to the Honorary Secretaries for their considerable help in disseminating information to prospective members.

Honours conferred on Members.—Details of members who had the distinction of being included in Her Majesty's Birthday and New Year's Honours Lists were published in the *Journal*, and those members have already been congratulated by Council. It is with regret that the Committee reports that Sqdn. Ldr. R. H. Stephenson, who was awarded an O.B.E., has since been killed in a flying accident.

Index of Members' Activities.—The compilation of an index covering the activities of corporate members in the United Kingdom was completed during the year. A little under 90 per cent. of the members responded to the Institution's circular. The index has proved to be most valuable to the Committee, and has shown that corporate members are engaged in every company in the industry and in the appropriate Government departments, as well as in the application of electronics to many other industries. It has also proved useful to the Institution in other ways, particularly to the Papers Committee which has now built up a substantial register of qualified readers in specialist subjects.

Appointments Register.—The severe shortage of qualified and experienced radio and electronics engineers has continued unabated, and this has been reflected to a large extent in the work of the Appointments Register, which dealt with a smaller number of requests from members requiring alternative employment. Nevertheless, 217 introductions were made which compares with 151 for the preceding year.

Enquiries were also received from a number of organisations overseas, in particular from Canada and America, and several members of the Institution emigrated to those countries during the past twelve months.

Apart from the normal employment service, a number of organisations approached the Institution for assistance in the appointment of engineers to senior positions, and the engagement of engineers in a consulting capacity.

EDUCATION AND EXAMINATIONS COMMITTEE

Twelve meetings of the Committee were held during the year. Professor E. E. Zepler, who had held the office of Chairman for seven years, retired from the Committee, and has been succeeded by Mr. E. W. Pulsford, B.Sc. (Associate Member). The Committee wishes to place on record its appreciation of the advice and guidance given by Professor Zepler during his nine years' service.

Graduateship Examination.—One of the most important duties of the Committee is to advise Council on the maintenance of the examination

standards of the Institution. The Committee has been particularly concerned with the revision of the examination syllabus, which has added considerably to its normal work.

Examination Entries.—The Committee is pleased to report a continued increase in the number of entries accepted for the Graduateship Examination. 1,198 candidates entered for the May and November Graduateship Examinations, compared with 1,149 in 1953. 321 candidates passed part of the examination and 81 completed the examination requirements thereby becoming eligible for election or transfer to Graduate or higher grade membership. This is a slight improvement on previous years, although the overall results are still generally disappointing.

An analysis of results shows that Advanced Radio Engineering remains the most difficult subject. In the 1954 examinations only 15.4 per cent. of the candidates succeeded in this part of the examination.

Exemptions.—Members will be aware that a list of degrees or alternative examination qualifications recognised for the purpose of exemption is given in the Institution's Membership Regulations. Most applications for exemption may therefore be dealt with by the secretariat, but where an application is made on grounds other than those listed in the regulations, the Committee considers each case. During the year there were 137 such applications, and only 27 were successful in securing full exemption; another 93 candidates were granted partial exemption, mainly from the first sections of the examination.

The Committee is constantly revising the list of exempting qualifications, and further revisions will be necessary in view of the alterations to the examination scheme which come into effect as from November 1956. A list of qualifications giving exemption under the revised scheme will be published in the *Journal* during 1955.

Theses.—The Committee considered eight theses which were submitted in lieu of the Graduateship Examination. Only two of these were found to be acceptable and the Committee again stresses the point made in the last Annual Report, that the submission of a thesis is by no means an easy method of entry into the Institution. An acceptable thesis must either be the result of original work or a scientific criticism of current practice; a review is not sufficient.

Examiners.—The Council expresses sincere thanks to the following members of the Institution who have assisted as examiners during the year:

F. Butler, B.Sc. (Member)
Sqdn. Ldr. M. E. Claxton, B.Sc., M.Ed. (Member)
D. A. Crowther, B.Sc. (Associate Member)
D. Fotheringham, B.Sc. (Associate Member)
S. Kelly (Member)
K. G. Lockyer, B.Sc. (Associate Member)

J. R. Miller (Associate Member)
W. T. Perkins (Associate Member)
E. T. A. Rapson, M.Sc.(Eng.) (Member)
W. P. Rowley, M.B.E. (Member)
H. Stibbe (Associate Member)

P. O. Wymer, B.Sc. (Associate Member)

The Council appreciates the heavy burden thrown upon examiners consequent upon the continued increase in examination entries and it is hoped that new arrangements for the marking of scripts will offer some relief to the assessors and facilitate the earlier publication of results.

Examination Centres.—Economic reasons dictate that new centres cannot be set up unless there is an adequate number of candidates. During the year, some reduction was made in the number of examination centres, without causing hardship to any candidate. 65 centres were used for the May and November examinations, and the Council expresses thanks to the universities, technical colleges and Service establishments concerned for the facilities provided.

Prizes.—Council has approved the award of prizes for the May and November examinations as follows: —

PRESIDENT'S PRIZE ... Patrick Joseph Murray.
ELECTRONIC MEASUREMENTS PRIZE ...
Alfred Dixon Brown.

It is a characteristic of recent examinations that fewer candidates have attempted to pass the entire examination at one sitting, and fewer still have succeeded. It is for this reason that the S. R. Walker Prize and the Mountbatten Medal have been withheld. In the case of the Audio Frequency Engineering Prize, no candidates were successful in this optional subject.

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From November 1956. the terms of reference of those Prizes which require the passing of the entire examination at one sitting will have to be revised to meet the new condition requiring candidates to complete the examination in a minimum of two sittings.

New Examination Scheme.—As announced in the last Annual Report, certain alterations in the structure of the examination will come into effect as from November 1956. Candidates will be required to write two three-hour papers on Physics instead of one as at present, and two new optional subjects. Applied Electronics, and Radar Engineering and Microwave Techniques. have been introduced. The examination will comprise two parts as follows : —

Section A	**Section B**
1. Physics (2 papers)	3. Mathematics
2. Principles of Radio Engineering	4. Advanced Radio and Electronic Engineering
3. Mathematics	5. Optional Subject

(Mathematics may be taken in either Section)

Candidates who have passed or obtained exemption from equivalent papers under the present examination scheme will be credited with this success under the new scheme.

Candidates will be required to complete Section A before taking Section B, and in this way the Committee hopes to obtain improved results in Advanced Radio and Electronic Engineering, and the optional subjects. At present, candidates tend to take these papers before they have succeeded in the Principles of Radio Engineering paper.

The Committee realises that by insisting upon the completion of Section A before taking Section B delay will be caused to some candidates in completing the examination requirements. It must be remembered, however, that the examination represents the result of three years' full-time study, and candidates giving adequate preparation to the subjects should experience no hardship.

Courses of study.—The number of courses of study in the United Kingdom designed specifically to cover the Graduateship Examination requirements, the City and Guilds of London Institute Full Technological Certificate, or a Higher National Certificate with radio or electronics subjects. has continued to increase. Courses are now available at 61 colleges, and a

list is published on page (xvi) of this *Journal*. Present results are not wholly satisfactory, but it may be too early to judge the efficacy of the new courses. bearing in mind that the requirements of the Graduateship Examination necessitate a three years' full-time course.

Most of the courses are restricted to a small area of the country. mainly London. and in general are still not adequate to serve the needs of the entire industry.

In the Commonwealth and overseas, there also appears to be a gradual increase in the availability of suitable courses at both universities and technical colleges. As evidenced by the examination results, however, the standard is still below that provided in the United Kingdom.

It is difficult to assess in advance the probable usefulness to the radio industry of the proposed Royal Colleges of Technology. The original proposals of the Committee on Higher Technological Education will not. it appears. be implemented in full and the Minister of Education is proposing to concentrate on the development of three colleges, the Royal Technical College, Glasgow, the Manchester College of Technology and the Imperial College of Science and Technology. The Minister's final proposals on this subject, which are due during the next session of Parliament. are awaited, but it would appear that the Minister will follow the advice of the National Advisory Council to encourage these Colleges to provide primarily practical courses of technology.

Applications for the Institution's approval of courses have increased and the Higher National Certificate course with Radio Engineering and Radio Measurements conducted by the Croydon Polytechnic now secures complete exemption from the Graduateship Examination, provided credits are obtained in all subjects. The Associateship Examination of the Royal Technical College, Glasgow, has also been approved for full exemption.

Other courses which have been considered for partial exemption have been the Higher National Certificate courses of the Wimbledon. Enfield and Twickenham Technical Colleges.

In dealing with the Higher National Certificate courses, the Committee has required the course to include three radio or electronic subjects in the A1 and A2 years, out of a total of six subjects, two of which are mathematics.

Where such courses have been approved, credits are required in all subjects. In the case of courses which have not been approved for full exemption and where exemption from all except the optional subject is granted, the candidate can secure exemption from this paper by obtaining an endorsement in a suitable radio or electronics subject.

In considering courses of study and examinations for exemption purposes, the Committee has noted a considerable variation in the pass marks. It is not always a fair indication of the standard of the examination to know the pass mark, without at the same time bearing in mind the standard of the question paper and method of assessment.

Recruitment.—The efforts of the Institution and many other organisations to secure an increase in the number of boys entering the industry as apprentices have met with some measure of success. The situation has now arisen where there is a shortage of places for student apprentices in the industry, *i.e.* apprentices who attend either technical colleges on part-time day release or sandwich courses in preparation for professional qualifications. The editorial in the March 1955 *Journal* referred to the importance of all sections of the industry playing their part in training engineers by promoting training schemes, particularly for the student apprentice. At present, the training of student apprentices is concentrated in a relatively small number of large firms who obviously cannot hope to provide engineers for the entire industry.

Representation on outside Committees.—The Institution continues to be represented on the Advisory Committees of the City and Guilds of London Institute for Telecommunications Engineering, Radio Service Work and the Radio Amateurs Examination. Council expresses grateful thanks to the Institution's representatives, Professor E. E. Zepler, G. Taylor and R. G. Holmes respectively.

Collaboration with the Radio Trades Examination Board.—For the first time, the Board's work was represented on the Technical Training Stand of the Radio Industry Council at the 1954 National Radio Show. As a result, over five hundred applications were received for more detailed information of the work of the Board,

apart from the considerable amount of literature distributed at the Exhibition. This interest will undoubtedly be reflected in the future work of the Board and it is hoped that the display will have encouraged many existing and prospective service engineers to obtain the Radio and Television Servicing Certificates.

The Board has approved an alteration to the regulations governing entry to the Radio Servicing Certificate Examination. Entries are now accepted from candidates with a minimum of three years' full-time gainful experience in commercial radio service work or, alternatively, one year's gainful experience, together with the completion of an approved course of training. The minimum age has also been reduced to eighteen years.

In the retail and wholesale trade, there has been a considerable extension of the apprenticeship scheme which has been operating under the auspices of the Radio and Television Retailers' Association since the autumn of 1952. Under this scheme, there is a full five-year indentured apprenticeship with part-time day release for attendance at a technical college for the full five years, the candidate completing his Radio Servicing Certificate after three years and his Television Servicing Certificate after five years.

Here again, the full effect of these schemes has not yet been experienced by the Board but it is certainly an interesting fact that the entries for the 1955 Radio Servicing Certificate Examination, which does not come within the scope of this Report, show an increase of 48 per cent. over the 1954 figure, the largest increase in any year since the Board's inception.

It is obvious that the need for the Board is now fully accepted by all those concerned in the training and employment of service engineers and it is hoped that in the not too distant future possession of the Radio and Television Servicing Certificates will be an essential qualification for those engaged in the maintenance of domestic radio and television receivers.

378 entries were received for the Radio Servicing Examination in 1954. 144 candidates were successful and 96 were referred in the practical test. These figures compare with 323 entries in 1953, of which 123 passed and 87 were referred.

For the first time, entries for the Television Servicing Certificate Examination were below those for previous years. Only 107 candidates entered, 55 of whom were successful, and 20

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referred in the practical test. These figures compare with 140 entries in 1953, of which 64 passed and 36 were referred.

Entry to the Television Servicing Certificate Examination is confined to those who have succeeded in the Radio Servicing Certificate Examination. Consequently, entries for the examination will not exceed the number of candidates successful in the Radio Servicing Certificate Examination. There will also be a wastage of students who do not proceed to the Television Examination. During the past three years the number of candidates succeeding in the Radio Servicing Certificate Examination has averaged 140, and this is the maximum number which can be expected to enter for the Television Examination.

The Radio Servicing Examination was conducted at 25 centres and 7 centres were used for the Television Servicing Examination. Thanks are expressed for the facilities provided by the technical colleges and to the examiners. In addition to the Institution's representation on the Board as well as the Examinations Committee, other members of the Institution have acted as examiners.

The Board's work would be equally impossible without the co-operation of those manufacturers who provide the receivers necessary for the practical tests, and their assistance in this matter is much appreciated.

The Council of the Institution has supported the Incorporation of the Board under the Companies' Act. Official Incorporation will be completed during the next twelve months and whilst this is a useful step in stabilising the future work of the Board, the Council is conscious of the need to contribute still further to the subsidy which the Board must receive from its constituent associations, which are the Radio Industry Council, Radio and Television Retailers' Association, Scottish Radio Retailers' Association, and the British Institution of Radio Engineers.

PROGRAMME AND PAPERS COMMITTEE

In addition to the normal meetings of the Committee which were held for the review of papers and arrangement of meetings, a sub-committee held joint meetings with the Technical Committee to deal solely with the papers submitted for the Industrial Electronics Convention.

Consideration of papers.—The Committee considered 88 papers for publication in the *Journal*. The proportion of papers accepted for publication without the necessity for extensive revision was 48 per cent., compared with 56 per cent. for the previous year. Papers rejected as being totally unsuitable for publication totalled 21, and the remaining papers required detailed revision. In addition, the Committee reviewed a number of papers published in the journals of other bodies with which the Institution has an agreement for reprinting, and recommended that four of these were likely to be of interest to members.

The sub-committee considered 56 papers for the Oxford Convention, 20 of which had to be refused, mainly due to the subjects being either outside the theme of the Convention, or a repetition of papers already accepted for inclusion in the programme. Thirty-six papers were finally selected for presentation at the Convention.

The Committee used a large panel of experts to assist in the arduous task of assessing papers and it is appropriate here to thank those referees for their services. In connection with the Convention papers, reports were completed in good time to permit preprints to be available at the Convention.

The Committee and referees continue to be of service in advising authors on the proper presentation of their manuscripts. A fault which frequently occurs is the tendency of inexperienced authors to assume either that the potential reader knows all about the background of the subject or, alternatively, that he knows nothing and hence must receive instruction in the basic principles of radio engineering! Achieving the correct balance is not easy but, in general, authors have been most co-operative.

In order to give maximum help to authors the Committee is revising the existing leaflet giving guidance to authors of *Journal* papers. These notes were originally published nearly 10 years ago, since when, of course, the scope of the *Journal* has widened considerably and changes have been made in the format and mode of presentation of papers. The proposed new publication, which it is hoped will be completed during the coming year, will give advice to prospective authors on the "mechanics" of writing a technical paper, including such points as preparation of illustra-

tions, the writing of the summary, oral presentation, etc.

The Committee continues to be concerned about the number of papers submitted. Taking into account Convention papers, the papers read before Sections, and those submitted for publication only, less than 100 manuscripts have been received during the year. The Committee again urges all members to submit contributions and to invite their colleagues to write papers for the Institution.

One type of paper which does not appear to receive sufficient attention is that giving an account of engineering development. The value of the engineering development paper was stressed in an editorial article in a recent issue of the *Journal* (April 1955). With the ever widening extent of radio and electronics applications the engineer needs to learn more of advances which, although outside his own field, may well have a valuable bearing upon it. Papers describing new developments or applications are, therefore, very useful.

There are also two other general types of paper which do not require a great deal of preparation, but which can make a valuable contribution to the professional journal.

Firstly, where a project is not completed, an interim report may be of interest and would come under the category of a short contribution. Secondly, it frequently happens that a particular problem has arisen, which has been solved for the case in hand, and which would be of sufficient value to form a short "research note." Both types of contribution need only amount to one or two thousand words.

A third suggestion is comment on papers already published—similar to "Letters to the Editor" sections in many commercial technical publications. Even though this mode of presentation is not strictly appropriate for a professional journal, members should regard it as a means of recording opinions and progress.

Local Sections.—Opportunity was taken during the 1954 Convention to hold a meeting of the Local Section representatives and the Programme and Papers Committee. Views were exchanged on matters of mutual interest, particularly with reference to increasing the number of Local Section papers submitted for publication in the *Journal*.

During the 1954-55 session, 51 meetings were held by Sections in the United Kingdom.

The 10 meetings held in London attracted an average attendance of 120 but attendance at Local Section meetings averaged 35.

Overseas Sections have maintained the achievement of 1953-54; indeed there were over 40 meetings of the Institution abroad during the twelve months under review. Nevertheless the principal difficulty of overseas sections is the limited nature of their programmes. Attendance at meetings was well maintained and in some sections, notably Madras and Bangalore, considerably increased.

Co-operation with the I.R.E., Australia.— Members will recall that in alternate years the Brit.I.R.E. and the Institute of Radio Engineers Inc., New York, select the most outstanding paper published in the Proceedings of the Australian Institution to receive the Norman Hayes Memorial Medal awarded by the Australian I.R.E.

The Brit. I.R.E. was asked to adjudicate this year and the paper selected as most deserving of the award for 1954 was that by Messrs. W. S. McGuire and A. G. Bird entitled "Experimental Radio Bearer Equipment for Carrier Telephone Systems." The friendly relations which exist between the Brit.I.R.E. and the Aust.I.R.E. include an arrangement for reprinting papers from the journals of each body and this paper was reprinted in the April 1954 issue of the *Brit.I.R.E. Journal*.

The Journal.—Volume XIV of the Institution's *Journal* was larger than any preceding volume, containing 652 pages. It is felt that for ease of handling and reference, consideration must now be given to either increasing the page size of the *Journal* or, alternatively, to dividing the year's issues into two parts.

Publication of the Convention papers gave emphasis in some issues of the *Journal* to Industrial Electronics, but over the year a reasonable balance was achieved by publication of a wide variety of papers on communications, television, etc. The techniques employed in industrial electronics are very diverse and most are derived directly, of course, from methods used by the radio and communications engineer.

Most of the Convention papers were published in the 1954 volume and the remainder will be contained in the first half of the 1955 volume. Taken as a group these issues of the *Journal* represent an extremely valuable symposium of the current state of the applica-

tion of electronics to a wide range of industries.

Notes on scientific and engineering items likely to be of general interest to members have continued to be a feature of the *Journal* contents, in addition to the usual publication of Institution notices, lists of new elections, examination results, etc.

The Audit Bureau of Circulation's latest certificate for the period ending December 1954 shows that the circulation of the *Journal* was 5,745, an increase of 513 over the figure for December 1953. A still further increase is shown for the period January-June 1955.

Requests for back numbers of the *Journal* are continually received from the libraries of industrial organizations, universities, and government departments, thus demonstrating the reference value of these proceedings. Many recent papers are now unfortunately out of print as it is impossible adequately to forecast the demand for individual issues.

The growing circulation of the *Journal* obviously has a bearing on its attraction as an advertising medium and it is gratifying to record an increase in the number of advertisers. The general standard of technical advertising in Great Britain is of a high level and the Council welcomes the inclusion of really informative announcements which it is felt are in the best interests of both members and advertisers.

As mentioned in the report of the Finance Committee, rising costs in the printing industry have had a severe restraining influence on publishing a larger *Journal*, as well as limiting the stock of copies in excess of immediate needs. Strict watch had been maintained on printing and paper costs, but the new arrangements for printing the *Journal* as from 1955 should curb the steep rise in costs.

Abstracts of papers.—Mention was made in the last Annual Report of the inclusion in the December 1953 *Journal* of abstracts of all papers published in the *Journal* from 1939 to 1953. These abstracts have now been reprinted as a separate booklet and include the papers which appeared during 1954, together with those papers read at the Convention. This booklet was extremely well received in the profession and in industry. Forming as it does a complete record of Institution papers on a wide range of subjects, it is of unique value to the practising engineer as well as to the prospective author.

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Year Book.—The sixth issue of the Institution's List of Members was published early in 1955 and, as already stated, contains the names of all corporate members as well as Companions, Associates and Graduates. Copies have been sent to all members.

In addition to the lists of committee members and the Memorandum and Articles of Association, a particularly useful feature is a complete table of the Premiums and Prizes awarded since 1940.

Premiums.—Council is pleased to announce the names of recipients of Institution Premiums for papers published in the *Journal* during 1954, and offers congratulations to the respective authors as follows: —

THE CLERK MAXWELL PREMIUM: F. N. H. Robinson, "Microwave Shot Noise in Electron Beams and the Minimum Noise Factor of Travelling Wave Tubes and Klystrons."

THE HEINRICH HERTZ PREMIUM: Dr. T. B. Tomlinson (Associate Member), "Partition Components of Flicker Noise."

THE LOUIS STERLING PREMIUM: L. H. Bedford (Member), "Problems of Television Cameras and Camera Tubes."

THE SIR J. C. BOSE PREMIUM: S. Deb, "Decay of Emission from an Oxide-Coated Cathode due to Adsorption of Matter Liberated from the Anode."

THE BRABAZON PREMIUM: J. W. Jenkins, J. H. Evans (Associate Member), G. A. Wallace and D. Chambers, "A High Definition General-Purpose Radar."

THE MARCONI PREMIUM: W. T. Brown (Associate Member), "Some Factors in the Engineering Design of V.H.F. Multi-channel Telephone Equipment."

THE LESLIE MCMICHAEL PREMIUM: Dr. G. N. Patchett (Member), "A Critical Review of Synchronizing Separators with Particular Reference to Correct Interlacing."

STUDENTS PREMIUM: R. W. Walker, "An Electronic Random Selector."

The A. F. Bulgin Premium and Norman Partridge Memorial Award have been withheld as no papers were considered suitable.

An announcement has already been made that the terms of award of the Students Premium have been reconsidered. As from 1956 a

Students' Essay Competition takes the place of this award. The competition will be open to Graduates under the age of 23 and to all Students, and will be on a set subject for each year. For the first competition the subject chosen is "Problems of Technical Training." In general, the choice of subject will be confined to topics on which those eligible to enter may be expected to have reasonable knowledge and will not necessarily be on a purely technical theme. Full details are to be announced shortly in the *Journal*.

Convention Premiums.—The Council set aside a sum of money to be awarded to authors of outstanding papers read during the 1954 Industrial Electronics Convention. The following recipients are congratulated on the high standard achieved by their contributions:

SESSION 1: P. Huggins (Associate Member), "Statistical Computers as Applied to Industrial Control."

SESSION 2: C. W. Miller (Associate Member), "Industrial Radiography and the Linear Accelerator."

SESSION 3: K. Kandiah and D. W. Chambers, "Multi-Electrode Counting Tubes."

SESSION 4: J. L. Thompson (Member), "Wire Strain-Gauge Transducers for the Measurement of Pressure, Force, Displacement and Acceleration."

SESSION 5: M. T. Elvy (Associate Member), "Electronic Heating and the Woodworking Industry."

Acknowledgments.—The Council wishes to thank the authorities of the universities, colleges, etc., who co-operated in providing facilities for the meetings of Sections in Great Britain and overseas. Particular appreciation is expressed to the authorities of Christ Church, Oxford, and of the Clarendon Laboratory, whose co-operation contributed so much to the success of the 1954 Convention.

During the year notices of Institution meetings and reports have been published in many technical and scientific journals and the Council thanks the respective Editors for their collaboration.

In the course of the year, Lt.-Col. J. P. A. Martindale, B.A., B.Sc. (Associate Member), was appointed Chairman of the Committee and Council records appreciation of the services given by the former Chairman, Mr. G.

Wooldridge, B.Sc.(Hons.) (Associate Member), who had to resign on receiving an overseas appointment.

Mr. J. H. Evans (Associate Member), who is now working in Canada, and Mr. A. J. Tyrrell (Member) also retired from the Committee.

LIBRARY COMMITTEE

The Institution's Library continues to provide useful assistance to members. Special bibliographies have been compiled on such subjects as Printed Circuits, Frequency Modulation, and Underwater Detection; references on these and other specialized subjects have been particularly requested by the membership.

Records show that during the last four years there has been over 100 per cent. increase in the number of books borrowed by members. The increased reading facilities provided in the Institution have been welcomed by members, and as expected, the number of callers, as well as the number of requests received through the post show a marked increase in the two or three months preceding the Graduateship Examination.

Members who visit the Library will see that the re-adjustment of office accommodation has permitted the installation of additional shelving to facilitate easy access to most of the reference works and current periodicals. It is regretted that the existing conditions at 9 Bedford Square do not permit of any further expansion. More extensive Library and reading rooms are necessary, however, and this important feature is borne in mind by Council when considering alternative accommodation for the Institution.

Apart from the requirements of members, increased enquiries have been received from the libraries of industrial organizations, public libraries, and other information organizations in Great Britain and overseas were dealt with. The Council welcomes all these opportunities of serving industry.

Arrangements for the publication of a revised library catalogue have been discussed with the Finance Committee and the new issue will be available during 1956. It is hoped that the new catalogue will be of value to all members, particularly to those using the postal service.

Publishers in this country and abroad supplied new technical books for review in the *Journal* prior to their addition to the Library.

The Committee expresses thanks for the co-operation thus given by publishers.

Reference has been made to the periodicals and journals which are available in the Library. It is believed that the Institution now receives at least one copy of every radio and electrical journal published throughout the world. In the main, these journals are received under an exchange arrangement with the *Brit.I.R.E. Journal*, and thanks are expressed to the publishing houses concerned for their collaboration.

As reported by the Programme and Papers Committee publication of "Abstracts of *J.Brit.I.R.E.* Papers 1939-54" has proved most valuable. As additions to staff and Institution accommodation permit, work will be continued on compiling abstracts on specialized topics, including reference to other technical journals published at home and overseas.

Gifts.—The Committee expresses thanks to all members who have presented books and periodicals to the Library, and particularly appreciates the continued generosity of Messrs. A. G. Egginton, L. W. Meyer and G. Wooldridge (Members). Mrs. W. A. Beatty, widow of a former Member of the Institution, also donated several books which were most useful additions to the Library.

TECHNICAL COMMITTEE

On his election to the General Council, Mr. F. G. Diver, M.B.E., (Member), was appointed Chairman of the Technical Committee, on which he has served for several years. Council wishes to express appreciation for the services given by Mr. E. A. H. Bowsher, the previous Chairman of the Committee.

Several new members were appointed to the Committee, which is now representative of many branches of the industry, the Scientific Civil Service, and the three Defence Services.

Reports.—The main work of the Committee was concentrated on the review "Materials used in Radio and Electronic Engineering". Two parts of this review. Aluminium and Aluminium Alloys and Piezo-Electric Crystals, were published in the January 1955 *Journal*, and both reports were well received.

The Committee is progressing further sections of the review, including Ceramics, Plastics.

Brass and other Non-Ferrous Metals, and Plating; at least two of these reports should be completed for publication during 1955.

The various sections of the review were prepared by sub-committees. and valuable assistance was also given by various manufacturers to ensure the authenticity of the information. It must be stressed that these reviews are only intended to provide members with a guide to the use of primary materials, and the bibliographies indicate where further information may be obtained.

Other reports in course of preparation by the Committee deal with electronic instruments.

Meetings of the Institution.—Reference was made in the last Annual Report to the part played by the Technical Committee in the arrangements for the 1954 Industrial Electronics Convention. As members are aware, over five hundred engineers attended the six separate sessions which were held in Oxford.

The Committee's co-operation with the Papers Committee was maintained, particularly in connection with the Convention and the organisation of the discussion meeting on "Maintainability of Services' Equipment". This meeting was attended by over three hundred members and guests who provided a high standard of discussion. and its success encourages the holding of further meetings of this type during the 1955-56 session.

The British Standards Institution.—Details were given in the last Annual Report of members of the Institution who serve on the various technical committees of the Telecommunication Industry Standards Committee. A further committee has since been set up, TLE/12—Transistors, on which the Institution is represented by Mr. B. R. A. Bettridge (Associate Member).

During the year each member serving on a B.S.I. Committee attended at least one meeting of the Institution's Technical Committee. In this way the Technical Committee had an opportunity of commenting on a number of draft standards and specifications as well as considering various ways of co-operating with the British Standards Institution.

Correspondence was also initiated with the American Institute of Radio Engineers on the possibility of greater co-operation on radio

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standards and specifications. Both bodies are represented on their own national organisations, i.e. the American Standards Association and the British Standards Institution, who in turn belong to the International Electro-technical Commission. The Council feels, however, that closer co-operation between the two Institutions could do much to ensure that due note is taken of their opinions when national standards are being prepared.

Technical advice.—Apart from the services rendered to members through the Appointments Register, the Technical Committee also considered requests made by individual firms and local Government authorities for the nomination of members to give technical advice, e.g. on the regulations concerning the installation of television aerials. Members have also been recommended as technical arbitrators and witnesses in legal disputes.

FINANCE COMMITTEE

The Income and Expenditure Account and Balance Sheet for the year ended 31st March, 1955, are published with this report, and show comparative figures for the preceding year.

Income and Expenditure Account.—Total revenue from combined sources of usual income again shows an increase. This is apart from receipts earmarked for the Building Appeal which include the first response to the President's letter circulated in mid-March.

A regular and satisfactory feature of the Accounts is the continual increase in subscriptions, due of course to the growing membership.

Compared with the preceding twelve months, there has been a slight reduction in the rate of increase in examination, entrance and transfer fees, although income from these sources is still higher than for any other previous year. Examination fees are a little lower because more candidaes are entering for only part of the examination at a time; this has been encouraged by the Education Committee, since in the past it was felt that too many candidates have attempted the entire examination without adequate preparation. The new examination regulations which come into force in 1956 will require a candidate to succeed in or obtain exemption from Section A of the examination before being permitted to enter for Section B.

Reference to the report of the Membership Committee will show that there has, in fact, been an increase in the number of members securing transfer to a higher grade but a slight decrease in the number of candidates successful in securing direct entry to the corporate grades of membership. The percentage is small, as evidenced by the increase in the total membership, but it has had a slight effect on revenue from entrance fees.

The reduction in those items has, howeer, been compensated for by the continuing demand for the Institution's *Journal* and revenue from those sales shows a further rise.

The main increase in expenditure has been in connection with publication of the *Journal*. A comparison with previous years will show that there has always been a natural increase in this item due to the larger print order and circulation. Last year additional costs had to be met because of new wage agreements in the printing industry coupled with a further rise in the cost of paper.

Publication of the *Journal* is one of the more important Institution activities but without making any changes which might limit the value of the proceedings, the Committee constantly reviews the cost. New arrangements are now being made for the printing of the *Journal,* and these, coupled with further advertising revenue, should prevent a further sharp increase in this expenditure. Indeed, if the new arrangements are successful, the Committee hopes to endorse the plans which are being made for improving the size and format of the *Journal*.

An additional item in printing costs last year was the List of Members—an essential publication, since the last issue was compiled in 1951.

Printing and publishing costs, expenditure on the 1954 Convention, and preliminary expenses for a Coat of Arms are, therefore, wholly responsible for the increase in expenditure.

The Committee wishes to comment on the co-operation afforded by the permanent staff of the Institution in effecting every reasonable economy and so keeping administrative expenses almost to the same level as the preceding year. There was, in fact, a considerable increase in the volume of work handled by the administrative staff, and taking into account also the rising

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costs, particularly in stationery, etc., the Committee feels that expenditure has been maintained at a very reasonable level.

There has been some saving during the year on the money expended on repairs to the Institution's premises.

Building Appeal.—During the year under review there was a considerable increase in donations to the Building Appeal compared with the preceding year. Members will recall that towards the end of the financial year the President asked every member to support the Institution's objective of acquiring its own freehold premises. The full result of the President's appeal is not, of course, shown in the current Accounts, but the immediate response was most encouraging: since the close of the financial year contributions have continued to be received from members and it is proposed to publish a list of subscribers during the next few months.

The Committee is also pleased to report that further donations were received from industrial organizations, and two companies have each promised to contribute £5,000.

As stated in the last Annual Report, at least £50,000 must be acquired to enable the Institution to purchase premises suitable for the provision of a lecture theatre and other facilities essential to the further development of the Institution's work. The Committee hopes, therefore, that members who have not yet subscribed to the Appeal will make every effort to do so, in the knowledge that their contribution will also help toward the encouragement of further support from industry.

Balance Sheet.—The Balance Sheet is self-explanatory in showing the financial position of the Institution at 31st March. The Committee makes a reservation on the actual valuation of the Library, which has been regularly written down every year but which, in the Committee's opinion, should now be revalued. It is hoped to carry out this work during the next twelve months.

CONCLUSION

In any report of this character it is inevitable that only the more outstanding features of the work of the Council and its Committees can be covered. It is hoped, however, that this report will indicate some measure of the services given to the Institution and members by the officers and those who are elected to Council and its Committees. Without such human endeavour the work revealed in this report could not have been attempted, nor a start made on the various new phases of the Institution's development.

Not the least of these was the considerable time given to launching the appeal for a building befitting the future work and responsibilities of the Institution. The Accounts show that there has been further progress toward achieving the first target of £50,000 and it is hoped that all members will support this appeal and thus justify the continuing help being given by the British radio industry.

In turn, the success of the work of Council and its Committees depends on the loyalty and enthusiasm of the staff of the Institution. The Council therefore records with pleasure its appreciation of the work accomplished by the staff, often in difficult circumstances.

1954 £		£ s. d.	£ s. d.
	Administration Expenses:		
7,737	*Salaries and State Insurance* ..	8,557 4 4	
378	*Pension Scheme*	378 2 0	
803	*Postage and Telephone*	985 3 1	
962	*Printing and Stationery*	965 7 4	
476	*Travelling and Entertaining Expenses*	430 8 0	
218	*Delegates' Expenses*	310 15 7	
540	*Council and Committee Expenses* ..	287 6 6	
84	*Audit Fees*	115 10 0	
452	*Bank Charges and Cheque Books*	451 6 4	
230	*Sundry Expenses*	227 12 2	
95	*Legal Expenses*	— —	
			12,708 15 4
	Institution Premises:		
1,519	*Rent, Rates and Insurance (Net)* ..	1,517 13 0	
325	*Lighting and Heating*	290 15 5	
398	*Office Expenses and Cleaning* ..	428 7 9	
901	*Repairs*	190 14 6	
			2,427 10 8
	Institution's Journal, List of Members and Reports:		
	Printing and Publishing less *Adver-*		
4,329	*tising Receipts*	5,187 19 7	
545	*Postage*	709 13 2	
235	*Envelopes and Wrappers*	317 12 8	
			6,215 5 5
	Examination Expenses:		
271	*Printing of Papers and Regulations*	302 2 11	
	Examiners' and Invigilators' Fees and		
460	*Expenses*	431 10 6	
91	*Hire of Accommodation*	81 16 0	
			815 9 5
	Section Expenses:		
457	*Printing, Stationery and Postage* ..	522 6 2	
363	*Hire of Accommodation, etc.* ..	251 13 2	
529	*Travelling Expenses and Subsistence*	423 7 4	
			1,197 6 8
—	**Preliminary Expenses for Coat of Arms**		162 5 0
203	**Grants to Other Institutions** ..		219 0 0
93	**Premiums and Awards**		144 13 4
—	**Convention Expenses**		632 7 8
	Depreciation:		
251	*Office Furniture and Fittings* ..	288 3 3	
70	*Library*	27 1 7	
			315 4 10
£23,015			**£24,837 18 4**

1954 £		£ s. d.
13,061	Subscriptions, including Arrears	14,235 6 10
165	Sundry Donations	— — —
636	Building Appeal Donations	2,053 18 4
2,387	Examination and Exemption Fees	2,196 5 11
1,408	Entrance and Transfer Fees	1,220 16 6
3,594	Sale of Examination Papers and Journals ..	3,827 7 10
135	Interest on Investments (Gross)	160 14 3
717	Radio Trades Examination Board — Secretarial Charges	875 0 0
912	Excess of Expenditure over Income	268 8 8
£23,015		**£24,837 18 4**

BALANCE SHEET

1954				£	s.	d.	£	s.	d.
£	*RESERVES*								
500	Library Reserve Account			500	0	0			
	Less Transfer to Reserve Account as per Contra			500	0	0			
							—	—	—
	CURRENT LIABILITIES								
2,643	Sundry Creditors			3,682	5	10			
1,840	Subscriptions and Examination Fees in Advance			2,446	6	6			
14,429	Bank Overdraft			16,884	8	5	23,013	0	9
	1954 CONVENTION								
123	Receipts, *less* Expenditure to date						—	—	—

NOTE: (i) The Balance on Reserve Account, namely, £2,723 8s. 10d., is after credit has been taken for Building Appeal Donations and Interest on Investments.

(J. L. THOMPSON (*Chairman. Finance Committee*)

Signed · G. A. TAYLOR (*Honorary Treasurer*)

(G. D. CLIFFORD (*General Secretary*)

£19,535

£23,013 0 9

AS AT 31st MARCH, 1955

1954 £		£ s. d.	£ s. d.
	FIXED ASSETS		
	Office Furniture and Fittings at Cost	4,740 10 8	
	Less Depreciation to date	2,097 10 8	
2,264			2,643 0 0
	The Louis Sterling Library at Cost	1,127 8 1	
	Less Depreciation to date	527 8 1	
550			600 0 0
	INVESTMENTS AT COST		
	General Fund:		
	£200 3% Savings Bonds 1960/70	200 0 0	
	£800 4% Consolidated Stock	712 15 6	
	£306 4s. 4d. British Transport 4% Guaranteed Stock 1972/77 ..	300 0 0	
1,150	(*Market Value* 31st March, 1955, £1,246 4s. 4d.)		1,212 15 6
	Building Appeal:		
	£1,000 4% Consolidated Stock	877 1 6	
	£1,500 3½% War Loan	1,130 0 3	
	£1,000 British Transport 4% Guaranteed Stock 1972/77 ..	1,015 3 8	
	(*Market Value* 31st March, 1955, £3,225 10s. 0d.)		
		3,022 5 5	
	Halifax Building Society	1,200 0 0	
2,779			4,222 5 5
6,743			8,678 0 11
	CURRENT ASSETS		
	General:		
2,929	Stock of Stationery, Journals and Examination Papers at Valuation	3,703 15 10	
	Sundry Debtors and Payments in Advance, including Subscrip-		
2,161	tions in Arrear, *less* Reserve against Subscriptions in Arrear ..	2,154 5 8	
83	Sections—Balances at Banks and in Hand	448 12 4	
22	Cash in Hand	18 2 5	
	Building Appeal:		
5,142	Cash at Bank	5,286 14 9	
			11,611 11 0
	RESERVE ACCOUNT		
	Balance as at 1st April, 1954	2,455 0 2	
	Less Transferred from Library Reserve Account per Contra ..	500 0 0	
		1,955 0 2	
	Add: Reserve against Subscriptions in Arrear ..	500 0 0	
	Excess of Expenditure over Income for		
	the Year	268 8 8	
		768 8 8	
2,455			2,723 8 10
£19,535			£23,013 0 9

ment 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, 1955, and the Income and Expenditure Account gives a true and fair view of the Excess of Expenditure over Income for the year ended on that date.

Brit. I.R.E. BENEVOLENT FUND

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, OCTOBER 26th, 1955, at 6.45 p.m., at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

AGENDA

1. To receive the Income and Expenditure Account and the Balance Sheet of the Benevolent Fund of The British Institution of Radio Engineers for the year ended March 31st, 1955.

2. To receive the Annual Report of the Trustees.
   (Published on pages 447-449 of this *Journal*.)

3. To elect the Trustees for the year 1955-56.

   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 an Annual General Meeting by all members *who have subscribed to the Fund* during the preceding twelve months, ending March 31st in each year, and the Trustees shall hold office until their successors are appointed.

   The present Trustees are:—

   The President of the Institution.
   The Chairman of the General Council.
   E. J. Emery (*Member*).
   A. H. Whiteley, M.B.E. (*Companion*).
   G. A. Taylor (*Member*) (Honorary Treasurer).

4. To elect Honorary Solicitors and Honorary Accountant to the Benevolent Fund.

   The Trustees recommend the appointment of:—
   Messrs. Braund & Hill, 6 Gray's Inn Square, London, W.C.1, as Honorary Solicitors.
   Mr. R. H. Jenkins, F.C.A., 42 Bedford Avenue, London, W.C.1, as Honorary Accountant.

5. Any other business.

By order of the Trustees.
(*Signed*) G. D. CLIFFORD.
(*Honorary Secretary*).

ANNUAL REPORT OF THE TRUSTEES OF THE Brit. I. R. E. BENEVOLENT FUND

In the last Annual Report the Trustees referred to their disappointment at having to announce that for the first time since the Institution's Benevolent Fund was established donations showed a decrease. It is, therefore, with considerable pleasure that the Trustees now report that 920 members of the Institution subscribed to the Fund during the year, compared with 606 members in the year ended 31st March, 1953. Whilst the average donation is less than that for the previous year, the increase in the number of members supporting the Fund has compensated for the drop in the average contribution.

In addition, the Fund has also benefited by a most generous donation of £1,000 given by Sir Louis Sterling, a Past President of the Institution. Sir Louis Sterling was a Trustee of the Benevolent Fund for very many years and has made regular annual contributions. He has always advocated the building up of the Fund's reserves in order to meet any future contingency, and his present contribution will do much toward the object of ensuring an adequate income from investments.

The Trustees appreciate that very few members are able to make large donations, but would again emphasize that every member can increase the value of his contribution, no matter how small, by completing a deed of covenant.

Past Annual Reports have given details of the advantages to be derived from this method of remitting annual contributions; for the benefit of new members, however, the Trustees reiterate that the completion of such a deed does not involve the covenantor in any additional payment. The advantage to the Fund lies in the fact that the Trustees can recover the income tax which will have been paid by the donor, thus almost doubling the value of the contribution.

Donations to the Fund have again been received from Electric and Musical Industries Ltd., who have made generous contributions during recent years, as well as from the Radio Industries Club of Manchester, who have regularly supported the Fund during the past three years. A new subscriber, to whom the Trustees especially extend their thanks, is the Radio Industries Club of London.

Expenditure.—The Trustees continued to give the maximum help possible to Reed's School, but were distressed to learn in January that the Governors of the School were reluctantly compelled to close the Girls' School as from the end of July 1955. This decision was taken only after every effort had been made by the School Governors to secure further financial assistance to meet the continually increasing costs of maintaining each child.

The Trustees of the Benevolent Fund were responsible for three children in the Girls' School, two of whom had almost completed their training. Arrangements have been made for them to continue studies for a commercial career at local technical schools. The third child had only been at Reed's School for one year and in view of her ability she has been accepted into the Royal Wolverhampton Grammar School, together with another girl whom the Trustees had nominated for admission to Reed's School in September next.

Notwithstanding the fact that the Institution has not at present any children in the Boys School, the Trustees feel that they should not withdraw the support hitherto given to Reed's School. It is proposed, therefore, to continue the policy of contributing yearly grants towards the purchase of bursaries which can be held for the benefit of the Institution's future nominations. In this connection, the Accounts show that during the year ended 31st March 1955 a further £250 was donated for this purpose.

Royal Wolverhampton School.—This grammar school is also an independent school for fatherless or orphan children and was established in 1850. The boys' and girls' schools house 350 children and both schools are recognised by the Ministry of Education. A grammar school course is provided leading to the General Certificate examinations both at ordinary and advanced levels.

THE BRITISH INSTITUTION OF RADIO ENGINEERS

BENEVOLENT FUND

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1955

1954 £		£ s. d.	1954 £		£ s. d.
190	Grants	253 6 0	614	Subscriptions and Donations	1,753 3 11
200	Purchase of Bursaries at Reed's School	250 0 0	206	Interest Received (Gross)	214 2 0
10	Postage and Stationery	5 3 0			
5	Sundry Expenses	6 2 8			
	Balance, being Surplus for the year carried to Reserve				
415	Account	1,452 14 3			
£820		£1,967 5 11	£820		£1,967 5 11

BALANCE SHEET AS AT 31st MARCH, 1955

£		£ s. d.	£ s. d.	£		£ s. d.	£ s. d.
	RESERVE ACCOUNT				**FIXED ASSETS**		
	Balance as at 1st April, 1954	4,757 6 7			*Investments at Cost:—*		
4,757	*Add* Surplus for Year	1,452 14 3			£200 3% Savings Bonds 1960/70 ..	191 3 6	
			6,210 0 10		£200 3% Savings Bonds 1965/75 ..	182 15 9	
					£400 3½% War Loan	356 13 0	
	CURRENT LIABILITIES				£1,000 British Transport 4% Guaranteed		
					Stock 1972/77	1,002 13 10	
27	Due to General Fund	— — —			£4,000 4% Consolidated Stock	3,526 16 0	
1	Sundry Creditor	— — —			Jays and Campbells (Holdings) Limited—		
					500 5½% Cumulative Preference Shares		
					of £1 each	354 2 0	
					Associated Newspapers Limited—200		
					Deferred Shares of 5/- each	166 4 6	
				4,613			5,780 8 7
	C. P. CLARKE ⎫				(*Market Value as at 31st March*, 1955,		
	A. H. WHITELEY ⎬ *Trustees*				£6,089 15s. 8d.)		
Signed	G. A. TAYLOR (*Honorary Treasurer*)						
	G. D. CLIFFORD (*Honorary Secretary*)				**CURRENT ASSETS**		
				—	Sundry Debtor	63 13 6	
				158	Income Tax Repayment Claims	256 18 4	
				14	Cash at Bank	109 0 5	
							429 12 3
£4,785			£6,210 0 10	£4,785			£6,210 0 10

I have audited the above written Balance Sheet dated 31st March, 1955, 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.

22nd *July*, 1955.
42, Bedford Avenue, London, W.C.1.

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

In view of the closure of Reed's Girls' school, the Trustees are especially grateful for the ready co-operation extended by the Governors of the Royal Wolverhampton School in immediately arranging to accept the girls for whom the Institution had undertaken responsibility. The school will in future accept the Institution's nominations of girls who would have been eligible for admission to Reed's School, and the Trustees feel that subscribers will give their approval to annual grants being made to the Royal Wolverhampton School.

The Trustees believe that by placing suitably qualified children of deceased members in this type of boarding school, the maximum support is given to the widow. In most cases it is found that if the mother is relieved of the main problem of the continued education of the children, she is able to undertake employment and thus have the satisfaction of contributing towards the support of her family.

Royal Wanstead School.—The last Annual Report referred in detail to the work of the Royal Wanstead School, which exists for children requiring primary and secondary education. A small yearly contribution has been given to this school and it is hoped that subscribers will support the Trustees' intention to retain the school on their lists for annual grants.

Other grants.—Four cases referred to in the last Annual Report were constantly before the Trustees during the year and all necessitated continued help.

The Trustees are happy to report that one of these members, after many severe operations and subsequent recuperative treatment, has now recovered sufficiently to undertake light employment. The Trustees were aware that this case would need help for a long period and express grateful thanks to the Electrical Industries Benevolent Association who have continued to share equally the grants which have been made.

A further case, also involving serious illness, was brought to the attention of the Trustees during the year. Here again the Trustees found that by providing relief from financial worry the applicant was helped back to normal health. This member, an Associate, has since been able to commence light duties.

An Associate Member was given financial aid when a business venture failed through his own ill health. Further help was also given by the Institution's Appointments Register finding him immediate employment and the Fund's honorary solicitor co-operated by giving the member legal advice.

Continued assistance is also being given to the mothers of the two children who have now left Reed's School until such time as the children are able to establish themselves in employment.

General.—The Trustees continue to find that the most genuine cases in need of assistance are very often the most diffident applicants. Apart from financial or similar assistance, the Trustees are often able to be of other help to members and their dependants who are in difficulty because of straitened circumstance caused by ill health. If any member knows of a colleague in distress because of such circumstances, it is hoped that advice will be sent to the Trustees as soon as possible so that, if justified, help can be given without the delay which can so often worsen the circumstances.

Finally, the Trustees wish to record their appreciation for the services given by Mr. Charles Hill and Mr. R. H. Jenkins in their capacities as Honorary Solicitor and Honorary Accountant respectively. In particular, Mr. Charles Hill has submitted to the Trustees a draft of revised conditions under which the Benevolent Fund might operate and during the next 12 months subscribers to the Fund will be invited to approve some alterations in the present rules under which the Fund is operated.

E

NOTICES

The Institution in India

With the development of the Institution's membership in India, it has been found desirable to set up a central office to deal with Institution matters under the aegis of the Indian Advisory Committee. The office will operate in Bangalore and will deal with all enquiries arising from India, and the distribution of Regulations, forms, and other literature. Correspondence should be addressed to The Honorary Secretary, Brit.I.R.E., P.O. Box 1505, Hebbal, Bangalore 6, India.

Brigadier B. D. Kapur, B.Sc. (Member), remains Chairman of the Indian Advisory Committee of the Institution, and Lt.-Col. B. M. Chakravarti (Associate Member) is the Honorary Secretary to the Committee.

These arrangements will relieve the five Section secretaries of a considerable amount of their work and leave them free in the arrangement of Local Section meetings.

Dr. D. G. Tucker

The announcement has recently been made that David G. Tucker, D.Sc. (Member), has been appointed to the Chair of Electrical Engineering at the University of Birmingham. He will take up his duties at the beginning of the 1955-56 academic year.

Dr. Tucker was for some years with the Post Office Research Station and since 1950 he has been in charge of a Division of H.M. Underwater Detection Establishment. He is the author of various books and a considerable number of papers in both professional and technical periodicals, including two in the *Brit.I.R.E. Journal*.

Television Advisory Committee

The membership of the technical sub-committee of the Television Advisory Committee has recently been broadened and one of the additional industrial representatives is Mr. L. H. Bedford, O.B.E., B.Sc. (Member), a Past President of the Institution.

Mr. Bedford was Chairman of the Institution's Technical Committee which drafted the Post-war Development Report, Part 2, which referred among other things to the future of television broadcasting in Great Britain.

Graduateship Examination, November 1955

The next examination will be held on **Wednesday, Thursday and Friday, November 16th, 17th and 18th, 1955.** Entries for this examination from home candidates must be lodged with the Institution not later than **October 1st.**

The closing date for oversea candidates for the May, 1956 Graduateship Examination is **November 1st, 1955.**

Medical Applications of an Electronic Computer

A new electronic computer—an analogue correlator—for analysing the rapid and complex electrical activity of the brain is now undergoing preliminary tests at the Massachusetts Institute of Technology and the Massachusetts General Hospital, in the United States.

It displays in a new and rather different form the information in the electrical impulses related to the nervous system's operating and controlling mechanism. By automatically comparing the impulses in one short time period with those which preceded them, the computer shows a time sequence of the electrical activity of the brain.

In an invited lecture at the University of Southampton, Dr. Norbert Wiener, Professor of Mathematics at M.I.T., recently described the use of this new equipment to show the rhythms of the well-known brain waves which have long been familiar to medical research.* The new form of presentation, Dr. Wiener said, now permits us to describe these as "an accurate clock in the brain of man—a clock of good consistency, beating about 10 times per second, and keeping phase with itself for perhaps hundreds of seconds."

The clock-like signals are found combined with a great number of tiny random pulses. The contribution of the new machine is to sort automatically this random activity in order to evaluate the consistent signals. In some individuals, Dr. Wiener said, these minute but precise electrical signals following one after another "stand out with the utmost clarity and persistence, continuing at about a constant level for what we know to be as much as fifteen seconds." In other cases, this signal is not so clear or persistent; for the present there seems no way of explaining these differences.

* See, for instance, H. W. Shipton, "An electronic trigger circuit as an aid to neurophysiological research," *J.Brit.I.R.E.* 9, p. 374, October 1949; W. G. Walter and H. W. Shipton, "A toposcopic display system applied to neurophysiology," *J.Brit.I.R.E.*, 11, p. 260, July 1951.

ELECTRICAL PULSE COMMUNICATION SYSTEMS

1—Information Theory and Pulse Systems*

by

Professor R. Filipowsky, Dr.Ing. (Member)†

SUMMARY

Information theory and its more specialized branch, communication theory, are based on the statistical definition for the information content of messages. Statistics deals with discrete elements and is therefore directly applicable to pulse systems. The "system engineer" has to use results of this theory for designing optimum communication systems.

Four classes of systems are distinguished: communication—data transmission—location—computers. The main sections in each system are: source—message encoding—signal formation—multiplexing (train formation)—wave formation (carrier modulation)—transmission over the medium—reception—decoding—destination. Some sections may be omitted in particular systems.

Information is defined and its transmission over all the sections of a system is discussed in the light of modern theory. Message encoding has to transform the multi-dimensional message space into the three-dimensional signal space at the same time allowing for sufficient reduction of redundancy. Signal encoding will reshape the signal space for matching a given channel. Authenticity examination at the receiving end will assure reliable service by error detection. Error correction methods may be employed to reduce equivocation (error expectancy).

1. Introduction

Electrical pulse communication systems may be broadly classified as: (1) Observation and Control Systems; (2) Conventional Communication Systems; (3) Location Systems; (4) Calculation Systems. The fields of application range from biology through geophysics, line and radio-communications, broadcasting, television, radar to atomic physics and mathematics. The present paper is restricted to the system aspect, i.e. it deals primarily with the organization of the electrical signals and waves carrying the information, but it excludes the circuit technique of producing and handling these signals.

All the systems have the purpose of transmitting information. This common aspect led to the development of a general theory of information with the broad aim of defining information, deriving expressions for the maximum theoretical information-handling capacity of transmission channels and converters, guiding system engineers in planning highly efficient systems and permitting the quantitative comparison of established systems.

2. History

Tables 1 and 2 demonstrate how the evolution of information theory followed closely the path of the pulse communication system development. The conventional broad definition of a "pulse" declares it as a time function (waveform) with sudden transitions (discontinuities) between periods of more or less smooth course. Telegraphy, telephony, facsimile, television, electro-physiology, radio-location and many more branches of electrical information transmission technique produce or convey information in pulse-like form. Some of them belong to the oldest members of the electrical communication family and we need not wonder that the tables range back in history over several centuries.

It is amazing and instructive to learn how the principal ideas of our most recent achievements were well formulated at times when their embodiment seemed quite impossible: the sampling theorem dates back to 1920, when no pulse communication system was known to make use of its statement. Pulse width modulation (PWM) was invented in 1924 and experimentally tested in the late thirties for the first time. Radio location by reflection (radar, according to Sir Edward Appleton's definition) is due to a patent of the year 1904, but only

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Table 1:

PRECURSORS AND PIONEERS OF PULSE COMMUNICATION SYSTEMS

Ancient times:	Smoke and drum signals in pulsive form for primitive communication (still in use with many African and Asian tribes).
1267:	**Roger Bacon** suggested the use of the "sympathetic needle" (lodestone) for communication to distant places.
1746:	**Watson** in England sent electric signals over nearly two miles of wire.
1753:	An anonymous worker[1]* and
1758:	a Scot named **Marshal** considered the first practical telegraph systems by using a separate wire for each letter of the alphabet.
1787:	**Lomond** used a pair of wires and some unknown code.
1823:	**Ronalds** converted these ideas to a single channel system, using a quantized p.p.m. system in most primitive form.
1829 and later:	**Charles Babbage,** Professor of Mathematics at Cambridge, commenced construction of two different kinds of mechanical automatic digital computing machines, resembling in principle their modern electronic counterparts.
1830 and later:	**Shilling, Gauss and Weber, Steinheil** suggested independently the use of multi-unit codes (on-off pulses) for telegraphy over a single wire.
1832:	**J. Henry** demonstrated the first electric telegraph using an electromagnet at the receiving end. He achieved audible reception (ringing a bell) over one mile.
1832:	**S. F. B. Morse** introduced his famous dot-dash code, taking advantage of the statistical aspect of English letter probability ("e" shortest symbol, "ch" or "j" longest symbols).
1838:	**Morse** demonstrated his telegraphic system over a distance of ten miles using a graphical recorder (tele-"graph") at the receiving end.
1843:	**A. Bain** invented the line scanning system for dead picture transmission (facsimile), which constitutes probably the first attempt of picture encoding.
1847:	**Morse** completed the first long distance telegraph channel (New York—Baltimore) over 200 miles.
1852:	**M. B. Farmer** invented the time-division multiplex system for telegraphy (U.S. Patent).
1853:	**Whitehouse** used for the first time the highly efficient 5 unit code commercially (first appearance of binary digital coding in telegraphy).

Table 2:

PRECURSORS AND PIONEERS OF MODERN INFORMATION THEORY

1380:	**Simonetta of Milan** published most probably for the first time in history a full statistics of letters in a modern language.
1629:	**Descartes** created the idea of an artificial universal language with small redundancy.
1658:	**Porta** used a table of letter statistics including digrams.
1661:	**G. Dalgarno,** a Scotsman, published "Ars Signorum", suggesting artificial words with consonants and vowels alternating, characterizing all objects, ideas, events, etc., in a well-classified manner. He proceeded from the general to the detailed adding more and more letters to a word in the prescribed manner. All these words would be easily pronounceable as consonants and vowels alternated.[7]*
1763:	Rev. **Thomas Bayes** formulated the famous "Bayes's theorem", relating to the relative probabilities of several competing hypotheses and their alterations by new observational facts. Applied to modern communication theory, this theorem leads directly to Shannon's theorem No. 10 and forms the basis for many other conclusions.[8]
1885:	**A. E. v. Granfeld** published the first comparative analysis of time division vs. frequency division, creating these two important definitions (see his book: "Die Mehrfach Telegraphie auf einem Drahte").

* The indices shown in these Tables refer to the special list of references given on page 454, not to the general references which will be found on page 467.

Table 1 (*contd.*)

1872:   **Bowditch** discovered the "on-off" action of nerve-cells, thus bringing biological events in connection with the wide field of pulse information systems.

1873:   **Heaviside** suggested useful methods for duplex telegraphy.

1874:   **Baudot** introduced his famous system of multiplex telegraphy.

1876:   **A. G. Bell** established the first telephone communication (U.S. Patent 174,465).[2]

1878:   **Stein** used an ordinary telephone to register heart pulses: (*Berliner Klin. Wochenschr.*, No. 49, 1878).

1884:   **P. Nipkow** (German patent 30,105 of 6th Jan) introduced and embodied by his famous disk the idea of time division and line scanning, applied to live picture transmission. Speaking in modern terms, he encoded television messages by translating the continuous brightness function of three variables $B = f(t, x, y)$ into a discontinuous signal function $V = V(t)$ of one variable.

1903:   **Miner and Patten** suggested the first time-division telephony multiplex system with mechanical rotating switches (U.S. Patent 745,734).

1904:   **C. Hülsmeyer** in Germany invented the "Telemobiloscope", the first radio location system.[3]

1907:   **O. Scheller** in Germany suggested the first beam direction-giving system on A—N pulse basis. (German Patent 201,496, C. Lorenz A.G.).[4]

1909:   **K. Lucas** observed the p.f.m. character of biological information transmission in nerves.

1914:   **Fournier d'Albe** invented the first machine to convert print directly into sound ("Optophone"), thus initiating the development of modern "sensory prosthesis".

1915:   **J. Carson** patented single side-band transmission and

1922:   **Espenscheid** demonstrated its practical feasibility, clarifying many doubts about the existence of side-bands.

1924:   (18th April) **R. A. Heising** filed his patent on pulse duration modulation (p.w.m.).

1925:   **G. Breit and M. A. Tuve** used electromagnetic pulses to prove the existence of ionospheric layers and to measure their height. This is probably the first demonstration of radio location by pulsive methods.[5]

Table 2 (*contd.*)

1905:   **A. Einstein** analysed the statistical movement in gases due to temperature.[9] His investigations and their further evolution by other scientists form the basis of substantial theorems of modern information and communication theory.

1918:   **W. Schottky** presented the first theory of thermal agitation noise, based on Einstein's work.[10]

1920:   **J. R. Carson** stated the fundamental sampling theorem, that $2ft$ samples will represent completely any signal with the highest frequency component f and the duration t.

1924:   **H. Nyquist** and independently **K. Küpfmüller** stated that $2Bt$ samples can be transmitted in t seconds over an ideal channel of bandwidth B without mutual interference. (Nyquist rate of transmitting telegraph signal.)[11]

1927:   **Gray, Horton and Mathes** proved that high definition television requires wide-band channels, thus destroying the hope of many "non-theoretical" inventors.

1927:   **R. V. L. Hartley** delivered at the International Congress of Telegraphy and Telephony his famous paper on "Transmission of Information", published in 1928.[12]
The main results of his theory are:

   (1) *Information* may be defined as: $H = n \log s$. ($n =$ number of code elements of a message, $s =$ number of possible states for each code element).

   (2) His *fundamental law* that the *capacity of a channel* to transmit information is proportional to the bandwidth of the channel and the transmission time.

   (3) If a telephone message is quantized, channel noise can be removed at the receiver.

   (4) *Maximum information* can be *transmitted* with uniformly spaced samples.

1928:   **H. Nyquist** considered the influence of noise on the quality of a transmission and concluded that there is no object in reducing the interference beyond the point where the signal can be deciphered with certainty and ease. He suggested an optimum code for maximum information transmission.[13]

1929:   **Scillard** made probably the first statement of the identity of entropy and information.[14]

1942:   **N. Wiener** submitted the N.D.R.C. report on the results of his theoretical investigation into the problem of filtering signals from noise and predicting future data. He gave a definition of the amount of information associated with a given probability function.[15, 16]

Table 1 (contd.)

1930: **F. Schröter,** Germany, invented the interlaced scanning system, using an odd number of lines and two frames per picture. His system is still incorporated in all television broadcasting standards all over the world. (German Patent 574,085). This invention constitutes an excellent example of how to match the encoding system to the minimum requirements of the destination (eye).

1934: (29th Sept.) **R. D. Kell** filed his patent on Pulse Position Modulation (p.p.m.).

1935: (27th Feb.) **Sir R. Watson-Watt** submitted his memorandum on "Detection and Location of Aircraft by Radio Methods" to the British Defence Committee. Full details are specified for pulse-location systems (Radar) including i.f.f. and many other features.[6]

1936: **E. H. Armstrong** gives the first published account of a successful demonstration of frequency modulation.

1936: **H. Dudley** demonstrated the first system of voice encoding, the VOCODER (followed 1939 by his VODER).

1939: (23rd Oct.) **A. H. Reeves** filed in France his Patent (No. 852,185) on Pulse Code Modulation (p.c.m.) (U.S. Patent 2,272,070).

During and after the last War thousands of scientists and engineers contributed to the tremendous progress of pulse information systems. The pioneers have been succeeded by the anonymous though not less enthusiastic professionals in the art.

This table contains only references to historical events of fundamental importance with direct relation to pulse information transmission methods. No claim of completeness is made and a plurality of equally important discoveries in related arts, for example the invention of the electron tube, have their indirect bearing on the progress of pulsive systems.

Table 2 (contd.)

1946: **D. Gabor** introduced the uncertainty principle $\Delta f.\Delta t \geq 1$ and proved that "Gaussian Signals" have the smallest possible time-frequency product of 1. This unit is named "logon", now considered as the unit of "structural information". He demonstrated that "complex signals" have no negative frequencies in the spectral function.[17]

1947: **W. G. Tuller** submitted his Dr. Thesis containing the improved Hartley law, which gives the transmission capacity for quantized signals in the presence of noise. He developed the concept of "coded transmission" and of "maximized information function".[18]

1947: **N. Wiener** and **H. Sullivan** came independently and by different approach to the same extension of Hartley's law.

1948: **S. Goldman** proved the existence of a threshold effect in all wide-band communication systems. (Trading band-width against signal-to-noise ratio.)

1948: **C. E. Shannon** recognized communication theory as a branch of statistical mechanics and put all the previous work together with many of his own contributions on a sound mathematical basis by establishing a homogeneous theory expressed in 23 theorems. He gave an exact proof for Tuller's version of Hartley's law in the presence of white noise, extending its application to all forms of electrical communication. He confirmed that the channel capacity thus calculated is a true maximum for the most ideal equipment and coding process.

1950: **D. Gabor** established a still more fundamental basis for modern information theory by directly deriving its principal statements from quantum analysis. At the same time he extended its applicability to all branches of modern physics, stressing that conducting an experiment and making observations means collecting more information.[19]

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17 *J. Instn Elect. Engrs*, 93, Part III, p. 429, 1946.
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came to full use 35 years later with pulse signals as the decisive means of yielding practical results. Many other similar events can be correlated from the tables.

Both tables illustrate excellently the trend towards higher transmission efficiency at the cost of simplicity in equipment. Marshal used in 1758 a separate wire for each letter of the alphabet, i.e. 26 channels for one simple message: in 1950 we find it natural to send hundreds of telegraphic messages together with tens of telephone conversations and several television performances over a single "wireless" channel. We are still, however, aware that we are wasting 90 per cent. or more of our most valuable asset in communications, channel capacity. In Table 1 we find the more ingenious systems advancing from decade to decade as the more accurate theoretical tools are presented simultaneously by famous scientists as shown in Table 2. The latter have helped concurrently in recognizing the deficiencies of new systems. At the beginning of the second half of this century we have been presented with theoretical instruments of tremendous power. The following paragraphs should serve to familiarize us with these theoretical aids and should give an abridged account of the vast possibilities which are now open to creative minds coming forward with new suggestions. Some systematization is required at this stage of development to discriminate between true progress and mere duplication or combination of well known facts.

3. Classification of Systems

There are four groups of pulse information transmission systems with distinct functional characteristics:

3.1. *Communication Systems*

Used in the restricted sense here, their main purpose is to establish communication between human beings, either over large distances, where the normal human senses fail to provide sufficient sensitivity or as an aid, whenever human sense is inadequate. This may be due to individual sensory deficiencies or due to excessive requirements. Hearing aids, reading devices for the blind and similar "sensory prosthesis" are familiar applications.

The common feature of all communication systems is the need to convey information, which normally will be handled by the human senses. Such information will be produced by human beings (voice, letters, pictures, living scenes, etc.) and/or will be intended for human beings and their senses (mainly ear and eye). The overall scheme of such "man-communication systems" is thus quite simple (Fig. 1a).

3.2. *Location Systems (Fig. 1b)*

These serve to determine the position of an object in space, on a plane or on a line. We saw that servo systems are still closely related to conventional communication systems by the fact that information is transferred from a source to a destination. Location systems however do not use a specific source of information, but information is created in the channel itself. The transmitter (sender) merely acts as the producer of signals, which may or may not carry additional information.

One very profitable classification of location systems divides them first into *range measuring* and *direction measuring* systems. The problem is now one-dimensional for each group of systems. Direction determining systems may be further subdivided into *direction finding* and *direction giving* systems.[1] All groups may operate either with continuous waves or with pulsive signals and all groups achieve distance measurement by time measurement, assuming constant and accurately known velocity of propagation.

3.3. *Observation and Control Systems (Servo Systems)*

If a physical magnitude (pressure, temperature, velocity, acceleration, etc.) or its variations act at the input and if the destination is an indicating or recording device, we speak of *"observation systems"* or, for higher accuracy, of *"telemetering systems."* Observation is frequently only the first object of the system. The second is *"action"* according to the observation. All systems combining observation with action are called servo systems.

The principal scheme of *observation and metering systems* is the same as for communication systems. *Servo systems* require a feedback channel over which a counter acting force (negative feedback) is brought back to the input to remove or compensate the cause of deviation from the standard (Fig. 1c).

The operation of servo systems may be a *continuous* and instantaneous one, requiring

the permanent connection between source and destination in one or both directions (a.v.c. in radio receivers, stabilization of power supplies are examples). The other alternative is a *discontinuous* (pulsive) operation. The error signal or the action device has in this case a threshold below which this system will not operate. Once the threshold level is reached action takes place and lasts for a fixed time or, more generally, until the error signal is small enough or of opposite polarity (the thermostat is a well known example).

The latter type is clearly of pulsive nature and will concern us here directly. But also the former type may use pulse communication to convey error signals or correction signals. Still more pulsive character may be seen in observation systems, which involve most of the biological (electro-medical) instruments like electrocardiograph or encephalograph. Telemetering systems require a large number of identical channels and pulse modulation multiplex systems offer particular advantages.

3.4. *Computers*

Some essential differences of these systems against conventional communication systems

justify their classification as an independent group:[2]

Firstly, a computing device cannot be allowed to make a single mistake. Secondly, a much larger amount of *a-priori* information has to be known to the machine in the form of tables, curves, etc., as is the case even in the most complicated secret communication systems. Thirdly, encoding, code-translation and decoding are essential features, for example to translate decade figures into binary digits. Codes may frequently change throughout the operation and many intermediate results will have to be stored temporarily. Fourthly, it may be left to the machine to change the instructions initially imposed on it, whenever partial results of the calculation process require so.

Whatever their position in modern communication theory might finally be, it is sure, that in their technique computers have much in common with pulse communication systems at least as far as the digital type of calculators are concerned. Fig. 1d is added to give some idea of the principal scheme of a digital computer.[3] Many other similar representations are conceivable. The source has to furnish information in a threefold manner: as *a-priori* information, as operating instructions, leaving alternatives to
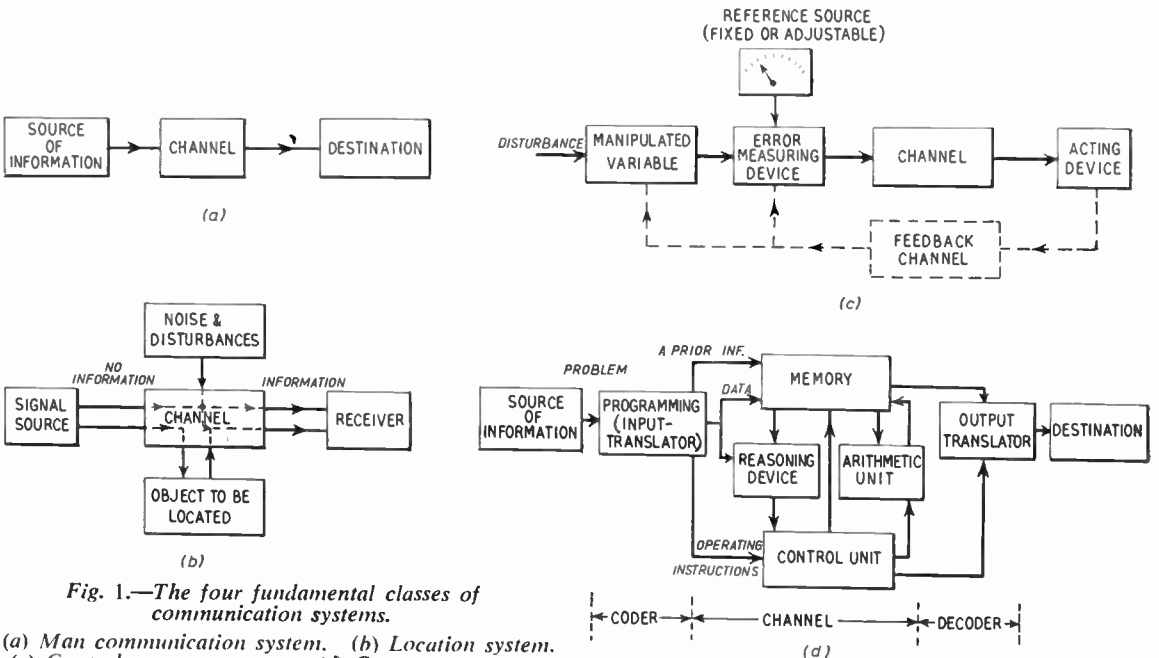

Fig. 1.—*The four fundamental classes of communication systems.*

(a) *Man communication system.* (b) *Location system.*
(c) *Control or servo system.* (d) *Computer system.*
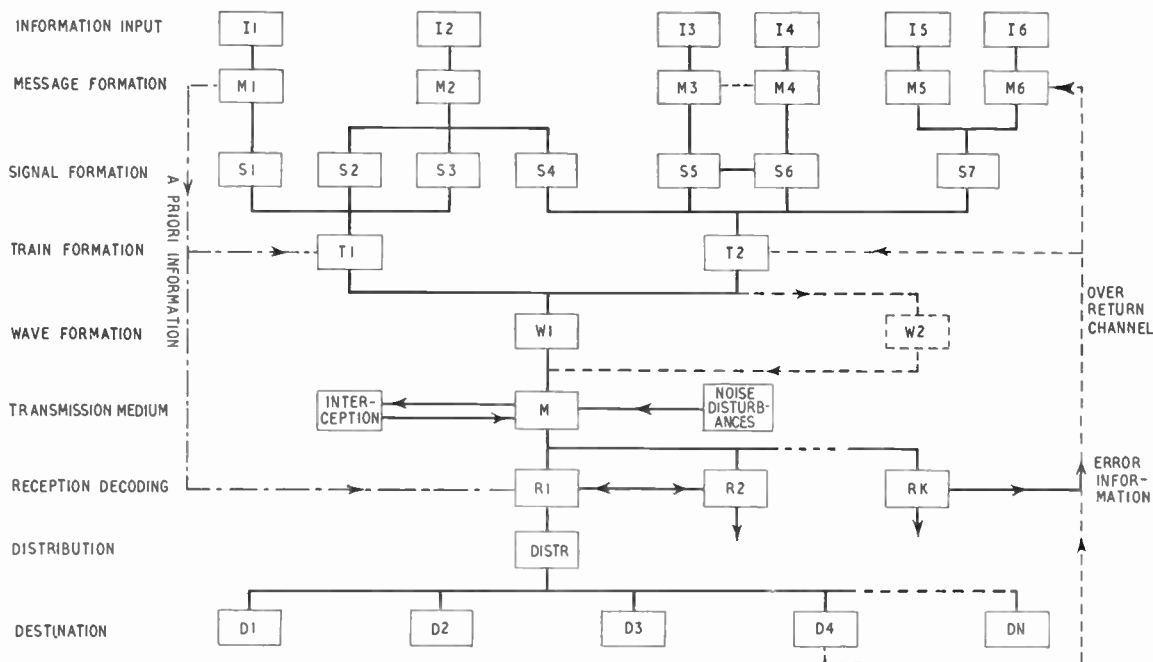
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Fig. 2.—Scheme of multichannel communication system.

the machine, and as specific numerical data. The destination will receive the result of the calculation as information output.

4. Main Sections of an Electrical Pulse Communication System

4.1. General Lay-out

A system may contain any number out of nine main divisions (Fig. 2, left margin). The most primitive system requires at least four (I1, M1, S1, D1).

4.2. Information Input

A complicated system may have several provisions for simultaneous information input and not all sources need be of the same type. (In television: audio and video information. In multiplex telephony: several independent speech conversations.)

4.3. Message Formation

A *transducer* will generally "pick-up" the information input from a non-electrical medium and deliver it in electrical form to the equipment. It may still not be useful in this form and a conversion process will be required

to "match" the "message" (a given amount of information) to one or more individual channels. The total process may be called message encoding. The receiver may get a good deal of information in advance, we call it "a-priori" information, including indications of the sources, codes, signals and waves in use. Some of these specifications may be changed instantaneously, in which case a special signal inserted into the common train has to inform the receiver at the correct instant. The dot-dash line at the left of Fig. 2 indicates this possibility. The dashed connection between M3 and M4 should point out that it is possible to control the encoding process in one channel in dependence on one or more other channels (television sound in other synchronization gaps).

4.4. Signal Formation (pulse modulation)

Once the message is available in electrical form as a single-valued time function (for continuous messages) or time series (for discrete messages) we have to form signals to carry the message. This is done in the sections marked S. Cross connections, such as between S5 and S6, are required whenever two or more channels

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co-operate in a system with improved overall transmission efficiency. Such systems distribute the available transmission capacity of the medium instantaneously to the co-operating channels in a form which offers largest capacity to the channel requiring it most at a given instant. At the same time an idle channel may be cut-off completely. The connection of M5 and M6 to one and the same signal source indicates the possibility of multiple modulation.

4.5. Train Formation

It is convenient to combine signals from many channels in a "multi-channel" system. Pulse signals can easily be arranged in a "train," reserving for each signal a well defined short time interval of the total transmission time, i.e. arranging them in time-division (TD). The "T" divisions can be by-passed in single channel systems.

4.6. Wave Formation and Transmission Medium

In many cases we cannot transmit the signals directly over the transmission medium. In radio, wave-guide, ultrasonic and other transmission facilities, a carrier wave is required which has to be modulated, either with the signal directly (in single channel systems) or with one or more channel trains (or channel groups in frequency division) containing multiplexed channels. This process is called wave formation.

4.7. Reception, Decoding, Distribution

The waves carrying the signals will arrive along with noise and disturbances at the receiving terminal. Two problems arise: Filtering and Error Detection. The different structure of useful signals and disturbances may be helpful to separate them. Special codes or signal characteristics may let us identify erroneous signals and correct them automatically in some cases. In other methods erroneous signals may be suppressed and returning an error signal to the sender may initiate their repetition. The delay involved at both ends by following this procedure can be kept small enough to avoid annoyance. The error signal may go to the train formation device or directly to the message encoder. The latter case may be taken as typical for servo systems.

Apart from these two problems, the receiver has to perform the reversed functions of the sender until the message can be delivered to the destination.

Several receivers may co-operate in the reception of a single wave to improve their detection abilities under severe disturbances in the medium (e.g. space diversity reception).

4.8. Destination

A good knowledge of the information characteristics of the destination is essential for the system engineer, as there is no point in transmitting a larger amount of information than the destination can absorb.

Error detecting can finally be left to the destination and error signals can well originate from this last section. The process will then be less automatic, but more subjective as far as human communications are concerned. In telephonic, telegraphic or teletype communications it is the normal practice to "break in" at a convenient instant and to ask for corrections. A return channel has to be permanently available for this purpose, unless some automatic channel switching mechanism is in operation.

5. Information Theory

5.1. Definition of Information

Having followed a message from information source to destination we find in all sections of a system the need for optimum matching. The equipment engineer has to match loads to networks and networks to sources to avoid losses and distortions. His commodity is energy or the rate of energy transmission: power. He may have a large voltage and a small current or vice-versa, the product alone is what matters.

The system engineer has likewise to match the destination to the channel and the channel to the source, or the contrary. His commodity has been called information, but we still have to define it. In the popular sense we understand by information any addition to our knowledge and this is exactly what it means also in the scientific sense. This would by itself already form an acceptable definition, if we only could define knowledge and even measure it. Generations of schoolmasters have been engaged in this problem but no satisfactory solution has emerged. So we have to define information directly and we can do best by splitting the problem and eliminating:

(a) the "semantic" or "metrical" information content,

(b) the "pragmatic" or "structural" information content,

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(c) the "mental" or "ideational" information content.

What remains is called the "selective" or "engineering" information content.

The "semantic" aspect refers to the absolute or ideal gain of knowledge as it might be experienced by a "superman" with a perfect memory and a complete stock of all human wisdom.

The "pragmatic" aspect refers to the individual gain of knowledge considering the limited capabilities of one particular "receiver." The amount of information in this category will depend on the structure in which the previously accumulated knowledge has been built up (Learning by a child).

The "ideational" aspect refers to the gain of knowledge under a particular selection rule established by an individual receiver. The artist's point of view for example falls under this category.

The "selective" aspect is the only one concerning us in the present investigation. The engineer cannot deal with the truth of a message, nor with its importance for one particular individual, nor with its aesthetic value. He is merely concerned with a pattern of characters (symbols) presented to him for transmission. If the pattern is limited in time or space or both, we call it a "message."

The more *"characters"* he has to handle in a message and the larger the number of *"symbols"* out of which a sender may select the characters, the more difficult will be his task. Naturally he will attribute a higher information content to the longer message using a highly flexible *"alphabet."* The number of message characters and the amount of choice left to the sender when selecting them will determine the *"amount of information"* from the communication point of view. This is directly applicable to *"discrete"* messages (consisting of clearly distinct symbols, like letter telegrams). In Section 5.4 it will be demonstrated that it is possible, although not easy, to dissect also all other *"continuous messages"* (voice, pictures, etc.) in a finite set of discrete symbols or whole messages.

We then may define *"selective information"* of a message as the quantity indicating the degree of choice left to the sender when selecting the message out of a complete set of possible messages.

5.2. *A Measure and Unit of Selective Information Content*

We defined a *"message"* as a limited *pattern of "characters"* each of them being selected from a finite number of possible *"symbols."* The message pattern may be maximally four dimensional (three space coordinates and time, as in stereoscopic television) and determines the *"character space"* in which each character of a message has its well defined place. Also the symbols may be arranged in a multidimensional *"symbol space"* (maximally three-dimensional for present day communication systems, for example, colour television—brightness, hue and saturation). For each character one and only one symbol can be selected and it may be specified by its coordinates in the symbol space. Character space and symbol space may be interleaved to form the "message space."

Knowing the number of characters in a message (n) and the number of symbols available for selection (s), it is easy to calculate the total number (M) of different messages of equal length which can be formed from the given character and symbol spaces:

$$M = s^n \quad \text{......................(1)}$$

The full set of possible messages is called the *"message ensemble."* Assuming that all messages of an ensemble have equal probability, we may define the *"information content"* of any message taken from the ensemble:

$$H = \log M = n \log s \quad \text{...............(2)}$$

The logarithmic measure is required to make H proportional to n (i.e. to the length of a message for one-dimensional character space). The base of the logarithm constitutes the unit of information. As the minimum number of s is two, we use this as the unit and call it one *Binary Digit* or one *Bit*. The unit of information is therefore contained in a message of a single character selected from two possible symbols, giving both symbols equal chances of being selected. This is a simple yes/no decision, very familiar to us from the radio "quiz" programme with 20 such elementary decisions.

5.3. *Statistical Structure of Message Ensembles*

In practical communication systems we rarely will meet an information source which produces a series of messages with absolutely random selection from the ensemble. Only in the case

of "white noise" may we experience this maximum uncertainty. Any other source will follow a particular selection scheme favouring some messages and neglecting others.

Statistical communication theory [4, 5, 6, 7] has extended the definition of information to cover all possible restrictions in the free selection of messages by postulating that the *average information content* of a message taken from an ensemble of messages "with restraint" is given by:

$$H = - \sum_{i=1}^{M} p_i \log p_i \text{ in bits per message } \ldots \ldots (3)$$

p_i is the probability of the i-th message being selected. The equi-probable case reduces eqn. (3) to eqn. (2) and at the same time maximizes H:

$$p_i = \frac{1}{M}; \quad H_{max} = -M\left(\frac{1}{M} \cdot \log\frac{1}{M}\right) = \log M$$

H may be called the *"entropy"* of the ensemble in analogy to the similar magnitude in quantum theory. For its determination we require the probabilities for all the messages in the given ensemble, which may be known as *"a-priori* information" from previous tests or can be gained only by very long observation of an unknown source. As some messages may be rare we have theoretically to investigate an infinite sample of messages in the past and our expectations for the future are only correct if again we refer the prediction to an infinite sample.[8]

If we can trace at all a particular selection scheme (set of probabilities) in a source, we call it a *"stochastic source."* If the probability that one character of a message will represent one particular symbol depends on the selection of a specified symbol for the previous characters, we call it a *"Markoff source."* In particular we speak of an *"ergodic source,"* when each reasonably large number of messages taken from the source will show the same probability pattern (constant entropy).

The difference between the maximum information content of an ensemble of messages (equiprobable case) and the entropy under given restraints is frequently designated as *"internal information"* of the source (H_{int}) and some authors associate this term with "negative entropy."

$$H_{max} = H_{int} + H$$

The ratio $\dfrac{H}{H_{max}}$ is the relative entropy (or message efficiency)* and an expression one minus this ratio is named *"redundancy."*

$$R = 1 - \frac{H}{H_{max}} = \frac{H_{int}}{H_{max}} \text{ in } \% \ldots \ldots \ldots (4)$$

Large redundancy is helpful in guessing the most likely structure of mutilated messages. Shannon[9] conducted experimental investigations of the predictability of English language and found that in 60 to 70 per cent. of the tests individuals of a good general education could guess correctly the next letter in a given text if all the 12 to 14 preceding letters were known.

Redundancy does however lead to a waste of transmission facilities wherever the error expectancy is low. Reducing redundancy to such an extent that the highest system efficiency will be secured, is the paramount aim of system engineers. They have to study the "fine structure" of the message probabilities to reach this aim.

The longer the messages of an ensemble, the smaller will be, in general, the entropy. Its minimum value (maximum redundancy) will be approached for extremely long messages. It is then convenient to subdivide the message in groups of characters, called "words" (the term is used for all sorts of symbols, not merely letters). They may be of different lengths and we designate them as digrams, trigrams, tetragrams . . . N-grams containing 2, 3, 4 . . . N characters each. Monograms are the characters themselves, provided consecutive characters are independent of each other. This is not the case in Markoff chains, where we may define a *"conditional probability"* (transition probability) $p_i(j)$ for the symbol j following the given symbol i and a *"joint probability"* $p(i,j)$ for the occurrence of the digram ij. It is evident that:

$$\sum_{j} p_i(j) = 1; \quad \sum_{i,j} p(i,j) = 1; \quad \sum_{i} p(i). \, p_i(j) = p(j)$$
$$\ldots \ldots \ldots \ldots (5)$$

where $p(i)$, $p(j)$ are the monogram probabilities of i and j respectively. These can be directly evaluated by statistical observation or calculated from the set of digram probabilities by:

$$p(i) = \sum_{j} p(i,j) = \sum_{j} p(i,j) \ldots \ldots \ldots (6)$$

---

* "Source efficiency" or "ensemble efficiency" might be preferable.

Also the conditional probability can be calculated from the set of digram probabilities by:

$$p_i(j) = \frac{p(i, j)}{\sum\limits_{j} p(i, j)} \equiv \frac{p(i, j)}{p(j)} \quad \ldots\ldots(7)$$

As the definition of entropy (equ. 3) applies to any length of message, we are free to take digrams only as full-scale messages and we can calculate the "*digram entropy*":

$$H(x, y) = -\sum\limits_{i, j} p(i, j) \log_2 p(i, j) \text{ bits/digram} \ldots(8)$$

with x and y standing for the first and second symbol respectively.

Knowing the digram probabilities, we may directly calculate the monogram entropies for the first and second characters respectively:

$$\begin{aligned} H(x) &= -\sum\limits_{i, j} p(i, j) \log_2 \sum\limits_{j} p(i, j) \\ &= -\sum p(i) \log_2 p(i) \\ H(y) &= -\sum\limits_{i, j} p(i, j) \log_2 \sum\limits_{i} p(i, j) \\ &= -\sum p(j) \log_2 p(j) \ldots\ldots\ldots\ldots(9) \end{aligned}$$

Considering that $p(i, j) \leqq p(i) \cdot p(j)$ we find that

$$H(x, y) \leqq H(x) + H(y) \quad \ldots\ldots\ldots\ldots\ldots(10)$$

the equality being valid in the case of independent characters only. Thus it is proved that any dependence of the probability distribution for one character on the symbols used for the previous character will reduce the entropy per character.

It remains to mention the definition of "*conditional entropy*"[10] of y, $H_x(y)$ as "the average of the entropy of y for each value of x, weighted according to the probability of getting that particular x.

$$H_x(y) = -\sum\limits_{i, j} p(i, j) \log_2 p_i(j) \quad \ldots\ldots(11)$$

with $H(x, y) = H(x) + H_x(y) = H(y) + H_y(x) \ldots(12$

Similar definitions have to be framed for trigram up to N-gram entropies.[9] An exact calculation for the entropies up to trigrams for the 26 letter alphabet of the English language gives a reduction of the entropy from 4·7 bits/character for equal probability over 4·14 (monogram), 3·56 (digram), 3·3 (trigram) to 2·62 (words of 4·5 letters average length). Considering the word probabilities along with the whole phrases might reduce the entropy to less than one bit/character, yielding more than 75 per cent.

redundancy. To find practical systems for the removal of such large redundancy resulting in theoretically possible improvements is the task for the near future. So far only discrete sources, particularly printed text in conventional languages, have been investigated. It is certain that other sources like speech or moving pictures have still much higher redundancy.

5.4. *Statistical Theory of Continuous Sources*

We have three distinct ways of classifying sources of information:

Firstly, into "*dead*" (still) and "*living*" (moving) *sources*, the former presenting the full message at a time (photographs, message forms for telegraphy); the latter producing a steady flow of information, which generally has to be handled without appreciable delay (speech, moving pictures, etc.).

Secondly, into "*discrete*" and "*continuous*" *sources*.

Thirdly, according to the number of dimensions in which the information is presented ranging from living teletype with one-dimensional character space and one-dimensional symbol space (Sect. 5.2) to stereoscopic colour television with four-dimensional character-space and three-dimensional symbol space.

Sources may be at the input of the communication systems or may act by interception in the medium (location systems).

Fortunately all these cases can be covered by the information theory as already established for the discrete case. The more elementary approach is a subdivision of the message space by dividing the continuum of messages into a large but finite number of small regions. The more rigorous approach is indicated in a preliminary study by Shannon,[7, 10] who claims that "with a great deal of abstract measure theory, information theory can be formulated in a completely axiomatic and rigorous manner which includes both the continuous and discrete cases and many others."

The elementary approach reduces the problem to one of the discrete case. It is evident that we shall meet everywhere in nature thresholds which determine the smallest discernible step for any magnitude. Thus a scale of steps can be defined for each coordinate of the message space. A volume having one unit step in each of its sides, may be called an "*information cell*." The system engineer has

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first to determine the size and shape of the information cell of the source to be used and, what is equally important, of the destination. There is no point in transmitting more information than the destination can pick up. Once the information cell is determined, we may count the number of cells separately for the character space (n) and the symbol space (s). All the previous equations are then directly applicable and we may calculate the various entropies as soon as the message probabilities are known.

The second more rigorous approach has to deal with sets of functions in place of the set of discrete messages previously discussed. There may be a finite set of continuous functions $f_k(x)$ ($k = 1, 2, \ldots n$) and we may consider each function as a separate message. Knowing the probabilities P_k, we may calculate the entropy. If certain limitations for example in the amplitude of a function and all its derivatives exist, we shall generally find that a finite set of discrete values for selected ordinates $x_1 \ldots x_m$ will completely specify the function within a given interval Δx (sampling theorem).

If a continuum of functions is available, but not a finite set, we may find the probability distribution for the parameters in place of the discrete probabilities P_k. We call a set of functions for which a probability measure is known an "ensemble of functions." The independent variable is usually the time. We call the ensemble "stationary" if the same ensemble results when all functions are shifted any fixed amount in time. In particular we speak of an ergodic ensemble, "if it is stationary, and there is no subset of the functions in the set with a probability different from 0 to 1 which is stationary".[10]

Circuit engineers deal with individual functions, representing particular wave forms. The system engineer has primarily to deal with ensembles of functions. For practical applications he will be fully satisfied with the first approach, using a "quantized message space", at least for preliminary calculations.

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5.5. Signal Analysis and Information Theory

The multi-dimensional message space has to be transformed into the three-dimensional signal space to express the given information in the most efficient and convenient form for transmission. All present day communication channels transmit information merely as time functions (series) of an electric magnitude, either power or voltage (current) across a fixed impedance. All channels are specified in terms of the maximum frequency (of a steady sinusoidal signal) which they are able to handle. It is therefore appropriate to specify a "signal space" in three coordinates (amplitude, time and frequency) in which time and frequency are the independent variables and amplitude is the dependent variable. We defined an information cell as the minimum quantum of the message
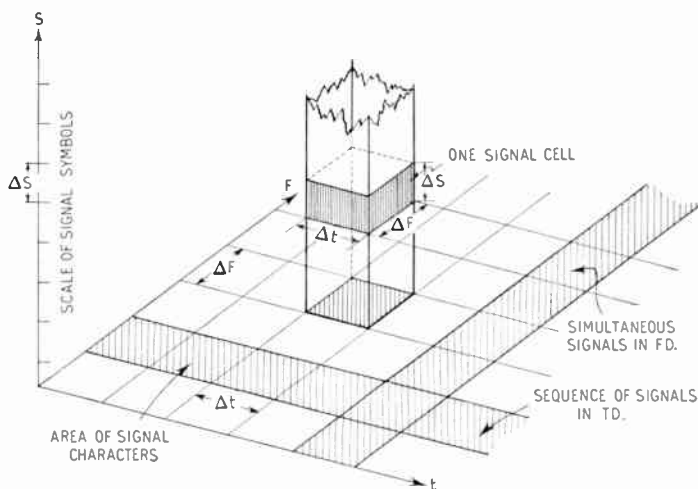

Fig. 3.—A signal cell in the three-dimensional signal space.

space, we shall similarly find a minimum quantum of the signal space, which we may call a "signal cell."

Three major problems are involved in the information matching process:

(1) Message encoding, which should compress the information of extended sources into one or more time functions (space matching) and which should remove much of the redundancy (entropy matching). The result is the three dimensional signal space with small redundancy.

(2) *Signal encoding* to reshape the signal space into a form which best matches the noisy channel. The signal space may be called *"channel space"* in the transformed condition.

(3) *Authenticity examination* to trace errors or mutilations of the received signal and to arrange for their automatic correction.

The first and second process combined constitute the total encoding action at the transmitter. It is not always necessary to specify separate sections of the equipment for the two different functions, but it will be useful to discriminate the two problems in any analysis.

Representing the signal space by a rectangular coordinate system with t, f and s axes, leads to a signal cell of a minimum volume $\Delta V = \Delta S \times \Delta f \times \Delta t$ (Fig. 3). The minimum amplitude quantum ΔS is prescribed by the ability of the equipment to discriminate between two amplitudes having a minimum difference of ΔS only. The number of possible amplitude steps is the highest integer, below $\frac{S_{max}}{\Delta S}$ in the case of a linear scale. S_{max} is the maximum tolerable peak to peak value of the signal. The bandwidth of the signal cell Δf is not independent of the "epoch" Δt. There is no theoretical lower or upper limit for either but only for their product:

$$\Delta f \times \Delta t \geqq 1 \quad \text{.................(13)}$$

This is the *uncertainty relation* of a signal cell,* analogous to the uncertainty relation of quantum physics. Frequency and time cannot both be defined simultaneously beyond a certain limit. A sharply defined frequency (permanent sine wave) leaves the epoch entirely undefined and defining a time instant exactly by a so-called delta-function signal (infinitely short signal of finite energy content but infinitely large amplitude) leaves the frequency entirely undefined. There are many practical signal forms between these two extremes, which require a certain minimum frequency band for transmission and at the same time have a minimum duration.

The *"Gaussian elementary signal"* has actually the theoretical minimum value of 1 for the product of "effective duration" and "effective bandwidth." Other elementary signals however may be more suitable from a practical point

* See Gabor (Ref. 11, page 14), where Δf and Δt are defined as *"effective bandwidth"* and *"effective duration"* in a manner which makes the uncertainty product 1 as a minimum.

of view (minimum intersignal interference). Their characteristics will be discussed in the succeeding parts of this paper.

Selecting the elementary signal specifies the uncertainty product which is between 1·2 and 1·8 in practical cases. Knowing the total bandwidth W of a channel and the transmission time T we may count the number of independent time-bandwidth areas as $\frac{W.T}{\Delta W.\Delta T}$. T may be equivalent to the message duration or to a convenient message interval (in case of living messages) or to any arbitrarily selected value in agreement with the entropy matching process. Any such elementary area forms in the signal space the base on which a set of signal cells, i.e. one *"signal element"*, can be erected. For each base-area we may select one and only one signal cell. (Fig. 3.) The information content of the signal space can now be calculated by using eqn. (2) as

$$H_{Smax} = \frac{W.T}{\Delta f.\Delta t} \quad \log_2 \frac{S_{max}}{\Delta S}$$

in bits per message of length T ......(14)

This assumes that all signal cells in the space should be used with equal probability within a reasonably large interval and that all signal elements may be independent of each other. If these conditions are not acceptable we may calculate the entropy of the signal space according to Sect. 5.3 considering the probability of the various "symbols," in this case of the various possible amplitude levels.

5.6. *Signal Encoding, Channel Space and Channel Capacity*

We have so far proceeded beyond the M block in Fig. 2 and enter now one or more S blocks. The information is here represented by the signal space and its structure.

A group of signal elements (Fig. 3) may simultaneously exist and occupy a wide frequency band (*frequency division* = FD) or all signal-elements may occupy the same frequency band and may be arranged in time sequence (*time division* = TD). There may be a large number of quantum steps in the signal space after the message encoding.† The number of possible quantum steps will be limited only by

† Actually it is the usual practice to keep a continuous message function non-quantized throughout the space matching procedure and in simple message encoding systems we retain preferably the continuous character also in the entropy matching process.

practical difficulties in discriminating too many different amplitudes and not by noise and disturbances as these may be excluded within the equipment.

Such considerations do not apply to the channel space (signal space within the transmission medium). Noise and disturbances are then of paramount importance. They limit the capability of the channel to carry information primarily by restricting the number of amplitude steps which can be distinguished. It has been proved[10, 11, 12, 13] that $\frac{P_s + P_n}{P_n}$ steps of a signal can be distinguished in the presence of "white" noise, if we understand by P_s the average signal power for maximum signal level and by P_n the average noise power. Observe that now the maximum total level is $P_s + P_n$, whereas maximum amplitude in eqn. (14) was S_{max} in the absence of noise.

Combining the result with the previous idea of signal cells in the signal space, we may define as the maximum information content of the channel space observed at the receiving decoder input:

$$H_{Rmax} = WT \log_2 \left(1 + \frac{P_s}{P_n} \right) \leqq 2 WT \log_2 \left(1 + \frac{S}{N} \right)$$

in bits per message (of length T) ......(15)

W...effective bandwidth of the channel (in cycles per second).

T...effective transmission duration of one message (in seconds).

P_s...average signal power in watts.

P_n...average noise power in watts.

S ...r.m.s. signal voltage in volts.

N...r.m.s. noise voltage in volts.

For living messages it is inconvenient to specify a particular message interval T. We preferably use the term *channel capacity* specified by:*

$$C = W \log_2 (1 + \frac{P_s}{P_n}) \text{ in bits/sec..........(16)}$$

From both the equations (15) and (16) we learn that bandwidth, transmission duration and signal-to-noise ratio (transmitter power) can be traded one against the others. For example, we may tolerate much higher noise level if we reduce the number of amplitude steps and reshape the signal space by extending its base either in the time-domain (longer transmission time for dead messages or encoding processes with delay involved) or in the frequency domain (increasing the channel bandwidth W). The minimum number of distinguishable amplitude steps is two and we call the corresponding signal elements: *binary digits* (Sect. 5.2). Elements which may assume any value out of n amplitude steps are called *n*-ary digits. The *signal encoding* process will in many applications convert the signal space of *n*-ary signal elements into a channel space of K-ary, particularly binary *channel elements*. For each signal element we have now a group of channel elements, which may be termed a *"channel character."* Any possible form, which a channel character may assume (due to any possible combination of channel elements) may be called a *"channel symbol."* For binary signal coding we may select any one out of 2^n channel symbols as a channel character consisting of *n*-channel elements. Signal encoding may also serve the opposite purpose, i.e. to increase the number of symbols per element when transforming from the signal space to the channel space (for example, facsimile over a practically noiseless channel).

We mentioned above that *amplitude quantization* is not necessarily involved in the message encoding process. We may now add that the signal encoding process may also be performed in the continuous range. In this case we cannot directly specify a limited number of channel symbols, but knowing the symbol thresholds of the original continuous message it is in every case possible to calculate the required number of amplitude steps for the signal function to retain the original granularity of the message. In the case of strong noise, it may not be possible to secure the necessary

* The relationship in this form is frequently known as the *"Hartley-Shannon law."* However neither of these two famous scientists has ever put a claim to be considered as the inventor or discoverer of this important relationship. In fact both authors and many other investigators have duly distributed the credit to several contributors. Nevertheless the designation is justifiable, as Hartley was the first to

establish a clear idea of the signalling speed being directly proportional to the channel bandwidth and Shannon was the first to render an exact mathematical proof for the quantitative influence of noise. Shannon's theory of the "continuous channel" involves also the non-white noise (arbitrary disturbances) and the case of peak-power limitation within the channel.

"fine-structure" of the symbol scale. Signal encoding may then divide the symbol range into two different channel elements, which can be continuously modulated. Such channel elements have been termed *indices*.

Operating also the time coordinate of the channel space continuously leads to the conventional communication systems. Quantizing the time-domain—we speak usually of "*sampling*"—leads generally to pulse communication systems.

5.7. *The Evaluation of Received Information*

All the further functions which may be performed with a signal within the channel (i.e. train formation, wave formation, duplexing etc.) as indicated in Fig. 2 constitute only linear transformations or non-linear distortions from the point of view of information theory. We may therefore turn to the receiving side where the "channel space" should be available for the evaluation of messages. Disturbances and noise may have changed the structure of the "channel space" and as a consequence of such interception within the medium there may be a certain amount of confusion in respect of the true messages selected from the channel space at the transmitting side.

Disturbances and noise are not predictable, but they have characteristics, which may profitably be used to distinguish them from the true

NON-PERIODIC FUNCTION $f_1(t)$
PERIODIC FUNCTION WITH PERIOD p

Fig. 4.—*Auto-correlograms of non-periodic and periodic functions.*

message. Moreover the receiver will be in possession of a good amount of *a-priori* information about the messages (message and signal codes, original structure of the message space, structure of the channel space, characteristics of the medium, etc.) which all may help in deciding about the authenticity of a message.

Two methods have been evaluated for this purpose: (*a*) The use of error detecting codes

in connection with error correcting systems. (*b*) Correlation methods to compare the receiver combination of signals and noise with the given general characteristics of signals alone and of typical noise alone.

The first method is excellently presented in an article by R. W. Hamming[14] and it will be summarized later in this paper. The second method is based on extensive investigations by many scientists[15-20] and follows a principle as old as criminology. We use "model waveforms" of all the signals or signal elements to be received and compare any incoming waveform with these standards with the help of an automatic correlator to consider all possible mutations which might hide the true character of the signals.

Scientifically we call the process *cross-correlation* and define it mathematically in the form

$$\Phi_{1,2}(\tau) = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{+T} f_1(t) . f_2(t + \tau)\, dt \quad \text{........(17)}$$

$f_1(t)$ and $f_2(t)$ are the two functions to be correlated, $\Phi_{1,2}(\tau)$ is the "*correlation function.*" [19]

The special case $f_1(t) \equiv f_2(t)$ defines $\Phi_{11}(\tau)$ the "*auto-correlation function.*" A graph showing any correlation function $\Phi(\tau)$ is called a "*correlogram.*" An "auto-correlogram of a non-periodic function has only one maximum at $\tau = 0$ and is symmetrical in respect of the *y*-axis. If the function is periodical, the correlogram will show repeated peak-values at $\tau = np$, p being the period Fig. 4). For discrete signals, $f(t)$ may be replaced by a time-series and the integral process converted to a summation.

Taking $f_1(t)$ as the superposition of signal and disturbances, but $f_2(t)$ as the model function of the signal only, results in the superposition of the auto-correlogram of the signal with the cross-correlogram of signal and noise. The investigation of this cross-correlogram may permit in many cases good detection of signals in the presence of heavy noise at the sacrifice of a small delay. Pulse communication systems offer the advantage of using a single standard
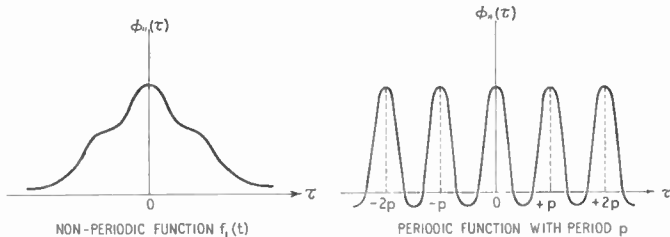
F

waveform for all signals (at least when using binary coding or time modulation).

Correlations are also of increasing importance in speech analysis and they may ultimately lead to a highly improved message encoder for speech.

The theoretical considerations of Sect. 5.3, where we discussed the importance of joint probability and conditional probability for Markoff processes, are readily applicable to the theory of the received information. We can only claim a certain very high probability that a received message is actually identical with the transmitted one. There is a certain probability that another message will have been transmitted. Calling x any of the transmitted messages, and y any of the received messages, allows the calculation of the actual *rate of transmission* over the channel as:

$$R_t = H'(x) - H'_y(x) \quad \text{in bits/sec.} \quad \ldots\ldots(18)$$

In this equation we understand by $H'(x)$ the entropy of the ensembles of messages in the message space or, briefly, the "*entropy of the message space*" as defined by eqn. (3). The dash on $H'(x)$ indicates that we calculate the *entropy per second* and not per character.

If there would not be a single error in a communication system we could take this value as the actual rate of information transmission. As this ideal situation cannot be reached we must, of course, deduct the amount of errors, to get the rate of transmission. Shannon[7, 10] has proved that it can be expressed as the difference of the entropy of the message space and the conditional entropy $H_y(x)$, both calculated per second. $H_y(x)$ may be calculated by following the advice of eqn. (11). It is defined as the uncertainty of the send message (x), when the received message (y) is known. This value has been christened "*equivocation*" by Shannon. Also the name "error expectancy" has been suggested.

We see now one more important design requirement for the system engineer: Keep the equivocation low!

This is an easy-going slogan, but its realization is a rather complicated process. First of all it is evident that overloading the channel, i.e. making H_s' the entropy of the signal space (per second) larger than C, the channel capacity, will lead to distortions and consequently to mutilations of messages. Even if H_s' is smaller than C, but $H_{s'max}$, the signal space entropy for

equiprobable distribution of all possible signal combinations (random selection of signal symbols) is larger than C, there may be short message intervals for which the channel capacity could be overloaded. The rule is therefore to make $H_{s'max}$ close to C and H_s' slightly smaller than C. For sources with large redundancy this can be achieved only by message encoding, as it implicitly means a small difference over $H_{s'max} - H_s'$, i.e. a small signal space redundancy.

Such considerations indicate that for a given channel we may not get the highest rate of transmission, if we use a source with an entropy of $H'(x)$ equal to the channel capacity C. In such a case $H'_y(x)$ would be much larger than for a source with a slightly smaller $H'(x)$. The true *system capacity* (C_s) should therefore be identified with the maximum possible rate of transmission:

$$C_s = \text{Max. } [H'(x) - H'_y(x)] \quad \ldots\ldots\ldots(19)$$

The *maximization of the system capacity* requires therefore:

(1) That the entropy of the source is somewhat below the channel capacity C, as given by eqn. (18).

(2) That, in cases where the maximum rate of information of the source is much larger than its entropy per second, we arrange for a highly efficient entropy matching device.

(3) That the most efficient signal waveform is selected, giving the best compromise between the requirements for a small uncertainty product ($\lambda t. \lambda f$), small interference between channel elements or channel characters or different channels, and good discrimination against noise and disturbances.

(4) That any signal encoding process, which might be used, will take full consideration of possibly unequal probabilities for mutilation of special channel elements, characters or combination of such.

(5) That a small redundancy may be given to the channel space to allow for error correction to the required extent.

(6) That all operations within the channel (modulation, multiplexing, duplexing, demodulation, etc.) may not materially increase the equivocation.

(7) That all possible methods are applied at the receiving end for keeping the equivocation low (correlation methods and error correction methods).

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The most difficult requirement is the second one, as in many systems the required delay for efficient coding will not be tolerable.

An improved theory is gradually being framed which will consider "short time entropies" and "instantaneous information contents." On the practical side, ways are being traced to trade instantaneously channel capacity between several channels of multichannel systems. Some of these ideas will be touched on in the later parts of this paper.

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National Radio Show 1955

The twenty-second National Radio and Television Exhibition was held at Earls Court, London, from August 26th to September 3rd; over the 8 days the attendance was 242,800 compared with 315,970 for last year, when it was open to the public for 10 days.

Three major developments in the domestic use of radio were featured—Band III television, v.h.f./f.m. sound broadcasting, and high-fidelity reproduction of sound. The extent of the first of these could be seen in the fact that every television receiver on show was suitable for receiving both Band I and Band III transmissions: in view of the more complicated nature of circuits for the higher frequency, manufacturers appear to have decided to keep costs down by concentrating on this type of set.

Successive Radio Shows have pointed the trend toward larger screens and this year receivers with 17-in. tubes predominated. The 21-in tube now appears in quantity-produced receivers, while the largest tube on show was a 27-in., although this was for export only. These larger tubes use 90-deg. scanning which assists in reducing the length of the tube. It did at one time appear that the 9-in. screen was obsolete and the 12-in. obsolescent, but two portable receivers using these sizes were shown. One was an a.c./d.c. set with 12-in. screen for carrying about within the home, the other a portable receiver with a 9-in. screen for operation from a 12-V car battery or a.c./d.c. mains and providing v.h.f. sound reception as well as two television bands.

At this stage in the development of television one does not expect any revolutionary circuits, and advances in this direction were confined to refinements to give better quality pictures. For instance, in switching from one channel to another, varying signal strengths will be encountered and many sets thus incorporate automatic gain control for both vision and sound. Many receivers will be operated under fringe conditions, and hence improved sensitivity and flywheel synchronization are essential features of the slightly more expensive sets intended for operation with weak signals. Flyback suppression circuits, necessary particularly with very bright pictures, are another field where improvements are shown, as well as in interference reduction by "black-spotting" circuits.

The design of the radio frequency amplifier and frequency changer stages of all television receivers is very much the same—the cascode circuit is almost universal as r.f. amplifier while a double-triode or triode-pentode is the usual choice for the frequency changer. There is, however, greater divergence in switching arrangements: usually these take the form of a turret carrying pre-tuned coils for each channel, but some manufacturers make use of the incremental inductance circuit.

Improvements in cathode ray tube design have led to the reduction of astigmatism by the use of better focusing units, either magnetic or, in some cases, electrostatic. Ion traps are incorporated in virtually all tubes to reduce ion burn and aluminized screens are becoming more general.

The industry's confidence in the future of v.h.f.-f.m. broadcasting could be seen in the fact that about half the sound receivers on show incorporated a v.h.f. band, either instead of, or in addition to, the usual short wave band. Broadly speaking these receivers can be grouped into those intended mainly to give better reception (from the interference point of view), and those where much greater advantage is taken also of the high fidelity reproduction obtainable. The B.B.C. gave demonstrations of comparative recordings of v.h.f. and medium wave reception which showed the advantages in overcoming interference.

A considerable number of radio gramophones incorporate the v.h.f. band, and provide enhanced reproduction through more advanced circuitry or multiple loudspeakers, or both. Increased attention this year was paid to the demand for the individual units in high-fidelity reproducing systems and this was combined with demonstrations of reproduction from disks and from tape, through ordinary single loudspeakers and through multiple reproducers, as well as striking demonstrations of stereophonic reproductions using two or three channels.

There were a number of interesting designs in the Exhibition of tape recorder/reproducers, notably one with a wide frequency response suitable for industrial and scientific recording which uses a 4-stage transistor amplifier on playback to eliminate mains hum.

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This year the exhibits of applications of electronics were combined in one display which also included the careers stand. A particular point was made of aircraft radio equipment for control, navigation and communication. Radar equipment for use on ships as well as underwater detection equipment for locating shoals of fish and showing the depth of water, together with an electronic pilot for automatically steering a ship on a predetermined course, demonstrated the growing importance of electronics at sea.

A few selected industrial applications of electronics were also shown and included industrial television camera units for use in hospital operating theatres, and various sorting and counting devices. An interesting example of the latter is used by the Royal Mint for separating silver from cupro-nickel coinage and depends for its operation on the differing damping effects on a tuned circuit of the two metals.

Examples of typical laboratory experimental work during a 4-years' course at a technical college were shown in the careers section, as well as examples of the work and practical training in radio and television servicing.

The three Services were again represented at this year's Show and as in previous years showed mainly working models simulating the operation of actual electronic and other devices.

S.B.A.C. 1955 Exhibition

Held at Farnborough for the past 8 years, the Society of British Aircraft Constructors Flying Display and Exhibition provides excellent opportunity for large-scale demonstration of the products of the radio-communications industry. This year's Exhibition included many interesting electronic control and measurement devices, as well as showing the latest advances in radio communication, navigational aids, and radar.

Air-to-ground communications now are moving to the u.h.f. bands because of the extreme congestion experienced on the v.h.f. bands, especially by high-flying aircraft. The equipment designed for these decimetric wavelengths embodies many advanced electronic and mechanical features, in particular the facility of selecting by means of a single knob any one of several hundred crystal-controlled channels.

Parallel with the use of communications in the u.h.f. band has gone the development of direction finding and navigational systems. Direction finding at these frequencies has the advantage of compact equipment but the disadvantage of being subject to considerable site error. Two types of d.f. aerial were shown, one making use of an array reflector rotating around a central co-axial aerial at 2,400 r.p.m., the other using a 12-element "commutator" aerial. In both types the relative phase of the incoming signal is used to determine bearing and the display is instantaneously given on a cathode ray tube.

The TACAN navigation system is an interrogator-responder aid which gives distance information to up to a hundred aircraft simultaneously, as well as continuous bearing information without the necessity of interrogation. The maximum range of the system is approximately 200 nautical miles and distances are presented to the pilot by counter figures on the indicator unit which also shows the bearing on a 360 degree compass scale. The beacons send out a coded identification signal and the system provides 126 operational channels, any one of which is immediately available to the pilot by rotation of a selector switch.

The question of enabling unskilled personnel to make routine checks on aircraft radio equipment was discussed in the *Journal* recently* and a test set for carrying out this operation was shown which has been developed in conjunction with the Royal Aircraft Establishment. Applicable to v.h.f. transmitter/receivers, it enables tests such as transmitter output and noise, and receiver sensitivity and noise, to be assessed on a go/no-go basis by connecting it to the mic./tel. and aerial sockets. The condition under test is then set up by simple selector switch and the indication is on a meter.

Other types of equipment shown included the latest versions of standard v.h.f. transreceivers as well as equipment for the h.f. aircraft bands, radio altimeters of the pulse and frequency modulator types and airborne search radar. It is interesting to note that the latter equipment, as well as the cathode ray direction finder display, make use of high intensity screens to make viewing possible under conditions of high ambient lighting such as control towers and high flying aircraft.

APPLICANTS FOR MEMBERSHIP

New proposals were considered by the Membership Committee at a meeting held on July 14th, 1955, as follows: 22 proposals for direct election to Graduateship or higher grade of membership, and 29 proposals for transfer to Graduateship or higher grade of membership. In addition, 31 applications for Studentship registration were considered. This list also contains the names of five applicants who have subsequently agreed to accept lower grades than those for which they originally applied.

The following are the names of those who have been properly proposed and appear qualified. In accordance with a resolution of Council and in the absence of any objections being lodged, these elections will be confirmed 14 days from the date of the circulation of this list. Any objections received will be submitted to the next meeting of the Council with whom the final decision rests.

Direct Election to Associate Member

BROWN, William Thomas. *Taplow.*
CARTER, John Paterson, M.Sc.(Hons.), *Wellington, New Zealand.*
GIBSON, George Angus, M.A.(Hons.), B.Sc. *Coventry.*
ROACH, Raymond Frederick. *Chislehurst.*
WHITE, Norman Leslie, B.Sc.(Eng.). *Brighton.*

Transfer from Associate to Associate Member

BANERJI, Biswa Nath, M.Sc. *Shillong, Assam.*
CROW, Stanley George. *London, N.9.*

Transfer from Graduate to Associate Member

BUDGEN, Ronald Pallister. *Southsea.*
CHAND, Flt. Lt. Satish, B.Sc.(Eng.), I.A.F. *Chandigarh.*
LANGTON, Charles Hazelhurst. *Ashton-under-Lyne.*
LOVATT, Harry William. *Stevenage.*
MURISON, Stanley Chandler. *Surbiton.*
ROBINSON, Geoffrey Thomas Graham. *Eastleigh.*

Transfer from Student to Associate Member

BROWNING, Robert. *Wells, Somerset.*
PROWSE, Michael John. *Staines.*

Direct Election to Associate

FORSTER, Aubrey. *Liverpool.*
GRIFFIN, Norman Bernard. *Port Harcourt, Nigeria.*

Direct Election to Graduate

BRIGGS, Peter George. *London, S.E.*18.
DAY, Ronald Charles Frederick. *Gillingham.*
FERGUSON, John. *Matlock.*
HARRIS, Ernest Jack. *Greenford.*
HARRIS, Peter Michael. *Sidcup.*
HART, Bryan Leonard, B.Sc.(Hons.). *Croydon.*
HOLLAND, John Phillip. *London, S.W.*12.
HOWE, Frank Ralph. *Colchester.*
MATTHEWS, Robert Edward. *Southend-on-Sea.*
MITCHELL, Clifford John. *Bexleyheath.*
PITTILO, Robert Dawson, B.Sc. *Glasgow.*
RAJAGOPALAN, Thittai Seshadri, M.Sc. *Tanjore.*
RAYNER, Stuart Verrinder. *London, N.*22.
SAUNDERS, Patrick William. *Walsall.*
SIVASWAMI, Flt. Lt. Rishiyur Subrahmanyam, B.A., B.E., I.A.F. *Bangalore.*
TALAPATRA, Sunilendra Mohan, B.Sc., M.Sc. *Jalpaiguri.*

Transfer from Student to Graduate

HAIRETAKIS, Emmanuel. *Piraeus.*
MELHOTRA, Ascharaya Lal, B.Sc. *Agra.*
OSBORNE, John, B.Sc. *Ilford.*
PAVEY, Arthur Robert Brian. *Warrington.*
SERVETAS, Evangelos. *Athens.*
WITCHELL, Alfred Reginald Thomas. *Coventry.*

STUDENTSHIP REGISTRATIONS

AGHARKAR, Balkrishna Dinkar. *Madras.*
AHUJA, Gajindar Singh, B.Sc. *Bangalore.**

BANERJEE, Shyamal Kumar, B.Sc. *Calcutta.*
BONNETT, James Harold. *Royston.**
BUEHLER, Walter. *Salmo, British Colombia.*

CHOUDHURY, S. K. *New Delhi.*
CODJOE, Joseph Milford Nii-Ahuma. *London, S.W.*12.

DAS, Chitta Ranjan, B.Sc. *Calcutta.*
DAVIS, Brian Michael. *Stockport.*
DAY, John Gordon Coryton. *Weybridge.**

GEORGE, Julian. *Birmingham.*
GRUZELIER, Graham Elliot. *Lower Hutt, New Zealand.**

HRISHI KESH, R. *Bangalore.*
HYDER, Thomas William. *Southampton.*

KRISHAN KUMAR LOROIYA. *New Delhi.*
KRISHNASWAMY, Subrahmanya, B.A. *Madras.*

LEGGETT, Geoffrey Charles. *London, W.*3.

MADHOK, Baldev Kumar Lal, B.Sc. *New Delhi.*
MEHTA, Vasantkumar Gulabdas. *Ahmedabad.*
MENTY, Edouard Sylvio. *Mauritius.*
MOHAPATRA, Dutta Hari, B.Sc. *Cuttack.*
MYCROFT, George Herbert, B.Sc. *Peterborough.*

NEED, Richard John. *Malvern.*

PEGRAM, Cyril James. *Ruislip Manor.*

RAHIM, Md. Abdur, B.Sc. *Rajshahi, East Pakistan.*
RAMACHANDRA MURTY, Swayampakula. *Kalahasti.*
REID, William Lawrence. *London, W.*13.
RICHARDS, William Milner. *London, N.*7.
RIESEL, Chaim Manfred. *Tel-Aviv.*
RIVERS-YOUNG, Rex. *Slough.*

SCHOFIELD, Paul. *London, W.C.*1.
SRINIVASAN, Ramaswamy. *Salem, Madras State.*

TAYLOR, William John. *Hitchin.*

VAN ZYL, Michiel Frederik. *Tiervlei, Cape Province.*
VEDWA, Rajendra Kumar. *Saliana.*
VENDRELL, Lieut. John, S.A.N. *Saldanha Bay, Cape Province.*

* Reinstatement.

AN S-BAND VARIABLE ATTENUATOR FOR HIGH-POWER WORKING*

by

B. E. Kingdon (Graduate)†

SUMMARY

The description is given of a waveguide insertion attenuator in which the loss in r.f. power is produced by the action of a column of water flowing in a glass tube mounted in the waveguide, continuous variation of attenuation being obtained by adjustment of the water column height. Resonance effects in the water column are exploited by choosing the cross-sectional dimensions of the glass such that an optimum attenuation per unit length of tube is obtained. Experimental results are given for a model covering the range 0 to 30 db, the input v.s.w.r. at $\lambda_a = 10\cdot00$ cm being $< 0\cdot87$ at any setting and $\geq 0\cdot97$ over the greater part of the range. Satisfactory operation has been achieved in an evacuated test-system fed by a magnetron delivering 2 MW peak power (200 W mean) at a wavelength of 10 cm. Various modifications in design are suggested for use with higher mean powers.

1. Introduction — Experiments on Fixed Attenuators

Fixed water attenuators of various kinds are described in current waveguide literature.[1] The most usual function of this type of attenuator is that of a matched terminating load in a high-power waveguide run. The power output of the system may be estimated from calorimetric experiments made with the load,[2,3] since the latter can be designed to absorb virtually the whole of the incident power by reason of the high dielectric loss of water at centimetric wavelengths.[4]

In other instances it may be necessary to vary the power fed to a system in order to determine its operating characteristics at different input levels, often for purposes of calibration. This could be achieved by the use of various forms of power-divider (e.g., rectangular waveguide magic-tees, circular waveguide variable ratio bridges, rat-races, directional couplers, etc.), but the usefulness of these is often reduced by virtue of the resulting awkward geometrical arrangements, by space limitations, and (where a series of fixed ratio bridges is used) by the undesirability of interchanging components during the course of an experiment. Also, to assist in obtaining stability of operation it is convenient to dissipate the unwanted portion of the power

in a matched load, and for high power levels the use here of some form of water load is generally to be preferred.

An alternative method of power control would be to use a series of water attenuators between the r.f. power source and the input to the system under investigation. By connecting different combinations of the attenuators to the water supply the insertion loss afforded may be varied in steps of any desired value. It is preferable that the input match of the attenuator unit should remain fairly constant throughout the range.

This latter system of control was used successfully in experiments on a 1·5 MeV linear electron accelerator,[5] where the investigation of anomalous r.f. losses in this machine was largely carried out by observing the variation in its performance over a wide range of input power levels. The higher values of power necessary were obtained by feeding the output of a VX 4061 magnetron ($\lambda_a \simeq 10\cdot00$ cm) through three water attenuators giving losses of 3, 6 and 12 db. By this means the accelerator input power could be reduced by a factor of 130 in steps of 3 db from the design peak value (1 MW), and since adjustment of the r.f. modulator controls provided up to 3 db initial change, smooth variation over the range 0–24 db was thus achieved.

The attenuators were made by mounting various lengths of "Phoenix" (borosilicate) circular glass tubing between the narrow faces of a section of No. 10 (i.e. 3 in. × 1½ in. o.d. × 0·080 in. wall) standard S-band rectangular

brass waveguide, operating in the H_{01} mode. To assist in obtaining a good r.f. input match each tube was tapered at either end where it passed through the guide wall. The tubes were finally waxed in position to give a vacuum-tight assembly, and during operation they were fed with tap-water running at full bore. The input v.s.w.r. of the assembly varied between the limits 0·88 and 0·96 at the design frequency, according to which tubes were in circuit, and the insertion loss of the system with all the tubes empty was negligible. No arcing was observed at high power, and the overall performance was satisfactory.

Preliminary low power experiments at $\lambda_a = 10\cdot00$ cm on this form of attenuator indicated that, for a given sample of water in a tube of given cross-sectional dimensions, the total attenuation produced (in db) was roughly proportional to the length of glass in the guide, and also depended to some degree on the method of insertion of the tube. For a given size of tubing the input match of the attenuator improved with increase of tube length. Those tubes which were measured when empty had voltage reflection coefficients $<0\cdot053$ (i.e. $>0\cdot9$ v.s.w.r.) and gave negligible insertion loss.

R.f. radiation from the exposed ends of the glass was experienced with the larger diameter tubes, and was more pronounced when the tube was filled with water. This was to be expected, since power leakage from a guide is proportional to the sixth power of the diameter of a hole in the guide wall,[6] and also depends on the permittivity (ε) of the medium enclosed by the hole. The value of ε for water at 20° C. is approximately 80 at 3,000 Mc/s, whereas with an empty tube the effective permittivity would be somewhat less than that for the glass alone ($\varepsilon = 4$), depending on the ratio of the cross-sectional area of glass to that of the hole. A further complication arises since the tube ends also act as dielectric rod aerials. However, the radiation may generally be suppressed by encasing the exposed length of glass in a metal tube joined to the main guide.[7] Given suitable dimensions the metal case will act as a waveguide below cut-off, so that any propagation along the ends of the glass tube will be rapidly diminished. This constructional refinement was incorporated in the attenuators used on the 1·5 MeV accelerator.

An unusual feature noted in these experiments was the variation of total attenuation (α) with the inner diameter (d) of the tube (α being defined in the usual logarithmic manner). For a given length (l) of glass, instead of the loss increasing smoothly with d as might be expected (i.e. α/d^2 being constant, since d^2 is proportional to the volume of water), it was found that tubes with internal diameters lying within a certain restricted range (about 8–10 mm.) consistently yielded greatly enhanced values of α. Using Malvern tap-water in a tube of normal wall thickness with $d = 9$ mm. and outside diameter $(D) = 11$ mm. an attenuation of about 12 db per foot length could be obtained, this figure being comparable with that afforded by tubing having twice this value of d. For a given length, the match of the smaller tube was better. Lead glass was also tried, and the limited amount of data acquired showed complete agreement with that for borosilicate tubing of the same dimensions.
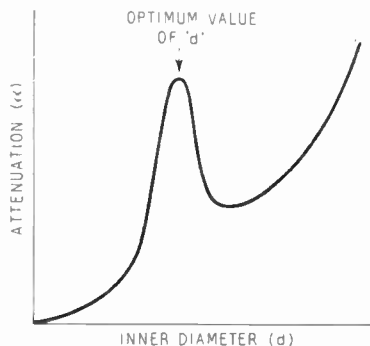

Fig. 1.—*Variation of attenuation with inner diameter of tube.*

From the results obtained it appeared probable that (for constant l) the variation of α with d was somewhat as predicted by the curve of Fig. 1. There were also indications that the tube wall thickness was a determining factor, and this is understandable since both the permittivity and the dielectric loss of glass are intermediate between those of air and water; the ratio: volume of water/volume of glass i.e., $d^2/(D^2 - d^2)$ should therefore be of some importance.

The general shape of the curve of Fig. 1 has been confirmed by M. G. Hine and J. B. Adams[8] of A.E.R.E., Harwell.* While Harwell tap-

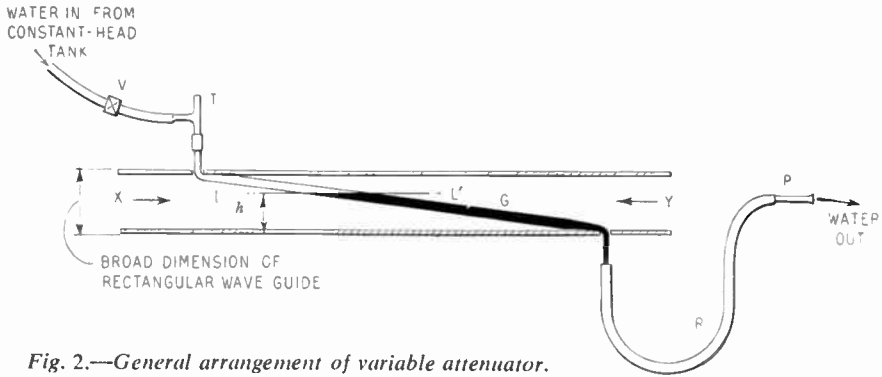* Now members of C.E.R.N., Geneva.

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Fig. 2.—General arrangement of variable attenuator.

water appears to have a somewhat higher loss than Malvern water, the results obtained by these workers also indicate a peak value of attenuation in the region of 9 mm water column diameter. K. J. Howard of A.E.R.E. has also constructed a 10-db attenuator, similar to those described above.

The success achieved with this type of fixed attenuator, coupled with the discovery of the optimum tube size, prompted the development of the variable attenuator considered below.

2. Variable Attenuator—Principle of Operation

The glass-tube attenuator described above may be adapted to act as a variable attenuator by adjustment of the water column height in the tube.[9] The geometry of the assembly should be such that the tube axis does not lie in a horizontal plane. The attenuation produced will then be directly proportional to the height of water column in the waveguide.

The general arrangement is shown in Fig. 2. The water level LL' in the glass tube G may be varied by adjusting the height of the horizontal outlet pipe P, which is attached by a rubber hose R to the lower end of the tube. Water from a constant-head tank (not shown) is fed to the upper end of the tube via control valve V and a glass T-junction injector T. The valve is adjusted to provide a steady replenishment of water, sufficient to prevent overheating of the attenuator through the dissipation of r.f. power.

Figure 3 illustrates the principle of injection used. Water from the tank runs at full bore in the horizontal arm A of the T-piece until it reaches the junction, when it falls steeply away into pipe B which is attached to the upper end of the attenuator tube. The upper end C of the T-junction is open to the atmosphere and provides an air path down the centre of the tube, so preventing the formation of bubbles or air-locks. The flow is thus made to enter the attenuator section as a thin film on the inner surface of the tube. This method of injection, plus the use of the constant-head tank, ensures stability of the water level in the main tube at any setting of the outlet pipe P.
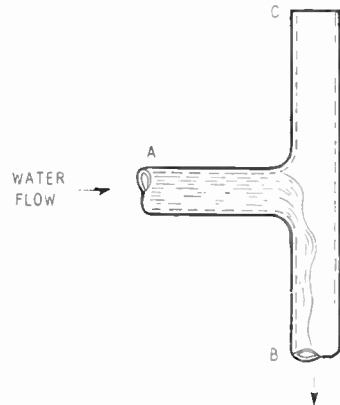
Fig. 3.—Glass T-junction injector.

The slanting arrangement of the main tube allows the upper surface of the water column to taper away gradually, thus reducing the mismatch offered to an incident r.f. wave.

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3. Prototype Model—Experimental Results

The specifications for a prototype attenuator were based on a consideration of its use in an S-band waveguide assembly fed by a 10-cm magnetron. With the valve operating conditions taken to be: pulse width $= 2\mu$ sec, pulse recurrence frequency $= 50$ c/s, peak power $= 2$ MW, the mean power to be handled is therefore 200 W. In order to dissipate substantially all of this power, whilst keeping the rise in temperature of the water to within $20°$ C, a flow of 150 cm^3/min. would have to be maintained.
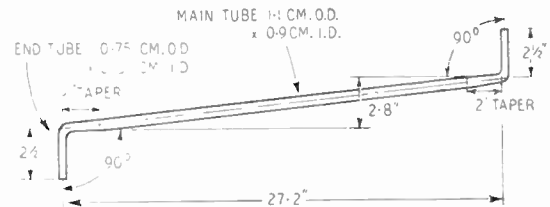
Fig. 4.—Glass attenuator tube.

The attenuator tube used was of "Phoenix" glass with dimensions as shown in Fig. 4. The tapered ends helped to preserve the r.f. match, while the narrow input and output tubes, bent to project at right angles from the guide walls, assisted in minimizing radiation losses. The diameter chosen for these end sections was a compromise, since no anti-radiation "caps" were fitted on this simple model, and while further reduction in the tube size would have helped to offset this, the resulting water turbulence at the upper bend would then have tended to block the air passage down the main tube and so render the system unworkable.

The glass was cleaned thoroughly with chromic acid and washed in distilled water. After being dried it was finally waxed in position between the longitudinal centre-lines of the narrow faces of a 32-in. length of standard brass waveguide (WG.10) fitted with choke couplers. To allow for insertion of the tube, one of the holes in the guide wall was elongated to $^{11}/_{16}$ in., the slot being covered by a soldered brass plate after positioning the tube.

Low-power tests were made using a c.w. klystron (CV35) operating at $\lambda_a = 10.00$ cm. Loss measurements were carried out by a "substitution" method,[10] the insertion loss of each

length of water column being read off calibrated variable attenuators (accurate to within $\pm 5\%$) on the power input side of the water load. A crystal detector and galvanometer, fed from the output end of the system via a "buffer" attenuator, indicated the point of balance. Standing wave tests were made with the water attenuator directly terminated by a tapered wooden load (v.s.w.r. $= 0.99(7)$). The more important results are given below.

(i) *No water:* The input v.s.w.r. of the guide and tube depended on the direction of power flow through the section, and was $0.92(5)$ in one direction and $0.94(5)$ for the other. This discrepancy can be attributed to the overall effect of several small mismatches, notably that due to elongation of the tube location hole (described above).

The insertion loss (α) of the complete section was found to be 0.1 db approximately.

(ii) *Static head of water:* For power flow in direction X (Fig. 2) the variation of input match with height of water column (h) is given in Fig. 5a (h being measured from the outer face of the lower guide-wall to the water surface, as shown in Fig. 2). The best and worst values of v.s.w.r. were $0.97(1)$ and $0.78(0)$ respectively, and with the tube full of water the match was $0.92(0)$ v.s.w.r. The undulating nature of the curve is due to the mismatch of the water column helping to cancel out that due to the glass tube and guide holes at some points, and adding to it at others.
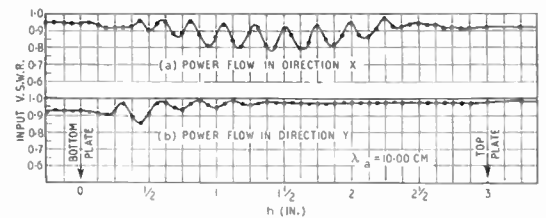

Fig. 5.—Prototype model (Static head)—Variation of input v.s.w.r. with height of water column.

With power flow in direction Y (Fig. 2) the v.s.w.r./h curve of Fig. 5b was obtained. As shown, the match varied between the limits $0.99(2)$ and $0.85(2)$ v.s.w.r. and was substantially constant at $0.97(5)$ over more than half the range. This latter effect results from the

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attenuation of the water column buffering the mismatch due to the column itself, which depends in part on the reflection at its upper surface.

For power flow in either direction the variation of α with h was found to be almost exactly linear over the whole range, as shown in Figs. 6 and 7, the maximum attenuation being approximately 28 db in each case. The slight peak in attenuation noted at the upper end of the range in Fig. 6 can be attributed to radiation effects;
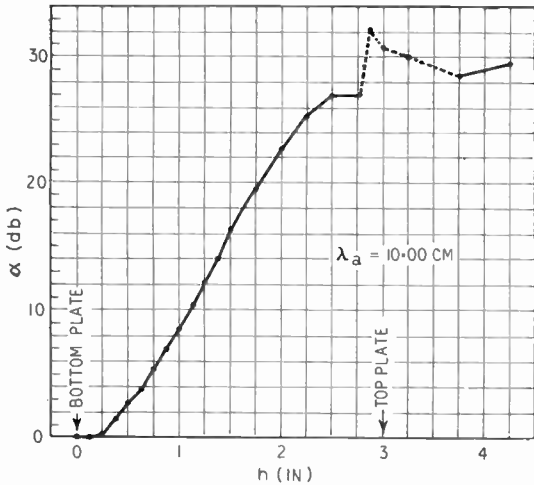
Fig. 6.—*Prototype model (Static head)—Variation of attenuation with height of water column. (Power flow in direction X).*
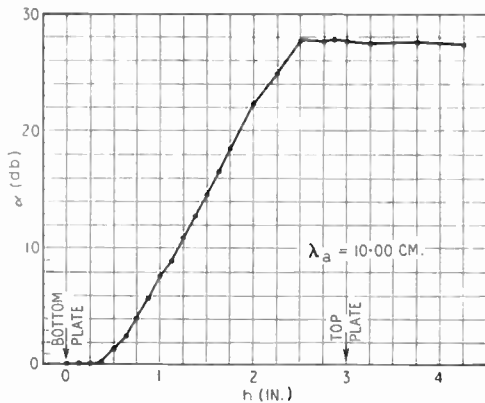
Fig. 7.—*Prototype model (Static head)—Variation of attenuation with height of water column. (Power flow in direction Y).*
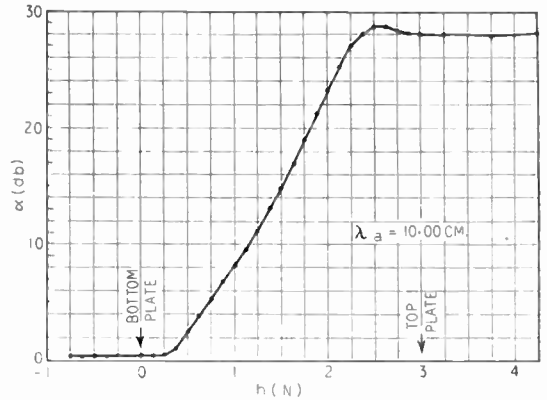
Fig. 8.—*Prototype model (Dynamic head)—Variation of attenuation with height of water column. (Power flow in direction Y).*

these are possibly assisted by the mismatch of the water column, since the peak is absent in Fig. 7, where the buffering effect of the column provides a better match.

(iii) *Dynamic head of water* (Flow 150 cm³/ min.): The α /h curve of Fig. 8 was taken with power flow in direction Y (Fig. 2). The attenuation remained constant at each setting of head, and comparison with Fig. 7 shows that the variation is virtually identical to that for a static head. The initial 0·4 db noted at the lower end of the range (Fig. 8) is the loss due to the water film alone; this was also checked for flows of 100 and 50 cm³/min. and found to be 0·3 db and 0·2 db respectively.
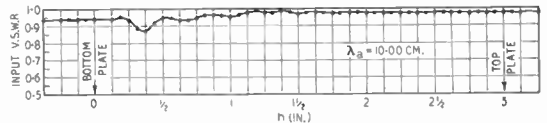
Fig. 9.—*Prototype model (Dynamic head)—Variation of input v.s.w.r. with height of water column. (Power flow in direction Y).*

Figure 9 gives the variation of input match with h for power flow in direction Y. The v.s.w.r. varied between 0·98(8) and 0·86(8), the fluctuation being smoother than that of the corresponding static head curve (Fig. 5b). This again was due to the effect of the water film.

No high-power tests were made on this model.

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4. Final Assembly—Experimental Results

A second model attenuator was constructed using a $33\frac{1}{2}$-in. length of No. 10 brass guide fitted with Inter-Service vacuum couplers. The general arrangement was as before, except that each end of the tube was held by a vacuum-sealed outlet assembly, shown in section in Fig. 10. This construction helped in preventing vibration of the tube, and in lessening the risk of accidental breakage.
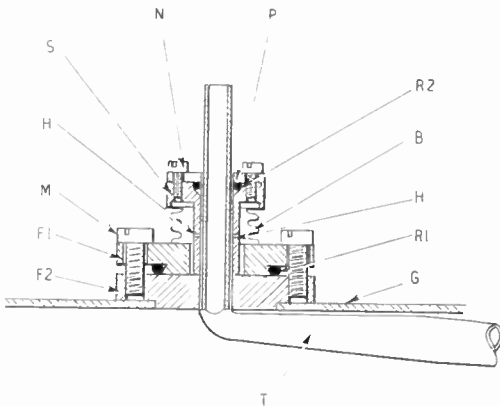

Fig. 10.—Vacuum-sealed outlet assembly.

In the Figure, the metal bellows B is soldered at its upper end to the "anti-radiation" sleeve S, and at its lower end to the loose flange F1. The latter carries a Gaco sealing-ring R1 and four 2 B.A. bolts M which locate in tapped holes in flange F2, soldered to the narrow wall of the main guide G. The upper face of sleeve S is recessed to accommodate a second Gaco ring R2 which grips tightly around the outside of the glass tube T, and is kept in position by four 6 B.A. bolts N passing through a retaining plate P. The lower end of the sleeve has a rounded edge which rests on the upper face of flange F2 and is held by the action of the bellows, evacuation of the latter being via the two small holes H in the sleeve wall. As on the previous model, allowance has to be made for the insertion of the tube by elongating the central hole in flange F2 carried at one end of the guide; this arrangement, together with the play afforded by the bellows, allows easy replacement of the tube and some relaxation of tolerance on the length of the glass.

Low-power tests were carried out on the model, which incorporated the identical glass tube used in the prototype version described above. The ancillary apparatus and methods of measurement remained as before, but in this case all the readings were taken with power flow in direction Y (Fig. 2). The following results were obtained : —

(i) *No water:* The variation of input match with λ_a is given in Fig. 11a. For the values of λ_a taken (9·90–10·10 cm) the change in v.s.w.r. was only about $\pm 0·5$ per cent of its value [0·96(5)] at 10·00 cm. The insertion loss of the guide and tube complete was found to be of the order 0·03 db at 10·00 cm.

(ii) *Dynamic head of water* (Flow 150 cm³/min.): With the tube full of water, the variation of match over the same 2 per cent wavelength band is shown in Fig. 11b, the overall change in v.s.w.r. being 4 per cent. The input v.s.w.r. at the centre of the band ($\lambda_a = 10·00$ cm) was 0·94(3).
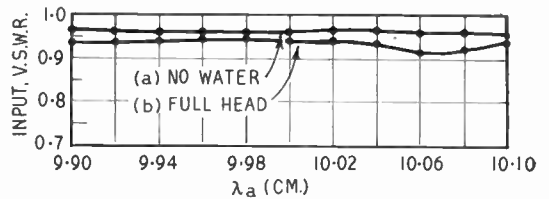

Fig. 11.—Final assembly—Variation of input v.s.w.r. with air wavelength (Power flow in direction Y).
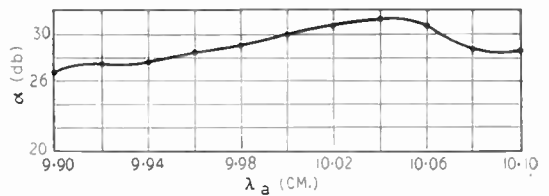

Fig. 12.—Final assembly (Full head)—Variation of attenuation with air wavelength. (Power flow in direction Y).

Figure 12 gives the maximum attenuation obtained at different values of λ_a within the band, the overall variation in α being 16 per cent. The loss of the water film itself was also checked at $\lambda_a = 10·00$ cm and found to be 0·7 db along the complete length of tube lying within the guide.
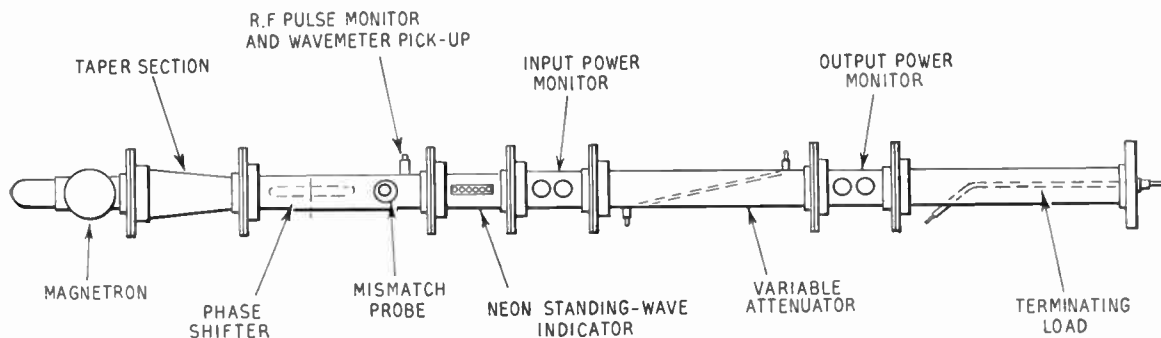
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TAPER SECTION

R.F PULSE MONITOR
AND WAVEMETER PICK-UP

INPUT POWER
MONITOR

OUTPUT POWER
MONITOR

MAGNETRON

PHASE
SHIFTER

MISMATCH
PROBE

NEON STANDING-WAVE
INDICATOR

VARIABLE
ATTENUATOR

TERMINATING
LOAD

Fig. 13.—High-power test assembly.

High-power tests were made using a VX4061 magnetron operating at $\lambda_a = 10.00$ cm. Fig. 13 gives the general assembly. As shown, the waveguide run was terminated by a reliable glass-tube water-load of standard pattern, and calibrated thermo-couples (S.T. & C. Nos. S10 A and B) were used to monitor the input and output power of the variable attenuator. The mean power handled was 200 W, and the water flow was adjusted accordingly to 150 cm³/min. With the system evacuated to a pressure of about 40 millimicrons of mercury, no arcing was observed at any setting of the attenuator when the magnetron was delivering its full 2MW peak power, and no stray radiation was detected. The stability of the attenuator was exceptionally good, and its performance was judged to be satisfactory in every way.

5. Conclusions. Future Development

The variable attenuator described provides a practical means of controlling the total power in an S-band waveguide system, and is particularly useful at high peak powers. Its application to other wavelength bands has not been investigated, but may prove worth while. The use of smaller guide sizes would affect the choice of tube diameter, however, and the singular dependence of attenuation on this diameter (noted in Section 1 above) may be considerably modified in effect, or even non-existent, at these shorter wavelengths. The question of turbulence would also prove more troublesome with smaller sizes of tube.

There is as yet no completely conclusive analysis of the mechanics of propagation in the attenuating section, but it could well be that the original H_{01} wave in the rectangular guide is converted by the introduction of the dielectric tube to a combined E and H mode having all six longitudinal and transverse field components present. By measurement of the standing wave pattern of Fig. 5a, it is found that this hybrid mode has an apparent guide wavelength of approximately 11 cm.

In the author's opinion, it seems probable from the dimensions of the system that a coaxial-type mode (somewhat resembling the E_{01} mode in circular waveguide) is set up in combination with H_1 and E_1 mode-types. The "E_{01}" component would conceivably appear as a surface wave on the dielectric tube as its configuration makes for little loss of power in the water column, and it would thus be probably responsible for the greater part of the propagation. On the other hand, the loss in the tube is most likely due to the H_1 and E_1 components, since these would have their greatest values of field-strength inside the water column.

The geometry of the attenuator provides a rough means of calibration, since the loss produced is approximately proportional to the height of water in the tube. In practice, however, the head of water can be adjusted to give the desired attenuation as indicated by thermocouples mounted on the input and output ends of the guide; this adjustment may be made automatic by the incorporation of a suitable servo system. Where the attenuator is used as a terminating load (i.e., with a full head of water) the power dissipated may alternatively be measured by a calorimetric method. Here, if the recommended arrangement with power flow in direction Y (Fig. 2) is used, the water output

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end carries the brunt of the power dissipation, and the heat losses prior to measurement would be small, thus making for accurate results. In terminating load applications where uniform dissipation per unit length of tube is desirable, some modification such as tapering the guide walls[11] might be introduced.
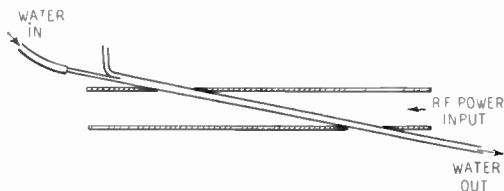

Fig. 14.—Modified attenuator arrangement for high mean power working.

An increased flow would be necessary for use with higher mean r.f. powers, and in order to avoid air-locks in the water system the tube could be inserted straight through the guide, as shown in Fig. 14. Radiation difficulties might be experienced even with the use of caps, due to the increased diameter of the portion of tube outside the guide and the larger holes necessary in the guide walls, but the power leakage could be minimized, and the match improved, by mounting the tube diagonally (i.e., corner to corner) across the guide; this arrangement was actually used in some of the fixed attenuators described in Section 1. Where still higher mean powers have to be dissipated, the water might be replaced by a suitable liquid having greater dielectric loss (e.g., brine).

In conclusion, it seems reasonable to expect that this type of attenuator would work well over a broad band of frequencies, and it should prove useful in many applications such as the production testing of S-band magnetrons, high-power coaxial-diode detectors, and various waveguide components.

6. Acknowledgments

7. References

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2. *Ibid.*, p. 204 et seq.
3. H. M. Barlow and A. L. Cullen, "Micro-wave Measurements," p. 225 et seq. (Constable, London, 1950).
4. C. G. Montgomery, *loc. cit.*, p. 195.
5. R. J. B. Hadden, "Linear Electron Accelerator with a Dielectric Loaded Waveguide." (A.E.R.E. Report No. GP/R 1161, July 1953.)
6. H. A. Bethe, "Theory of diffraction by small holes," *Physical Review*, **66**, 1944, p. 163.
7. F. G. Terman and J. M. Pettit, "Electronic Measurements," p. 680. (McGraw-Hill, New York, 1952.)
8. M. G. Hine and J. B. Adams, British Patent Application No. 30000/52.
9. L. B. Mullett and B. E. Kingdon, British Patent Application No. 29999/52.
10. C. G. Montgomery, *loc. cit.*, p. 808.
11. *Ibid.*, p. 200.

GRADUATESHIP EXAMINATION—MAY 1955

<u>SECOND</u> PASS LIST

This list contains the results of the remaining oversea candidates not included in the list published on page 428 of the August issue of the *Journal*. A total of 597 candidates entered for the Examination.

The following candidates, having completed the requirements of the Graduateship Examination, are eligible for transfer or election to graduateship or higher grade of membership.

ADUR, Mohanrao Narayanrao. (S) *Bombay*.

GOKHALE, Narayan Ramchandra. (S) *Bombay*.
GURBAX SINGH. (S) *Ju'lundur*.

HALBE, Madhusudan Narayan. (S) *Poona*.
HARCHARAN SINGH. (S) *Mhow*.

JOSHIRAO, Bhalachandra G. (S) *Poona*.

KANDASAMY, Manicavasagam. (S) *Pa!amcottah*.

MEHAR SINGH. (S) *New Delhi*.
MENON, Karunakaran C.P. (S) *Chittur-Cochin*.

RAJA, Manakrulam Krishna. (S) *Meerut*.
RUBIN, Moshe. (S) *Haifa*.

SAXENA, Mahinder Sahai. (S) *Ferozepore*.
SOOD, Ramesh Chander. (S) *Bombay*.
SUBBARAMU, Kattepur Ramaswamy. (S) *Bombay*.

TALWALKAR, Krishnaji Balbhim. (S) *Poona*.

UDYAVER, Manohar Shriped. (S) *Bombay*.

The following candidates were successful in the Parts indicated.

ARORA, Vir Arjun. (S) *Jaipur*. (I, IIIa).
ASLAM, Mohammed. (S) *Lahore*. (I).

BALASUBRAMANIAN, Mallagi Ramanatha. (S) *Madras*. (IIIb).
BEN-DOR, Baruch. *Bne-Brak, Israel*. (I, II).
BHARGAVA, Una Shankar. (S) *New Delhi*. (IV).
BHOWMICK, Saurendra Nath. (S) *Bangalore*. (II, IIIa).
BRAUN, Simon. (S) *Haifa*. (IIIb).
BRUNNER, Amos. (S) *Tel-Aviv*. (II, IIIa).
BUCHBINDER, Martin J. (S) *Tel-Aviv*. (I, II, IIIa).

CHABRIA, Bihari. (S) *Bombay* (IIIa).
CHARANJIT SINGH. (S) *Agra*. (IV).
CHATURVEDI, Ram Nath. (S) *Deoria*. (IIIa).
CHEW BAK KHOON. (S) *Singapore*. (I).
CHIMNI, Inderjit Singh. (S) *Hyderabad* (IIIb).
COLLINS, William Clarence. (S) *Ottawa*. (II).
CRACHAM, Shaul. (S) *Kfar Ono, Israel*. (IIIb).

DADDS, Dean Wilfrid. (S) *Port Hedland, Western Australia*. (I).
D'SOUZA, Denis. (S) *Bombay*. (IIIa).
DUGGAL, Jagmohan Sarup. (S) *Bombay*. (IIIb).

GANDOTRA, Indar Mohan. (S) *Gurdaspur*. (II, IIIa).
GOGATE, Bhalchanra Damodar. (S) *Gurgaon*. (IIIa).
GOUTAMA, Mysore Ananthamurthy. (S) *Bombay*. (IIIb).
GOVINDAKRISHNAN, Tirunilayi Krishnan. (S) *Bombay*. (IIIb).
GOVINDARAJAPURAM, R. Gayatri Vallabhan. (S) *Bombay*. (IIIb).
GULATI, M. L. *New Delhi*. (I).
GURDIAL SINGH. (S) *Kuala Lumpur*. (I).
GURMEL SINGH. *New Delhi*. (I).

HATTANGADI, Bansidhar Srinivas. (S) *Gwalior*. (IIIa, IIIb).
HEBBAR, Hanglur Rajagopal. (S) *Madras*. (IIIa).
HSU SIN PO. (S) *Singapore*. (I).

JOGDAND, Keshav Raghunath. *Bombay* (I).

KANWAR, Randhir Singh. (S) *Delhi*. (IIIb).
KAPOOR, Mulk Raj. (S) *New Delhi*. (I, II).
KARTAR SINGH BAWA. (S) *Gurda:pur*. (IIIa).
KATARIA, Prem Nath. (S) *Simla* (IIIa).
KHAMBADKONE, Merlidhar Ramrao. *Bombay*. (I)
KRIEGER, Moshe. *Tel-Aviv*. (I, IIIa).
KRISHNASWAMY RAO, M. S. (S) *Bangalore*. (I.)
KUNDU, Sati Nandan. *Kanpur* (I, II).

LAKDAWALA, Homi Feroze. (S) *Bombay*. (IIIb).
LAKSHMINARAYANAN, A. K. (S) *Tirunelveli*. (II).
LUTHRA, Suraj Parkash. (S) *Ludhiana*. (IIIb).

MAHAJAN, Prabhakar Shankar. (S) *Nasik City*. (I).
MAHAJAN, Raj Kumar. (S) *Lucknow*. (IIIb).
MASAND, Bragwan M. (S) *New Delhi*. (IIIb).
MATHEWS, Abraham. (S) *Agra*. (IIIa).
MATHUR, Suresh Chandra. *Delhi*. (IIIa).
MEHTA, Gunvant Jagjivandas. (S) *Umrala*. (IIIb).
MEYER, Leighton Francis. (S) *Wellington, New Zealand*. (I).
MITRA, Nihar Ranjan. (S) *Howrah*. (I).
MOHAN, Singh Sawhney. (S) *New Delhi*. (IIIb).

NALLIAH, Stephen Chelvarasa. *Madras*. (I, IIIa).
NARASIMHAN, K. Srivasachary L. *Bangalore*. (I).
NARAYANA RAO, Nannapaneni. (S) *Madras*. (IIIb).
NEUMARK, Nathan. (S) *Haifa*. (II, IIIa).
NG SONG KANG. (S) *Singapore*. (I).

PRASAD RAO, G. S. (S) *Jatni*. (I).

RAHEJA, Udhavlal Topandas. (S) *Bombay*. (IIIa, IIIb).
RAIKWAR, Sham Sher Singh. (S) *Dehra Dun*. (I).
RAUDNITZ, Jacow. *Tel-Aviv*. (IIIa).
RODDY, Dennis. (S) *Toronto*. (IV).
ROY, Arun Kumar. (S) *Jamshedpur*. (II).
ROY, George. (S) *Calcutta*. (IIIa).

SEKHRI, Guatam Dev. (S) *Bangalore*. (II).
SEN GUPTA, Rabindra Nath. *Calcutta*. (I, II).
SHARP, Gregor Hugh. (S) *Sydney*. (IIIb).
SHEMY, Kalman (S) *Tel-Aviv*. (I, IIIb).
SIVASUBRAMANIAN, K. P. *Poona*. (IV).
SODHI, Kulwant Singh. (S) *Rohtak*. (IIIb).
SOKHI, Sohan Singh. (S) *Bombay*. (IIIa).
SMITH, Terence William. (S) *M.E.A.F*. (IIIa).
SMOOHA, Menashe. (S) *Kiryat Ouno, Israel*. (I, II).
SREEDHARA, Mijar Kanakabettu. (S) *New Delhi*. (IIIa).
SRINIVASAN, Viswanathan. (S) *Bangalore*. (II, IIIa).

TALWAR, Satish Kumar. *Agra*. (I).
TANEJA, Manohar Lal. (S) *Delhi*. (IIIb).
TARLOCHAN SINGH. (S) *Jhansi*. (I).
THADANI, Hiro K. *New Delhi*. (IIIa)
THAMPI, Sridhar Ramavarma Srikumaran. (S) *Madras*. (I).
TOLE, Yashavant Dattatray. (S) *Jabalpur*. (I, II).
TURNER, Brian Robert. (S) *Bermuda*. (I).

UPPAL, Kanwal Krishan. (S) *New Delhi*. (IIIa).

VENKATARAMAN, Anthiyur Raju. (S) *Bangalore*. (IIIb).
VENKATARAMANI, B. *Madras*. (IV).
VENKATESWARAN, Vadakanthara V. (S) *Bangalore*. (IIIb).
VENKATESWARLU, Uppala. (S) *Krisna*. (IIIb).

YOUNG, William Arthur. (S) *Mombasa*. (IV).

(S) denotes a Registered Student.

# of current interest . . . .

British Radio Industry Statistics

According to the Board of Trade accounts, exports of all types of radio equipment for the first half of 1955 were over half a million pounds greater than for the corresponding period of 1954.

The greatest increases were of valves and cathode ray tubes which rose from £1·04 million to £1·25 million and sound reproducing equipment which increased from £121,000 to £610,263.

On the other side of the account, however, imports of all types of equipment have nearly doubled, £6,019,235, as compared with £3,857,788 for the same period last year.

While normally it might have been thought a large amount of this equipment was in the form of valves and components which might subsequently be re-exported, this is not in fact the case. Imports of valves and cathode ray tubes are slightly down compared with 1954 but the general category which includes broadcast receivers, sound equipment and components has increased more than three times and stands at £3,553,258 for January to June of this year.

The Atlantic Telephone Cable

The cable-laying ship H.M.T.S. *Monarch* sailed from the Thames on the 30th July with 1,300 nautical miles of cable and 29 flexible repeaters to lay the first deep-sea section of the transatlantic telephone cable which is to link the U.K., Canada and the U.S.A.

The contract for this project was announced in November, 1953, the cost then being estimated at £12·5 million. Since that time costs have risen on both sides of the Atlantic and the final cost is now expected to be £15 million.

Monarch has already laid 200 miles from Newfoundland earlier this year. The deep-sea section will join the Newfoundland cable and cross the Atlantic at depths of up to 2½ miles to the Rockall Bank about 500 nautical miles from Britain. Later another cable will be laid from Rockall to Oban.

The cable, costing nearly £5 million, has been manufactured at a specially built factory of Submarine Cables Ltd. at Erith on the Thames. Since the beginning of July the *Monarch* has been loading the cable over special gear from the works at the rate of up to 100 miles a day. Cable for the opposite direction, now being made, is due for completion by the end of 1956.

Third International Conference of Communications

Further details are now available of the Conference to be held in Genoa at which the International Prize to honour the memory of Christopher Columbus will be awarded. Extending over 5 days from October 8th to 12th, papers will be read by international experts on all aspects of communication, including land, sea and air transport, and telecommunications.

Telecommunications will be the subject of the meetings on October 11th and in addition to papers by Dr. Vladimir Zworykin and M. Maurice Ponte, the work of Guglielmo Marconi will be commemorated, both by papers and by experimental demonstrations of radio transmission.

Australian Television Channels

The Australian Postmaster General has recently announced the allocation of frequency channels to Sydney and Melbourne National and Commercial Television stations. These are:—

National stations—Channel 2 (63 to 70 Mc/s).
Commercial stations—

Channel 7 (181 to 188 Mc/s).
Channel 9 (195 to 202 Mc/s).

I.T.A. Development in the Midlands

Details have now been issued of the estimated service area of the Independent Television Authority's Lichfield transmitter which is expected to come into operation early in 1956. The primary service area should extend about 30 miles west (Wellington), 35 miles north (Matlock), 35 miles east (Market Harborough) and for over 50 miles to the south (area of the Vale of Evesham).

The estimated population within the whole area is approximately six millions and there are at present about 800,000 television licence holders.

The effective radiated power of the transmitter will initially be at least 144 kW and may be increased later to 200 kW or more. The aerial will be carried on a 450-ft. self-supporting tower, the base of which is 500 ft. above sea level.

The Independent Television Authority has now moved to its permanent headquarters at 14, Princes Gate, London, S.W.7. Telephone number KNIghtsbridge 5341.

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