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

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REPORT OF THE TWENTY-SEVENTH ANNUAL GENERAL MEETING

THE INSTITUTION'S TWENTY-SEVENTH ANNUAL GENERAL MEETING (the nineteenth since incorporation) was held at the London School of Hygiene and Tropical Medicine, Gower Street, London, W.C.1, on Wednesday, October 8th.

Mr. Paul Adorian (President) was in the Chair and was supported by other Officers of the Institution and members of the General Council. Over 60 Corporate Members had signed the Minute Book when the meeting opened.

1. To confirm the Minutes of the 26th Annual General Meeting held on October 11th, 1951

A report of the last Annual General Meeting was published on pages 413-416 of the *Journal* dated October 1951. The President's proposal that these Minutes of the proceedings be signed as correct was carried unanimously.

2. To receive the Annual Report of the General Council. (Published on pages 461-474 of the September 1952 *Journal*)

Mr. Adorian first paid tribute to the work of the Chairmen of the various Standing Committees whose individual reports were incorporated in the Annual Report. Every aspect of the Report showed further extension of the Institution's activities coupled with a growing membership, primarily based on increasing examination entries.

Referring to the work of Committees, Mr. Adorian stated that it was with regret that he had to announce the retirement of Sir Louis Sterling from all public offices. Before his election as President in 1942 Sir Louis had been a tower of strength and his help in recent years on the Council and Finance Committee had been particularly welcome. Mr. Adorian felt that the membership would wish to send some special message of appreciation to Sir Louis, and this was approved unanimously.

Mr. Adorian then recalled the reference made at the last Annual General Meeting on the possibility of a change in the Institution's name. No special wish was expressed on that occasion and subsequently the concensus of opinion from outside Great Britain indicated considerable support for retaining the present title. The matter was, however, still under consideration by the Professional Purposes Committee.

The President said that the widespread recognition now being given to the Institution's membership and examination was a matter for considerable pleasure. In particular he wished to refer to the formation of further Sections overseas and to express thanks to those members who voluntarily gave service to the Institution on Section Committees.

During the year under review, the Institution had suffered a further loss by the death of Mr. Leslie McMichael, President between 1944-46. Members would recall that Mr. McMichael had been instrumental in the formation of the South African Section and had rendered valuable service in cementing the cordial relations which existed between the Australian I.R.E. and the Brit. I.R.E.

Before moving the adoption of the Report, Mr. Adorian said that reference must be made to the honour and privilege of the Institution in having the Patronage of Her Majesty the Queen.

All members had felt greatly honoured by His late Majesty King George VI becoming first Patron, and the honour conferred on the Institution by Her Majesty was a cause for great satisfaction.

Mr. Adorian then formally moved the adoption of the Annual Report of the General Council.

Mr. W. McMenemy (Member), seconding the motion, said that to one who was serving on the Membership Committee, the growth of the Institution's status in step with its growth in numbers was a matter for great satisfaction. He considered that insistence on the strictest scrutiny of all applications for membership was amply justified by results.

The Report was approved unanimously.

3. To elect the President

Mr. Adorian announced his intention of departing from the formal Agenda by postponing the election of President until the end of the meeting when the work relevant to his own year of office had been completed.

4. To elect the Vice-Presidents

The Council had recommended for re-election as Vice-President, Mr. Leslie H. Paddle, who was residing in Canada. Mr. Adorian spoke of Mr. Paddle's work for the Institution in the past and of the value of his experience in plans for forming Sections in the Dominion.

The election of Rear-Admiral C. P. Clarke, C.B., D.S.O., as a Vice-President, would continue the Institution's 15 years' association with the Royal Navy. Mr. Adorian felt sure that in Rear-Admiral Clarke's present position as Director of the Naval Electrical Department, his advice and help would be of great value in the affairs of the Institution.

In formally submitting the election of Professor Zepler as a further Vice-President, Mr. Adorian considered that there was little need for him to refer to Professor Zepler since many of the younger members at least had come under his eye in qualifying for membership of the Institution. Professor Zepler had rendered sterling service for many years as an examiner, as a member of the Education and Examination Committee and subsequently as its Chairman, and as a member of the Council.

Approval was unanimously given to the re-election of Mr. Paddle, and the election of Rear-Admiral Clarke and Professor Zepler as Vice-Presidents.

Before proceeding to the next item, Mr. Adorian referred to Article 25 of the Institution's constitution, which permitted the election of four Vice-Presidents. Although in recent years this had not been done, the Council had decided to seek the meeting's approval of the election of Sir Ernest Fisk. It had not been possible to publish the nomination in the July *Journal* but, if agreeable to the members present, the election could be confirmed, after the requisite seven days, notice, at the general meeting to be held on November 5th. The nomination was unanimously approved.

5. To elect the General Council

Mr. Adorian referred to the fact that only once in the past five years had the General Council's nominations been subjected to additional nominations by the membership; the measure of confidence thus shown in the Council was most satisfying. As no opposition had been received to the nominations published in the July *Journal*, the President declared that those members were now elected to the General Council.

Mr. Adorian congratulated the new members on their election and expressed thanks to the retiring members for their services.

6. To elect the Honorary Treasurer

Mr. Adorian said that Mr. S. R. Chapman, who had served most assiduously as Honorary Treasurer since 1945, had not sought re-election but had agreed to accept office if elected. After paying tribute to Mr. Chapman's work on behalf of the Institution, Mr. Adorian formally recommended his re-election for the year 1952/53.

The proposal was carried unanimously.

7. To receive the Auditor's Report, Accounts and Balance Sheet for the year ended March 31st, 1952

In the absence of Mr. Chapman, who had unavoidably been prevented from attending the meeting, the President called upon Mr. G. A. Taylor, a member of the Finance Committee, to present the Accounts and Balance Sheet.

Mr. Taylor said that emphasis had, unfortunately, been on rising costs, often out of proportion to the increased consumption due to the upward trend in the cost of materials. Mr. Taylor referred to the regrets which the Finance

Committee felt at the restriction of expenditure on items which would provide further facilities for the membership; they were, however, convinced that the aim should be on building up reserves to meet unusual expenditure. He had been asked by the Honorary Treasurer to draw particular attention to the costs of, for example, conventions; the high standard which the Institution had for these very popular functions should in the future be at least partly financed from built-up reserves to prevent the whole of the charges being borne in any one year.

Mr. Taylor then spoke of the great help given to the Committee by Mr. Adorian's personal attention to increasing the revenue for the Building Fund. It was gratifying to be able to record that, even though every item of expenditure showed an increase, all items of revenue, and in particular the Building Fund, also were higher. The increases in normal revenue were of course built up by the constantly increasing membership, while increased revenue from the sale of the *Journal* was a welcome contribution to the Institution's income and an indication of the status of the Institution.

Passing to the Balance Sheet, Mr. Taylor referred to the growth of the fixed and current assets which were financed laboriously from normal income, with the exception of £400 donated some years ago and the recent generous contributions to the Building Fund.

Thus the earnest endeavour of the Finance Committee was to add to those assets while reducing the liabilities which had been incurred by special expenditure.

Summing up, Mr. Taylor said that the Committee was satisfied that the Institution had reasonably held its own during the past year and he therefore proposed the adoption of the Accounts, Balance Sheet and Auditor's report for the year under review.

In seconding the motion, Mr. J. L. Thompson congratulated Mr. Taylor on deputizing so ably for the Honorary Treasurer.

The Accounts were adopted unanimously.

8. To appoint Auditors

Mr. Adorian said that the acceptance of the Accounts reflected in some measure the Institution's satisfaction with the Auditors, who had been responsible for them for 13 years. He therefore recommended the reappointment of Messrs. Gladstone, Jenkins & Co.

The proposal was carried unanimously.

9. To appoint Solicitors

While not the concern of the meeting Mr. Adorian wished to place on record appreciation of the work done voluntarily for the Benevolent Fund by the Institution's solicitors. In Institution affairs Mr. Charles Hill was regarded by every officer as almost a pillar of the Institution and he had pleasure in recommending the reappointment of Messrs. Braund and Hill as Solicitors.

The proposal was carried unanimously.

10. Awards to Premium and Prize Winners

The presentation of awards Mr. Adorian considered to be the most pleasant side of the meeting and he regretted that all contributors to the Institution's Proceedings could not be thanked personally and be awarded premiums.

Premium and Examination Awards were then made in accordance with the details published in the September 1952 *Journal*. Rear-Admiral Clarke presented the Mountbatten Medal.

11. Any other business

No other business having been notified, Mr. Adorian proceeded to the remaining item, that of the election of President.

Mr. Adorian first thanked the Institution for the honour he had received of serving as President for two years and he was also grateful to the Officers, members of Council and Staff for their help during his period of office.

He was pleased that one of his last duties had been in assisting the Committee responsible for the choice of the 12th President of the Institution and it was with great satisfaction that he reported the unanimous nomination of Mr. William E. Miller.

Mr. Miller was an example of a member who by unstinted service justified in every sense the honour of President of the Institution. Well known throughout the radio industry he had been chairman of every Institution Committee at one time or another, a member of the General Council and its Chairman, and for the past four years a Vice-President of the Institution.

The retiring President then called on members to acclaim the election of Mr. William E. Miller as President for 1952/53.

REPORT OF THE ANNUAL GENERAL MEETING OF SUBSCRIBERS TO THE BENEVOLENT FUND

1. To receive the Annual Report of the Trustees

and

2. To receive the Auditor's Report, Accounts and Balance Sheet for the year ended March 31st, 1952

Mr. Adorian stated that the Annual Report of the Trustees had been published on pages 475-477 of the *Journal* for September, 1952, but he proposed that the first two items of the agenda should be dealt with together, for which purpose he called upon Mr. G. D. Clifford, Honorary Secretary to the Trustees.

Mr. Clifford said that the Fund had only been in existence for just over 10 years and he was sure that all subscribers would be happy to feel that there was machinery ready to give the best possible help in time of need. Help had been given in full and reasonable measure to every applicant and the fact that the Trustees had managed to do so, while at the same time building up the resources of the Benevolent Fund, should be a matter of great satisfaction.

The Balance Sheet showed how investments were being built up and from the income account it could be seen that as the membership grew so did the amount donated to the Benevolent Fund. Mr. Clifford particularly commended to members the Deed of Covenant scheme for augmenting their regular donations.

Particular mention should be made of the great work of Reed's School which had been in existence for 140 years. There were now about 260 children at the two schools, and that number could not be exceeded until building was possible. There was naturally considerable competition for entrance, and the Governors nominated candidates for the vacancies which remained after taking into account candidates awarded Presentations or Bursaries and candidates for whom full fees were to be paid.

It was the intention of the British Institution of Radio Engineers Benevolent Fund Trustees to finance Presentations or Bursaries to the School, but meantime the Trustees were grateful for the help given by the School in undertaking the education and boarding of dependants of deceased Members.

The motion was seconded by Mr. E. A. W. Spreadbury, a subscriber to the Fund, who felt that all subscribers would agree that the aims of the Fund were being carried out in a very adequate and praiseworthy manner.

The proposal for the adoption of the Accounts was unanimously carried.

3. To elect the Trustees for the year 1952-53

On behalf of the subscribers, Mr. Adorian first thanked the Trustees for the past year for their valuable services. He then proposed that the following should be elected for the year 1952-53:—

The President of the Institution.

The Chairman of the General Council.

Mr. A. H. Whiteley, M.B.E. (Companion).

Mr. E. J. Emery (Member).

Mr. S. R. Chapman, M.Sc. (Member), Honorary Treasurer.

Mr. G. D. Clifford, Honorary Secretary.

4. To elect the Honorary Solicitor and the Honorary Auditor to the Benevolent Fund

Mr. Adorian said he could not speak too highly of the voluntary services rendered to the Fund by Mr. Charles Hill and Mr. R. H. Jenkins as Solicitor and Accountant respectively. He formally moved their re-election and this motion was carried unanimously.

Following the conclusion of business of the Annual General Meetings, Mr. W. E. Miller, M.A. (Cantab.), gave his Inaugural Address as President.

At the conclusion of Mr. Miller's Address, a vote of thanks was moved by Mr. L. H. Bedford, O.B.E., M.A.(Cantab.), a Past-President of the Institution

The Presidential Address will be published in the *Journal* for January, 1953.

PREMIUM AND PRIZE WINNERS, 1951

Dr. Herbert Paul Williams, who was born in Germany in 1913, gained his B.Sc. degree in Physics and Mathematics in 1933 after studies at Chelsea Polytechnic. After two years in the laboratory of Murphy Radio, Ltd., he carried out ionospheric research at King's College, London, obtaining his Ph.D. in 1938.

Dr. Williams was then appointed a research engineer with Standard Telephones and Cables, Ltd., where he remained until 1947, when he became head of the Television Department of A. C. Cossor, Ltd. Since 1949 he has been head of the Electronics Department in the Fairey Aviation Company's Research Division.

The author of a well-known textbook on aerials and papers in technical journals, Dr. Williams first received the Clerk Maxwell Premium in 1947. The 1951 award is for the paper "Subterranean Communication by Electric Waves."

Elected an Associate Member in 1948, Dr. Williams served during 1950 on the Programme and Papers Committee.

George Robert Beswick, born in Grimsby in 1912, received his general and technical education in Bristol. His early experience was in chemical engineering with the Imperial Smelting Company, specializing in electronic measurement and control. In 1939 he became head of the spectrographic laboratory of Birmetals, Ltd., and later of the metallurgical research department. Earlier this year he joined the special circuits section of the English Electric Co. at Luton as a development engineer.

Mr. Beswick registered as a Student of the Institution in 1951 and was elected an Associate Member in March 1952 following success in the Graduateship examination. He received the President's Prize as the most successful candidate amongst those passing the entire examination at one sitting, and the Electronic Measurements Prize as the most outstanding candidate taking that subject in Part IV.

Graham Estyn Roberts, born in 1913 at Bombay, was educated at Rydal School. His early technical training was with H. C. Atkins Laboratories and later he became a television test engineer with Ultra Electric, Ltd.

In 1946 Mr. Roberts joined the Decca Navigator Company as an electronics engineer. He is in charge of a section designing electro-mechanical computers for navigational systems. This work formed the subject of his 1951 Convention paper on "The Design and Development of the Decca Flight Log," for which he received the Brabazon Premium.

Mr. Roberts was elected an Associate Member of the Institution in September of this year.

Colin James White was born in 1924 in London, and was educated at Eltham College. In 1942 he joined the Royal Air Force and served throughout the war until 1952 in the Signals branch, being mainly concerned with the installation of ground radio stations. After a few months with the Services Equipment Division of Marconi's Wireless Telegraph Co., Ltd., Mr. White joined the engineering division of the B.B.C. in May, 1952.

Registered as a Student in 1950, Mr. White qualified for transfer to Graduate in November 1951. He received the Mountbatten Medal as the candidate passing highest in all subjects while serving in H.M. Forces.

NOTICES

Institute of Technology, Loughborough College

As a result of representations from the Leicestershire Local Education Authority, the Minister of Education has decided to relieve the Authority of responsibility for maintaining the Engineering and Science Departments of Loughborough College and to organize them as a separate establishment maintained principally by grant from the Exchequer.

Loughborough College is widely known for the training of engineers, and its students are drawn from all parts of the United Kingdom and from abroad. In view of the increasing burden on the Leicestershire ratepayers for the small number of Leicestershire students in attendance (about 50 out of a total of over 800) the local Education Authority asked the Ministry of Education to assume financial responsibility for the Science and Engineering Departments. The new College will be known as the Institute of Technology, Loughborough College.

Insignia Award in Technology

The City and Guilds of London Institute* has previously awarded certificates in technology at three levels: Intermediate, Final, and Full Technological Certificates respectively. The Institute now considers that, in certain branches of industry, additional encouragement and recognition could usefully be given at a higher level than the Full Technological Certificate and has established under its Royal Charter an Insignia Award in Technology which will lay emphasis upon technical training based on practical experience. The main tests for the award of the insignia are the preparation and submission of a thesis or report and the subsequent interview by a panel of the Award Committee. In exceptional circumstances, the panel may require the candidate to sit for a special written examination.

Briefly, the general conditions governing the award are that the candidate should be not less than 30 years of age, have completed a full period of apprenticeship and obtained the Full Technological Certificate of the City and Guilds of London Institute in the appropriate branch of technology. He must also have had seven years' suitable industrial experience.

The main sections of industry at present approved for the award are the chemical, constructional, electrical, mechanical and textile industries. Under the Electrical Industries section are included Communication (Line and Radio), Electronic Equipment and Measuring Equipment.

After qualifying for the award of the Insignia, the candidate will receive a warrant specifying the section of the industry and branch of technology in which his knowledge and skill are recognized. In addition, the candidate will be authorized to use the letters C.G.I.A.

Copies of the general regulations governing the Insignia Award, together with notes for the guidance of candidates and an application form for the registration, can be obtained from the Director of the Department of Technology (I.A.), 31 Brechin place, South Kensington, London, S.W.7.

* *J.Brit.I.R.E.*, 11, Feb. 1951, p. 73.

The Trotter-Paterson Memorial Lecture

The Second Trotter-Paterson Memorial Lecture, arranged by the Illuminating Engineering Society in memory of two of its distinguished past-presidents, Mr. A. P. Trotter and Sir Clifford Paterson, F.R.S., will be given at the Royal Institution on Wednesday, January 28th, at 6 p.m.

Dr. E. D. Adrian, O.M., P.R.S., Master of Trinity College, Cambridge, will lecture on "The Nervous Reactions of the Retina."

Members of the Institution will be welcomed at this Lecture; admission is by ticket only, obtainable from the Secretary, I.E.S., 32, Victoria Street, London, S.W.1.

Standardization of Hacksaw Blades

An agreement has just been concluded between the British Hacksaw Makers' Association and the Hacksaw Manufacturers' Association of America, Inc., for the standardization of hacksaw blades. The agreement provides that from the 1st January, 1953, the American, British and Canadian hacksaw industries will have a common list of hacksaw sizes.

The list is intended to be simpler, and yet more comprehensive and effective, than either the previous American or British lists. A comprehensive research programme has been carried out jointly since 1949 in order to ensure that the combinations of length, width, thickness and tooth numbers included will meet all normal sawing requirements and will provide maximum efficiency and economy.

CURRENT RADIO INTERFERENCE PROBLEMS*

by

E. M. Lee, B.Sc. (Member)†

A Paper presented before the London Section of the Institution on April 16th, 1952

SUMMARY

The paper deals almost entirely with interference with television reception which is already a much more serious problem than interference with other services. After a brief historical review the most prominent interfering items revealed by the G.P.O. statistics for 1951 are discussed as regards their cause, responsibility, specifications and cure. The interference clauses of the Wireless Telegraphy Act of 1949 are reviewed, together with the work of the Postmaster General's Advisory Committees set up under the Act. Evidence is given of the improved performance of petrol engines resulting from the fitting of ignition suppressors. Steps which are being taken by the radio industry to meet their share of the responsibility are described.

1. Introduction

The author has been privileged to hold a watching brief for some years for the British Institution of Radio Engineers on a number of committees dealing with the technical aspects of electrical interference with radio and television services. This work has fallen largely on the electrical industry, and it was therefore logical for the Postmaster-General to ask the Institution of Electrical Engineers to advise him on the subject several years ago. A discussion on the subject at the I.E.E. was opened by A. Morris on November 22nd, 1933. The I.E.E. called in the help of the British Standards Institution (B.S.I.) and the British Electrical & Allied Industries Research Association (the E.R.A.) and, in addition, all other interested bodies have been represented directly or indirectly on the appropriate committees of these three bodies. Some twenty committees and sub-committees have been engaged (with a break for the war years) since about 1933. The Radio Industry Council (R.I.C.) and its predecessor, the Radio Manufacturers Association, has had an average of a dozen engineers distributed among these committees and it has been the custom of these Radio Industry delegates to meet every two or three months to report and compare notes as to how their various committees are progressing and on the policies being pursued. It is in the course of representing the R.I.C. on several of the committees that the author was asked simultaneously to hold a watching brief for other radio bodies including this Institution; this paper thus serves as the latest of a series of reports of the activities of these committees in recent years as well as being a review of the whole field of interference suppression.

It is proposed to take the G.P.O. monthly statistics of radio and television interference complaints and investigations as being a fair indication, with one important exception, of the nature and extent of present-day interference problems. The exception is motor ignition interference and this will be explained a little later in the paper. The statistics are compiled from the reports of the G.P.O. interference suppression engineers all over the country. In supplying these figures to the Radio Industry Council the G.P.O. emphasize that they do not necessarily indicate the actual extent of interference caused by individual items, since they do not show the number of receivers affected by each source. They also point out that in many cases the public do not make complaints about known sources. The problem is so great that there are some 600 Post Office engineers engaged upon it, and the service is costing about £300,000 to £400,000 a year; the G.P.O. are very anxious to reduce this cost.

The figures reveal that as television increases the number of complaints is likely to be multiplied four or five times since there is one complaint for every 24 television licences compared with one for 115 licences for sound radio alone.

* Manuscript received March 27th, 1952.

† Belling & Lee, Ltd.

U.D.C. No. 621.397.82.

The title of the paper means, therefore, that we must deal mostly with television interference. The earlier history of radio interference work up to 1938 is covered by the paper by Gill and Whitehead.[1]

Experience shows that suppressors fitted to deal with sound radio interference are nearly always ineffective in abating television interference. Fortunately television interference suppressors are usually cheaper, smaller and lighter than medium- and long-wave suppressors.

Table 1 shows an analysis of interference complaints investigated by the G.P.O. during the 12 months ending December 31st, 1951. The author is responsible for the grouping under the three offending industries. This table will be referred to frequently throughout Sections 2, 3 and 4 of the paper.

The misleading figure in this table is 5·1 per cent. for motor ignition interference. The reason for the very few complaints is that every viewer knows the cause of motor-car interference, has

TABLE 1

Analysis of Interference Complaints investigated by G.P.O. during the Year 1951

GROUP	CAUSE	SOUND NUMBER	SOUND %	TELEVISION NUMBER	TELEVISION %
RADIO INDUSTRY RESPONSIBLE	Faulty Receivers	8644	12·6	3439	8·4
	Mis-operation of Receivers ...	455	0·7	404	1·0
	Inefficient Aerial/Earth Systems	13715	20·0	1279	3·2
	Radio Transmitters—Amateur ...	331	0·5	302	0·7
	,, ,, —Others ...	460	0·7	204	0·5
	Medical and Industrial H.F. ...	14	—	278	0·6
	Radiation from I.F. Oscillators ...	—	—	224	0·5
	,, ,, T.V. Time Bases ...	3739	5·6	—	—
	External Cross Modulation ...	417	0·6	10	—
		27775	40·7	6140	14·9
ELECTRICAL INDUSTRY RESPONSIBLE	Small Motors: Sewing Machines ...	1377	2·0	5547	13·5
	Small Motors: Hair Dryers	346	0·5	1762	4·3
	Small Motors: Fans	384	0·6	721	1·7
	Small Motors: Drills	938	1·4	619	1·5
	Small Motors: Vacuum Cleaners ...	576	0·8	565	1·4
	Small Motors: Refrigerators	1552	2·2	529	1·3
	Small Motors: Calculating Machines ...	244	0·4	207	0·5
	Small Motors: Washing Machines ...	215	0·3	70	0·2
	Small Motors: Miscellaneous	4163	6·1	2385	5·8
		9795	14·3	12405	30·2
	Faulty Wiring of Buildings ...	3848	5·6	239	0·6
	Overhead Power Lines	592	0·8	835	2·0
	Underground Power Lines ...	485	0·7	—	—
	Lamps—Vacuum	27	—	850	2·1
	,, —Fluorescent	1805	2·6	67	0·2
	,, —Sodium	613	0·9	13	—
	,, —Neon Signs	338	0·6	399	1·0
	Thermostats, Irons, Bed-Warmers	2514	3·7	803	2·0
	Sundries	4456	6·4	4288	10·3
	Unknown : Presumed "Electric"	16217	23·6	12908	31·6
		40690	59·2	32807	80·0
MOTOR INDUSTRY RESPONSIBLE	Ignition of Cars & Motor-Cycles ...	74	0·1	2070	5·1
	,, ,, Tractors	8	—	24	—
	,, ,, Stationary Engines ...	5	—	20	—
		87	0·1	2114	5·1
Totals		68552	100·0	41061	100·0

had it explained by his radio dealer, knows that the Post Office engineers can do nothing about it, and has read in the press that the Government are expected to make suppression compulsory. Thus the lack of complaints is a measure of public patience and not of public annoyance. Nevertheless most viewers put motor-car interference at the top of the list of their television annoyances and the R.I.C. assesses it as being 85 per cent. of the television interference problem.

So much for the magnitude of the problem; let us now examine the groups and some of the more troublesome items.

2. Interference caused by the Radio Industry

2.1. *Causes Under Listener's or Viewer's own Control*

Post Office complaints which prove to be under the listener's own control, namely, "Faulty Receivers," "Mis-operation of Receivers" and "Inefficient Aerial and Earth Systems" total 33·3 per cent. for sound radio and 12·6 per cent. for television. This suggests that viewers seek and accept the advice of their retailers far more than is the case with listeners to sound only. Too many sound receivers are sold as packets over the counter, whereas television sets and their aerials are usually installed by the retailer. Post Office engineers should not be called in to deal with these three causes of bad reception; G.P.O. publication B.0007 helps in diagnosing faults on the screen.[23] The Radio Industry Council, through its constituent, the Radio and Electronic Component Manufacturers Federation, has produced two valuable publications on aerials, one is a grading of broadcast receiving aerials[2] and the other a guide on types of television aerials;[3] the latter is particularly useful to landlords and local authorities who may be in doubt as to what aerials to permit. The R.E.C.M.F. has also published a simple guide on interference suppression, entitled "Down with Interference." Other publications on good practice for receiving installations are B.S. 905[4], C.P. 307,201[5] and various B.B.C. publications.

2.2. *Transmitting Amateurs*

Transmitting amateurs cause a few complaints but are being most helpful and the Radio Society of Great Britain has published extremely good booklets to guide them in avoiding "T.V.I." as they call it.

2.3. *Other Transmitters*

The sub-heading "Other Transmitters" varies from the Eiffel Tower television transmission interfering with the B.B.C. Alexandra Palace programmes on the south coast of England to radar services and military walkie-talkie sets used on Army exercises. Usually the listener or viewer can improve or cure the trouble by simple wave traps or directional aerials. Deliberate jamming by foreign stations is, however, another matter.

2.4. *Medical and Industrial R.F. Equipment*

Valve-operated medical and industrial R.F. equipments are powerful sources of television interference. The appearance varies from a herring-bone pattern all over the screen to broad white horizontal bands in the severest cases. Directional aerials can help some conveniently situated viewers, but cannot help the in-line viewer. Therefore the interference must be stopped at source, and fortunately this is quite practicable by either of two methods:—

(1) The equipment can be sharply tuned to one of the internationally permitted free radiation bands which are as follows: 13·56 Mc/s, 27·12 Mc/s and 40·68 Mc/s, the first two being preferred in this country.

(2) The equipment and load (patient or work) can be screened in a suitable cage. During the war such screening cages were compulsory,[6] but, unfortunately, the order was withdrawn immediately the war ended. Valuable experience has, however, been obtained and many operators have been sufficiently public-spirited to continue using screens.

Our knowledge has been augmented by recent work by the E.R.A.[7] This shows that solid or perforated or expanded metal sheet is superior to woven mesh which has become tarnished, and that a well-made screened compartment with well-bonded doors and other openings and H.F. filters on incoming conductors can achieve attenuation of the order of 40 to 50 db for a single screen or 80 to 100 db for a double screen.

In the range 10-50 Mc/s attenuations up to 73 db have been measured for a single screen, and 140 db for a double screen. The filters are more likely than the screens to limit the attenuation.

The work also reveals that screened enclosures can be set in resonance (internally or externally) at frequencies determined by their dimensions and contents, if there is a very small hole or crack in the screen; even the small holes in perforated zinc sheet will suffice. The hole is rather like the probe used to excite or tap a cavity resonator. At these critical frequencies a single screen becomes "transparent" to H.F. fields, and a double screen becomes 90 per cent. transparent.

Filters for power leads into screened enclosures have been improved by using "bushing" type capacitors which have far lower inductance than other types. Fig. 1 shows a typical filter for 15 A, 250 V, and Fig. 2 an assembly of large bushing capacitors.

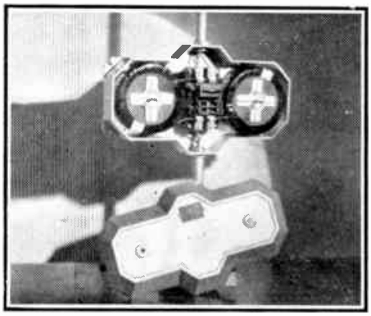


Fig. 1. Typical filter for 15A, 250 V.

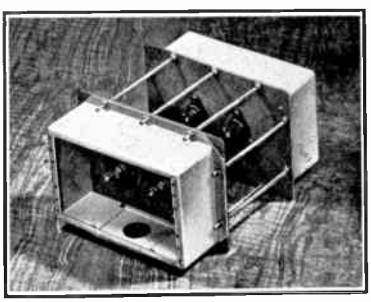


Fig. 2.—Assembly of large bushing capacitors.

Impressive claims are sometimes made for the performance of screened rooms. One manufacturer claims over 100 db suppression from 100 kc/s to 10,000 Mc/s for a copper wire mesh double screen! He makes no mention of resonant frequencies nor of what measurement technique or equipment he used; the author would be interested to know the method used for making such measurements at 10,000 Mc/s, and whether the complete polar diagram was taken since unexpected directional effects can be found.

Fig. 3.—Double-screened room with double sliding doors.

Code of Practice No. C.P.1002[21] deals with abatement of interference from electro-medical and industrial R.F. equipment. Fig. 3 illustrates one construction of double-screened room and its double sliding doors with multi-contacts. G.P.O. publication C.2201 gives further advice.[24]

2.5. *Radiation from Local Oscillators and Television Timebases*

The next two items of Table 1 show that television has repaid with interest the annoyance it was getting from the local oscillators of badly designed sound receivers. This radiation from the line scan timebase generator of television receivers can cause widespread interference to sound receivers. It occurs more with newer high-efficiency timebases than with the older circuits and the G.P.O. figures for the first half of 1952 show that it is increasing. A partial remedy in the case of existing television receivers is to coat the inside of the cabinet with a conducting paint.

Most television receivers made since 1950 have incorporated precautions recommended by the set-makers' section of the Radio Industry Council, who have tentatively adopted a limit that the line timebase radiation should not produce more than 50 μV (with an upper tolerance to 100 μV) in a 4-ft.-long vertical rod aerial placed anywhere on a 9-ft.-radius circle whose centre is approximately at the centre of the picture screen. For precise specification this centre is taken as 3 ft. in front of the rearmost point of the set. Thus the circle extends to 6 ft. behind the set and about 9 ft. in front.

This voluntary limitation is far more stringent than the requirement of B.S.800 for interference from electrical appliances where 100 μV per metre is specified at 30 ft. The figure may be changed in either direction when statistical results have been collected and examined.

2.6. *External Cross Modulation*

This accounts for 0·6 per cent. on sound and is negligible on vision. It includes re-radiation of signal plus interference from power lines, telephone lines, house wiring, gutters, pipes, etc., and also the "Luxembourg effect."

2.7. *Interference Limiters*

It is a fair question to ask whether the Radio Industry is doing all it can to reduce the sensitivity of receivers (and aerials) to interference.

The answer for the vast majority of manufacturers is "Yes." Aerial systems are freely available to improve the signal-to-noise ratio on both sound and vision. Sound receivers—particularly those for television sound—have noise limiters which give considerable reduction of impulsive interference such as car ignition. On vision, however, we can at present do very little interference limitation without spoiling the picture quality. In fringe areas, i.e. weak television signal areas, it is customary for installers to narrow the band-width of a receiver deliberately in order to narrow the interference acceptance band; the eye gets a false impression that definition is improved when interference or "screen noise" or "snow-storm" is reduced, though in reality definition, as such, has deteriorated.

2.8. *Effect of Television Modulation*

Opinions differ as to whether the U.S. negative modulation or the British and French positive modulation is better from the interference point of view: a full discussion of this is outside the scope of this paper.

2.9. *Effect of Television Polarization*

Vertical polarization is less influenced by aircraft reflections which cause picture flutter. Horizontal polarization is, however, a little less prone to some kinds of interference than vertical; in this country we have reserved horizontal polarization for the future weaker British television transmitters. The use of both polarizations has been shown by the B.B.C. to give 12 db reduction in the mutual interference between stations sharing the same frequency.

2.10. *Brush Discharge*

Queries have been raised as to whether brush discharges inside television sets can cause interference. The answer is "No" or "Very little." We can get quite "a strong smell of electricity" due to ozone, and even hear slight brushing discharge without it being noticeable on the screen or the loud-speaker. Generally a brush discharge must take place on the aerial itself before it interferes with the receiver.

2.11. *Mains Filters*

It is not possible to predict just when an external mains filter unit inserted at the power supply socket to a radio or television receiver will effect a worth-while reduction of interference.

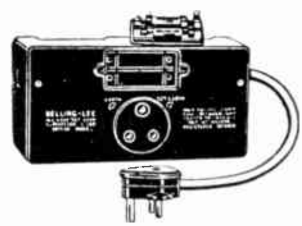


Fig. 4.—Mains filter unit.

It is always simple to try out. It is often helpful in reducing timebase interference escaping from a television receiver. A typical filter is shown in Fig. 4.

2.12. *R.I.C. Actions*

In general, it can be said that the Radio Industry Council is very alive to its responsibility to encourage all its member firms to do all in their power to remove this first group of interference sources, but it cannot compel firms to follow its advice. It does, however, ensure that offending equipment cannot be shown at its exhibitions.

So much for the Radio Industry's share of the responsibility.

3. Interference caused by the Electrical Industry

3.1. *Small Motors*

Interference from electrical apparatus and installations seems to be 10 or 12 times as troublesome to television as to sound broadcasting. In spite of the limited hours of television programmes we see that small motors alone already cause more complaints on vision than sound. This television interference is radiated, not conducted.

Very small television suppressors are effective on small motors, and electric sewing machines, which head the list, also need suppressors on their speed controllers. The capacitors can be of any value from 200 pF to 5,000 pF; bushing type high permittivity ceramic capacitors are very convenient but must be of the types to comply with the safety requirements and tests. Inductors, if air core, are merely about 5 ft. of wire on small tubular formers, but can be a fraction of the size with only about 13 in. of wire if wound on suitable iron dust or flake cores. For example, a 1-A television choke on an iron dust core is only about ¼ in. diameter and ¾ in. long.

3.2. *Wiring and Supply Lines*

"Faulty wiring of buildings" is usually due to bad contacts in switches, fuse-holders, conduit, etc., but can also be due to conduit or lead sheathing making a rubbing contact with a water or gas pipe.

3.3. *Overhead Power Lines*

These cause little interference when thoroughly wet, but they can cause severe annoyance when the atmosphere is damp, but the insulators are only moist, and, in some cases, interference is caused when they are quite dry. A great deal depends on the design of the H.T. insulators and the state of maintenance of the system. Cracked or chipped insulators are bad unless wet. It is also suspected that partial coating with salt or soot from the atmosphere will cause noise unless thoroughly wet. Any surface irregularity distorts the field, causes stress concentrations and local breaking down of the air. A wet surface restores uniformity.

3.4. *Lamps*

3.4.1. Vacuum Lamps

The appearance of vacuum filament lamps in the table as having caused 850 complaints of television interference may be a surprise. (There were a further 136 cases in January 1952.) The offending lamps are nearly all of the type known in the industry as "rough service" lamps; they have double-wreath type filaments and are intended for public services such as traffic lights, transport, and other long-life requirements and in situations of high vibration or bumping in factories. They should not normally be found in private dwellings, but the interference is revealing their unexpected presence.

The interference from these lamps on either a.c. or d.c. is very powerful, and has been investigated by the lamp manufacturers. It can be picked up 200 to 300 yd. away. Its spectrum is a series of sharp peaks throughout the television and adjacent bands. These peaks move in frequency with temperature and voltage changes, but there are so many of them that the effect on a wide-band receiver such as a television set is similar to random noise.

The full explanation of this oscillation is not yet known, but there are four cures, most of which prejudice the illuminating efficiency:—

1. Screen the lamp with metal.
2. Reduce voltage considerably.
3. Fix a large magnet on the side of the lamp.
4. Let gas in.

Carbon filament lamps also interfere if run below their correct voltage, such as occurs during supply voltage cuts.

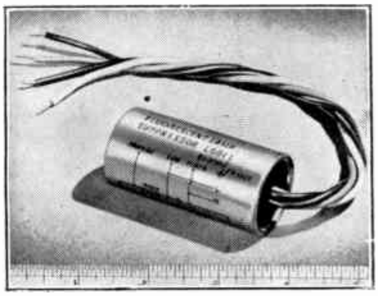
3.4.2. Fluorescent Lamps

Fluorescent lamp interference is nothing like so simple or positive. All fluorescent lamps generate very weak H.F. interference, but this is well below the level specified as annoying in B.S. 800 and normally does not need suppression unless a receiving aerial is too near. This has nothing to do with the starter switches, which usually have suppression capacitors fitted.

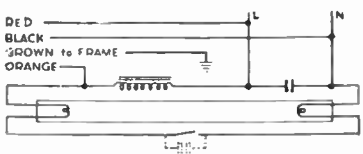
Very occasionally fluorescent lamps develop intense interference at some stage in their lives. Tapping, or even moving the lamp, stops the noise for a time—usually about 15 minutes. Switching off and on again will stop or greatly reduce the noise for a few minutes. Observers have noted that the noise comes and goes with the appearance and disappearance of a hot spot on the cathode, i.e. the tapping, etc., causes hot spot and noise both to go for a time. Lamp manufacturers have not yet solved the problem.

The interference is completely silenced by fitting extra capacitors as shown in Fig. 5(*a*) depicting a multiple capacitor unit whose circuit is shown in Fig. 5(*b*).

At radio and television exhibitions where many hundreds of fluorescent lamps are in use, one cannot risk one or more of them developing this intense interference, so all of them have to have these suppressors.



(*a*)



(*b*)

Fig. 5(a).—Multiple capacitor unit for suppressing interference from fluorescent lamps. (b) Method of connecting the suppressor unit.

3.4.3. Sodium Lamps

Sodium street lights are increasing as a source of interference on sound broadcasting. It is understood that the British Electrical Authority suppress individual units whenever a complaint is brought to their notice by the G.P.O., but there seems no justification at present for calling for them all to be suppressed.

3.4.4. Neon Signs

Neon signs are, unfortunately, very expensive to suppers. Anybody with car radio knows how virulent these signs can be and pities the local residents. In cost, size and weight the necessary 50-henry choke is about the same as the sign transformer and a sign needs the same number of each. A cheaper cure is badly needed.

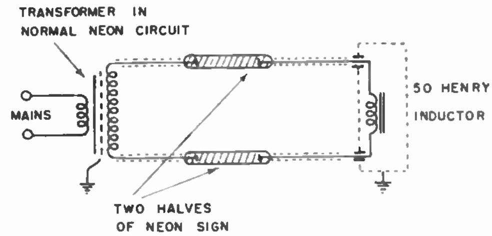


Fig. 6.—Interference suppression choke for neon signs.

Fig. 6 shows the method of connecting the choke; it has to work at 15,000 V above earth.

3.5. *Thermostats*

The most prevalent items are bed-warmers, since these are often left on during the evening viewing hours, and electric irons which also seem to be used a great deal during the same periods. Iron thermostats usually create noise each time the iron is dumped down on the work or stand, as well as when the thermostat makes and breaks contact. The annoyance from irons can be greatly reduced by fitting snap-action thermostats instead of the usual cheaper slow-action dithering and buzzing contacts. Complete suppression is expensive and bulky; high-temperature components are needed. A suppressor at the plug end of the flex is only partly effective on medium waves and ineffective at television frequency. The E.R.A. in Report No. M.T.97[8] describe an ingenious re-design of an iron in which the heating element is used as a pair of inductors to suppress the thermostat by splitting the element at its centre to insert the thermostat, and lengthening each half-element winding to increase its inductance by using a wire of lower resistivity. A capacitor is housed in the handle. Iron manufacturers, however, say that this cure is too expensive. The least expensive compromise or semi-cure for new irons is, perhaps, the snap action thermostat together with television chokes in the handle, and capacitors to assist on medium and long waves at the plug end of the flex. This is one of many examples of "split suppression" of portable appliances.

A suggestion worth trying for suppressing existing irons is to fit a suppressor in the flex lead about 12 to 18 in. from the iron and take the weight of the suppressor on one of the new spring anchor posts recently introduced for fitting to ironing boards. This would considerably reduce the length of radiating flex.

An example of thermostat which has now been suppressed by the makers is D.D.T. evaporators, which were once high up on the Post Office list, but have now disappeared.

Blanket and heating pad thermostats should be suppressed by fitting a small high-temperature capacitor and series resistor close to each thermostat inside the fabric; this is far more effective than any external suppressor unit. The capacitor and resistor spark quench circuit is only effective in reducing the radio interference annoyance up to a loading of about 150 W.

3.6. *Sundries*

This heading mostly covers contact devices such as bells, flashers, lift control contacts, toy trains, etc. These are mostly old problems with well-established remedies which are not expensive in relation to the cost of the offending appliances. One new item is windscreen wipers on buses and trolley-buses; these are very troublesome on wet days to viewers residing near a bus stop but, at the instigation of the Radio Industry Council, an inexpensive suppressor has been developed and fitted by most public transport authorities in the television areas (see Fig. 7).

Fig. 7.—Suppressors for use with windscreen wipers.

An example of an item almost impossible to suppress is the argonarc welding equipment which uses high frequency to ignite the arc, and requires screening of the whole equipment and work. Fortunately it is not often used near domestic premises.

There is hope that a new electronic H.F. generator will create for less interference. It is understood that an electronic surge injector used instead of the high-frequency spark oscillator equipment results in the a.c. argon-arc being able to weld at less than 50 V r.m.s. open circuit and that in the case of aluminium welding it is reduced to as low as 30 V r.m.s. open circuit.

Another nearly impossible item is the "Dodgem" cars or boats in fun fairs where the electric power is picked up from an overhead wire mesh and returned via the steel floor or water.

3.7. *Unknown*

This large block of complaints is described by the P.O. engineers as "Source unknown—not heard by P.O. investigator." In other words, the interference did not occur during the visit. From the circumstances and answers to questions it is usually concluded that the elusive cause is probably an intermittently used item of electrical apparatus, but the figure no doubt includes a few cases of intermittent receiver faults. The January 1952 statistics show a reduction under this heading to 22 per cent. for sound and 21 per cent. for vision.

4. Motor Industry Responsibility

If every viewer troubled by ignition interference filled up a P.O. complaints form, the G.P.O. would have another half a million cases on their outstanding complaints file.

The G.P.O., the A.A., and R.A.C., the Television Society, the B.B.C. and the Radio Industry Council have all been appealing to the owners of 4½ million cars, vans and motor-cycles to fit suppressors. So far only about ¼ million are suppressed. These figures exclude the Armed Services vehicles which are suppressed. Large operators have suppressed their fleets, some did not need to do so as they are diesel-engined.

The *A.A. News Bulletin* says as follows: "We make no apology for again asking all members to fit suppressors to their cars and motor-cycles. It has been proved beyond all doubt that this does no harm to the engine and that the effect on performance is negligible, and so is the cost—only a few shillings.

"'Unsuppressed' engines play havoc with television programmes. Will you please help to overcome this avoidable problem, which is spoiling the enjoyment of many thousands of A.A. members?"

The R.I.C. has said that for a start it would be satisfied with a single suppressor in the distributor to coil lead costing only two or three shillings, although the limits laid down in B.S. 833[13] require additional suppressors in 40 per cent. of cases. The Council says that the simple

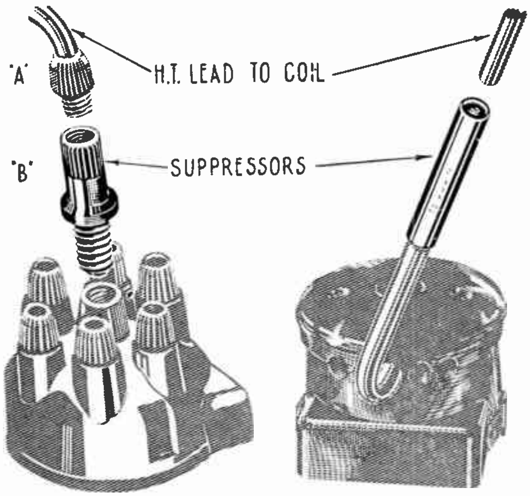


Fig. 8.—Two types of distributor lead suppressors.

single resistor makes so much improvement even to this awkward 40 per cent. and gets them so near the acceptance level that it would be satisfactory at least for the time being. Half of the 40 per cent. come down to within 6 db of the specified limit.

Two designs of distributor lead suppressors are shown in Fig. 8 and a plug suppressor combined with terminal shroud in Fig. 9.

It is interesting to note in passing that post-war cars are at least as troublesome as pre-war models. The reason is that the strips of resilient non-metallic damping material introduced between the steel panels to remove squeaks have spoilt the screening effect of the body and more than offset any advantage that might have materialized from the shortening of ignition leads by better location of the coil and distributor.

The I.E.E. and B.S.I. have jointly published a Code of Practice No. C.P.1001[14] which gives

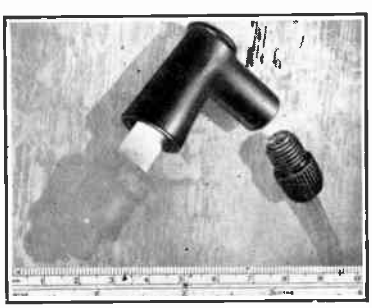


Fig. 9.—Right-angled sparking plug suppressor combined with terminal shroud.

detailed information and advice on this subject.

We have to ask ourselves why it is that over 4 million private owners of cars, vans and motorcycles are so lacking in neighbourliness that they will not spend two or three shillings to stop spoiling the pleasure of every viewer they pass?

With most it is just apathy.

A few think the Government or B.B.C. should pay.

A trifling but obstinate few are under the erroneous impression that an ignition suppressor is detrimental to the performance of an engine. Usually a garage mechanic is supposed to have expressed that opinion. Some motor mechanics adopt the attitude that suppressors are just another item to suspect and check when an engine gives trouble. What is the statistical and scientific truth of the matter?

The Society of Motor Manufacturers and Traders, the makers of ignition equipment, the A.A. and the R.A.C. insist that there is no disadvantage.

Motoring magazines support the campaign.[22]

The Fighting Services have suppressed over half a million vehicles without any trouble.

The Research Association of the Institution of Automobile Engineers[10] found that any resistor up to half a megohm could be used under all conditions, except that three very old and obsolete engines were found in which the cylinder head was so badly designed (had so little turbulence) that if one used socketed plugs or anti-oiling plug extension sleeves (instead of re-boring the engine) one could get uneven slow running and loss of power when going up hill in too high a gear with a suppressor fitted.

Aircraft always have resistors in their plugs to reduce plug erosion; they dare not fly without.

Car radio users nearly always have to fit them.

Several of the largest motor manufacturers are now fitting suppressors to all their new cars.

Many experts in England, U.S.A. and Germany have proved conclusively that ignition resistors assist cold starting of an engine.[12]

At least one sparking plug manufacturer advertises that his included resistors greatly prolong plug electrode life.

Two distributor makers are now building resistors into their distributor caps or distributor rotor arms where they cannot be removed, and where the motorist will automatically pay a trifle for them.

Much information is given in E.R.A. Reports Nos. M.T.28, 48, 53, 62 and 75, the principal worker being W. Nethercot.

The action of suppressor resistors is shown in Fig. 10. Curve (*a*) shows that without a resistor the spark capacity current peaks up to 150 to 200 A at the first half-cycle, which lasts only a matter of 0·15 microsecond, and then tails off exponentially, but that the oscillations are sufficient to cause severe impulsive interference at each spark. The frequency lies between 30 and 50 Mc/s. Curve (*b*) shows that a 10,000-Ω resistor reduces the first peak amplitude to about 0·5 A but extends its duration to 5 microseconds, i.e. about 30 times as long. (Even this lengthened capacity spark lasts only one/two-thousandth of a revolution or one-sixth of a degree in a high-speed engine running at 6,000 r.p.m.). The trail of oscillations is damped out so that we have only one pulse of greatly reduced amplitude and frequency. A resistor as low as 150Ω renders the discharge non-oscillatory but does not reduce the current sufficiently. The prolonging of the first spark presumably assists the improved cold starting since it increases the probability that the spark will encounter and ignite one or more of the wet fuel globules. A technical expert on ignition advances the theory that the lower heat in the suppressed spark avoids blowing the globules away from the spark; in other words, the unnecessarily violent unsuppressed spark is like the well-known use of dynamite to put out an oil-well fire!

Fig. 11 shows how the cold starting of a car was improved by various values of plug

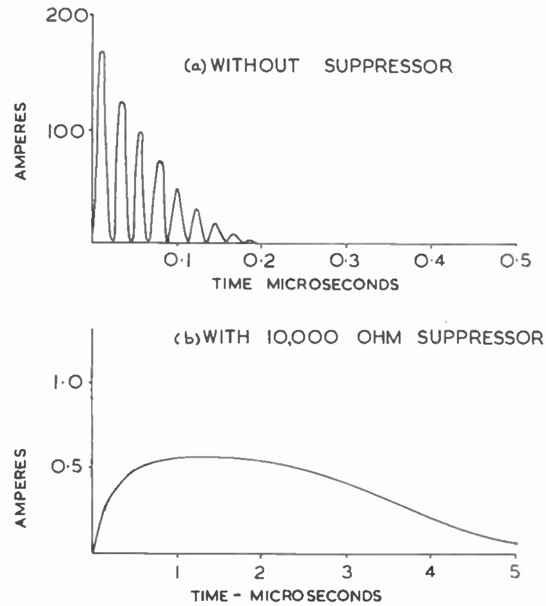


Fig. 10.—Illustrating the reduction of the oscillatory nature of the ignition capacity spark current by introduction of a suppressor resistor.

suppression resistors. These tests were carried out by Messrs. J. Lucas, Ltd., some 10 years ago on a typical four-cylinder o.h.v. engine at 0°F with plug gaps of 0·020 in. and using screened ignition leads. The test was the customary one in the automobile industry of gradually increasing the primary volts on the ignition coil until a satisfactory fire was obtained. The graph shows that

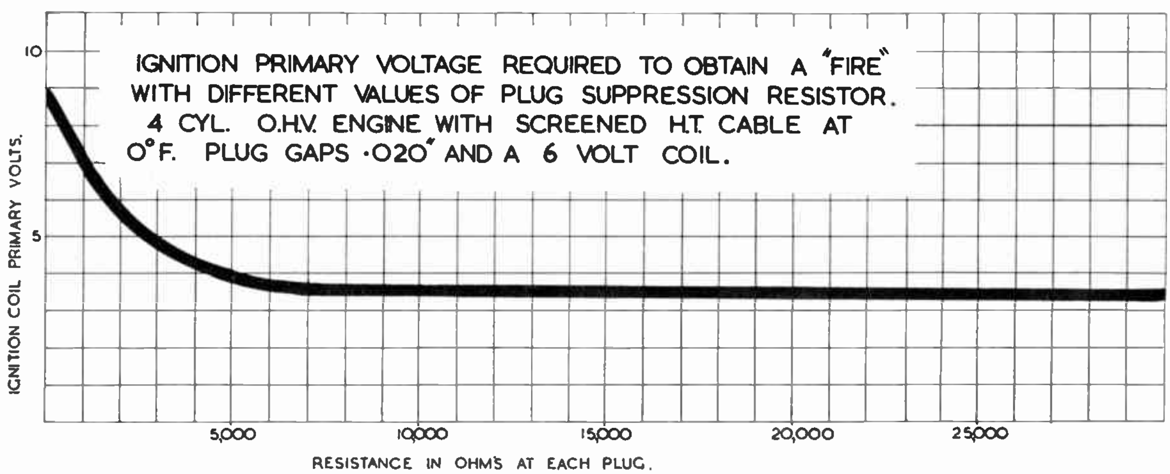


Fig. 11.—Illustrating the improvement to "cold starting" of a car engine by the use of resistors in the plug leads.

with no resistors 9 V was necessary, whereas the car had only a 6-V supply, and that the desired safe figure of 4 V was not achieved until the plug resistors had been increased to 5,000 Ω. At 7,000 Ω the curve became asymptotic at 3·5 V for this particular engine, but the effect was still improving slightly even at 25,000 Ω. More recently the U.S. Army has obtained similar and even more striking results.

The reduced electrode burning or "erosion" results from the greatly reduced current.

The values of resistors necessary to produce these various effects are as follows:—

To reduce plug erosion: aircraft use 1,500 Ω or over.

To improve cold starting: 5,000 Ω effective, but 100,000 Ω better in bad cases.

To suppress interference: any value above 5,000 Ω.

To lower engine efficiency: over 500,000 Ω (sometimes as high as 2 MΩ).

To retard ignition: very high resistance values —a small increase in plug gap or length of ignition leads has a greater effect.

The compromise value chosen for suppressors is 10,000 Ω. Thus, if suppressors are fitted at the plugs as well as at the distributor centre the resistance in each circuit is 20,000 Ω.

A word should be said about reliability of ignition suppressors. Tests are laid down in B.S. 833[13] but these are not a substitute for long experience. Life tests should be carried out at typical working temperatures. It is found that plug suppressors need higher grade resistor pellets than distributor suppressors, due to the difference in working temperature. In both cases the pellet must be at least $\frac{5}{8}$ in. long to avoid any risk of sparking or tracking over its surface. There have been a few cases—only a dozen or so —of resistors burning out or sparking over in the course of the last 25 years. These have usually been due to the wrong grade of resistor being used by mistake. Such failures, however few, have been magnified out of all proportion and damaged the reputation of the millions of suppressors that have given no trouble in all parts of the world.

The Post Office figures include a few tractors. It will be sufficient to mention that there has been one case reported of a tractor tripping off the responder beacon of an airfield blind approach system.

5. Legislation and Specifications

Having briefly surveyed some of the highlights of the interference problem under the three industry groups, let us now survey the recent progress made by the various bodies which are interesting themselves in it.

5.1. *The Wireless Telegraphy Act*, 1949

This Act, which received the Royal Assent on July 30th, 1949, was the culmination of 16 or more years' work by a large number of advisory committees and sub-committees to which all the bodies interested have contributed. The work was originated by an earlier Postmaster-General asking the I.E.E. to advise him on the subject. This was done in the 1936 report of the I.E.E. to the Postmaster-General[25] which recommended the enactment of enabling legislation under which he could operate Regulations made on the advice of the then Electricity Commissioners and working on the basis of British Standard specifications. A Bill was drafted, but, owing to Parliament being pre-occupied with the 1936 to 1939 rearmament programme and other matters, it was never presented.

After the war the Postmaster-General asked the I.E.E. to bring its report and advice up to date in the light of intervening technical changes and the liquidation of the Electricity Commissioners. This was done after a thorough review through the network of technical committees and culminated in the Act as stated above. Unfortunately the appeal of the Radio Industry that the Bill should be debated as a non-party matter was unheeded, and a lively political argument took place in both Houses. The bone of contention in the Commons was over the powers of entry into premises, and in the Lords over the expense. The Lords actually passed an amendment, later rejected by the Commons, to the effect that any suppression expense in excess of two shillings should be paid by the body requesting the suppression, e.g. the B.B.C.

The Act as it stands requires the Postmaster-General to appoint and consult an Advisory Committee (or Committees) chosen from a panel nominated by the President and Council of the I.E.E. and consisting of experts and representatives of the main interests effected either favourably or adversely by suppression, and in the light of their advice to make Regulations for compulsory suppression. These Regulations can put the onus to secure and maintain adequate suppression on the user of apparatus liable to interfere, and can require makers or assemblers or importers of apparatus to ensure that it is non-interfering when sold or offered for sale.

The Regulations may prescribe the limits of tolerable radiated interference fields and the maximum interfering energy which may be injected into electric lines. These limits can be different for different appliances and for differing places and times of use and differing frequency bands. The Regulations, however, cannot go higher than three million Mc/s. A Regulation will only be enforceable after the serving of a Notice by the Postmaster-General requiring suppression to be effected within not less than 28 days. The Act lays down appeal procedure, right of search. and penalties for refusal to comply with a Notice issued under a Regulation.

Three Advisory Committees have been appointed and two have issued their advice to the Postmaster-General—one on ignition and one on refrigeration interference—the third committee is on small motors. The Assistant Postmaster-General stated in the Commons on March 19th, 1952, that a Regulation on ignition interference had been drafted and was to be referred to the Advisory Committee before being laid before the House. At that date he still seemed to be blissfully ignorant of the sad failure of all propaganda efforts to secure voluntary suppression of ignition on existing cars.

On March 31st, 1952, he told the House that the report of the Advisory Committee on refrigerator interference was now in the Library for inspection. The report recommends legislation to come into force six months after promulgation of the Regulation. The limits of B.S. 800 for mains-injected interference have been incorporated and, in addition, a limit of 750 μV mains-injected interference is laid down for the television band (40-70 Mc/s). No limit is required for radiated interference in this case.

As it has generally been assumed that the Postmaster-General and his advisers will make use of British Standard Specifications in drafting Regulations, the positions with these specifications is of great interest and is summarized as follows:—

5.2. *Interference Limits*

B.S. 800[15] lays down limits for radiated field and mains-injected interference. It was first published in 1939 and its first revision was published in September 1951. It still covers only the frequency band from 200 kc/s to 1,605 kc/s, but a re-draft has now been circulated for comment covering the television band from 41 to 68 Mc/s where limits are proposed which are half the values given below.

If the interference persists longer than one-fifth of a second, or is repeated more frequently than once every two seconds it is regarded as "Continuous Noise" and the limits are:—

Radiated Interference—100 μV per metre at any point 10 yd. or more from the appliance or any surrounding screen.

Mains-Injected Interference—1,500 μV measured between each line terminal and earth.

For shorter and rarer bursts of interference the definition "Discontinuous Noise" applies, and the limits prescribed by statistical sampling formulae are less stringent.

The earlier issue of B.S. 800 specified 500 μV for mains-injected interference, but the methods of test, the tolerances and the methods of sampling were also different. The revision makes matters a great deal easier for the electrical manufacturer. As regards television interference the B.B.C. has assisted with tests before audiences and their findings on tolerable interference limits for television interference are given in their Research Department Report No. G.046 of 1950.[20] Briefly, they find that a signal-to-interference ratio of 45 db is required for satisfactory viewing.

5.3. *Interference Measuring Sets*

B.S. 727[16] first published in 1937, specified the characteristics and performance of apparatus for the measurement of radio interference over the frequency ranges 150-240 kc/s and 550-1,500 kc/s. Part Two is in an advanced stage of preparation, covering the frequency range 30 Mc/s to 150 Mc/s. Much time has been spent discussing the time constants of the output meters and in endeavouring to secure international agreement through the C.I.S.P.R. (Committée Internationale Speciale des Perturbations Radiophonique of the International Electrotechnical Commission).

An addendum to Code of Practice C.P.1001[14] published in July, 1950, describes a simple portable equipment for assessing the radiation by ignition systems in the television band; it works at one spot frequency of 48 Mc/s.

5.4. *General Principles of Interference Abatement*

A Code of Practice to be issued jointly by the

I.E.E. and B.S.I. is in an advanced stage of drafting. It incorporates and expands the explanatory matter and certain appendices which previously appeared in several B.S. specifications, particularly the original B.S. 613 on Components.

5.5. *Components for Interference Abatement Devices*

A second revision of B.S. 613[17] is now being completed, the previous revision being June 1940, and the original June 1935. An important new conception in specifying capacitors for long life is being incorporated. A section dealing with complete filter units is included. This work has involved getting a wide measure of agreement with the electrical industry on important matters of principle concerning safety from shock. Briefly these decisions are as follows.

Double insulation of an appliance as an alternative to earthing is now accepted. This enables suppressor capacitors up to a value of 0·05 μF to be connected from windings to the inner frame and neither the inner frame nor the outer metal casing is earthed. This dispenses with the use of R.F. inductors for medium- and long-wave suppression. Earthing has always made suppression more difficult.

Capacitors from live main to earth must now in all circumstances be limited to 0·005 μF. Previously much larger values could be used on fixed apparatus which was solidly and permanently earthed. It was later felt that it was too great a risk to accept that an appliance always became lethal if its earthing failed, i.e., without needing any insulation failure.

Three-pin suppressor plugs are now made possible by allowing the following maximum capacitance values between pins:—

Line to earth	..	0·005 μF
Neutral to earth	..	0·05 μF
Line to neutral	..	0·1 μF

The neutral-to-earth value was the subject of long and wide discussions. The value chosen is such that if the earth connection fails and simultaneously the phasing is reversed so that the frame of an appliance becomes live at 250 V through the 0·05-μF capacitor, then the user could get an unpleasant shock which would be "educative" but not dangerous (not more than 4 mA). That is to say, a shock well below the limit of ability of any human being to let go but sufficiently painful to give a warning that something is seriously wrong and needs expert attention.

Until this principle was accepted the neutral-to-earth capacitor in a plug could not exceed 0·005 μF and was practically useless for suppression. The new value is still low, but suffices in some cases, and in others it enables "split suppression" to effect the cure by reinforcing smaller capacitors and/or television inductors built into the appliance.

Other developments in the component field have been bushing capacitors and improved core materials such as "Caslam" for R.F. inductors.[18]

5.6. *Ignition and Motor Vehicle Suppression*

B.S. 833[13] of 1939, together with Code of Practice No. C.P.1001[14] of 1947, and its addendum of July, 1950, gives very complete guidance on suppression. The documents also deal with auxiliary items such as windscreen wipers.

A revision of B.S. 833 circulated for comment in November, 1950, and now in course of publication, specifies the following limits for interference fields at 10 yd. from a vehicle:—

Frequency Band	Max. Field Strength	Band width of Measuring Set
200 kc/s to 30 Mc/s	100 μV/m	9 kc/s
30 Mc/s to 150 Mc/s	50 μV/m	100 kc/s

5.7. *Electromedical and Industrial R.F. Equipment*

These are covered by Code of Practice No. C.P.1002 of 1947, which also deals generally with the construction of screened enclosures.[21]

5.8. *Trolley-buses and Tramways*

These are still covered by the original B.S. 827[9] of 1939. The only new work has been the new windscreen wiper television interference suppressor.

5.9. *Marine Installations*

B.S. 1597[11] of 1949 is still quite up to date. It sets a very stiff specification for the capacitor manufacturers.

5.10. *Radio Receiving Equipment*

B.S. 905[4] went to press rather hurriedly in 1940 and has been severely criticized by its own co-authors—The Radio Industry Council—ever since. A more practicable revision is well advanced, but it has had to move hand-in-hand with the revision of B.S. 415[19] on the safety requirements for radio and television receivers.

6. Acknowledgments

The author wishes to thank the General Post Office for permission to use its statistics and illustrations, and for the loan of some of the slides and samples shown at the reading of the paper. Also his colleagues on the R.I.C. Interference Suppression Committee for their reports on which he has drawn freely, the members and secretariats of all the committees referred to herein, and his colleagues in Belling and Lee, Ltd., who have assisted in supplying and checking information for the paper and with the demonstrations.

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TELEVISION DEVELOPMENTS IN BRITAIN

Television Advisory Committee

The Postmaster-General announced in the House of Lords on October 29th that the constitution of the Television Advisory Committee would be as follows:—

Admiral Sir Charles Daniel, K.C.B., C.B.E., D.S.O. (Chairman),
Sir Edward Herbert, Kt., O.B.E.,
The Hon. Charles McLaren,
E. M. Fraser, C.B.E.,
G. Darnley Smith, and
C. O. Stanley, C.B.E.

(The two latter members represent the Radio Industry Council.)

In addition, the Director-General of the B.B.C. and senior officials from the Treasury, Ministry of Supply and the Post Office will also serve.

The terms of reference of the Committee are:—

"To advise the Postmaster-General on the development of television and sound broadcasting at frequencies above 30 megacycles per second and related matters, including competitive television services and television for public showing in cinemas and elsewhere."

Ship-to-Shore Television Experiment

In collaboration with the Southern Region of British Railways, the B.B.C. has carried out experiments to ascertain the possibility of obtaining television pictures from a cross-channel steamer on the Dover/Boulogne service.

A mobile transmitter of the Television Outside Broadcast fleet was taken aboard the Southern Region's motor-car ferry—the "Lord Warden"—and transmitted special signals to a receiver mounted on the R.A.F. radar tower at Swingate, near Dover. The transmitter operated in the 190 Mc/s band with a power of 340 watts and the tests were made during the normal service run of the ferry. No cameras were used for these initial tests, but the strength of the signal received at Swingate was measured and interference also observed.

Reasonably satisfactory signals were received at Swingate during the entire journey to Dover, although a certain amount of interference from other transmitting stations was experienced. These tests indicate that provided certain precautions are taken there is every reason to believe that satisfactory pictures can be obtained from the "Lord Warden" next Spring.

Temporary Low-Power Television Stations

The Government has now decided to allow temporary transmitters to be installed at Pontop Pike, in North-East England, and near Belfast in Northern Ireland, so that viewers in the neighbourhood of these stations may have television in time for the Coronation.

The B.B.C.'s plan for five permanent medium-power stations is still deferred, but at the two sites mentioned it is proposed to use temporary transmitters having a power of 1 kW vision and ¼ kW sound. These will not give the range and quality that will ultimately be obtained from the permanent medium-power stations and there will be a greater risk of breakdown.

The transmissions from both stations will be horizontally polarized. The frequencies used will be:—

Pontop Pike: Vision 66·75 Mc/s,
Sound 63·25 Mc/s.
(Shared with Wenvoe)
Belfast: Vision 45·0 Mc/s,
Sound 41·5 Mc/s,
(Shared with Alexandra Palace)

The transmitter at Pontop Pike is expected to serve about one million people within a radius of some 20 miles, which includes Tyneside; the transmitter in Northern Ireland will serve about half a million people in the city of Belfast and its immediate surroundings.

The High-Power Television Transmitter for Scotland

The B.B.C. high-power television transmitters at Kirk O'Shotts were brought into service on August 17th last, to replace the medium-power transmitters which had carried the programme since March. The station is located roughly midway between Glasgow and Edinburgh on a site 900 ft. above sea level; the 750-ft. mast brings the total height of the vision and sound aerials to over 1,600 ft., an important factor in securing the greatest possible service area in hilly country.

The vision transmitter, manufactured by Electric & Musical Industries, Ltd., differs from those installed at the earlier stations at Sutton Coldfield and Holme Moss,* in that low level modulation is used. The new design has not only enabled a considerable reduction to be made in the

* *J.Brit.I.R.E.*, **9**, Jan. 1950, pp. 18-19, and **10**, Jan. 1951, p. 33.

TELEVISION DEVELOPMENTS—(contd.)

physical size of the transmitter, but it offers increased over-all efficiency with a consequent saving in power consumption.

The vision programme is received at the station over the G.P.O. distribution network which consists of a 1-in. tube coaxial cable system from London to Birmingham, ⅜-in. tube coaxial cable system between Birmingham and Manchester, and a radio-relay link between Manchester and Kirk O'Shotts.

Vision signals are fed to the modulation amplifier which consists of (*a*) a three-stage d.c. input amplifier using receiver-type valves exclusively and having a cathode-follower output, (*b*) a linearity correction amplifier and (*c*) a pre-modulation V.F. amplifier, also with a cathode-follower output, feeding the grids of the modulated amplifier. The black level is finally clamped at the input to the pre-modulation amplifier. The fact that this clamping has to be separated by a considerable number of stages from the transmitter output could introduce variations in the transmitted black level unless special precautions were taken. This possible difficulty is overcome by the inclusion of a black level R.F. feed-back circuit which monitors the black level at the transmitter output and injects a suitable correcting signal into the vision circuits. A further advantage of this technique is that it tends to reduce any mains hum introduced by the class "B" R.F. amplifiers forming the later stages.

The modulation is applied to the grids of a pair of ACT.27 air-cooled triodes which operate as an earthed grid push-pull modulated amplifier having an output of approximately 600 W peak white. This stage is preceded by a pre-modulation R.F. amplifier, a frequency multiplier and the crystal oscillator stage.

The modulated amplifier output is fed to a chain consisting of three push-pull earthed-grid class "B" linear wide-band R.F. power amplifiers in series. The first employs a pair of ACT.27 air-cooled triodes and produces an output of 3 kW; the second is fitted with ACT.26 air-cooled triodes and has an output of 12 kW; the third uses a pair of BW.165 water-cooled triodes. The transmitter will be operated with an output power of 50 kW.

From the outputs of the modulated amplifier, inter-stage couplings of the wide-band three-stage coupled-circuit type are used, and these are so tuned that their pass-band centre frequency is about 0·7 Mc/s below the carrier frequency. The two side bands are thus not symmetrical—the upper one being slightly attenuated—but a filter is used to obtain the final asymmetric side-band condition. A further three-stage coupled circuit is used at the anodes of the output amplifier and this is also arranged to change from a balanced to an unbalanced load to feed the coaxial output transmission line.

The high-power sound transmitter, manufactured by Standard Telephones & Cables, Ltd., is of the conventional high-power class "B" modulated type. Modulation is applied at the anodes of both the penultimate and the final R.F. stages. The transmitter uses air-cooled valves throughout and has a carrier output of 18 kW at 100% modulation.

The output of the vision transmitter is passed to the vestigial side-band filter which consists of a constant-resistance filter of the transmission-line type. It is composed of two complementary networks, the high-pass section being terminated by a constant resistance absorber load and the low-pass section by the aerial system.

The combining unit into which the outputs of both the vision and sound transmitters are fed consists of a "sound-pass/vision-stop" filter inserted between the sound transmitter and the common output, and a "vision-pass/sound-stop" filter between this point and the vision transmitter output.

From the output of the combining unit the signals are fed to the common aerial at the top of the 750-ft. mast. The transmission line used for this purpose is of a new design. It is of the coaxial tube type having an outer conductor made from a 5-in. diameter copper tube. The inner conductor, however, is not a copper tube but consists of a locked coil wire rope the outer layer of which is composed of wires made from high conductivity copper. This rope, together with the outer tube, is suspended pendulum fashion from the top of the mast.

By suspending and loading the transmission line in this way the electrical uniformity tends to increase towards the upper end, which is useful in reducing the formation of echoes; these have the greatest time-delay when the irregularities producing them are at the greatest distance from the transmitter.

AN EXPERIMENTAL SYSTEM FOR SLIGHTLY-DELAYED PROJECTION OF TELEVISION PICTURES*

by

Paul Mandel, Ing.El.†

A Paper presented at the Fifth Session of the 1951 Radio Convention on August 24th in the Cavendish Laboratory, Cambridge

SUMMARY

The paper describes the essential features of an experimental television system for projection on cinematograph screens. The high-definition flying-spot scanner, the broadband microwave relay, the electronic film registering apparatus and the rapid film processing are dealt with together with an account of the performances of each part of the apparatus and the physical limitations of the system.

1. Introduction

The problem of presenting television pictures for large audiences is by no means new. The difficulties resulting from the need of obtaining with a simple apparatus a considerable luminous flux (of the order of several thousand lumens), and the necessity of obtaining a high contrast range (50 : 1 or more), without sacrificing the fine details of the picture, could not be simultaneously mastered in spite of the most interesting results obtained by combined efforts over long years.

The cathode ray tube retained generally the favour of the research laboratories,[1,2,3,4,5] while the Swiss School favours the Eidophor System[6]; however the use of an intermediate film, first proposed by the Fernseh[7], has recently returned to prominence.

On the basis of the 819-lines high definition standard, work was begun some two years ago to try to obtain a satisfactory solution of the question. An experimental system was developed and is currently perfected to this end. The description of the complete apparatus and of the results obtained is the purpose of this paper.

2. General Description of the Experimental Apparatus

It was felt at the very beginning that a standard television picture analyser having the highest performances, and capable of maintaining this performance during the time needed for the development of the other parts of the system would be most useful. As the primary source of the picture, the 35-mm standard film was chosen. The reasons for this choice are:

High resolution,

Extended contrast range,

Invariability in time,

Ease of the optical control, and

The facility of comparison of the final result with the initial picture under identical conditions.

The analysis of the film is performed by a "flying-spot" scanner using a cathode ray tube. by an optical split system to allow interlaced scanning, followed by a photo-electric multiplier.

The well-known advantages of this analyser, absence of dark spots, the perfect linearity of the electro-optical response, and a well-defined black level in the video signal, were a great help throughout. The excellent resolution and negligibly low noise level which could be finally obtained justified the choice of this scanning method.

The video signal is carried from the scanner, by a U.H.F. broadband relay system to the registering apparatus, where the picture is reproduced with negative polarity on the screen of a high-voltage cathode ray tube. A synchronously-driven cinematographic camera registers the picture without any partial loss of frames. The exposed film runs continuously through the developing, fixing and drying apparatus, and, after 65 seconds delay, feeds a

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† La Radio Industrie, Paris.
U.D.C. No. 621.397.5 : 535.88 : 778.5.

motion-picture projector equipped with a high powered arc lamp. In this part of the apparatus 16-mm film is used. The sound is simultaneously registered so that the film can be used later on for delayed projection and kept in stock as long as desired. Fig. 1 presents diagrammatically the arrangement described.

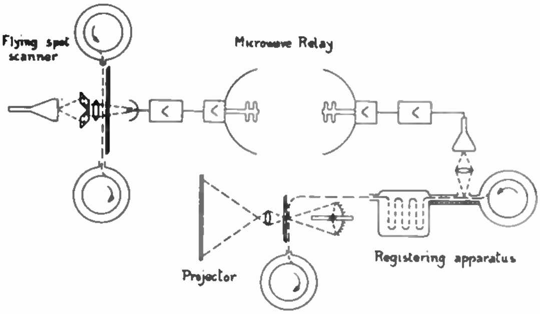

Fig. 1.—Diagrammatic representation of the complete system.

3. Detailed Description

3.1. *Optical System of the Flying-Spot Scanner*

To allow the analysis of the picture by two interlaced frames in 1/50th sec for each frame (corresponding to the French standard), the film runs with a constant speed of 25 pictures/sec through the apparatus, and the scanning is performed by a split optical system.[8] The primary light source is formed by the spot (Po) of a cathode ray tube tracing two interlaced frames of constant brilliance on the screen. A part of the luminous flux issued from the spot is split up by two total reflecting prisms (P1, P2), giving, with the aid of a lens system (L), two identical images of the spot in the plane of the film (F), the separation between both being equal to half of the picture height (h). The vertical speed of the spot picture is the same as the speed of the film in the window but in the opposite direction. The relative velocity allows the scanning of the film in 1/50th sec, the time needed for the latter to run over half the height of the window.

A synchronous shutter (Sh) having equidistant apertures equal to half the picture height is placed in the immediate vicinity of the window. Running synchronously and in phase with the picture of the scanning spot, it allows one or the other spot picture to scan alternatively the upper or the lower half of the window and to obtain accordingly two successive interlaced scans of the film frame, during the time of 1/25th sec, i.e. the time needed for each film frame to cross the window.

Figure 2 shows the optical system of the flying-spot scanner.

The luminous flux crossing the film is proportional to the transparency of the scanned point. It is collected by a condenser and projected on a photo-electric cell which is combined with an electron-multiplier having a particularly low noise level. The output of the multiplier is connected through a suitable compensating electrical network to the first stage of the video amplifier.

The optical quality of the prisms must be very high, in order not to limit the resolution by lack of superposition of two successive frames. The lens system had to be specially designed to keep the aberrations to a minimum in spite of the split system and to assure the uniformity of the brilliance of both the scanning spots across the window resulting from the oblique incidence of the light on the lens system. The difference in luminosity of the spots would result for obvious reasons in a disturbing (25 c/s) flicker in the televised picture.

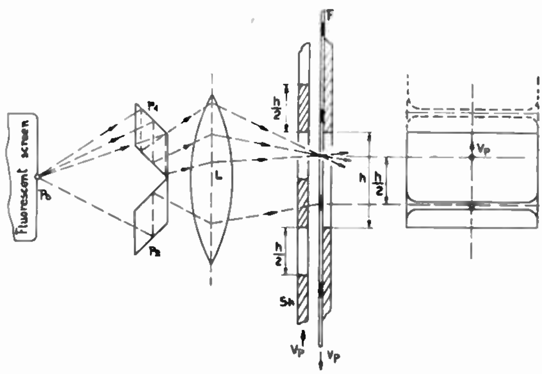

Fig. 2.—Optical system of the flying-spot scanner.

It was found that the residual 25 c/s flicker using the full aperture of the carefully designed optical system remains prohibitive. Very satisfactory results would be obtained by limiting the aperture of the system on the front side. However, the amplitude of the video signal is correspondingly reduced by this arrangement. The residual 25 c/s flicker could be eliminated without the limitation of the incident luminous flux by the periodic modulation of the intensity of the scanning spot[9] or by the periodic modulation of the video gain by means of a 25-c/s signal of suitable wave form.[10] The first method has its limitations in the saturation effect of the fluorescent screen, the second in the noise level of the multiplier. Each of them gives excellent results in connection with a well-designed optical system. The influence of film shrinkage can be quickly compensated by a slight axial displacement of the prism system or of the cathode ray tube. It was not thought to be necessary to make this adjustment automatic.

The continuous speed of the projector is stabilized against instantaneous phase changes by an elastically-coupled high-speed fly-wheel system and the cylindrical surface of the main sprocket drum is carefully ground to obtain the highest possible uniformity of film speed. As a result of these precautions we could note no loss of detail resulting from the lack of superposition of successive frames. Stability observations using standard 35-mm film prints gave as a result a fixity of the picture which was at least as good as with ordinary intermittent projectors using "Maltese Cross" driving systems.

In order to keep absorption losses to a minimum, the prism system was manufactured using a special glass with very slight absorption from 3,000 Angstroms up. The lens system is coated to diminish reflections in the blue-green region of the spectrum, and is corrected for the same visibility band.

3.2. *The Cathode Ray Scanning Tube*

The performance of the whole system depends to a high degree on the quality of the scanning tube. Very small spot sizes of about 0·05 mm and high current density are desired from the electro-optical point of view, and high luminous efficiency and small time constant of the screen phosphor are of considerable value in order to facilitate the electrical compensation of the luminous lag of the screen.[11] The small aperture angle of the electron beam issuing from the electron gun helped to obtain the uniformity of the concentration on the whole screen area. This uniformity is needed to obtain constant light output (particularly violet and ultra-violet) for each point of the scanned picture, the efficiency of most screen materials being a function of the current density in the spot.

A simple magnetically-focused triode gun was consequently developed for scanning purposes. The active diameter of the spot was measured with the aid of the resolution pattern and was found equal to 0·07 mm for a beam current of 50 μA, the beam being accelerated by a tension of 30 kV. Commercially available tubes gave similar results but the uniformity of concentration which could be obtained was however sometimes less satisfactory in the corners of the picture.

Fig. 3.—The complete scanning apparatus.

The ideal screen material would have an optical response presenting no lag behind the electronic excitation. Of all the various screen materials which could be tested, a specially-treated very pure zinc oxide powder came nearest to this condition. The ultra-violet output, separated by a Wratten 18 type filter, presents a small time lag of the exponential type, which could be easily compensated by a suitable RC network, but the loss of luminosity owing to the heavy absorption of this radiation by the lens system increased the noise-to-signal ratio considerably. Moreover the crystal structure of the screen is more apparent in form of a sandy background on the picture if the ultra-violet component is used exclusively. Consequently the full luminous spectrum was used during further development.

3.3. *The Video Amplifier*

The use of the total light emission and the resulting more complicated form of the decrease of the screen luminosity leads to a more complicated compensation of the time lag by three suitable RC networks incorporated into the first stages of the video amplifier.

The method has given perfect results, the compensation for the above-mentioned screen material being very stable. Slight adjustments are needed only after replacement of a scanner tube, or after considerable modifications of the beam current, or of the accelerating potential.

The noise level, which depends on the sensitivity of the photo-cathode and on the quality of the multiplier is, in the case of the analysis of standard black and white motion picture prints, negligibly low (about 30 db peak-to-peak video to r.m.s. noise); the noise is imperceptible from a viewing distance greater than three times the height of the picture.

The output of the amplifier is proportional to the transparency of the film due to the linear response of the photo-cathode of the multiplier and of the video amplifier. The luminous output of the cathode ray tubes used for registering or for control purposes is on the contrary a non-linear function of the modulating voltage.[12] To compensate this property of the registering tube, and with the purpose of taking care within certain limits of the gamma of the film used for registering, a "gamma correction" was incorporated in the video amplifier. The correction is made by the use of the non-linear characteristics of a suitably-chosen amplifier tube. The black reference level given by suppression of the scanning beam of the amplifier tube at the end of each line and of each frame is restored by a synchronously-driven clamping system[13] on the grid of the stage. The degree of the correction can be changed by the alteration of the reference level on the non-linear characteristic of the tube.

The bandwidth of the video amplifier is 15 Mc/s to 3 db down and no phase correction is used. The nominal video bandwidth is 10·5 Mc/s.

Figure 3 shows the complete scanning apparatus.

Great care was taken to keep permanently the geometrical distortions of the picture on a low level by the use of passive correcting networks and by inverse feedback in the scanning circuits and by avoiding as far as possible the use of the non-linear regions of the deflection tube characteristics. The geometrical distortions are less than ±4 per cent. in each field element, representing 1/64th of the whole picture area.

The 30-kV d.c. supply for the scanner tube works as a quadrupler using cascaded filament transformers for the valves; the valves in each stage are duplicated to minimize interruptions in the event of a heater failure. The whole compact unit is oil immersed. The power supply to the rectifier is at 50 c/s. The breakdown voltage of the polyethylene h.t. cable is sufficiently high to use an oil-tight metallic cone in the place of the usual ceramic insulator which would be of considerable dimensions.

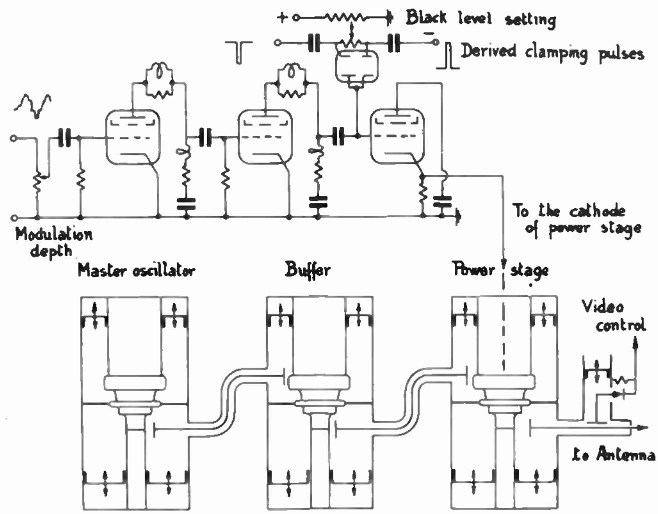

Fig. 4.—Basic circuit diagram of transmitter

3.4. *The Microwave Relay*

The broadband microwave relay was developed to provide point-to-point connections for distances of the order of 25 miles. The choice of its characteristics was guided by the desire to obtain a simple and stable apparatus working if necessary for an indefinite number of hours, with a minimum of maintenance personnel.

The carrier frequency was chosen to be 940 Mc/s. It allows the use of small high-gain parabolic mirror antennas and allows the generation easily of an output peak power of about 5 W. The above considerations, and the width of the video band, led us to use amplitude modulation of the carrier, introduced on fixed black level on the cathode of the output stage.

This stage is separated from the master oscillator by a buffer amplifier.

All the H.F. circuits are of the cylindrical cavity type. The thermal frequency drift of the pilot is compensated by a suitable choice of the different metals used in the construction of the cavity with the result that no appreciable warming up time is needed before the transmission, the remaining drift not causing a perceptible change in the received picture in spite of the partial suppression of one sideband in the receiver. All power amplifiers are of the grounded-grid type using lighthouse type tubes.

Figure 4 represents the basic circuit of the transmitter. Fig. 5 shows the external views of the relay at the Milan Fair.

A small wide-band cavity, loosely coupled to the transmitter output, derives, with the aid of a silicon crystal, a video signal for control purposes which is carried back to the control rack through a cathode follower by a coaxial cable.

The transmitter itself is fixed in a watertight box on the back of the parabolic mirror. The quarter-wave transmitter dipole is located in the focus of the parabola, the focal length itself being an odd multiple of a quarter-wave length. A parasitic reflector is used to reinforce the illumination of the mirror. Quarter-wave chokes are disposed to stop the waves on the outer surface of the rigid coaxial structure designed to support mechanically, and to feed the radiator.

The power gain of the mirror over an isotropic radiator is 20 db, and the beam aperture for half power is 9 deg. The voltage standing wave ratio of the antenna feed is better than 1 : 1·15 over the whole bandwidth of 30 Mc/s.

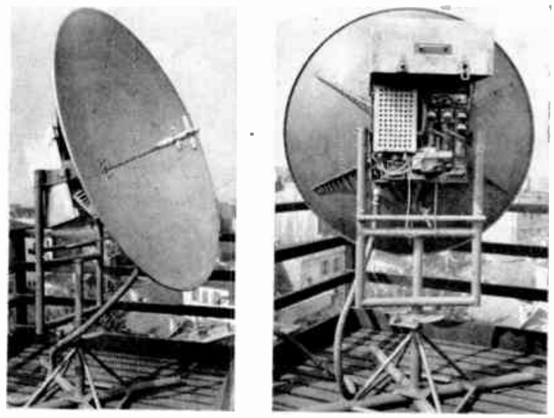

Fig. 5.—Transmitter assembly as used during Milan Fair.

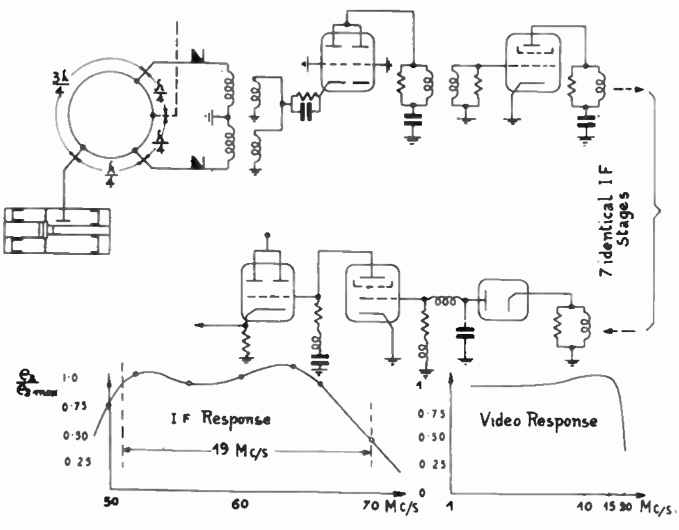

Fig. 6.—Basic circuit diagram of the receiver and frequency response characteristics of the I.F. and video amplifiers.

The transmitter is fed and controlled by a separate rack containing the stabilized power supplies, the video input and output controls, a direct viewing tube and a synchronized oscillograph.

3.5. *The Receiver*

The superheterodyne type receiver of the microwave relay makes use of the same type of directional antenna as used for the transmitter. The gain of both antennas over isotropic reflectors being 40 db, and the maximum power output very nearly 5 W, the received power is the same as would be obtained by the use of simple dipole antennas and a power output of 40 kW. The antenna input and the local oscillator output are fed in a Magic-Tee circuit in closed annular form, the push-pull output of which is

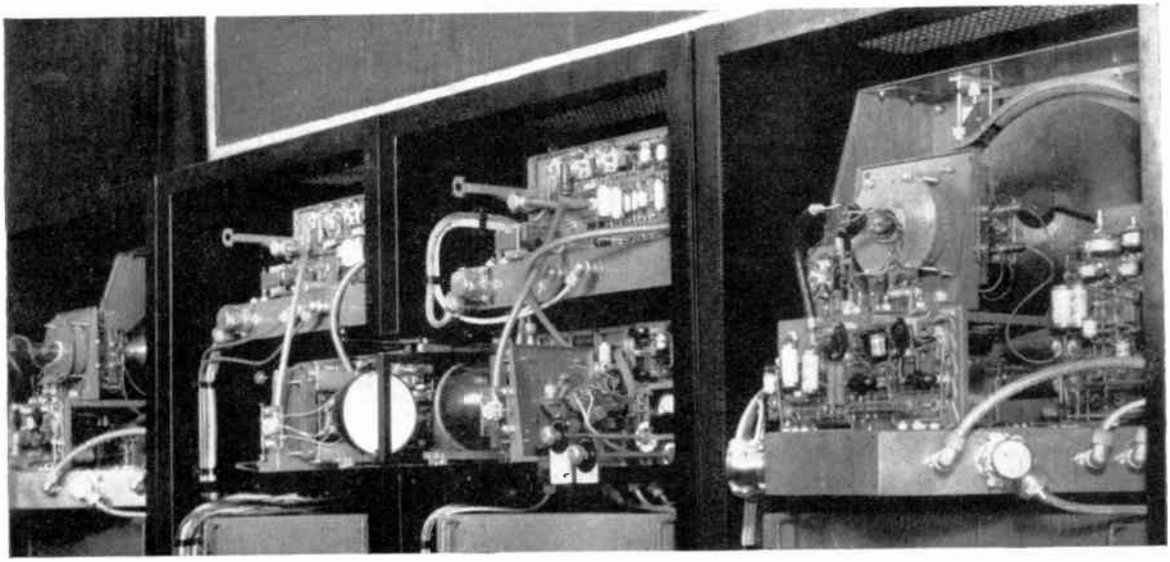

Fig. 7.—Racks containing control and monitor circuits, power supplies, and the registering equipment. The camera unit has been removed so that the twin registering kinescope tubes and mirror can be seen.

connected by suitable quarter-wave transformers to the mixer crystals. The resulting intermediate frequency is injected by the aid of bifilar transformers having a ratio 1 : 1 into the first stage of the I.F. amplifier. The I.F. amplifier is composed

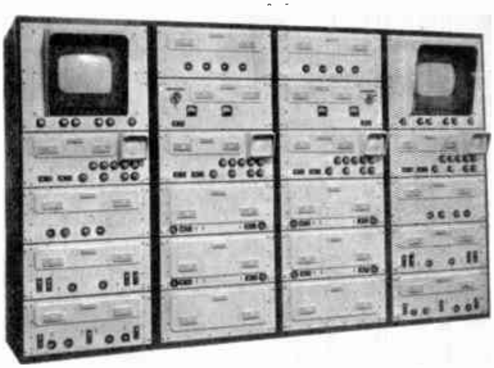

Fig. 8.—Front view of the racks shown in Fig. 7.

of seven stages of double-tuned filters and uses miniature pentodes with the exception of the first tube which is of the grounded-grid triode type. The noise factor of the complete receiver is 18 db, including the mixer.

The video detector is followed by a suitable amplifier stage and by a cathode follower. The sensitivity for 1 V peak-to-peak output is about 100 μV. The mixer and the receiver are located in a watertight box on the back of the receiver parabola.

Figure 6 shows the basic circuit of the receiver together with the frequency characteristics of the I.F. and the video amplifiers.

The receiver is controlled at distance by a separate rack containing the power supplies and the means to control the signal level and the sensitivity.

3.6. *The Registering Process*

After amplification and after restoration of the black level by auxiliary pulses derived from the synchronizing pulses, the video signal is applied in positive or negative polarity to the control electrode of the transcriber kinescope. A rotatable mirror between the twin registering tubes reflects the picture from one or from the other screen in the direction of the registering film camera. The synchronously-driven camera is equipped with a fast speed shutter mechanism (the corresponding shutter angle being only 36 deg) running in phase with the television picture at the speed of 25 frames/sec. Hence no single television field is lost for the photographic registering, which makes use of a 16-mm film covered by a highly sensitive low-grain emulsion, specially treated to withstand the relatively high temperature of the developing apparatus. The accompanying sound is simultaneously registered on the film in the usual manner. The registering makes use generally of a television picture of negative polarity, in order to obtain after developing a positive print ready to be projected. The inverse polarity can of course be used to get a negative print if desired for other purposes than that of immediate projection.

The film runs continuously from the camera through a dark tunnel in the rapid developing apparatus; the picture appears 65 seconds later developed, washed, fixed, washed and dried on a hot air stream, ready for projection. The mechanism of this part of the equipment is a particularly simple one: once the starting end of the film is introduced in the developing

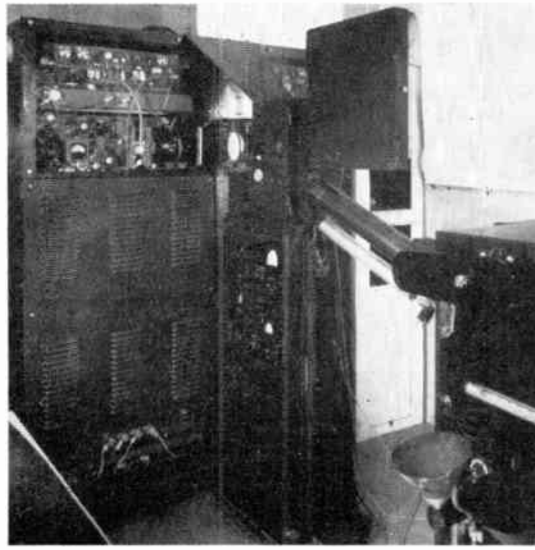

Fig. 9 (above).—Rear view of the registering apparatus with camera unit in position.

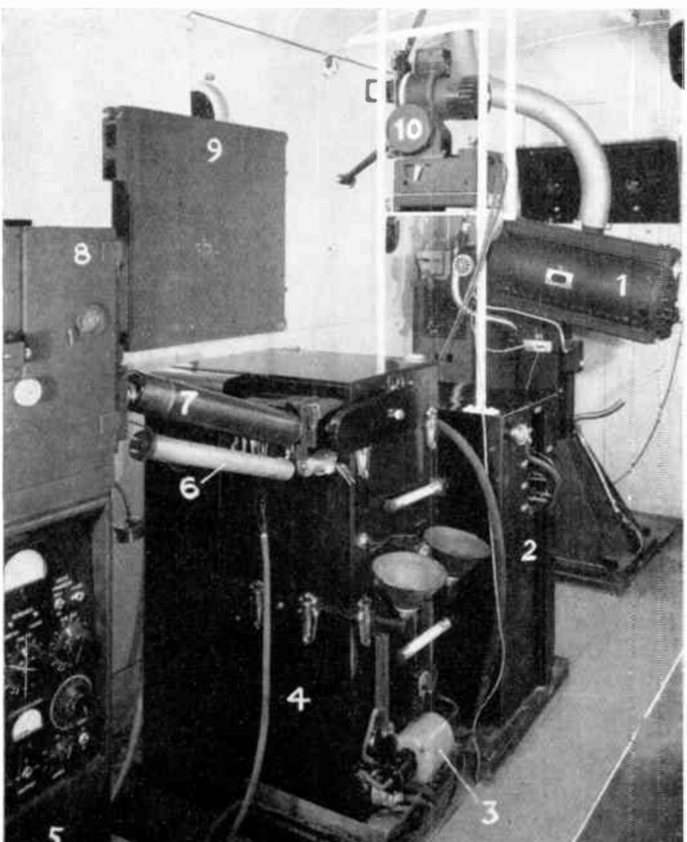

Fig. 10 (left).—General view of the kinematograph equipment.

1 High power projector
2 Air filter and blower apparatus
3 Circulation pump
4 Developing apparatus
5 Sound registering equipment
6 Heater for film tunnel
7 Film tunnel
8 Registering camera
9 Film spool
10 Control projector

machine, it follows automatically on a helicoidal path, guided by revolving rubber drums through the different sections. The total delay of about 65 seconds is split up in the following manner:—

Developing	.. ..	6·5 sec.
Washing	.. ..	6·5 sec.
Fixing	.. ..	19·5 sec.
Washing	.. ..	13·0 sec.
Drying	.. ..	19·5 sec.

After this, the film runs through a low power control projector preceding the high power principal projector whose light source is an 80-A arc lamp. The total mean luminous flux through the window is about 2,000 lumens, allowing an illumination of 170 Lux on a screen 4 m wide.

The layout of the various items of the registering and developing apparatus and the other kinematograph equipment is shown in Figs. 7, 8, 9 and 10.

4. Results of the Field Tests of the Apparatus

Preliminary to the field test of the complete apparatus, each essential unit was separately tested. The resolution of the flying-spot picture was found to be equal to 900 picture elements along the horizontal scan and about 650 picture elements in the vertical direction, as measured with the help of a high contrast 35-mm film, representing a standard test pattern.

The maximum distance which could be covered by the microwave relay before additional receiver noise could be detected on the picture was measured as being about 25 miles, in the case of an unobstructed optical path of propagation. The stability of the transmission could be observed to be sufficiently high with no change in the picture quality or intensity, over periods of observation covering several hours of continuous service. As for the testing of the registering apparatus, the primary picture was given by the flying-spot scanner in form of a resolution pattern, of a gradation scale or any other chosen subject on positive or negative print. The temperature, the concentration of the film baths, the light output of the registering tube, and the f-number of the recording lens were fixed during this phase of the work.

It is interesting to note that under the quite special registering conditions compared to ordinary studio conditions, the upper limit of registered details is not fixed by the grain of the emulsion, but by the spot size of the registering

Fig. 11.—Reproductions of frames transmitted over the radio link and registered and developed in the equipment described.

tube, and by the mechanical vibrations of the camera, or by the aberrations of the photographic lens with a too-high aperture when using a less sensitive emulsion. The best resolution which could be obtained was about 10 per cent. less (800 picture elements along a line) than that in the original picture. Work is currently proceeding to determine the factors limiting the contrast range which is inferior to that obtainable on a good motion picture print.

The complete apparatus was first tested during the second "Salon du Cinéma" in Paris, from October 5th to 20th, 1950, working every day for about two hours in connection with an outdoor pick-up TV equipment during the peak visiting hours of the Exposition.[13] During the month of December it was installed in the "Cinéma Madeleine" in Paris. Two different kinds of pictures are registered and projected:

(1) From the "Gaumont Palace" where a mobile TV pick-up unit is installed and from where the signal is transmitted by the microwave relay.

(2) From the studios of La Radiodiffusion Française, the picture being radiated by the Eiffel Tower Transmitter.

It was our feeling that immediate comparison between normal motion pictures and televised films on the screen of a theatre would be most useful to complete the laboratory measurements and tests. The results of this field test are being used, together with the results of the work during the Milan Fair, to guide further development of the whole unit.

5. Acknowledgments

The electronic apparatus described was developed by the Television Laboratories of La Radio-Industrie S.A., the registering camera, the developing apparatus and the projection units by the Etablissements Andre Debrie. The Sté. Pathé-Kodak manufactured the special 16-mm film material. The author is particularly indebted to MM. Steen and Burgert of La Radio-Industrie S.A. staff for their valuable help during the development of the apparatus.

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15. *Le Film Français*, No. 317, Nov. 17th, 1950.

At the conclusion of the presentation of the paper at Cambridge, the author demonstrated a film which had been transmitted over the radio link and registered and developed. Fig. 11 shows two frames from this film.

APPLICANTS FOR MEMBERSHIP

New proposals were considered by the Membership Committee at a meeting held on October 22nd, 1952 as follows: 13 proposals for direct election to Graduateship or higher grade of membership and 17 proposals for transfer to Graduateship or higher grade of membership. In addition 43 applications for Studentship registration were considered. This list also contains the name of one applicant who has subsequently agreed to accept a lower grade than that for which he 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 Full Member

MUKERJI, Gopal Chandra, M.Sc. *Banaras, India.*

Direct Election to Associate Member

HOWES, Ralph. *Reading, Berkshire.*

ISHERWOOD, Charles Fitton, B.Sc.Tech. (Hons), *Kuala Lumpur, Malaya.*

PARTELOW, Alston Leonard, Squadron Leader, R.A.F., O.B.E. *London, W.C.2.*

ROBSON, Eric Richard. *Slough, Buckinghamshire.*

Transfer from Associate to Associate Member

ELLESWORTH, George, B.Sc.(Eng.). *Quorn, Leicestershire.*

Transfer from Graduate to Associate Member

MORLEIGH, Sidney. *London, N.W.10.*

Transfer from Student to Associate Member

CRETCHLEY, Ronald Richard, B.Sc.(Eng.). *Swindon, Wiltshire.*

Direct Election to Associate

BANERJI, Biswa Nath, M.Sc. *London, W.2.*
BILBROUGH, Jack. *Newcastle-upon-Tyne.*

COLLINSON, Thomas. *Malmesbury, Wiltshire.*

PAINOANKAR, Nagesh Gangaram. *Bombay.*

SHAH, Saleemulla, Captain, Indian Army. *London, W.5.*

Transfer from Student to Associate

JAHANBIN, Ahmad Ali. *Wembley, Middlesex.*

TEJUJA, Mohonlal Moolchand. *Bombay.*

Direct Election to Graduate

CROOK, Maurice Howard. *Southampton.*

FULLERTON, John Raymond, Flight Lieutenant, R.A.F., D.F.C., D.F.M. *Hemswell, Lincolnshire.*

SMITH, Darrell Alfred. *Milton-under-Wychwood, Oxfordshire.*

Transfer from Student to Graduate

ADAMS, Hubert Charles Barton. *Welling, Kent.*
AVINOR, Michael. *Tel Aviv, Israel.*

HODGSON, John. *Bournemouth, Hants.*

KATHURIA, Mohindar Singh, B.A. *Sidcup, Kent.*

MILNE, James. *Glasgow.*

PADMANABHAN, Nambiar K. P., B.Sc. *London, N.15.*

PAINTER, Arthur Robert. *Tenbury Wells, Worcestershire.*

RAJKUMAR, G. M. *Colombo.*

SEN GUPTA, Ranjit Kumar, M.Sc. *Lucknow, India.*
SIVARAMAKRISHNA, K. S., Lieutenant, Indian Army, B.E. *Poona, India.*

THOMAS, Newton V., Flight Lieutenant, Indian Air Force, B.Sc. *Bangalore, India.*

WILKINSON, William Dinsdale, B.Sc. *London, S.W.16.*

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AITKEN, Alan Brown. *Dunbartonshire.*
AKHURST, Denis Osmund, B.Sc. *Beeston, Nottinghamshire.*
ALIMUNDO, Desmond. *Khartoum.*

BHATTI, M. Bashir. *Lahore, Pakistan.*
BISPING, Piotr. *London, N.22.*

COGGON, Brian. *Grimsby, Lincolnshire.*
COLLINS, William Clarence. *Ottawa.*

DOBBIN, Robert George. *London, S.E.8.*

ELLIS, Alfred Brian Edwin. *Eglinton, Northern Ireland.*
ELLIS, Derek Vincent. *Stockton-on-Tees, Co. Durham.*

FAIZ, Victor Naimat. *Karachi.*
FALCON, Gordon Leslie. *Standish, Lancashire.*
FERNANDO, Ira Barry Evertsz, Lieutenant (L), R.Cy.N. *Colombo.*

GEHRELS, Jacob-Frederick. *Halfweg, Holland.*

HIGGINS, Gordon Leonard. *Meifod, Montgomeryshire.*
HUTCHINGS, Giles Samuel. *London, N.W.3.*

KANE, Donald. *London, N.W.11.*
KAPOOR, Sukl Deu. *Poona, India.*
KARAS, Witwold Wale. *London, S.W.19.*
KOHLI, Purshotam Lal, 2nd Lieutenant, Indian Army. *Hyderabad.*

LUTHRIA, Vasudeo Notandas. *Bombay.*

MACKINTOSH, Robert. *Glasgow.*
MEHTA, Mahendrakumar C. *London, W.2.*

NANDA, Jagbir Singh, Captain, Indian Army. *Mhow, India.*
NG, Song Kang. *Singapore.*
NUNES, Edward Vincent. *Bombay.*

PATTIHAL, Narhar Shankar. *Bombay.*
PEARCE, Raymond Albert. *Keighley, Yorkshire.*
PIPER, Edwin Anthony. *Harrow Weald, Middlesex.*

RAJAN, Mehta M., M.Sc. *Borivli, Bombay.*

SCOTT, Walter. *London, W.1.*
SHAHZAD, Iqbal Hasan. *London, W.4.*
SHANBHAG, Dayananda Laxman. *Madras.*
SINGH, Mohinder. *London, W.2.*
SIPAHIMALANI, B. Kishinchand. *London, W.2.*
SOOD, Ramesh Chander. *Bombay.*
SRINIVAS K. Venkataramaiyer, B.Sc. *Bombay.*
SRINIVASAN, Rangaswamy, B.Sc. *London, W.2.*

TILMOUTH, Percival Charles. *London, S.W.2.*

VENKITESWARAN, N. Harhariyer. *Matunga, Bombay.*

WADVA, Kuldip Singh, B.Sc. *Bombay.*
WOOD, James Gladstone Stewart. *Wellington, New Zealand.*

ZANGAR, Oscar. *Haifa, Israel.*

ACOUSTICS IN RELATION TO RADIO ENGINEERING*

by

E. G. Richardson, B.A., Ph.D., D.Sc.†

A Paper presented before the North-Eastern Section on March 14th, 1951, the Scottish Section on October 4th and 5th, 1951, and the London Section on October 11th, 1951.

SUMMARY

The paper demonstrates analogies between acoustic and electromagnetic phenomena. The ideas of acoustic impedance, resonators, filters, transmission lines, waveguides and radiators are discussed in relation to the comparable electromagnetic cases. Phenomena experienced in the applications of "sonar" and sound ranging are compared with the propagational effects experienced in the ionosphere by electromagnetic waves.

1. Introduction

There has been a constant interchange of ideas between acoustics and electrical communication in the past 100 years. In the concluding years of the last century, telegraphy advanced rapidly and the principles of electrical communication, especially through cables under the sea, were laid down by Kelvin and others. These principles were rather slow to be adopted in sound, but in the nineteen-twenties a number of workers, led by Webster, adapted the idea of impedance to the construction of acoustic resonators, columns of air and filters.

The next interchange of ideas, starting at about the same time, was mainly in the other direction. The use of ultrasonic radiation for the detection of ships and obstacles under the sea ("sonar," as the Americans call it) contained the basic principles of "radar" for detection of obstacles in the atmosphere. Finally, the more recent development of waveguides in radio-communication stems from an observation of Rayleigh that the velocity of propagation of sound in tubes can be affected by cross-modes of vibration. From this it is evident that the borrowing of ideas has not been all in one direction. The object of this paper is to demonstrate some of the techniques used in sound under the specific headings of transmission and radiation because of their interest in comparison with radio techniques and the possibility of deriving new ideas from these analogies. Few workers in sound these days can afford to ignore the developments which have taken place in radio transmission and radiation in recent years.

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2. Acoustic Impedance and Resonators

We begin then with the idea of acoustic impedance. An alternating pressure (p), like e.m.f., acting on a fluid, gives rise to an alternating current which we usually call the particle velocity. Since in transmission between solid boundaries we are mostly concerned with conduits of circular or rectangular cross-section, we find it more convenient to multiply the mean particle velocity over an area by that area and call this the "volume velocity," χ, like current.

We then define the acoustic impedance Z as p/χ. The difference in phase between p and χ gives rise to reactance. Often in acoustics we can afford to neglect viscous—which, of course, corresponds to ohmic—resistance in relation to reactance unless the propagation is taking place in a capillary tube.

As in electro-magnetism, we envisage two kinds of reactance. That part of an air chamber or conduit in which pressure rather than flow predominates is called a capacitance, C—its mechanical analogue being a piston and cylinder—while that part where the contrary is true is an inertance, L—like mass in mechanics and inductance in electricity.

Often these overlap so that a "real" stratum of air has both C and L. We cannot usually separate them off neatly into condensers and coils, and calculate their values from clear-cut formulae as in electricity, but there is one case where this may be done. This is the Helmholtz resonator (Fig. 1*c*) which may be regarded as an inertance—in respect of the air in the neck—and a capacitance—the cavity—in series.

As long as our conduits and connectors are short compared with the wavelength we can still treat them as "lumped" impedances.

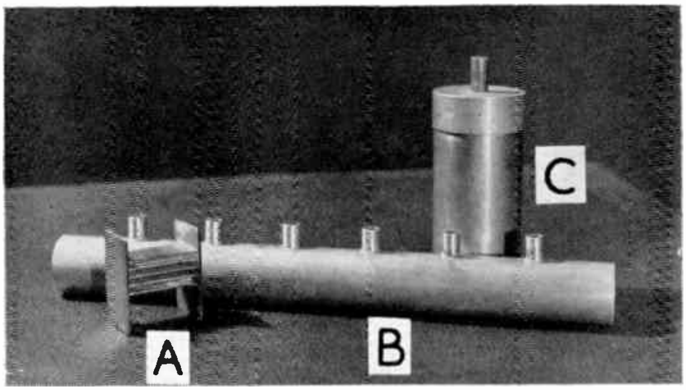

Fig. 1.—Acoustic analogues of electro-magnetic apparatus.

A recent application of Helmholtz resonators, anticipated in a somewhat different form by the Ancient Greeks who set empty vases in their auditoria for the same purpose, is to improve the acoustics of music studios and concert halls. The material takes the shape of a honeycomb made of asbestos sheet or similar material applied to the walls so as to form cavities which communicate with the atmosphere through perforations in the outer face of the honeycomb. These resound more or less to sounds incident on them from the room and then re-emit the sounds in all directions. Thus, a desirable condition of diffuse sound is set up in the room. Such resonators must be regarded as in "parallel" and there is coupling—as it were, mutual inductance—between their vibrations via the air outside.

3. Filters

A natural extension of a common apparatus in electrical transmission is the construction of acoustic filters. Filters usually consist of a reiterated series of impedances, Z_1, in a line interspersed with branch impedances, Z_2. They act by repeated interference so that, if the line is long enough, signals will only get through if $0 > Z_1/Z_2 > -4$. As the impedance is a function of frequency, this condition, of course, limits the signal frequency which can get through.

Stewart first constructed such filters using a tube about 1-2 in. wide as a transmission line with holes at intervals leading to Helmholtz resonators (low pass) or via necks to the open air (Fig. 1*b*) (high pass). Their respective cut-off pulsatances are

$$\omega_0 = \frac{1}{2\sqrt{[C_1(L_1+4L_2)]}}$$

$$\text{and } \omega_0 = \frac{1}{2}\sqrt{\frac{(L_1+4L_2)}{L_1L_2C}}$$

Fig. 2 shows an interesting filter for very-low-frequency (infrasonic) transmission. It consists of mercury pellets having inertance (equal to their mass) L, separating capacitances C of air. It is a low-pass type of cut-off period $\pi\sqrt{LC}$ and was used to remove a high overtone from the 7 c/s air pulsations produced by a reciprocating engine; cf. the wave-diagrams "before" and "after," shown on the right. Below is the equivalent electric circuit. Actually the cut-off is modified by the weight and viscosity of the mercury represented in the diagram by c and r respectively.

Acoustic filters have been applied to the smoothing of the output from loud-speakers and gramophone sound-boxes, and as silencers for internal-combustion engines. The cut-off is not so sharp as in the corresponding electrical case, owing to the difficulty of separating the inertance and capacitance factors in the same volume of air and, perhaps, to the finite size of each element in relation to the wavelength, especially at high frequencies. Whatever theory may indicate, an acoustic filter when constructed and tested often behaves like a combination of band filters. That is why, except for the applications already noted, they have rather an academic interest.

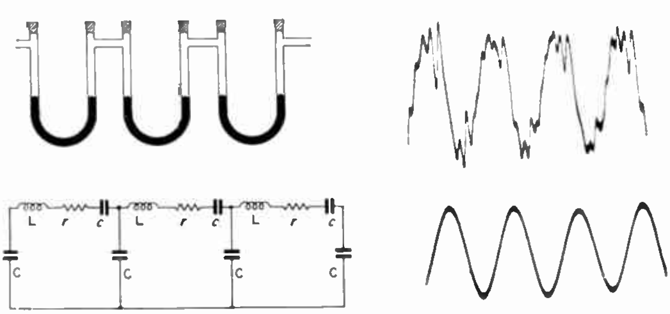

Fig. 2.—Low-frequency filter to purify output from generator.

4. Transmission Lines

When an acoustic conduit is long compared to the wavelength of the sound transmitted, we must consider its reactance as distributed—l and c per unit length respectively. The velocity of sound in the tube will then be $v = \sqrt{(l/c)}$ and the characteristic impedance of the tube ρv where ρ is the density of the air. For a tube of length L and cross-section S, the impedance to a tone of pulsatance ω "looking-in" at $x = L$ in terms of that at $x = 0$ (Z_0) is

$$Z_L = \frac{i\rho v}{S}\left[\frac{Z_0 \cos\frac{\omega}{v}L - \frac{i\rho v}{S}\sin\frac{\omega}{v}L}{Z_0 \sin\frac{\omega}{v}L + \frac{i\rho v}{S}\cos\frac{\omega}{v}L}\right]$$

This formula may be compared with that of the impedance of a cable. From this we can derive (by putting $Z_L = 0$ and Z_0 equal to whatever input impedance is appropriate), the resonant frequencies of the column.

Extensions of this formula to compound pipes, pipes with side-holes, conical pipes, etc., enable the organ-builder and wind-instrument maker to predict the size and shape of the columns to be used for given frequency-production in the instruments which he fashions.

Also by using side-pipes in conduits one-quarter wavelength long, undesirable even harmonics may be filtered out between a transducer and a measuring system, a method which may recall the $\lambda/4$ "stubs" used for the same purpose in H.F. radio transmission.

Bridges for comparing acoustic impedances have been devised by N. W. Robinson[3] and others on the principle of an a.c. bridge in which the source is a telephone diaphragm, and a stethoscope device replaces the vibration galvanometer.

Figure 3 shows an acoustic transmission line by which Hall[4] measured the impedance of a terminating specimen at one end, while a telephone source drives the tube from the other. The "line" is an annular groove of rectangular cross-section cut in a brass bed-plate. The top of the groove is closed by a tight-fitting plate which can be rotated and in doing so carries a microphone round the groove. Thus, the pressure amplitude along the line can be plotted by rotating the upper plate and observing the maxima and minima of microphone response. This

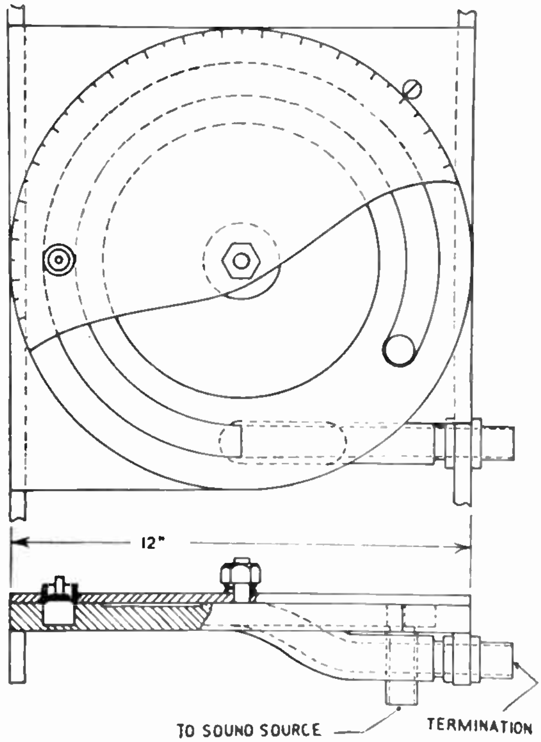

Fig. 3.—Instrument to measure terminal acoustic impedance.

"standing-wave ratio" enables the terminating impedance to be calculated.

We also meet the acoustic analogue of the skin effect to upset our calculations. It is well known that the steady one-way (laminar) flow at low speeds of a fluid in a tube satisfies the parabolic or Poiseuille distribution of velocity with radial distance, but that, at high speeds where turbulence supervenes, a rather flat-topped distribution of velocity takes its place. In alternating flow, however, there is a peak of velocity[5] near the wall whose distance (δ) therefrom is given by $\delta\sqrt{\omega} =$ constant. This may be compared with the corresponding formula for the case of a cable carrying an H.F. current. Fig. 4 shows the three types of flow: (*a*) one-way (laminar), (*b*) alternating, (*c*) a.c. + d.c. ("combined") flow, which the writer has explored by means of a hot-wire anemometer. There is probably no analogue in radio to turbulent flow, though one of the features of turbulence, the enhanced "eddy viscosity" which replaces

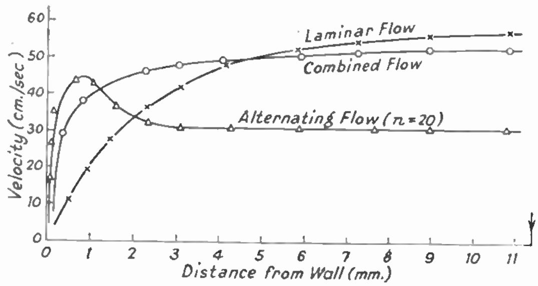

Fig. 4.—Types of flow in tube.

molecular viscosity, has an effect like that of the non-linear relationship between induction and magnetic field at current values approaching saturation in ferro-magnetic materials.

5. Waveguides

Turning now to the comparatively new development of waveguides, it may surprise readers to learn that the principles of their construction were laid down (in acoustics) by Lord Rayleigh in 1897.[6] The existence of cross-modal vibrations in columns of air was first suspected when it was found that, above a certain frequency, the nodes and antinodes were not uniformly distributed along the column. In both acoustic and electro-magnetic cases the wave equation must be written in terms of cylindrical co-ordinates and solved for the appropriate boundary conditions.

In the sound conduit the particle velocity must be parallel to the wall and the pressure gradient perpendicular to the wall zero at that boundary.

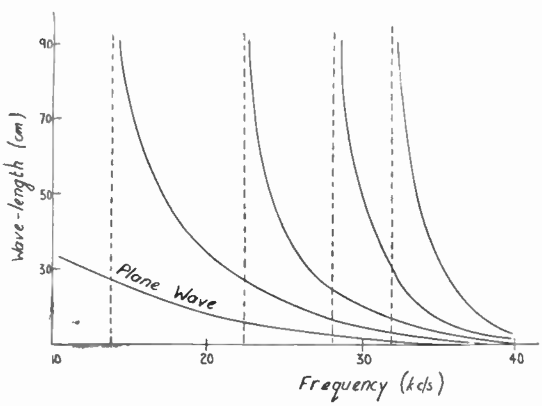

Fig. 5.—Dispersion of sound velocity in a tube.

In the waveguide the electric field cannot be parallel to a metallic boundary. Cross-sections of sound wave patterns in tubes look like those of membranes, but there is a variation from section to section, the whole forming a three-dimensional standing-wave system, just as do the corresponding patterns of the electric and magnetic fields in a waveguide. These patterns may be verified either by use of a pressure probe (Pitot-tube) or velocity device (hot-wire anemometer) traversed across various sections of the column.[7]

Radial ("dominant") modes are also observed when high-frequency (ultrasonic) waves of compression are sent along rods. It was in this way that the salient feature of such guides was first demonstrated as a variation of velocity with frequency (or wavelength). The phase velocity of a given mode increases with decrease of frequency until the cut-off frequency is reached, when the tube ceases to propagate energy. These facts are shown for an air column in Fig. 5, in examining which we must remember that the phase velocity is the product of frequency and wavelength. The vertical broken lines indicate the cut-off frequencies for the various modes; as the frequency corresponding to a given mode rises, the wavelength falls until the product equals the velocity of plane waves in air. (Unless the tube is narrow, this equals the free-space velocity.) Such a guide can carry acoustic plane waves. *Per contra*, plane electro-magnetic waves cannot be transmitted in a waveguide for they would violate the boundary conditions (see above).

6. Radiation

Turning to radiation, we find in sound radiation resistances at the end of columns like those of waveguides where plane waves turn to spherical. The same problems of mis-match arise because the characteristic impedance of plane waves is ρv, independent of frequency, whereas that of spherical waves contains a frequency-dependent term.

To retain a nearly plane wave in the atmosphere after the sound has left the tube, a form of trumpet must be attached of an aperture (d) at least ten wavelengths (λ) wide, such as that which is commonly fixed on the end of waveguides. Fig. 6 shows how the radiation from a source is affected by the ratio of diameter of the transmitter to the wavelength. The "wings" of

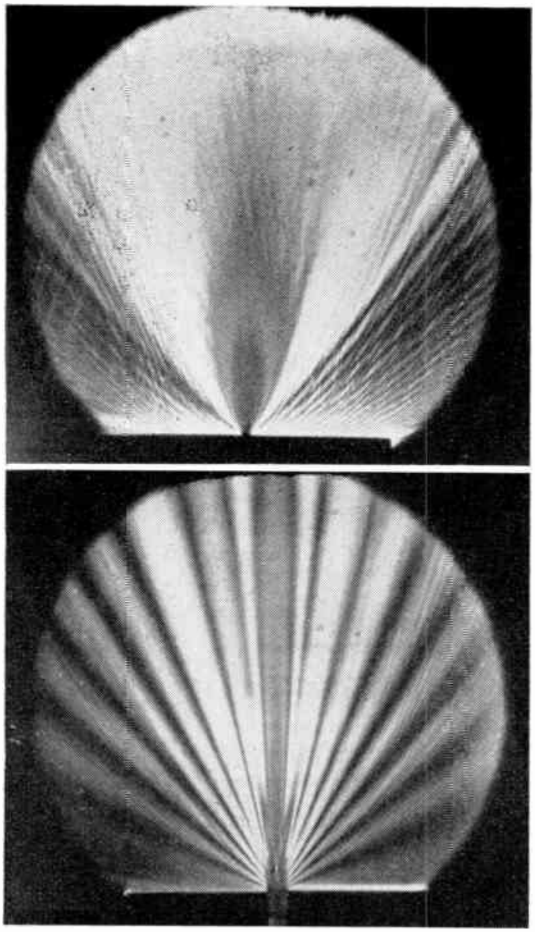

Fig. 6.—Diffraction of ultrasonic waves emerging from an orifice (Hiedemann).

diffracted energy are close together and at small angles to the axis when $\lambda = 7{\cdot}5\ d$ (lower photograph), but wide-spread at $\lambda = 1{\cdot}3\ d$ (upper photograph). These photographs were taken by the "schlieren" method, using ultrasonics from quartz crystals as radiators.[8]

To diffract acoustic energy we may use a grating or lattice (like those used in spectroscopy) of which a three-dimensional example, consisting of a number of parallel wires about 2 mm diameter separated from each other by an equal distance, is shown in Fig. 1*a*. These like their analogues in optics and X-ray studies have the property of concentrating the energy in certain directions.

Another device for focusing is the acoustic lens or prism which in the old days was usually a balloon filled with carbon dioxide, but now can be a regular series of suitably dispersed solid bodies like the slats of a Venetian blind or—having closer analogy to the grating of Fig. 1*a*—a set of rods end-on to the sound. The essential feature is that sound rays passing through the centre shall be more retarded than those passing the edges.

Figure 7 is a photograph of an interesting lens, the refracting medium consisting of blocks of little metal discs so distributed as to focus energy at a point on the axis of the system. This array was originally constructed to form an electromagnetic lens at the Bell Telephone Laboratories, but serves equally well to concentrate high-frequency sound.[9]

In this connection, it is interesting to note that Jordan and Everitt[10] have used a vertical pipe pierced with fine side holes mounted over a loudspeaker unit as a model of an antenna, plotting the acoustic field round the source by means of a microphone. By using the analogy between the acoustic and the electro-magnetic fields, they were able to predict the behaviour of a designed

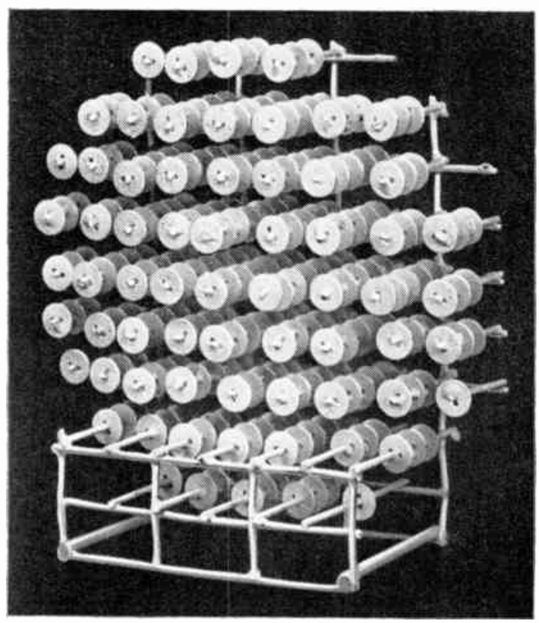

Fig. 7.—Acoustic or electro-magnetic lens (Bell Telephone Co.).

antenna, in advance of construction of the actual antenna. Everything in the full-size field can be imitated in this way, including mutual action of several antennae, except, of course, polarization effects.

In theory, the acoustic analogue of the antenna is a vertical stretched string driven by attachment to some sort of vibrator at the lower end and fixed at the upper end, but the string, owing to the very small surface it presents to the ambient fluid, is a very poor radiator. Hence the preference for the pipe analogue and—to let it radiate in the same fashion as an antenna—the provision of a stopped upper end and a series of fine holes in the side.

7. Propagation Through Water

Finally, let us discuss the analogies in long-distance propagation. Taking first the sea as medium, it is well known that owing to variations of density, salinity and temperature, a sound beam emitted horizontally just below the surface is normally bent slightly down in our latitudes (Fig. 8), and under certain conditions where the surface water is abnormally warm (in the tropics, for instance) it may be very much so. Under these conditions, sonar detection (except of the sea bed) will obviously fail in quite a short distance. Where, however, the surface stratum is colder, perhaps where fresh water from arctic estuaries overlays a gulf stream, good conditions for detecting surface ships and submarines exist owing to the way that the sound wave "skips" along under the surface (Fig. 8).

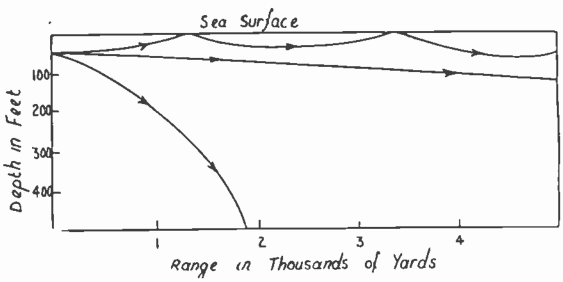

Fig. 8.—Sound rays in the sea.

Deeper still in the oceans the velocity of sound, which falls in the (generally) cooler water at depth, reaches a minimum and thereafter rises owing to the increase of pressure overweighing the temperature effect. Such a region acts as a "duct" to sound, for once the sound has got into it, divagations of the beam from the forthright direction can make it encounter regions of greater velocity from which it is reflected back into the straight path, so minimizing attenuation. Within the duct, in fact, the sound is propagated in a somewhat similar way to the sound in a conduit, to which Fig. 5 refers.

The detection of the position and nature of the sea bed by an ultrasonic beam inclined downwards under water is a well-known application of sonar. A model of this echo-sounding device was used during the last war in radar trainers.

Since the velocity of sound in water is 1,500 m/sec, whereas that of electro-magnetic waves is 30 million m/sec, it is evident that a model radar echo-map using ultrasonics may be constructed to one twenty-thousandth scale of the actual thing, that is, supposing the time scale is to remain unchanged. Thus, to model the device in which an aircraft pilot flying at 5,000 ft., say, obtains by radar echoes the position and nature of the terrain beneath him, a quartz crystal of frequency about 15 Mc/s, just under water in a tank 3 in. deep, may pulse towards the floor of the tank. A smooth bottom imitates, for radar, the specular reflection which electro-magnetic waves suffer at the sea surface; a sandy bottom, the diffuse reflection from a rough ground.

In the actual trainer, a radar emitter and receiver in the same building and controlled by the trainee monitored the ultrasonic circuits, while the quartz was carried slowly along the tank (at the scale speed) to simulate the steady flight of the aircraft at constant height.

The detection of underwater obstacles is not so simple as those surrounded by air. It is a question of matched impedances. If the characteristic impedance (expressed by the product of velocity of sound and density) of the obstacle is nearly the same as that of water, little sound energy will be returned to the listening station. It is for this reason that a hoped-for peacetime application of the asdic, that of the detection of icebergs in fog by underwater sound, failed—the respective impedances being too nearly matched. Using the same idea, the Germans in the last war coated some of their submarines with rubber loaded with metal to make detection more difficult. Tanks containing water for sound experiments may be lined with spikes of similar material to reduce echoes and simulate "free-field" conditions for model experiments.

To use the sea as a medium for transmitting speech, the same techniques may be used as with radio waves in the atmosphere, i.e. an ultrasonic carrier wave can be modulated at sonic frequencies. In this way signals have been sent up to 20 miles under good conditions. The optimum carrier frequency is limited at the lower end by spreading of the energy into "wings" and at the upper by the frictional attenuation which increases as the square of the frequency.

Before leaving the sea, it might be mentioned that workers in underwater acoustics suffer from something rather like "atmospherics," which limit the signal range. This background noise may be severe and is variously ascribed to surf-breakers, to turbulence caused by ships' "wake" and, in some waters, to noisy denizens of the deep of which the croaker and the snapping shrimp, inhabitants of American coastal waters, are the most infamous.

8. Propagation Through the Atmosphere

Since the first world war, the propagation of sound from large explosions above ground for great distances has been systematically observed. The most carefully co-ordinated and widespread observations have been made in connection with the pre-announced explosions at Oldebroek, 1923, La Courtine, 1924, and Juterbog, 1926. The main anomalies noted in the propagation of such sounds to great distances are (1) abnormally high velocities in the neighbourhood of the explosion with considerable mechanical movement of the air, (2) a second zone of normal velocity, (3) a third zone of complete silence, (4) a fourth zone where the sound reappears with renewed intensity, but takes an unusually long time to arrive.

The occurrence of this outer zone of audibility is ascribed to sound rays which left the source at a considerable angle of elevation but were bent until, after passing through the upper regions of the atmosphere, they returned to earth at a distance of 180 kilometres or more from the source. The abnormal intensity, having regard to the distance travelled by the sound, at the inner edge of this abnormal zone, is ascribed to the incidence, at this edge, of a number of waves which have traversed different paths, and also to the slight damping suffered by these waves, as compared with the damping of the waves which pass along the earth's surface.

The return of the sound-waves to earth may take place in two ways: either they may be reflected at a discontinuity in the atmosphere

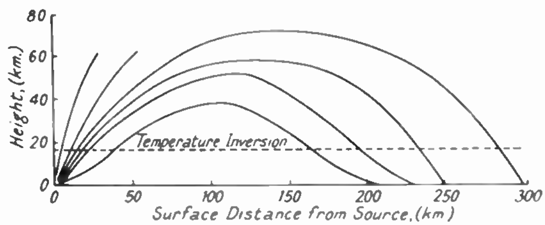

Fig. 9.—Sound rays in the atmosphere.

between two layers of gas of different density, or they may be more or less gradually bent back by gradual changes in the properties of the medium which they traverse.

For the first 17 kilometres up, the temperature decreases at a known rate, while the composition of the atmosphere remains practically constant, so that we can calculate the path and velocity of the sound in this lower region (or troposphere) with fair certainty. It is then a matter of putting forward hypotheses for the velocity of sound above 17 kilometres and testing these against the known time of propagation of the sound through this region into the abnormal zone on the earth, and such a hypothesis must make the summit-velocity high, otherwise these high-penetrating rays would not get back to earth within the prescribed surface-distance (180 to 300 kilometres). The simplest hypothesis seems to be the supposition that from 17 kilometres the velocity rises again at such a rate that at 30 to 40 kilometres the surface velocity is equalled and exceeded. This fits the observed time of passage of sound to the abnormal zone, giving the rays which penetrate to the outer edge of the abnormal zone an original inclination of about 45 deg. at the source, and a "summit-level" of 60 kilometres (Fig. 9).[11]

In spite of the possibility of variations in the path of the sound through the stratosphere due to movements of the atmosphere therein, the definition of the zone formation on the earth points to permanent conditions above which influence the propagation of sound. Attempts are now being made to send self-recording sound apparatus up to the stratosphere, carried by a balloon, and so to get direct measurements of the time of passage of the sound over a few feet at great altitudes. When the velocity of sound at different heights has been determined by methods such as those outlined, no doubt the effects of slight seasonal and casual changes could be eliminated by averaging the data over a sufficient number of explosions, leaving those effects due to temperature and molecular weight alone. Information on the constitution of the matter in these regions is scanty, and it is to be hoped that these prearranged explosions will provide unexpected knowledge of this subject.

These acoustic phenomena recall similar ones experienced when radio-waves are propagated in the atmosphere. In radio, in fact, one finds similar anomalies both in velocity and attenuation, some to be ascribed to purely electrical effects; Heaviside and Appleton layers, meteor tails, electrically charged clouds, etc.; others are more truly meteorological; changes of refractive index with density and humidity and the existence of ducts which result from this. Those unacquainted with these radio phenomena should study the report on "Meteorological Factors in Radio-Wave Propagation," issued jointly by the Physical Society and the Royal Meteorological Society in 1946.

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