Founded 1925

Incorporated by Royal Charter 1961

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

Volume 44 No. 8

August 1974

The Radio and Electronic Engineer

The Journal of the Institution of Electronic and Radio Engineers

Start Again?

JUST as this Journal was being assembled, the Institutions of Civil, Mechanical and Electrical Engineers publicly announced their joint proposal that the Council of Engineering Institutions should be replaced by a single Institution of Engineers. This concept has not yet been discussed by the Board of CEI but the text leading up to the proposal is printed on pages 390–391 of this issue so that every member may have the opportunity, through his Local Committee and in other ways, to express his opinion to the IERE Council.

There are bound to be opposing views. It is, however, vitally important to the country and future generations of engineers that the final decision should be in the best interest of the entire profession and not impair the right of the specialist to be recognized for his own particular knowledge and ability.

In the confines of this hurried introduction it is not possible to highlight all the possible arguments. For instance, as a federal body CEI may not have succeeded in meeting every Institution's desires. It has however, brought the fifteen societies together in order to obtain common agreement on such matters as legislation, overseas relations, equivalent standards of membership and professional examinations. CEI has also been the focal point for securing combined action for building an 'Engineers Centre'. This project could house all the Institutions, maybe effect economies in administration, and certainly provide better facilities for all chartered engineers—and yet preserve the autonomy of each Institution. Are sweeping changes a prerequisite of the unanimity required for continuing such co-operation?

The plan is perhaps not so much revolutionary as going back in time to having just one professional body for all engineers. But have the last 170 years proved disastrous? There could only be one Institution when the practice of engineering was only a small part of the economic life of the nation. As technology developed new Institutions were formed in the tradition of the old Guilds. Each was devoted to advancing knowledge in its own special field and securing opportunities for 'new' learning by urging the creation of new faculties in Universities and other schools. The proposal recognizes the importance of the learned society activities of the separate Institutions; whether or not they may continue (or afford) to exercise their authority on matters of education and encouragement of research and new techniques must depend on the statutes of the proposed new body. Care must be taken to allow maximum opportunity to each branch (Institution) to develop its own technology unfettered by a managing Council having a majority representation of the larger (and older) branches of engineering.

It is fortuitous that this issue also contains the 49th Annual Report of the Institution for it provides members with immediate opportunity to note the present problems which confront the IERE as an independent body and is a guide to the continuing growth of this Institution.

The proposal of the three larger and older Institutions also coincide with plans to commemorate the Golden Jubilee of the IERE. Much has been accomplished but how many engineers will believe the past achievements will be swamped by the all-pervading character of one large Institution and the possible personal advantage of being incorporated under the generic title of 'Engineer'? On this last point there will equally be the argument that public protection is best afforded by insistence on satisfactory evidence as to what 'kind' of engineer.

Every Institution has built a considerable heritage for successive generations of members. Each one must now consider whether or not to start again.

G.D.C.

Future Organization of the Engineering Profession

A discussion paper prepared by the Presidents of the Institutions of Civil, Mechanical and Electrical Engineers suggesting that consideration be given to replacing the CEI by an Institution of Engineers responsible for all professional matters; and advocating that the existing Chartered Institutions should confine themselves to the advancement of knowledge in their respective fields of engineering.

THE PROBLEM

1. The Council of Engineering Institutions (CEI) has been in existence as such for eight years, but if its prior existence as the Engineering Institutions Joint Council is taken into account, it is twelve years old. A number of changes have been considered during the past two years or so; under the designation 'CEI phase 2', reflecting the view that the CEI has reached a plateau following the initial climb from its beginning; that its present position is not satisfactory; and that it is time to move on. A more fundamental approach to the matter, however, requires consideration of the question: does the CEI, as conceived over a decade ago, meet the requirements as we see them today?

2. The reason for the formation of the CEI is to be found in the history of the development of the engineering profession, which may usefully be reviewed as a basis for considering a plan for further development.

3. The present institutions have all developed along similar lines to undertake similar functions. They have started as learned societies and then have developed functions that may be described as the organization, representation and control of their members, of which the setting of standards of qualifications has been an important item. These latter functions will be called 'professional' functions to distinguish them from the learned-society functions.

4. The uncontrolled and uncoordinated formation of societies with these functions and aspirations as the result of the voluntary efforts of persons with common technological interests (some of them quite narrow) led to a situation in which the learned-society needs of engineers were reasonably well catered for, but in which professional identification and control were seriously deficient. The CEI was formed to attempt to repair this deficiency.

5. The CEI's main undertaking so far has been to establish common standards of qualification. This has been pursued with reasonable success, although progress has been slow and much remains to be done. The CEI has been far less successful, however, in representing the profession to Government and the public, and it shows little sign at present of being able to overcome the factors which have inhibited its success in this area, although this is one of the most important functions for which the CEI was created.

6. At the same time, the growing complexity of engineering and the growing interdependence of what have traditionally been regarded as discrete technologies have shown a weakness in the present learned-society structure. This is manifested in a lack of flexibility to enable 'cross-disciplinary' subjects to be dealt with adequately in a manner acceptable to the engineers working in those fields, and in the less-than-satisfactory relationships between the CEI and some of the non-chartered learned societies.

7. The original weakness of the uncoordinated institutions lay in their undertaking both the learned-society and the professional functions, because the price paid for the high standard of learned-society activity resulting from the creation of numerous specialized institutions was fragmentation of the engineering profession which deprived it of any recognizable identity and cohesion. The formation of the CEI (which has eschewed any function in the learned-society role other than co-ordination) has improved the situation, but the continuing weakness in the professional field may be attributed to the fact that the exercise of the professional function is still tied to a learned-society structure which is not well suited to dealing with such matters. Thus, any important professional matter requires reconciliation of the views of 15 independent learned societies, each with an equal voice. This is notwithstanding that the matters to be considered have no relation to particular branches of technology which the institutions severally represent, and that the institutions themselves represent widely different numbers of engineers who, as individuals, have an equal interest in the action taken.

8. The present weakness in the professional field is frustrating not only to the officers of the institutions upon whom responsibility for action falls, but also to the general membership of the profession. The complaint most frequently heard from individual engineers, particularly the younger engineers, is that the profession has no identity and no voice in the community. These sentiments are most frequently summed up in complaints of inadequate status.

9. How, then, can the present deficiencies be corrected?

10. It would seem from the analysis of the difficulties rehearsed in the previous paragraphs that what is needed is a structure which separates, more completely than at present, responsibility for the professional and the learned-society functions; gives the individual engineers a focus for identification with, and loyalty to, the engineering profession as a whole while preserving the loyalties which members display to their chosen branches of engineering; and preserves all the present freedoms to develop learned-society activities, while providing for greater flexibility to deal with new technologies that now emerge with increasing frequency.

11. The professional functions which, with advantage, might be separated from the learned-society functions are:

(a) setting the standards of education, training and experience required to be met by candidates for the basic professional qualification of 'Chartered Engineer';

(b) assessing the qualifications of individual engineers and granting the designation 'Chartered Engineer' to those meeting its standards;

(c) making and enforcing rules of professional conduct; and

(d) representing the engineering profession as a whole in its relations with the public, the Government, and other organizations.

A POSSIBLE SOLUTION

12. The CEI, as a federation of institutions, should be replaced by a body with a different structure and function. This new body will be referred to here as 'The Institution of Engineers' (IE).

13. The IE should take over responsibility for the professional functions listed in paragraph 11 above; in carrying out its functions of setting standards and assessing qualifications referred to in paragraphs 11(a) and 11(b) it should act with the advice of persons who should be nominated by the Institutions, but who should then act in a personal capacity.

14. Individual engineers should join the IE and pay to it annual dues sufficient to cover the cost of its (professional) activities and to provide a reasonable sum to support the activities of the learned institutions upon which development of the technology depends. The latter part of the annual subscriptions should be assigned to the learned institutions according to some formula to be agreed.

15. Each person who joined the IE should be required to join a learned institution within one of the technological groups referred to in paragraph 17. This should entitle him to receive the 'free' publications of that institution, and to attend 'free' meetings of *any* institution and make use of their libraries and similar facilities traditionally available without extra charge. Persons who wished to join more than one institution would pay additional fees. Students and graduates aspiring to chartered professional status should be encouraged to join the IE, and thus associate themselves with the learned institutions of their choice. (A condition might be made, after due notice, that membership of the IE for, say, three years would be a prerequisite for registration as a Chartered Engineer.)

16. The learned institutions should relinquish in part their control of their membership in the following sense. They should be required to accept, upon nomination by the IE, any students and any graduates working in their respective fields. They should also be required to accept into corporate membership any Chartered Engineers whom the IE endorsed as having been made Chartered Engineers as a result of qualification in their respective fields. The institutions should, however, remain free to accept into membership, corporate or non-corporate, any other persons whom they considered acceptable. The institutions should remain wholly responsible for the granting of Fellowship, as their sole qualifying function.

17. The chartered institutions should be organized in a small number of technological groups and provision should be made for inclusion, within these groups, of non-chartered institutions which provided learned-society services suitable for chartered engineers and persons aspiring to chartered status.

18. Each group should have a co-ordinating committee, representative of the societies which it comprised; but institutions within a group should be encouraged to merge to transform the group into a single institution, the special technologies of the previous institutions being handled by substantially independent divisions of the new, enlarged, institution. The merit of such an arrangement would be to provide greater flexibility to deal with changing technological requirements, since changes can be made in a divisional structure without the difficulties that attend adjustment between separate sovereign institutions. Whether or not such mergers were to take place, institutions within a group should make arrangements to avoid independent overlapping activities within the group.

19. Provision should be made for the creation (and dissolution) of cross-disciplinary societies to deal with subjects which involved the interests of more than one group.

20. Although institutions would receive a learned-society grant from the IE, they should remain free to earn additional funds from remunerative activities. They should retain freedom to charge annual dues over and above those received through the IE.

21. Institutions and divisions of institutions should remain responsible for social and similar activities which encourage a sense of community amongst engineers with similar technological interests.

22. The Institution of Engineers itself should be governed by a Council comprising about ten or twelve members elected by all Chartered Engineers by means of the single transferable vote (proportional representation). The IE should appoint a Chief Executive who would be supported by staff appropriate to its functions.

23. It is envisaged that, under an arrangement like this, the Institution of Engineers would petition for incorporation by charter and would seek charitable status. Chartered Institutions would retain their charters and simply allow any specific provisions for professional activities to become dormant. In the event of the mergers proposed in paragraph 18, it is envisaged that chartered institutions would jointly petition for a charter of incorporation of a combined institution which, in accordance with normal practice, would revoke the provisions of the previously existing charters, the latter remaining as muniments in the safe-keeping of the combined institution.

Some Background Information

About eighteen months ago the Institution of Electrical Engineers and the Institution of Mechanical Engineers embarked on discussions which examined the feasibility of closer association between the two Institutions, possibly leading to a merger. It is understood that the wider proposals subsequently put forward for an 'Institution of Engineers' have led to detailed consideration of the merger proposals being taken very slowly, presumably since some of the objects of a merger—e.g. integration of services—would be rendered superfluous.

Earlier the Institution of Civil Engineers and the Institution of Mechanical Engineers, whose buildings are adjacently situated, combined certain of their central services, but fuller implementation has not proceeded.

During 1969-70 exploratory talks were held between the IERE and the Institution of Electrical Engineers but without any concrete, mutually acceptable proposals being produced. Similar exchanges of views have taken place between other Institutions within the Council of Engineering Institutions, again without any fundamental changes being agreed for consideration by their members.

Contributors to this issue

After wartime service in the RAF, **Mr. D. J. Whythe** studied at Imperial College, London, and in 1949 graduated with first-class honours in electrical engineering. He has worked since then as an engineer in the Research Department of the BBC and has been engaged upon various aspects of both sound and television broadcasting. He has originated patents and has written several articles and papers for publication in the technical press, two of which gained IEE awards.

Mr. T. A. Moore graduated in electrical engineering at University College, Cork, in 1969, and the following year joined the BBC Engineering Research Department at Kingswood Warren. Since joining the BBC, he has been concerned with the development of a direct reading chromaticity meter, and investigating moiré effects in video tape recording and he is now working in the field of digital techniques for the distribution of audio and video signals for broadcasting.

Dr. Zdeněk Mack graduated from the Faculty of Electrical engineering of the Technical University in Prague. He worked on research projects in the television and servomechanism system fields; at present he is head of the department of stereo broadcasting at the Tesla Electronics Research Institute in Prague. He is a member of the Czechoslovak national commission of CCIR and author of various papers, especially from the field of television and broadcasting stereophony. He is the holder of several patents in these areas which have been registered in many countries.

Professor Alec Gambling (F. 1964)(M. 1968) occupies the chair in Electronics at the University of Southampton. The fuller biography appears on page 429 of this issue.

Dr. R. E. Chaddock graduated with honours in physics from Reading University in 1964, and was awarded his doctorate in 1968 by the same University for research into infra-red materials and multilayer filters. For the next two years he was employed on infra-red detectors and imaging systems at Mullard Southampton, where subsequently he was responsible for the development of u.h.f. hybrid integrated circuits. In April 1974, Dr. Chaddock joined Marconi Space and Defence Systems, Frimley, as a Principal Engineer in the Space and Instrumentation Division.

UDC 621.391.827: 621.396.74.029.53

Reduction of mush-area distortion in common-frequency m.f. transmitter networks

D. J. WHYTHE, B.Sc.*

SUMMARY

The present crowding of the medium-wave band has made it necessary for several transmitters which broadcast the same programme to operate at a common carrier frequency. Reception is impaired by ground-wave interference between pairs of such transmitters in regions where the ratio of their field strengths is less than about 10 dB. At night, mutual interference is caused by sky-wave signals from other transmitters in the group.

The results of laboratory tests are given which assess the improvement to daytime reception that would result if the times of arrival of the two modulations were equated in these regions. The practicability of implementing such an arrangement is discussed and the preliminary results of a field trial are given.

* *British Broadcasting Corporation, Research Department, Kingswood Warren, Tadworth, Surrey.*

1 Introduction

The present crowding of the medium-wave band has made it necessary for several BBC transmitters that broadcast the same programme to operate at a common carrier frequency. Under these conditions, daytime reception is impaired by their mutual interference in certain so-called 'mush' areas where the field-strengths of two transmitters are approximately equal. Listeners in those areas may gain some improvement by suitably orientating their receivers but, in general, the impairment is noticeable wherever the field-strength ratio is less than about 10 dB and it may be severe where the ratio is less than about 6 dB.

In the great majority of cases, under daylight conditions only two transmitters contribute significantly to the resultant signal, but there may be others in which signals from more than two transmitters need to be considered. This paper considers the improvement that would result if the times of arrival of the modulations of the two dominant signals were equated at a suitable point within the mush area.

2 The Character of the Impairment

It is shown in the Appendix that, for sinusoidal modulation, the effective modulation depth (m_1) at the receiver detector (and hence, assuming perfect a.g.c., the amplitude of the audio output signal) when the carriers are in additive phase in a two-transmitter situation is given by

$$m_1 = m(1+a^2+2a\cos p\tau)^{\frac{1}{2}}/(1+a) \qquad (1)$$

where m = modulation depth at the transmitter,

$p/2\pi$ = modulation frequency,

a = ratio of the two carrier amplitudes,

and τ = difference between the times of arrival, at the receiving point, of the two modulations. (This assumes uniform delay at all modulation frequencies, i.e. it neglects dispersion—see Sections 5.3 and 5.5.)

Thus, for this carrier-phase condition, there is never any non-linear distortion due to overmodulation at the detector but, unless τ is so small that $\cos p\tau \simeq 1$ at the highest modulation frequency, there is a linear frequency-spectrum distortion (or 'combing') over the audio-frequency band because the amplitude of the audio signal varies from m to $m(1-a)/(1+a)$ as a function of modulation frequency.

As also shown in the Appendix, the effective modulation depth when the two carriers are in subtractive phase is given by

$$m_2 = m(1+a^2-2a\cos p\tau)^{\frac{1}{2}}/(1-a) \qquad (2)$$

If τ is so small that $\cos p\tau \simeq 1$ at the highest modulation frequency, the only impairment is that due to noise as the carrier-amplitude ratio approaches unity. If τ is appreciable, however, there will be certain modulation frequencies for which the effective modulation depth at the receiver detector is $m(1+a)/(1-a)$ and, unless either a or m are small, gross non-linear distortion will occur due to overmodulation at the receiver detector.

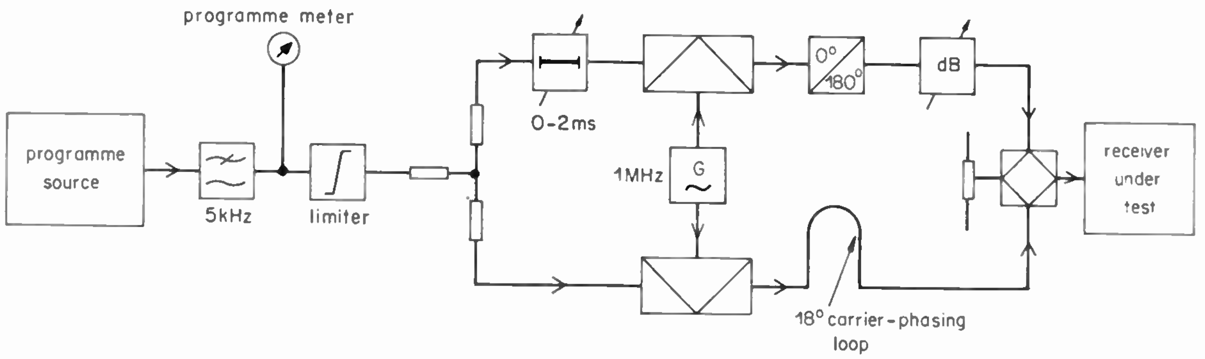


Fig. 1. Experimental arrangement for subjective tests.

In a practical situation with transmitters using independent high-stability drives, the finite beat-frequency between the two carriers causes the phase difference at a fixed receiving point to vary steadily between the additive-phase and subtractive-phase conditions; hence the character of the impairment to the received signal varies slowly from one of the above extremes to the other.

If the times of arrival of the two modulations were equated (i.e. $\tau = 0$) along a particular (hyperbolic) locus, the signal received at any point along that locus (using a receiver with perfect a.g.c.) would never suffer either spectral or non-linear distortion even if the two field-strengths there are equal. The only impairment would be a worsening signal/noise ratio whilst the two carriers are in near-cancelling phase. There would be areas nearby, however, in which the field-strengths are either equal or nearly equal but in which the times of arrival of the two modulations differ by up to a few hundred microseconds. In those areas the received signal would suffer, to some degree, both the spectral and the non-linear types of distortion. Thus it is necessary to assess the resulting distortion as a function of both time-delay and relative field strength, so that the effect over the whole of the service area can be predicted. For that reason, a series of laboratory tests was performed.

3 Laboratory Tests

Subjective tests were performed using the arrangement shown in Fig. 1. The programme source was a tape recording of typical BBC Radio-1 programme; this was bandwidth-restricted to about 5 kHz and was used to amplitude-modulate, with 12 dB compression, two separate outputs from a 1 MHz crystal oscillator. The two modulated signals were combined and fed to the receiver under test. The amplitude of the output signal from one modulator was set such that, at the receiver, it corresponded to a field strength of 3 mV/m, a value typical of that over the majority of the areas in question. Provision was made to introduce known delays (uniform over the programme bandwidth) in the programme feed to the other modulator, and to attenuate its output signal by known amounts. A preliminary series of tests was carried out using two separate carriers with a beat frequency of one cycle in about 20 seconds, and with various amplitude ratios. The results showed that the non-linear distortion that occurred during the near-cancelling carrier-phase condition was subjectively far more disturbing than either the linear combing distortion that occurred during the additive carrier-phase condition or the increase in noise level that occurred during the near-cancelling condition. The arrangement shown in Fig. 1, using two synchronous carriers with a constant phase difference, was therefore adopted, partly for economy in time but mainly because, with differing carrier frequencies, the very critical subtractive-carrier-phase condition occurred at different instants in the programme for the various tests and was found to lead to inconsistent results. Since it would have been unreasonably pessimistic to adopt a continuously-cancelling carrier phase (namely 180°), a phasing loop was added as shown in Fig. 1 by which a phase difference of 162° was maintained between the two carriers. Because this is 18° away from the cancelling-phase condition, the resulting distortion is that which is exceeded for 10% of the carrier-beat period (i.e. is exceeded for 10% of the time).

Two experienced listeners took part in the tests and, using a fairly good-quality modern medium- and long-wave battery portable, were asked to assess the quality of reception for various carrier–amplitude ratios and

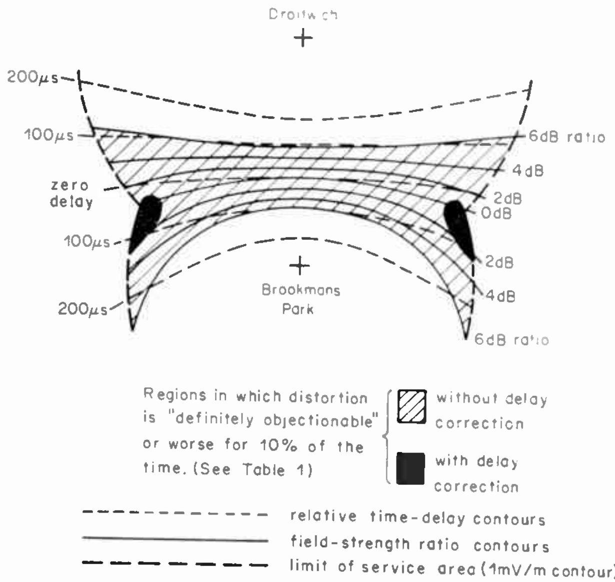


Fig. 2. Reduction of distortion within idealized service area.

relative audio delays, for programme content comprising either speech (news bulletin) or music ('pop' group). Because the normal subjective grades were found to be unsuited to the gross distortions which occurred, the following scale was decided upon.

GRADE	CONDITION
1	no perceptible impairment
A	distortion perceptible but not objectionable
B	distortion somewhat objectionable
C	distortion definitely objectionable
D	distortion very objectionable
E	programme barely intelligible
F	programme quite unintelligible

The results when using music (which was found to be slightly more demanding than speech) are given in Table 1.

Table 1. Subjective grading of distortion exceeded for 10% time, using music programme

Carrier-amplitude ratio, dB	Subjective grade for audio-frequency delay equal to: 0	30 μs	50 μs	83·5 μs	250 μs	1 ms	2 ms
0	A	B	C	D	F	F	F
1	A/1	B/A	B	D/C	F	F	F
2	1	A	B/A	D/C	F	F	F
3	1	1	A/1	C/B	E/D	F	E
4	1	1	1	B	D/C	E	D/C
5	1	1	1	A	C/B	D	B
6	1	1	1	1	B/A	C	A
7	1	1	1	1	A	B	A
8	1	1	1	1	A	A	A/1
9	1	1	1	1	1	1	1

The results in Table 1 were found to be in accord with those obtained during the preliminary tests, when the two carriers were steadily beating. It is therefore considered appropriate to use them for planning and prediction purposes and, because distortion rather than noise was by far the dominant impairment, they may be taken to apply wherever the field strength of either signal exceeds 1 mV/m, a value that has been suggested as representing the limit of the service area.[1]

4 Improvement to Reception under Idealized Conditions

The BBC transmitters at Droitwich and Brookmans Park (radiating Radio-1 at 1214 kHz, 247 m) are known to cause this type of mutual interference in an area about 60–65 km from Brookmans Park, where the field strength from each transmitter is about 3 mV/m. Under the present arrangements for feeding programme to the transmitters, the times of arrival of the two modulations differ by about 2 ms in the areas concerned. Idealized field-strength-ratio contours of those two transmitters are drawn in Fig. 2, assuming that the equi-field condition occurs at 62·5 km from Brookmans Park† and that the field-strength of each transmitter varies inversely as the square of the distance. The contours are drawn to the assumed circular limits of the two service areas, namely 1 mV/m. Hyperbolae are also drawn in Fig. 2 which show the relative delays between the times of arrival of the two modulations over the affected area, assuming that delay (~2 ms) is inserted in the programme feed to the Brookmans Park transmitter so as to equate the times of arrival of the two modulations at the point on the straight line joining the two transmitters at which the two field strengths are equal.

Based on the results of Table 1, Fig. 2 shows the considerable proportion of the mush area over which reception is improved under these idealized conditions. In practice, however, this proportion is likely to be less than that shown because the practical field-strength contours are not as regular in shape as the idealized contours shown in Fig. 2 and, furthermore, the long-term stability of both the field-strength contours and the delays in the programme circuits may not be sufficient to maintain the optimum condition over very long periods. In addition, contributions from other transmitters in the common-frequency groups‡ may be significant in certain parts of the mush areas. The impairment that they might cause to reception was not assessed as part of the laboratory tests. On the other hand, the technique would bring improvement to parts of the service areas without causing degradation elsewhere. A field trial is therefore being conducted in order to obtain information in a practical situation.

5 Field Trial

The purposes of the field trial are to assess the feasibility of implementing the arrangement, the resulting improvement to reception, and its stability with time. The first two aspects have been assessed and are discussed in Section 5.5.

In the near future the modulation-frequency bandwidth at BBC medium- and low-frequency transmitters will be restricted by a filter giving progressive attenuation at frequencies above 5 kHz. Furthermore, the i.f. filters in virtually all m.f. and l.f. receivers in current use in the UK heavily attenuate the transmission sidebands corresponding to modulation frequencies above about 4 kHz. It is therefore assumed that equalization of modulation delays at frequencies up to only 4 kHz will be adequate.

5.1 Delay Tolerance

It is considered that the delay tolerance can best be expressed in terms of the permissible phase difference, as a function of frequency, between the two modulations. Table 1 shows that, for a 1 dB carrier-amplitude ratio, the distortion becomes 'perceptible' when the two modulation delays differ by more than about 30 μs. It

† The transmitter power at Brookmans Park is greater than at Droitwich but the equal-field condition occurs at this distance because of the directional properties of the aerial at Brookmans Park.

‡ The term 'common-frequency groups' is preferred rather than the more commonly-used term 'synchronous groups' because the carriers, although at nominally identical frequencies, are not synchronized.

is considered that this distortion was likely to have been most noticeable on components of the modulation at frequencies in the range 1 kHz to 2 kHz, at which this delay error corresponds to a phase difference of 10° to 20°. Modulation-delay equalization of this type has recently been tried in Australia[2,3] between transmitters 4QB and 4QO at Pialba and Eidsvold (Queensland). It would appear that some difficulty was experienced in maintaining delay equalization to within an initial target of ±25 μs at modulation frequencies above 1 kHz, and phase correction to within ±9° at modulation frequencies below 1 kHz.[2] From the information available, it is difficult to assess the long-term stability achieved; all that can be deduced is that the arrangement improved reception in an area in which the field–strength ratio was such as to permit a delay-equalization tolerance of ±100 μs.[3] In the present circumstances, therefore, it would appear reasonable to aim for phase equalization to within ±30° at modulation frequencies from 50 Hz to 4 kHz.

5.2 Delay Measurement

It is required to measure the phase difference, as a function of modulation frequency, between signals travelling by two paths from the programme origination point to the listener's receiver. This measurement cannot readily be made directly during daylight hours because the programme modulation would be unsuitable; nor can it be made directly after dark because of interference from the sky-wave. It must therefore be made indirectly, by measuring the individual phase characteristics of the programme circuits to the two transmitters, and of the two transmitters themselves, and allowing for the propagation times from the two transmitters to the receiving point.

A method of measurement involving a spare two-way programme circuit to each transmitter was adopted by the Australian Post Office,[2] but it is likely to be more convenient in the UK to measure the phase characteristic of each circuit relative to a common reference such as the signal received from a v.h.f. transmitter (see Sect. 5.5).

5.3 Delay Correction

Phase measurements on typical programme circuits imply that there is little dispersion (i.e. the group delay† is substantially constant) over the middle range of audio frequencies. Dispersion at frequencies below 400 Hz is caused by repeater amplifiers and other terminal equipment but it is not large and could most probably be corrected by means of simple circuits of the type shown in Fig. 3. Dispersion at high frequencies arises if part of the programme circuit consists of inductance-loaded lines. Such dispersion is severe but, provided the cut-off frequency of the loaded sections exceeds about 12 kHz, overall dispersion correction to within ±30° is likely to be straightforward up to 4 kHz.

In addition to correction for dispersion, delay correction is required which is continuously variable up to 3 ms‡ and is stable in the long term to within ±5 μs. It is likely that this can conveniently be provided by means of 'bucket-brigade' delay lines which are now available in integrated-circuit form. They accept and deliver an analogue signal but the delay which they introduce is determined by the frequency of an oscillator which 'clocks' samples of the input signal, through storage elements, to the output.

† Group delay here is defined by $d\phi/d\omega$ where ϕ is the phase angle at frequency $\omega/2\pi$.

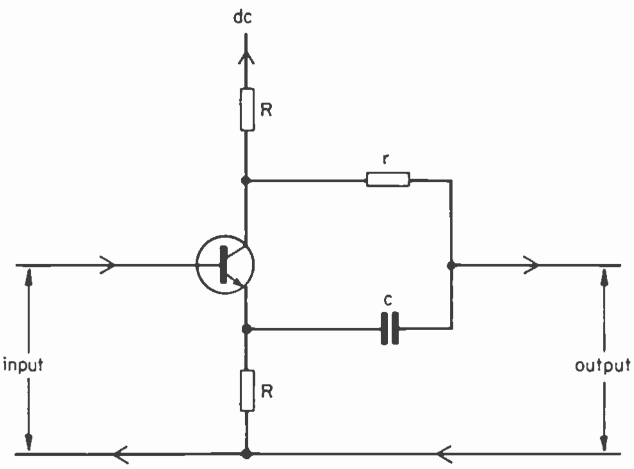


Fig. 3. Network for low-frequency dispersion correction.

5.4 Measurement of Field-strength Ratio

Measurements of field-strength ratio need to be made over the whole of the mush area, in order to decide the optimum point at which the two modulation delays should be equated and to assess, in conjunction with the results given in Table 1, the likely improvement. These measurements can best be made by using an omnidirectional aerial and measuring the max/min ratio of the resultant carrier amplitude as it varies over a carrier-beat cycle. The minima may be difficult to measure accurately in regions where the field-strength ratio is approximately unity, due either to the presence of non-cancelling sidebands or to low-level signals from other stations in the common-frequency group. These aspects are discussed in the next Section.

5.5 Preliminary Results

It was decided to conduct the field trial between the Radio-1 transmitters at Droitwich and Brookmans Park (see Sect. 4). Reception would most probably have been improved over the greatest area if the two modulations had been co-phased at the point on the line joining the transmitters where their two field strengths are equal. Preliminary measurements of the field-strength ratio (performed as described in Sect. 5.4), however, had shown the equal field-strength locus to pass near Bedford, which lies some 25 km East of the line joining the transmitters, and it was decided to co-phase the modulations in that vicinity in order to provide the maximum improvement for the greatest number of listeners.

‡ This applies if only the transmitters at Droitwich and Brookmans Park are considered. Some 7 ms would be required if other transmitters in the common-frequency group were included.

The difference between the phase characteristics, as a function of frequency, of the programme circuits from Broadcasting House to the two transmitters was measured by feeding tone, out of programme hours, at specified frequencies to both m.w. transmitters and to a v.h.f. transmitter at Sutton Coldfield. The phase of the tone incoming to each m.w. transmitter was measured relative to that of the demodulated signal received from Sutton Coldfield and each result was corrected for the propagation delay from Sutton Coldfield. It was initially assumed that the phase characteristics of the two transmitters would be sufficiently similar for them to be neglected. The two results were therefore subtracted and, to that difference, was added the difference in propagation times from Brookmans Park and Droitwich to a reference site near Bedford where the two modulations were to be co-phased. The resultant phase characteristic represents the correction required in the programme feed to Brookmans Park. This, shown in Fig. 4, was resolved into the dispersion characteristic shown in Fig. 5 plus a phase characteristic, linear with frequency, corresponding to 1·97 ms delay, and was realized by using seven sections of the type shown in Fig. 3 together with a 'bucket-brigade' delay module clocked at 134 kHz.

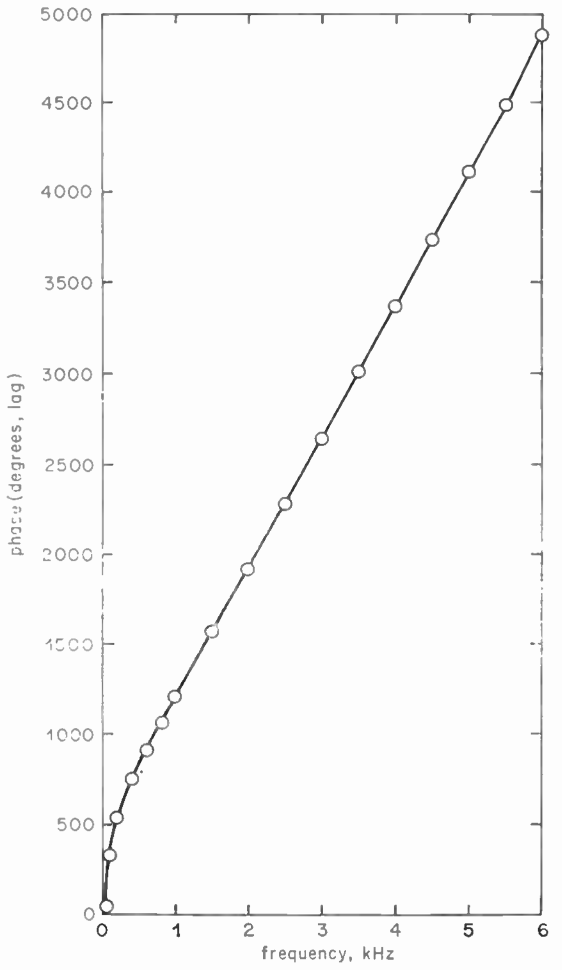


Fig. 4. Overall phase correction required in programme feed to Brookmans Park.

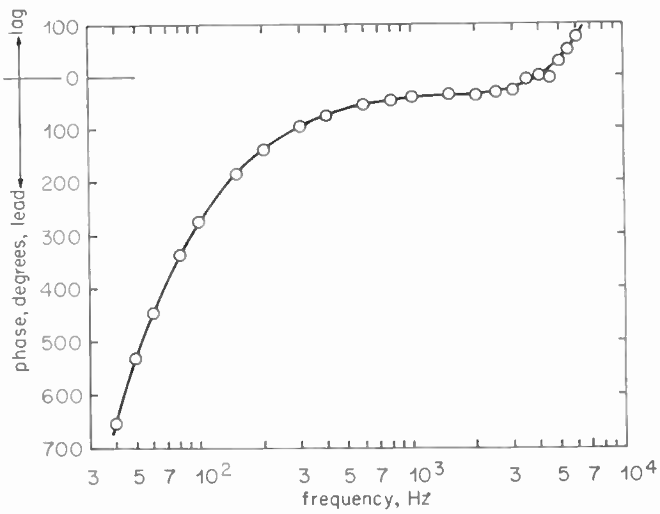


Fig. 5. Dispersion correction required in programme feed to Brookmans Park.

As a precaution, shortly before inserting this phase-correction network into the programme feed, a test signal comprising a series of uni-directional pulses was sent, out of programme hours, to both Brookmans Park and Droitwich in order to establish, from the polarity of the pulses modulated onto the radiated carriers, that no adventitious phase reversal had occurred since the time when the phase characteristics were measured.

The phase-correction network was put into circuit on a trial basis from 22nd to 25th April and during that period, the quality of the received signals with and without the correction was assessed along the region of the equal-field-strength contour from Cambridge to Thame. The assessments were made using a receiver fitted with a vertical rod aerial in order to gain no discrimination against either of the two transmitted signals and hence for the assessments to represent the worst cases. During an initial assessment at the reference site about 5 km South of Bedford (where the field-strength ratio was 1·5 dB) it was observed that, by judging the quality of the received programme with various clocking frequencies applied to the 'bucket-brigade' delay module after providing the dispersion correction, it was possible to optimize subjectively the delay for that particular site to within about ± 15 μs. Judged in that way, the optimum clocking frequency was found to be 132 kHz† and it was set to that frequency for all the subsequent assessments.

The improvement brought about by the phase correction was found to be very promising, although reception was not perfect even at the reference site. There was no evidence of the linear combing distortion (see Sect. 2) at any of the test sites but, at sites where

† This corresponds to about 30 μs more delay than was predicted but the difference can be explained because (a) the reference site chosen at Bedford was about 5 km from the one originally envisaged and (b) subsequent phase measurements at the two transmitters showed that, although their dispersion characteristics were identical, the delay in the Droitwich transmitter was 15 μs greater than in that at Brookmans Park.

the field-strength ratio was 1·5 dB, some residual non-linear distortion that would be graded C on the scale given in Sect. 3 was evident during the period of carrier near-cancellation. This would be expected at the assumed limits of the service area, but it was not expected to be so severe at the reference site. The reason for it has not yet been investigated but it may have been caused, at least in part, by small differences in the modulation depth or dynamic characteristics at the transmitters. Towards the assumed limits of the service area, of course, listeners can gain further benefit from the directional properties of the ferrite dipoles in their receivers, a facility that is denied them at or near the centre of the mush area where the two signals arrive along nearly reciprocal bearings.

The presence of the phase correction was found to facilitate very considerably the measurement of field-strength ratio in so far that non-cancelling sidebands (see Sect. 5.4) were found to cause negligible error at the minima wherever the field-strength ratio exceeded 1 dB (i.e. max/min ratios less than 25 dB). The presence of low-level signals from other stations in the common-frequency group was found, as would be expected, to make the measurement of field-strength ratio difficult and it may prove necessary to refine the measurement procedure. The effect that their presence has on the residual distortion during the periods of carrier near-cancellation also merits further study.

6 Conclusions

This paper has shown that, under idealized conditions, the mutual interference between two common-frequency medium- or low-frequency transmitters could be very greatly reduced over a large proportion of the affected area by suitably phasing their programme feeds. In practice, this improvement may not be gained over such a large proportion of the affected area, partly because of the irregular shape of the field-strength contours and partly because of instability in either the field-strength ratio or the relative modulation phase at particular locations. Instability of the relative modulation phase could occur either gradually due to drift or suddenly due to adventitious switching operations. The technique may therefore require the operational staff to include the measurement of phase among their other routine measurements on the programme circuits. The full improvement can be obtained during daylight reception only. Little or no improvement would be expected after dark because of sky-wave propagation but further experience is required before the effect on reception after dark is known.

Suitably phasing the programme feeds should improve reception for some listeners without causing degradation for any others. A field trial is therefore being conducted, the preliminary results of which appear very promising. It is proposed to continue the trial for a 3- or 4-month period in order to assess both the stability of the arrangement and the demands that it imposes operationally.

7 Acknowledgment

The author wishes to thank many colleagues for their helpful advice and assistance during the course of this work, and the Director of Engineering of the BBC for permission to publish this paper.

8 References

1. Phillips, G. J., 'Quality criteria, protection ratios, and protected field strengths', *BBC Engineering*, No. 97, pp. 16–20, March 1974.
2. Subocz, M. and Yelverton, W. A., 'Measurement of Delay on Programme Lines to Synchronous Transmitters at Eidsvold and Pialba, Queensland', Res. Lab. Rep. No. 6088, P.M.G.'s Dept. H.Q. Australia, 1967.
3. Medlin, N. J., 'The application of engineering planning principles to a specific m.f. broadcasting project'. I.T.U. Seminar on the Planning of Broadcasting Systems in Asia, Jakarta, November 1973.

9 Appendix: Analysis of two-signal reception with common-frequency working

For sinusoidal modulation, the combined signal received from two transmitters can be represented by

$$E = (1 + m \sin pt) \cos \omega t + a[1 + m \sin p(t-\tau)] \cos(\omega t + \phi) \quad (3)$$

where m = modulation depth
$p/2\pi$ = modulation frequency
$\omega/2\pi$ = carrier frequency of one transmitter (to be termed the 'reference transmitter')
a = ratio of the carrier amplitudes
τ = difference between the times of arrival, at the receiving point, of the two modulations
and ϕ = instantaneous phase difference between the two carriers at the receiving point. This is given by

$$\phi = \theta + bt \quad (4)$$

where θ is a constant phase difference and bt is a phase difference which increases progressively with time at a rate proportional to the difference frequency between the two carriers.

For simplicity, equation (3) may be re-written as

$$E = x \cos \alpha + y \cos \beta \quad (5)$$

where $x = (1 + m \sin pt)$
$\alpha = \omega t$
$y = a\,[1 + m \sin p(t-\tau)]$
and $\beta = (\omega t + \phi)$.

The significance of this expression is made clear in the vector diagram of Fig. 6 in which OC represents the vector sum of the two received signals, OA and OB. These two signals are both varying in amplitude according to their modulations, their phase difference $(\beta - \alpha)$ is steadily increasing according to the difference in carrier frequency between the two transmitters, and the entire diagram is rotating at ω, the angular carrier frequency of the reference transmitter.

The envelope of the combined signal (E) is given by

$$V = [x^2 + y^2 + 2xy \cos(\beta - \alpha)]^{\frac{1}{2}} \quad (6)$$

and, since $(\beta - \alpha)$ varies at infra-audio rate (e.g. less than 2π radians per second), the resultant modulation conditions can be studied for certain fixed values of $(\beta - \alpha)$, recognizing that the envelope will vary steadily from

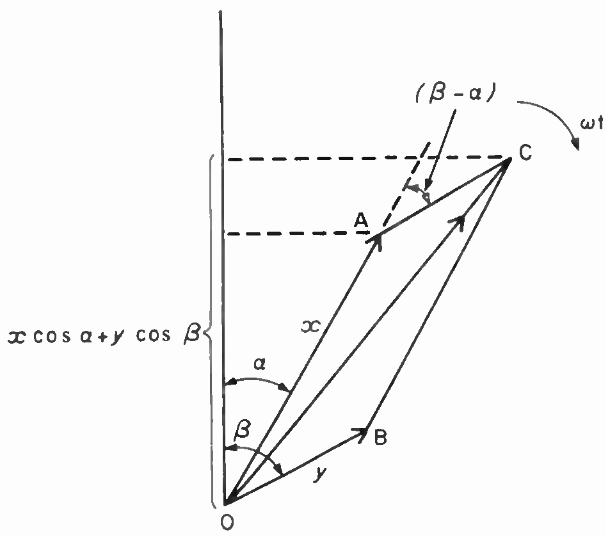


Fig. 6. Vector representation of equations (3) and (5).

one to the other of these conditions over a period of several seconds.

Condition 1 : $(\beta-\alpha) = 0$

This corresponds to carrier addition, whereupon

$$V = x+y = (1+a) + m \sin pt + am \sin p(t-\tau) \quad (7)$$

Since τ is constant with time, this may be re-written as

$$V = (1+a) + m_1' \sin pt \quad (8)$$

where

$$m_1' = m(1+a^2+2a \cos p\tau)^{\frac{1}{2}}. \quad (9)$$

The presence of the signal from the second transmitter increases the mean carrier level (over the period of the modulation) from 1 to $(1+a)$ and the effect of the receiver a.g.c., in correcting for this, is to make the amplitude of the audio output signal equal to

$$m_1 = m(1+a^2+2a \cos p\tau)^{\frac{1}{2}}/(1+a) \quad (10)$$

For all carrier ratios (a) and modulation delays and frequencies ($p\tau$), the effective modulation depth (m_1) of the resultant signal at the detector can never exceed m. Thus, when the carriers are adding, there is never any non-linear distortion due to overmodulation at the detector but there is a linear spectral distortion (or combing) over the audio band in so far that the amplitude of the audio output signal varies as a function of $p\tau$, from m at values of $p\tau$ equal to 0, 2π, 4π, etc. to $m(1-a)/(1+a)$ at values of $p\tau$ equal to π, 3π, 5π, etc. It is interesting to note here that the depth of this combing is equal to $(1-a)/(1+a)$ independently of m, so the degree of linear distortion which occurs during the period of carrier addition is independent of the modulation depth.

Condition 2: $(\beta-\alpha) = \pi$

This corresponds to carrier subtraction, whereupon

$$V = x-y = (1-a) + m \sin pt - am \sin p(t-\tau) \quad (11)$$

and, as before, this may be written as

$$V = (1-a) + m_2' \sin pt \quad (12)$$

where

$$m_2' = m(1+a^2-2a \cos p\tau)^{\frac{1}{2}}. \quad (13)$$

The action of the receiver a.g.c. is to make the amplitude of the audio output signal equal to

$$m_2 = m(1+a^2-2a \cos p\tau)^{\frac{1}{2}}/(1-a). \quad (14)$$

If τ is very small such that $\cos p\tau \simeq 1$ at all modulation frequencies, the effective modulation depth at the detector (m_2) is equal to m and there is no distortion but, as the carrier ratio approaches unity, an increase in noise level occurs due to the action of the receiver a.g.c. and, of course, the effective carrier level may fall below the a.g.c. range.

If τ is appreciable, there will be certain modulation frequencies at which $\cos p\tau = -1$, and the effective modulation depth at the detector will be equal to $m(1+a)/(1-a)$.

Manuscript first received by the Institution on 18th March 1974 and in final form on 7th June 1974. (Paper No. 1596/Com 95.)

Sir Owen Richardson, F.R.S.

Nobel Prizewinner in Physics 1928

By Professor W. A. GAMBLING, D.Sc., Ph.D., C.Eng., F.I.E.R.E.*

SUMMARY

O. W. Richardson was a prolific scientist who published the first of his 133 papers, on the mechanism of thermionic emission, when he was only 22 and the last at the age of 74. This essay traces his development of the science of thermionics.

Nowadays every schoolboy knows that if a refractory metal, such as tungsten, is heated sufficiently in a vacuum or in an inert gas then a stream of electrons is emitted from the surface. The laws governing this emission are well understood, for a pure metal at least, and the effect has been of almost incalculable technological importance for the past sixty years. This came about because, in studying the production of electrons by a heated wire filament in a vacuum, Fleming discovered the principle of rectification in the thermionic valve which rapidly gave rise to the development first of radio and then electronics, both of which have had a profound effect on the development of civilization as we know it. Electron formation by hot surfaces, like many other scientific discoveries, was put to practical use long before it was properly understood and to Sir Owen Richardson goes the credit for his ingenuity and persistence in unravelling an exceedingly difficult problem.

As early as 1901 he proposed a theory which is still accepted, in only slightly modified form, today. A metal consists of an assembly of relatively immobile atoms which have each lost one or more outer electrons. The atoms are therefore positively charged and the released electrons are free to move about in the lattice formed by the atoms. The metal as a whole is stable and has no net charge. The cloud of mobile electrons cannot escape from the surface of the metal at normal temperatures because of a potential barrier at the surface. Put in simple terms this means that if an electron were to leave the metal an unneutralized positive charge would remain which would, in fact, attract the electron back again. The mobile electrons move throughout the metal lattice with random velocities just like the molecules of a gas but the number which have a high energy and therefore a high velocity, increases as the temperature is raised. Richardson postulated that at a sufficiently high temperature a measurable number of electrons acquire sufficient energy to overcome the potential barrier and thus escape from the surface of the metal and he deduced that the emitted current I is related to the temperature T by

$$I = AT^{\frac{1}{2}} \exp\left[-\frac{\phi}{kT}\right] \qquad (1)$$

where A, ϕ are constants characteristic of the emitting surface and k is Boltzmann's constant.

Ten years later he modified the formula to

$$I = AT^{2} \exp\left[-\frac{\phi}{kT}\right] \qquad (2)$$

which is the form still accepted today. Although the second equation looks rather different from the first, with $T^{\frac{1}{2}}$ replaced by T^2, it is nevertheless very difficult to distinguish between the two experimentally because of the overriding effect of the exponential term.

With present-day technology it is easy to demonstrate that the current of electrons emitted by a body raised to a sufficiently high temperature is due to thermionic emission and in order to appreciate the very considerable difficulties which had to be overcome at the turn of the century it is necessary to recall that the vacuum techniques of that time were very rudimentary. The pumps, for example, were hand operated and outgassing methods hardly existed. The hot wire used for observing emission would heat the walls of the vessel thus producing copious emission of gas which continued almost indefinitely. As Richardson himself[1] stated, 'I have often heated a wire in a tube for weeks in succession in order to make sure that the currents observed were stable and not coming from residual gas'. Furthermore the materials available were often insufficiently pure and, as the above equations indicate, the emission depends in a very sensitive manner on the work function so that quite small amounts of impurity can have a considerable effect on the experimental results obtained. Nowadays the thermionic emission of electrons has been so long accepted, and is of such technological importance, that students do not often appreciate the many other processes which can and did occur in Richardson's experiments, and also those which were thought to exist.

The problem which faced Richardson, and his contemporaries, was as follows. It had been shown in the early eighteenth century that a hot body could produce electricity, for example an iron ball at red heat in air can retain a negative but not a positive charge. In the late nineteenth century it was found that many effects were

* *Department of Electronics, University of Southampton, Southampton SO9 5NH.*

observed when hot wires of various materials were placed near an insulated plate in different gases. However there was a tendency for the plate to acquire a positive charge at low temperatures and high pressures and a negative charge at high temperatures and low pressures, and this charge came from, or was at least produced by, the hot wire. At the time, also, considerable advances had been made in the understanding of the conduction of electricity through gases which was attributed to minute, electrically charged particles, or ions. The concept of ions, which is a term now applied to charged atoms or molecules, and their movement under the influence of electric fields, had been brilliantly used to explain the many complicated phenomena of electrical discharges in gases by J. J. Thomson. It was natural, therefore, for it to be thought that the emission from hot bodies could be explained in the same way. There seemed to be every likelihood that, in some way, the hot metal ionized the surrounding gas and that a difference either in the velocities of the positive and negative ions, or in their chemical affinity for the metal, gave rise to the positive or negative currents observed. The results obtained in an evacuated chamber were attributed to residual gases left behind by the relatively crude vacuum equipment available at the time. An alternative possibility was that the heat of radiation by the hot body was somehow involved.

A great stimulus was provided by J. J. Thomson in 1899 who showed that the discharge from a white-hot carbon filament in vacuum (so-called) was carried by tiny negatively-charged particles, very much smaller than the lightest atom, called electrons. At about the same time theories of conduction of electricity in metals had been proposed which involved the free movement of negative charges within the metal. These developments led Richardson to believe that the electrons, and possibly the positive ions as well, which were observed near hot bodies came from the bodies themselves and that any gases present were only of minor importance. As a result he derived the first of the formulae given above. The next, and far more difficult task, was to verify it experimentally.

With the impure materials and simple apparatus available to Richardson various kinds of emission were normally observed. When a metal is first heated it often gives a large emission of positive ions due to impurities, which can sometimes be completely driven off by prolonged heating so that eventually the effect may be eliminated. Particles of the metal being investigated may also be released in ionized form giving rise to another type of positive current. It is also possible for atoms or molecules of any gas present to become ionized on collision with the hot metal. The amount of energy required to release an electron from a surface is denoted by the constant ϕ, the work function, and the emission of electrons from a surface is very strongly dependent on this quantity. Some metals melt, and even boil, at temperatures lower than those necessary to give adequate amounts of electron emission and these are, of course, not suitable for experimentation. Despite these difficulties Richardson showed, first for platinum in 1901 and soon after for carbon and sodium, that equation (1) was

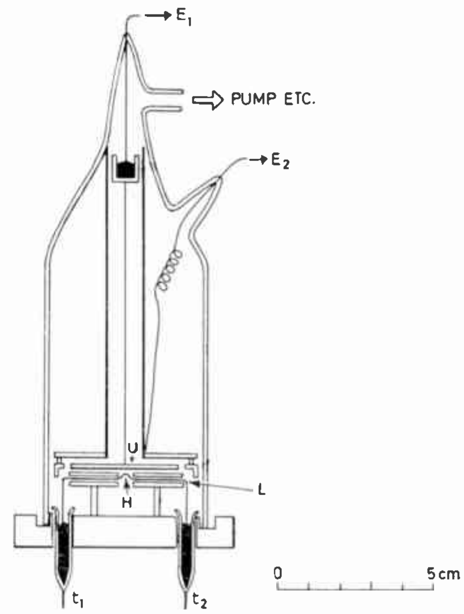


Fig. 1. Apparatus used to measure the velocity distribution of electrons emitted from a hot surface.

The small piece of thin platinum foil H at the centre of the metal plate L is heated electrically through terminals t_1 and t_2. The current collected by the platinum-coated electrode U is measured as a function of the (negative) potential applied to it.

obeyed. Similar results were then obtained with a wide range of other materials by other investigators. Thus the theory that electrons in effect, 'boil off' a metal when it is heated, in a similar way to molecules boiling off as steam when water is heated, was verified.

As with all scientific advances this was not the end of the matter, for new theories must always be tested to their limits and they can also be used to predict further new knowledge. For example there is the well-known effect that when one end of a metal wire is joined to a wire of a different material then an electrical voltage appears at the free ends. This is because the free electrons in the two metals have slightly different average energies and Richardson was able to show that this 'contact voltage', as it is called, is equal to the difference of the work functions of the two metals and he confirmed this by experiment.

Furthermore, according to the theory some of the electrons which are released during thermionic emission leave the metal with almost zero velocity whereas others leave with quite high velocities—in fact the emission velocities range from zero to high values although the number of fast electrons is small. Thus even if the collecting electrode is at a small negative potential, thereby exerting a repelling force on the electrons, the faster electrons can overcome this opposition and are still collected. Indeed if the current flowing at different repelling voltages is measured then the number of electrons emitted in different velocity ranges can be found. In this way Richardson found that the distribution of velocities among the emitted electrons was just that predicted by Maxwell, 50 years earlier, for a gas of the same molecular weight at the temperature of the metal.

This result was remarkable as the first experimental demonstration of the Maxwellian velocity distribution (Figs. 1 and 2).

A corollary of the theory was that since energy is required to cause the emission of electrons then because this energy is provided by the emitting body it must therefore be cooled in the process. Richardson calculated the magnitude of this effect and, with collaborators, confirmed it experimentally. In the same way if a stream of electrons flows into a metal from outside then they give up an amount of energy depending on the work function which should be independent of the temperature of the metal and the attracting voltage. This was also confirmed (Fig. 3).

Scientific progress is rarely simple and straightforward and in a brief article it is not possible to give any details of the experimental difficulties or of the results obtained. Although the emission equation was verified by many different workers the values obtained for the constants in the equation, especially the work function ϕ, sometimes differed considerably. This was undoubtedly due to the different methods of preparation of the materials, the effects of impurities and the large and unpredictable influence of residual gases present. The experimental results were therefore not universally accepted as proving the theory of thermionic emission. Some people still held the view that the explanation lay in chemical interaction between the hot metal and surrounding gas. This hypothesis was very elegantly shown by Richardson to be untenable when ductile tungsten wire became available in 1913. With this he was able to obtain much larger emission currents which enabled him to prove that the total mass of the electrons emitted far exceeded that of any of the materials which could have been chemically consumed.

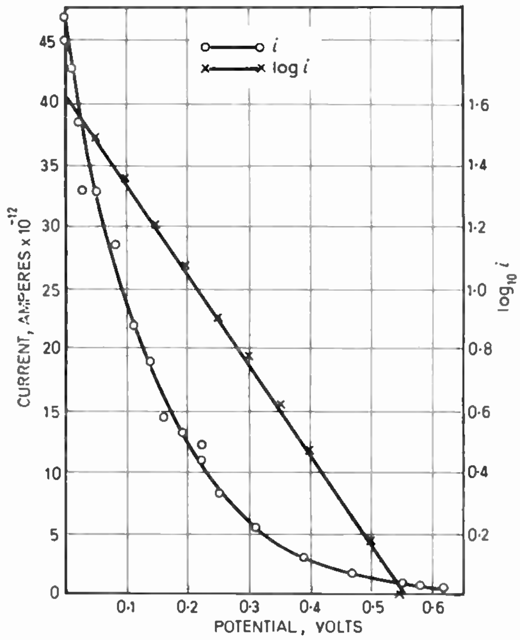


Fig. 2. Typical results obtained with the apparatus shown in Fig. 1.

The variations of the logarithm of the current collected by electrode U with retarding voltage is linear as predicted by theory. From the slope of the line obtained for a range of conditions Richardson deduced a mean value $R = 3{\cdot}719 \times 10^3$ for the universal gas constant compared with the theoretical value, accepted at the time, of $3{\cdot}711 \times 10^3$. He observed that this excellent agreement was partly fortuitous.

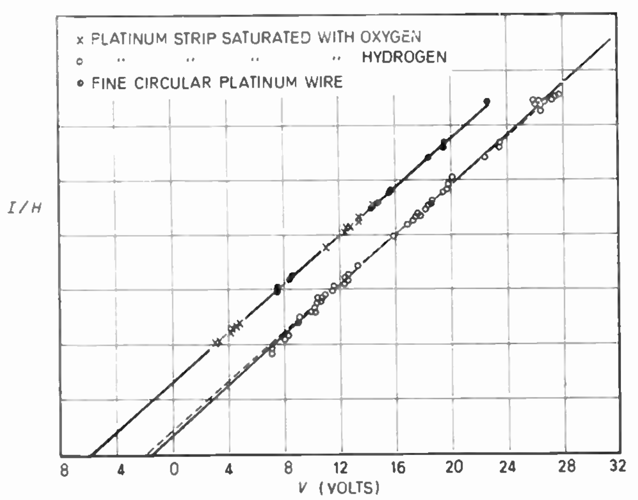


Fig. 3. Determination of the heat liberated during electron absorption on a surface.

A very thin strip of the metal to be tested was mounted in a vacuum between two high-temperature filaments. The metal strip formed one arm of a very sensitive Wheatstone bridge, so that the change in resistance, and thus in temperature, experienced by the strip as electrons were absorbed could be derived. The quantity of heat absorbed H as a function of the voltage V between strip and filaments, and the current I, was then measured as V was varied. The graph shows the observed dependence of H/I on V and the intercept of the extrapolated line with the V axis gives the heat liberated per electron in (negative) equivalent electron volts, ~ 6 V in this case.

The points which fall on the right-hand full and dashed lines have been arbitrarily moved a distance corresponding to 4 V in this direction to avoid confusion.

At the same time as these researches were being carried out other methods of obtaining the emission of electrons from solids were being studied. Perhaps the most important of these was photoelectric emission. It was known empirically that light of frequency greater than a critical value, which was characteristic of the material, would cause the emission of electrons from its surface. Light of longer wavelength, no matter how great its intensity, was unable to cause such emission. No satisfactory explanation of this effect was available until, in 1905, Einstein made the daring and epoch-making suggestion that light, and indeed all electromagnetic radiation, is not continuous but consists of discrete wavelets which fly through space like a hail of shot with the velocity of light. He deduced the elegantly simple relation that the energy E of each wavelet or quantum of radiation is related to its frequency by $E = hf$ where h is Planck's constant. The explanation of photoelectric emission now became almost childishly easy. Since a fixed amount of energy is required to release an electron from a metal, then light of low frequency, containing photons of low energy, cannot cause emission. Photons having more than this minimum amount of energy on the other hand, corresponding to light of higher frequency, can cause emission.

The amount of energy required to release an electron from a surface, as expressed by the work function ϕ, can thus be determined by measurements of thermionic emission and of photoelectric emission. Richardson, together with the famous American scientist K. T. Compton, showed that the two methods give the same results so providing further evidence in favour of the thermionic theory and of Einstein's postulate.

Photoelectric emission was also important for another reason, as it had been suggested as another alternative to thermionic emission and provided, as it were, a further rival theory. Any hot body in equilibrium with its surroundings produces electromagnetic radiation extending over all frequencies, the so-called black-body radiation. It follows that the portion of this radiation which has a frequency greater than the critical value is capable of causing the emission of electrons by the photoelectric effect, and moreover the resulting emission will increase very rapidly with temperature as does thermionic emission. Indeed Richardson's analysis indicated that the formula describing the integrated photoelectric effect is of the same form as equation (1) and it is therefore not easy to differentiate between the two processes experimentally. Following some fairly sophisticated measurements of photoelectric constants, however, he was able to show that the electron currents produced by any black body radiation which might be present were considerably smaller than those actually measured. That thermionic emission was the dominant process had thus, at last, been clearly and unambiguously established.

As a result of further study Richardson subsequently modified his expression for the emitted current density to that of equation (2). As remarked above it was not possible to differentiate between the two equations (1) and (2) experimentally even though measurements were made, for example, on tungsten over such a wide range of temperature that the current changed in the colossal ratio of 10^{12} : 1. Both equations could be made to fit the results, within the experimental error, but with different values of A and ϕ of course (Fig. 4).

Nevertheless many problems remained. We know that Richardson had correctly deduced the mechanism of emission and had produced a theory which agreed with the experimental observations. On the other hand the equation relating the magnitude of the current to the temperature was not unambiguous and, as we have seen, fitted the 'integrated photoelectric' theory as well as the thermionic theory. At the same time the quantum theory of radiation and matter was being rapidly developed and in a sense it was fortuitous, and perhaps fortunate, that the form of equation deduced has turned out to be the correct one. It is interesting to consider the reasons for this since they also illustrate the effect which Richardson's work had on the electron theory of metals. The latter theory was invoked in order to explain the high electrical conductivity of metals and it was supposed that the outermost electrons of the constituent atoms were free to move about at will and were limited only by reflexions at the boundaries. It was natural to take the analogy with a gas further and to assume that the velocities of the electrons were the same as those of an ideal classical gas of the same mass and at the same temperature. As remarked earlier this meant that at any instant of time there would be electrons of all velocities present but most would be moving at roughly the average velocity which is determined by the temperature. Just as with a gas the number of electrons within each small range of velocity, or energy, values was to be given by the Maxwell distribution law. The fact that the measured velocities of electrons produced by thermionic emission *outside* the metal followed the same law was taken as confirmation of the Maxwellian distribution *inside* the metal. Indeed on the classical theory, which ignored quantum effects, this was a necessary corollary. However on a non-classical theory the same argument would not necessarily apply and the energy distribution of electrons in metals was in dispute for a considerable time. Richardson

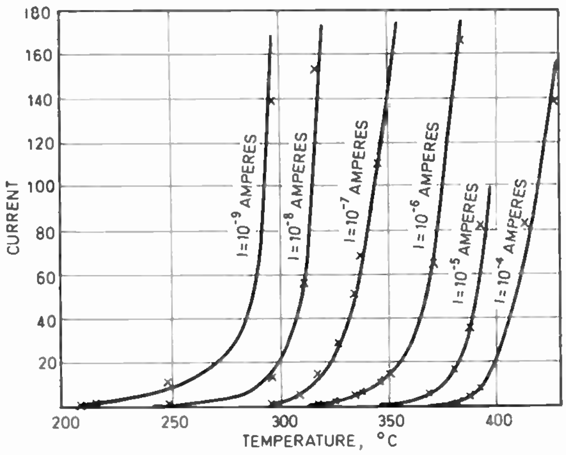


Fig. 4. If the material experimented on is in a condition which does not change with lapse of time the rate of emission of electrons increases with enormous rapidity as the temperature is raised. This is true whether the substance under investigation is in a good vacuum or is surrounded by various gases. The extreme rapidity of this variation is well shown in these graphs which represents the results of Richardson's early experiments with sodium. The observations recorded extended over a range of temperature from 217°C to 427°C whilst the corresponding currents increased from $1{\cdot}8\times10^{-9}$ A to $1{\cdot}4\times10^{-2}$ A. Thus with a rise of temperature of a little over 200°C the current increases by a factor of 10^7. In order conveniently to exhibit all the values on the same diagram the curve is shown by means of a number of branches, in each of which, proceeding from left to right, the scale of the ordinates is successively reduced by a factor of 10. Thus, starting from the left-hand side, in the first curve the unit of current is 10^{-9} A, in the second 10^{-8}, and so on. The various crosses which lie vertically over one another represent the same observation on different scales. It will be noticed that the successive branches are very similar to one another; so that the general character of the temperature variation is much the same at all temperatures. As the temperature is reduced the current continuously approaches the value zero but never actually reaches it. The experiments to which the Figure refers were probably affected to some extent by the presence of a surrounding gaseous atmosphere, but however carefully gaseous contamination has been avoided, it has always been found that the general character of the temperature variation is of the kind shown in the Figure. The difference between different substances lies in the temperature at which the emission becomes appreciable; and this temperature determines the whole scale of the diagram. With most substances the currents cannot be measured on a sensitive galvanometer at temperatures below 1000°C. A correspondingly larger interval of temperature is then required in order to change the current in a given proportion.

himself was of the opinion that the classical theory did not apply but he was unable to deduce the correct one.

In some respects the classical theory had been perfectly satisfactory. It provided an explanation for the high electrical and thermal conductivities of metals and the fact that these properties are directly related, as well as correctly predicting the observed variation of thermionic emission with temperature. In other respects it was completely at variance with the experimental facts and particularly with the measured values of the specific heats of metals. The specific heat is simply the amount of energy required to raise the temperature of unit volume of a substance by 1 K. Any heat applied to a metal is taken up partly by the atoms, which increase in amplitude of vibration about fixed points, and partly by the free electrons. If the latter behaved like an ideal gas, as required by the classical theory, then all the electrons would have their energies increased and it can easily be shown that in this case the calculated specific heat would be 50% greater than that actually measured. It was as if with increasing temperature the electrons, in practice, did not take up very much energy from the heat source. Further evidence of the same, rather unexpected, kind came from some accurate measurements with the same tungsten filament of both the work function using the cooling effect and thermionic emission over a range of temperatures. These results again showed that the average energy of the electrons in a metal seemed to be independent of temperature and provided another nail in the coffin of the classical theory.

The explanation of this dilemma was provided by Pauli and Sommerfeld in 1927 when they pointed out that at the high concentrations in metals the electrons must obey the statistical laws of Fermi and Dirac. These are considerably different from those of the classical theory in which the energies of all the electrons decreases with falling temperature so that at a temperature of zero degrees absolute all the electrons are stationary. In the Fermi–Dirac theory, on the other hand, the electrons can only take up a certain discrete (although very large) number of energies and only one electron can have each permitted value of energy. Thus in an approximate fashion it may be said that even at zero temperature only one electron can be at rest, one can have the next smallest energy and so on, with the result that the total energy of the electrons is no longer zero but is a finite, calculable value. All the possible energies up to a given level, that is the Fermi level, are taken up and there are no electrons present with a higher energy. As the temperature is raised, only the electrons with the highest energies, i.e. those near the Fermi level, increase their energies but the bulk of the electrons, except for temperatures far above room temperature, are unaffected. The lack of electronic contribution to the specific heat was now easily explained because only a very small fraction of the electrons present are able to absorb thermal energy.

As in the classical theory, when the temperature is raised a sufficient number of the more energetic electrons acquire enough energy to escape from the surface to give a measurable emission current and the theory predicts an equation of the form of equation (2). It also predicted that the emitted electrons *outside* the surface would have a Maxwellian velocity distribution and was therefore in agreement with the experimental facts concerning thermionic emission. Here then was the theory which Richardson was seeking. The final blow had now been dealt to the classical theory of the electron energy distribution in metals and the Fermi–Dirac distribution was confirmed by some elegant experiments performed by Davisson and Germer. It had been shown by de Broglie that all matter exhibits both wave and particle properties although the wave-like behaviour is normally only observable for bodies of atomic size or smaller. We have already noted the wave and particle nature of light quanta for example. Davisson and Germer passed a beam of slow electrons into various metal crystals. The equivalent wavelength of the electrons depended on their energy in the crystal which in turn depended on the Fermi energy and the work function. The wavelength of the electrons was measured from their angle of reflection by the crystal lattice from which the Fermi energy was obtained. This showed quite clearly the correctness of the new theory.

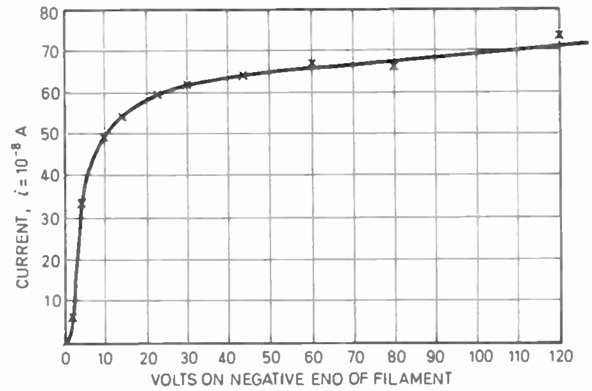


Fig. 5. The type of curve connecting the current and applied potential difference which is most frequently obtained under fairly good vacuum conditions. This represents observations made by Richardson with a U-shaped carbon filament surrounded by a cylindrical electrode, the pressure being 0·003 mm. It will be seen that approximate saturation is attained at about 30 V, although there is a further rise of about 10% of the total value on increasing the voltage to 120. This further increase is almost always, as here, proportional to the increase in the applied potential. It usually diminishes with continued use of a given tube, and it appears to be due either to the evolution of gas from the hot filament or to the presence of a layer of condensed gas on the electrode, or to both these circumstances. Richardson stated he had not observed this effect in a tube which had been well glowed out and exhausted in the vacuum furnace before testing, although a case of its appearance under these conditions had been recorded by K. K. Smith.

A further consequence of the quantum theory is that it gave a numerical value for the constant A which turned out to be independent of the material. A was thus shown to be a universal constant of value 120×10^4 A m^{-2} $(K)^{-2}$. Unfortunately even recent experimental determinations are not in very good agreement with this prediction and range from 4·6 to 170 and even 1380 for nickel. The reasons for the wide discrepancies are still not properly understood and in practice there are probably several causes. Richardson attributed the variation to contamination of the surface and impurities, which undoubtedly can have a considerable effect, pointing out that even so his emission equation was still obeyed (Fig. 5). This explanation is not so easily invoked with present-day techniques in which quite pure surfaces can be prepared in conditions of very high vacuum.

One difficulty which arises is that while in Richardson's equation the work function ϕ is assumed to be constant, in practice it varies with temperature probably sufficiently to cause a significant change in A. Another is that thermionic emission measurements are normally made with polycrystalline materials. It is now known that the different faces of a crystal have different work functions and since the emission is so critically dependent on the work function most of the current comes only from those exposed faces of low work function and the effective emitting area may be much smaller than the apparent surface area. A third source of error is due to electric fields which may be present at the surface. As electrons are released into the space surrounding the emitter they form a negative space charge which tends to repel any further electrons which appear and return them to the surface. The 'space-charge limited' current measured at the collecting electrode is thus less than the emitted current and a false reading is obtained. The usual remedy is to increase the positive voltage on the collector so that the negative electric field due to space charge is always more than counteracted. Unfortunately the positive field which now exists at the surface enables more electrons to escape because the effective height of the potential barrier at the surface is reduced. The resulting increase in current and its dependence on the electric field at the surface is known as the Schottky effect. Fortunately the effect of field-enhanced emission can be corrected for and the Richardson constant A and the work function ϕ can still be obtained from measurements. It was noted earlier that the force preventing the release of low-energy electrons from a surface is assumed to be mainly due to the electrostatic attraction of the effective positive charge left behind in the surface—the so-called 'image' force. The theory of the Schottky effect takes into account this image force and the good agreement with experiment is important because it provides the most direct experimental proof, and confirmation, of the image-force concept.

When the field at the surface becomes very high, of the order 10^9 V/cm, the potential barrier not only becomes lower but its thickness is decreased and electrons which are not energetic enough to surmount the barrier are enabled to tunnel through it thus causing an appreciable emission even at low temperatures. This phenomenon does not come under the heading of thermionic emission and will therefore not be considered further but interestingly enough it is used in a technique to measure the work function of the different faces of a metal crystal.

It will be clear from this brief account of Richardson's work that the correct interpretation of the phenomena of thermionic emission had to await the development of the quantum theory and was closely bound up with it. Indeed his work contributed in no small measure to a better understanding of quantum concepts as well as providing a correct understanding of 'thermionics', to use a term which he himself coined.

The technological importance of thermionic emission cannot be over-estimated because from it and the electron tube grew first radio, then radar and eventually electronics, or information engineering, as we know it today. It is probably true to say that all this would have come about even without a proper understanding of the fundamental processes, by using an empirical approach, so that we remember Richardson for his contribution to physics rather than to technology. With the rapid growth of solid-state devices the applications of thermionic emission are decreasing, in electronics at least, but it has provided an enormous and varied base on which to build the future. It has certainly had a profound effect on all our lives.

Considering the importance of his work and the remarkable way in which it has stood the test of time it seems incredible that Richardson should have read his first classic paper explaining the mechanism of thermionic emission at the age of 22 (in 1901) to the Cambridge Philosophical Society. This was only one year after graduating with first-class honours in Natural Science at the University of Cambridge. When 24 he was elected Fellow of Trinity College, Cambridge and when 25 he was awarded a D.Sc. by the University of London. Besides his researches in thermionics Richardson made contributions to many branches of physics. For example in his early days in Cambridge he studied, among other topics, diffusion of hydrogen through palladium and platinum, ionic recombination, and the diffusion of dissociated gases in solution. In 1906 he was appointed a Professor of Physics at Princeton University where his research activities ranged over the gyromagnetic effect, pressure shift of spectral lines, ratio of charge to mass of positive ions, gravitation, theory of dispersion and many others. His work on thermionics continued, of course, and his measurements on the velocity distribution of the emitted electrons were made at Princeton, as well as those on the heating and cooling effects and the theory of contact voltages. He and K. T. Compton together played a large part in the verification of Einstein's theory of photoelectric emission. As well as the emission of electrons he investigated the emission of positive ions from hot metals and other materials.

In 1913 he was elected Fellow of the Royal Society and returned to England the following year to become Professor of Physics at King's College, London, when his first book[2] 'The Electron Theory of Matter' was published. Two years later followed[3] 'The Emission of Electricity from Hot Bodies' which gives an excellent account of the subject up to, and including, that time. At King's College his publications embraced metallic conduction, spectroscopy, conduction in metals and photoelectric emission. From 1924 onwards he was able to devote more time to the activity which he loved best on his appointment as Yarrow Research Professor by the Royal Society. An important new phase of his work then began with a detailed study of the spectrum of molecular hydrogen to which he made further important contributions and a book on this topic appeared in 1934. Other work included X-ray spectroscopy, the structure of the Hα and Dα lines and further research on the emission of charges, and the interaction of charges with surfaces.

In addition to the honours already mentioned and the award of the Nobel Prize for Physics in 1928 he received honorary degrees and two honorary Fellowships. The Royal Society presented him with the Hughes Medal (1920) and he was elected a President (1921) of the British Association (Section A) and President of the Physical Society (1926–1928) of which he acted as its honorary Foreign Secretary (1928–1945). He was knighted in 1939.

Sir Owen Richardson was a brilliant and prolific scientist (his last paper was published at the age of 74) as well as being a quiet, kindly and generous person.[4,5] He died in 1959.

Acknowledgments

This essay is published with the kind permission of Fratelli Fabbri Editori, Milan, Italy.

Grateful acknowledgment is also made to Professor W. C. Price, F.R.S., of King's College, University of London, for kindly providing a copy of the College's portrait of O. W. Richardson, and to Longmans, Green & Co., Ltd. for permission to reproduce diagrams and extracts from Richardson's book, 'The Emission of Electricity from Hot Bodies.'[3]

References

1. Richardson, O. W., 'Thermionic phenomena and the laws which govern them', 'Nobel Prize Lectures: Physics 1922–1941', p. 224 (Elsevier, London, 1965).
2. Richardson, O. W., 'The Electron Theory of Matter' (Cambridge University Press, 1916).
3. Richardson, O. W., 'The Emission of Electricity from Hot Bodies' (Longmans, Green, London, 1916).
4. Foster, E. W., 'Sir Owen Richardson, F.R.S.', *Nature, London*, **183**, p. 928, 1959.
5. Wilson, W., 'Owen Willans Richardson', *Biographical Memoirs, Royal Society*, **5**, p. 207, 1959.

Manuscript received by the Institution on 10th October 1973. (*Paper No. 1597.*)

STANDARD FREQUENCY TRANSMISSIONS—June 1974

(Communication from the National Physical Laboratory)

June 1974	Deviation from nominal frequency in parts in 10^{10} (24-hour mean centred on 0300 UT)			Relative phase readings in microseconds NPL—Station (Readings at 1500 UT)		June 1974	Deviation from nominal frequency in parts in 10^{10} (24-hour mean centred on 0300 UT)			Relative phase readings in microseconds NPL—Station (Readings at 1500 UT)	
	GBR 16 kHz	MSF 60 kHz	Droitwich 200 kHz	*GBR 16 kHz	†MSF 60 kHz		GBR 16 kHz	MSF 60 kHz	Droitwich 200 kHz	*GBR 16 kHz	†MSF 60 kHz
1	0	+0·1	−0·1	699	599·7	**17**	0	0	−0·2	698	596·9
2	0	+0·1	−0·2	699	599·2	**18**	0	0	−0·1	698	597·1
3	0	+0·1	−0·2	699	598·7	**19**	0	0	−0·2	698	596·8
4	+0·1	0	−0·2	698	598·8	**20**	0	0	0	698	596·5
5	0	0	−0·2	698	598·9	**21**	0	0	−0·2	698	596·9
6	0	+0·1	−0·2	698	597·9	**22**	0	0	−0·2	698	597·0
7	0	0	−0·1	698	597·7	**23**	+0·1	+0·1	−0·2	697	596·4
8	0	0	−0·2	698	597·6	**24**	+0·1	+0·1	−0·2	696	595·8
9	0	−0·1	−0·1	698	598·1	**25**	0	0	−0·2	696	595·6
10	−0·1	−0·1	−0·2	699	598·9	**26**	0	0	−0·2	696	595·3
11	0	0	−0·2	699	598·2	**27**	0·1	+0·1	−0·2	696	594·7
12	0	0	−0·2	699	597·9	**28**	0	0	−0·2	696	594·4
13	+0·1	0	−0·2	698	597·6	**29**	+0·1	+0·1	−0·1	695	593·5
14	0	+0·1	−0·2	698	596·8	**30**	0	0	−0·2	695	593·2
15	0	0	−0·1	698	596·4						
16	0	0	−0·2	698	596·6						

All measurements in terms of H-P Caesium Standard No. 334, which agrees with the NPL Caesium Standard to 1 part in 10^{11}.

* Relative to UTC Scale; (UTC_{NPL} − Station) = + 500 at 1500 UT 31st December 1968.

† Relative to AT Scale; (AT_{NPL} − Station) = + 468·6 at 1500 UT 31st December 1968.

UDC 621.376.32

Comparison of transformerless ring modulators and cross modulators

ZDENĚK MACK, Ph.D.*

SUMMARY

Two types of transformerless modulators with single-ended outputs are compared: ring modulators and cross modulators. Equivalent circuits, transfer ratio, efficiency, carrier power and diode operating conditions are considered. It is shown that the cross modulator outperforms the ring modulator in many respects. Some practical applications of the cross modulator are given together with the results obtained.

* *Tesla Electronics Research Institute, Novodvorska 994, 142 21, Prague 4, Czechoslovakia.*

List of Symbols

MO1, MO2	ring modulators in Fig. 2; modulation signal applied to M, M′ or Y, Y′ terminals, respectively
MC	cross modulator, Fig. 3
$u(t)$	modulating signal
U_m	modulating signal amplitude
U_ω	one-sideband amplitude of the output signal
$\frac{U_\omega}{U_m}$	transfer ratio
U_{mr}, U_{mD}	modulating signal amplitude across conducting and non-conducting diodes, respectively
U_Ω	switching signal amplitude
$U_{\Omega d}, U_{\Omega D}$	switching signal amplitude across conducting and non-conducting diodes, respectively
η	modulator efficiency
R_{i1}, R_{i2}	modulator input impedances
R_s	modulator output impedance
$i_{1,2}, s$	normalized modulator input and output impedances, respectively
R_m	modulating source resistance
R_l	load resistance
l	normalized load resistance
R_c, R_y, R_p, R_x	modulator resistances (Fig. 2, Fig. 3)
x_0, x_c	normalized modulator resistances
k_0, k_c	coefficients of equation (2)
R_d, d	resistance and its normalized form of conducting diodes

1 Introduction

The ring modulator has been used successfully in transmission of a.m. signals with suppressed carriers, especially at high modulation levels, if low harmonic distortion is required. This type of modulator (Fig. 1) uses transformers and thus matching, single-ended output, etc., can be achieved easily. For i.c. techniques and if relatively wideband and linear-phase operation is required, transformerless modulators become necessary.

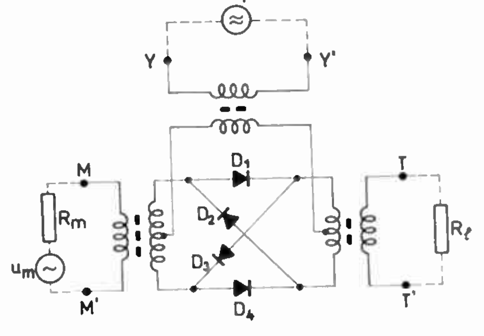


Fig. 1. The ring modulator.

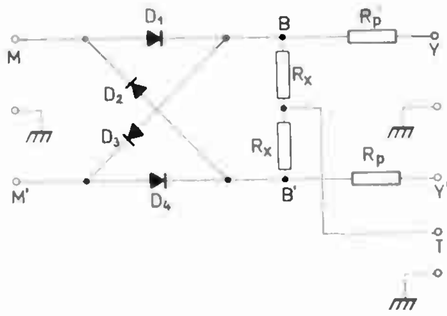


Fig. 2. The transformerless ring modulator.

The ring modulator from Fig. 1 can also be modified by inserting impedances into its branches, so that no transformers are needed and single-ended output remains possible—Fig. 2 shows the modification. The modulator in Fig. 2 can be operated in two ways: either the modulating signal is applied to terminals M, M′ and the carrier wave to Y, Y′, or conversely; in either case the output terminal is T.

Except the ring modulator in Fig. 2, other transformerless double-balanced diode modulators exist as well. One of these interesting modulator types is shown in Fig. 3;[8,9,10] it may be considered dual to that of the ring modulator and should not be mistaken for the 'star-modulator'.[1,5] The modulator consists of an impedance bridge to whose branches conversely polarized diodes are joined. Opposite ends of the diodes are connected to a common point—the output. This modulator will be called the 'cross modulator' because of its topological configuration.

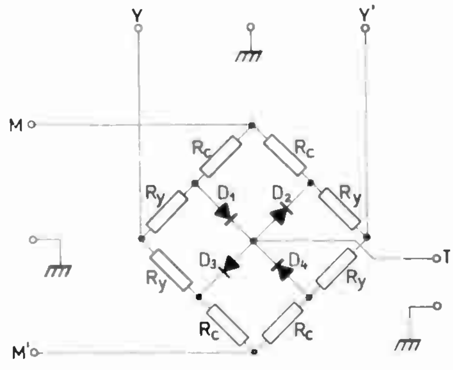


Fig. 3. The cross modulator.

The properties of modulators in Figs. 1 and 2 have been the subject of a number of works, mainly by Tucker.[3,4] The modulator shown in Fig. 3 has not yet been analysed and compared with other types.

The purpose of this paper is to compare the basic properties of the cross modulator with those of the ring modulator shown in Fig. 2 and to determine preferred applications. It will be shown that the cross modulator brings some advantages in utilization.

For the sake of brevity we will denote the ring modulator as MO1 or MO2 (modulating signal applied to M, M′ or Y, Y′ terminals, respectively) and the cross modulator as MC.

2 Method of Comparisons and Assumptions

For our comparison linear theory was chosen:[2] linear diode characteristics and rectangular carrier wave were assumed. Instead of the term 'carrier wave' we will use rather the term 'switching signal'. With resistances in series with the diodes, linear theory gives more accurate results than is the case when using transformers.

This investigation compares: (1) equivalent circuits, (2) efficiency, (3) transfer ratio, (4) switching signal power or level, and (5) operating conditions of the diodes. These parameters are compared for two different cases of operation:

(i) The modulator is matched to the load and in a restricted sense to the modulating source as well.

(ii) The modulator is matched to the load, but instead of the input matching, another condition is fulfilled.

The modulators are compared subject to the following conditions: (a) modulating source provides a harmonic signal with an amplitude U_m, and the switching signal is a rectangular waveform with an amplitude U_Ω, (b) the source impedance of the switching signal is zero, (c) diode characteristics permit the diode equivalent cir-

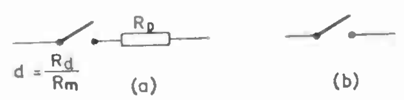


Fig. 4. Equivalent circuit of diode; R_d is the resistance of the conducting diode.

cuits according to Fig. 4(a) or 4(b) to be utilized; the source and load impedances R_m, R_l are real resistances and the modulator elements R_p, R_x, R_c, R_y have the same character.

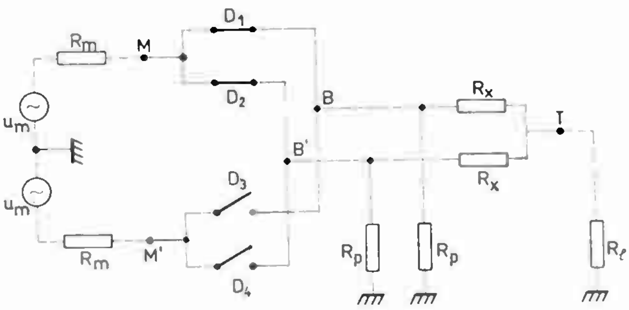
Under the given conditions the output signal is a rectangular waveform of amplitude U_2 and according to Belevitch,[2] one sideband output level is $U_\omega = (2/\pi)U_2$. We will consider the transfer ratio of the modulators defined as U_ω/U_m.

The modulators consist of paired resistors R_p, R_x, R_c and R_y, through which the carrier and the modulating signals are passed and the output is formed. Parameters k_0, k_c will now be introduced expressing the relative values of these pairs:

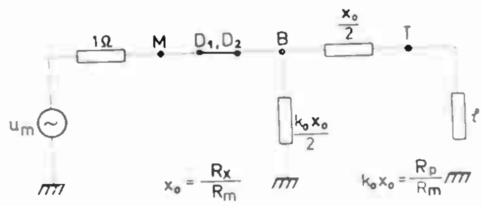
$$k_0 = \frac{R_x}{R_p} \quad \text{and} \quad k_c = \frac{R_c}{R_y}. \tag{1}$$

All resistances are normalized with respect to the internal resistance of modulating source R_m which due to this fact equals 1 ohm. The normalized resistances are denoted by 'lower case' letters as follows:

$$i = \frac{R_i}{R_m}, \quad s = \frac{R_s}{R_m}, \quad l = \frac{R_l}{R_m}, \quad x_{0,c} = \frac{R_{x,c}}{R_m}. \tag{2}$$



(a) Redrawn circuit of modulator MO1.



(b) Equivalent circuit with respect to modulation transmission.

Fig. 5

3 Comparison from the Modulation Transmission Point of View

3.1 Equivalent Circuits and Basic Parameters

Under the assumptions given in section 2, the circuit of the modulator MO1 (Fig. 2) can be redrawn according to Fig. 5(a). Points B and B′ are alternately connected to the modulating source by the switches. With the switch closed, the modulation energy is transmitted to load and the equivalent circuit used for determining modulation transmission is shown in Fig. 5(b). A similar arrangement is used for modulators MO2 and MC—their circuits are shown in Figs. 6 and 7.

The comparison of equivalent circuits from the case of modulation transmission shows that MC and MO1 are series-type modulators whereas MO2 is a shunt-type modulator. The modulators MC and MO1 are made up like a T-pad network and differ by location of their switches. The value of input impedance varies between two values which alternate each half-period of the switching signal. During the first, 'active' half-period, when energy is transferred from source to load, the input impedance is R_{i1}; during the second, 'passive' half-period, the input impedance is R_{i2}. The variation of impedance as seen at the second input terminal is delayed by one half-period. The output impedance R_s does not depend on the states of the switches and thus its value is the same during the active and passive half-period, which means $R_{s1} = R_{s2} = R_s$.

From the circuits in Figs. 5(a), 2, 7(a), expressions for the normalized input impedances i_1, i_2 and output impedances s being functions of modulator constants can be derived:

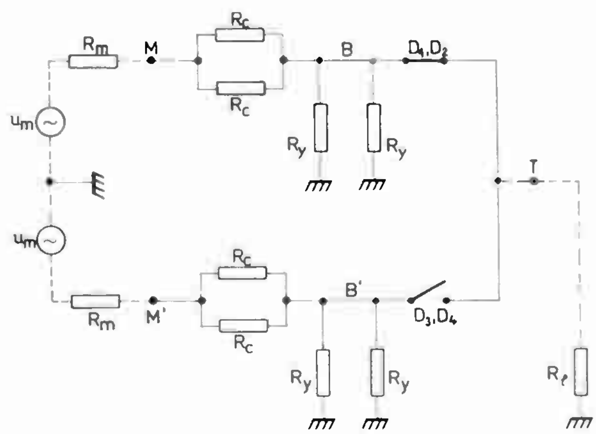
$$i_{1,2} = I_{1,2}(k_{0,c}, x_{0,c}, l) \tag{3}$$

$$s = S(k_{0,c}, x_{0,c}) \tag{4}$$

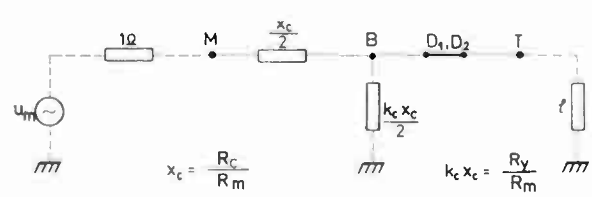
and from the circuits in Figs. 5(b), 6, 7(b) it is possible to derive the transfer ratio U_ω/U_m. Actual expressions are given in Table 1.

Table 1

	MODULATORS		
	MO 1	MO 2	MC
INPUT IMPEDANCES $i_1 =$	$\frac{k_0 x_0 (x_0 + 2\ell)}{2(k_0 x_0 + x_0 + 2\ell)}$	$x_0(k_0+1) + \frac{x_0 \ell}{x_0 + \ell}$	$x_c\left(\frac{1}{2} + \frac{k_c \ell}{k_c x_c + 2\ell}\right)$
INPUT IMPEDANCES $i_2 =$	∞	$k_0 x_0$	$\frac{1}{2} x_c (1 + k_c)$
OUTPUT IMPEDANCES $s =$	$\frac{1}{2} x_0 + \frac{k_0 x_0}{k_0 x_0 + 2}$	$x_0 \frac{1 + x_0(k_0+1)}{1 + x_0(k_0+2)}$	$\frac{1}{2} \frac{k_c x_c (x_c+2)}{2 + x_c(k_c+1)}$
$\frac{U_\omega}{U_m} =$	$\frac{\frac{4}{\pi} k_0 x_0 \ell}{(x_0+2\ell)(k_0 x_0+2)+2k_0 x_0}$	$\frac{2}{\pi} \cdot \frac{i_1 - (k_0+1)x_0}{1 + i_1}$	$\frac{4}{\pi} \cdot \frac{s}{x_c+2} \cdot \frac{\ell}{s+\ell}$



(a) Redrawn circuit of modulator MC.



(b) Equivalent circuit with respect to modulation transmission.

Fig. 7

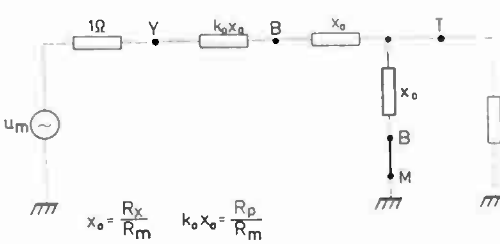


Fig. 6. Equivalent circuit of modulator MO2 with respect to modulation transmission.

The power delivered by the modulating source during the active and passive half-periods is:

$$P_{m1,2} = \left(\frac{U_m}{\sqrt{2}}\right)^2 \frac{1}{1+i_{1,2}} \qquad (5a)$$

and the efficiency is given by

$$\eta = \frac{P_\omega}{P_{m1}+P_{m2}} \qquad (5b)$$

where $P_\omega = (U_\omega/2)^2(1/l)$ is the power of one sideband applied to the load.

3.2 Matched Modulator

Keeping in mind that the input impedance alternates between the values i_1 and i_2, a continuous matching at one input terminal is impossible. Therefore the case when the maximum energy is transmitted from the modulation source to the load will be considered. This needs matching in the active period only, i.e. $R_{i1} = R_m$, expressed in the normalized form

$$i_1 = 1. \qquad (6)$$

The matching condition at the output,

$$s = l, \qquad (7)$$

can be fulfilled in the both half-periods.

Substituting relations (3) and (4) into matching conditions (6) and (7), we obtain modulator constants as functions of the load,

$$x_{0,c} = X_{0,c}(l) \quad \text{and} \quad k_{0,c} = K_{0,c}(l), \qquad (8)$$

whose actual forms are listed in Table 2. The transfer ratio U_ω/U_m and the input impedance i_2 can then be derived from the relations given in Table 1.

Table 2

MATCHED MODULATORS	MO 1	MO 2	MC
$x_{0,c}$ →	$\frac{x_o}{2} = \sqrt{\ell(\ell-1)}$	$x_o = \frac{\ell}{\sqrt{1-\ell}}$	$\frac{x_c}{2} = \sqrt{1-\ell}$
$k_{0,c}$ →	$k_o = \frac{1}{\ell-1}$	$k_o = \frac{1-2\ell}{\ell}$	$k_c = \frac{\ell}{1-\ell}$
$\frac{U_\omega}{U_m}$ =	$\frac{2}{\pi}\cdot\frac{0.5\ell}{1+\sqrt{1-1/\ell}}$	$\frac{2}{\pi}\cdot\frac{0.5\ell}{1+\sqrt{1-\ell}}$	$\frac{2}{\pi}\cdot\frac{0.5\ell}{1+\sqrt{1-\ell}}$

Figure 8 shows the plots of the parameters as functions of $l(=s)$. The considered matching conditions are fulfilled for modulator MO1 when $l > 1$, for MO2 when $l < 0{\cdot}5$ and for MC, when $l < 1$.

In the region $l < 1$, more advantages are gained by the use of modulator MC instead of MO2 because the first one can be operated over the entire region $l < 1$; it is more efficient (due to higher input values of i_2), while its transfer ratio equals to that of MO2.

The main advantage of the cross modulator in this case is that it may be matched all over the region $l < 1$, with a good efficiency. This advantage is a substantial one, because situations occur in this region when the input and output modulator impedances are selected with respect to capacitances and operating frequency: as modulator outputs contain frequencies much higher than that of the modulation, the ratio R_l/R_m is just less than 1.

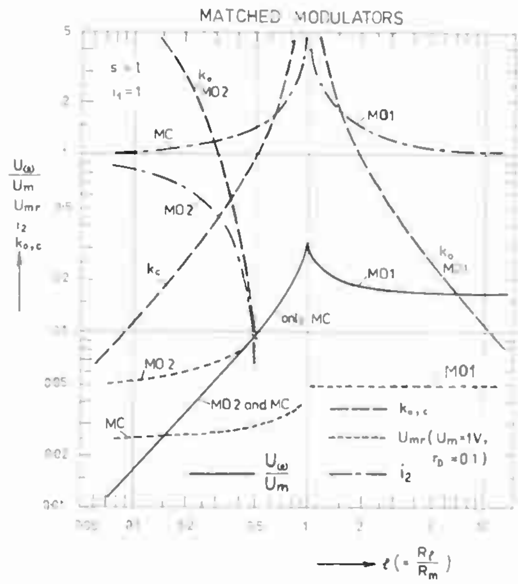


Fig. 8. Calculated parameters of matched modulators related to modulation transmission.

Around the point $l = 1$ the matching conditions can hardly be met due to high values of k_0 or k_c. The following Section presents a suitable operation mode for this case.

3.3 Second Operation Case

As input matching is not considered here, modulator properties can be controlled by parameters k_0 and k_c. The case $k_0 = k_c = 1$ will be considered, providing suitable operation conditions. If $l(=s)$ and k_0, k_c are given, modulator constants $x_{0,c}$ can be determined by eqn. (4).

In Figs. 9 and 10 values are plotted which have been calculated according to the expressions in Table 1. The realization region is now unlimited for any modulator type. Transfer ratio and efficiency are monotonic functions similar for all modulator types: for $l \to 0$ they approach zero, for $l \to \infty$ they approach a certain limiting value.

The highest transfer ratio U_ω/U_m can be obtained: in the region $l < 1$ by modulator MC and in the region $l > 1$ by modulator MO1. The modulator MO2 has always a lower transfer ratio which for $l \ll 1$ approaches that of the modulator MC.

The plots of efficiency are similar to the plots of transfer ratio: the plots show that the cross modulator is the most efficient one in slightly greater region ($l < 1{\cdot}7$).

3.4 Modulation Levels across the Diodes

The levels of the modulating signal are derived from the equivalent circuits in Figs. 5(b), 6 and 7(b). Actual expressions are given in Table 3.

U_{mD} and U_{mr} are the levels across the conducting and nonconducting diodes, respectively. Values U_{mr} are plotted for $U_m = 1$ V and $r_D = 0{\cdot}1$ in Fig. 8 for the case of a matched modulator, in Fig. 9 for the second opera-

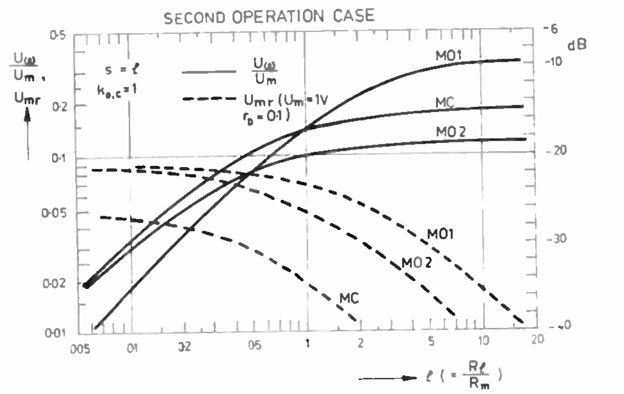


Fig. 9. Transfer ratio and modulation level across a conducting diode for the second operation case.

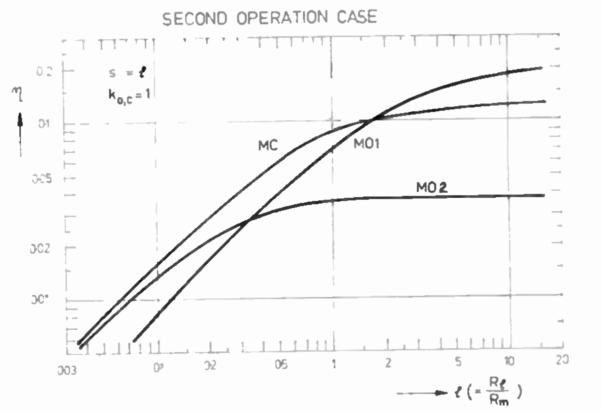


Fig. 10. Efficiency of the modulator for the second operation case.

tion case (r_D is the resistance of parallel-connected conversely polarized diodes).

It is worth mentioning that the level U_{mr} in the modulator MC is lower than that of both types of ring modulators due to the fact that the diodes are located at the output (Fig. 5(b)), where the modulation level is low. This means that the operation point on the conducting-diode characteristic moves according to the modulating signal along the shortest path; thus the diode characteristics are of minimum influence.

Table 3

	MO1	MO2	MC
$\frac{U_{mD}}{U_m}$ =	$\frac{1+2i_1}{1+i_1}$	$\frac{i_1 - k_o x_o}{1+i_1}$	$\frac{1}{2}\left(\frac{2i_1-x_c}{1+i_1}+\frac{k_c x_c}{1+i_2}\right)$
$\frac{U_{mr}}{U_m}$ =	$\frac{r_D}{1+i_1+r_D}$	$\doteq \frac{r_D}{1+k_o x_o+r_D}$	$\frac{1}{2}\frac{(2i_1-x_c)\,r_D}{(1+i_1)(\ell+r_D)}$

Table 4

		MO1	MO 2	MC
NONCONDUCTING DIODES	$\frac{U_{\Omega D}}{U_\Omega}$ =	$\frac{d}{d+k_o x_o}$	1	$\frac{1}{k_c+1}$
CONDUCTING	$\frac{U_{\Omega d}}{U_\Omega}$ =			$\frac{d}{d+k_c x_c}$
i_Ω =		$k_o x_o + d$	d	$\frac{(d+k_c x_c)(k_c+1)}{2k_c+1+\frac{d}{x_c}}$

4 Modulator Properties from the Point of View of the Driving Signal

4.1 Equivalent Circuits and Basic Relations

The equivalent circuits of the modulators are shown in Fig. 11. An interesting difference appears between the ring and cross modulators. In the ring modulators, pairs of conducting as well as non-conducting diodes are connected in parallel. On the other hand, in the cross modulator each diode pair has its individual branch, so that across a non-conducting diode there is a higher carrier voltage than on a conducting one. This fact contributes to more effective utilization of carrier level and power.

From the equivalent circuits the ratio can be derived of the switching signal level U_Ω on the Y (by the MO2 on the M) terminals to the level of this signal across a conducting and non-conducting diode, $U_{\Omega d}$, $U_{\Omega D}$, respectively:

$$\frac{U_{\Omega d}}{U_\Omega} = F_d(x_{0,c}, k_{0,c}, d), \tag{9}$$

$$\frac{U_{\Omega D}}{U_\Omega} = F_D(x_{0,c}, k_{0,c}) \tag{10}$$

The actual form of these equations is given in Table 4.

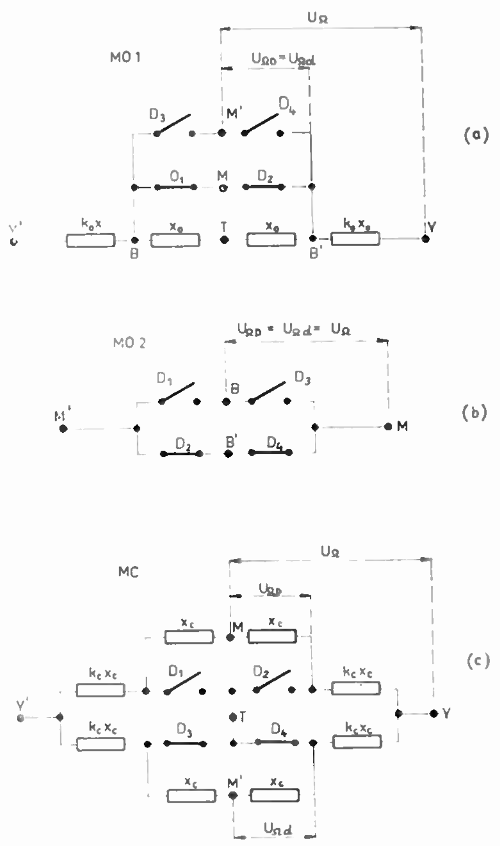


Fig. 11. Equivalent circuits with respect to switching signal.

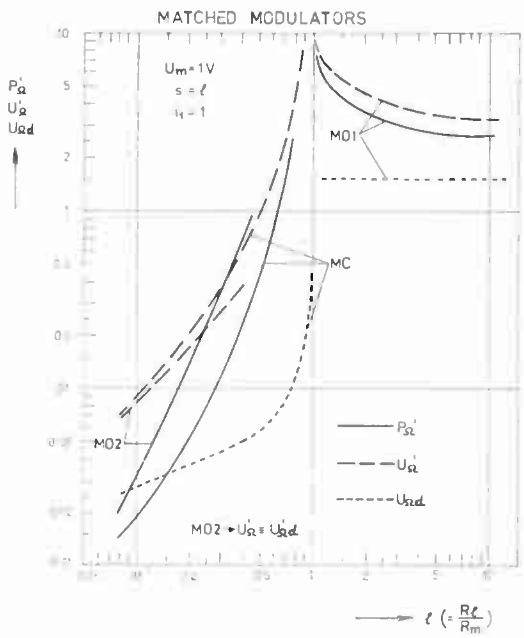


Fig. 12. Switching signal power and level at terminal Y, and/or M and switching signal level $U_{\Omega d}$ across conducting diodes.

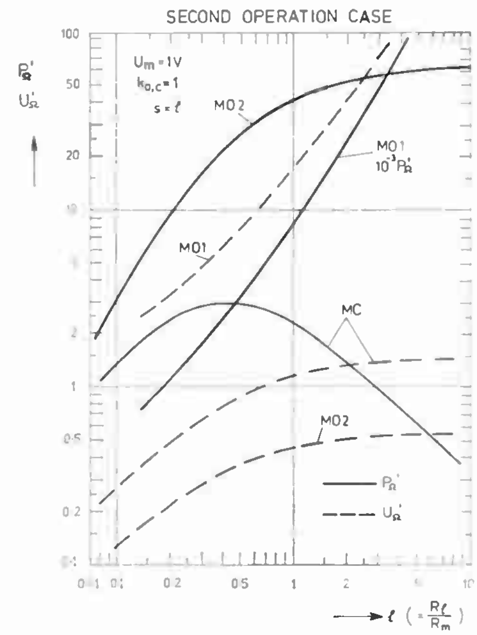


Fig. 13. Required minimum power and switching signal level for the second operation case.

This Table also states the relations for relative input impedances i_{Ω} on the Y (respectively M) terminal.

4.2 Required Signal Level

The switching signal opens diodes or closes them, therefore the switching signal level across the diodes should always exceed the modulating signal level. A theoretical minimum of switching level at Y and/or M terminals can be considered which results in equal switching and modulation levels across the conducting and non-conducting diodes. For comparison this minimum switching level will be considered; in practice the switching level must, of course, exceed this minimum value.

The minimum switching signal level across non-conducting diodes, $U'_{\Omega D}$, and across conducting diodes, $U'_{\Omega d}$, should therefore be

$$U'_{\Omega D} = U_{mD} \quad \text{and} \quad U'_{\Omega d} = U_{mr}, \tag{11}$$

where U_{mD} and U_{mr} are taken from Table 3.

Two levels on terminals Y and/or M correspond to the two mentioned levels $U'_{\Omega D}$ and $U'_{\Omega d}$, the necessary minimum level for modulator operation denoted U'_{Ω} is the larger one.

The values of U'_{Ω}, calculated for the case of a matched modulator, are shown in Fig. 12 and for the second operation case in Fig. 13, both for $U_m = 1$ V.

The minimum driving input power at modulator terminal Y and/or M is thus (for a rectangular switching signal),

$$P'_{\Omega} = \frac{U'^2_{\Omega}}{i_Y}, \tag{12}$$

which is plotted in Figs. 12 and 13.

4.3 The Comparison of Necessary Switching Levels and Powers

If the modulator is matched, it can be seen from the curves in Fig. 12, that of both modulator types, MO2 and MC, which have a common realization region $l < 1$ (Sect. 3), type MC requires lower switching power P'_{Ω} but a slightly higher level of U'_{Ω} than the type MO2. The modulator MO1, whose realization region is $l > 1$, requires a substantially higher switching power P'_{Ω} as well as level U'_{Ω} than type MC. Only in the vicinity of point $l = 1$ these values are approximately equal for both types.

For the second operation case, the curves in Fig. 13 show that the modulator MC requires the lowest

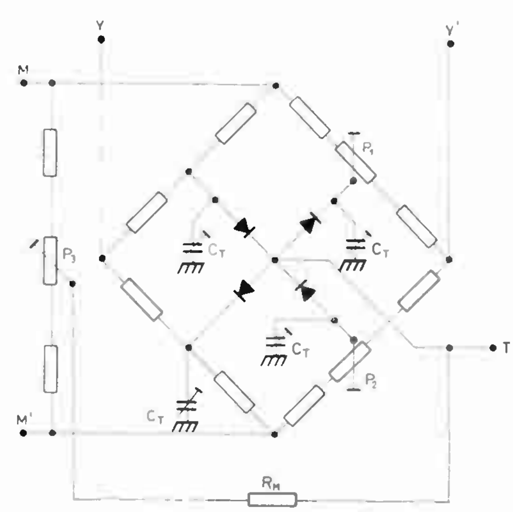


Fig. 14. Cross-modulator configuration with balancing elements, proven in practice.

switching power, especially for $l > 1$. On the other hand, modulator MC requires a switching level about twice that of MO2, but this level is still substantially lower than that of MO1.

From the point of view of the switching signal the modulator MC is advantageous except in cases the switching level is limited and there is a high power available. The low values of P'_{Ω} of modulator MC are given by the advantageous form of its equivalent circuit, mentioned in section 3.

5 Cross Modulator Applications

Figure 14 presents a cross modulator configuration with balancing elements which has been proved in practice. From the switching signal side, the modulator is balanced by potentiometers P1, P2 (real components) and by capacitances C_T (imaginary components), including semiconductor diode capacitances. From the modulating signal side, the modulator is balanced by potentiometer P3. The cross modulator in Fig. 14 has been used in several measuring instruments,[6,7,11] where it operated at frequencies from 10 Hz to 1 MHz. Practical applications proved the advantages of this modulator type. Availability of large output signals with low harmonic distortion should be emphasized.

Achieved suppression of carrier and its harmonics (38 kHz) was 60–80 dB as related to output envelope level, while non-linear distortion of transmitted modulation at the output level of 3 Vp−p was less than 0·1 %.[7] Modulation and signal sources were of a very simple design.

6 Conclusion

The comparison of the cross and ring modulators in two operating modes may be briefly outlined as follows (both types MO1 and MO2 are considered as a 'ring modulator'):

(1) From the point of view of the transfer ratio and efficiency the modulators complement each other —the cross modulator is advantageous when the value of the load resistance is equal to or less than the modulating source resistance.

(2) The cross modulator has always better diode operating conditions.

(3) From the point of view of the switching signal the cross modulator can save a substantial amount of power.

Hence, the use of the cross modulator may provide either circuit simplification or parameter improvement.

7 References

1. Prokott, E., 'Modulation' (S. Hirzel, Leipzig 1943).
2. Belevitch, V., 'Linear theory of bridge and ring modulator circuit', *Electrical Communication*, **25**, pp. 62–73, March 1948).
3. Tucker, D. G., 'Balanced rectifier modulators without transformers', *Electronic Engineering*, **22**, pp. 139–41, April 1950.
4. Tucker, D. G., 'Modulators and Frequency Changers for Amplitude Modulated Line and Radio Systems' (MacDonald, London 1953).
5. Henkler, O., 'Übertragungstechnik im Fernmelde-Weitverkehr' (Verlag Technik, Berlin 1956).
6. Mack, Z., 'Stereo-service generator SC-A', *Funk-Technik*, No. 15, pp. 532–4, 1968.
7. Mack, Z., 'Simple generation of a high-quality stereo multiplex test signal', *Tesla Electronics*, **2**, No. 1, pp. 17–22, 1969.
8. Frank, R. L., 'Balanced modulator circuit', U.S. Patent No. 2, 842, 744.
9. Mack, Z., 'Synchronous sterophonic balanced demodulator', Czechoslovak Patent No. 122, 168.
10. Mack, Z., 'Circuit for suppressing unwanted frequency components' Czechoslovak Patent No. 137, 880.
11. Mack, Z., 'An accurate stereophonic demodulator', *Tesla Electronics*, **7**, No. 2, pp. 35–42, 1974.

Manuscript first received by the Institution on 13th December 1973 and in final form on 9th April 1974. (*Paper No. 1598/CC 207.*)

UDC 621.3.049.776:621.318.4

The application of lumped element techniques to high frequency hybrid integrated circuits

R. E. CHADDOCK, B.Sc.(Hons.), Ph.D*

Based on a paper presented at the IERE Conference on Hybrid Microelectronics held at Canterbury on 25th to 27th September 1973.

SUMMARY

Lumped element techniques as employed in a production range of high-frequency hybrid power amplifiers are described in the first part of this paper. The lumped inductor is a component not commonly employed for integrated circuits and such an application requires novel design considerations. In the second part, some of these are identified from the theory of lumped inductors and compared with the practical case.

* *Formerly with the Development Department, Mullard Southampton; now with Marconi Space and Defence Systems, Frimley, Surrey.*

1 Introduction

Much progress has been made in miniaturizing high-frequency equipment in recent years. The use of lumped elements in a high frequency integrated circuit was described in 1964 by Uhlir[1] and a number of papers have since described experimental monolithic and hybrid circuits. Integrated circuits are particularly attractive in the high-frequency region beyond 50 MHz because parasitic inductances and capacitances can be brought under close control. In this paper we are most concerned with the region between 50 and 1000 MHz, in which these parasitic reactances are becoming of great influence, an importance which increases with frequency. The remarks to follow apply with minor modifications up to about 10 GHz.[2]

Modern tendencies are toward broad bandwidth systems, with low loaded Q, which minimize the extent of circuit tuning in manufacture and subsequent operation, and as a consequence the circuits can tolerate components of relatively low unloaded Q-factor (< 50). In the following, the application of lumped element techniques to power amplifiers is mentioned, because it is in these units that the advantages of the lumped approach are most marked, although the results are more generally applicable.

2 The Integrated Power Amplifier

It is well known that modern high-frequency power transistors have very low impedances and when in discrete form the ratio of reactive to resistive parts is rather high for convenient matching to external circuits. However, this is an ideal application for hybrid technology when the matching components are integrated into the transistor header, thus reducing common lead inductance and improving gain, stability and wideband performance.

A typical power amplifier combines inductive and capacitive elements for the necessary impedance transformation. Such a circuit function is not easily simulated at high frequencies by active components and as a consequence a typical integrated circuit is less compact and contains a greater variety of elements than the low-frequency version.

3 The Hybrid Lumped Element Approach

3.1 Lumped Elements

The realization of such elements for an integrated circuit requires some new concepts.

Traditionally high frequency circuits have utilized distributed lines, because of the difficulty in making passive components sufficiently small to be truly lumped. Such lumped devices produced by conventional etching and winding processes are also very large compared with transistor chips. However, modern transistor technology provides photoresist techniques of high definition (fractions of a micron) which enable the necessary passive component miniaturization to be achieved.

The resulting lumped elements possess a number of advantages over distributed elements. First, the approach

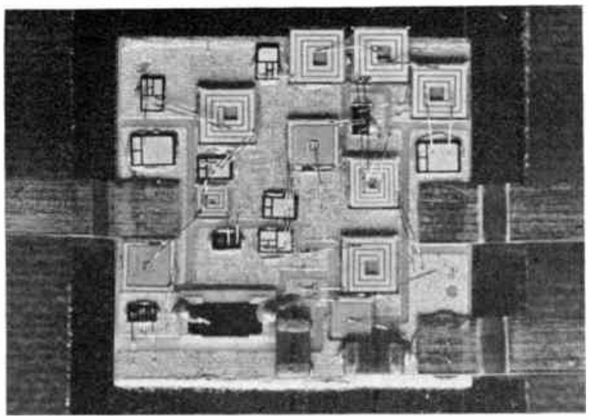


Fig. 1. Two-stage hybrid u.h.f. power amplifier module BGY22.

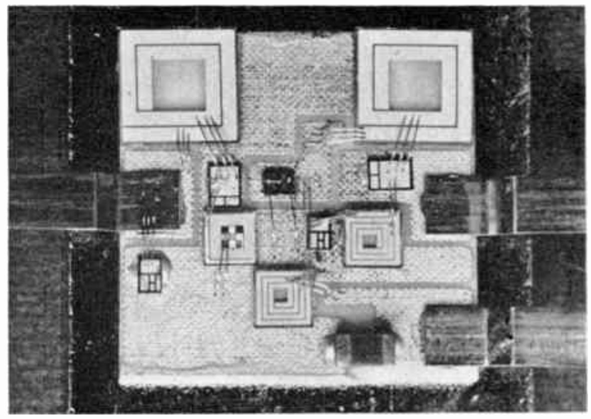


Fig. 2. Single stage add-on u.h.f. hybrid module BGY23.

is more flexible in that we can employ standard ranges of components which can be added as required, and which are more amenable to customer specials and limited batch production. Secondly, there is a considerable size advantage. Thus, in order for a component in free space to be lumped, its maximum dimension must be less than about a tenth of the wavelength. For example, at 100 MHz a lumped inductor should be less than about 3 cm in diameter and at 1 GHz less than 3 mm; because the component values required for tuning decrease with increasing frequency, the physical sizes likewise decrease and therefore both lumped inductors and capacitors can be made well within these physical limits. By comparison, distributed lines may be of the order of a quarter-wavelength, which in free space implies about 7 cm at 1 GHz and 70 cm at 100 MHz. Although meander and loaded lines are used to control these dimensions, the advantages of lumped elements in miniaturization are overwhelming, and therefore have been used mostly in this work.

3.2 The Hybrid Form

Integrated circuits have been realized in a number of ways at high frequencies. Monolithic circuits are difficult, mainly because the requirement of low-loss substrates for inductors is in contradiction to the necessity of using the silicon transistor chips of the current technology. A semi-monolithic approach has therefore been employed in the past[3] in which transistor chips are added to a substrate produced as an entity and containing interconnected inductive, capacitive and resistive elements. In the more flexible hybrid approach employed here and elsewhere each component can be produced by optimum means, without the restriction that materials and processes for each device be compatible with all others. Thus each component is produced as part of an array of identical elements upon a slice of appropriate material, much as transistors are made. The wafer can then be pre-tested, scribed and sorted, and this is ideal for a production system. Individual components may then be added to a metallized substrate, thus integrating the matching circuits into the transistor header. Figures 1 and 2 show examples of this approach, being two of a production range of high frequency power amplifiers. Each has a 12 mm square beryllia substrate, metallized using a thick film process.

A further stage of integration also employed is to produce all the inductors integrally with the substrate metallization, and to add only capacitors and transistors, each again made by optimum means. Figure 3 depicts

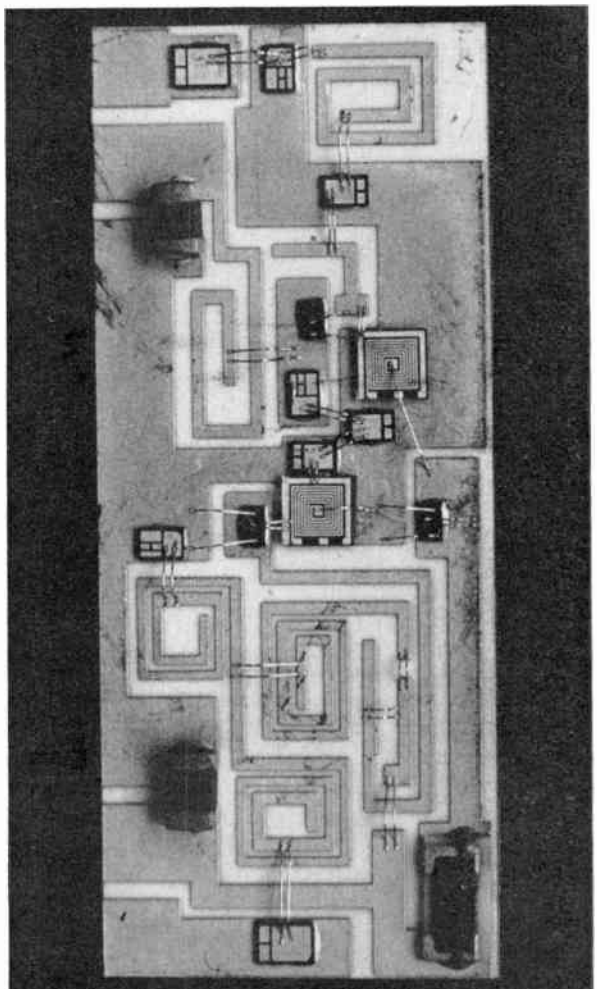


Fig. 3. Two-stage module with integral inductors.

such an approach, this item employs a 10 mm by 25 mm alumina substrate, metallized using a thin film process to achieve better definition for the integral inductors. The layout design now becomes more arduous as both design of all the individual inductors and also the way in which they fit into the layout must be considered. A number of practical aspects affect this inductor and layout design stage, and these are considered in Section 4.

A more complete discussion of comparative merits of hybrids versus monolithics, and distributed versus lumped elements is not given here as ample discussion for the particular case of high frequency circuits may be found in the literature (for example, Ref. 3). Similarly the available technologies are not explicitly described[4, 5]

4 Design of Lumped Elements

The particular requirements of a lumped element design depend upon the frequency of operation. At high frequencies (for example 4 GHz) component values are small and dimensions are also minimal, approaching the limits of the technology. However, values at v.h.f. and u.h.f. typically vary between less than one to a few hundred nanohenrys for inductors and from one to a few hundred picofarads for capacitors. The practical realizations of such values occupy areas of between one and fifty square millimetres for inductors and one to six square millimetres for capacitors. Thus, capacitors are not the crucial size problem at these frequencies, but careful attention needs to be paid to inductor design.

4.1 Inductor Design

A number of published equations exist for calculating the low-frequency inductance of different geometries. (See, for example, the summary in Ref. 6.) The literature also contains corrections made to allow for current crowding effects at high frequencies.[7] In addition, methods to allow for inductor end effects are available.[8] Most of the more exact expressions for inductance are sufficiently complicated to deter the designer from arriving at the best inductor sizes and shapes to fit within an available layout. That is, if he is still to take into account the demands of circuit design, for example in regard to losses. It is also relevant that repositioning a critical miniature component by a few millimetres can produce drastic changes in circuit performance, and accurate calculation then becomes superfluous for a complex circuit. There are in addition a number of significant deviations in a practical situation not included in even the more rigorous treatments, but appropriate corrections can be simply added and are discussed in Section 4.2. When combined with corrections where relevant, the simple theory outlined in this Section is adequate for the design stage. Hybrid assembly then permits tuning of individual components by wire bond variation during development. Component batch variability is usually non-critical in a good broad-band electrical design, but the considerable adjustment latitude of the hybrid approach is often helpful for extreme variations at the production stage. The simple theory of planar inductors now follows.

4.1.1 *Inductance*

At high frequencies all conductors possess significant inductance. A simple form of component is the straight strip of rectangular cross-section, for which

$$L = 2l\left(\log\frac{l}{w} + 1{\cdot}19 + 0{\cdot}22\frac{w}{l}\right) \tag{1}$$

where L is in nanohenrys and l is length and w the width, both in centimetres.

A strip can be an inconvenient shape when joining adjacent circuit elements and could in practice form part-perimeter of a circle; provided the radius is much greater than the strip width, equation (1) can be used with little loss of accuracy. As an example, a strip of width 100 μm and length 2 mm will have an inductance approaching 2 nH. Often in practical assemblies such small values are formed entirely from the bond wire loops connecting adjacent components; vice versa, allowance must be made for inductive interconnexions during design. The inductance of simple interconnexions is represented graphically in Fig. 1 of Reference 3, which graph also allows estimation of losses.

Inductance values required at v.h.f. and u.h.f. frequencies in general are large enough to require multi-turn planar arrangements for compact layouts. An expression which has been found most useful is that given by Wheeler for a circular spiral geometry of round conductor cross-section:

$$L = \frac{393n^2a^2}{8a+11c} \tag{2}$$

where a is the average radius, c is half the difference between the outer and inner diameters, both in centimetres, and n is the number of turns.

4.1.2 *Losses*

From expression (2) it is seen that to attain a specific inductance the choice is between a large number of turns of small radius or vice versa. For miniaturization the former is preferable, where the fabrication technology permits adequately high resolution. However, circuit losses require limiting to acceptable levels, and this aspect creates a trend towards large inductor dimensions. A compromise is therefore frequently necessary.

The Q of a spiral inductor is given by the expression

$$\frac{Q}{L^{\frac{1}{2}}} = \frac{2{\cdot}4w}{k}\left(\frac{f}{\rho d}\right)^{\frac{1}{2}} \tag{3}$$

where d is the outer diameter (cm), f is the frequency (GHz), ρ is resistivity in Ω-cm, and k is a numerical factor to allow for current crowding effects.

4.2 Practical Aspects of Inductor Design

4.2.1 *Inductor size and track design*

In order to maximize Q, a large turn-width to coil diameter (w/d) ratio is required and this implies narrow spaces between turns. Also, it has been calculated[9] that maximum Q is obtained when the inner coil diameter (d_i) is one-fifth of the outer diameter so that flux lines may pass through the coil. If we use this criterion it follows then, to a first approximation, that

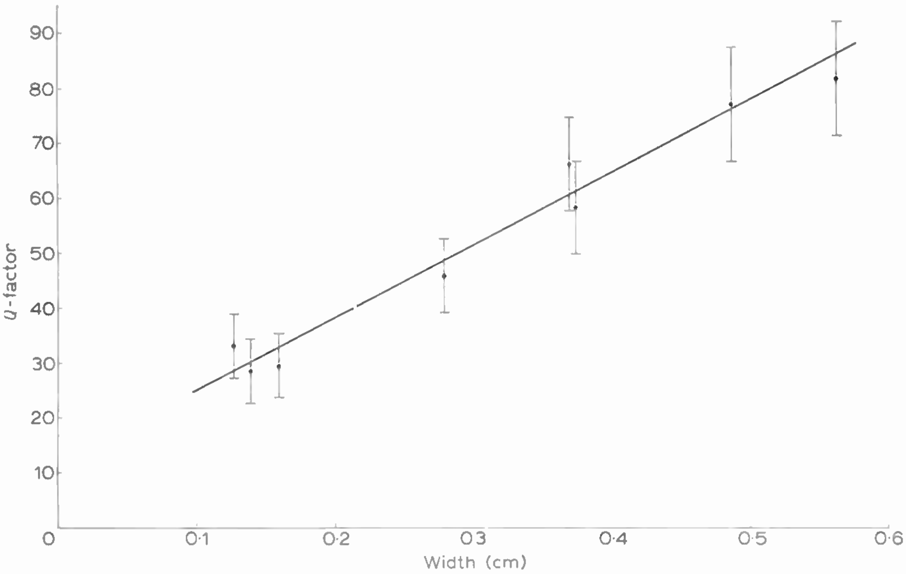


Fig. 4.
Q-factor at 500 MHz as a function of inductor width. Design parameter $d_i = 0{\cdot}2d$.

$$Q_{max} = 2{\cdot}2\frac{d}{k}\left(\frac{f}{\rho}\right)^{\frac{1}{2}} \qquad (4)$$

where interturn spacing (s) is assumed here to be sufficiently small to be neglected. The product $k(\rho)^{\frac{1}{2}}$ may be calibrated from a few Q measurements on coils made by the intended process and to the same design, thus giving a value for k usually within the range 1·5 to 3. In Fig. 4, measured Q-factors of a number of inductors are plotted against d, and it can be seen that equation (4) is well obeyed for coils of this design. Since d is the only factor completely under the designer's control, the importance of correctly relating coil diameter to the required Q is therefore demonstrated. Once d is decided, the number of turns to form a required inductance can be established from the modified form of equation (2):

$$L = 5{\cdot}21n^2d. \qquad (5)$$

Note that L changes rapidly with the number of turns.

There are, of course, physical limitations on the track-width and turn-separation possible, and these are set by the resolution capability of the hybrid technology employed. When producing designs for a specific layout the procedure is assisted by an examination of the family of curves formed by plotting L against d as a function of the number of turns. An example of such a graph is Fig. 5. Here the dotted lines represent the resolution limits s = 50 µm, 100 µm and 250 µm. To the right-hand side of each line, allowable practical solutions exist.

So far we have established a system to choose the coil dimensions (d, d_i and n) that will satisfy the electrical parameters (L and Q) taking into account the resolution of the intended technology. The next step is to provide means of allowing for some further aspects which are important in practical design work.

4.2.2 *Square spirals*

Thus far it has been assumed that the multi-turn inductors are composed of circular spirals. In fact, for

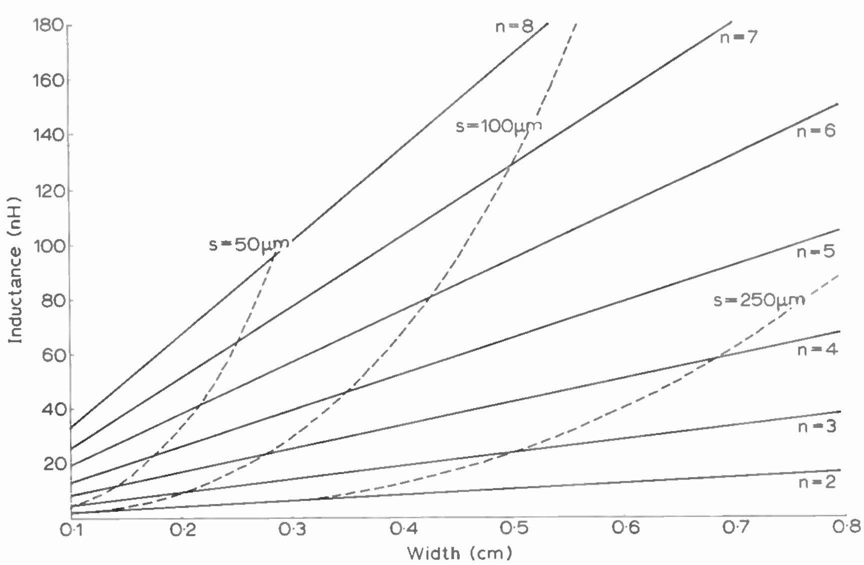


Fig. 5. Inductance as a function of inductor width for different numbers of turns (n).
Design parameters: $d_i = 0{\cdot}2d$ and $w = 2s$. The dashed curves illustrate design resolution limits. Practical designs exist to the right-hand side of each lower limit specified for inter-track spacing (s).

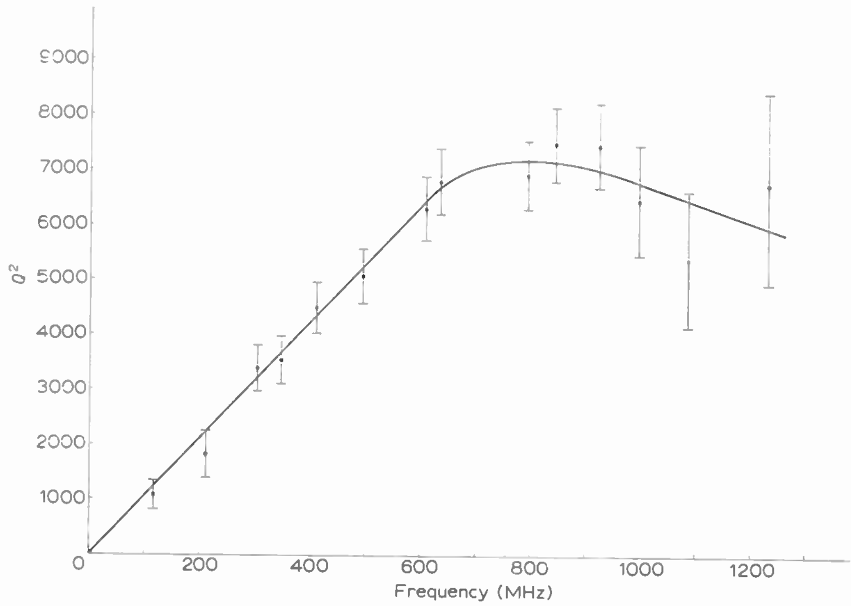


Fig. 6. Q^2 as a function of frequency. Design parameters: $n = 2$, $d = 0{\cdot}4$ cm, $w = 0{\cdot}05$ cm and $s = 0{\cdot}006$ cm.

the same outer diameter the maximum inductance is obtained with a square geometry. This increase is a function of the ratio of metal thickness to overall size; the function is rapidly changing but for 1 mm wide coil and metal thickness 20 µm, will mean an inductance increase of about 20% and for 8 mm coils, an increase of 25%. A decrease in Q is also observed, but of less than 10%. Square spirals also have the advantages of higher packing density and ease of artwork production and for these reasons are more common than the circular variety.

4.2.3 *Frequency dependence of losses*

The theory of equation (3) is based upon a resistive loss mechanism and predicts that Q is proportional to the square root of the measurement frequency. Usually this is correct, but Fig. 6 shows a plot of Q^2 against frequency for a two-turn coil, 4 mm square. It can be seen that the Q-factor departs from theory above 700 MHz. At this frequency the total conductor length is approaching one-tenth of the wavelength and so distributive effects may be important through depressing the inductance of such large coils at this frequency. Incidentally, from curves such as Figs. 5 and 6 it is possible to rapidly estimate the Q of different proposed coils at all frequencies within the measured ranges.

4.2.4 *Metallization thickness and losses*

The effect of limited metal thickness upon losses has thus far been neglected; increasing thickness degrades edge definition and also makes processing more difficult, and so the minimum acceptable thickness should be employed. Figure 7 is a plot of Q against gold thickness for a 12 nH inductor (2 mm square and $3\frac{1}{2}$ turns) at

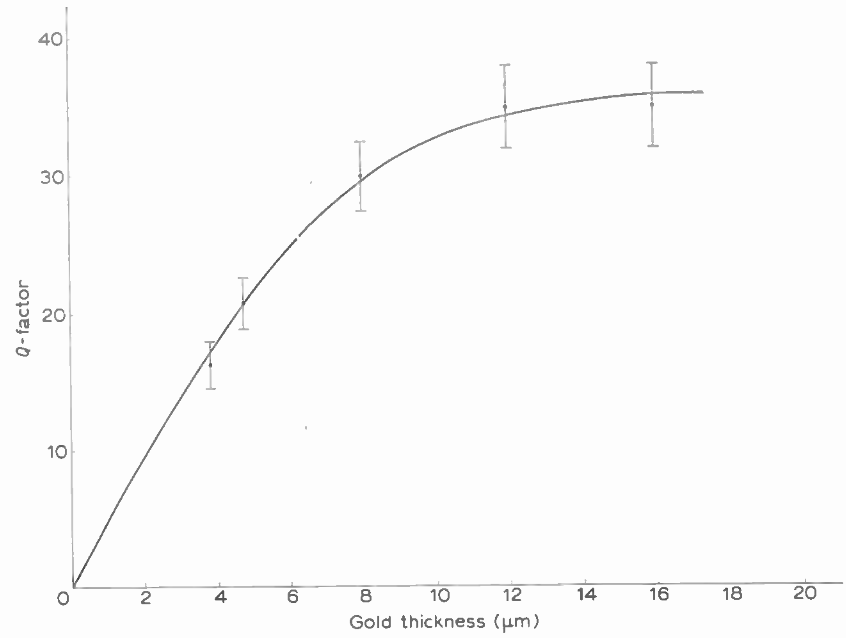


Fig. 7. Q-factor as a function of gold thickness.
Design parameters: $n = 3\frac{1}{2}$, $d = 0{\cdot}2$ cm and $w = 0{\cdot}016$ cm.

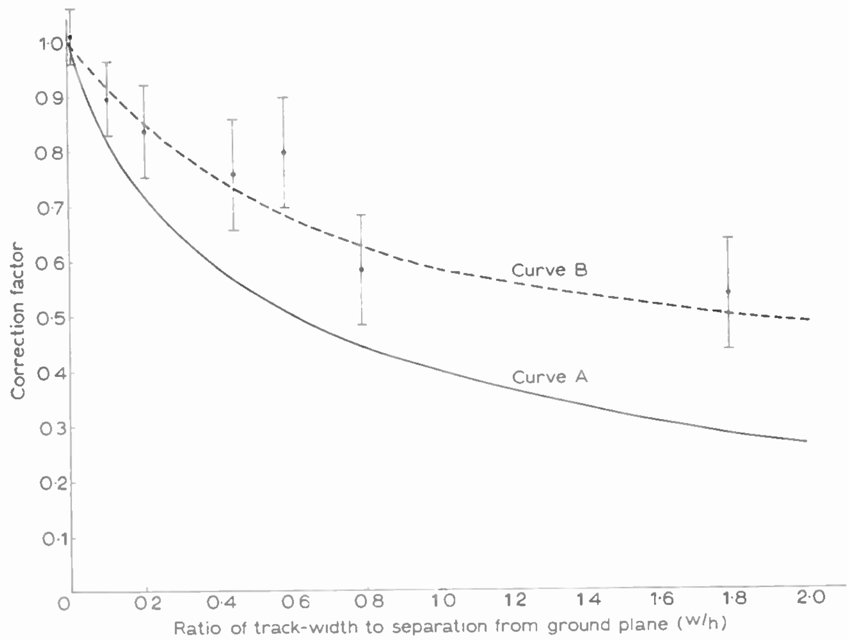


Fig. 8. Correction factor giving inductance depression resulting from the proximity of an earth plane. Curve A—theoretical assuming TEM propagation mode, Curve B—observed depression.

500 MHz. It is evident that most of the current is carried in the 10 μm surface layer of gold at 500 MHz. Since the skin depth is 3·4 μm it is apparent that at least three times this value is desirable. Skin depth is inversely proportional to the square root of frequency, and so at 50 MHz, 30 μm is required and at 5 GHz only 3 μm. Thus the operating frequency strongly influences the choice of metallization technique.

4.2.5 *Presence of extraneous grounds*

Until now it has been assumed that any ground plane beneath an inductor is at infinite spacing. Parasitics result from departure from this assumption, and the effects have been estimated[4] by considering the inductor and ground as forming a strip line. It is a conclusion of this approach that the separation of inductor to ground (h) should be at least ten times the inductor track width to achieve the unshielded inductance value. To allow for departure from this rule a correction factor can be computed as a function of track to separation (w/h). This calculated curve (A) is shown in Fig. 8. Also shown is the observed depression of inductance (curve B), which is found to be considerably less. The discrepancy is probably due to the fact that the mode of propagation in a coil structure is not TEM as assumed for the calculated curve. This is fortunate because in practice the ideal earth plane spacing is difficult to achieve for high-Q coils (which means wide tracks) at v.h.f. and u.h.f. using, for example, 0·6 mm alumina substrates. In such an instance, correction of calculated inductances for small earth plane spacing using curve B has been found to produce acceptable results for the designs used in this work.

It is also found that coils may be brought into closer proximity to each other than the five turn-widths indicated by the theory of distributed lines. This is probably a consequence of the containment of field within the lumped inductors employed.

4.3 Summary of Inductor Design Aspects

The inductive element is difficult to integrate, first because larger areas are required than for transistors, particularly at v.h.f., and secondly because low-loss substrates are necessary. In fact the most important aspect to control is that of losses. A good design in this respect has inner diameter one-fifth of outer dimension, small spacing between turns, and metal thickness at least three skin depths. For any specific technology the designer most easily controls the unloaded Q-factor by attention to the coil diameter. There is a lower limit to this coil size set by the required Q-factor and also the limitations of the technology. The upper limit is established by the difficulty of predicting distributive effects which may depress calculated inductance, and also by the obvious requirements of miniaturization.

The number of turns required for a specific inductance and whether a design is physically allowed by the technology to be employed, can be established most easily by graphical means. Such means are most useful when designing complete circuit layouts. Allowance must be made for the effects of finite substrate thickness which may depress calculated inductance values.

4.4 Other Passive Components

Thus far we have concentrated on the more critical passive component, the inductor. Two common capacitor forms are the sandwich and interdigitated structure. The capacitance per unit area formed by the interleaved fingers of the latter simple structure, which is planar, is too small for general use below about 4 GHz and the sandwich construction is preferred. In any one circuit design, a range of capacitors may be needed, for example, from 1 to 50 pF. A monolithic approach using conveniently a single deposited dielectric thickness would thus require a 50 to 1 range of areas. On the other hand, hybrid assemblies (as described in this paper) can employ with advantage a range of oxide thicknesses, thus minimizing the areas. Consequently, sandwich capacitors are usually much smaller than inductors at high frequencies, and space considerations are non-critical. The design of capacitors is straightforward, once the permittivity of the dielectric has been determined and is not considered here. Similar remarks apply to the design of resistors. Actual fabrication technologies involved in the hybrid approach are not the subject of this paper and references have already been given.

5 Conclusion

Integrated circuits provide a means of obtaining better performance from high frequency power transistors, in addition to the more compact form of an integrated circuit. Hybrid forms are in many ways more practical than monolithic designs for v.h.f. and u.h.f. equipment. Because inductors are needed for impedance transformation, such integrated circuits are typically larger than low frequency items. Lumped element techniques can be successfully employed and have many advantages over the more traditional distributed line approaches, particularly in obtaining smaller dimensions, broader bandwidths and design and manufacturing flexibility.

However, some different criteria to those at low frequencies must be used when designing the lumped element inductors. The considerations outlined in this paper allow the designer to take some account of both electrical and physical requirements, although these may be contradictory. Early attention is emphasized to the problem of inductor losses, which can be a crucial factor in miniaturizing lumped element designs at high frequencies. This is especially so for v.h.f. and u.h.f., because the resolution which is possible with existing technologies is so good, that over-miniaturization is tempting, particularly to realize monolithic designs. Attention is drawn, therefore, to the importance of correctly choosing inductor dimensions in order to prevent excessive losses, and also to the selection of a consistent technology.

A production range of power amplifiers is now available, and with correct choice of technology and careful attention to design, hybrid lumped element circuits of greater variety will become available as production items at high frequencies.

6 Acknowledgment

The author wishes to thank the directors of Mullard Ltd. for permission to publish this paper.

7 References

1. Uhlir, A., Jr., 'Microwave applications of integrated circuit techniques', *Proc. Inst. Elect. Electronics Engrs*, **52**, No. 12, pp. 1617–23, December 1964.
2. Aitcheson, C. S., *et al.*, 'Lumped microwave circuits', *Design Electronics*, 9, No. 1, pp. 30–9, October 1971.
3. Caulton, M., Knight, S. P. and Daly, D. A., 'Hybrid integrated lumped-element microwave amplifiers', *IEEE Trans. on Microwave Theory and Techniques*, **MTT-16**, No. 7, pp. 397–404, July 1968.
4. Sobol, H., 'Technology and design of hybrid microwave integrated circuits', *Solid State Technology*, **13**, No. 2, pp. 49–57, February 1970.
5. Keister, F. Z., 'An evaluation of materials and processes for integrated microwave circuits', *IEEE Trans.*, **MTT-16**, No. 7, pp. 469–75, July 1968.
6. Terman, F. E., 'Radio Engineer's Handbook', pp. 47–64 (McGraw-Hill, New York, 1943).
7. Cockcroft, J. D., 'Skin effect in rectangular conductors at high frequency', *Proc. R. Soc.*, **122**, No. A790, pp. 533–42, February 1929.
8. Corkhill, J. R. and Mullins, D. R., 'The properties of thick film inductors', *Electronic Components*, **10**, No. 5, p. 593, May 1969.
9. Dukes, J. M. C., 'Printed Circuits, Their Design and Application', pp. 120–135 (Macdonald, London, 1961).

Manuscript first received by the Institution on 1st June 1973 and in final form on 21st March 1974. (Paper No. 1599/CC208.)

UDC 681.327.8:621.396.7

Digital transmission codes: properties of HDB3 and related ternary codes with reference to broadcast signal distribution

T. A. MOORE, B.E., M.Eng.Sc.*

SUMMARY

An investigation has been carried out to assess the implications for broadcast signal distribution of the use of HDB3 as the proposed customer interface code in the Post Office digital communication network. HDB3 is a three-level transmission code with no d.c. component and with a bound on the maximum number of successive equilevel symbols. These two characteristics are important since a.c. coupling may then be employed in the transmission path and virtually continuous timing information can be extracted from the coded signal.

The properties of related transmission codes, including the class of alphabetic (or block) codes were also investigated, in view of the likely adoption of one of these (4B 3T) by the Post Office as a line transmission code at the higher bit rates.

The effect of transmission-code digit errors on the decoded binary sequence was studied and suitable error correction schemes are outlined. An experimental HDB3 codec was constructed, primarily to demonstrate the feasibility of such transcoding at bit rates up to the order of 120 Mb/s, using commercially available integrated circuits.

* *British Broadcasting Corporation, Research Department, Kingswood Warren, Tadworth, Surrey.*

1 Introduction

A digital transmission code converts a source signal (usually binary) into a form more suitable for transmission over conventional links. As such, it generally has a small low-frequency content with a null at zero frequency (or d.c.), thereby permitting a.c. coupling in the link; the code also ensures that level transitions are never absent for more than a short period in order to facilitate the regeneration of the timing waveform at each repeater in the link.

In the proposed Post Office digital communications network a customer interface code will carry the signal from the source to the multiplexer and again from the demultiplexer to the receiver; a different code, the line code, will be used for long-distance transmission and is intended to operate at a 120–140 Mb/s bit rate.

HDB3, which has achieved wide acceptance in Europe as a transmission code, is proposed for use as the customer interface code; there is less certainty regarding the choice of line code for trunk routes, but this may be 4B 3T. Both these codes, and the related codes discussed here are ternary (i.e. three-level), d.c.-free, and maintain a bound on the maximum number of successive symbols of the same level.

This paper assesses the implications of using these codes, in particular for broadcast signal distribution. Their spectra are described, as is the susceptibility of the decoded binary signals to transmission errors. Since the customer will be expected to provide the digital signals to the network in interface code form, one possible design of an HDB3 codec is given in Section 7.

2 Digital Transmission Code Requirements

The desirable properties for a digital transmission code may be summarized as follows:

(i) Spectrum: The spectrum of the coded signal should have a null at zero frequency to avoid the need for d.c. coupling at any point in the transmission path.

(ii) Power content: To minimize power feeding requirements the total signal power should be as low as possible for a given peak-to-peak signal swing.

(iii) Timing information: In order that virtually continuous timing information be included in the transmitted signal, the maximum number of successive symbols of the same level should be restricted.

(iv) Bit-sequence independence: The transmission code should be able to accept any binary sequence as the input.

(v) Symbol rate: The transmission symbol rate must be low enough to allow the signal to be transmitted within the available bandwidth; on the other hand the number of code levels should be low enough to provide an acceptable error performance in a given noise environment.

(vi) Error extension: For the purposes of this paper this is defined as the mean number of errors in the decoded binary sequence per transmission error; this quantity should be as low as possible. (When the symbol rate differs in the transmitted and binary streams the ratio of symbol error rates will be the product of the error extension and the symbol frequency ratio.)

(vii) Error monitoring: Some form of in-service error-monitoring facility is desirable in a transmission code.

(viii) Framing: In block codes the relative position of a symbol within a block must be known; hence block synchronization must be maintained at the decoder. In addition, since the detection of framing loss is generally accomplished by monitoring the occurrence of certain illegal symbol combinations, it is important to ensure that the block synchronizer is not easily 'fooled' by errors in transmission.

(ix) Instrumentation: The design of the encoder, decoder and error monitor associated with a given code should be realizable without undue difficulty using commercially-available devices.

3 Description of Transmission Codes for Broadcast-Signal Distribution

3.1 Code Types

The transmission codes under consideration for reasons given in Section 1 may be divided into two classes, referred to as high density bipolar and alphabetic, or block, codes. The three levels of the ternary transmitted signal are denoted as +, 0 and −.

3.2 High-density Bipolar Codes

In a bipolar signal a binary zero is coded as 0, and a binary one alternately as + or −; this alternate mark inversion (a.m.i.) process ensures that no d.c. component exists in the signal. To obtain a higher timing content the bipolar signal may be modified to a high-density bipolar signal by replacing long strings of zeros in the encoded signal with filling sequences whose presences are indicated by the inclusion of marks disobeying the a.m.i. rule (referred to as violations). Among such codes are HDB*n*, where $n = 2, 3\ldots$ and refers to the permitted maximum number of successive zeros. A variant of HDB*n* is CHDB*n*; C stands for compatible, since it is possible with this class of codes to design a decoder which is independent of *n*. Finally, the code B6ZS proposed in the USA[1] also belongs to the class of high-density bipolar codes.

Denoting a bipolar mark obeying the a.m.i. rule (i.e. of opposite polarity to the previously transmitted mark) as B, and a violation (i.e. of the same polarity as the previously transmitted mark) as V, then the rules for encoding into HDB*n* may be summarized as follows:

(i) A binary one is coded as B

(ii) A binary zero in a block of *n* or less zeros is coded as 0.

(iii) A sequence of $(n+1)$ zeros in the binary signal is coded into one of the following $(n+1)$-long filling sequences

(a) B0...0V

or (b) 00...0V, where

(iv) the choice of filling sequence (a) or (b) is determined by the stipulation that successive violations, V, be of alternate polarity.

(v) A long sequence of binary zeros is broken up into blocks of $(n+1)$ zeros, starting from the beginning. These blocks are treated by rules (iii) and (iv), the 'remainder' of *n* or less zeros being treated by rule (ii).

In filling sequence (a) above, V is the same polarity as B; thus there are only four possible filling sequences determined as follows:

Previous mark (B or V)	Previous violation (V)	Filling sequence
+	+	−0...0−
−	+	00...0−
+	−	00...0+
−	−	+0...0+

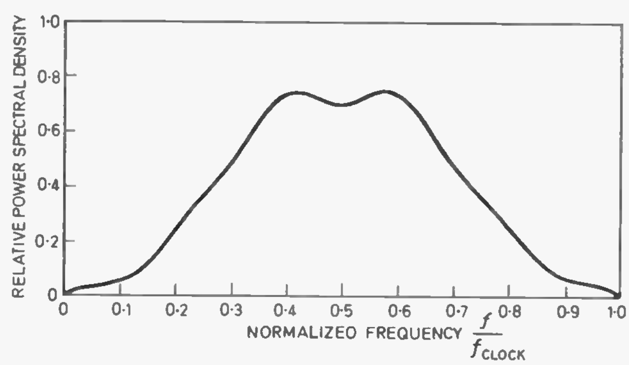


Fig. 1. HDB3 power spectrum.

Table 1

4B 3T code book

4-bit binary word	Running digital sum 1, 2, 3		Running digital sum 4, 5, 6
0 0 0 0	+ + +		− − −
0 0 0 1		0 + −	
0 0 1 0		− 0 +	
0 0 1 1		+ − 0	
0 1 0 0		0 − +	
0 1 0 1		+ 0 −	
0 1 1 0		− + 0	
0 1 1 1	+ 0 0		− 0 0
1 0 0 0	0 + 0		0 − 0
1 0 0 1	0 0 +		0 0 −
1 0 1 0	+ + −		− − +
1 0 1 1	− + +		+ − −
1 1 0 0	+ − +		− + −
1 1 0 1	+ + 0		− − 0
1 1 1 0	0 + +		0 − −
1 1 1 1	+ 0 +		− 0 −

The following example with $n = 3$ illustrates the procedure:

Binary	1 1 0 0	0 0 0 1	0 0 1 0	0 0 0 1	1 1 1 1	0 0 0 0	0 0 0 0	1 0 1 1	0 0 0 1
Bipolar	+ − 0 0	0 0 0 +	0 0 − 0	0 0 0 +	− + − +	0 0 0 0	0 0 0 0	− 0 + −	0 0 0 +
HDB3	+ − 0 0	0 − 0 +	0 0 − +	0 0 + −	+ − + −	0 0 0 −	+ 0 0 +	− 0 + −	0 0 0 +

The example given above in the lower line illustrates, for $n = 3$, that the HDBn sequence contains at most n successive zeros and that two adjacent marks are never of the same polarity.

With CHDBn the filling sequence of $(n+1)$ symbols is of the form

00. . .000V or

00. . .0B0V

With B6ZS, 6 successive zeros are replaced by the sequence 0VB 0VB.

The symbol rate of these modified bipolar coded signals is equal to the bit rate of the incoming binary signal.

With decreasing n, the timing content of the HDBn and CHDBn signals increases, as does the average power. Because of the additional storage required, instrumental complexity for coding and decoding increases as n is increased. HDBn codes are slightly less complex than CHDBn to instrument. Because it has only two possible filling sequences (compared to four in the cases of HDBn and CHDBn), B6ZS is easier to instrument than the comparable HDB5 or CHDB5 codes.

3.3 Alphabetic Codes

With alphabetic codes the incoming binary signal is divided into blocks of a certain length, and to each binary block there is assigned a block of ternary symbols. In general, the transmission symbol rate will differ from source bit-rate; it is, of course, essential at the receiver to frame the ternary blocks correctly. The choice of ternary block transmitted is dependent on the running digital sum (or digital integral) of the coded signal. A transmission null at d.c. is achieved since the code tends to choose a ternary word in such a way as to reduce the running digital sum if it exceeds some set value or to increase it if not; thus the time integral is caused to vary within a fixed range about this set value.

Table 2

MS 43 code book

4-bit binary word	Running digital sum 1		2, 3		4
0 0 0 0	+ + +			− + −	
0 0 0 1	+ + 0			0 0 −	
0 0 1 0	+ 0 +			0 − 0	
0 1 0 0	0 + +			− 0 0	
1 0 0 0		+ − +			− − −
0 0 1 1			0 − +		
0 1 0 1			− 0 +		
1 0 0 1		0 0 +			− − 0
1 0 1 0		0 + 0			− 0 −
1 1 0 0		+ 0 0			0 − −
0 1 1 0			− + 0		
1 1 1 0			+ − 0		
1 1 0 1			+ 0 −		
1 0 1 1			0 + −		
0 1 1 1		− + +			− − +
1 1 1 1	+ + −			+ − −	

The simplest alphabetic code is pair-selected ternary in which both the binary and ternary words are 2 digits long.[2] In general, however, because of the number of ternary combinations available, the ternary symbol rate can be less than the source bit-rate. Two codes,[3,4] which convert blocks of 4 binary digits into blocks of 3 ternary symbols are 4B 3T and MS 43: they are described by their code books shown in Tables 1 and 2. These codes are attractive from bandwidth considerations since their symbol rate is three-quarters that of a comparable bipolar signal.

Timing information may be extracted from the encoded signal since the maximum number of successive symbols of the same level is a fixed number when alphabetic codes are used; this equals 6 and 5 in the cases of 4B 3T and MS 43 respectively. The block framing may be checked and corrected because, in the preferred codes, loss of block synchronization gives rise to occasional inadmissable ternary combinations (such as 000 in the case of 4B 3T).

4 HDB3 Properties

4.1 Spectrum

The power spectrum of an HDB3 signal is roughly similar to that of a bipolar signal which, for a random symmetric binary source,† is sinusoidal, peaking at half symbol rate and with spectral nulls at d.c. and symbol rate. Calculation of the spectral density of a code may be carried out by treating the coded sequence as a Markov process[5] and by suitable manipulation of the transition probability matrix.[6] Figure 1 shows the computed spectral density under conditions of a random symmetric binary input; the pulses in the encoded sequence are assumed to be much narrower than the clock period

† A random symmetric source is one in which the probability of a binary 1 or 0 at any time instant is independent of the previous transmitted sequence; in addition a 1 or 0 is equally likely.

(so that mathematically they are taken to be Dirac delta functions).†

The power content of an HDB3 signal is 11% greater than that of a comparable bipolar signal, and arises because of the injection of filling sequences where the bipolar signal contains long strings of spaces.

4.2 Error Performance

We now consider the susceptibility of the decoded binary signal to HDB3 transmission errors.

Assuming the simplest form of decoder (in which each violation and the third previous symbol in the received sequence are set to zero), a single transmission error can cause up to three errors in the decoded binary sequence. For example, the sequence 1101, coded as + −0+ would become +00+ if the second symbol were in error, and would then be decoded as 0000, introducing three errors. Appendix 1 gives details of the effects of various transmission errors on the binary decoded signal. It may be seen that an isolated transmission error can cause (depending on the encoded signal) 0, 1, 2 or 3 errors in the decoded signal. These errors are, however, localized within a block of five symbols; two errors, spaced four clock periods apart are possible, as are three errors in a block of four consecutive bits.

For the decoding technique outlined above, CEPT‡ studies have shown that the error extension (as defined in Section 2) would lie in the range 1·7 to 2·0 and that the adoption of a different decoding strategy (detecting the triplet 00V and setting V, together with the third previous symbol, to zero) would reduce the extension to the range 1·3 to 1·7.

Error monitoring is possible by detecting whether successive violations in the received signal alternate in polarity; two successive violations of the same polarity imply an error on transmission. It is therefore possible to detect the occurrence of an error between two deliberate (i.e. encoded) violations in the transmitted signal; for a random symmetric input binary source these occur on average once every thirty symbols.

5 Properties of Other Codes

5.1 Spectra

As n is increased, the spectral properties of the HDBn and CHDBn modified codes approach those of a pure bipolar code; B6ZS has slightly more energy at half symbol rate.[1]

Because of the small range to which the running digital sum is confined in the case of the alphabetic codes under consideration, transmission nulls exist at d.c. (and at clock frequency). For the alphabets shown in Tables 1 and 2,§ the spectra (assuming a random symmetric binary input) of 4B 3T and MS 43 are shown in Fig. 2. The spectra were computed as described in Section 4.1 for HDB3.

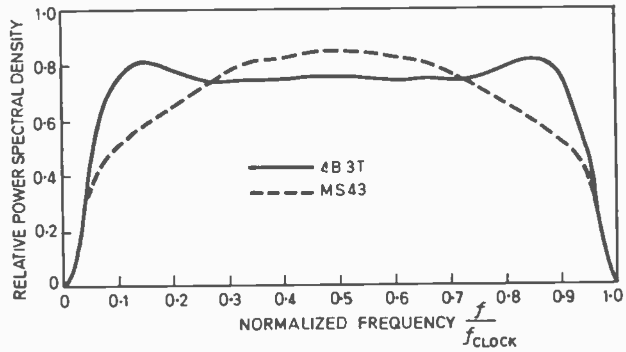


Fig. 2. 4B 3T and MS43 power spectra.

5.2 Error Performance of Alphabetic Codes

The error performance of a block code is dependent on the choice of alphabet; the error extension is equal to the average distance (in the Hamming[8] sense) between the binary words corresponding to the transmitted sequence, and the decoded sequence in error. Since decoding is by means of a 'look-up' table, a single transmission symbol error does not effect more than a single binary word (corresponding to the ternary word affected by the transmission error).‖ It is expected that the error extension could be kept below half the binary word length (the value achieved for a random alphabet allocation).

Error monitoring for alphabetic coding can be of a relatively crude form; an error is presumed to have occurred if, at the decoder input, the running digital integral leaves its allowable range. However, a more elaborate form of error monitoring, involving re-encoding at the decoder and comparing the re-encoded and received signals, is also possible; since this would detect an anomalous choice of alternative ternary blocks it would respond to a greater proportion of errors as soon as they occur, and may therefore be preferred.

A complication can arise with alphabetic codes since transmission errors can cause a spurious detection of loss of word synchronization. (Loss of synchronizing is detected by the occurrence of 'illegal' ternary word combinations, such as 000 in the case of 4B 3T). In addition, loss of word synchronization can cause the error monitor to register falsely. Distinguishing between loss of synchronizing and a high transmission error rate is generally not easy at the decoder.

† For pulses which are mathematically Dirac delta functions, the spectrum is periodic in frequency (with period equal to the clock frequency); this periodic continuation is not shown in the diagrams. The power spectral density of the transmitted signal depends upon the selected pulse shape; it may be computed by multiplying together the power spectral density using Dirac delta functions (given above) and that of the selected pulse shape.

‡ CEPT—Council of European Postal and Telecommunication Administrations—is an international organization for co-operation between European Postal and Telecommunication Authorities.

§ For a random symmetric binary input the spectra are, in fact, independent of the first columns of Tables 1 and 2, i.e. of which binary 4-bit words are assigned to the various blocks. It may be noted that all ternary combinations (except 000) are used.

‖ It has been estimated that the use of a scrambler to reduce word-patterning effects under conditions of a steady input signal would increase the spread of errors in the decoded binary signal caused by isolated transmission errors.

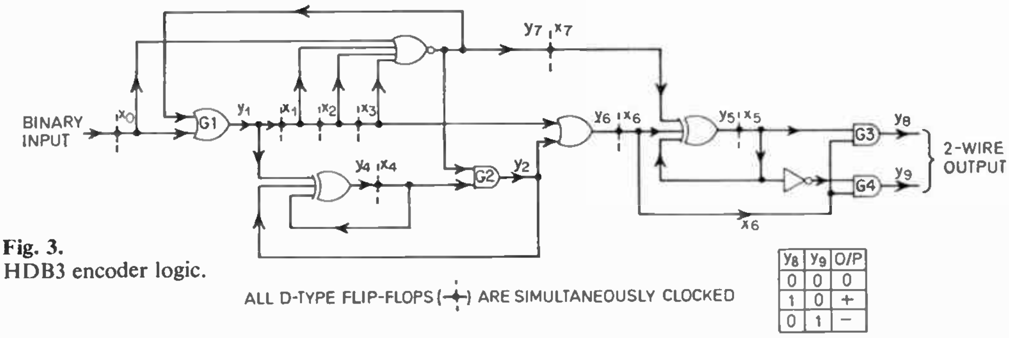


Fig. 3.
HDB3 encoder logic.

6 Error Correction

With the HDB3 code, an isolated transmission error can cause a number of errors in the decoded binary signal, as described in Section 4.2, separated by at most four clock periods; with 4B 3T and MS 43 codes the errors in the decoded signal caused by a single transmission error are, by the nature of the codes, confined to a block of four bits. The similarity of short burst errors in binary code to the errors caused by isolated transmission errors suggests that methods employed for burst error correction would also be suitable for dealing with the effect of (isolated) transmission code errors. In particular, any error correcting code designed to correct bursts of up to 5 or more (4 in the case of 4B 3T and MS 43) would be suitable for dealing with the effects of isolated errors on transmission.†

7 HDB3 Codec Design

This Section gives details of a design for a HDB3 encoder and a HDB3 receiver, incorporating a decoder and error monitor. The codec logic functions are first outlined; the design of the instrumentation to realize the logic is then given.

7.1 Encoder Logic

An HDB3 encoder must:

(i) detect when four 0's are about to be transmitted and insert a mark at the end of the 4-long sequence;

(ii) determine whether a 'filler' (the bipolar mark at the beginning of a filling sequence) should be inserted;

(iii) determine the sign of each transmitted mark.

Using the notation of Fig. 3, if a row of four 0's in the output sequence (x_0, x_1, x_2, x_3) is detected a mark (violation) is inserted by means of y_7 through gate G1, this is done three clock periods later. The signal x_4 decides whether a filler is inserted, and is gated through G2 by y_7 (the four-zero detector). y_6 (or x_6) then determines whether a mark or space is to be transmitted; x_5 determines the sign of the transmitted marks and changes at every bipolar mark (B). The encoder output is specified by the signals y_8 and y_9 as follows:

y_8	y_9	Output
0	0	0
1	0	+
0	1	−

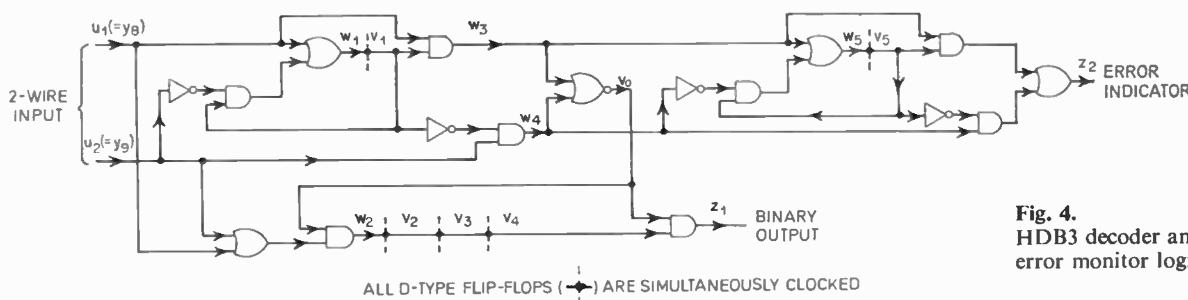


Fig. 4.
HDB3 decoder and error monitor logic.

7.2 Receiver Logic

A HBD3 decoder detects a violation in the incoming sequence by comparing the signs of successive marks, and changes the violation to a zero and also causes the third previous symbol to be zero. An error monitor operates by comparing the signs of successive violations; if they are equal it indicates a transmission error.

Referring to Fig. 4, v_1 stores the sign of the previously received mark ($v_1 = 1$ for +, 0 for −). Hence $w_3 = 1$ for a + violation, $w_4 = 1$ for a − violation and $v_0 = 0$ if any violation occurs. v_5 stores the sign of the previous violation and z_2 is a logical 1 if two successive violations are of equal polarity.

† If it is required to correct for errors caused to the line-coded signal, it is not necessary to employ burst-error correction methods to the lower order bit-rate signals. Since bit interleaving is employed in the multiplexers, a short burst-type error in the decoded line signal is converted, by the demultiplex action, into a number of single errors in some of the channels which comprise the line signal.

7.3 Logic Design Details

The design philosophy entails synthesizing explicitly only those variables used as the inputs to flip-flops. To obtain maximum clock rate, a given signal is allowed to pass through at most one gate between the output of one register and the input to another; this minimizes the signal propagation time. The availability of complex function gates in emitter-coupled logic allows the synthesis of each variable as a (Boolean) product of sums. Moreover, each flip-flop has a logical complement output available, obviating the need for inverters in the circuits.

The following functions were synthesized:

$$\bar{y}_1 = (x_1+x_2+x_3).\bar{x}_0$$

$$\bar{y}_4 = (x_0+x_1+x_2+x_3).(x_0+\bar{x}_4).(\bar{x}_0+x_4)$$

$$\bar{y}_5 = (\bar{x}_7+\bar{x}_5+\bar{x}_6).(\bar{x}_7+x_5+x_6).$$
$$.(x_7+\bar{x}_5+x_6).(x_7+x_5+\bar{x}_6)$$

$$\bar{y}_6 = (x_0+x_1+x_2+\bar{x}_4).\bar{x}_3$$

$$\bar{y}_7 = x_0+x_1+x_2+x_3$$

$$\bar{y}_8 = \bar{x}_6+\bar{x}_5$$

$$\bar{y}_9 = \bar{x}_6+x_5$$

$$\bar{w}_1 = \bar{u}_1.(u_2+\bar{v}_1)$$

$$\bar{w}_2 = (\bar{u}_1+u_2+v_1).(u_1+\bar{u}_2+\bar{v}_1)$$

$$\bar{w}_5 = (\bar{u}_1+\bar{v}_1).(u_2+\bar{v}_5).(\bar{v}_1+\bar{v}_5)$$

$$z_1 = v_4.(\bar{u}_1+\bar{v}_1).(\bar{u}_2+\bar{v}_1)$$

$$\bar{z}_2 = (v_5+v_1+\bar{u}_2).(\bar{v}_5+\bar{v}_1+\bar{u}_1)$$

The registers forming x_7 and x_6 (from y_7 and y_6) in the encoder are instrumentally necessary to avoid the signal $x_3 \rightarrow y_7 \rightarrow y_5$ passing through two gates in succession.

The three-level coded signal output is obtained by an analogue subtraction of the signal y_9 and y_8; similarly at the receiver input u_1 and u_2 are obtained by level-detecting the incoming (coded) signal.

7.4 Instrumentation

An experimental HDB3 encoder and decoder (including provision for error monitoring) were constructed with emitter-coupled logic devices (using a family with a 2 ns propagation delay). Satisfactory operation was achieved at clock rates of up to 120 MHz; no insuperable instrumental problems should arise in the construction of a model for operational service.

8 Conclusions

The investigation described in this report was carried out to assess the likely effect on broadcast signal distribution of the choice of HDB3 as the interface code, and the probable choice of 4B 3T as the line code in the proposed Post Office digital signal network.

The nature of the code is such that isolated transmission errors give rise to short burst errors in the decoded binary signal. This suggests the use of burst-error-correction techniques when the HDB3 signal is subject to an error-rate above the acceptable level without correction. However, it is likely that, as the interface code will be used only for relatively short-distance transmission on coaxial cables, the error rate will be low enough on circuits using HDB3 alone to give an acceptable error performance without advanced error protection techniques.

Similarly with alphabetic codes, isolated transmission errors again give rise to short bursts of errors in the decoded signal, provided that the signal is transmitted as encoded (that is, not 'scrambled'); this implies that, for error correction purposes, a system capable of dealing with bursts of up to 4 or more errors would be suitable. Many such methods have been proposed, and in general it is possible to convert any single error-correcting code to a burst error-correcting code by a process of interleaving.

Although attractive as a transmission code from bandwidth considerations, an alphabetic code such as 4B 3T suffers from the disadvantages (compared to bipolar and its derivations) that word synchronization must be maintained at the receiver and that no simple form of reliable error monitoring is possible; in addition, it could be difficult to distinguish between the effects of synchronizing loss and errors incurred on transmission. It is hoped that practical experience will be gained from a proposed Post Office experimental high-bit-rate link in the South of England in 1975.

Finally, the paper gives a design of a HDB3 codec, which gave satisfactory operation at clock rates of up to 120 MHz.

9 Acknowledgments

The author wishes to thank Mr. Uphill of the Post Office Research Department and Messrs. Schickner and Zick of the Post Office Telecommunications Development Department with whom helpful discussions have been held.

The author is indebted to the Director of Engineering of the BBC for permission to publish this paper.

10 References

1. Croisier, A., 'Compatible high-density bipolar codes: an unrestricted transmission plan for p.c.m. carriers', *IEEE Trans. on Communication Technology*, **COM-18**, pp. 265–8, June 1970.
2. Sipress, J. M., 'A new class of selected ternary pulse transmission plans for digital transmission lines', *IEEE Trans.*, **COM-13**, pp. 366–72, September 1965.
3. Jessop, A., 'High capacity p.c.m. multiplexing and code translation', IEE Colloquium on P.C.M., Paper No. 14, IEE Colloquium Digest 1968/7.
4. Franaszek, P. A., 'Sequence-state coding for digital transmission', *Bell Syst. Tech. J.*, **47**, pp. 143–57, January 1968.
5. Balakrishnan, A. V., 'Communication Theory', Chapter 2, (McGraw-Hill, New York, 1968).
6. Yasuda, H. and Inose, H., 'Direct calculation method for power spectra of pulse sequences by means of transition probability matrices', *Electronics and Communications in Japan*, **53-A**, No. 11, pp. 366–72, 1970.
7. Croisier, A., 'Introduction to pseudo-ternary transmission codes', *IBM J. Res. Dev.*, **14**, pp. 354–67, April 1970.
8. Hamming, R. W., 'Error detecting and error correcting codes', *Bell Syst. Tech. J.*, **29**, pp. 147–60, February 1950.

11 Appendix

Effect of HDB3 transmission errors on the decoded signal

The following Table details the effect of various transmission errors on the decoded binary sequence, for a wide range of input signals. The simplest form of decoder is assumed, in which any mark disobeying the alternate-mark-inversion rule is set to zero, together with the third previous symbol. An asterisk (*) denotes which encoded symbol is affected by a transmission error, *1* or *0* denote an error in the decoded binary sequence. Errors involving two-level transitions (+ to −, − to +) are not considered; they are generally much less frequent than errors involving single-level transitions.

The previous bipolar mark, and the previous violation are both assumed to have been negative (−).

Encoded signal	Received signal	Decoded Signal	Note
+−+*00+	+−000+	11000*1*	3
+−+0*0+	+−+−0+	11*1*10*1*	5, 1, 3
+−+0*0+	+−++0+	*0*10000	8, 6
+−+00+*	+−+000	11*1*000	9, 5
+−+−*+00+	+−+0+00+	1*0*1*00*000	2, 7, 6
−+*000+	−0000+	*00001*	2, 3
+0*00+	+−00+	1*1*00*1*	1, 3
+00*0+	+0−0+	10*1*0*1*	1, 3
+000*+	+00−+	100*11*	1, 3
+000*+	+00++	*00000*	8, 6
+000+*	+0000	10000	9
+−+*00−	+−000−	11*0000*	2, 4
+−+*000−	+−0000−	11*00000*	2, 4
+−+0*0−	+−+−0−	11*0100*	1, 4, 6
+−+0*0−	+−++0−	*0*11001	8, 6
+0−+0*−	+0−++−	101101	8, 6
+−*0+	+00+	*0000*	2, 4, 6

Notes

1. A space is changed to a bipolar mark.
2. A bipolar mark is changed to a space.
3. A mark which was a violation is interpreted as a bipolar (alternate mark inversion, a.m.i.) mark.
4. A bipolar (a.m.i.) mark is interpreted as a violation.
5. A bipolar mark in a filling sequence is interpreted as an (ordinary) bipolar mark.
6. The third previous symbol to a wrongly-interpreted violation is set to zero.
7. A bipolar mark in a filling sequence is interpreted as a violation.
8. A space is changed to a mark disobeying the a.m.i. rule, and interpreted as a violation.
9. A violation is changed to a space.

Manuscript received by the Institution on 28th November 1973. (Paper No. 1600/Com 96).

INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

Notice of Annual General Meeting

NOTICE IS HEREBY GIVEN that the THIRTEENTH ANNUAL GENERAL MEETING of the Institution since Incorporation by Royal Charter will be held on THURSDAY, 3rd OCTOBER, 1974, at 6 p.m. at the Institution of Electronic and Radio Engineers, 8–9 Bedford Square, London, W.C.1.

AGENDA

1. To receive the Minutes of the Twelfth Annual General Meeting of the Institution since Incorporation by Royal Charter held on 25th October 1973 (Reported on pages 757–761 of the December 1973 issue of *The Radio and Electronic Engineer*.)
2. To receive the Annual Report of the Council for the year ended 31st March 1974. (Published in this issue of *The Radio and Electronic Engineer*, pp. 431–448.)
3. To receive the Auditor's Report, Accounts and Balance Sheet for the year ended 31st March 1974. (Published in this issue of *The Radio and Electronic Engineer*, pp. 441–442.)
4. To confirm the election of the Council for 1974–5.

   In accordance with Bye-Law 49 the Council's nominations were sent to Corporate members by a Notice dated 28th June 1974 included with the June 1974 issue of *The Radio and Electronic Engineer*. As no other nominations have been received under Bye-Law 50, a ballot will not be necessary and the following will be elected:—

The President

For Re-election: I. Maddock, C.B., O.B.E., D.SC., F.R.S.

The Vice-Presidents

Under Bye-Law 46, all Vice-Presidents retire each year but may be re-elected provided they do not thereby serve for more than three years in succession.

For Re-election:

P. A. Allaway, C.B.E., D.TECH.; Professor W. Gosling, A.R.C.S., B.SC; A. St. Johnston, B.SC.

For Election:

H.R.H. The Duke of Kent, G.C.M.G., G.C.V.O.; Professor W. A. Gambling, PH.D., D.SC.

The Honorary Treasurer

S. R. Wilkins

Ordinary Members of Council

Under Bye-Law 48, Ordinary Members of Council are elected for three years and may not hold that office for more than three years in succession.

FELLOWS

For Election to fill the sole vacancy:

Professor D. E. N. Davies, D.SC., PH.D.

MEMBERS

For Election to fill the sole vacancy:

M. S. Birkin

The remaining members of Council will continue to serve in accordance with the period of office laid down in Bye-Law 48.

5. To appoint Auditors and to determine their remuneration. (Council recommends the re-appointment of Gladstone, Jenkins & Co., 42 Bedford Avenue, London, W.C.1.)
6. To appoint Solicitors. (Council recommends the re-appointment of Braund and Hill, 6 Gray's Inn Square, London, W.C.1.)
7. Awards to Premium Winners.
8. Any other business. (*Notice of any other business must have reached the Secretary not less than forty-two days prior to the meeting.*)

By Order of the Council.

30th August 1974

GRAHAM D. CLIFFORD, *Secretary.*

(*This notice has already been sent to all Corporate Members in the U.K.*)

NOMINATIONS FOR ELECTION TO COUNCIL

Brief Biographical Notes

In accordance with Bye-Law 43 the Council's nominations for election to the 1974-75Council were notified to Corporate Members in the June issue of the Institution's Journal.

FOR RE-ELECTION AS PRESIDENT OF THE INSTITUTION

Ieuan Maddock, C.B., O.B.E., D.Sc., F.R.S. (Fellow 1955, Member 1943) is Chief Scientist in the Department of Industry, a position he has held since 1971. Before moving to the then Ministry of Technology in 1965, where he was latterly Controller, Industrial Technology, he had been associated with the British nuclear weapons project since its inception. Dr. Maddock is a graduate of the University of Wales and in 1970 he was awarded an Honorary Doctorate of Science by the University; in 1967 he was elected to Fellowship of the Royal Society.

Dr. Maddock was elected a member of Council in 1960 and served terms of office as a Vice-President from 1963–1966 and from 1969–1972. (See also Journal for August 1973.)

FOR RE-ELECTION AS VICE-PRESIDENTS OF THE INSTITUTION

Percy Albert Allaway, C.B.E., D.Tech. (Fellow 1971) is Chairman of EMI Electronics Ltd. and is Chairman or a member of the Board of numerous associated and subsidiary companies. He serves on various industrial and government committees, including the National Electronics Council on which he represents the Conference of the Electronics Industry. Dr. Allaway was first elected to the Council of the Institution in 1972 and he was elected Vice-President in 1973.

Professor William Gosling, B.Sc. (Fellow 1968) was appointed to the newly-founded Chair of Electronic Engineering at Bath University of Technology in January of this year. He was previously at the University College of Swansea for some 16 years and had been Professor of Electronic Engineering since 1960. He is Chairman of the Professional Activities Committee and was elected a member of the Council in 1970. He became a Vice-President in 1972.

Andrew St. Johnston, B.Sc. (Fellow 1960) is a Director of Vaughan Programming Services and has been concerned with the development and applications of electronic digital computers since 1949 when he joined Elliott Brothers Ltd. Mr. St. Johnston was a member of the Council from 1963–1965 and has served as Vice-President in 1967–1970 and since 1972. For the past three years he has been a member of the Professional Activities Committee.

(For fuller biographies of these Vice-Presidents please refer to the Journal for September 1972.)

FOR ELECTION AS VICE-PRESIDENTS

Professor Alec Gambling (Fellow 1964, Member 1968) has held the Chair in Electronics at the University of Southampton since 1964. He is at present Dean of the Faculty of Engineering and Applied Science. Professor Gambling graduated in Electrical Engineering from the University of Bristol; his Ph.D. was awarded by the University of Liverpool and his D.Sc. by the University of Bristol. Before going to Southampton, Professor Gambling was lecturer at the University of Liverpool and he also spent two years as a postdoctoral research fellow at the University of British Columbia. He has also held appointments as visiting professor at the Bhabha Atomic Research Centre, Bombay, and at the University of Colorado.

He has taken an active part in Institution affairs, serving as Chairman of the Southern Section Committee and an Ordinary Member of the Council; he was a Vice-President from 1970–1973 and he has now been nominated for election to this office for a further period.

Professor Gambling has contributed numerous original papers and reviews to the technical literature on a wide range of subjects, his main research interests being in microwaves, lasers and, more recently, optical-fibre communications.

H.R.H. The Duke of Kent, G.C.M.G., G.C.V.O. (Fellow 1973, Companion 1972) was educated at Eton and Le Rosey, Switzerland, and entered the Royal Military Academy in 1953. He was commissioned as a Second Lieutenant in the Royal Scots Greys in 1955, promoted to Lieutenant in 1957, Captain in 1960, and Major in 1967. He has wide interests at home and overseas and is at present serving in the Ministry of Defence Procurement Executive. His Royal Highness is Deputy Chairman of the National Electronics Council.

P. A. Allaway

W. Gosling

A. St. Johnston

W. A. Gambling

H.R.H. The Duke of Kent

S. R. Wilkins

D. E. N. Davies

M. S. Birkin

FOR RE-ELECTION AS HONORARY TREASURER

Sydney Rutherford Wilkins (Fellow 1942, Member 1935, Associate 1934) has been Managing Director of Fleming Instruments Ltd. since 1970; he was previously with Avo Ltd. for 35 years. A member of the Council since 1968, Mr. Wilkins was appointed a Vice-President in 1972, and he was first elected Honorary Treasurer last year. (A fuller note on his professional career was published in the Journal for September 1972.)

FOR ELECTION AS ORDINARY MEMBERS OF COUNCIL

From the Class of Fellows

Professor David Evan Naunton Davies, M.Sc., Ph.D., D.Sc. (Fellow 1974, Member 1962) has occupied a Chair of Electrical Engineering at University College since 1971. A graduate of the University of Birmingham, he held lectureships there from 1961–1967 when he was appointed Assistant Director of Electrical Research at the Railway Technical Centre of the British Railways Board at Derby. While he was at Birmingham, Professor Davies held an honorary appointment as a Senior Principal Scientific Officer at the Royal Radar Establishment and while at Derby he was Industrial Professor of Electrical Engineering at the University of Technology, Loughborough. Professor Davies has contributed numerous papers to the Journal and other technical and scientific publications on a variety of subjects, notably on aerial arrays and signal processing. He has been actively concerned with the Institution's learned society activities as a member of conference organizing committees and on group committees; he was elected to Council as a Member in 1972, on which occasion a fuller biography was published (September 1972 Journal).

From the Class of Members

Michael Sambrook Birkin (Member 1963) is head of the Automation Section at the Railway Technical Centre of British Railways Board at Derby where he is responsible for research and development into train control systems for new rail projects. Educated at the then Royal Technical College, Salford, he served a student apprenticeship with Metropolitan-Vickers Ltd., Manchester, and after holding posts with various industrial companies he joined the Railway Technical Centre in 1967. He has been a member of the Automation and Control Group Committee for the past four years and he also served on the Control and Automation Divisional Board of the IEE.

The 48th Annual Report of the Council of the Institution

For the year ending 31st March, 1974

The Council has much pleasure in presenting the 48th Annual Report of the Institution —the 13th since Incorporation by Royal Charter. The Annual General Meeting will be held on Thursday, 3rd October, 1974 in the Institution's Lecture Room, 9 Bedford Square, London, W.C.1, commencing at 6 p.m.

INTRODUCTION

FOR over thirty years the Institution's Annual Report has been presented in the same style. From its acceptance it appears to meet the demands of members to be kept fully informed about the Institution's work.

There is inter-dependence in every phase of activity but each member probably has a greater interest in some sections than others; this preference can lead to constructive comment and often participation in the work of one or the other of the Committees without whose industry there would not be a Report! As with membership of the Council, there are regular changes in the membership of Committees so that the Institution is a self-regulating society—only members may decide its policy and work load. The success of this arrangement has been proved by the achievements of Councils and Committees who served the Institution in the past and this Annual Report is an account of the present stewardship.

There have been failures or delays in securing desirable objectives. For many members there is disappointment that the place of the professional engineer in society is not properly understood. This is not self-vanity or a quibble about any precedence in society for we are all inter-dependent. More than ever the world depends on technology and the assurance of reliability that only comes from engineers having a deep sense of responsibility. Acknowledgment of that responsibility gives encouragement at all levels and not least in attracting the recruits that are so sorely needed.

All this highlights the fact that the profession of engineering is only faintly understood by the public, for the mechanic and technician are also, in the modern idiom, described as 'engineers'. By collectively establishing a register of Chartered Engineers the Institutions took the first positive step in publicly defining the training and experience demanded of a truly professional engineer. This last year has also seen acknowledgment by the chartered engineer of the importance of giving recognition to trained technicians and mechanics by extending the Engineers Registration Board. All the work involved is one of the important reasons why the Institutions should have a federal association—The Council of Engineering Institutions.

The continued growth of the IERE not only adds strength to its support of the registration scheme; it also enables the Institution to extend its learned society activities so as to mirror the important role which radio and electronics has in the engineering profession. There is something, therefore, for every member in this Report and as the Institution continues to grow so will there be further opportunities for members to serve themselves and each other in the expansion of the Institution's work.

Between them the Council and the Standing Committees held 86 meetings in Great Britain during the year ended 31st March 1974. At these meetings reports from Committees and representatives who serve the Institution in other countries were also considered.

For ease of reference this 48th Annual Report is mainly presented according to the work of the Standing Committees.

Forty-five items which required decisions or recommendations on policy were dealt with by the Committee during the year; they included such diverse subjects as improving public recognition of the professional engineer; changing attitudes in industrial relations; promoting acceptance of British qualifications in the European Economic Community and elsewhere abroad; the formation of new Specialized Groups to meet the needs of IERE members; commercial exhibitions; future policy on housing and staffing; and arrangements to celebrate the Golden Jubilee year of the Institution in 1975–76.

In particular, the Committee reports on:

Revision of IERE Bye-laws. All the Chartered Engineering Institutions have broadly agreed upon a 'Code of Conduct' and 'Rules for Professional Conduct and Regulations for the enforcement of the Code and Rules'.

The extent of the Institution's agreement was reflected in the changes in Bye-laws proposed to IERE members in September 1972. The Council received Privy Council approval to the revised Bye-laws on 3rd December 1973. The Rules and Regulations are included as appendices to the revised Bye-laws.*

Admission of Mature Candidates to Membership. Last year's Report included reference to the 'mature' candidate. It is important that every member should know that most professional bodies and indeed all the engineering Institutions have, in the past, given special consideration to applicants who have had outstanding experience; such proven ability sometimes compensates for the candidate's inability to comply entirely with *current* academic regulations based upon present-day tutorial courses which were not available to the candidate at the onset of his career. These 'mature' candidates have made and continue to make valuable contributions to the profession; their membership of the appropriate Institution affords mutual advantages.

The Privy Council has, however, now ruled that the admission of mature candidates to membership should be phased out over the next ten years and this requirement is now included as Bye-laws 13 and 14(b). The belief of the IERE Council that this ruling could be detrimental to the profession is shared by other constituent members of the Council of Engineering Institutions (CEI). In consultation with the Membership and Education Committees, the Council will therefore continue to promote discussion within CEI on this regulation.

The Engineers Registration Board. Support has been given by the Institution to the setting up of an Engineers Registration Board and this has now been accomplished by the Council of Engineering Institutions establishing three registers: (1) for Chartered Engineers, (2) for Technician Engineers and (3) for Technicians. As with nearly all the chartered Institutions the IERE is only directly concerned with the first two registers as explained in the section of this report dealing with membership. By establishing progress in these various levels of registration, it is hoped that Government will agree that the three registers should be a basis of any national register that may be required in the future.

The work of compiling the registers also assists the work of the CEI which is concerned with securing agreement within the European Economic Community of mutual recognition of professional qualifications and so facilitate the mobility and interchange of engineers in Europe. This is not going to be an easy task, since the qualifications required of a professional engineer vary between different countries. The period of practical and responsible experience required in the United Kingdom for recognition as a professional engineer is a significant difference from the registration requirement of almost all other European countries.

The Technician and the Technician Engineer. The Council has been pleased to note the role played by the Society of Electronic and Radio Technicians (SERT) in forming the second and third engineering registers.

The Society was founded as a result of the success which attended the Institution's sponsorship of the Radio, Television and Electronics Examination Board (RTEEB) which was incorporated in 1955. Incorporation had been preceded in 1937 by the Institution inaugurating a Radio Servicing Certificate in order to encourage the training of radio technicians. The question eventually arose as to how successful candidates could be helped to keep their knowledge up-to-date. With this in view the IERE helped to establish the Society of Electronic and Radio Technicians (SERT). The IERE continues to have a close association with both the RTEEB and SERT and has proposed that now both bodies are well founded there is much to commend a merger of the two organizations. This proposal was, at the end of March 1974, being discussed between RTEEB and SERT. Meanwhile the Institution continues to give small financial support to RTEEB.

Conferences and Exhibitions. Reference is made later in this report to the Institution's increasing activity in promoting symposia and conferences. In recent years commercially organized exhibitions have also included a programme of lectures; invitations to the IERE to be associated with such exhibitions have therefore increased.

The Executive believes that the Institution's acceptance of such an invitation must be determined by whether it would constitute a service to members; implement the Institution's Charter '. . . to advance the science and practice of radio and electronics'; if the work involved can be undertaken by existing Institution staff; and finally whether the cost of overheads would cause financial loss to the Institution. If the Institution accepted such an invitation it should control the lecture programme and retain the entire right to the publication of contributions as Conference Proceedings.

The Golden Jubilee. Preliminary plans are being made to mark the fiftieth anniversary of the foundation of the Institution. Two main features will be a Banquet in The Guildhall in the City of London on 23rd October 1975 and a conference centred at King's College, Cambridge, throughout the week commencing 28th June 1976.

Other events are being planned and Council has invited Local Sections to submit their own special programmes to celebrate the Institution's Jubilee.

Institution Headquarters. For several years the Council has reiterated its views that it would be most helpful to all chartered engineers if the present fifteen chartered bodies could be centrally accommodated within one building and thereby use common services which should lead to economies in administration and yet provide more extended services to members.

The siting of such a building, the overall cost and possible Government support have been continually discussed since CEI was formed. For the present it does not seem that the

* Royal Charter and Bye-laws (Revised April 1974) now available to members, price 50p (post free).

project is capable of fulfilment within the foreseeable future. Alternative plans are being discussed between various groups of Institutions.

Meanwhile, the Executive Committee is immediately concerned with adequate housing and staff necessary for efficient administration of the Institution's affairs. The report on finance deals with the disposal of one of the Institution's buildings. Some economy has been achieved thereby, as well as securing a contribution to the cost of providing additional office space in 8 and 9 Bedford Square. On completion of this work there will be adequate facilities for some years ahead. Moreover, better accommodation should help to overcome present difficulties of staff recruitment.

Special Postscript. Although an obituary of Professor Emrys Williams was published in the March 1974 Journal, the Executive Committee wishes to record its sadness at this loss. For thirty years Professor Williams had been continually involved in a wide range of Institution activity; this experience enabled him to bring to the Executive invaluable counsel and guidance. No other member has ever served on the Executive Committee for so long and his services will be sorely missed.

OVERSEAS RELATIONS

The constantly changing pattern of international relations has thrown up the need, on political and economic grounds, for closer understanding between the countries of Europe. In such matters the interests of members of every Institution are best served by a federal body representing all engineering disciplines. In this respect Britain is fortunate in having established in 1965 the Council of Engineering Institutions; if the EEC is to provide a viable contribution to the world's use of technology, it is increasingly important for engineers on the mainland of Europe also to speak with a common voice. It is therefore imperative to establish certain common standards among all 'qualified' engineers of Europe. Some progress is now being made towards this objective, and the British Government is, for example, prepared to negotiate a basis of mutual recognition of qualifications of engineers and is favourably considering the CEI examination formula but only as a basis for its negotiations.

Notwithstanding the fact that the total corporate and non-corporate membership of constituent Institutions within CEI is now just on 320,000, the Department of Trade and Industry has asked CEI to see how best those engineers who appear to have appropriate qualifications, *but who are outside membership of the Chartered Engineers' Institutions*, can be accommodated in any European agreement for cross-recognition. Obviously discussions continue, and on a very wide front, on this important issue, but this particular Annual Report can only record happenings. In the IERE's opinion (which is not purely of self-interest), the CEI should insist on the standards of its Institutions being the basis of British qualifications.

CEI is the British member of the European Federation of National Associations of Engineers (FEANI). The entry of Britain into the EEC has caused increased interest in the FEANI Register since 229 applications from European Societies were received during the year.

Entry into the European Economic Community has tended to overshadow Britain's relationship with more distant communities but this should not be taken to mean that older associations are in any way less important. The CEI is also the approved British member of the Commonwealth Engineering Conference (CEC), and the World Federation of Engineering Organizations (WFEO), and carries responsibility for much of the international representation of British professional engineers. The IERE has nevertheless not abrogated its responsibility towards its overseas members, and accordingly it continues to maintain offices in Bangalore and Ottawa which service the Indian and Canadian Divisions respectively and to maintain active Divisions or Sections in New Zealand, France, Israel and South Africa.

Requests are still received from members in other countries asking the Council to agree to the formation of new Sections. This indicates a wish for the Institution to remain a single unitary society rather than to reconstruct on a federal basis. This does not gainsay the wish of the Council to continue the present association with, for example, the Institution of Radio and Electronics Engineers of Australia. Similarly, the Council of the Institution pursues a policy of co-operation with other indigenous bodies and in no way seeks to enter into competition with them. An example of this is in New Zealand where negotiations are going forward for all members of the IERE in New Zealand to enter into membership of the Electro Technology Group of the New Zealand Institution of Engineers.

Finally, the Council reports that an invitation for a party of members to visit the European Centre for Space Technology was accepted as an opportunity for a meeting of European members.

Council would particularly like to draw the attention of members who are travelling, temporarily or permanently, to any part of the world to the services of the Institution overseas. Whether coming to or leaving Great Britain, introductions can be arranged in most countries for meeting fellow members. Prior advice to the London, Ottawa or Bangalore offices will be welcomed.

PROFESSIONAL ACTIVITIES COMMITTEE

While the Professional Activities Committee has overall responsibility for the co-ordination of all Learned Society activities of the Institution, the majority of meetings, colloquia and conferences organized on a national basis are promoted by one or other of the Specialized Group Committees. Thus, the main function of the Professional Activities Committee is one of co-ordination and forward planning. For example, the specialized group structure is kept under continual review and where necessary the terms of reference of the various Groups are modified or new Groups formed so that the needs of members and of the profession are fully met.

The Council has approved the formation of a new Group to be concerned with Production Engineering. There is a continuous development of production techniques which is unique to the electronics industry. The purpose of this new

Group will, therefore, be to disseminate knowledge in the area of production technology which will not only be of interest to members who are directly engaged in production but also to those who are engaged on research and development projects which will eventually result in saleable products.

Meetings Held in London. It has been previously reported that all over Great Britain and indeed in London attendances at evening lecture meetings have continued to decline over the last few years but, at the same time, whole-day and half-day colloquia have increased in popularity. There are a number of contributory reasons; most important is the greater depth in which a subject can be treated at the longer meeting. Consequently, there has been a significant increase in the number of colloquia which have been held during the last year. This, however, is not to say that there is no place left for the evening meeting and, provided that the subject and speaker are carefully chosen, members may welcome the occasional evening meeting. Another significant trend has been the increasing co-operation between the various Learned Societies; in addition to meetings held in co-operation with other engineering Institutions, successful events have been held in co-operation with such bodies as The British Institute of Radiologists, The Hospital Physicists' Association and The Biological Engineering Society.

During the year, 20 evening meetings and 24 colloquia were held in London. Of these, 4 of the evening meetings and 13 of the colloquia were held jointly with other Institutions. Some idea of the increase in the Learned Society activities of the Institution can be gained by comparing these figures with those for the previous year when 17 evening meetings and 14 colloquia were held.

Clerk Maxwell Memorial Lecture. An outstanding feature of the year's programme was the delivery of the Eighth Clerk Maxwell Memorial Lecture by Dr. Wernher von Braun. Dr. von Braun, Vice President—Engineering and Development, Fairchild Industries and formally Deputy Associate Administrator of NASA, took as his subject 'Our Space Programme after Apollo'. His lecture, which was of absorbing interest, and included many colour slides, was delivered before a packed lecture theatre. The full text of his lecture was published in the June 1974 issue of *The Radio and Electronic Engineer* and will subsequently be re-published in 'The Collected Clerk Maxwell Memorial Lectures'. This volume contains the full text of all of the lectures given in this series.

Local Sections in Great Britain. The fifteen local sections which operate in Great Britain outside London have had an active and successful year. Between them they have held 128 technical meetings and, in addition, a number of the sections have arranged visits to places of technical interest and have held various social events. The local sections have also increased their co-operation with other professional bodies and 46 of the technical meetings were held jointly with other organizations.

Although the Chairmen of the local sections are *ex-officio* members of Council and thus meet regularly it is, nevertheless, found beneficial to hold special meetings of the local section Chairmen at which problems of common interest can be discussed. Such a meeting was held in November 1973 and, in addition to the local section Chairmen, it was attended by the President, two Past Presidents and appropriate members of the Institution's staff. A wide ranging discussion was held which covered many aspects of the Institution's work including the future pattern of section meetings, the exchange of information between sections, the impact of CEI and the arrangements for celebrating the Golden Jubilee of the Institution in the sections.

Conferences Organized by the Institution. During the year three major Conferences were organized by the Institution. The first of these was on Video and Data Recording and was held at the University of Birmingham from 10th to 12th July 1973. This was a truly international event and of the 37 papers presented, 15 were by overseas authors. The attendance of 315 included 74 engineers from USA, France, Sweden, Germany, Netherlands, Eire, Denmark, Hungary, Norway, Japan, Canada and Switzerland. Co-sponsors of the Conference were The Institution of Electrical Engineers, The Institute of Electrical and Electronics Engineers, The Royal Television Society and The Society of Motion Picture and Television Engineers. During the Conference, numerous requests were made, particularly by overseas visitors, for a further Conference on this subject to be held in two to three years' time: plans for this are now proceeding.

The second Conference was on Hybrid Microelectronics and this was held at the University of Kent at Canterbury from 25th to 27th September 1973. At this Conference 37 papers were presented before an audience of 266 and again there was good overseas participation of both authors and delegates. This was, in fact, the third Conference in a series: the first of these being Applications of Thin Films in Electronic Engineering held in 1966 and the second Thick Film Technology held in 1968. Plans are now in progress for a fourth Conference in this series to be held in September 1975. Co-sponsors of this Conference were The International Society for Hybrid Microelectronics, The Institution of Electrical Engineers, The Institute of Electrical and Electronics Engineers and The Institute of Physics.

The third Conference held during the year was of a somewhat different nature and dealt with The Electronics Industry and Higher Education. This was held at Royal Holloway College, Egham, from 28th to 31st March 1974. The purpose of this Conference was to bring educationalists and industrialists together and attempt to bridge the interface between industry and education. In this it was undoubtedly successful. In all 31 papers were presented and these were of a very high standard. It was, however, unfortunate that this Conference came at the end of the power crisis and of the three day working week and thus the attendance of 98 was rather lower than it would have been. This Conference differed in two respects from the majority of Institution Conferences: first, all of the papers presented were from invited speakers rather than as the response to a 'Call for Papers', secondly, it was held at a weekend instead of mid-week as is more usual. The success of the latter variation could not be gauged due to the unsettled industrial conditions prevailing at the time. The Institution of Electrical Engineers was a co-sponsor of this Conference.

The full text of the papers presented at the first two Conferences are published in IERE Conference Proceedings Nos. 26 and 27 respectively, and these are currently on sale from the Institution's Publications Department. Due to the speed with which these volumes are produced, compared with a standard text book, they represent the most up to date treatises available on their respective subjects. Thus, they serve an excellent purpose in their own right in addition to the inherent value of the Conference itself.

Joint Conferences. In addition to the Conference organized by the IERE, the Institution acted as co-sponsor for a number of other Conferences including:

Computer Aided Control System Design
Software Engineering for Telecommunications Switching Systems
Propagation of Radio Waves at Frequencies above 10 GHz

The Teaching of Electronic Engineering in Degree Courses
International Marine and Shipping Conference
Fifth Control Convention on Modelling and Simulation for Applied Control Systems
Organization and Management of Computer Based Control and Automation Projects
Radar—Present and Future
Software for Control
NELCON 73—Signal Processing (New Zealand)
Noise and Vibration Control for Industrialists
Microwave '73
IFAC–IFIP Fourth International Conference on Digital Computer Applications to Process Control

The Institution is also represented on the Local Committees of CEI which now operate in twelve centres throughout the UK and five Joint Committees of Graduates and Students. These local associations arrange meetings with as wide an appeal to the different engineering disciplines as possible. Participation in student recruitment and in careers symposia and similar ventures are important activities in these Local Committees.

All of the above are examples of the increasing inter-institutional co-operation which is being promoted for the benefit of members of all Institutions.

Representation on BSI Committees. For many years the Institution has been a firm believer and supporter of work on standardization. For this reason a number of Institution members are appointed to technical committees of the British Standards Institution and a list of these is given in Appendix 7. Increasingly, the work on standardization tends to be of an international character and a number of the IERE representatives on BSI Committees are especially active in this enterprise.

Regrettably it must be reported that the work of the British Standards Institution may have to be curtailed because of a loss in subscriptions and especially a reduction in Government subsidy.

Representation on Other Organizations. The Institution is also represented on a number of outside technical committees and organizations; details of these appointments are given in Appendix 6.

Convention of the Electro-technical Societies of Western Europe. The formation of this association was referred to in last year's Annual Report and the second meeting of the Convention was held in Brussels in November 1973. This meeting was attended by members of Institutions of electronic and electrical engineers of Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom, and further discussions took place on various ways of valuable international co-operation. An important result of this co-operation is a greater participation in all Conferences and the publicizing of the various events held in different countries. The Convention was a major sponsor of 'Eurocon 74' which was held in Holland in April 1974.

Acknowledgments of Council. The Council especially wishes to thank universities, technical colleges and other organizations for providing accommodation for meetings; the editors of scientific periodicals for publicizing details of Institution meetings and other activities in Great Britain and overseas; the many Institution members who contribute to the success of Learned Society activities by serving on various Institution committees (national and local) and also the many members who represent the Institution on BSI and similar organizations.

EDUCATION AND TRAINING COMMITTEE

The activities of the Committee during the last four months of 1973 were largely of a 'review and consolidation' character. Having in previous years studied, and largely approved, the recommendations of the Haslegrave Report, and having more recently similarly studied, and severely criticized, the DES proposals for the structure and terms of reference of the Technician Education Council which was being established in accordance with those recommendations, it could do little further in that area until the official reaction to its criticisms was known. The Final Draft of the Institution's proposed Training Requirements for Professional Electronic Engineers had earlier been submitted for the approval of Council, and the Committee found itself obliged to recommend delaying their publication because of the anticipated appearance of a new CEI Statement on Training. Even in the area of its recommendations for the revision of the CEI Part II examination Regulations and Syllabuses, it could do little more than observe and comment on the extent to which these had been followed in respect of the requirements for the May 1974 and subsequent examinations.

Towards the end of the year, the Committee learned that most of its criticisms of the organization of the Technician Education Council had been met, and that the proposed CEI Statement on Training Requirements had been submitted for approval by the Board, and that it might therefore be possible to recommend publication of the IERE's own Training Requirements early in 1974. However, the Draft CEI Statement contained so much that some Institutions found unacceptable that it was referred back for further study. This further study led to a series of re-drafts, and the Committee eventually decided to appoint a small Working Group to deal with the matter because the proposed time-scale for re-submission to the CEI Board could not otherwise be met. It is hoped that by the time the full Committee next meets the CEI Draft will be close enough to final form for any possible points of conflict with our own proposed document to be taken into account before its publication.

The Committee also had under review the problem of diminishing support for evening meetings of the associated Education and Training Group, and decided as an experiment to abandon these for a year in favour of half or one-day conferences or symposia on topics of general rather than specialist interest. Appropriately, one suggested topic for such a symposium is the difference between UK and Continental opinion of the relative merits of generalization and specialization in the content of courses of study undertaken by intending Professional Engineers. It is also hoped, in view of the apparent intention of the Technician Education Council to use a modular structure for courses leading to its awards, and the disquiet felt in many quarters about possible abuse of the modular system at this and higher levels, to organize a fully representative symposium on this subject.

ACADEMIC STANDARDS COMMITTEE

This is only the second report of this Committee which was appointed after the Institution held the last IERE Graduateship Examination in 1970. In replacing the former Examinations Committee, the present Committee is now responsible for assessing the academic qualifications of applicants for membership and framing recommendations for adjustment or additions to the list of exempting qualifications. For these purposes the Committee has to contribute to and work within the definitions prescribed by the CEI.

Strict enforcement of the new (CEI) regulations on examination exemption as from January 1974 meant that a large number of candidates had only until the end of 1973 to complete courses and, in many cases, parts of examinations which would not, after 1973, be accepted for exemption from the CEI examination. The Academic Standards Committee, therefore, found it increasingly difficult to recommend means by which applicants could make good any shortfall in their qualifications in the time left. In many cases the only possible recommendation was the submission of a 'Technical Paper'. This involved some pressure on the Committee in examining the papers and, where necessary, arranging a viva voce examination. Inevitably, and with regret, it has not been possible to assist all such candidates; some have been the victims of the CEI decision to enforce new regulations by a specific date but it is hoped that the candidates involved will re-organize their study programmes and eventually qualify under the new scheme.

The ending of the 'bridging scheme' has removed a major part of the Committee's work load, but on behalf of the Council it still supervises IERE sponsorship of entries to the CEI examinations which for 1974 totalled 435 candidates (12% of the total entry from all Institutions). It is not yet possible fairly to compare this entry with those for the IERE Graduateship Examination (over 800 in 1970) because the joint Institutions' scheme (CEI) was only held for the first time in 1967.

Additionally, the IERE Committee is still asked to assess various combinations of qualifications—generally of overseas origin—against the standards required for entry to, or exemption from, Part 1 of the CEI examination. This, in turn, involved comment on a CEI proposal to publish a 'Professional Review'—a somewhat misleading title—expressing some opinions within CEI of the academic training and experience required of a candidate for registration as a chartered engineer. The Membership Committee of IERE concurred with the view that 'blanket' regulations could not apply to all Institutions. Difference of opinion between the various constituent Institutions on the need for publishing such a 'Review' has still to be resolved.

The Committee also considered the proposed Constitution and terms of reference of both the Technician Education Council and the equivalent Scottish body, SCOTEC. This resulted in the Institution joining with the IEE (its partner on the Joint Committee for H.N.C.s and H.N.D.s in Electrical/Electronic Engineering), in submitting to the Department of Education and Science, a number of major changes. Ten out of these twelve recommendations were accepted.

The Academic Standards Committee also prepared recommendations for the procedure to be followed by applicants seeking election as 'Mature Candidates' to the grade of Associate Member and T.Eng. registration. Subject to certain minor amendments, this procedure is now being adopted by the E.R.B.

By publishing this report, the Council acknowledges, with appreciation, the work of a new Standing Committee so obviously alive to ensuring adequate opportunity for the radio and electronic engineer and technician to secure registration.

MEMBERSHIP COMMITTEE

Approval by the Privy Council of changes in the Institution's Charter and Bye-laws dealing with admissions is reflected in the state of membership. By lowering the age limit for entry to corporate membership (Fellows and Members) on the same basis as that of other Institutions, the IERE has enabled a larger number of Graduate members to transfer to a higher grade of membership. This fact, coupled with usual Institution growth, has resulted in a 15% increase in the number of corporate members as shown in Table 1.

Implementation of the new Bye-laws also resulted in the transfer of over 400 Associates to the new grade of *Associate* Member and their registration with the Engineers Registration Board as Technician Engineers.

The Committee regrets to report that there was also an increase in the number of resignations; this was partly due to the new CEI regulations for registration as 'Chartered Engineers' which invoked, from January 1974, more stringent academic qualifications. This especially applied to Graduates who could not see a reasonable prospect of becoming Chartered Engineers without improving their academic qualifications as now required. Notwithstanding these losses, Table 1 also shows that there has been an overall increase in the *total* number of members.

During the year the Committee considered 1726 proposals; 606 for direct election, 1119 for transfer, and 1 reinstatement.

As a final statistical note the Committee reports that from Great Britain alone over 2000 enquirers requested information about the possibility of their securing membership; similar enquiries were dealt with by the Ottawa and Bangalore offices and other Institution representatives outside the United Kingdom.

Last year's report reiterated the need to stimulate recruitment of younger people to engineering in general and especially to the ranks of the 'professional' engineer.* The original proposal of the IERE that the CEI should act for all Institutions in catering for the student of engineering who is not yet committed to a specialization has not found favour with the majority of its sister Institutions. There is still a CEI Committee considering all levels of recruitment to engineering, but the IERE adheres to the view that the future of the engineering profession is largely dependent on the encouragement given to students, and thereby influencing the right type of recruitment. The Council is therefore pursuing its original proposal even if it is only supported by a few Institutions.

The Engineers Registration Board for Technician Engineers has, as expected, attracted a large enrolment. Now that IERE Bye-laws permit the election of such registrants as Associate Members the Council is concerned with the first two legs of the registration scheme as operated by CEI; some of those Associate Members may well be encouraged to continue with their studies to qualify for transfer to professional grading especially if allowance is made for them, in time, as 'mature' candidates.

* See *The Radio and Electronic Engineer*, p. 573, September 1973.

Table 1. **Institution Membership April 1973 to March 1974**

	Membership at 31.3.73	Additions: Direct Elections	Additions: Reinstatements	Additions: Transfers	Total Additions	Deductions: Deaths Resignations Removals	Deductions: Transfers	Total Deductions	Nett Gain (+) or Loss (−)	Membership at 31.3.74
Honorary Fellows	10	—	—	—	—	—	—	—	—	10
Fellows	677	7	—	19	26	9	—	9	+17	694
Members	6015	184	1	918	1103	95	17	112	+991	7006
Total Corporate Membership	**6702**	**191**	**1**	**937**	**1129**	**104**	**17**	**121**	**+1008**	**7710**
Graduates	5915	92	—	34	126	116	907	1023	−897	5016
Companions	19	2	—	—	2	2	1	2	0	19
Associates	906	31	—	4	35	17	417	434	−399	507
Associate Members	—	38	—	412	450	—	—	—	+450	450
Students	1649	228	—	—	228	40	45	85	+143	1794
Total Membership	**15191**	**582**	**1**	**1387**	**1970**	**278**	**1387**	**1665**	**+305**	**15496**

Note from Council. Membership of all engineering Institutions is still voluntary. Nevertheless, a high standard of membership is preserved because of the care exercised by the Membership Committee, assisted by corporate members who sponsor proposals and the establishment officers and teachers who give advice to potential members. For all these services the Council records its thanks.

PAPERS COMMITTEE

During the past year the Committee has continued to examine ways in which it can carry out more effectively its main task of obtaining papers for publication and assessing their suitability for inclusion in the Institution's Journal. This continuing re-examination of the role of the Journal as part of the Institution's 'learned society' activities endeavours to follow the change of emphasis in the needs which members require their Journal to meet.

Encouragement of Papers. One of the Committee's greatest problems is to encourage submission of papers which will result in the Journal achieving, over a period, reasonable balances in all respects: between theory and practice, over a variety of subject areas, and in the sources from which papers are received. As far as subject area is concerned this is probably least difficult to balance since there tend to be 'fashions' in subjects and several papers on an up-and-coming new technique will be found more useful and interesting to members than papers on established topics which have been in the text books for several years. There must, of course, always be a leavening of surveys and tutorial papers to meet the needs of those whose professional activity does not always require them to be in the forefront of knowledge.

It is always more difficult to achieve a balance over the main areas of activity—university and college research, Government research and development, and industrial research, development and production. The imbalance of contributors in these respects does certainly not reflect the considerable work undertaken in these three sectors which are of interest to the professional engineer. The emphasis laid on the desirability of writing papers for engineering journals seems to depend on the amount of time that an engineer is permitted to devote to this task and far more papers are published from university sources than from Government and industry put together. This breakdown applies whether the sources are from the United Kingdom or overseas, and is common to most engineering journals.

No doubt there are cogent reasons why this should be the case, but it is the Committee's view that while not wishing to reduce the number of papers published from university sources, encouragement of papers from elsewhere would have the effect of adjusting the balance between theory and practice by placing greater emphasis on engineering realization.

In last year's Annual Report it was suggested that a more enterprising attitude on the part of both individual engineers and their employers would be much to their advantage as well as to the general development of engineering.

One of the ways in which the Committee is endeavouring to improve the balance of contributions to the Journal is by selecting appropriate papers for reprinting from the proceedings of Institution conferences and colloquia and by issuing specific invitations to submit papers for consideration for publication to authors who have addressed meetings of Local Sections. From the point of view of subject matter, conferences and colloquia tend to cover subjects which are new and expanding, while Local Section papers tend to deal with established subjects to a rather greater extent. It is a curious fact that the authorship of papers read at local meetings includes a far greater proportion of engineers from industry than does the authorship of papers submitted for publication.

The Committee does urge authors who have presented papers of wider interest and value not to limit their presentation to a meeting, but to submit manuscripts to the Institution for possible publication.

Feature Issues. Following the successful issue of the Journal published in January/February 1973 to commemorate the 25th anniversary of the invention of the transistor, the Committee has introduced the concept of an occasional feature issue on a particular theme. In November 1973 the theme was 'Optical Fibre Research and Communications' and in January 1974 seven papers were collected together on 'Logic Design'.

These have received favourable comment from many quarters and future plans for further feature issues include 'Ionospheric Radio Wave Propagation' and 'Applications of Epitaxial Magnetic Film Garnets' later this year. During 1975 issues will be devoted to Surface Acoustic Wave Electronics, Marketing, Costs and Reliability, and Consumer Electronics.

While the Committee endeavours to balance the level of treatment within a particular feature issue, it would not be in the general interests of members for too great a proportion of issues during the year to be devoted to single themes. It is hoped that the present level of activity will be found a reasonable compromise.

The close resemblance of a feature issue to the proceedings of a symposium or colloquium has led to useful discussions being initiated with the Professional Activities Committee so that on occasions an issue could perhaps originate from some of the papers given at a meeting and in other instances the published papers could serve as the basis for a subsequent meeting.

Assessment. During the period from April 1973 to March 1974 the Committee has considered a total of 173 papers. This is rather less than in 1972–73 but the number accepted for publication was about the same, while the number of rejected was nearly 20% less. As in previous years, a number of papers from Institution conferences were put forward by the appropriate Organizing Committee for consideration for publication and twelve were in fact reprinted. These were from the conferences on Video and Data Recording and on Hybrid Microelectronics, both of which were on basically electronic engineering themes rather than on applications of electronic techniques.

Details of papers considered by the Committee are as follows (1972–73 figures in parentheses):

Number of papers considered:	173	(190)
Accepted for publication:	86	(85)
Returned for revision:	23	(26)
Rejected:	64	(79)

The category 'Returned for revision' refers to papers which the Committee felt ought to be published but required rewriting because of substandard presentation, inadequate explanation or insufficient results. The different lengths of time taken by authors to carry out revision means that it is not easy to state precisely what proportion of papers were accepted after such revision, and some indeed decide not to embark on the task. During the year under review 12 papers of those accepted had previously been returned for revision; 15 of the 79 papers published in the 1973 volume, which partly overlaps this period, had been referred for revision.

While an occasional author may express the view that his paper has been rejected unjustly, the Committee is encouraged by the appreciative comments of many authors, not always those whose papers have been accepted, for the helpful suggestions and observations which have been made by referees and sent to them with the Committee's decision. The concept of the professional engineering journal depends very much on the independent and disinterested professional opinions given by referees and it is believed that many engineers welcome the opportunity to lend the profession their specialized knowledge in this way. In choosing referees, the Committee has to weigh up the advantages of a small (and therefore perhaps overworked) panel who can achieve maintenance of very consistent standards but may have certain gaps in their overall technical coverage, against a much wider panel of referees who can therefore be relied upon to cover between them completely the whole field of electronic engineering but who may by their very number and diversity tend to judge papers with rather different criteria. The advantages of a panel with comprehensive knowledge and experience are felt to outweigh the problem of referees using different criteria and the Committee therefore regards its first important task in assessing papers as being to establish and appropriately 'weight' common factors and valid areas of disagreement between the two or more referees who report on the paper. The Committee's work would be impossible without the help of referees who are usually members of other committees or sometimes outside experts and their conscientious and unpaid assistance should be gratefully acknowledged by all who appreciate and are anxious to maintain the Journal's high standards.

Premiums. During the past year the Committee, with the permission of the Council, has carried out a careful and lengthy reappraisal of the system for awarding premiums to authors of outstanding papers published in the Journal. The function of Institution Premiums is recognized as being firstly to encourage the submission of papers to the Journal, and secondly, and not less important, to reward the outstanding contributions. By attaching to papers the cachet of an Institution Premium there is established a standard by which it is believed that the Journal may be judged.

The group of premiums and awards which has been built up since the establishment of the first premium in 1946 has tended to be somewhat piecemeal and the Committee's recommendations to the Council have led to the association of a premium with a broad interpretation of each of the main subjects that are relevant to the Journal's interests.

Because some of the premiums carried the original values appropriate to the dates at which they were founded, there was a great disparity among their values and, more important, some were, because of the effects of the changing worth of money, well below the sum that the prestige of the award could reasonably expect. The values have therefore been increased and the new scheme of twenty premiums should maintain its relevance both for subject coverage and monetary reward for some considerable time.

The full list of premiums with their terms of award and values was published in the April 1974 issue of the Journal and details will be regularly repeated in the announcement pages of future Journals.

For the year 1973 eleven of the premiums have been awarded and details were first announced in the June issue of the Journal and are reproduced in Appendix 9 of this report.

INSTITUTION PUBLICATIONS

The Radio and Electronic Engineer. Only a very few comparatively minor modifications were made to the layout of the Journal at the beginning of 1973, the most important of which was for the second section of the Journal to adopt the heading of 'IERE News and Commentary' to cover Institution affairs, professional news and matters of general technical interest. The first part of the Journal continues to contain the customary group of between five and eight technical papers in an average issue.

The size of the 1973 volume was very similar to that for 1972, 772 pages as compared with 776. The breakdown of papers and general material was as follows (1972 figures in parentheses):

Papers:	643 pages (568)
General:	129 pages (208)

There were altogether 79 papers published during the year, 4 more than last year, and the greater number of pages of papers printed, despite the fact that 11 issues appeared, can be attributed to the inclusion of 18 papers in the double January/February number which was the Transistor Commemorative Issue.

Costs of Publication. The widespread publicity which has been given to the closure of newspapers and magazines in Great Britain will have made every member aware of the financial problems involved in any form of publication. Steeply rising costs in paper and all the items which go towards the final printing and not enough advertising revenue seem to be the main problems.

Advertisement revenue continues to be considerably below what might be expected of a journal having the quality and quantity of readership of *The Radio and Electronic Engineer*. Advertisement rates have been unchanged since the beginning of 1972 and the revenue for 1973 decreased by 6% compared with 1972.

Needless to say, the comment encountered in every form of business has to be made regarding the increase in all costs associated with the Journal during the year. Increases in printing and paper costs were made during the first half of 1974 and in June postage rates were increased. The effect of all these increases cannot long delay the date for a further increase in the subscription rate of the Journal to non-members.

Circulation. The interruption to the steady increase in circulation of *The Radio and Electronic Engineer* which occurred during 1972 has fortunately not continued and for 1973 the average monthly circulation as certified by the Audit Bureau of Circulations was 15,341 (see accompanying diagram). Although the number of subscribers to the Journal from libraries of universities, Government departments and industry in the UK and abroad is steadily increasing it is considered still to be nowhere near the potential level justified by the Journal's content.

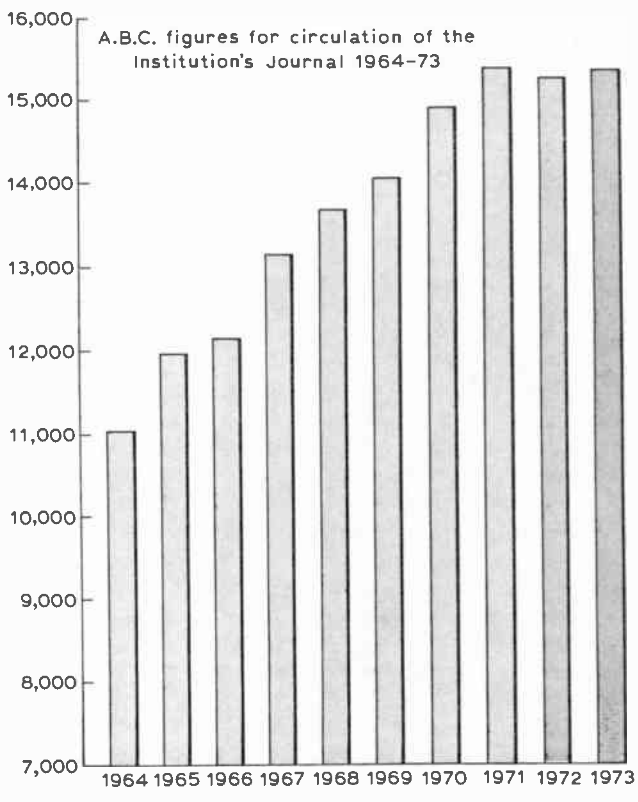
During 1974 a drive to increase circulation as well as sales of other publications has been launched, backed up by a comprehensive new catalogue giving details of all the material now available from the IERE.

ALPSP. The Institution has been a member of the Association of Learned and Professional Society Publishers (ALPSP) since its formation in 1972 and has actively supported the Association's compaign to protect journals such as ours from the effects of unauthorized photocopying. It cannot be too frequently stated that only authorized libraries are permitted to make single copies of copyright material from journals for private study and research. Despite offers from overseas of royalties for permission to reproduce the Journal photographically in quantity, this stand is insisted upon. The copyright enjoyed by a professional journal ultimately protects the interests of the members since its financial independence is the only way of ensuring publication of papers untrammelled by special interests.

ALPSP also collated information on such matters as postal charges, paper costs and VAT liability and acts as a means whereby the views of its members can be made known to Government departments, etc., and influence the impact that these burdens have on non-profitmaking bodies such as Institutions and learned societies.

National Electronics Review. The Institution continues to edit this bi-monthly journal on behalf of the National Electronics Council. The *Review*, which is now in its tenth year of publication, has an increasing readership among engineers and others who have a particular interest in the impact of electronics on the social and economic life of the country. In addition to including details of the work of the National Electronics Council, the *Review* also includes regular series of articles on university research and company profiles. In addition, it deals with advances in technology which are likely to have wide ranging effects in the future, as for example, satellites for maritime communication and navigation and new forms of automatic control for land transport.

The *Review* is available on a reduced subscription rate to members of the Institution and sample issues are available on request.



Overseas Publications. The publication of *IEE–IERE Proceedings—India* continues from Bangalore on a bi-monthly basis and is sent to members of both Institutions in India. The six issues contained a total of 25 papers and comprised 250 pages of text which compares favourably with 21 papers and 232 pages for 1972. Local news, technical as well as general, and announcements from the Institutions add to the value of the Indian 'Proceedings' to members.

Conference Proceedings. During 1973 the Institution held two major conferences for which volumes of proceedings were published as follows:

Video and Data Recording (No. 26)
Hybrid Microelectronics (No. 27)

In addition a volume of papers was prepared for a one-day colloquium on 'Remote Control System Organization' (No. 28). The three volumes contained 752 pages of text.

IERE Conference Proceedings have established themselves as a sought-after series and sales all over the world, some of them on a standing order basis, are growing and several earlier numbers are now out of print.

LIBRARY AND INFORMATION SERVICE

Despite the advent of computer-based information retrieval systems, there is no diminution in the demand for conventional library and information services and these continue to be met for an increasing number of members.

The stock of technical books available on loan is continually being increased and up-dated and during the year 143 new titles were acquired and many of these were reviewed in *The Radio and Electronic Engineer*. Requests for books not held in stock because the demand is insufficient to warrant acquisition, can usually be obtained through the Institution's arrangements with other bodies such as the National Lending Library.

A considerable number of both British and overseas periodicals are regularly received and many are subsequently bound for reference purposes. In most cases photocopies can be supplied of individual papers and there is an increasing demand for this service.

There has also been a growing use of the Institution's Book Supply Service. This service enables members to obtain copies, via the Institution, of most of the books reviewed in *The Radio and Electronic Engineer* at list price plus a uniform charge of 25p to cover postage and packing.

In order to increase the usefulness of the library service to members an extensive overhaul of the indexing systems has been put in hand.

FINANCE COMMITTEE AND ADMINISTRATION

Every member is affected by the decline in currency values. In Great Britain the internal purchasing power of the £ sterling declined between October 1964 and March 1974 by 45%. For correct perspective it must be noted that every other country has similar problems; for example, during the same period the French franc declined by 39% and the German D-mark by 32%.* Outside Europe currency values have suffered even worse misfortunes.

As such inflation continues unabated, all Institutions are faced with the problem of maintaining services on a fixed revenue whilst coping with ever increasing charges for all the materials, housing and staff needed for their activities. How effectively the IERE has coped with its domestic problem is shown in the appended accounts and Auditors' Report.

Income and Expenditure Account. Subscriptions again showed an increase over the previous year. Entrance and transfer fees showed a large increase over the previous year for the reasons given in the report of the Membership Committee. The demand for Institution publications continues as shown in the sales figures.

Whilst income rose by £10,600, overall expenses increased by £11,400; nearly £6000 of this was for higher cost of premises and over £2000 for additional Journal costs.

Administration costs show the higher cost of telephone and postage; both items will show further increases in the next twelve months. There will also be an increase in salary charges because the Institution has continued to experience considerable difficulty in recruiting adequate staff which, in the London area, is an acute problem. It is hoped that this handicap will be rectified by the revised staff salary and pension scales and the improved working facilities described in the report of the Executive Committee.

These higher charges will be met in 1974–5 by the increased subscriptions which came into force on 1st April 1974, coupled with the economy of disposing of the lease of 50 Bloomsbury Street. This sale has enabled the Institution to recoup most of its capital expenditure on that building and to divert it to improving and now extending accommodation in 8 and 9 Bedford Square as shown in the additional income and expenditure account.

Help from Members. Fighting inflation calls for economy of operation wherever possible. After examining several schemes it is believed that a substantial decrease in costs can be obtained by collecting subscriptions through the Direct Debit System. This is a development of the Banker's Order system which depended on the requisite Bank Order. Many of these forms went astray in the Post Office and Banks.

When the Direct Debit System is utilized no slips are used and therefore no annoyance can arise from losses. No postage to, or from, the member is required—a very important financial point to-day. The Institution's computer service feeds in amounts to the bank's computers, crediting the Institution and debiting the members' accounts. Costly reminder slips do not have to be printed.

The help of every member in using this system is solicited so as to reduce unproductive costs.

Acknowledgments

Appended to this Report is the annual record of members who give their services freely in one or more departments of Institution activity. Their recommendations and decisions have been implemented by a relatively small staff. In a very difficult year especial thanks are given to all who have actively helped in securing the Institution's continued progress.

* According to *Parliamentary and Common Market News*, July 1974.

INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

GENERAL ACCOUNT

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1974

1973 £	£	Expenditure		£	£
		Administration Expenses			
	60,886	Salaries and State Insurance ..		59,398	
	4,030	Superannuation Scheme.. ..		6,493	
	6,789	Postage and Telephone		8,008	
	3,474	Printing and Stationery		3,988	
	4,306	Computer Service		4,698	
	1,421	Travelling and Entertaining ..		1,493	
	2,716	Council and Committee Expenses		2,774	
	844	Delegates' Expenses		899	
	971	Bank Interest and Charges ..		839	
	573	Audit Fees		573	
	65	Legal Charges		—	
	1,437	Sundry Expenses		1,946	
87,512					91,109
		Institution Premises			
	6,557	Rent, Rates and Insurance (Net)		9,445	
	985	Lighting and Heating		1,036	
	3,736	Office Expenses and Cleaning ..		4,016	
	4,641	Repairs and Maintenance ..		6,589	
15,919					21,086
		Institution Journal			
	39,595	Publishing Journal	41,282		
		Less:			
	5,724	Advertising Receipts	5,384		
	33,871			35,898	
	12,719	Postage		12,397	
	900	Envelopes and Wrappers ..		1,400	
47,490					49,695
1,084		**General Meeting and Conference Expenses**			925
		Divisions and Sections Operating Expenses			
	3,920	Salaries, Printing, Stationery, Postage and Office Expenses		4,147	
	3,847	Hire of Accommodation, Lectures and Meeting Expenses ..		4,284	
	1,688	Travelling Expenses		1,679	
	1,728	Indian Proceedings		1,167	
11,183					11,277
3,367		**Subscription to the Council of The Engineering Institutions**			3,638
382		**Grants to Other Institutions** ..			570
430		**Premiums and Awards**			448
		Depreciation			
	1,002	Office Furniture and Fittings ..		927	
	556	Library		664	
1,558					1,591
3,210		**Surplus for the Year Carried Down**			2,408
£172,135					£182,747

1973 £	Income	£
138,019	Subscriptions received, including arrears ..	141,204
57	Donation from Industry	52
818	Exemption Fees	1,318
4,620	Entrance and Transfer Fees	8,029
27,513	Sales of Journal and Publications	29,670
1,108	Dividends and Interest on Investments (Gross)	2,474
£172,135		£182,747

1973 £		£
11,163	Balance as at 1st April, 1973 Brought Forward	7,953
(7,953)	Balance Carried Forward	6,820
£3,210		£14,773

1973 £		£
3,210	Surplus for the year on Income and Expenditure Account brought down	2,408
—	Profit on Sale of Investments	1,541
—	Costs of Improvements to Leasehold Premises recovered on assignment this year	10,824
£3,210		£14,773

INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

BALANCE SHEET AS AT 31st MARCH, 1974

1973 £	£		£	£
		General Account		
(7,953)		Balance as at 31st March, 1974		6,820
		Premises Improvement Reserve		
	1,666	Balance at 1st April, 1973 ..	2,290	
	624	*Add*: Donations received during year	327	
2,290				2,617
		Deferred Revenue		
20,286		Subscriptions in Advance ..		20,626
		Current Liabilities		
	37,568	Sundry Creditors..	36,243	
	35,410	Bank Overdraft	32,388	
72,978				68,631
£87,601				£98,694

Note: At 31st March, 1974 there were capital commitments amounting to £5,500 (1973–Nil)

Signed

I. Maddock (*President*)
S. R. Wilkins (*Honorary Treasurer*)
G. D. Clifford (*Secretary*)

1973 £	£		£	£
		Fixed Assets		
		Alterations and Improvements to Leasehold Premises:		
		8 & 9 Bedford Square, London.		
	6,618	Balance at 1st April, 1973 ..	8,618	
	2,000	*Add*: Expenditure during year	8,306	
	8,618		16,924	
	1,500	50 Bloomsbury Street, London	—	
10,118				16,924
	23,348	Office Furniture and Fittings at Cost	23,605	
	14,329	*Less*: Depreciation to date ..	15,257	
9,019				8,348
	10,452	Library at Cost	12,089	
	5,454	*Less*: Depreciation to date ..	6,117	
4,998				5,972
24,135				31,244
27,255		**Investments** (at Cost—see attached schedule) .. .. (Value at middle market price £21,805 (1973–£26,409))		31,280
		Current Assets		
	14,378	Stock of Institution Publications at lower of cost or estimated realizable value	15,615	
	159	Income Tax repayment claim ..	177	
	9,743	Sundry Debtors and Prepayments	11,149	
	9	Section Balances at Bank and in hand	284	
	11,870	Balances at Banks overseas ..	8,903	
	52	Cash in hand	42	
36,211				36,170
£87,601				£98,694

AUDITORS' REPORT TO THE MEMBERS OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

In our opinion the Accounts set out on pages 441 to 442 give a true and fair view of the Institution's affairs at 31st March, 1974 and of the surplus for the year ended on that date and comply with the Royal Charter and Bye-Laws of the Institution.

50 Bloomsbury Street, London, WC1B 3QT
30th August, 1974.

GLADSTONE. JENKINS & CO.
Chartered Accountants.

SCHEDULE OF INVESTMENTS AS AT 31st MARCH, 1974

Nominal		*Cost* £
500	Allied Textile Co. Ltd. 25p Ordinary Shares ..	511
£1,000	7¾% Barnet Corporation 1982/4	983
1,500	B.B.A. Group Ltd. 25p Ordinary Shares ..	1,115
£500	Beecham Group Ltd. 5% Convertible Unsecured Loan Stock 1984/94	486
700	Boots Pure Drug Co. Ltd. 25p Ordinary Shares	882
1,000	British Oxygen Co. Ltd. 25p Ordinary Shares	653
£500	British Petroleum Co. Ltd. 8% Cumulative First Preference Stock	685
800	Courtaulds Ltd. 25p Ordinary Shares ..	1,175
200	Decca Ltd. 25p Ordinary Shares	645
125	Decca Ltd. 25p 'A' Ordinary Shares ..	424
200	Distillers Co. Ltd. 50p Ordinary Shares ..	342
320	Dunlop Co. Ltd. 50p Ordinary Shares ..	560
600	E.M.I. Ltd. 50p Ordinary Shares	1,078
320	English China Clays Ltd. 25p Ordinary Shares	495
374	Grattan Warehouses Ltd. 25p Ordinary Shares	802
500	Edward G. Herbert Ltd. 25p Ordinary Shares	205
1,000	I.C.I. Ltd. £1 Ordinary Shares	2,712
300	Inchcape & Co. Ltd. £1 Ordinary Shares ..	795
£270	Inchcape & Co. Ltd. 12½% Unsecured Loan Stock 1993/98	99
£1,000	Islington Corporation 10% Redeemable Stock 1982/3	995
	Carried forward	15,642

Nominal		*Cost* £
	Brought forward	15,642
505	Lonrho Ltd. 25p Ordinary Shares	1,088
600	Marks & Spencer Ltd. 25p Ordinary Shares ..	1,792
£1,000	Middlesex County Council 6¼% Redeemable Stock 1975/7	973
£2,000	New Zealand 7¼% Stock 1977	1,987
500	Plessey Co. Ltd. 50p Ordinary Shares ..	1,074
400	Shell Transport & Trading Co. Ltd. 25p Ordinary Shares	1,442
£1,000	Slough Corporation 8¾% Redeemable Stock 1979/80	990
£521.20	Southern Rhodesia 6% Stock 1978/81 ..	515
£500	Stock Exchange 7¼% Mortgage Debenture Stock 1990/95	485
£500	Thorn Electrical Industries Ltd. 5% Convertible Unsecured Loan Stock 1990/4 ..	522
660	Transport Development Group Ltd. 25p Ordinary Shares	347
£2325.40	9% Treasury Stock 1978	2,100
£2,000	12% Treasury Stock 1983	1,910
500	United Gas Industries Ltd. 25p Ordinary Shares	413
		£31,280

Appendix 1

Membership of the Council and its Committees as at 31st March 1974

The Council of the Institution

President:

Ieuan Maddock, C.B., O.B.E., D.Sc., F.R.S. (*Fellow*)

Past Presidents:

Major-General Sir Leonard Atkinson, K.B.E., B.Sc. (*Fellow*)
Harvey F. Schwarz, C.B.E., B.Sc. (*Fellow*)
A. A. Dyson, O.B.E. (*Fellow*)

Vice-Presidents:

P. A. Allaway, C.B.E., D.Tech. (*Fellow*)
Professor G. B. B. Chaplin, M.Sc., Ph.D. (*Fellow*)
Air Commodore S. M. Davidson, C.B.E. (*Fellow*)
Professor W. Gosling, B.Sc. (*Fellow*)
A. St. Johnston, B.Sc. (*Fellow*)

Ordinary and ex-officio Members:

Captain A. W. Allen, R.N.(Ret.) (*Member*)*
P. Atkinson, B.Sc. (*Member*)*
Professor H. E. M. Barlow, Ph.D., F.R.S., F.C.G.I. (*Honorary Fellow*)
G. R. Barnes (*Member*)*
H. Blackburn (*Member*)
N. E. Broadberry (*Member*)*
D. Chalmers (*Fellow*)*
P. D. Cooper (*Member*)*
Professor D. E. N. Davies, D.Sc., Ph.D. (*Member*)
C. R. Fox (*Associate Member*)
D. J. Henman (*Member*)*
C. Heys (*Fellow*)*
R. C. Hills, B.Sc. (*Fellow*)
J. R. James, Ph.D. (*Member*)
I. D. Jefferies (*Member*)*
H.R.H. The Duke of Kent, G.C.M.G. G.C.V.O. (*Fellow*)
Brigadier R. Knowles, C.B.E. (*Fellow*)
G. Lauder, B.Sc. (*Member*)*
Professor D. W. Lewin, M.Sc. (*Member*)
P. L. Mothersole (*Fellow*)
Professor K. G. Nichols, B.Sc., M.Sc. (*Fellow*)
J. D. Parsons, B.Sc., M.Sc.(Eng.) (*Member*)*
G. Phillips (*Associate*)
J. Powell, M.Sc. (*Fellow*)
A. S. Prior (*Member*)*
A. M. Reid (*Member*)*
A. J. Shapland (*Member*)*
K. R. Tulley, B.A. (*Member*)*
M. M. Zepler, M.A. (*Member*)

Honorary Treasurer:

S. R. Wilkins (*Fellow*)

Director and Secretary:

Graham D. Clifford, C.M.G. (*Fellow*)

* *Chairman of a Local Section in Great Britain and* ex-officio *a Member of Council.*

Standing Committees of the Council

Executive Committee

Chairman:
The President

P. A. Allaway, C.B.E., D.Tech. (*Fellow*)
Major General Sir Leonard Atkinson, K.B.E., B.Sc. (*Fellow*)
A. A. Dyson, O.B.E. (*Fellow*)
Professor W. A. Gambling, Ph.D., D.Sc. (*Fellow*)
Professor W. Gosling, B.Sc. (*Fellow*)
D. W. Heightman (*Fellow*)
A. St. Johnson, B.Sc. (*Fellow*)
H. F. Schwarz, C.B.E., B.Sc. (*Fellow*)

Finance Committee

Chairman:
F. N. G. Leevers, B.Sc.(Eng.) (*Fellow*)

J. G. Geary, B.Sc. (*Fellow*)
D. W. Heightman (*Fellow*)
A. S. Pudner, M.B.E. (*Fellow*)
G. A. Taylor (*Fellow*)
S. R. Wilkins (*Fellow*)

Education and Training Committee

Chairman:
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)

H. Arthur, M.Sc., Ph.D. (*Fellow*)
Major General P. H. Girling, C.B., O.B.E. (*Fellow*)
B. F. Gray, B.Sc.(Eng.), A.C.G.I. (*Fellow*)
Professor D. P. Howson, B.Sc., M.Sc., D.Sc. (*Fellow*)
C. H. G. Jones (*Member*)
F. R. J. Langridge (*Fellow*)
Inst. Captain P. J. Poll, M.Sc., B.A. (*Member*)
W. D. Thomas (*Member*)
A. G. Wray, M.A. (*Fellow*)

Academic Standards Committee

Chairman:
K. E. Everett, Ph.D., M.Sc.(Eng.) (*Fellow*)

P. Atkinson, B.Sc.(Eng.) (*Member*)
W. L. Price, O.B.E., M.Sc. (*Fellow*)
A. Tranter, B.Sc.(Eng.) (*Member*)
Col. J. Vevers, O.B.E. (*Fellow*)

Membership Committee

Chairman:
J. Powell, B.Sc., M.Sc. (*Fellow*)

Rear Admiral Sir Peter Anson, Bt., C.B. (*Fellow*)
C. W. Brown, M.A. (*Member*)
R. F. C. Butler, M.A. (*Member*)
E. Carr (*Member*)
R. M. Clark (*Member*)
D. N. J. Cudlip (*Member*)
D. Dibsdall, O.B.E., B.Sc.(Eng.) (*Member*)
Wing Cdr. P. J. Dunlop, RAF(Ret.) (*Fellow*)
J. D. Esler (*Member*)
N. L. Garlick, M.Sc.(Eng.) (*Fellow*)
R. C. Hills, Esq., B.Sc.(Eng.) (*Fellow*)
H. Hudson (*Member*)
I. C. I. Lamb, M.B.E. (*Member*)
Col. R. W. A. Lonsdale, B.Sc., REME (*Fellow*)
G. H. Pegler (*Fellow*)
S. H. Perry (*Member*)
R. S. Roberts (*Fellow*)
S. J. H. Stevens, B.Sc.(Eng.) (*Fellow*)
Group Capt. G. Taplin, D.U.S., B.Sc., RAF (*Fellow*)
I. S. Thompson (*Member*)
W. F. Williams, B.Sc., Ph.D. (*Fellow*)
G. Wooldridge, M.Sc., Ph.D. (*Fellow*)
M. M. Zepler, M.A. (*Member*)

Professional Activities Committee

Chairman:
Professor W. Gosling, B.Sc. (*Fellow*)

Lt. Col. F. G. Barnes, M.A. (*Member*)
Professor D. S. Campbell, B.Sc., D.Sc., D.I.C. (*Fellow*)
J. R. Halsall, Dip.El. (*Member*)
A. Hann, Esq., B.Sc. (*Fellow*)
Brigadier R. Knowles, C.B.E. (*Fellow*)
R. Larry (*Fellow*)
F. Oakes (*Fellow*)
J. M. Peters, M.Sc.(Eng.) (*Fellow*)
A. St. Johnston, B.Sc. (*Fellow*)
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)
F. E. Whiteway, B.Sc.(Eng.) (*Fellow*)
W. E. Willison (*Member*)

Papers Committee

Chairman:
J. R. James, Ph.D., B.Sc. (*Member*)

L. W. Barclay, B.Sc. (*Fellow*)
J. Bilbrough (*Fellow*)
L. A. Bonvini (*Fellow*)
H. R. Bristow, Ph.D. (*Member*)
W. G. Burrows, Ph.D. (*Member*)
R. J. Cox, B.Sc. (*Member*)
K. J. Dean, Ph.D., M.Sc. (*Fellow*)
Professor E. A. Faulkner, Ph.D. (*Fellow*)
K. G. Freeman, B.Sc. (*Member*)
Professor D. W. Lewin, M.Sc. (*Member*)
T. B. McCrirrick (*Fellow*)
E. Robinson, Ph.D. (*Fellow*)
L. A. Smulian, B.Sc. (*Fellow*)
A. G. Wray, M.A. (*Fellow*)

Trustees of the Institution Benevolent Fund

Colonel G. W. Raby, C.B.E. (*Fellow*)
The President (*ex-officio*)
G. A. Taylor (*Fellow*), *Honorary Treasurer*
Graham D. Clifford, C.M.G. (*Fellow*) *Honorary Secretary*

Specialized Group Committees

Aerospace, Maritime and Military Systems

Chairman:
T. W. Welch (*Fellow*)

N. G. V. Anslow (*Member*)
Lt. Col. W. Barker, REME (*Member*)
Professor J. W. R. Griffiths, Ph.D. (*Fellow*)
A. Hann, B.Sc. (*Fellow*)
A. Harrison, B.Sc. (*Fellow*)
J. A. C. Kinnear (*Fellow*)
R. N. Lord, M.A. (*Member*)
C. H. Nicholson (*Fellow*)
D. M. O'Hanlon (*Fellow*)
C. Powell (*Fellow*)
J. Savage (*Companion*)
Wing Cdr. G. E. Trevains, RAF (*Fellow*)
R. M. Trim, O.B.E. (*Fellow*)
K. Vesely (*Fellow*)

Automation and Control Systems

Chairman:
Professor D. R. Towill, M.Sc. (*Fellow*)

P. Atkinson, B.Sc.(Eng.), A.C.G.I. (*Member*)
M. S. Birkin (*Member*)
M. T. Challenger (*Member*)
A. E. Crawford (*Fellow*)
A. F. Giles, B.Sc. (*Fellow*)
J. R. Hallsall, Dip.El. (*Member*)
W. F. Hilton, D.Sc. (*Fellow*)
Inst. Cdr. D. J. Kenner, RN(Ret.) (*Member*)
Brigadier R. Knowles, C.B.E. (*Fellow*)
J. L. Paterson (*Member*)
R. W. A. Siddle (*Member*)
D. E. O'N. Waddington (*Member*)

Communications

Chairman:
Professor J. W. R. Griffiths, Ph.D. (*Fellow*)

A. R. Bailey, M.Sc., Ph.D. (*Fellow*)
L. W. Barclay, B.Sc. (*Fellow*)
R. W. Cannon (*Fellow*)
Professor D. E. N. Davies, D.Sc., Ph.D. (*Member*)
L. W. Germany (*Fellow*)
A. N. Heightman (*Fellow*)
R. C. Hills, B.Sc. (*Fellow*)
Cdr. D. W. Jackson, RN (*Member*)
J. J. Jarrett (*Member*)
G. R. Jessop (*Member*)
A. A. Kay (*Fellow*)
R. Larry (*Fellow*)
P. L. Mothersole (*Fellow*)
R. S. Roberts (*Fellow*)
J. Savage (*Companion*)
K. E. Ward (*Member*)
M. M. Zepler, M.A. (*Member*)

Components and Circuits

Chairman:
Professor D. S. Campbell, D.Sc. (*Fellow*)

W. D. Benson (*Member*)
J. S. Brothers (*Member*)
G. W. A. Dummer, M.B.E. (*Fellow*)
A. F. Dyson (*Member*)
Professor A. G. J. Holt (*Member*)
J. B. Lock (*Member*)
D. R. Ollington (*Fellow*)
F. G. Parker, B.Sc. (*Member*)
A. Pugh, Ph.D. (*Member*)

Computer

Chairman:
Professor D. W. Lewin, M.Sc. (*Member*)

Lt. Col. W. Barker, REME (*Member*)
K. D. F. Chisholm (*Fellow*)
S. G. Crow (*Fellow*)
K. J. Dean, M.Sc., Ph.D. (*Fellow*)
P. M. Elliott (*Member*)
G. S. Evans (*Fellow*)
D. Hogg (*Fellow*)
D. T. Law (*Member*)
D. M. MacLean, B.Sc. (*Fellow*)
Wing Cdr. D. G. L. Packer, D.U.S., RAF (*Member*
T. J. Stakemire (*Member*)
E. R. Tomlinson (*Member*)
W. E. Willison (*Member*)

Management Techniques

Chairman:
Air Commodore S. M. Davidson, C.B.E. (*Fellow*)

D. W. Bradfield, B.Sc. (*Member*)
P. Diederich (*Member*)
G. L. Hamburger, Dr. Ing. (*Fellow*)
J. Langham Thompson (*Fellow*)
M. W. Lauerman, M.A. (*Member*)
D. M. Neale, B.Sc. (*Fellow*)
F. Oakes (*Fellow*)
D. Simpson (*Fellow*)
S. J. H. Stevens, B.Sc.(Eng.) (*Fellow*)
F. J. Wakefield (*Member*)

Medical and Biological Electronics

Chairman:
R. Brennand (*Member*)

C. M. Cade (*Fellow*)
K. Copeland (*Member*)
R. E. George (*Member*)
W. G. Gore (*Member*)
A. J. Huelin (*Member*)
L. W. Price, M.A. (*Member*)
D. W. Thomas, Ph.D. (*Member*)

Appendix 2

Representatives of the Institution on the Board and Committees of the Council of Engineering Institutions

Board
Major-General Sir Leonard Atkinson, K.B.E., B.Sc. (*Past President*) (until 24th January 1974)
Professor Emrys Williams, Ph.D., B.Eng. (*Past President*)*
Graham D. Clifford, C.M.G. (*Fellow*)
P. A. Allaway, C.B.E., D.Tech. (*Fellow*) (from 22nd February 1974)

General Purposes and Finance Committee
Major-General Sir Leonard Atkinson, K.B.E., B.Sc. (*Past President*)

Finance Sub-Committee
J. Langham Thompson (*Past President*)

Education and Training Committee
Professor Emrys Williams, Ph.D., B.Eng. (*Past President*)*

Exemptions Sub-Committee
K. E. Everett, Ph.D., M.Sc. (*Fellow*)

Training Sub-Committee
H. Arthur, M.Sc., Ph.D. (*Fellow*)

Careers and Recruitment Sub-Committee
D. L. A. Smith, B.Sc. (*Fellow*)

* Professor Williams died on 13th February 1974.

Student and Graduate Recruitment Sub-Committee
Major-General Sir Leonard Atkinson, K.B.E., B.Sc. (*Past President*): *Chairman*

Membership Committee
J. Langham Thompson (*Past President*)

Overseas Relations Committee
Graham D. Clifford, C.M.G. (*Fellow*)

The above Committees were replaced by the following new Committee structure as from 24th January 1974.

Executive Committee
P. A. Allaway, C.B.E., D.Tech. (*Fellow*)

Standing Committee A
Professor Emrys Williams, Ph.D., B.Eng. (*Past President*)*

Standing Committee B
Professor W. Gosling, B.Sc. (*Fellow*)

Standing Committee C
R. J. Clayton, C.B.E., M.A.†

† Joint representation of IEE and IERE.

EEC Working Party
G. Wooldridge, M.Sc., Ph.D. (*Fellow*)

Board Working Party on Industrial Affairs
M. W. Lauerman, M.A. (*Member*)

CEI–CSTI Interdisciplinary Board
R. C. Slater (*Member*)

Council for Environmental Science and Engineering
Professor H. E. M. Barlow, Ph.D., F.R.S. (*Honorary Member*)

British National Committee on Ocean Engineering
P. W. Warden (*Member*)
M. J. Tucker, B.Sc. (*Member*) (*Alternate*)

Engineers Registration Board
Technician Engineer Section Board, Supervisory Committee and Admission Committee
K. J. Coppin, B.Sc. (*Member*)
Technician Engineer Section Qualifications Committee
Colonel R. W. A. Lonsdale, B.Sc. (*Fellow*)

Appendix 3

Institution Representation at Universities, Polytechnics and Colleges

University of Aston in Birmingham
Convocation
Professor D. G. Tucker, D.Sc., Ph.D. (*Fellow*)

Barnsley College of Technology
Engineering Advisory Committee
D. Shaw, B.Sc. (*Fellow*)

Bournemouth College of Technology
Electrical Engineering Advisory Committee
J. F. Noyes (*Member*)

University of Bradford
Court
Major-General Sir Leonard Atkinson, K.B.E., B.Sc. (*Past President*)

Darlington College of Technology
Electrical Engineering and Science Advisory Committee
R. W. Blouet (*Member*)

East Ham Technical College
Electrical Engineering Advisory Committee
D. W. Bradfield, B.Sc. (*Member*)

Glamorgan Polytechnic
Advisory Committee for Electrical Enginering
I. D. Dodd, B.Sc. (*Member*)
Advisory Committee for Applied Physics
Professor Emrys Williams, Ph.D., B.Eng. (*Past President*)*

Glasgow College of Technology
Advisory Board
R. D. Pittilo, B.Sc. (*Member*)

City of Gloucester College of Technology
Electrical Engineering Advisory Committee
H. V. Sims (*Fellow*)

Huddersfield Technical College
Engineering Advisory Committee
R. Barnes (*Member*)

City of Liverpool Polytechnic
Electrical Engineering Advisory Committee
A. W. Mews (*Member*)†

Newport and Monmouthshire College of Technology
Engineering Advisory Committee
Professor Emrys Williams, Ph.D., B.Eng. (*Past President*)*

* Professor Williams died on 13th February 1974.

City of Nottingham Education Committee
Electrical Engineering Advisory Committee
F. W. Hopwood (*Member*)

Reading College of Technology
Board of Governors
Major-General Sir Leonard Atkinson, K.B.E., B.Sc. (*Past President*)

Southall College of Technology
Governing Body
B. S. Pover (*Member*)
Administrative Committee
A. G. Wray, M.A. (*Fellow*)

South East London Polytechnic
Governing Body
J. I. Collins (*Fellow*)
Electrical Engineering and Applied Physics Consultative Committee
L. W. D. Pittendrigh (*Fellow*)

Southampton College of Technology
Engineering and Science Advisory Committee
Professor K. G. Nichols, M.Sc. (*Fellow*)

Stannington College of Further Education, Sheffield
Electrical and Telecommunications Consultative Committee
P. A. Bennett (*Fellow*)

University of Surrey
Court
Graham D. Clifford, C.M.G. (*Fellow*)

Wakefield College of Art and Technology
Engineering Advisory Committee
G. F. Lane-Fox (*Member*)

University of Wales Institute of Science and Technology
Court
Professor Emrys Williams, Ph.D., B.Eng. (*Past President*)*

Watford College of Technology
Engineering Advisory Committee
F. P. Thompson (*Member*)

Widnes Technical College
Electrical and Instrument Engineering Advisory Committee
D. Chalmers (*Fellow*)

Willesden College of Technology
Electrical Engineering Advisory Committee
F. A. Wilson, C.G.I.A. (*Member*)

† Mr. Mews died on 3rd June 1974

Appendix 4

Representatives on Joint Committees for the Awards of National Certificates and Diplomas in Engineering

England and Wales

Higher National Certificates and Diplomas in Electrical and Electronic Engineering
B. F. Gray, B.Sc.(Eng.) (*Fellow*): *Chairman*
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)
A. Tranter, B.Sc.(Eng.) (*Fellow*)

Ordinary National Certificates and Diplomas in Engineering
B. F. Gray, B.Sc.(Eng.) (*Fellow*)

Scotland

National Certificates in Electrical and Electronic Engineering
D. S. Gordon, Ph.D., B.Sc. (*Member*)
A. L. Whitewell, B.Sc. (*Fellow*)

Northern Ireland

Higher National Certificates in Electrical and Electronic Engineering
Captain A. W. Allen, RN(Ret.) (*Member*)
J. A. C. Craig, B.Sc. (*Member*)

Ordinary National Certificates and Diplomas in Engineering
J. A. C. Craig, B.Sc. (*Member*)

Appendix 5

Institution Representation on Other Educational Bodies

City and Guilds of London Institute
Telecommunications Advisory Committee
B. F. Gray, B.Sc.(Eng.) (*Fellow*)
Joint Advisory Committee for Radio, Television and Electronics
W. B. K. Ellis, B.Sc. (*Member*)
Radio Amateurs' Examination Advisory Committee
R. G. D. Holmes (*Fellow*)

Council for National Academic Awards
Electrical and Electronic Engineering Board
B. F. Gray, B.Sc.(Eng.) (*Fellow*)
A. G. Wray, M.A. (*Fellow*)

London and Home Counties Regional Advisory Council for Technological Education
Advisory Committee on Electrical and Electronic Engineering
K. J. Coppin, B.Sc. (*Member*)

North Western Regional Advisory Council for Further Education
Specialist Advisory Committee for Nautical Education
A. G. Brown (*Member*)

Radio, Television and Electronics Examination Board
W. B. K. Ellis, B.Sc. (*Member*)
J. W. Graham (*Member*)
N. G. Green (*Member*)

Yorkshire Council for Further Education
Engineering County Advisory Committee
F. O. M. Bennewitz (*Member*)

Appendix 6

Members Appointed to Represent the Institution on External Bodies

Royal Society
Committee on Scientific Information
Admiral of the Fleet the Earl Mountbatten of Burma, K.G., F.R.S. (*Past President*)
Panel on Mechanized Information Retrieval
Graham D. Clifford, C.M.G. (Fellow)

Convention of the Electrotechnical Societies of Western Europe
Professor W. Gosling, Ph.D. (*Fellow*)
R. C. Slater (*Member*)

British National Committee for Non-Destructive Testing
A. Nemet, Dr.Ing. (*Fellow*)

British Nuclear Energy Society
R. J. Cox, B.Sc. (*Member*)

IEE Committee on Radio Equipment for Civil Aircraft
R. N. Lord, M.A. (*Member*)

Medical Research Council Committee on Non-Ionizing Radiations
R. N. Lord, M.A. (*Member*)

National Council for Quality and Reliability
F. G. Diver, M.B.E. (*Fellow*)

National Electronics Council
I. Maddock, C.B., O.B.E., D.Sc., F.R.S. (*President*)
Graham D. Clifford, C.M.G. (*Fellow*)

Parliamentary and Scientific Committee
Executive Committee
J. Langham Thompson (*Past President*)
Graham D. Clifford, C.M.G. (*Fellow*)

British Electrotechnical Approvals Board
R. S. Roberts (*Fellow*)

Economic Development Committee for the Electronics Industry
Working Group on Scientific and Technological Manpower
Graham D. Clifford, C.M.G. (*Fellow*)

Association of Learned and Professional Society Publishers
F. W. Sharp (*Fellow*)

UK Automation Council
A. St. Johnston, B.Sc. (*Fellow*)

UK Liaison Committee for Sciences Allied to Medicine and Biology
R. E. George, B.Sc. (*Member*)

Standing Committee of Kindred Societies
Major-General Sir Leonard Atkinson, K.B.E., B.Sc. (*Past President*)
Graham D. Clifford, C.M.G. (*Fellow*)

Appendix 7

Members representing the IERE on Technical Committees of the British Standards Institution

TLE/–	**Telecommunication Industry Standards Committee**	Brigadier R. Knowles, C.B.E. (*Fellow*)
TLE/5	**Electronic Tubes and Valves**	G. R. Jessop (*Member*)
TLE/5/8	**Tube and Valve Performance—Light Conversion**	I. J. P. James, B.Sc. (*Fellow*)
TLE/8/7	**Electronic Instruments for Voltage Measurement**	D. L. A. Smith, B.Sc. (*Fellow*)
TLE/8/8	**Oscilloscopes**	D. Styles (*Member*)
TLE/12/5	**Microwave Semiconductor Devices**	R. R. Harman (*Member*)
TLE/16	**Electronic Reliability**	Brigadier R. Knowles, C.B.E. (*Fellow*)
TLE/17	**Integrated Electronic Circuits**	T. M. Ball (*Member*)
TLE/17/1	**Performance of Integrated Electronic Circuits**	T. M. Ball (*Member*)
TLE/23	**Safety of Telecommunication and Electronic Components and Equipment**	Lt. Col. F. R. Spragg, REME (*Fellow*) and D. M. Field (*Member*)
TLE/24	**Electro-Acoustics**	S. Kelly (*Fellow*)
TLE/24/1	**Audio Engineering**	S. Kelly (*Fellow*)
TLE/25	**Radio Communications**	R. Larry (*Fellow*)
TLE/25/4	**Aerials**	C. Hale (*Member*)
TLE/26	**Performance of Household High Fidelity Audio Equipment**	R. S. Roberts (*Fellow*)
E/–/12	**Maintenance/Terotechnology**	L. A. Bonvini (*Fellow*) Colonel R. W. A. Lonsdale (*Member*)
ELE/103	**Medical Electrical and Radiological Equipment**	R. Brennand (*Member*)
ELE/103/2	**Electro-Medical Equipment**	A. J. Huelin (*Member*)
ELE/103/–/4	**Safety—Medical Electrical and Radiological Equipment**	A. J. Huelin (*Member*)
ELE/103/–/5	**Installations—Medical Electrical and Radiological Equipment**	A. J. Huelin (*Member*)
ELE/TLE/1	**Terminology Common to Power and Telecommunications**	E. H. Jones, B.Sc.(Eng.) (*Fellow*)
ELE/TLE/1/1	**Fundamental Terminology**	E. H. Jones, B.Sc.(Eng.) (*Fellow*)
ELE/TLE/1/10	**General Heavy Electrical Terminology**	E. H. Jones, B.Sc.(Eng.) (*Fellow*)
ELE/TLE/1/20	**Magnetism Terminology**	E. H. Jones, B.Sc.(Eng.) (*Fellow*)
ELE/TLE/2	**Graphical Symbols for Electrical Engineering and Telecommunications**	R. A. Ganderton (*Member*)
MEE/10/2	**Drawing Practice for Point to Point and Circuit Diagrams**	D. M. Field (*Member*)
M/68/6	**Audio Aids (School Music)**	M. H. Evans (*Member*)
ELCP/–	**Codes of Practice Committee for Electrical Engineering**	Brigadier R. Knowles, C.B.E. (*Fellow*)
ELCP/29	**Diodes, Transistors and Related Semiconductor Devices**	G. Hennessey (*Fellow*)

Committees of Sections outside Great Britain also nominate members to serve on national bodies and this information is circulated to local members. In countries where there is no formal local section there is usually a member who acts as an Institution representative and is prepared to assist in local affairs involving a knowledge of radio and electronic engineering.

Appendix 8

Award of Institution Premiums for 1973

Main Premiums

HEINRICH HERTZ PREMIUM *Value £50*
(Physical or mathematical aspects of electronics or radio)
'The Theory of Cylindrical Antennas with Lumped Impedance Loadings'
by Professor B. D. Popović (University of Belgrade).
(Published in the April 1973 issue of the Journal)

MARCONI PREMIUM *Value £50*
(Engineering of an electronic system, circuit or device)
'Multiple Channel U.H.F. Reception on Naval Ships'
by H. P. Mason (Admiralty Surface Weapons Establishment).
(May)

Specialized Technical Premiums

LORD BRABAZON PREMIUM *Value £25*
(Aerospace, maritime or military systems)
'Data Compression Techniques as a Means of Reducing the Storage Requirements for Satellite Data: A Quantitative Comparison'
by Dr. L. F. Turner (Imperial College).
(October)

A. F. BULGIN PREMIUM *Value £25*
(Theory or practice of electronic components or circuits)
'The Design of a Precision Video Delay Line'
by L. E. Weaver (B.B.C. Designs Department).
(December)

REDIFFUSION TELEVISION PREMIUM *Value £50*
(Advances in communications or broadcasting engineering)
'An Experimental Differential P.C.M. Encoder–Decoder for Viewphone Signals'
by G. A. Gerrard and Dr. J. E. Thompson (Post Office Research Department).
(March)

P. PERRING THOMS PREMIUM *Value £50*
(Radio or television receiver theory or practice)
'A V.H.F. Surveillance Receiver Adapted for the Reception of Suppressed Carrier Double-Sideband Transmission'
by Dr. R. C. V. Macario (University College, Swansea).
(July)

J. LANGHAM THOMPSON PREMIUM *Value £50*
(Theory or practice of control engineering)
'The Application of a Commutated Filter to the Design of a Frequency Response Analyser'
by Dr. C. J. Paull (University of Nottingham) and W. A. Evans (University College, Swansea).
(June)

SIR CHARLES WHEATSTONE PREMIUM *Value £25*
(Electronic instrumentation or measurement)
'The Computation of Best Windward and Running Courses for Sailing Yachts'
by J. Elliot (EMI Electronics).
(December)

General Premiums

ARTHUR GAY PREMIUM *Value £25*
(Production techniques in the electronics industry)
Electrolytic Capacitors: Their Fabrication and Interpretation of Their Operational Behaviour'
by Dr. A. R. Morley (Plessey Company) and Professor D. S. Campbell (Loughborough University of Technology).
(July)

ADMIRAL SIR HENRY JACKSON PREMIUM *Value £25*
(History of radio or electronics)
'The Struggle for Power, Frequency and Bandwidth'
by C. S. den Brinker (Texas Instruments).
(January/February)

ERIC ZEPL PREMIUERM *Value £25*
(Education of electronic and radio engineers)
'The Influence of Semiconductors on the Teaching of Electronics'
by Dr. K. J. Dean (South East London Technical College).
(January/February)

The following Premiums are withheld because there were not any sufficiently outstanding papers falling within the terms of award.

CLERK MAXWELL PREMIUM *Value £75*
(Most outstanding paper of the year irrespective of subject)

CHARLES BABBAGE PREMIUM *Value £25*
(Electronic computers)

LESLIE MCMICHAEL PREMIUM *Value £25*
(Management techniques in electronic engineering)

DR. NORMAN PARTRIDGE PREMIUM *Value £25*
(Audio frequency engineering)

LORD RUTHERFORD PREMIUM *Value £25*
(Nuclear physics or engineering)

DR. V. K. ZWORYKIN PREMIUM *Value £50*
(Medical and biological electronics)

SIR JAGADIS CHANDRA BOSE PREMIUM *Value £25*
(Indian paper)

HUGH BRENNAN PREMIUM *Value £25*
(North Eastern Section paper)

LOCAL SECTIONS PREMIUM *Value £25*
(Read before Local Section in British Isles and subsequently published in the Journal)

IERE News and Commentary

Subscription Rates for 1975

Subscribers to the Journal are asked to note that from January 1975, subscription rates will be as follows:

	£ Sterling	$US Dollars	Rs Rupees
1 year	14·00	38·00	250
2 years	25·00	68·00	450
3 years	35·00	96·00	630
Single copies	1·25	3·50	23

All the above rates include postage by surface mail.

The last increase in the subscription rates was made two years ago since when the overall costs of printing, paper and postage alone have risen very considerably.

Reduced Rates for IEE Publications

Under the mutual arrangements existing between the two Institutions, members of the IERE may subscribe to IEE periodicals at the following reduced rates which apply for 1975. (The subscriptions to non-member customers are shown in brackets.)

Electronics and Power	£14·25	(£19·00)
Single copy	£ 1·40	(£ 1·90)
Proceedings IEE (p or m)*	£44·25	(£59·00)
Combined p and m	£66·40	(£88·50)
Single copy p or m	£ 4·50	(£ 6·00)
Electronics Record	£15·00	(£20·00)
Single copy	£ 4·50	(£ 6·00)
Power Record	£15·00	(£20·00)
Single copy	£ 4·50	(£ 6·00)
Control & Science Record	£15·00	(£20·00)
Single copy	£ 4·50	(£ 6·00)
Electronics Letters (p or m)	£27·00	(£36·00)
Combined p and m	£40·50	(£54·00)
Single copy p or m	£ 2·50	(£ 3·60)

* paper or microfiche

Rates for airmail supplement will be supplied on request. Members are asked to place their orders through the IERE Publications Department, 9 Bedford Square, London, WC1B 3RG, to ensure that they are granted the special rate.

Golden Jubilee of the Institution

The meeting at which this Institution was formed was held in London on 31st October 1925. During 1975–1976 a series of commemorative events will be held and details of these will be announced in the Journal.

The opening event of what will undoubtedly be a memorable year will be an Institution banquet at the Guildhall, City of London, on Thursday, 23rd October 1975.

In July 1976 the Golden Jubilee convention will be held at the University of Cambridge and will provide a unique survey of the past, present and future of electronics and radio engineering.

Conference on 'Instrumentation in Oceanography'

A Conference on 'Instrumentation in Oceanography' will be held at the University College of North Wales, Bangor, from 23rd to 25th September 1975. It is being organized by the Institution of Electronic and Radio Engineers, with the association of The Institution of Electrical Engineers, The Institute of Electrical and Electronics Engineers, The Institute of Physics, The Institute of Acoustics, The Royal Institute of Navigation and The Society for Underwater Technology.

In 1966 the IERE organized the first Conference to be held in Europe on 'Electronic Engineering in Oceanography'. This was held at the University of Southampton. It was followed by a second Conference on 'Electronic Engineering in Ocean Technology' which was held at University College of Swansea in September 1970. Both of these Conferences were attended by international audiences.

Ocean technology is an area of continuing progress and of increasing interest. Indeed, throughout the world there is a growing awareness of the need to exploit the resources both in and under the oceans. It is for this reason, that in September 1975, the third Conference in this series will be held under the title of 'Instrumentation in Oceanography'. The Conference will be of three days duration and the venue this time will be the University College of North Wales, Bangor, which itself has a flourishing department of physical oceanography.

Offers of papers for presentation at this Conference are now invited. These should describe new work on any aspect of 'Instrumentation in Oceanography' including the following:

- Sea Bed Exploration
- Fisheries
- Precision Navigation
- Underwater Navigation and Communication
- Hydrographic Survey
- Oceanographic Sensors
- Telemetry

Members and others wishing to offer papers for presentation should submit a synopsis of 200 to 300 words as soon as possible and not later than 31st December 1974. Offers of papers and requests for further information should be addressed to: The Conference Secretariat, Institution of Electronic and Radio Engineers, 9 Bedford Square, London WC1B 3RG. (Telephone 01-637 2771).

Nominations for John Smeaton Award

As announced in the June Journal, CEI in association with the Smetonian Society, is establishing an award for outstanding achievements in engineering to mark the 250th anniversary of the birth of the eminent engineer John Smeaton. Nominations for the first award, to include a brief citation, are requested to be notified to CEI's Secretary by the end of October, 1974, for consideration by the Award Committee under the chairmanship of Sir Angus Paton, Immediate Past Chairman of CEI.

Training in the Practical Use of Vacuum

The British Vacuum Council, comprising representatives of the Institution of Electrical Engineers, the Institution of Mechanical Engineers, the Institute of Physics and the Metal Society, and an observer on behalf of the Institution of Electronic and Radio Engineers, has established a committee to consider whether the facilities for training in the practical use of vacuum science and technology available in this country are adequate to the needs of science and industry and what action could be taken or promoted by the Council to remedy any deficiencies.

Members working in any field in which vacuum (coarse to ultra-high) has significant applications are invited to express their views to the British Vacuum Council on the adequancy or otherwise of training facilities in this country, and the type of remedial action which they think most appropriate. Replies should be as specific as possible on such matters as the level of sophistication appropriate to the particular field of interest; the aspects of vacuum of principal concern; and the delicate matter of what level of investment in time and money in such training would be justified. It does not matter if the problems are specific to a narrow field; such specific and practical considerations will lend point and realism to the discussions of the committee.

Contributions should be sent without delay to the Deputy Secretary, IERE, who will arrange for them to be sent to the British Vacuum Council.

Winston Churchill Travelling Fellowships

The Winston Churchill Memorial Trust has announced the categories for which Fellowships will be given in 1975.

Two of the categories may well be of interest to professional engineers, namely for designers for safety in the home, and on worker participation. In addition, for the first time there is an 'open category' under which awards will be made to those having an outstanding project which could benefit by a visit to countries overseas.

Requests for forms to apply for Fellowships should be sent to: The Winston Churchill Memorial Trust, 15 Queen's Gate Terrace, London, SW7 5PR, sufficiently early to enable the completed application form to reach the Trust Office by 6th November 1974.

Further information can be obtained from the above address or by telephoning 01-584-9315.

The Queen's Award to Industry 1975

The Office of The Queen's Award to Industry have announced that application forms for the 1975 Awards are now available. The Award can be applied for by United Kingdom based organizations of any size producing goods or providing services, who seek recognition for outstanding achievement in increasing the exports of this country or in advancement of product or process technology.

The last date for application is October 31st, 1974. Guidance notes are incorporated in the application forms. Enquiries about eligibility for the Award and application forms should be made to: The Secretary, Office of The Queen's Award to Industry, 1 Victoria Street, London, SW1H OET (Tel: 01-222-2277).

The Queen's Award Scheme was instituted by Royal Warrant in 1965 and is made to 'industrial units' and not to individuals. Any organization in the United Kingdom, the Channel Islands or the Isle of Man contributing to either the visible or 'invisible' foreign currency earnings of the country, or a significant advance in the application of technology is eligible to apply to the extent that it carries out activities which meet the Award criteria.

The Awards are made by the Queen on the advice of the Prime Minister, who is assisted in making his recommendations by an Advisory Committee which includes representatives of industry and commerce, the trade unions and the engineering institutions. The Awards, which are announced each year on the Queen's actual birthday, April 21st, are held for 5 years with entitlement during that period to use the emblem of the Award in a variety of ways.

Design Council 'Molins' Design Prize

An annual competition to encourage the art, science and practice of engineering design in mechanical, electrical and electronic engineering in universities, colleges and polytechnics has been announced by the Design Council. Called the Design Council 'Molins' Design Prize, the scheme has been sponsored by Molins Ltd, the precision engineering company based in South-East London, and will be administered by the Design Council, in association with the Institution of Mechanical Engineers and the Institution of Electrical Engineers.

Prizes will be given annually and the competition will be open to students (excluding post-graduates) following diploma or degree courses in engineering or engineering science at a university, college or polytechnic in Great Britain. Students undertaking courses in other disciplines may also be eligible at the discretion of the organizers. Entries must be made through colleges and each college will be allowed only one submission per year.

Three principal prizes of £500, £250 and £100 will be given and, in addition, the judges will have the right to commend other submissions they feel worthy of particular note. The judging panel will be selected by the Design Council in association with the Institution of Mechanical Engineers and the Institution of Electrical Engineers.

The closing date of first submissions is 31st October 1974 and the winners will be announced early in 1975. Full details and submission forms for the competition can be obtained from Mr. Anthony H. L. Key, The Design Council, 28 Haymarket, London SW1, Y4SU (Telephone 01 839 8000).

OBITUARY

Sir Robert Wynne-Edwards, C.B.E., D.S.O., M.C., M.A., C.Eng., F.I.C.E.

All Chartered Engineers will learn with great regret of the death on 22nd June, at the age of 77, of Sir Robert Wynne-Edwards, the Council's first Chairman and a former President of the Institution of Civil Engineers. Sir Robert spent about half his career as a Contractor's engineer on civil engineering projects, originally in Canada and later in Britain, during which time he was engaged in both construction and design in the fields of heavy underwater foundations, harbour work, hard and soft ground tunnelling, large-scale excavation and dams.

During the Second World War Sir Robert was seconded, as Director of Plant, to the Ministry of Works. In 1945 he became a director of Richard Costain Limited who later set up with John Brown and Company a firm—Costain John Brown—for building oil refineries. Sir Robert became managing director of this company in 1948. Although remaining on the Board, Sir Robert resigned as managing director shortly before his election as President of the Institution of Civil Engineers in 1964. Sir Robert received a knighthood as Chairman of CEI in 1965. Characteristically he accepted chairmanship of CEI in 1964, knowing that for one year this onerous appointment would overlap with that of being President of ICE (1964–65).

Members' Appointments

CORPORATE MEMBERS

Mr. John R. Brinkley (Fellow 1952, Member 1948), who has been Managing Director of Redifon Telecommunications Ltd. for the past two years, has now also been appointed Chairman of the Company; he has joined the Board of Rediffusion Ltd., and has been appointed Chairman of Redifon Electronic Systems Ltd., and a member of the Board of Redifon Flight Simulation Ltd.

Sqn. Ldr. J. M. Brown, RAF (Fellow 1973, Member 1959), who was Officer Commanding Radar Support Squadron at RAF Staxton Wold, has moved to the Royal Radar Establishment as Senior Project Officer (ADRS) on the Radio Introduction Unit.

Brigadier Royston Knowles, C.B.E. (Fellow 1962) retired from the Army on 1st July; his final appointment was Project Manager responsible for co-ordinating future REME management and engineering information systems at HQ Technical Group REME. Brigadier Knowles has been a member of the Council of the Institution since 1972 and he serves on the Professional Activities Committee and the Automation and Control Systems Group Committee; he is Chairman of the Organizing Committee for the forthcoming conference on Advances in Automatic Testing Technology. In September Brigadier Knowles will take up the appointment of Secretary of the Institute of Quality Assurance.

Professor G. D. Sims, O.B.E., Ph.D. (Fellow 1966) has been appointed Vice-Chancellor of the University of Sheffield. Since 1963 he has been Professor and Head of the Department of Electronics at the University of Southampton and has held the posts of Dean of the Faculty of Engineering and Applied Science, and Senior Deputy Vice-Chancellor. Professor Sims has a formidable list of Government, academic and other appointments to his credit and he has recently been appointed to the Annan Committee of Inquiry into the Future of Broadcasting. He has been a member of the British Library Organizing Committee and serves on the Economic Development Council for the Electronics Industry, being Chairman of its Manpower Working Group, which produced notable reports on 'Manpower in the Electronics Industry' (1971) and 'Electronics and the Schools' (1972). Professor Sims is a graduate of Imperial College, University of London, and before his appointment as Lecturer in the Department of Electrical Engineering at University College, London, he was for six years at the Research Laboratories of the General Electricity Company and for two years at the Atomic Energy Research Establishment. He has written about 50 papers on various aspects of electronics and education including Journal papers on 'Microwave Semiconductor Devices' and (as a co-author) on 'The Future Education of Electronic Engineers'.

Sqn. Ldr. P. S. Baxter, RAF (Ret) (Member 1969) has joined Shawinigan Engineering Co. Ltd. of Montreal as Assistant Project Manager for two Canadian International Development Agency (CIDA) power transmission projects in Tanzania. Before his retirement from the RAF in February of this year, Sqn. Ldr. Baxter was for three years Staff Engineer Officer, Communications and Electronics Division, at NATO Headquarters, Oslo.

Sqn. Ldr. H. M. Bryant, RAF (Ret.) (Member 1956) has joined the Jet Propulsion Laboratory at Pasadena, California, where he will be concerned with NASA's *Mariner-Viking* project which involves, in particular, the proposed safe landing on Mars on 4th July 1976. For the past five years Sqn. Ldr. Bryant was at the Hartebeesthoek Deep Space Tracking Station in South Africa.

Mr. E. E. Clark, B.E.M. (Member 1963, Graduate 1958) is now General Manager of Underwater and Marine Equipment Ltd., Farnborough, Hants. He was previously with Elliott Automation at Frimley.

Mr. B. R. Clifford (Member 1972, Graduate 1967), who is an Engineer III with the Ministry of Defence Procurement Executive, has been appointed Resident Technical Officer (Naval) at the Rochester works of Marconi Elliott Avionic Systems Ltd.

Mr. G. D. Cutler (Member 1958) is now Chairman and Joint Managing Director of Tekflo Ltd., Weymouth. He was previously with Elmed Ltd., also of Weymouth.

Mr. P. F. Davies, M.Sc. (Member 1973, Graduate 1968), who was a Senior Engineer with Hawker Siddeley Dynamics, has been appointed Research Officer in the Scientific Services Department of the Central Electricity Generating Board, Harrogate.

Mr. R. Deb Gupta, B.Sc.(Eng.) (Member 1973), who was a Design and Development Engineer with AEG Telefunken, Berlin, for four years, has joined GEC-Elliott Automation Ltd., Lewisham, as a Design Engineer concerned with digital systems.

Mr. G. A. Duguid (Member 1971), who joined Rank Video in January this year as a Senior Engineer in charge of the computer controlled editing complex, has now been appointed Planning and Installation Supervisor.

Cdr. M. G. M. W. Ellis, RN (Member 1972) has been appointed a Lecturer in the Faculty of Tactics and Weapons in the US Naval War College at Newport, Rhode Island. He was previously in the Directorate of Naval Operational Requirements, Ministry of Defence.

Sqn. Ldr. R. K. Gray, Dip.El., B.Sc. (Member 1961) has been posted to the Headquarters of RAF Training Command, Brampton, Huntingdonshire. He was previously at the RAF Technical College at Halton.

Mr. M. R. Green (Member 1963, Graduate 1961) has been appointed Company Quality Assurance Manager with Marconi Space and Defence Systems Ltd. at the Applied Electronics Laboratory in Portsmouth.

Mr. R. K. Hibbard (Member 1970, Graduate 1968), who was a Lecturer at Norwood Technical College, has been appointed Senior Lecturer in the Department of Technology of the College, Swindon.

Mr. V. Jeyasingam (Member 1973, Graduate 1967) has been appointed a Projects Engineer with the Malaysian Broadcasting Department. He was previously a Technical Assistant with the Outside Broadcast Division of Television Malaysia.

Mr. F. J. Marley (Member 1967, Graduate 1964) has been appointed Production Manager in the Military Systems Division of Ferranti Ltd., Wythenshawe. He was previously a Project Manager.

Mr. P. E. Scott (Member 1973, Graduate 1970), who was Senior Engineer with Marconi Space and Defence Systems, has joined the Ministry of Defence (Navy) as a Professional and Technical Officer Grade 2.

Mr. J. A. Stanley (Member 1970, Graduate 1964) has joined Data Recall Ltd. as a Senior Development Engineer. He was previously a Design Engineer with Teradyne Ltd. of Esher.

Sqn. Ldr. I. G. C. Stephens, RAF (Ret) (Member 1957) is now an Inspector in the Management Services branch of the Department of Science, Canberra. He was previously Royal Navy *Ikara* Project Co-ordination Officer with the Australian Department of Supply.

Mr. S. R. Taylor, M.Sc. (Member 1970, Graduate 1964) has moved from GEC-Elliott Process Automation Ltd., Leicester, where he was a Senior Engineer, to the appointment of Engineer in the Training Simulators Group of the Military Systems Division of Ferranti Ltd., Wythenshawe.

NON-CORPORATE MEMBERS

Mr. R. W. Allis (Graduate 1972) is now Development Manager with Park Air Electronics Ltd., Stamford, Lincolnshire.

Mr. M. J. Gay (Graduate 1968) has joined the Atmospheric Physics Research Group at the University of Manchester Institute of Science and Technology as a Research Assistant.

Mr. K. Kumar, B.Tech. (Graduate 1973) has been appointed Quality Assurance Engineer in the Product Quality Engineering Department of Philips Croydon. He was previously a Quality Assurance Engineer at the Bradford factory of the British Radio Corporation.

Mr. A. G. Leitch (Graduate 1970) has joined the Bristol Engine Division of Rolls-Royce (1971) Ltd. as a Senior Technical Engineer following his retirement from the RAF in the rank of Sergeant.

Mr. H. R. Machin (Graduate 1968) is now a Senior Electrical Engineer (Communications) with the Royal Australian Navy. Before going to Australia in 1970, Mr. Machin was an Engineer, Grade 6, in the Chief Engineer's Department of the London Electricity Board.

Mr. H. M. Morton (Graduate 1973), who is with Plessey Telecommunications Ltd., has been promoted to Engineer.

Mr. P. Mansell (Graduate 1970), who has been a lecturer in Electrical and Electronic Engineering at Guildford County Technical College since 1968, has been appointed Electrical Training Officer with W.D. and H.O. Wills, Ltd., Bristol.

Mr. F. B. Norman (Graduate 1969) has been appointed Engineering Technologist with GTE Lenkurt Electric (Canada) Ltd. He was formerly an Equipment Engineer with Stromberg Carlson.

Mr. E. G. Parker (Graduate 1972) is now a Departmental Manager with Northern Electric Wire and Cable Division, Kingston, Ontario. Before emigrating to Canada last year, Mr. Parker was with British Insulated Callender's Cables Ltd., Prescot, Lancs.

Mr. H. Vartanian (Graduate 1968) has been appointed Manager of HMV Engineering Company, Beirut, Lebanon. He was previously Supervisor, Panels Department, with Honeywell International B.V. in Beirut.

Obituary

The Council has learned with regret of the deaths of the following members.

Allan Robin Wood Blanchard (Member 1947, Associate 1941) died on 23rd April 1974 of a heart attack at the age of 58 years; he leaves a widow.

Educated in London and Torquay, Allan Blanchard entered the radio industry and worked for several companies during the pre-war years, including Tannoy Products Ltd. and the R.G.D. Co. Ltd. In 1940 he became a Wireless Instructor with the Royal Artillery and latterly was a Warrant Officer in the Wireless Workshops of the Military College of Science at Bury.

On demobilization he was for a time with Cossor Radar Ltd., Chadderton, as Chief Technical Writer on radar and allied equipment and later joined Salford Electrical Instruments Ltd., becoming Chief Sales Engineer for thermostatic products. In 1957 Mr. Blanchard went to Fielden Electronics Ltd., Wythenshawe, with whom he remained until his death. He was for several years Manager of the Industrial Electronics Division and subsequently became Commercial Sales Manager.

Alexander Bruce Henderson (Graduate 1969) died on 25th April 1974 after a long illness. He was 36 years of age and leaves a wife and three young children.

Educated at Alan Glen's School, he entered into a student apprenticeship with Colvilles Ltd., where he was concerned with installation and maintenance of electrical drives, etc., for steel mills; during this period he studied at Coatbridge Technical College for the Higher National Certificate in electrical engineering which he completed in 1959. From 1961 Bruce Henderson was with Ferranti Ltd. and in 1964 he joined Satchwell Appliance Controls Ltd. as a Design Engineer. He obtained H.N.C. endorsements in 1966 and 1968 in control engineering and applied electronics following further studies at Stow College and Napier Technical College.

In 1967 Bruce Henderson joined the Regional Computing Centre of the University of Edinburgh, working with a small team of engineers and technicians on developing a multi-access terminal network based on the Centre's System 4–75 computer. This network currently supports some one hundred and thirty on-line teleprinter terminals in the University and Research Council community. He played a major role in establishing the Centre's position in University data communications and was latterly working on plans for an extension of these facilities to the other Scottish Universities. F.E.J.B.

Thomas Smith (Member 1959) died on 2nd May 1974 at the age of 48 years after an illness of several months. He leaves a widow.

Educated at Wolsingham Grammar School, Tom Smith worked with Marconi's Wireless Telegraph Company as a junior technical assistant in the early years of the war. Following four years' service with REME as a telecommunications mechanic, he was demobilized in the rank of Sergeant, and from 1948 to 1951 studied at the Northern Polytechnic for the Polytechnic's Diploma and the City and Guild's Full Technological Certificate. For the next four years he was with EMI Research Laboratory as an engineer working on a guided weapon project.

He then joined the Ministry of Supply and for three years was an Experimental Officer in charge of the Electronics Section of the Tropical Testing Establishment in Nigeria. In 1961 he went to the Plessey Company as an Installation Engineer and he continued in this capacity until a few months before his death. Tom Smith travelled throughout the world installing and commissioning radar, navigational and other electronics equipment for military and civil authorities and was responsible as Plessey Services' Site Manager for the detailed negotiations affecting this work. His last assignment was installing and commissioning an instrument landing system at Dar es Salaam Airport.

Edward Chilcott (Member 1971, Graduate 1964) died on 2nd June 1974 as the result of a heart attack at the age of 49 years. He leaves a widow and two daughters.

Following education at Sutton High School, Plymouth, Edward Chilcott entered the Post Office, and as a Technical Officer worked at GPO short wave radio receiving and transmitting stations. During this period he studied at South Dorset Technical College for the H.N.C. which he gained in 1964 with electronics endorsements. In 1964 he entered technical education and was an Assistant Lecturer at South Cheshire Central College of Further Education, Crewe, until 1968 when he moved to Peterborough Technical College as Lecturer Grade 2. Here he taught electronics subjects for the Higher National Certificate for the next six years.

Stephen Frank Dainty (Graduate 1973, Student 1970) died in June aged 25 years.

Stephen Dainty was educated at Leigh Grammar School and in 1969 joined the UKAEA Reactor Materials Laboratories at Culcheth as a student apprentice working on electronics development. He studied for the Higher National Diploma on a sandwich course at Manchester Polytechnic and was successful in 1970. He subsequently completed the CEI Part 2 course and in January 1972 joined the British Aircraft Corporation's Military Aircraft Division at Warton as an Electronic Development Engineer. He continued with this company until his untimely death.

INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

Applicants for Election and Transfer

THE MEMBERSHIP COMMITTEE at its meetings on 28th December 1973, 9th and 23rd July 1974 recommended to the Council the election and transfer of 32 candidates to Corporate Membership of the Institution and the election and transfer of 18 candidates to Graduateship and Associateship. In accordance with Bye-law 23, the Council has directed that the names of the following candidates shall be published under the grade of membership to which election or transfer is proposed by the Council. Any communications from Corporate Members concerning those proposed elections must be addressed by letter to the Secretary within twenty-eight days after the publication of these details.

Meeting: 28th December 1973 (Membership Approval List No. 189)

GREAT BRITAIN AND IRELAND

CORPORATE MEMBERS

Transfer from Graduate to Member

ADAMS, Derek William. *Cheltenham, Gloucestershire.*
ARTHUR, Brian Charles. *Hayes, Middlesex.*
BIGGS, Brian Lawrence. *Bracknell, Berkshire.*
CHANNE, Ajit Singh. *London, S.E.9.*
COLLINS, Peter Stanley. *Cranfield, Hertfordshire.*
DALTON, Roger William. *Prescot, Lancashire.*
DAWSON, Peter. *Bedale, Yorkshire.*
DU PUGET PUSZET, Edward. *Reading, Berkshire.*
FRENCH, Dennis Richmond. *London S.W.15*
FIELD, Brian Charles. *Oxford.*
JOHNSON, Raymond Michael. *Bracknell, Berkshire.*
RANCE, John Harold. *Newbury, Berkshire.*
ROBERTS, Derek Wyn. *Gloucester.*
ROGERS. John Arthur. *West Bergholt, Essex.*
SALTER, Martin Thomas Ardley. *Thatcham Berkshire.*

Transfer from Associate to Member

LASSMAN, Henry. *Bishop's Stortford, Hertfordshire.*

Transfer from Student to Member

FERGUSON, Murdo McRae. *London, N.W.2.*

Direct Election to Member

MITCHELL, Christopher Michael. *Camberley, Surrey.*
ROSSER, William. *St. Albans, Hertfordshire.*

OVERSEAS

CORPORATE MEMBERS

Transfer from Graduate to Fellow

GALLAGHER, Thomas. *Illinois, U.S.A.*

Transfer from Graduate to Member

FLANAGAN, James. *Dar-Es Salaam, Tanzania.*
HARLOW, Clive. *Sao Paulo, Brazil.*
MONTORO, Manuel G. *Madrid, Spain.*
NEWMAN, Robert Hanmer. *Virginia, U.S.A.*
RODEN, Michael Thomas. *New Jersey, U.S.A.*
SPRAGG, Roger David. *South Australia.*

Direct Election to Member

AHMAD, Rashid. *Rawalpindi, Pakistan.*

Meeting: 9th July 1974 (Membership Approval List No. 190)

GREAT BRITAIN AND IRELAND

CORPORATE MEMBER

Transfer from Member to Fellow

LUSKOW, Alfred Allan. *Welwyn Garden City, Hertfordshire.*

NON-CORPORATE MEMBERS

Direct Election to Associate

COOPER, Anthony Herbert George. *Southend-on-Sea, Essex.*
UNSWORTH, Samuel Robert. *Belfast, N. Ireland.*
GRACE, John Hornby. *Welwyn, Hertfordshire.*

Direct Election to Associate Member

BODDIE, Gavin Lionel. *Leyland, Lancashire.*
CALLOW, Peter Andrew Frederick. *West Wickham, Kent.*
SMITH, James William. *Plymstock, Devon.*

OVERSEAS

CORPORATE MEMBER

Transfer from Student to Member

OLOMU, Solomon Ovenseri. *Lagos, Nigeria.*

NON-CORPORATE MEMBERS

Direct Election to Associate Member

SOME, Chong On. *Tao Payoh, Singapore.*

STUDENTS REGISTERED

CHEONG, Sun Sin. *Singapore 3.*
LEONG, Kin Pun. *Singapore 3.*
MENON, Vatsan. *Singapore 19.*
TAN, Hock Heng Stephen. *Singapore 3.*
TEH, Swee Heng. *Penang, Malaysia.*
YAP, Shau Tat. *Singapore 3.*
YEO, Mang Song. *Singapore 6.*

Meeting: 23rd July 1974 (Membership Approval List No. 191)

GREAT BRITAIN AND IRELAND

CORPORATE MEMBERS

Transfer from Member to Fellow

HOLDER, Phillip Roy. *Wallington. Surrey.*
TOWLE, Roland Kenneth. *Cranford, Middlesex.*

Direct Election to Fellow

EVANS, Raymond Vincent. *Malvern, Worcestershire.*

NON-CORPORATE MEMBERS

Transfer from Student to Graduate

TILBURY, Rowland Peter. *South Queensferry, West Lothian.*

Direct Election to Graduate

ORIRE, Oyewole Benson. *London, N.W.10.*
SINCLAIR, Donald Alexander. *Aberdeen.*

Transfer from Graduate to Associate Member

LING, Frank Austin. *London, S.E.9.*
RENNISON, Brian. *Carlisle.*

Transfer from Student to Associate Member

LUCKMAN, Ian Frederick. *Bridgwater, Somerset.*

Transfer from Student to Associate

YAWSON, Andrew Eshun. *London, N.22.*

Direct Election to Associate

EGLISE, David. *Windsor, Berkshire.*

STUDENTS REGISTERED

MILLER, David Gordon. *Winchester, Hampshire.*
OWEN, David James. *Crownhill, Plymouth.*

OVERSEAS

NON-CORPORATE MEMBERS

Transfer from Student to Associate Member

LEE, Foong Sam. *Wilayah Persekutuan, Malaysia.*

Transfer from Student to Associate

ODEGBAYIKE, Maurice Olufemi. *Lagos, Nigeria.*

STUDENTS REGISTERED

ALEBIOSU, Christopher Abiodun. *Via Ilesha, Nigeria.*
WONG, Koon Yoong. *Singapore.*

Addendum

Meeting: 28th December 1973 List No. 180 published May 1974

GREAT BRITAIN AND IRELAND

CORPORATE MEMBERS

Transfer from Graduate to Member

APPLETON, Ray Robin. *Warrington, Lancs.*

OVERSEAS

CORPORATE MEMBERS

Direct Election to Member

OJEI, Jeremaih Emeka. *Lagos, Nigeria.*

Recent Accessions to the Library

This list of additions to the Library covers January–July 1974. *With the exception of titles marked* 'REF', *which are for reference in the Library only, these books may be borrowed by members in the British Isles by personal call or by post. Information on loan conditions can be obtained from the Librarian, Mrs. S. A. Clarke. The dates shown in brackets refer to reviews or shorter notices which have appeared in* The Radio and Electronic Engineer.

General

Walford, A. J.
'Guide to reference material'. Vol. 1. Science and technology. *Library Association*, 1973. 3rd ed. REF.
'Whitaker's Almanack'. *J. Whitaker & Sons*, 1973. REF.
Thewlis, J.
'Concise dictionary of physics and related subjects.' *Pergamon Press*, 1973. REF.
'Dictionary of radio and television terms: English–German, German–English.' *Siemens/Pitman*, 1972. REF.
'Guide to the press of the world.' *Wm. Dawson & Sons*, 1972. 70th ed. REF.
'Directory of British associations and associations in Ireland.' *CBD Research*, 1974/5 ed. REF.
'Cassell's directory of publishing.' (Great Britain, Commonwealth, Ireland, South Africa and Pakistan.) *Cassell*, 1973. 1973–74 ed. REF.
'Publishers in the United Kingdom and their addresses.' *J. Whitaker & Sons*, 1974. REF.

Public Administration

'Civil Service year book.' *HMSO*, 1974 ed. REF.
'The Navy List.' *HMSO*, Spring 1974. REF.

Trade

'Kemp's directory.' *Kemp Group*, 1973–74 ed. 2 vol. REF.
'Export Handbook. Services for British exporters." *BOTB*, 1974. 7th ed. REF.
'British Standards yearbook.' *BSI*, 1974. REF.
'Electrical and electronic trades directory." *Peter Peregrinus*, 1973. 91st issue. REF.

Languages

'Cassell's German and English dictionary.' *Cassell*, 1974. 12th ed. REF.
'Cassell's new French–English, English–French dictionary.' *Cassell*, 1973. 8th ed. REF.

Mechanical Engineering

CONTROL THEORY

Atkinson, P.
'Feedback control theory for engineers.' *Heinemann Educational Books*, 1972. 2nd ed. [December 1973.]

Electrical and Electronic Engineering

CABLES AND WIRING

Harper, Charles A., (*ed.*)
'Handbook of wiring, cabling and interconnecting for electronics.' *McGraw-Hill*, 1972. [December 1973.]

ELECTRICAL SCIENCE

Watkins, Glyndwr and Jones, W. E.
'Examples in electrical science for electrical installation students, 4th and 5th years.' *Blackie & Son*, 1972.

CIRCUIT THEORY

Carter, G. W. and Richardson, A.
'Techniques of circuit analysis.' *Cambridge University Press*, 1972. [December 1973.]
Meadows, R. G.
'Problems in electrical circuit theory.' Part 1. *Cassell*, 1972.
Rogers, F. E.
'Illustrations in applied network theory.' *Butterworths*, 1973.
Kroupa, Venceslav F.
'Frequency synthesis: theory, design and applications. *Griffin*, 1973. [April 1974.]

ELECTRONICS

Jolly, W. P.
'Electronics.' *Teach Yourself Books*, 1972.
Pridham, G. J.
'Electronic devices and circuits.' Vol. 3. *Pergamon Press*, 1972.
Lewis, Rhys.
'Electronic systems for radio, television and electronic mechanics.' *Macmillan*, 1973. [December 1973.]
Olsen, G. H.
'Electronics: a course book for students.' *Butterworths*, 1973.
Ahmed, H. and Spreadbury, P. J.
'Electronics for engineers: an introduction.' *Cambridge University Press*, 1973. [April 1974.]

SEMICONDUCTOR DEVICES

Jolly, W. P.
'Cryoelectronics.' *English Universities Press*, 1972. [April 1974.]
Nag, B. R.
'Theory of electrical transport in semiconductors." Vol. 3 International series of monographs in the science of the Solid State. *Pergamon Press*, 1972. [December 1973.]
Tepper, Irving
'Solid state devices.' Vol. 1 Theory. *Addison-Wesley*, 1972.
Towers, T. D.
'Elements of linear microcircuits.' *Iliffe*, 1973. [December 1973.]
Yunik, Maurice
'Design of modern transistor circuits.' *Prentice-Hall*, 1973.
'Field-effect transistors.' *Mullard*, 1972. [December 1973.]
Planer, G. V. and Phillips, L. S.
'Thick film circuits.' *Butterworths*, 1972. [December 1973.]

PHOTOELECTRIC SYSTEMS

Smith, P. S.
'50 Photo-electric circuits and systems.' *Iliffe*, 1972.

Telecommunication

David, Dr. Edward E., Jnr. and Denes, Dr. Peter B. (*eds.*)
'Human communication: a unified view.' Vol. 15 Inter-university electronics series. *McGraw-Hill*, 1972.
Brown, J. and Glazier, E. V. D.
'Telecommunications.' *Chapman & Hall*, 1974. 2nd ed.

RADIOCOMMUNICATION

Warring, R. H.
'Ham radio: a beginners guide.' *Lutterworth Press*, 1972.

TRANSMITTERS AND RECEIVERS

McMullen, T. (*ed.*)
'FM and repeaters for the radio amateur.' *American Radio Relay League Inc.*, 1972.

TELEVISION

Black, Peter
'The mirror in the corner: people's television.' *Hutchinson*, 1972.
King, Gordon
'Beginner's guide to television. *Newnes–Butterworths*, 1972. 5th ed.

APPARATUS

Alkin, E. G. M.
'Sound with vision.' Sound techniques for television and film. *Butterworths/BBC*, 1973. [April 1974.]

Chemical Technology

ADHESIVES

'Adhesives directory.' *Dimbleby Printers*, 1972–73 ed. REF.

Computers

Oberman, R. M. M.
'Electronic counters.' *Macmillan*, 1973.

Forthcoming Institution Meetings

London Meetings

Wednesday, 25th September

AEROSPACE, MARITIME AND MILITARY SYSTEMS GROUP

Colloquium on Radar for Vehicle Guidance

POSTPONED

Thursday, 3rd October

ANNUAL GENERAL MEETING

IERE Lecture Room, 9 Bedford Square, London WC1, 6 p.m. (Tea 5.30 p.m.)

Wednesday, 9th October

COMPONENTS AND CIRCUITS GROUP

Colloquium on H.F. HEATING—CIRCUITS AND TECHNIQUES

IERE Lecture Room, 10 a.m.

Advance registration necessary. For further details and registration forms, apply to Meetings Secretary, IERE.

A survey of available power sources for h.f. heating
By W. D. Wilkinson (*Stanelco*)

No longer a toy (Requirements of h.f. heating equipment in the industrial environment)
By F. Watts (*Vauxhall Motors*)

Drying non-metallic substances at high frequency
By Dr. J. Lawton (*Electricity Council Research Centre*)

Radio interference from r.f. heating equipment
By A. S. McLachlan (*Home Office*)

Controlled r.f. power generation using magnetically beamed triodes
By R. Whittle and J. J. Behenna (*STC*)

Thyristor convertors for induction heating and hardening and melting applications
By H. G. Matthes (*AEG*)

The future of semiconductors in r.f. heating
By G. Garrard (*Texas Instruments*)

Developments in r.f. heating techniques and their influence on the process heating field
By H. Barber (*Loughborough University*)

Wednesday, 16th October

JOINT MEETING WITH IEE
EDUCATION AND TRAINING GROUP

The Technician Education Council

By F. Fidgeon (*Technician Education Council*)

IERE Lecture Room, 6 p.m. (Tea 5.30 p.m.)

Thursday, 17th October

JOINT IEE/IERE MEDICAL AND BIOLOGICAL ELECTRONICS GROUP

Colloquium on ELECTRONICS IN AUDIOLOGY

IERE Lecture Room, 10 a.m.

Advance registration necessary. For further details and registration forms, apply to Meetings Secretary, IERE.

Wednesday, 23rd October

AUTOMATION AND CONTROL SYSTEMS GROUP

Colloquium on IMPLEMENTATION AND RELIABILITY OF AUTOMATED SYSTEMS

IERE Lecture Room, 10 a.m.

Advance registration necessary. For further details and registration forms, apply to Meetings Secretary, IERE.

Tuesday, 29th October

JOINT MEETING OF COMMUNICATIONS GROUP AND AUTOMATION AND CONTROL SYSTEMS GROUP

Colloquium on SIGNAL PROCESSING IN COMMUNICATIONS SYSTEMS

IERE Lecture Room, 10 a.m.

Advance registration necessary. For further details and registration forms, apply to Meetings Secretary, IERE.

Some examples of adaptive signal processing using tuneable filters
By R. C. Weston (*SRDE*)

An adaptive detection system for time varying pulse signals
By V. McKinley and Dr. F. C. Monds (*Queen's University, Belfast*)

Adaptive techniques for high resolution spectrum estimation
By Dr. T. S. Durrani and D. Farrier (*Southampton University*)

Comparison of optimal delta modulators for low bit-rate transmission.
By D. W. W. Rogers and Dr. R. Barrett (*Hatfield Polytechnic*)

Optimum filters for digital amplitude and phase modulation systems
By Dr. M. Tomlinson (*Plessey*)

Some considerations relating to the properties of the Hadamard transformation and its application in data compression
By Dr. L. F. Turner (*Imperial College*)

Digital demodulation for a.m. signals
By Professor A. M. Rosie and Dr. A. J. Ruddell (*University of Strathclyde*)

Iterative detection processes
By A. Clements and Dr. A. P. Clark (*Loughborough University*)

Digital filters with multi-shift sequences within a sampling period
By K. M. Wong (*Plessey*) and R. A. King (*Imperial College*)

Kent Section

Wednesday, 25th September

Flight Simulation

By G. R. Wilson (*Redifon Flight Simulators*)

Lecture Theatre 18, Medway and Maidstone College of Technology, Maidstone Road, Chatham, at 7 p.m.

Thursday, 17th October

Modern Colour Television Receivers

Lecture Theatre 18, Medway and Maidstone College of Technology, Maidstone Road, Chatham, at 7 p.m.

Wednesday, 27th November

Problem Solving and Decision Making in Management

By P. J. Curra

Lecture Theatre 18, Medway and Maidstone College of Technology, Maidstone Road, Chatham, at 7 p.m.

East Anglian Section

Thursday, 10th October

ANNUAL GENERAL MEETING

The Saracen's Head Hotel, High Street, Chelmsford, 7 p.m.

Thursday, 24th October

JOINT MEETING WITH IEE

The Electronic Organ—the Organ of the Future?

By C. C. H. Washtell

Swaffham Prior Church, Swaffham Prior, Nr. Cambridge, 6 p.m. (Tea 5.30 p.m.)

The electrophonic organ was designed and built by the lecturer and is installed in the church at Swaffham Prior, near Cambridge. It can produce results which, in many respects, are indistinguishable from the traditional north European organ of the late XVII century. In other respects it exploits the foibles of electronic sound generation. Particular features include the ability to produce 'chiff' and the 'breathing' of each sound. The lecture will include a practical demonstration of the organ.

Thursday, 24th October

Recent Advances in Display Techniques

By D. W. G. Byatt (*Marconi Research Laboratories*)

The Civic Centre, Chelmsford, 6.30 p.m. (Tea 6 p.m.)

Current display techniques applied to data handling displays such as radar and computer control systems are described together with the application of new materials. In particular the use of light-emitting semiconductors and electro-optic materials will be discussed.

Thursday, 21st November

Digital Adaptive Electronic Circuits

By I. Aleksander (*University of Kent*)

University Engineering Laboratories, Trumpington Street, Cambridge, 6.30 p.m. (Tea 6 p.m.)

Thames Valley Section

Wednesday, 16th October

Colour Television

By A. C. Maine (*IoW Technical College*)

J. J. Thomson Physical Laboratory, University of Reading, Whiteknights Park, Reading, 7.30 p.m.

This lecture will review the progress of colour television from the early Baird experiments to the present day quality transmissions. After an outline of the principles involved, the advances made in receiver design will be examined, with particular reference to the various types of display tube and electronic devices available. The lecture will be illustrated by slides and demonstrations.

Thursday, 14th November

Hybrid Computers and their Applications

By Dr. R. L. Davey (*Imperial College*)

J. J. Thomson Physical Laboratory, University of Reading, Whiteknights Park, Reading, 7.30 p.m.

South Western Section

Tuesday, 8th October

JOINT MEETING WITH IEE

Seminar on ADVANCES IN TELECOMMUNICATIONS

The Seminar will begin with an introductory lecture at 6 p.m. followed by a buffet dinner in the Senior Common Room at the University of Bath at 7.15 p.m. and finally by a discussion with a panel of experts from 8.15 p.m.

There will be a charge of £1.00 per head for dinner, payable in advance. Tickets can be obtained from Mr. B. Bolton, School of Electrical Engineering, University of Bath, Claverton Down, Bath. Payment by cheque would be preferred and these should be made payable to B. Bolton. The closing date for dinner bookings will be Wednesday, 2nd October 1974.

The Senior Common Room Bar will be open for those who do not wish to dine.

It should be stressed that these seminars are not intended to be research colloquia. The Committee hopes that members who are new to the field will look upon this as an opportunity to find out about advances in telecommunications and that members who are more familiar with the subject will take the opportunity to share their experience and to put questions to the panel.

It may be necessary to place a limit on the numbers attending the dinner and early booking is advisable.

Wednesday, 23rd October

JOINT MEETING WITH IEE

The Digital Data Network

By M. Foulkes (*Post Office Telecommunications*)

Westinghouse Canteen, Chippenham, 6 p.m. (Tea 5.30 p.m.)

Tuesday, 12th November

JOINT MEETING WITH IEE

Colour Television

By D. Barnes

The College, Regent Circus, Swindon, 6.15 p.m. (Tea 5.45 p.m.)

Wednesday, 13th November

CEI MEETING

Off-Shore Energy in British Waters

By D. E. Rouke (*Deputy Chairman, British Gas Council*)

No. 1 Lecture Theatre, School of Chemistry, University of Bristol, 7 p.m. (Tea 6.30 p.m.)

Wednesday, 13th November

JOINT MEETING WITH IEE

The Life and Work of a Sound Recording Engineer

By R. Auger

The Main Lecture Theatre, Plymouth Polytechnic, 7 p.m. (Tea 6.30 p.m.)

Southern Section

Wednesday, 16th October

JOINT MEETING WITH IEE

Chairman's Address—Gigawatt Power Transmission

By Dr. B. M. Weedy (*Southampton University*)

Lanchester Theatre, Southampton University, 6.30 p.m. (Tea from 5.45 p.m. in Senior Common Room)

Thursday, 17th October

Underwater Acoustic Imaging

By S. O. Harrold (*Portsmouth Polytechnic*)

South Dorset Technical College, Weymouth, 6.30 p.m.

A review of underwater acoustic imaging methods will include the use of lenses and mirrors and outline the special problems associated with the relatively long wavelengths involved. Details of the f.e.t. scanned ultrasonic image converter developed at the Portsmouth Polytechnic will be given. This uses f.e.t. analogue gates to sequentially-sample a matrix of piezoelectric transducer elements. Results will be presented showing its performance in a conventional ultrasonic camera system using an acoustic lens, together with those obtained when the lens is replaced by an on-line computer. The computer is programmed to introduce a form of spherical phase function to the received transducer matrix signals in order to create a focusing action.

Thursday, 24th October

JOINT MEETING WITH IEE

Automatic Weather Stations

By H. R. S. Page (*Plessey Radar*)

Farnborough Technical College, 7 p.m. (Coffee and biscuits available in Refectory from 6.30 p.m.)

Meteorological records have been kept since the 17th Century. Until recently, most of the useful weather information was gathered from manned sites on land or sea. The advent of improved sensors to withstand long periods of unattended operation in harsh environmental conditions and reliable solid state electronics, enables this to be realised economically, with the use of remote, automatic monitoring stations. The paper will cover the following topics: network and systems concepts; new sensors and sensing techniques: outstation philosophy, design and construction; transmission and recording media; control receiving station configurations; data presentation and display; and other applications.

Wednesday, 30th October

AUTONULL—The Suppression of Large Interfering Signals in Single and Multi Equipment Installations

By M. M. Zepler (*Plessey*)

H.M.S. *Collingwood*, Fareham, 6.30 p.m. (Tea 6 p.m.)

In radio receiving systems large unwanted signals often cause severe interference to the reception of small signals. These large interfering signals can originate from a variety of sources, and can be at frequencies both in and out of the receiving band. Methods are described of suppressing the unwanted signal in both co-sited installations where the large signal may be at or near the frequency to which the receiver is tuned.

Wednesday, 6th November

Why 110° Colour?

By A. W. Lee

Lecture Theatre F, University of Surrey, Guildford, 7 p.m.

The paper deals with the background and the reasons for the change to wide-angle television tubes. It compares the advantages and disadvantages of toroidal and saddle type deflexion units. The author explains how a line time-base works with particular reference to thyristors, oscillations and the manner in which the circuit controls the energy it contains. A forecast is given of probable future developments.

Friday, 15th November

Automatic Weather Stations

By H. R. S. Page (*Plessey Radar*)

Newport (IoW) Technical College, 7 p.m.

(See Farnborough meeting on 24th October)

South Wales Section

Wednesday, 9th October

Charge Coupled Devices

By Dr. J. D. E. Beynon (*Southampton University*)

Department of Applied Physics and Electronics, U.W.I.S.T., Cardiff, 6.30 p.m. (Tea 5.30 p.m.)

Although the charge-coupled device was conceived only three years ago it is already challenging many conventional integrated circuit techniques, particularly in the memory and solid-state imaging field. This is because of the device's extreme simplicity which is leading to circuits having high packed density, low power dissipation and low cost per function. The lecturer will explain the operation of the charge-coupled device and describe some of the techniques used for fabricating c.c.d. circuits. Some of the c.c.d.s many present and future applications will be discussed.

Wednesday, 23rd October

JOINT MEETING WITH IEE

What are the Wild Waves Saying?—An Early History of Radio Detection

By V. J. Phillips (*University College of Swansea*)

University College of Swansea, 6.30 p.m. (Tea 5.30 p.m.)

Wednesday, 13th November

JOINT MEETING WITH IEE

Mobile Radio in the Era of Spectrum Congestion

By Professor W. Gosling (*University of Bath*)

Department of Applied Physics and Electronics, UWIST, Cardiff, 6.30 p.m. (Tea 5.30 p.m.)

West Midland Section

Wednesday, 2nd October

JOINT MEETING WITH R.AE.S.

Redundancy in Avionics Systems

By R. K. Barltrop (*Marconi-Elliott*)

R.A.F. Cosford, 7.15 p.m. (Tea 6.30 p.m.)

Thursday, 7th November

JOINT MEETING WITH IEE

The 25 metre Steerable Aerial at the Radio and Space Research Field Station

By J. A. McGivney (*Science Research Council*)

Lanchester Polytechnic, Coventry, 6.30 p.m. (Tea 6 p.m.)

Wednesday, 13th November

Using Digital Integrated Circuits

By J. A. Scarlett (*Exacta Circuits*)

City of Birmingham Polytechnic, 7.15 p.m. (Tea 6.30 p.m.)

East Midland Section

Thursday, 17th October

Digital Differential Analysers and Analogue Computers

By W. Forsythe (*Loughborough University*) Leicester University, 7 p.m. (Tea 6.30 p.m.)

Tuesday, 12th November

JOINT MEETING WITH IEE

Stereophonic and Ambisonic Reproduction of Sound

By Professor P. B. Fellgett (*University of Reading*)

Room J002, Edward Herbert Building, Loughborough University, 7 p.m. (Tea 6.30 p.m.)

South Midland Section

Thursday, 3rd October

Digital Television

Speaker from I.B.A.

B.B.C. Club Evesham, 7.30 p.m.

Tuesday, 29th October

Developments in Digital Transmission Systems

By G. H. Bennett (*P.O. Telecommunications*)

Gloucester College of Technology, Gloucester, 7.30 p.m.

Tuesday, 12th November

JOINT MEETING WITH IEE

Radar Approach to Weather Forecasting

By Professor E. D. R. Shearman (*University of Birmingham*)

G. C. Club, Benhall, Cheltenham, 7.30 p.m.

North Eastern Section

Wednesday, 2nd October

Sonar and Underwater Communications

By Dr. V. G. Welsby (*University of Birmingham*)

Main Lecture Theatre, Ellison Building, Newcastle upon Tyne Polytechnic, Ellison Place, 6 p.m. (Refreshments available in Staff Refectory 5.30 p.m.)

A review of modern techniques based on the use of sound waves in the sea and in lakes, rivers, etc. is given, and systems for diver communication and navigation are described. High resolution sonars, sometimes using focused acoustic arrays, have uses which range from the study of the behaviour of fish shoals to aiding police searches in muddy canals. Acoustic telemetry is used to control submersible vehicles and to channel collected information back to the surface. Acoustic waves are used to count migrating fish in rivers.

Monday, 4th November

JOINT MEETING WITH IEE

Computer Control System for Electrical Distribution

By D. H. Jones (*Midland Electricity Board*) and R. J. Scott-Kerr (*Consultant*)

University of Newcastle upon Tyne, Merz Court, 6.15 p.m. (Tea 5.45 p.m.)

Merseyside Section

Wednesday, 16th October

Colour Television—From the Studio to the Viewer

By C. White (*Granada Television*)

The Department of Electrical Engineering and Electronics, University of Liverpool, at 7 p.m. (Tea 6.30 p.m.)

Wednesday, 13th November

Satellite Earth Stations 1962-1974

By D. I. Dalgleish (*P.O. Telecommunications*)

Department of Electrical Engineering and Electronics, University of Liverpool, 7 p.m. (Tea 6.30 p.m.)

The basic requirements of Earth stations will be examined. Developments at the P.O. Earth Station, at Goonhilly from 1962 to 1974 will be surveyed and a brief look at the future will be taken.

Yorkshire Section

Thursday, 14th November

Development of Digital Transmission Systems

By G. H. Bennett (*P.O. Telecommunications*)

York College of Further Education, 6.30 p.m. (Tea 6 p.m.)

North Western Section

Thursday, 17th October

Current Trends in Semiconductors

By Dr. K. J. Dean (*SELTEC*)

Bolton Institute of Technology, 6.15 p.m. (Tea 5.45 p.m.)

Thursday, 14th November

Medical Electronics

By E. T. Powner (*UMIST*)

Lecture Theatre R/H10, UMIST, 6.15 p.m. (Tea 5.45 p.m.)

Scottish Section

Wednesday, 6th November

Napier College, Edinburgh, 7 p.m.

and

Thursday, 7th November

Glasgow College of Technology, 7 p.m.

Calculator Technology

By R. Bilton (*Hewlett-Packard*)

Northern Ireland Section

Thursday, 3rd October

ANNUAL GENERAL MEETING at 7 p.m.

Modern Trends in Mobile Radio

By W. Stevenson (*Motorola*)
Cregagh Technical College

Tuesday, 12th November

JOINT MEETING WITH IEE

50th Anniversay of Broadcasting in Northern Ireland

The Ulster College, Jordanstown, 7 p.m.

Conference on

'Environmental Sensors and Applications'

Organized by THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS with the association of The Institution of Electrical Engineers. The Institute of Physics and The Institute of Electrical and Electronics Engineers.

18th and 19th November 1974

At the Royal Society, Carlton House Terrace, London

PROVISIONAL PROGRAMME

Monday, 18th November 1974, 10.30 a.m. to 5.45 p.m.
Opening Address

AIR POLLUTION

'Correlation Spectroscopy and Air Pollution'.
DR. P. M. HAMILTON and DR. K. W. JAMES, *CERL.*

'Measurements of Air Pollution with Fast-Response Apparatus'.
DR. M. J. G. WILSON and DR. D. H. SLATER, *Imperial College.*

'Infra-Red Detectors and Their Application to Pollution Monitoring'.
DR. C. W. SHERRING, *Plessey Company.*

'The Point Visibility Meter—A Forward Scatter Instrument for the Measurement of Aerosol Extinction Coefficient'.
J. V. WINSTANLEY, *Plessey Radar.*

'The Role of an Integrating Nephelometer in Visibility Measurement and Atmospheric Pollution Studies'.
J. A. GARLAND and P. E. GIBBONS, *AERE.*

'A Continuously Recording Aerosol Photometer for Monitoring Respirable Airborne Dust'.
R. J. SEANEY and P. HODSON, *SMRE.*

'Solid State Sensors for Gas Detection'.
J. G. FIRTH, A. JONES and T. A. JONES, *SMRE*

'Electrochemical Gas Sensors Based on the Metallized Membrane Electrode'.
DR. I. BERGMAN, *SMRE.*

COMPUTER ANALYSIS

'Computer Aided Sensor Selection and Optimisation'.
D. M. BALSTON, R. J. DREWETT and O. E. MORGAN, *Plessey Radar Research Centre.*

'The Application of Pattern Classification Techniques to Skylark Rocket Imagery'.
E. S. OWEN-JONES, *Bedford College.*

Tuesday, 19th November 1974, 9.30 a.m. to 6 p.m.

METEOROLOGICAL SENSORS

'Instrumentation for Boundary Layer Research in Meteorology'.
D. TRIBBLE, *Imperial College*

'A New Generation of Sensors for Automatic Weather Stations'
F. T. LUDBROOK, *Plessey Radar Research Centre.*

'Certain Sensors, Their Application and the Nature of the Errors'.
F. COX and J. V. SIMS.

REMOTE ENVIRONMENTAL SENSING

'Millimetre Radiometry as a Tool for Remote Sensing of Atmospheric Parameters'.
DR. D. L. CROOM, *Appleton Laboratory.*

'Meteorological Radar Techniques'.
C. WARNER, T. PRATT, A. M. R. AL-UBAYDI and J. A. EDWARDS *University of Birmingham.*

'Acoustic Radar Techniques'.
I. A. BOURNE, *University of Melbourne.*

'Radar Sensing of the Atmosphere'.
DR. B. C. TAYLOR, *RRE.*

'Meteorological Applications of Lidar'.
A. WHITELEY, J. V. WINSTANLEY and M. J. ADAMS, *Plessey Radar Research Centre.*

MONITORING SYSTEMS

'Short-Stay Measurement of Environmental Parameters in the Urban Environment'.
DR. S. B. REED, *GLC.*

'The Instrumentation of Tethered Balloons for Air Pollution Research'.
J. PARKER, *Warren Spring Laboratory.*

'Automatic Plant Watering Employing Fast, Compact, Soil Moisture Sensors'.
D. B. CARPENTER, P. COOKE and D. A. BAKER, *University of Sussex.*

'A Submersible Water Quality Station'.
H. R. S. PAGE, *Plessey Radar.*

Further information and registration forms are available from the Conference Department, Institution of Electronic and Radio Engineers, 8–9 Bedford Square, London WC1B 3RG. Telephone: 01-637 2771.

AVIONICS NEWS

Radar Facilities for UK Airspace Extended

The London Air Traffic Control Centre at West Drayton (LATCC) has now taken over the control of aircraft flying on airways in the Lichfield and Hawarden sectors previously undertaken by Preston Air Traffic Control Centre. This is the first stage of a programme intended to bring all UK airspace under the control of two Centres (London and Prestwick) and involves the introduction of new radar systems and air traffic control procedures. Completion of the full programme will make LATCC responsible for UK airspace as far north as the Scottish Border.

The improved radar facilities provided for this first stage incorporate a new Plessey AR-5 primary radar at Clee Hill, Shropshire. This modern 23 cm m.t.i. radar is equipped with dual transmitters which can be operated simultaneously and complements the Cossor secondary radar installations already operating from the same location. The radars are linked by a broad band microwave system to LATCC, a distance of over 100 miles, where processing equipment, also supplied by Plessey, is employed to display to air traffic controllers aircraft position data, labelled with identity and height information.

In addition the radar coverage available at LATCC is greatly extended by the linking of the Marconi S 264A primary radars and Cossor secondary radars at St. Annes, Lancashire, to West Drayton using modern Plessey digital extraction, transmission and processing equipment. These techniques so successfully introduced for the first time on the Burrington radar service in May 1973 provide the air traffic controller with fully processed and labelled displays of greatly improved clarity. British industry in conjunction with the Telecommunications Division of the National Air Traffic Services has been responsible for these major technical improvements at a cost in the order of £1·5 M.

New Requirements for Cockpit Voice Recorders and Flight Data Recorders

From 1st January 1975 the Civil Aviation Authority will make it mandatory for British registered aircraft to carry cockpit voice recorder systems and underwater sonar location devices. It will also widen the range of aircraft required to carry flight data recorders and will extend the range of information to be recorded. These specifications relate to aeroplanes type-certificated after 1st April 1971 and to the *Boeing* 747. Consultation with the industry on the mandatory carriage of cockpit voice recorders on other aeroplanes, including *Tridents*, has taken place, and meanwhile British Airways European Division and some other operators are making arrangements to install cockpit voice recorders voluntarily.

The requirements for conventional subsonic aeroplanes (Flight Data Recorder Systems Specification No. 10) are:

(a) Aeroplanes of a total maximum weight authorised of between 5700 kg–11399 kg.—either a voice recorder *or* a Flight Data Recorder to record parameters 1 to 9.

(b) Aeroplanes of a total maximum weight authorised of between 11400 kg–26999 kg.—a voice recorder *and* a Flight Data Recorder to record parameters 1 to 10.

(c) Aeroplanes of a total maximum weight authorised of 27000 kg and over—a voice recorder *and* a Flight Data Recorder to record parameters 1 to 26.

The parameters to be recorded are:

1. Time.
2. Pressure altitude.
3. Airspeed.
4. Normal acceleration.
5. Compass heading.
6. Gyro pitch attitude.
7. Gyro roll attitude.
8. Engine power.
9. Flap angle.
10. 'Press to transmit' action.
11. Lateral acceleration.
12. Longitudinal acceleration.
13. Reverse thrust.
14. Leading-edge high lift devices.
15. Airbrakes or spoilers.
16. Pitch trim.
17. Temperature.
18. Undercarriage.
19. Primary flying controls.
20. ILS localizer signal.
21. ILS Glidescope signal.
22. Radio altitude.
23. Essential a.c. voltage or frequency.
24. Warnings.
25. Automatic flight control system engagement.
26. Automatic flight control system mode.

The requirements for cockpit voice recorder systems (Specification No. 11) are:

Four channel simultaneous recording and synchronization

Recording speed variation

Continuity, retention and erasure of record

Monitoring of proper operation

Input circuit design, audio frequency response, distortion, noise level without input signal, coupling between audio circuits, flutter

Microphone assembly, frequency response, harmonic distortion, insulation resistance

Identification in crash conditions, crash protection

Test procedures—impact, sea water immersion, environmental

Installation and maintenance

The requirements for underwater sonar location devices (Specification No. 12) are prescribed for aeroplanes of 27 000 kg or more certificated on or after 1st April, 1971 and for aeroplanes of 230 000 kg or more certificated after 1st January, 1970. They include:

Acceptable performance standards—operating frequency, operating depth, pulse length, pulse repetition rate, operating life, acoustic output, operating temperature, actuation, radiation pattern

Environmental tests—storage temperature, inadvertent operation, vibration, impact, static crush

Installation and maintenance

The specifications have been drawn up by the CAA Airworthiness Division in consultation with the Departments of Industry and Trade (including the Accidents Investigation Branch), the RAE, the SBAC, BALPA, British Airways and representatives of the independent airlines and the EEA. Specifications Nos. 11 and 12 are broadly similar to USA TSO–C84 and USA Advisory Circular No. 21–10 respectively.

Airworthiness Specifications Nos. 10, 11 and 12, are available of charge from Civil Aviation Authority Airworthiness Division, Requirements & Publications Section, Brabazon House, Redhill, Surrey, RH1 1SQ.

Technical News

Electronic Control of Engine Speed

The recent interest in the reduction of petrol consumption and in the control of exhaust gas pollutants has emphasized the benefits to be obtained from the introduction of electronic ignition systems. It is expected in some circles that electronic ignition will become standard equipment on some production vehicles within 2½ to 3 years.

When an electronic ignition system has been specified for a vehicle, it is a relatively simple matter to enlarge the system to perform other functions derived from the ignition signal. Siemens have developed a circuit that derives a signal from the contact breaker and uses it to provide ignition pulses to the ignition coil, to indicate the instantaneous rpm (tachometer), and to limit the maximum rpm achieved by the engine. This last function has not normally been implemented on petrol-engined vehicles, but the need for an accurate and reliable control of maximum engine speed is becoming apparent as engines become more powerful and operate at higher engine speeds.

The circuit shown was fitted to a 2·6 litre, 6-cylinder car and tested with the engine speed limiter to cut out at 6,600 rev/min and to cut back in at 6,500 rev/min. When the engine was accelerated to maximum speed a slight but discernible vibration was felt by the driver as the ignition cut out, which informed the driver that the time had come to change to a higher gear. The circuit is designed so that the possibility of mis-timed sparks is eliminated at the moment of cut-off, so that back firing does not occur. The point at which the ignition is cut can be adjusted by R6, and the circuit can be altered for engines with different numbers of cylinders by altering an RC network.

The circuit is in three main parts: the tachometer, the engine rpm limiter and the electronic ignition. The spark timing is derived from the contact breaker and fed to a monostable multivibrator to provide the tachometer signal of 1 V per 1000 rev/min, indicated by a moving coil voltmeter. This signal is filtered and integrated before comparison with a d.c. voltage derived from a resistor chain in the TCA335A, which is a high gain operational amplifier. The output from the op. amp. controls transistors T4 and T5 when the maximum rpm is exceeded, and prevents the contact breaker signal from driving the ignition output transistors T6 and T7. The feedback resistor R7 prevents misfiring by ensuring that the ignition is switched off at the correct moment.

Television Satellite for Indian Villages

At least 5000 villages of India will be reached directly through television when an instructional television experiment gets under way in a year's time.

The satellite was launched in the United States on 30th May. ATS-F, as it will be known until it stabilizes in orbit, is the first direct-broadcast satellite to be built in the U.S. It has a 30-metre antenna and is powerful enough to broadcast direct to home or community receivers without relay. Once in synchronous orbit, it will be tested for almost a year for beaming programmes to rural America; then it will be moved to a position over the Indian Ocean to cover the Indian subcontinent.

As at present scheduled, there will be four hours' telecast every day, 90 minutes of it in the morning for schools. Four sound channels will use Hindi, Kannada, Oriya and Telugu. By any yardstick this promises to be one of the most important experiments ever conducted.

Medical Equipment Industries Group Formed

The five major trade associations whose members are engaged in the design, manufacture and supply of equipment to the medical and hospital services in the UK and overseas have come together to form the UK Medical Equipment Industries Group.

The objects of the Group are to provide a forum for the discussion of subjects of mutual interest and to provide a collective voice and channels of communication for t e industries concerned in negotiations with Governme it Departments and other bodies in the UK and overseas anJ, in particular, the European Economic Community.

The scope oı the Group takes in medical equipment for dental, diagnostic, surgical, therapeutic and also veterinary practice. The membership comprises the X-Ray Division of the Control and Automation Manufacturers' Association, the Electro-Medical Trade Association, the Scientific Instrument Manufacturers' Association of Great Britain, the British Dental Trade Association and the British Surgical Trades Association. The Headquarters of the Group is at 8 Leicester Street, London WC2H 7BN.