Whither the British Radio and Television Industry?

The Presidential Address of

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In acknowledging the honour that you do me in electing me your President for the coming year, I am reminded of many words of wisdom that have been spoken by former Presidents. In his 1973 address, Sir Ieuan Maddock, on the question 'Is the engineer to be on tap or on top', said 'The answer to this can only come from the engineer himself through his performance and his ability to meet the needs of his organization, his company or his country. It is by consistent success in meeting these needs within the resources available and to the time targets that have to be set, that he wins respect.'[1]

I suppose you could say that in being elected to this position as an engineer I am reaching the 'top' and it is that thought which encourages me to offer you my Presidential Address this evening in two parts. In the first part, which is concerned with the profession and the Institution as people, I will attempt to draw from my own background of education, training and experience some thoughts on how things should go in the future, highlighting some key points which will have my particular attention during my Presidential year. In the second part I shall be concerned with those sections of the work of the profession with which I am most familiar—research and development and manufacture of domestic radio, television and allied equipment. I shall again be looking at the past as I have known it and attempting to draw from that some points to the best way ahead for the nation in this fast-moving and highly competitive area of

electronic and radio engineering. First then the profession as people; and here I would like to set the scene with a word or two on my own background.

PART I: THE PROFESSION AND THE INSTITUTION

Personal Background

I was fortunate to have the last three years of my formal education up to the age of 16 at junior technical college. All the subjects in the syllabus, well balanced with practical laboratory and workshop work of that three year course, without exception, have proved to be valuable as a basic education for my future career. I did not go to University and I started work at 16 years of age repairing radios at a minimal wage, in my spare time following the pastime of amateur radio. Subsequently I found the need for greater academic knowledge of the subject and therefore, with the aid of correspondence courses, a certain amount of night school and private study, I eventually passed the Institution's graduateship examination. This course was what has been termed the 'hard way' but the on-the-job experience gained in the several years up to passing the Institution's examination was probably more directly of value to my future career than that I might have acquired had I had the wherewithal to go to University.

Lessons to be learnt from that background

From details of my career, which have been published,[2] it is evident that each major step, generally at 5 or 6 year intervals, provided more experience and knowledge for the

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next, i.e. it was almost a continuous educational process. In this respect, over the years, Institution meetings and conferences have been a valuable means of keeping in touch with new technology and thought, as well as establishing friendly and useful contact with other engineers in similar fields.

I believe one significant lesson is being increasingly recognized and it is summarized very well by Mr. G. F. Bevis in a recent article in which he says, 'The fact which is generally intuitively recognized by teachers but is very rarely rationalized, is that motivation is the most significant factor controlling the progress of a student's development ... motivation derived from such factors as the students being able to recognize the relevance of their study and finding their study both enjoyable and satisfying.'[3]

Practical work has been important at all stages of my career. In this respect the new syllabus produced for the Associated Examining Board by Professor Chaplin's team at Essex University for a new 'A' level Electronic Systems course for sixth form students is obviously a move in the right direction in attracting the interest of our younger generation into the field of electronics. Lord Mountbatten gave particular emphasis to this aspect in his address to the National Electronics Council in June this year.[4]

The report produced by the investigation team of the British Association for the Advancement of Science, in August last year, also was a valuable contribution to high-lighting the need for properly integrating the full spectrum of engineering education and training including in-career training, and for providing the necessary capacities for both the education and training.[5] There is also a need for the young to be encouraged to try engineering preferably on the basis of contact with real work. The sandwich course is an excellent way for undergraduates to obtain industrial experience, but I hear complaints from University people that in fact very few suitable places are provided by Companies.

In a world which is daily amassing more and more scientific and technological knowledge it becomes evident that we must be increasingly selective in what is regarded as essential for inclusion in educational syllabuses, i.e. to be retained in the memory of the students. Although I am no expert on the subject, I believe the memory capacity of the average human has not markedly changed over the centuries but the material available to be memorized has increased many fold! There are also obviously wide variations between individuals in memory access time, logic processes and the like. These factors need further clarification in setting qualifying standards and aptitude testing for the future.

I believe that of equal importance with educational qualifications in ensuring success in a future career are the personal characteristics of the individual which can only be fully assessed in the working environment, e.g. initiative, industriousness, imagination, observation,

ability to communicate, co-operation, integrity, leadership, awareness and so on. Thank goodness genetic engineering has not yet arrived to produce all individuals to an identical pattern for a particular following! This being so, it is evident that educational and training syllabuses *must be flexible* to allow for variations in students' characteristics and capabilities. Such syllabuses should also provide basic economic and business training. Any subsequent assessment must give adequate weighting to the characteristics I have listed.

No matter how much some people would have us all reduced to an average level of performance and reward, there will always be leaders who rise out of this mediocrity and we could do with a few more such men right now.

All the foregoing is of importance at the present time when we are faced with increasing youth unemployment and if we are going to re-establish the good name of Britain in industry, technology and innovation. I hope that Sir Montague Finniston's Committee recognize the points I have made and weigh them in the balance with the contrary view of those who press for ever more academic loading on the budding chartered engineer.

The Technician and the Engineer

There is a need for our profession to think more about itself vertically and rather less about its horizontal contacts with other disciplines. Namely, to associate technician, technician engineer and chartered engineer more closely in electronic engineering terms: each recognizing the true value of the others and all endeavouring to keep the path open from bottom to top for those who want to travel that way and are able to demonstrate the potential and/or achievement to make the grade.

I feel this very strongly because I have moved from the levels of the technician to the career of a professional engineer. In this connection I have always thoroughly supported the Institution's views on the value of the technician to the community and I for one do not wish to see barriers erected between technician and professional engineer in terms of required qualifications; I would leave open the opportunities for logical advancement from one stage to the next. Also it would be of value to young graduates as a means of widening their experience to do a spell as technicians in the early part of their career.

The Institution

Some of these thoughts will be my guide in the work I will do as your President in these most interesting and, at this particular time, most important areas of our professional affairs.

I take up the position at a period immediately following major changes including the move to new headquarters and implementation of various other cost saving policies. The net effect we believe will be a better service to members. During the course of the year I look forward to visiting as many Local Sections as possible to discuss

these and related issues, particularly from the viewpoint of the younger Graduate or Member.

The Journal of the Institution has a world-wide reputation for the standard of specialist and original papers published. Members will undoubtedly have been pleased to read in the September 1978 issue that plans are in hand to widen the scope of the Journal with more general interest papers—without reducing the present standard in any way.

I have so far refrained from comment on CEI. What started out as a simple scheme for a Council of Engineering Institutions to deal with matters of common interest seems to me to be developing into a complex organization, taking over functions which previously were done by the specialist institutions. The new Charter even allows for individual membership of CEI as a professional Institution, without the requirement of being a member of one of the Constituent Institutions! Congratulations to our former President, Dr. Percy Allaway, on his nomination as Vice-Chairman of CEI. We look to him to guard our interests during this difficult year.

PART IIA: RESEARCH AND DEVELOPMENT

In the second part of my address I shall deal with the British Domestic Television and Radio Industry under two main headings, (A) Research and Development, and (B) Manufacture, on the basis that the former has to be in a healthy state to provide the life blood for the latter! Without adequate and planned research and development, manufacturing activities are bound to fade into obsolescence and lose business to competition. I shall review some new openings where the United Kingdom may still have the opportunity to gain if active objective research is undertaken.

Present Status in U K

Considering research and development within the United Kingdom Television Industry there has been, in recent years, much criticism of Britain for lagging behind such countries as Japan, USA and West Germany in technological innovation. With certain notable exceptions this criticism is largely justified.

In the early days, thirty or forty years ago, Britain did make major contributions to the development of Television, so what has transpired since then? I believe we still have the potential researchers and innovators given the right direction and encouragement. It is evident in many instances that there has been insufficient foresight, and inadequate capital backing for long term projects of a research and development nature. The short-term 'profit now' attitude, let's-use-someone-else's-technology-and-save-unpredictable-R&D-costs, has often prevailed.

Many technologies are now so complex that the efforts of the one-man-in-his-backshed innovator are becoming more and more ineffective, e.g., micro-circuits, video recording techniques, picture and data display devices and the like. Even for initial research projects the capital cost of necessary equipment has often been considered prohibitive and in any case teams of specialists are needed.

Assuming the capital is available there is always the risk that the ultimate product will not match up to a competitor in the UK or abroad and therefore the investment will be lost. These risks have to be budgeted for if we are going to make basic progress overall.

As examples of recent developments in my field where the UK could be said to have missed opportunities because very little, if any, serious research and development was done, one can quote (a) video cassette recorders and (b) video disc players. So far as I am aware *no* original British work has been done in the research and development stages of these products yet it has been clear for several years that there would be a large international market. It is too late to start now because product development is virtually complete and the UK will therefore be initially importing and possibly later manufacturing here under licence. The research and development work on home video cassette recorders (v.c.r.s) was commenced in Europe and Japan as long ago as 1967 but the launching did not take place until 1977 in USA and 1975 Europe. The world market is anticipated as 1·5 million units for 1978 growing to over 2 million in subsequent years.

The video disc is being developed in USA, Europe and Japan, after nearly ten years of research expenditure which must have run into several million dollars as well as involving large scale and costly pre-production trials. The pay-off will be world-wide domestic sales of video records and players which will eventually replace the audio long-playing record because stereo sound also accompanies the video recording. Only one or two systems will be accepted for world standards so the losers may have to write-off their development costs.

Allied to home cassette recorders are relatively inexpensive and very compact electronic monochrome and colour cameras. Instant production of home movies is thus available when the camera is connected to the v.c.r.—instead of needing to wait for film processing. Again, I regret to observe that UK is *not* in the forefront. The development work has already been done in Japan, Europe and USA. Compared to a broadcasting studio camera at £20,000, home colour cameras are now announced in the £600 bracket. Obviously performance is not as good but it is acceptable for home purposes and there is continuous development effort to improve performance.†

The foregoing examples also illustrate another characteristic of Japanese research and development work, i.e. the *rate* at which new or improved developments are achieved and put into production compared with elsewhere.

† A short demonstration of a home colour camera and v.c.r. was given at this point (see Fig. 1).

Fig. 1. Modern 26-inch colour television receiver incorporating Teletext and Viewdata with video cassette recorder and home colour camera, as demonstrated.

The receiver can be remotely controlled from a hand-held key pad by means of infra-red radiation. In addition to vision and sound controls, Teletext and Viewdata can be displayed and controlled, and in the case of the latter operated interactively, using the remote key pad. The normal receiver functions can also be operated by 'touch-buttons' (channel switching) and by slider potentiometers (vision and sound controls).

What action can be or is being taken?

The aims and objectives of the National Electronics Council include the following:

Initiation, encouragement and co-ordination of research in the field of radio and electronic science and engineering.

With the vast potential effort, know-how and facilities already available in the UK in universities, laboratories and industry, it is obvious that we should be able to equal the performance in research and development of any of our competitors—given the initiative, encouragement, proper co-ordination and effective management—and the right attitude! Too much research is done on a casual 'this year—next year—sometime—never,' basis. I refer to the need for more objective research and development, properly managed and progressed, where a sense of urgency prevails and at the same time having flexibility to change course if necessary as dictated by events in the course of a project.

As to whether or not the N.E.C. policy succeeds will largely depend on the methods and procedure used, first in the initial assessment of and the budgeting for proposed projects, secondly, in the control and progressing of accepted projects with dedicated Managers and the minimum of bureaucracy and large committees!

Considering time scales, it will be seen from the two examples quoted above, i.e. video recorders and video disks, that major research and development projects are necessary. To arrive at satisfactory products cheap enough to be acceptable on the domestic markets, a period of ten years may be required. This is where the foresight is required to start early when the project may barely seem feasible.

On this basis we ought to be following up, say, three or four major projects over a ten-year period with staggered starts. Allowing for 50% failure we could hope for two

successful products with national/international domestic market potential each ten years—thus to fill capacity becoming available!

I have not referred to individual companies in the foregoing comments but have rather talked on a national basis. Obviously in practice individual projects could be tackled by one or more companies, in conjunction with what other laboratory and engineering services may be required. In some large projects co-ordination on a national basis may well be necessary but we should in general preserve the benefits of competition! Obviously also we shall not progress far unless adequate risk capital can be made available for approved projects. In this connection the National Research and Development Corporation, the Departments of Trade and Industry and the National Enterprise Board appear to be fulfilling the need.

An estimate shows that expenditure on Research and Development in the UK barely represents 1% of total turnover. This compares with a figure of 4% for Japan. Obviously if the UK is to improve its performance in Research and Development, we shall have to increase funding in this connection, which is tantamount to saying that the engineer strength requires increasing.

The component industry do, of course, undertake Research and Development in their own right as suppliers to the equipment makers. Several of the major component makers are multi-national and figures are not available for their Research and Development contribution to the UK domestic market.

Possibilities for the U K to Lead in New Development
Data Systems

There are some developments where the UK has led in the research phases and provided exploitation is not delayed a good market should follow. In the case of the television data display system known as Teletext and the

allied Post Office Prestel Viewdata system the research and development work has been done in the UK—as has the associated microcircuit development. We should, therefore, benefit by licensing the manufacture or use of these systems abroad and also by the sale of the l.s.i.s and equipment. These products are examples of good on-the-spot co-operation in the development stages, between the main equipment makers and the electronic component makers—an essential feature in such projects.

Television receivers are adapted for Teletext by the addition of the necessary large-scale integrated and pro-grammed memory circuits, mounted in module form, for the decoding and processing of the data signals.[6] These signals are, of course, carried on the same transmission channels as normal television signals. To appreciate the complexity of the processes and circuits involved one has only to see the size of experimental rigs which, even so, used ordinary i.c.s—120 of them—plus other items! All this circuitry has been condensed on a module measuring 15 cm × 10 cm approximately and using six l.s.i.s and three i.c.s.

A good measure of standardization has been agreed between the BBC, the IBA and the Post Office, as to character display and other parameters and therefore much of the Teletext circuitry can be used with View-data. The signal decoding and control circuits need to suit the slower rate digital P.O. signal over cable and are special to Viewdata. For this purpose additional modules are added to the television receiver.

Both Teletext and Viewdata circuits and assemblies call for extremely high capital cost equipment for manu-facture and automatic test, as well as the earlier develop-ment costs. Therefore, the ultimate unit cost to the customer is very dependent on the production quantity and rate upon which the capital costs may be recovered. This consideration produces a chicken and egg situation, and a degree of subsidy may well be necessary in the early stages to encourage sales at reasonable prices and thus build up quantities.

With the increasing use of the television receiver as a viewing unit in the home or office, for all the new facilities I have outlined—plus such items as video games, security surveillance and the like, it is evident that more than one receiver per home will become the rule rather than the exception. The demand for small size sets is already increasing.

For data purposes only, particularly in the office, it is probable that the Viewdata circuitry will be contained in a relatively compact box unit upon which the viewing unit (set) can stand. It is in this connection that the flat picture display devices, to which I will refer shortly, will find the first application.

Apart from the *reception* of data, however, the inter-active or two-way data facility which can be carried over the telephone lines *from* the subscriber (at 75 bit rate) will open up a whole new avenue in communication. For this application of course suitable compact data printer

terminals would be necessary at the subscriber's location or on a portable basis.†

Flat Panel Picture Displays

In connection with data and picture display devices it is evident that the conventional cathode-ray tube will eventually be superseded though the provision of a satisfactory alternative is still some way off. The flat panel display is, for example, an area of research and development which is being currently tackled in several countries. I would have thought this item was worth a co-ordinated British effort. In fact, I believe some work is being done but probably not on an effective scale.

The first flat picture display to be marketed will probably be in monochrome only and indeed experi-mental systems have already been satisfactorily demon-strated. These may well first be used for data and other displays, where there will be obvious advantages over the bulky cathode-ray tube obviating the need for e.h.t. voltages. Combined with micro-circuits some very com-pact display units will be possible. A good deal of research still has to be done to produce a satisfactory colour display including improvement in light output. Most displays so far demonstrated consist of arrays of light emitting or light controlling elements which are illuminated sequentially by fast switching systems. The most promising results so far have been obtained with gas discharge (or plasma) cells which can also be designed to produce primary colours for colour display by the use of phosphors. Electro-luminescent and liquid crystal arrangements have also been experimentally demon-strated. Complexity arises from the fact that more than 300,000 light elements are needed for a full resolution television display.

Further Possibilities for UK Research and Development and Industry

I will now consider briefly other areas where recently introduced Government or international policies could produce further openings for British initiative.

Annan Committee Report and Government White Paper

In July this year, following study of the 1976 Report of the Committee under Lord Annan on the Future of Broadcasting,[7] the Government issued a White Paper on Broadcasting.[8] From an engineering and industry view-point the main features of the White Paper are:

(a) The IBA's supervisory responsibilities will be extended to embrace cable services, including pilot schemes of pay-television and other forms of local broadcasting.

(b) An Open Broadcasting Authority (OBA) will be

† The President then referred to the National Teletext Week to publicize the new service which had just been held and to the initial field trials of Viewdata which were currently proceeding. A short demonstration of a television receiver which incorporated Teletext and Viewdata circuits was given (see Fig. 1).

established to supervise a new service on the fourth television channel; and a Welsh language service will have priority on the fourth channel in Wales.

(c) Both BBC and independent local radio services will be permitted to expand.

In respect of Cable Television it is recognized, quoting Section 174, 'The technological question for the future is whether this country should aim to have a nationwide wideband cable system capable of meeting all our communications needs. The decisions taken today must not prejudice possible future developments. The Post Office Review Committee recommended, and the Government accepts, that the option for a nationwide wideband cable system for telecommunications as a whole must be kept open, and that the Post Office should safeguard it in technical terms by insisting that all future developments of wideband cable television should use technology which will be compatible with such a system.'

Concerning Pay TV over cable, Section 178 states 'The Government is not prepared at this stage to dismiss the possible advantages of Pay-TV, or to conclude that the disadvantages which it might hold could not be overcome. Whether the disadvantages can be overcome is a question to which experimentation might hold the answer. Provision will therefore be made in the new legislation to enable pilot schemes of pay-TV to be authorized subject to careful regulation to guard against the possibly damaging effects which pay-TV might have on television as a whole and on the cinema industry.'

Cable Television

Whilst cable television in Britain—which serves some 2 million homes—is relatively in the doldrums, in several countries it is making considerable progress as a means of conveying reliable television channels in greater number and selection than can be received off-air. Some of the channels are devoted to Pay or Subscription TV generated by, or on behalf of, Cable Companies, i.e. not broadcast over the air in the first place.

The favourable decision by the Government in allowing pilot schemes of Pay-TV together with local community television could give the cable companies a much-needed boost, and at the same time give the public greater choice. In the field of Cable Television and allied telecommunications currently the first early applications of glass fibre optical cable are being made. We may expect considerable growth in this area over the next ten years.

Satellites for Broacasting

The positioning of synchronous satellites for European broadcasting in the 12 GHz band have been agreed within the European Broadcasting Union. Because Britain is now well covered with a large chain of u.h.f. transmitters and a further national channel could be accommodated on u.h.f., it is unlikely that satellite broadcasting will be used for some time. However,

other parts of Europe and the World less well provided with ground transmitter coverage are actively pursuing the provision of this form of broadcasting.

Together with a special dish antenna installation, a convertor to receive these transmissions on a standard television set might cost £120. However, since the received angle over the horizon is relatively low, many homes would be screened by larger buildings, etc. particularly in large towns. In such cases, it will be more economic to retransmit the satellite signals over cable systems whereas villages and isolated communities could receive direct. There will obviously be opportunities for the United Kingdom in this field.

Radio, Audio and other Developments

Broadcast Traffic Information. The White Paper on Broadcasting for July 1978 states in Clause 188: 'The Annan Committee recommended that a new broadcast traffic information service should be established, but only at such time as the road traffic authorities and the Government considered they were able to provide and finance it (108). A Department of Transport Working Group has been set up to identify the service which a broadcast traffic information system could provide and to evaluate the costs and benefits which might be expected. The Working Group is expected to report soon.'

In the meantime, field trials and development have been proceeding on the BBC's CARFAX proposal which is a medium frequency system.[9] Here a single m.f. channel with time division multiplex would serve most of the United Kingdom.

V.H.F. Station Identification. It is often difficult positively to identify a v.h.f. f.m. broadcast sound signal when tuning on the normal receiver dial. Tests currently under way in Europe involve inserting station identifying coding on the normal v.h.f. signal. Transmission on these lines would mean station identity could be displayed on an l.e.d. array on the receiver thus doing away with difficult-to-read dials!

Micro-processors. I have not specifically referred to micro-processors—a rather overworked word in recent years! These particular forms of l.s.i.s are, of course, already used in the domestic field for such applications as remote control, video games and data systems. It is evident that many other applications will be devised, particularly for signal processing and control purposes. Nevertheless, there will still be a large proportion of normal sized hardware, which cannot be made in 'micro' proportions, to keep the equipment design engineer busy!

Union Attitudes to New Technologies and Products

In recent years we have, regretfully, had several examples of union action 'killing the goose that lays the

golden egg'. So far as our industry is concerned it is to be hoped that these short-sighted policies will not continue. I have in mind such actions as refusal to work on, install or service new equipment without additional pay (even though normal annual reviews have been made). The launching stage of new products only comes after the investment of high capital sums in the pre-production period and is, therefore, a critical non-profit stage in the life of the product.

Maximum effort and co-operation from all staff is therefore required to get the new product 'off the ground' and thus bring in the orders which in turn increase production *and* preserve jobs in the future.

PART IIB: MANUFACTURE

Market Size and Growth Characteristics

In initiating new research and development projects, and for estimating production rates build up to sub-sequent maximum output levels, it is essential to have reliable forecasts of market demand at target prices. This information will set the levels of capital investment which can be made in research and development in tooling and in automatic processes etc. to obtain a return within an economic selling price.

In the case of products like domestic television, which eventually find their way into most homes in a country, there is a characteristic growth pattern. Figure 2 illustrates this characteristic graphically for colour television in the UK, Japan and the USA. The time scale has been adjusted to a common start year and correction has been made for total market size. It will be noted that there is remarkable correlation in the early years and there would have been closer correlation in the case of the

UK but for ill-considered government short-term action in taking-off and re-applying purchasing controls in the period 1971–74. This sort of 'stop-go' action completely upsets the momentum of the whole industry which can seldom make rapid mid-course corrections to increase or decrease production levels. The result is extra capacity and output coming on stream just when the demand is reducing! The industry is still suffering from the after-effects of this excess capacity. Politicians must realize that you cannot at will just push switches to increase or decrease output overnight. A year is a short time in such considerations. Let us hope that governments and parties are becoming rather more enlightened in these matters nowadays.

Without an efficient and high level home market production in the television receiver and allied fields a country cannot gain export orders on a worthwhile scale. Japan is the prime example of a healthy home market and good export performance. Last year 46% of their colour television receiver output of 9·5 million was exported, of which 57% went to North America. It should be emphasized that for Japan, in concentrating only on the small tube and portable set sizes under 20 inches, the export handling and quality problems were reduced against the 22-inch and 26-inch sizes popular in Europe. Their exports were also more successful in the USA because of the common N.T.S.C. standard 525-line systems used in both countries, i.e. the home product was suitable for that export market. However, with the increasing value of the yen relative to other currencies, the United Kingdom should now have a better chance of competing on a price basis. Other Far East countries are likely to be a bigger threat.

Because adequate local manufacturing capacity for
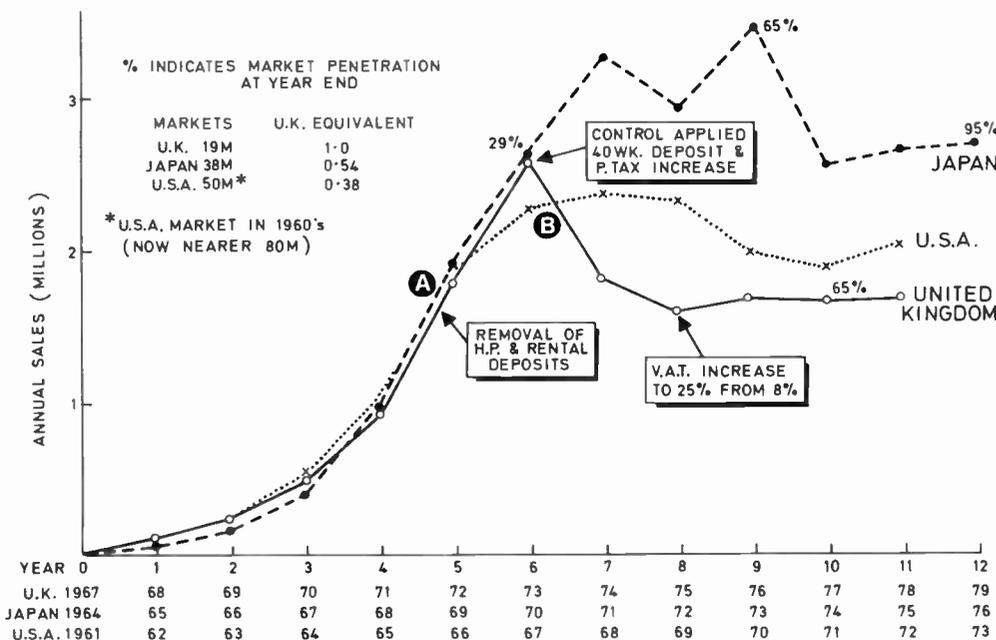
Fig. 2. Annual sales of colour television sets, with UK, Japan and USA equated to same time and market scales.

At Time 'A' the UK industry made decisions to invest large sums to increase capacity for television set and tube manufacture. This capacity was coming on stream 12–18 months later (Time 'B') when government controls decreased demand by 30%.

World Radio History
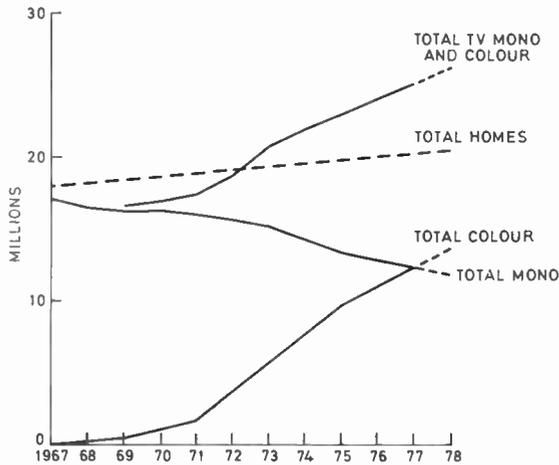
Fig. 3. Totals of UK home television sets for period 1967–77, including the increasing number of 'two-set' homes.

conventional television receivers is available in most countries, Britain's chances of gaining large scale export business are remote but some progress can, and is, being made with the right products in a few territories using the 625-line standard. For example, in the year 1977 310,000 colour television sets were imported from all parts whilst 224,000 UK-made sets were exported. Total production was 1·60 million in the UK, i.e. imports represented 18·3 % of total availability and exports 14 % of UK production.†

Figure 3 shows the cumulative growth curve of UK colour television receivers to a penetration of 65 % of homes. Early receivers of the first generation ten years old are now being replaced on an increasing scale. The increasing replacement set demand should compensate for the reducing demand for first-time sets and allow a relatively steady production rate of the order of 1·75 million per year. Additionally, there is an increasing demand for compact second sets in the home, mostly of small size (12 in–16 in) screens and of portable design both monochrome and colour. We should aim to make these here—even though there is no UK manufacture of cathode-ray tubes in these sizes.

Other products designed for domestic use, such as video cassette recorders, apart from the disadvantages of their relatively high price, have to compete with colour television for priority in the home. Disposals are therefore likely to follow a similar growth curve to Fig. 2 but at a reduced rate which might be one-third or less that of colour television. Nevertheless, these new products will, with proper overall planning, take up productive capacity thrown up by the television receiver industry. This capacity will increasingly result from labour and space saving technology of latest television receiver designs—a subject I will deal with later.

† Source of British industry statistics was the British Radio Equipment Manufacturers Association.

Other Statistics

In 1977 the total UK sales turnover in the domestic radio, audio and television markets was some £775M of which 55 % was television and the balance radio and audio. A total of some 50,000 people was employed in manufacturing whilst on the distribution and services side the number employed was of the order of 100,000. Statistics are not available on the number of engineers and technicians in these totals.

Additionally, in the electronic component industry supplying the domestic market it is estimated that a further 7,500 people were employed to supply £90M worth of components, not including cabinets. In total, some 120,000 are employed in the component industry but separate figures are not available for supplies to the main equipment sectors, i.e. Domestic, Capital Goods, Telecommunications, Computers and Control and Instrumentation.

The Consumer Electronics Sector Working Party of the Electronic Economic Development Council reported in December 1977 that the 'fixed assets' of the radio and television industry were working at 50 % of potential and should be rationalized by 20–30 %.[9] Some steps have been taken towards this end and are inevitably resulting in some redundancies. However, the indications are such that there should at least be stability of employment from 1979 onwards.

Television Receivers—the Present State of the Art

Television receivers as we know them, using cathode-ray tube picture displays, have reached a stage in engineering development where performance, reliability
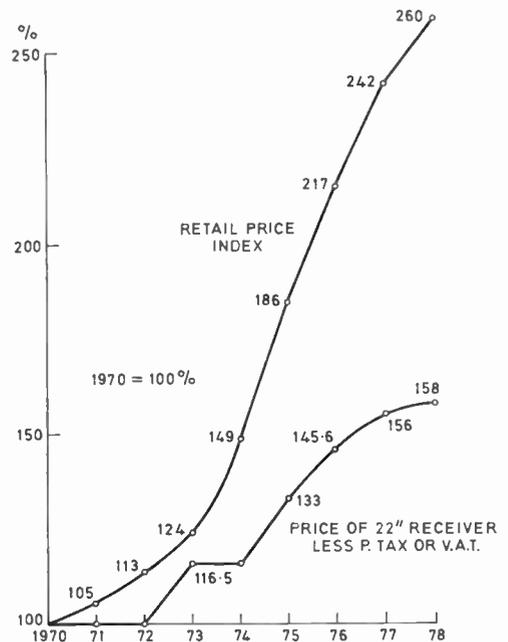

Fig. 4. Colour television receiver price compared with Retail Price Index 1970–78.

and cost are generally acceptable to the public. The receiver design engineer is becoming more and more a systems man, using large sections of the circuits in micro-electronic integrated form, designed and pre-fabricated at factory sites which may be anywhere in the world. Discrete transistors and other large components are still necessary in power circuits, for scanning, video drive, e.h.t. and the like.

Colour receiver development in the past two years has been mainly concerned with refinement of control facilities and channel selection including the use of ultra-sonic and, more recently, infra-red remote control. The latter use binary and simple microprocessor techniques and the change to varicap tuning from mechanical means opened up these possibilities. In these developments European, including UK, manufacturers have been ahead of Japan and USA.

Conventional i.f. circuits are currently being replaced with surface acoustic wave filters. Apart from reducing the number of i.f. coils requiring adjustment to about three small filters or traps, these s.a.w. filters bring advantages of stability, improved skirt response and small size. The improved response is important for Teletext reception, also for adjacent channel reception on cable television.

For a restricted but relatively high cost market, e.g. for schools and educational purposes, specialized large screen receivers are manufactured. There is also some revival of projection television using special cathode-ray tubes to produce pictures of the order of 2 metres × 1·5 metres.

Cost Reduction

Whilst maintaining receiver performance and reliability there has been continuous development to keep cost to a minimum off-setting inflation and the industry has a remarkable record in this connection. Figure 4 illustrates this point and also suggests that in the circumstances of excess capacity and inflation manufacturers were not making an adequate return on capital!

There has also been a considerable reduction in the number of discrete components and assemblies per receiver, particularly with the increased use of i.c.s, Figure 5 shows this reduction—in broad terms—for the past few years. Cathode-ray tube improvements with the introduction of in-line 'self-converging' tubes and yoke assemblies have materially reduced factory set-up and test labour requirements. Automatic panel insertion and test methods are also coming on stream. All this means that the required factory space for assembly and test of the basic television set at a given rate is approximately *halved* and the personnel requirement similarly halved on what would have been necessary 7 years ago. It is un-likely that major savings of this order will be made in the near future. In terms of work and material content UK latest designs should be competitive with those of any country. Of course, new developments like Teletext and
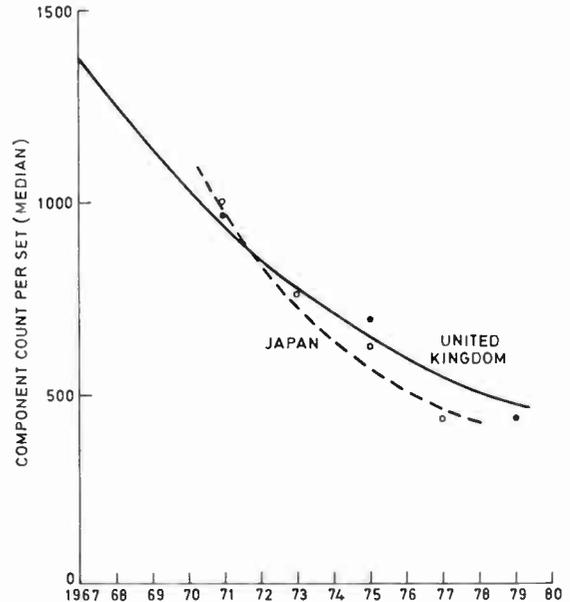

Fig. 5. Component count per set for colour television receivers (median values).

remote control will increase the material and work content, progressively off-setting some of the savings made in the basic television set.

Quality and Reliability

In addition to cost reduction, concentration has also been on improving colour set reliability. Large service organizations, such as my own company operates, with literally millions of colour television receivers in the field, produce reliability statistics for feed back to manufacturing engineering departments. Resulting from studies of these statistics improvements are made in component and assemblies as a continuing process. Figure 6 shows the remarkable progress made in reduction of television set failures over the past ten years.

The coming of integrated circuits has not been without reliability problems, particularly of thermal shock, i.e. hot/cold cycling, and susceptibility to static charges.

Reliability engineering has also been concerned with improvement in initial set reliability in the first 100 hours
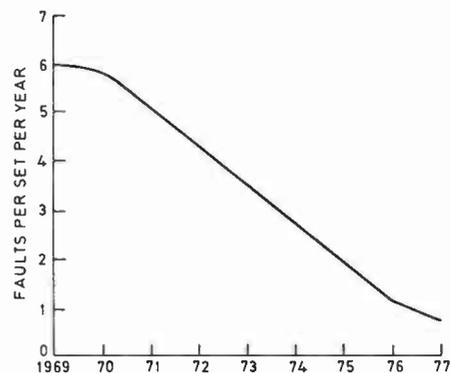

Fig. 6. Reduction in failures per unit per year resulting from service experience.

Table 1

Material source by country for typical British television industry colour receiver

Item	Source	Percentage of Total Cost† (%)	UK share (%)
Colour tube	UK 32%; N. America 32%; Japan 31%; Europe 5%	35	11
Deflection components	All in-line types as above	8·5	3
Cabinet and back	UK	10·5	10·5
Chassis metalwork	UK	2	2
Mouldings	UK	2·5	2·5
Major assemblies including line output transformer, tuner, tripler, chokes	Line output transformers: all UK; Tuners 95%; Triplers and chokes 70%	13	11·75
Printed panels	UK	2·5	2·5
Integrated and l.s.i. circuits	Worldwide	2·5	1·0
Transistors	UK 50%; Europe 40%; Far East 10%	5	2·5
Diodes	UK 15%; Europe 40%; Far East 40%; USA 5%	1·5	0·25
Capacitors	UK 45%; Europe 20%; Far East 35%	4·5	2·25
Resistors	UK 30%; Europe 40%; Far East 30%	2·0	0·5
Speaker assembly	UK 75%; Europe 25%	1	0·75
Delay line and I.F. coils	Delay line: mainly UK; I.F. coils: Far East 85%; Europe 15%	1	0·5
Miscellaneous and presentation	UK	5	5
Trolley stand and packing	UK	3·5	3·5
		100	60

† Approximate figures.

or so of use, and resistance of transit handling. Soak testing of all sets on a production line is now almost universal—for 24 hours or so. Current British manufactured television receiver reliability should now be equal to, or better than, that of any country.

Sources of Manufacture

It is instructive to review the sourcing of the main materials and parts used in the typical modern television receiver. Table 1 gives this information and makes obvious how much is imported that should desirably be made here! In this respect however, high cost British labour is to some extent competing with such countries as Taiwan and Korea. Figure 7 brings out this problem as a major one for Britain and the Western World. Fortunately, from a UK viewpoint, the Far East type of activity is much more suited to lightweight, small, mass-produced components and assemblies rather than complete bulky equipment such as colour television sets.

In the case of small radios, i.e. portable and car, and some audio equipment, more than 90% is imported from Far East sources and it is unlikely that this pattern will change. Some larger audio music-centres and hi-fi equipment continue to be made in UK and sold successfully.

Industry Prospects and Conclusions

From a design, quality, reliability and cost viewpoint, I believe it can be shown that we in the UK now make domestic electronic equipment, particularly television, which is equal to, or better than, the competition from
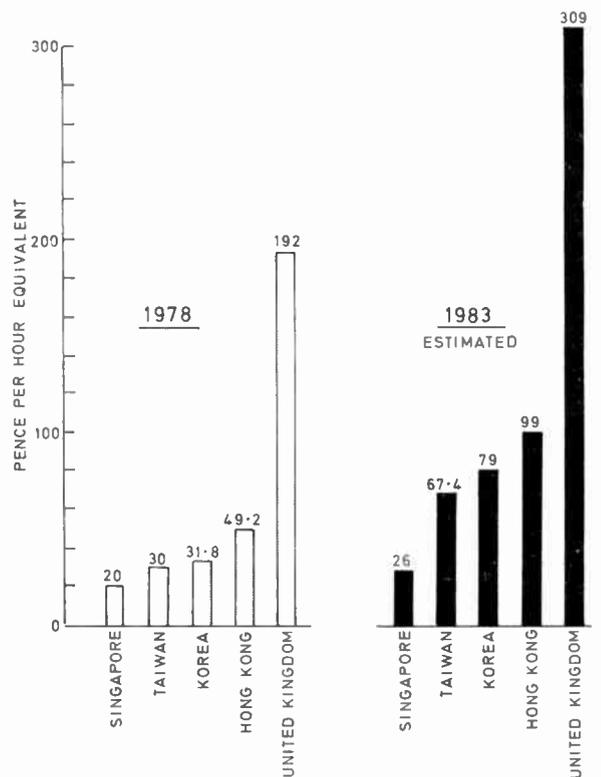

Fig. 7. Comparison of the hourly unit costs of production line workers in the UK and in the Far East.

any country. We also possess the manufacturing know-how to produce equipment as cost effectively as anyone else. What we have to do is to sell these facts to our customers in the UK and abroad—and ourselves.

Because of excess capacity resulting mainly from earlier government stop-go policies the industry is currently still 'licking its wounds' but is consolidating into more compact and effective units. Apparently some people conclude that the Japanese can do this more effectively in this country than we can ourselves. At least the Japanese are prepared to invest their capital into such activities where UK sources are sometimes reluctant.

I believe that given the right attitudes in companies from management to production line, and financially, we can do as well as anyone else. It goes without saying that we also need a long spell of economic stability free from excessive and rapidly changing government controls.

After a year or so running at current levels of output we should see progressive improvement as new products gain momentum and add sales to an increasing television set replacement market. The 80s should be set fair for the domestic electronics industry, not ignoring the point that it is largely a leisure industry and many people are saying we should be working shorter hours to reduce unemployment, i.e. increase leisure!

I have emphasized the need for continuous and properly controlled research and development to keep our industry fed with new products for future manu-facture. This means, one way or another, ensuring the availability of an adequate force of dedicated engineers and technicians, but that brings me right back to where I started, the Institution, and here I must conclude.

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(Address No. 54.)

IERE News and Commentary

Electromagnetic Compatibility

In this issue and in February there will be published a selection of papers from the IERE Conference on Electromagnetic Compatibility which was held in Guildford in April 1978.

The volume of Conference papers, which has been temporarily out of print, is now available again and copies may be obtained from the Institution, price £16·00 ($44 US). post free. The full list of papers given at the Conference will be found elsewhere in this issue.

Preparing for WARC

A massive (600 pages) report has been produced at a recent Special Preparatory Meeting to provide the technical information likely to be needed by the World Administrative Radio Conference (WARC) when it reviews the Radio Regulations in October.

In carrying out its task the SPM confined its activities to technical matters which it believed would be relevant to the established agenda of the WARC. The report is in consequence concerned primarily with the specification of technical criteria which would (a) enable a re-allocation of frequencies for existing services to be made, and (b) indicate frequencies most suitable for possible new services, in both cases giving particular attention to the criteria determining the feasibility of frequency-sharing. The Report also contains a chapter describing basic propagation characteristics which underline the conclusions reached with respect to (a) and (b) and gives consideration to some matters of terminology, monitoring and identification of the optimum use of the frequency spectrum.

In view of the relatively infrequent occurence of WARCs, compared to the frequency of Plenary Assemblies of the CCIR, and of the continuing rapid development of the technology of radio communications, the SPM believes that special attention should be given to the latest version of CCIR Recommendations, for example, on the propagation of radio waves in relation to the design and operation of radio communication services and on the technical characteristics of equipment and systems on which the efficient use of the frequency spectrum and geostationary satellite orbit is critically dependent.

A very important part of the work of the SPM has been to evaluate the technical factors influencing the way in which services can share different parts of the radio frequency spectrum. The meeting defined the minimum conditions under which individual services could adequately operate thus the way to additional sharing possibilities.

As a result of its deliberation the WARC may well make considerable modifications to existing arrangements in the allocation of the spectrum between 40 and 300 GHz. The SPM has provided the technical data as to the suitability of this part of the spectrum for different services, always bearing in mind the possibilities of sharing arrangements between space and terrestrial services.

The report is being distributed as a document for the 1979 WARC. It cannot be purchased and is not available to the public.

Harbour Radar for Shetland Oil Terminal

At the Sullom Voe oil terminal in Shetland Decca Radar have recently installed a harbour radar system to monitor tanker movements down the Voe to the terminal. The promontory of Vats Houllands is the natural site for a radar, having all-round surveillance. However, the displays need to be at Stella Ness (opposite the main terminal) where all the other port facilities are concentrated. The solution is a remote, unmanned Decca HR 18 mounted on a 27 m tower at Vats Houllands, its radar data being transmitted by Ferranti microwave link to Sella Ness. The direct path from one to the other could be impeded by the upperworks of tankers in the intervening turning circle, so the microwave transmitter is aimed at a special 'billboard' on the hill of Garth near the shore to the east, the signals being reflected to a receiving aerial mounted on a 21 m tower near the Port Operations Room. The link is fully duplicated and has space diversity facilities to ensure good reception under all conditions.

The remote radar is controlled by u.h.f. from the Operations Room, where there are four 41 cm (16 in) fixed coil displays each fitted with Deccaspot (in this case a total of 280 spots denoting channel edges, depth contours, buoy positions and the tanker turning cycle). Equipment at Vats Houllands includes dual-channel transceivers, dual-channel interface and link, control unit and monitor display (for visiting maintenance engineer), also generator, batteries and charger to ensure continuity in the event of mains failure.

The navigational equipment of two pilot boats includes Marconi 300B transponders, which are triggered by the harbour radar system to produce coded responses on the latter's displays ensuring that the boats' whereabouts are always known.

Build your own Business Competion

The 'Build Your Own Business Competition', designed to help the creation and development of new businesses in the North of England, has recently been announced.

Organized by Enterprise North and Durham University Business School, in association with Shell U.K. Limited, the competition which is worth £10,000 to the winner, is expected to draw entries from all over the country. The winner must agree to set up his business in the Northern Region, a development area comprising Northumberland, Durham, Cumbria, Cleveland, and Tyne and Wear, where the availability of grants and loans may help to stretch resources for a new venture.

There are three main prizes—£10,000, £5,000 and £2,500—but it will not be just the prizewinners who will benefit. Every entrant who complies with the rules will be offered practical help and advice by the organizers on small business aspects like raising capital, location and company law.

Entry is open to anyone over 18 with an idea for a manufacturing or service business. The prizewinners will be chosen by a selection committee on the basis of the business idea, its likelihood of success and—most important—the ability and determination of the entrant to put the idea into practice.

Enterprise North is an advisory organization formed and run by local businessmen to encourage the creation and development of business in the North. It operates through new enterprise panels throughout the region, and works closely with the Business School which was founded in 1967.

Further information and entry forms can be obtained from John Eversley, 'Build Your Own Business' Competition, Durham University Business School, Mill Hill Lane, Durham DH1 3LB. (Tel. Durham 41919.).

CEI News for Members

Executive Committee Meeting

At its meeting on 9th November, the Executive Committee of the Council of Engineering Institutions agreed that further evidence will be submitted to the Government's Committee of Inquiry into the Engineering Profession and discussed a draft.

Regulations to be recommended to the next meeting of the Board of CEI under the new Supplemental Charter and Bye-Laws were considered in detail. (That meeting will take place on Thursday, 25th January, 1979). Particular attention was given to the investigatory and disciplinary procedures to be adopted in the event of an alleged breach of the Professional Engineer's Code of Conduct.

CEI Elections and the Single Transferable Vote

As announced in the November Journal, the distribution of voting papers for the election of 16 Individual Members to the CEI Board was made to all Corporate Members of the IERE in the December issue. The completed documents must be returned to the Electoral Reform Society using the ad-dressed envelope which was also enclosed with the list of nominations and the ballot paper, by 15th February 1979. There are 119 valid nominations and the declarations of those elected will be made at the CEI's Annual General Meeting on 15th March 1979. A special meeting of the Board, the first attended by the elected members, will be on 10th April.

There have been a number of enquiries made to CEI and the Institutions relating to the Single Transferable Vote system which is being used for the Board Elections. Full details are contained in the booklet ' How to Conduct an Election by the Single Transferable Vote ' which costs 65p from The Electoral Reform Society of Great Britain, 6 Chancel Street, London, SE1 0UX.

Supplemental Charter and Bye-Laws

The Supplemental Charter and new Bye-Laws of CEI have been printed and any individual member of CEI may have a copy on request to the Executive Secretary, CEI, 2 Little Smith Street, London SW1P 3DL.

Forthcoming Conferences

Microprocessing 79

For the theme of their third conference on microprocessors, the Yorkshire Section have taken the theme, ' Micros in Society '. This one day meeting, which is being co-sponsored by the British Council of Productivity Associations, will be held on Tuesday 24th April 1979 at the Royal Station Hotel, York. The aim of the organizers has been to collect together authoritative speakers to discuss the potentialities of micro-processors and suggest how these can be exploited to the full without upsetting the economy and society in general.

The programme and registration details may be obtained from the Honorary Secretary, Mr B. Mann, 65 Westfield Lane, Kippax, Leeds LS25 7JA.

International Conference on Charge Coupled Devices

The 5th International Conference on Charge Coupled Devices will be held in Edinburgh from 12th–14th September 1979. This conference series alternates between San Diego and Edinburgh, and the 5th Conference will aim at present state-of-the-art developments in CCD technology and design techniques. However, the emphasis of this Conference will be on the application of CCDs to novel systems designs.

Review papers on the major areas of CCD use—memories, imaging, signal processing—will be presented and the technical programme will contain sessions on developments in the technology; new device structures; signal processing in sonar, radar and telecommunications; visible, IR and low-light-level imaging and other novel systems applications.

The Conference is being jointly organized by Wolfson Microelectronics Institute and the Centre for Industrial Consultancy and Liaison of the University of Edinburgh, in association with the Institution of Electrical Engineers, Institute of Physics, the Institution of Electronic and Radio Engineers and the Royal Signals and Radar Establishment.

Further information from: Mr. W. Campbell, Centre for Industrial Consultancy & Liaison, University of Edinburgh, 16 George Square, Edinburgh EH8 9LD. (Tel: 031 667 1011, ext. 2369).

World Telecommunications Meeting

Fourteen countries participated in TELECOM 71, the first World Telecommunication Exhibition. At TELECOM 75, 37 countries were represented. To date, Administrations and companies from 40 countries have already announced their participation in TELECOM 79, among them, for the first time, Australia, New Zealand and the Soviet Union. In addition, INTELSAT, the operating organization for a world-wide space communication network, is representing in its pavilion more than 100 Member countries. The Exhibition falls right at the beginning of the important World Admin-istrative Radio Conference.

Thirty-four national and international institutes of tele-communications and electronics engineers are co-sponsoring with the ITU the 3rd World Telecommunication Forum, held within the framework of TELECOM 79.

Part I of the Forum, 'Telecommunication Perspectives and Economic Implications', from 19th to 21st September, 1979, will bring together the world's telecommunication policy-makers from Administrations and industry as well as financiers to find solutions to investment and policy problems involved in the future development of the integrated world telecommunication network.

Part II, to take place on 23rd to 26th September, will be a Technical Symposium on the 'Integration of the World Telecommunication Network', and is being supported by a great number of national and international institutes of communications and electronics engineers.

The first ITU Centenary Prize will be awarded during TELECOM 79 to honour an individual or a group of individuals whose activities on behalf of the development of the world-wide telecommunication network have gained international recognition.

Further information on the Forum or the Exhibition may be obtained from: TELECOM 79 Secretariat, International Telecommunication Union, CH-1211 Genève 20 (Switzerland) (Telex: 23 000 CH).

Forthcoming Institution Meetings

London

Tuesday, 23rd January

JOINT IERE/IEE MEDICAL AND BIOLOGICAL ELECTRONICS GROUP

Colloquium on NAVAL AND UNDER-WATER MEDICAL ELECTRONICS

Royal Institution, Albemarle Street, London W1, 2.00 p.m.*

Tuesday, 30th January

COMMUNICATIONS GROUP

Colloquium on H.F. PROPAGATION FORECASTING

Royal Institution, Albemarle Street, London, W1, 10.30 a.m.*

*Advance registration necessary. Further details from Colloquium Registrar, IERE.

Beds and Herts Section

Thursday, 25th January

Electronics in observational astronomy

By J. C. D. Marsh (*Director, Hatfield Polytechnic Observatory*)

Hatfield Polytechnic, 7.45 p.m. (Tea 7.15 p.m.)

Synopsis: The crude manual operation of the astronomers' telescopes has been replaced with complex and sophisticated electronic controls. The observer's eye has been superseded by electronic detectors, photon counting systems and image intensifiers.

Cooled pre-amplifiers, phase-sensitive detectors feeding integrating digital voltmeters produce computer compatible signals allowing real-time checking and analysis as the observations proceed.

Some of these advanced techniques will be reviewed and discussed.

Thursday, 22nd February

Modern radio receiver design

By R. Sutton (*Eddystone Radio*)

Bedford College of Higher Education, Mander Site, 7.45 p.m. (Tea 7.25 p.m.)

Thursday, 29th March

Optical fibre communications

By Professor W. A. Gambling (*University of Southampton*)

Hatfield Polytechnic, 7.45 p.m. (Tea 7.15 p.m.)

East Anglian Section

Wednesday, 24th January

Introduction to lasers and some applications

By S. Lazenby (*Ferranti*)

King Edward VI Grammar School, Broomfield, Chelmsford, 6.30 p.m. (Tea 6.00 p.m.)

Thursday, 25th January

JOINT MEETING WITH IEE

Microprocessors in instrumentation

By Dr. D. B. Everett (*National Institute for Medical Research*)

University Engineering Laboratories, Trumpington Street, Cambridge, 6.00 p.m. (Tea 5.30 p.m.)

Thursday, 8th February

JOINT MEETING WITH CES

It's safer and more comfortable in the air

By Dr. B. Hutchinson (*Chelmer Institute of Higher Education*)

Ransome Hoffman Pollard Social Centre, Bishop's Hall Lane, off New Street, Rochester, Chelmsford, 7.30 p.m.

Thursday, 15th February

JOINT MEETING WITH CES

Surround sound

By R. I. Collins and C. P. Daubney (*IBA*)

Chancellor Hall, Market Place, Chelmsford, 6.30 p.m. (Tea 6.00 p.m.)

Wednesday, 21st February

Design and development with microprocessors

By P. G. Whitham (*Marconi Avionics*)

Havering Technical College, Lecture Theatre B109, Ardleigh Green Road, Hornchurch, 6.30 p.m.

Thursday, 22nd February

JOINT MEETING WITH IEE

Computer-aided circuit design

By R. Spence (*Imperial College*)

University Engineering Laboratories, Trumpington Street, Cambridge, 6 p.m. (Tea 5.30 p.m.)

East Midland Section

Tuesday, 13th February

JOINT MEETING WITH IEE

The engineer and employment legislation: is there a need to know?

By R. Palmer (*Leicester Polytechnic*)

Lecture Theatre J001, Loughborough University of Technology 7.00 p.m. (Tea 6.30 p.m.)

Synopsis: The vast range of employment legislation has severely limited the engineer's freedom to recruit, train, transfer or dismiss the staff he controls. He now needs the co-operation of the personnel manager as a fellow professional responsible for an equally complex resource. The speaker (a former member of the Technical Manufacturing and Personnel Department of Texas Instruments Ltd.) will outline the key areas of legislation of special interest to the engineer.

Kent Section

Monday, 5th February

JOINT MEETING WITH IEE

The hovermarine, past, present and future

By E. G. Tattisill (*Hovermarine*)

Seeboard, Parkwood, Maidstone, 7.00 p.m.

Wednesday, 7th March

The Boeing 747 avionics and navigation system

By Clive Gibson (*British Airways Flight Instrument and Control Department*)

Marconic Avionics Conference Room, Rochester, 7.00 p.m.

Merseyside Section

Wednesday, 7th March

Coal face automation engineering at the Mining Research and Development Establishment

By D. K. Barham and J. H. Hvidsten (*M.R.D.E.*)

The Feathers Hotel, 121 Mount Pleasant, Liverpool 3, 7.00 p.m.

North Eastern Section

Tuesday, 13th February

Digital communications

By Dr. Robinson (*GEC Hirst Research Research Centre*)

Newcastle upon Tyne Polytechnic, Ellison Building, Ellison Place, 6.00 p.m. (Tea 5.30 p.m.)

Tuesday, 13th March

Medical electronics

By Dr S. J. Meldrum (*St. Bartholomew's Hospital, London*)

Newcastle-upon-Tyne Polytechnic, Ellison Building, Ellison Place, 6.00 p.m. (Tea 5.30 p.m.)

Northern Ireland Section

Thursday, 8th February

Signal processors

By Dr. F. C. Monds (*Wolfson Research Laboratories, Queen's University, Belfast*)

Castlereagh College of Further Education, 7.00 p.m.

Wednesday, 7th March

Megaw Memorial Prize Lectures

By Final Year Engineering Students of the Queen's University, Belfast

Ashby Institute, Stranmills Road, Belfast, 6.30 p.m.

North Western Section

Thursday, 22nd February

Modern trends in diagnostic scanning

By a Lecturer from Manchester University Medical School

UMIST, Renold Building, Sackville Street, Manchester, 6.15 p.m. (Light refreshments available before lecture.)

Wednesday, 28th March

JOINT MEETING WITH IEE

Electronics for off-shore oil rigs

By J. Couser (*Ferranti Off-shore Systems*)

Lancashire County Cricket Club, Talbot Road, Old Trafford, 6.15 p.m. (Light refreshments available before the lecture.)

Scottish Section

Tuesday, 13th February

The use of microprocessors in data collection and analysis for respiratory investigation

By Dr. I. G. Logan (*Glasgow Royal Infirmary*)

Ingram Hotel, Ingram Street, Glasgow, 6.30 p.m.

Southern Section

Friday, 9th February

Quadraphonic broadcasting

By R. I. Collins and C. Daubney (*IBA*)

Isle of Wight College of Arts & Technology, Newport, 7.00 p.m.

Thursday, 15th February

A silicon digital magnetometer device

By Professor G. G. Bloodworth (*University of York*)

South Dorset Technical College, Weymouth, 6.30 p.m.

(For synopsis refer to October or November Journal, Southern Section meeting of November 22nd.)

Tuesday, 20th February

Designing with microprocessors

By P. Cooke (*University of Sussex*)

Brighton Technical College, Pelham Street, Brighton, 7.00 p.m.

Thursday, 1st March

Digital signal processing

By Professor D. R. Wilson (*Polytechnic of Central London*)

Crawley College of Technology, 7.00 p.m.

Wednesday, 14th March

Radio astronomy

By Dr. M. Kemp (*University of Cambridge*)

University of Surrey, Guildford, 7.00 p.m.

Wednesday, 21st March

ANNUAL GENERAL MEETING

Followed by Electronics in supertankers

By A. M. Bate (*London and Overseas Freighters*)

Boldrewood Lecture Theatre, Medical School, University of Southampton, 6.30 p.m.

South Midland Section

Tuesday, 13th February

JOINT MEETING WITH IEE

Viewdata

By Dr. E. Insam (*GEC Hirst Research Centre*)

BBC Engineering Training Centre, Wood Norton Hall, Nr. Evesham, Worcs. 7.30 p.m.

Wednesday, 14th March

Holography

Malvern, 7.30 p.m.

(Details of speaker and venue to be announced.)

South Wales Section

Wednesday, 14th February

JOINT MEETING WITH IEE

Automobile electronics

By W. F. Hill (*Lucas Electrical*)

Room 112, UWIST, Cathays Park, Cardiff, 7.00 p.m. (Buffet following lecture.)

Tuesday, 6th March

Digital television

By a speaker from IBA Engineering Division, Winchester

Room 112, UWIST, Cardiff. 6.30 p.m. (Tea 5.30 p.m.)

South Western Section

Monday, 5th February

JOINT MEETING WITH IEE AND RAeS

Observation of the world's weather in a satellite age

By Dr. B. J. Mason (*Director General, Meteorological Office*)

Queens Building, School of Engineering, University of Bristol, 6.00 p.m. (Refreshments 5.15 p.m.)

Tuesday, 6th February

JOINT MEETING WITH IEE

Electronic processing of electroencephalograms

By Dr. B. W. Jervis and M. Nichols (*Plymouth Polytechnic*)

Main Lecture Theatre, Plymouth Polytechnic 7.00 p.m. (Tea 6.30 p.m.)

Tuesday, 13th March

Tropospheric propagation: do we rely on wave scattering?

By Dr. W. G. Burrows (*Brunel Technical College*)

Brunel Technical College, Room C1-1 (Cabot), Ashley Down, Bristol, 6.00 p.m. (Tea 5.30 p.m.)

Thames Valley Section

Thursday, 15th February

Charge coupled devices

By Dr. G. F. Vanstone (*Technical Director, Racal Microelectronic Systems*)

The Caversham Bridge Hotel, Reading, 7.30 p.m.

Thursday, 22nd March

The 64K R.A.M.

By S. Kitchiner (*Texas Instruments*)

The Caversham Bridge Hotel, Reading, 7.30 p.m.

West Midland Section

Wednesday, 31st January

Recent developments in mobile radio communication

By M. R. J. Bayley (*Pye Telecommunications*)

The University of Birmingham, 7.00 p.m. (Tea 6.30 p.m.)

Thursday, 15th February

Semiconductor sources in optical fibre transmission systems

By Dr. D. H. Newman (*Post Office Research Centre*)

Post Office Training College, Stone, 7.00 p.m. (Tea 6.30 p.m.)

Wednesday, 14th March

Robotics

By Dr. Colin Page (*Lanchester Polytechnic*)

Lanchester Polytechnic, Coventry. 6.30 p.m. (Tea 5.45 p.m.)

Synopsis: This lecture deals with the growth in the use of industrial robots and with future developments which will find their way onto the shop floor in the next few years. Representative machines are described, and the ways in which actual industrial robots differ from the classic robots of science fiction are discussed. The problems involved in realizing truly general-purpose robots are outlined and current developments in this area are described briefly.

Yorkshire Section

Tuesday, 13th February

The OSCAR communications satellite

By J. A. Ward (*G4JJ*)

University of Leeds, 6.00 p.m.

Wednesday, 14th March

Microprocessors in land mobile radio

By Dr. O. Downing (*University of Bradford*)

University of Bradford, 7.00 p.m.

Tuesday, 27th March

Prestel: The Post Office Viewdata Service

By K. E. Clarke (*P.O. Research Centre Martlesham*)

University of Leeds, 6.30 p.m.

PROGRAMME OF MEETINGS

The combined programme of meetings which gives details of I.E.E. and I.E.R.E. meetings in London, and in the Beds. and Herts, East Anglia, Kent and Thames Valley Section for the second half session. (February–May 1979) is being sent to members in these areas with the present issue of the Journal. Members whose normal place of residence is outside the South East but who are able to attend these meetings, may obtain a copy of the combined booklet by application to 99 Gower Street, enclosing a stamped addressed envelope.

Reliability and its Impact in Computer Applications

Computer users' concern for the reliability and integrity of their systems has undergone an almost cyclic transformation in the past few decades. Early computers suffered from the inherent unreliability of their many discrete components, which made system failure frequent and maintenance complex and time-consuming. Consequently much effort and ingenuity was expended in those days in devising fault detection and automatic correction techniques to help defend the computer against the effects of hardware failure to which it was prone. Later however, with the advances in manufacturing technology exemplified by medium-scale and large-scale integration, these problems were alleviated considerably, both by improved component reliability and an increase in density of logic gates per replaceable pack, which reduced the difficulty of maintenance. Concern over hardware unreliability therefore abated.

More recently, however, the problems of ensuring reliability and integrity have again come to the fore on different grounds. Though technology continues to improve components, the increasingly stringent reliability requirements of certain modern applications, for example aerospace control systems, more than offset the advances in hardware and necessitates more reliable design. Moreover, the size and complexity of many modern software systems, for example very large data bases, and the degree of reliance that some organizations must place on them have intensified concern for their dependability.

In addition to the problem posed by failing hardware and incorrect software the current widespread use of computers in government and commerce has added a fresh responsibility to the system designer's burden. That is, preserving the integrity of the large reserves of commercially valuable and personally sensitive information stored at many sites. Commercial data must be secured against being falsified for gain, and both commercial and personal data, when they are essentially private, must be safeguarded from unauthorized access. Maintaining security and privacy must, therefore, be considered a feature of reliable computer application.

Faced with these problems and requirements the system designer may adopt two basic approaches to reliability enhancement. The first is to design the system to be failure and error free by selecting only the most reliable components and testing both the hardware and software designs exhaustively. The alternative is to accept the inevitability of errors arising, whether from hardware failures or faults in design, and to provide the system with adequate means of detecting, containing and recovering from them.

In practice the design of an error-free system is often unfeasible. The complexity of the hardware interconnections and software interactions in large modern systems renders exhaustive testing unmanageable. Also certain errors will arise only under unpredictable combinations of circumstances for which the test designer cannot provide.

The alternative approach, the provision of facilities for error detection recovery, entails supplementing the system with components or software that are redundant to its original logical design. This redundancy is of three kinds: Hardware; Software; Time.

Redundant hardware is used in fault detection by processing the same data in parallel with two or more identical units and comparing their outputs. Also, in the event of failure, redundant components may be switched in as standby spares. Redundant software likewise has several functions. It consists of the steady programs and data sets to be used when originals are mutilated, and the rest and recovery programs and data that would not be needed if errors never arose. Time redundancy occurs when actions are repeated to eliminate the effects of transient faults.

In order to maximize the effectiveness of recovery it is essential to limit as far as possible the corruption caused by error before recovery is initiated. A basic precept of system design for error containment and recovery therefore is the *principle of isolation*, which requires that processes should remain strictly separate from one another and that nothing can be shared or transmitted between them except by explicit arrangement. The techniques devised to maintain the isolation of processes delimit the resources used by them, thereby restricting the propagation of errors across process boundaries and reducing the extent of recovery required to restore an error-free state. Happily, because of their restrictive nature, the techniques evolved to reduce the propagation of involuntary errors are also well suited to preventing deliberate access to programs and data by unauthorized processes. Therefore, common strategies may be devised to preserve the integrity and security of information in the system.

Whatever facilities are provided to enhance the reliability and integrity of a system, they inevitably involve extra cost. This is realized not only in the additional effort involved in designing and implementing the system initially, but also in the continuing operational overhead needed to maintain the recovery facilities. If reliable systems are to be implemented cost-effectively a means of quantifying reliability for particular applications and of projecting the reliability gain for a given investment must be derived. Research into reliability theory has defined some basic measures by which to evaluate systems and has evolved some mathematical modelling techniques for predicting the reliability of specific systems. However, the usefulness of current models is probably limited to the evaluation of alternative designs.

The state of the art in building reliable computer systems is currently highly dynamic. Accelerating progress in both theory and implementation has enabled designers to build systems that tolerate and recover from a wide variety of hardware failures, often using techniques evolved in the early days of computing. The development of the disciplines for building equally resilient software systems is less advanced, but is the subject of considerable research which gives hope of progress.

The first volume of a recently published 650-page Infotech Report, 'System Reliability and Integrity', contains a detailed analysis of the subject examining; the causes of unreliability and methods of reliability assurance; the cost/benefits of reliability techniques; the state of research in fault tolerant computing; architectural designs for system reliability and integrity; the principal approaches to security and privacy in computer systems. A 30-page bibliography offers a critique of the most important available literature. The second volume has 19 invited papers from world experts on subjects such as fault tolerance, reliability modelling and degradation, and on error detection and correction.

The price of the report is £225, or £159 if bought as part of the complete 1978 Series of State of the Art Reports. Further information may be obtained from: Infotech International Limited, Nicholson House, Maidenhead, Berkshire SL6 1LD, England (Tel. Maidenhead 35031, s.t.d. code 0628).

Letter to the Editor

From: C. S. den Brinker, M.Sc., C.Eng., F.I.E.R.E.

'What's in it for me?'

There must be a large number of readers who experienced the same uncomfortable feelings that I had after reading our Secretary's editorial comments in the November issue of *The Radio and Electronic Engineer.* I have no doubt that this particularly logical and precise exposition is worthy of being read and re-read. Nevertheless, the question 'What's in it for me?' will continue to be asked by young professional engineers and herein lies the dilemma.

I believe that older members like myself would do well to remember what it was like to be at the start of one's career. At that stage, our peers and in particular our superiors seemed to say that graduation was but the first step in a sequence of passing qualifying hurdles and that the becoming of a Chartered Engineer was part of a natural succession. The conclusion that the young engineer tends to come to is that, provided he pays his fees and provided he is qualified to become a member, his standing is improved and this is the main purpose of the exercise. Recent moves in upgrading the entrance requirement as proposed by the IEE will only enforce his albeit misbegotten belief.

How few of us can, in the light of this sort of activity, explain to the younger generation that the quintessence of professionalism is not to create a selective club, but to help to create a society in which we all will be enabled to continue our training and, furthermore, that he must accept that this is an on-going process. It is the 'aims and objective statement' about the furtherance of the art and science which should be regarded as being of paramount importance. On joining any reputable institution, the prospective member should be encouraged to accept that all that any institution can offer is to aid his maturation as a technologist and that this is a lengthy process. A recent survey in the USSR seems to show that the peak of one's technological career is not reached until the age of 45. Moreover, I believe that we are now living in a society where, because of over-specialization, one can no longer expected to receive one's broad spectrum stimulation in any other way than from those of our peers who do not form part of our immediate working environment, i.e. in a learned society environment. Of course, one can extend this argument to multi-discipline cross-fertilization and the CEI.

Having made these obvious and general observations, I must now make the point for specifically joining the IERE. I believe that I have taken my own membership seriously in that I have actively participated in the activities of our Institution. On balance, however, I cannot ignore the fact that I have probably received more than I have ever given.

For example, when together with a small group of concerned colleagues, I became involved in the setting-up of the now thriving Beds & Herts Section, we relied to a large extent on the help and encouragement received from HQ. This period illustrated again to us that our Institution, probably more than any other, is in fact concerned with individuals and it is this message that all of us should put over to the aspiring members.

Our brutal answer to the young impatient and often impecunious engineer to the question 'What's in it for me?' should be:

'Do not look for immediate returns, your initial contribution in terms of money and time is no different than the fees and attendance required of you during your undergraduate studies. The latter provided you with an initial appreciation of the basic technical tools. In this sense, your institutional activity is no more nor less than an extended post-graduate course which, combined with your in-job training, will aid your professional maturation, i.e. a very economic and effective way of receiving a continuous part-time post-graduate education.

'Like any post-graduate student you are, in time, expected to offer some professional and original contribution to all of us. In this sense, our Institution differs from a post-graduate school, the IERE is there for our mutual benefit!'

Taken to its logical conclusion, we must continue the fight to get away from the idea of an exclusive club, i.e. we must continue to stress that the entrance requirements are no different from the A levels required before undergraduates are admitted to University, i.e. a cumbersome and clumsy selection system. It is only partially justifiable on the grounds that it indicates, to some extent, the degree of compatibility required for the establishment of a per group. I personally wish that we would establish a more stringent test of commitment to the aims of the Institution because an increased level of membership involvement would ensure that we, as a body, could speak with greater authority on matters concerning our activity in the society we live in, rather than rely on the Finniston Inquiry to deal with the standing of engineers. I believe that this Inquiry highlights our failure to deal with our own affairs.

CARL S. DEN BRINKER

Redifon Telecommunications Ltd,
Broomhill Road, London SW18 4JQ
30th November 1978

Standard Frequency Transmissions

(Communication from the National Physical Laboratory).

	Relative Phase Readings in Microseconds NPL—Station (Readings at 1500 UTC)		
November 1978	MSF 60 kHz	GBR 16 kHz	Droitwich 200 kHz
1	0·0	1·7	57·0
2	−0·2	1·7	57·4
3	−0·1	1·9	57·7
4	0·0	1·9	58·0
5	0·0	1·4	57·7
6	−0·2	1·4	57·0
7	−0·1	1·6	56·3
8	−0·1	1·6	55·6
9	0·0	1·4	54·9
10	0·0	2·1	54·1
11	+0·2	1·9	53·5
12	0·0	2·9	53·0
13	0·0	2·4	52·4
14	−0·1	1·0	51·9
15	0·0	1·2	51·2
16	−0·1	2·0	50·4
17	0·0	1·9	49·8
18	0·0	2·4	49·3
19	−0·2	2·9	48·6
20	+0·2	3·4	48·0
21	+0·2	0·8	47·4
22	+0·3	2·1	47·3
23	−0·1	3·6	46·6
24	+0·1	2·6	45·9
25	0·0	2·1	45·2
26	0·0	2·1	44·5
27	0·0	2·1	43·8
28	−0·2	2·1	43·1
29	+0·5	1·6	42·4
30	+0·9	1·8	41·8

Notes: (a) Relative to UTC scale $(UTC_{NPL}-Station) = +10$ at 1500 UTC, 1st January 1977.
(b) The convention followed is that a decrease in phase reading represents an increase in frequency.
(c) Phase differences may be converted to frequency differences by using the fact that $1\mu s$ represents a frequency change of 1 part in 10^{11} per day.

Colloquium Report

Analogue Filters

*Organized by the Components and Circuits Group
and held in London on 15th November 1977*

The Colloquium was divided into three sessions, two of which were devoted to particular types of filter. The first session dealt with active and LC filters, the final session dealt with the broad category of electro-acoustic filters, and the middle session covered additional design methods and types of filter.

The morning session opened with a paper by Dr. W. Saraga (Imperial College) entitled 'Active filters—a survey' which covered the development of active filters during the last two decades. The main disadvantages of resistively terminated LC filters is that conventional inductors (above about 1 μH) cannot be realized in microelectronic form, and passive RC filters cannot be highly selective since the Q-values never exceed 0·5. Active RC filters, which include transistor amplifiers, overcome this problem but the responses are very sensitive to component variations. The speaker reviewed various methods of design, including the cascading of bi-quadratic sections, the simulation of the structure and elements of resistively terminated LC filters, and multi-feedback structures.

The second paper, by Dr. D. G. Haigh (Imperial College), was entitled 'Some network transformations by terminal interchange'. The speaker showed how he generalized a transformation given by Hilberman and obtained five new networks from any given three-terminal active network. The new networks resulted from all the possible rearrangements of the original input, ground and output terminals. Several examples were given of novel active filter structures which resulted from single and repeated use of this design method.

The next paper, by Dr. L. F. Lind and Mr. S. E. Nader (University of Essex), entitled 'Realizable filters that minimize intersymbol interference',* was delivered by Dr. Lind. He explained that in the design of a data transmission filter, an important requirement is that the filter (normalized with respect to the Nyquist frequency) should provide a relatively large impulse response at $t = \pi$ seconds, and near-zero responses at multiples of this period, in order to minimize intersymbol interefrence. Results were given for all-pole filters which had very low intersymbol interference, good selectivity and did not require phase correction.

The final paper in the morning session, entitled 'Unconventional active RC filter designs simulating lossless ladder filters and having desirable attributes', was given by Dr. A. G. Constantinides (Imperial College). The speaker reviewed the

methods available for avoiding inductors in resistively terminated LC filters. In addition to inductor simulation and impedance scaling, filter structures may be obtained by using signal flow diagrams or scattering parameters. An entirely different approach was then described in which the port network variables are linearly transformed; the resulting non-physical variables are then interpreted as voltages in the active RC domain. Examples were given.

The afternoon session began with a paper by Mr. A. H. Boyce (Marconi) entitled 'The design of analogue filters with the aid of a computer'. Various stages in the design of filters using the insertion-loss method were identified and described. A transfer function is obtained which satisfies a given filter specification, and from manipulation of this function, circuit values are eventually calculated. Analysis by computer then verifies the circuit which may need modifying by computer then verifies the circuit which may need modifying to allow for practical component variations, as well as losses and strays. Optimization techniques are useful in the final stage.

The next paper, by Dr. P. B. Johns (University of Nottingham), discussed 'Transmission-line modelling and sensitivity evaluation for lumped network simulation and design in the time domain'. A new approach was described for time-domain analysis and the design of lumped networks. Lumped elements are modelled by transmission-line sections or stubs and the modelled network is analysed using the transmission-line matrix method. Sensitivities with respect to the design variables are used in optimization procedures. Formulating the state-space equations is avoided and numerical errors may be represented by stray components which provide a physical interpretation. Numerical stability is guaranteed.

The second session ended with a paper by Professor J. D. Rhodes (University of Leeds) on 'Prototype manifold multiplexers', in which he first described the main steps in the design of prototype multiplexers which contain bandpass channels connected to a common manifold feed. From these prototypes, lumped-element, microwave or optical multiplexers may be designed. The main problem is to avoid the destructive interaction of the various channels. The given design method resulted in a significant improvement in channel performance. Examples were provided of practical multiplexers required in satellite communications.

The final session, which was devoted to electro-acoustic filters, started with a paper by Mr. A. J. L. Muir (Plessey Telecommunications) on 'The performance and design of a quartz crystal band pass filter for use in digital transmission systems'. The speaker described the design of a receiver i.f. filter which was required to limit noise bandwidth prior to detection and to provide rejection of adjacent channel signals. The relative frequency drift between transmitter and receiver affects the filter design since the use of large guard bands to allow for this drift widens the noise bandwidth and spoils the spectrum shaping in matched systems.

The paper by Dr. H. M. S. Zakaria (Racal-Amplivox) was entitled 'Description and design of electrostatically-driven mechanical filters'. The speaker explained that electro-mechanical resonators with their inherent stability and high-Q properties provided an alternative to traditional LC circuits. Flexurally vibrating mechanical resonators with input and output electrostatic transducers were proposed for low-frequency operation. The electrical equivalent circuit was derived from energy consideration and by analogy between electrical and mechanical networks. The resulting networks may be designed using image-parameter or insertion-loss methods. A synthesis procedure and fabrication techniques were described, and performance characteristics of experimental models were shown.

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* Published in *The Radio and Electronic Engineer*, **48**, no. 12, pp. 612–18, December 1978.

The Colloquium ended with a paper by Dr. R. F. Mitchell (Philips) on 'Surface acoustic wave filters—a bird's eye view'. The speaker described surface acoustic wave (s.a.w.) transversal and resonant filters. S.a.w. transversal filters are small, rugged and reproducible, and operate in the range 10–1500 MHz. Amplitude and phase may be controlled separately. Several design methods are available and the resulting filters are suitable for mass production. The main drawbacks are high insertion loss (10–20 dB) and broadband operation (minimum bandwidth about 100 kHz). S.a.w resonant filters are still in the research phase but the technology is rapidly

progressing. With resonators coupled in a manner analogous to the monolithic crystal filter, clean resonances and 60 dB stop-band discrimination are possible.

Comments both at and subsequent to the Colloquium indicate that it was very successful. Material was presented at different technical levels which encouraged questions from both specialists and beginners.

It is intended to hold another colloquium on filters during the session 1979–80.

J. K. STEVENSON

Swing to Integrated Circuits in UK Components Market

The most significant contribution to the dynamic growth of electronics as an industry during the past twenty years has been the introduction of semiconductor devices, which have displaced the thermionic valve from all but a few specialized applications. According to the latest estimates released by the ECIF's Semiconductor Product Group, the UK market for semiconductors of all types increased in 1977 to £251M, representing a 39% growth on 1976 and a 83% growth on 1975.


Fig. 1.   Growth of UK market for semiconductor components.

This market figure is divided into £130M for integrated circuits (44% growth on 1976) and £121M for discrete semiconductors (33% growth). The UK is thus the first major country worldwide to follow the US in using more of the comparatively advanced integrated circuits than the lower technology discrete semiconductors. This reflects the strength and innovative qualities of the UK electronics industry.

The accompanying graph illustrates the rapid expansion of the market over the past ten years, and also shows that the growth rates are expected to moderate somewhat in 1978.
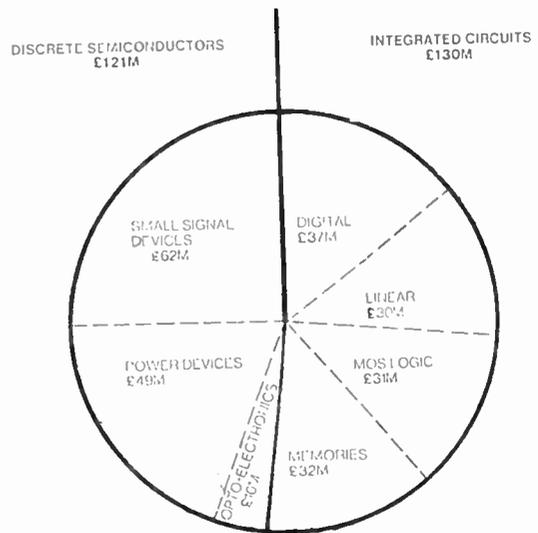

Fig. 2.   1977 UK market for semiconductor components.

Very commendably, UK manufacturers have maintained their share of the home market against lively competition and have increased their share of export markets. While imports for the year have grown by 37%, from £120M to £164M, exports have increased by 50%, from £58M to £87M. However, this still leaves a net trade deficit of £77M.

The pi-diagram shows the breakdown of the 1977 semiconductor market by product type. In the light of recent technological advances, as well as the current interest shown by Government, trades unions and the public in microprocessors, ECIF wishes to make this observation—every microprocessor is an integrated circuit, but not every i.c. is necessarily a microprocessor. In fact, at present microprocessors represent less than 2% of the UK integrated circuit market (included mainly in the m.o.s. logic category), but in five years' time it is likely to grow in volume by 15 times to reach 10% of the market.

Members' Appointments

CORPORATE MEMBERS

S. O. Ajani (Member 1973, Graduate 1969) has been promoted to Assistant Chief Engineer in the Research and Development Department of the Federal Radio Corporation of Nigeria.

N. Brayford (Member 1973, Graduate 1970, Associate 1969) who has been with the British Steel Corporation since 1969, has moved from the Teeside Division where he was Process Control Engineer (Steelmaking) to BSC Stainless, Sheffield, as Senior Development Engineer (Process Control Systems).

R. F. Burns (Member 1973, Graduate 1964), formerly Manager, Rank Telecommunications has been appointed Engineering Manager, Socom Services Limited, Coulsdon Surrey.

C. Foxwell, B.Sc. (Member 1973, Graduate 1967) has moved from Harold Whitehead & Partners, Management Consultants, to become Manager of Honeywell's European Training Centre at Bracknell. He has served as a member of the Thames Valley Section Committee.

O.O. Gbeminiyi, M.Sc. (Member 1967, Graduate 1969) is now Chief Engineer of Sumitomo Electric Industries Ltd, Ibadan, Nigeria. He joined the Company in June 1977 following three years on the staff of the Department of Electrical and Electronic Engineering at Auchi Polytechnic.

C. Hooper (Member 1972, Graduate 1967) has been appointed Video Technical Manager with Rank Audio Visual Ltd. For the past few years he has been with Ferranti Computer Systems Ltd as a Senior Systems Engineer.

D. A. Wilson, M.Sc. (Member 1972 Graduate 1970) has left North Eastern Gas where he was an assistant C & I engineer, to take up a similar appointment with the Central Electricity Generating Board at the Hartlepool Nuclear Power Station.

A. W. Moss (Member 1961), formerly Group Manager (Information Systems) with Cable and Wireless, is now Group Manager, Support Services in the Company's Communications Systems and Services Department.

V. E. Nwebube (Member 1973, Graduate 1966) has returned to Nigeria from the UK where he has been for the past 10 years with Rediffusion Engineering Ltd, and has joined the Federal Radio Corporation at Enugu as a Senior Engineer.

Commander U.K. Pisharody, V.S.M., IN (Member 1967, Graduate 1960) has been appointed Manager (Development and Engineering) in the High Power Communication Equipment Division of Bharat Electronics Ltd, Bangalore. He was previously Deputy Chief Inspector in the Chief Inspectorate of Warship Equipment (South Zone), Bangalore.

P. Huffam (Member 1970) has been appointed Personnel Officer with Mid-Northland Cooperative Dairy Co., Ltd, Whangarei, New Zealand. After retiring from the Royal New Zealand Navy with the rank of Lieutenant Commander in 1975 he was for three years Staff Development/Training Officer for the New Zealand Refinery Co., Ltd.

R. H. Jones (Member 2973, Graduate 1967) is now National Sales Manager with G. E. C (Pty) Ltd., Johannesburg. He previously held a similar appointment with Circuitaire (Pty) Ltd.

M. W. Lauerman, M.Sc. (Member 1921, Graduate 1968) who moved into Local Government from the Electrical Research Association where he was a Project Manager with the Technological Planning Unit, has recently been appointed Assistant Director (Planning, Development and Research) in the Social Services Department of Kent County Council. Mr Lauerman served for some years on the Institution's Management Techniques Group Committee and he represented the IERE on the CEI Industrial Relations Working Party.

Sqn. Ldr P. A. G. Leech, RAF (Member 1972) has been posted to Cyprus as Officer Commanding No. 12 Signals Unit, following Staff appointments at the Ministry of Defence (Air).

A. Marshall, B.Sc. (Member 1977) who was an Avionics Systems Engineer with British Aerospace, Kingston upon Thames, has joined the Systems and Weapons Division of EMI Electronics Ltd. as a Systems/Trials Engineer.

R. J. Oliver (Member 1973, Graduate 1963) is now with the Medway Area Health Authority as Chief Medical Physics Technician at St. William's Hospital, Rochester. He was previously Chief Technician in the Chemical Laboratories at the University of Kent at Canterbury where he was responsible for a wide range of electronic and allied equipment.

H. Petts (Member 1973, Graduate 1968) who has been on the staff of the Cable and Wireless Engineering College, Porthcurno, Cornwall, for the past four years, has taken up the position of Engineer in Charge of the International Telephone Switching Centre in Hong Kong.

Wg Cdr I. S. F. Read, RAF (Ret.) (Member 1962, Graduate 1954) has joined the British Standards Institution as a Technical Officer. His latest appointment before retiring after 39 years' service was as RAF adviser to the Radio and Navigation Department at the Royal Aircraft Establishment, Farnborough.

Flt Lt D. H. Rycroft, RAF (Member 1973, Graduate 1968) has been posted to RAF St. Mawgan as Officer Commanding, First Line Servicing, Nimrod Aircraft. For the past ten years he was a Project Officer concerned with airfield radio navigation aids at RAF Support Command Signals Headquarters.

D. Smith (Member 1973, Graduate 1968) is now a Standards Engineer with the Switching Main Exchange Products Division of Standard Telephones and Cables Ltd.

E. R. Valentine (Member 1971, Graduate 1967) has joined Digital Equipment Company Limted as Marketing Manager of the Components Group. He was previously a Product Manager with GEC Semiconductors Ltd.

G. W. E. Vincent, P. Eng. (Member 1976, Graduate 1969) has been appointed a Regional Manager (Ottawa and Eastern Region) for the Electron Device Group of Varian Associates of Canada Ltd. From 1971 until taking up his present position Mr Vincent was a Marketing Engineer, Electronics Systems, with Hermes Electronics, Ltd., Dartmouth, N. S.

P. C. Wilmot (Members 1976, Graduate 1970) is now a Senior Designer with W. Vinten, Ltd, Bury St. Edmunds. From 1976 to 1978 Miss Wilmot was a Development Engineer in the Cybernetics Division of Messerschmitt-Boelkow-Blohm, GmbH, Munich, working on automatic test equipment particularly with reference to e.m.c. of equipment subsystems.

P. Wesson (Member 1965, Graduate 1962) is now General Service Manager for the Scientific Equipment Division of Fisons Ltd. following Fisons' acquisition of A. Gallenkamp & Co. with whom he had been Group Service Organisation Manager since 1976.

NON-CORPORATE MEMBERS

G. C. Briggs (Graduate 1969), who has been with Marconi Instruments Ltd since 1959, has been appointed Sales Director.

Flt Lt D. M. H. Brown, RAF (Graduate 1968) has completed a tour of duty at RAF Leuchars and is now on the staff of RAF Support Command as SE3B1

K. D. Brown (Graduate 1970) has left the Army where his last posting was as WO 1 (ASM) and Assistant Project Officer to the Rapier Support Group, Telecommunications and Radar Branch, REME, and is now with Marconi Space and Defence Systems Ltd, Portsmouth, as Senior Engineer concerned with post-design services in the Military Communications Division

R. B. Davis, B.Sc.(Eng.), A.K.C., Royal Signals (Graduate 1977) has completed the Royal Signals Officers Communications Qualifying Course and has been posted to 3rd Armoured Divisional Headquarters Signal Regiment.

G. R. Exeter, B.Sc. (Graduate 1976) has taken up an appointment as a Design Engineer in the Linear Design Department of National Semiconductor (UK) Ltd, Greenock. He was recently in the Development Laboratory of Rank Radio International Ltd. Plymouth.

S. O. Foye (Graduate 1971) who has been with Nigerian Paper Mill Ltd, Jebba, Kwara State since 1973, is now Chief Engineer.

P. J. Goillau, B.Sc., M.Sc. (Graduate 1974) has joined GEC Elliott Process Automation Ltd Leicester as a Systems Engineer after completing a CASE SRC Research Studentship at Loughborough University developing predictive computer aids for industrial process control.

E. G. Parker (Graduate 1972) has been appointed Plant Manager of Northern Telecommunications Canada Ltd, at Regina, Saskatchewan.

R. Dowlman (Associate Member 1976) has recently joined Occidental of Libya Inc.,

Tripoli, as Communications Foreman concerned with microwave and tropospheric communications; he was previously with ADMA-OPCO in Abu Dhabi.

Fg Off. I. D. Matthews RAF (Associate Member 1974) has completed his initial Engineering Course at the RAF College Cranwell following 12 years non-commissioned service and has been posted to RAF Rudloe Manor as Communications Officer No. 6 Signals Unit.

J. J. Mizzi (Associate Member 1975) who was a Lecturer in the Education Department of the Government of Malta is now a Lecturer at Paddington College, London, teaching radio, television and electronics.

J. B. A. Oyekenu (Associate Member 1972) is now a Principal Technical Officer with the Federal Radio Corporation of Nigeria at Ibadan.

N. M. Smith (Associate Member 1975), formerly Supervisor of Electrical and Electronic Services at Marischal College, University of Aberdeen has joined the

British Gas Corporation as an Electrical Instrument Engineer.

S. A. Snook (Associate Member 1974), formerly of the BBC's Designs Department, has joined Oakside Industrial Holdings Ltd of Uxbridge as Group Chief Engineer. While with the BBC Mr Snook was responsible for technical liaison with industry and the commercial exploitation by licensing of BBC engineering designs. Previously he was involved with the development of analogue and digital broadcast equipment. In 1977 he obtained the Certified Diploma in Accountancy and Finance.

G. H. Sutherland (Associate Member 1977) is now a Professional and Technology Officer 1 in the Directorate of Telecommunications of the Scottish Office.

Lt S. H. Brooks, B.Sc., RN (Associate Member 1977) has successfully completed a degree course at the Royal Naval Engineering College, Manadon, and has been posted to RNAS, Yeovilton.

Applicants for Election and Transfer

THE MEMBERSHIP COMMITTEE at its meeting on 7th December 1978 recommended to the Council the election and transfer of the following candidates. 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 communication from Corporate Members concerning the proposed elections must be addressed by letter to the Secretary within twenty-eight days after publication of these details.

December Meeting (Membership Approval List No. 253)

GREAT BRITAIN AND IRELAND

CORPORATE MEMBERS

Transfer from Member to Fellow

CARTER, Alan Peter. *Shalford, Nr. Guildford.*
HALE, Clifford. *Winchcombe, Cheltenham.*
EMBREY, Derek Morris. *Lisvane, Cardiff.*
PHILLIPS, Vivian Jones. *Sketty, Swansea.*

Transfer from Graduate to Member

ATKINSON, Richard. *Broadstone, Dorset.*
CHAPMAN, Roy. *Paisley, Renfrewshire.*
HART, Kenneth Edward. *London.*

Transfer from Associate Member to Member

GIRARD, Anthony Edward. *Bromley, Kent.*

Direct Election to Member

ALLEN, John Michael. *Longniddry, East Lothian.*
CHEN, Frank Ling Chun. *Whitley Bay, Tyne & Wear.*
DAS, Tarun Chandra. *Morden, Surrey.*
GREGORY, Roy Derek. *Oxton, Birkenhead.*
HORSFIELD, Allan. *Peterborough.*
POWELL, James. *Bristol.*
SCHOFIELD, Paul Francis. *Coundon, Coventry.*

NON-CORPORATE MEMBERSHIP

Transfer from Student to Graduate

BALLINGER, Timothy James. *Helensburgh, Dunbartonshire, .*

MORRIS, Leigh Timothy. *Pontefract, West Yorkshire.*

Transfer from Student to Associate Member

GRUBB, John Arthur. *Rossbrien, Limerick.*

Direct Election to Graduate

ALLENBY, Ian Ralph. *Harlow, Essex.*
HOME, Michael John. *Henley-on-Thames Oxfordshire.*
LEE, Wai Sun. *London.*
NASIRU, Shehu Adebayo. *London.*
PHILLIPS, Graham Ivor. *Wantage, Oxfordshire.*

Direct Election to Associate Member

ELSWOOD, Keith Phillip G. *Southampton.*
NWANERI, Hugh Friday. *Hull.*
RUSH, David Alexander. *Crediton, Devon.*
WOOD, Keith Trotter. *Bassingbourn, Herts.*

Transfer from Student to Associate

ORAM, John Walter. *Gravesend, Kent.*

Direct Election to Student

HADFIELD, Martin John. *Hunstanton, Norfolk.*
KING, Stephen Charles. *Bristol.*
KRETSCHMER, Gordon Bernard. *York.*
KWAN, Ka Ying. *Colchester, Essex.*
LOW, Hon Siong W. *Swansea.*
MERIZIAN, Elia Karim. *Hull.*
METHVEN, Christopher John. *Fleet, Hants.*
MILLER, Anthony Paul. *York.*
MORGAN, Ian James. *Llanfairfechan, Gwynedd.*
NG, Kwong Fai. *Colchester, Essex.*

OVERSEAS

CORPORATE MEMBERS

Transfer from Graduate to Member

AKINWUMI, Joshua Modupe A. *Lagos, Nigeria.*
KAMBOH, Muhammed Younus. *Bramalea, Ontario, Canada.*

Direct Election to Member

FAIRLEY, John Maxwell. *Brigachtal, West Germany.*
MAITRA, Jayanta Kumar. *Bombay.*

NON-CORPORATE MEMBERSHIP

Transfer from Student to Graduate

WU, Hon Fai. *Hong Kong.*
YIP, Chi Keung. *Hong Kong.*
YUNG, Tak Yim. *Hong Kong.*

Transfer from Student to Associate Member

CHEUNG, Kuen On. *Hong Kong.*

Direct Election to Graduate

CHAN, Yan Lam. *Hong Kong.*
OMORUTO, Francis Emmanuel E. *Kampala, Uganda.*

Direct Election to Associate Member

CHOY, Shi Hung. *Hong Kong.*
GOH, Hock Kim. *Singapore.*
HAGAN, Robert Bruce. *Lagos, Nigeria.*
MAKINDE, Cyril Adekola. *Addis Ababa, Ethiopia.*
WONG, Song Sheong. *Singapore.*
WOODLOCK, Clive Richard. *Hamilton, Bermuda .*

Direct Election to Student

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CHENG, Tung Sang. *Hong Kong.*
CHEUNG, Koon Wah. *Hong Kong.*
CHING, Hau Sing. *Hong Kong.*
CHOW, Wing Keung. *Hong Kong.*
GOH, Tong Nam. *Singapore.*
LEUNG, Yiu Bun John. *Hong Kong.*
LI, Siu Wah Eric. *Hong Kong.*
NAIDU, K. Prabu. *Singapore.*
SEAH, Meng Hwee J. *Singapore.*
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Contributors to this issue

Alan Prior (Member 1965, Graduate 1962) joined Marconi's Wireless Telegraph Co. Ltd. in 1959 as Special Trainee. After completing his training he was employed as a Development Engineer on radar equipment and later he was appointed Section Leader of the Control Electronics Section. Subsequently he was promoted to be Group Chief of the Control Systems Group. Currently Mr Prior is Principal Project Engineer responsible for special development contracts with Marconi Radar Systems Ltd.

Paul Hibbert graduated from Imperial College, London, in 1969 with an honours degree in Physics. He then joined the Central Applications Laboratory of Mullard Limited in Mitcham as a Development Engineer and worked on m.o.s. memory systems for computers. In 1971 Mr Hibbert went to Marconi Radar Systems Ltd. in Chelmsford as a Development Engineer and since then he has been with the Radar.

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Patrick Fowler read for the Mechanical Sciences Tripos at Cambridge University and received a BA degree in 1948. After instructing in radar maintenance during National Service, his training was completed as a graduate apprentice with the British Thomson Houston Co. in Rugby. For five years he studied vibration problems and developed instruments to balance large turbo-alternators and other machines in their own journals. Since joining the Atomic Energy Authority in 1957 he has developed instruments used for the control of nuclear reactors and for some 15 years electrical interference studies and related topics have formed an increasing part of this work which has branched out from a background study through diagnostic techniques to the development of components with good screening properties. The title of the section he leads is 'Electronic Techniques' but the work embraces service on IEC working groups and BSI technical committees of r.f. cables and connectors.

Michael Gibson (Member 1964) obtained a Diploma in Electronics at Bolton Technical College and since then has been employed by the Marconi International Marine Co. Ltd. He joined the D/F Section in 1960 and eventually became Chief of the Section where he was concerned with providing technical services and with the introduction and evaluation of new designs of direction finders, autopilots and navigational aids for ships. Later he was appointed Chief of Standardisation and also assists the Technical Director with day to day administration. The achievement of electromagnetic compatibility of shipborne installations is an important aspect of his activities. Mr Gibson has served on the East Anglian Section Committee for several years and is currently its Chairman.

Reynold Rosenberg completed a student apprenticeship with Associated Electrical Industries (Manchester) Ltd. and obtained the B.Sc. degree from the University of Salford in 1964. For the next seven years he was engaged on the design and development of microwave systems for radar and missile applications with AEI and EMI Electronics Ltd., and in 1971, he moved into the marketing and sales aspects of microwave instruments and components with Marconi Instruments Ltd., Sanders Division. Three years later, he joined Hawker Siddeley Dynamics (now British Aerospace Dynamics Group), to work on electromagnetic compatibility of the Orbital Test Satellite (OTS). He is now responsible for the e.m.c. aspects of several other spacecraft systems, as well as the provision of a Government approved e.m.c. test facility for spacecraft for civil and military use. He was the author of papers at the EMC Symposium in Montreux in 1977 and the European Space Agency EMC Seminar in 1978.

C. V. Chakravarthy obtained his B.Sc. degree from Bangalore University in 1967, B.E. and M.E. degrees in electrical communication engineering from the Indian Institute of Science, Bangalore, in 1970 and 1972 respectively, and the Ph.D. degree from the Indian Institute of Technology, Kharagpur in 1977. Since 1975 a Lecturer in the Department of Electronics and Electrical Communication Engineering at IIT Kharagpur, Dr Chakravarthy's main research interests are in digital communication and digital signal processing.

Electromagnetic compatibility in the mercantile marine situation

M. GIBSON, C.Eng., M.I.E.R.E.*

SUMMARY

Some idea of the magnitude of the problem of electromagnetic interference and methods of its propagation on board ship are given. The present situation relating to marine e.m.c. specifications is described and the need for agreed and accepted marine e.m.c. specifications, not only nationally but internationally, is proposed. Present installation techniques and measures used to minimize interference on commercial marine installations is given. Specific examples of interference at sea are quoted and some details of a proposed IEC specification are listed. An example is given of the e.m.c. design of a compact radio telephony equipment.

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1 Introduction

The first ship radio installation was fitted in 1897 and radio was first used to summon assistance for a ship in distress in 1899. Today radio still retains its importance for summoning assistance for ships in distress and for the safety of life at sea. To help ensure the effectiveness of equipment in this role it is necessary to ensure that interference from other electrical or electronic apparatus on board ship does not reduce the effectiveness of the main and reserve radio installations. The lives of passengers and crew might come to depend upon being able to receive the weakest of signals which, so easily, might be lost in a mush of noise produced by other equipment on board ship. In its role of private and commercial communications radio has greatly expanded and now all ocean going vessels and many varieties of smaller craft are fitted with various types of transmitters and receivers ranging from l.f. through to u.h.f. Also fitted are varying numbers and types of electronic aids to navigation and other electronic equipment for purposes such as control, data acquisition and processing, monitoring, surveillance and entertainment.

2 Dissemination of Electromagnetic Interference

Potential producers of interference include radio, electronic equipment and a variety of electrical equipment including motors, generators, regulators, fluorescent lights, thermostats etc. The mains supply and various communications networks (such as telephone, loudspeaker address and fire alarm systems) spread throughout the ship and can form highways along which interference may propagate. Radio receiving aerials have to be mounted in the open high up on a ship and may pick up interference radiated by current carrying conductors run above decks or directly by radiation from interference producing sources located above decks. Radiation interference from equipment or cables below deck is much less likely due to the screening effect of the metal decks and bulkheads used in ship construction. The use of out and return leads not run as a close-coupled pair or use of an earth return path can increase greatly the radiation or induction from such cables and is to be avoided. Screened cables should be used for all sensitive circuits. Electrically-continuous metal conduit or trunking should be used to restrict the possibilities for radiation and induction.

3 UK Marine Radio Frequency Interference Specifications

BS 1597, relating specifically to radio frequency interference suppression on marine installations, was first issued in 1949 and specified limits for the interference voltages appearing at the receiver terminal end of the receiving aerial feeder. Such has been the increase in spectrum usage that now it is virtually impossible to ensure that there will be unoccupied parts of the band

where measurements may have to be made. In recognition of this BS 1597 was revised in 1975 and now specifies that this measurement be made at the receiver input terminal end of the receiver aerial feeder with the receiver aerial disconnected.[1] The new limit specified is that interference levels measured shall not exceed $2 \mu V$, in the bandwidth of the measuring sets specified in BS 727: 1967, over the frequency range 15 kHz to 100 MHz when all electrical and electronic equipment in the ship is operating under normal and emergency seagoing conditions.[2] Also specific maximum limits are laid down for the radio frequency emission voltages appearing at the terminals of each piece of electrical and electronic equipment on board ship. These limits vary between about 300 and 3 mV over the frequency band 15 kHz to 100 MHz for equipment fitted within the bonded metallic structure of the ship. For equipment fitted above decks or in vessels constructed with non-conducting materials the maximum limits quoted are 20 dB lower. Codes of practice for installations are contained in BS 5260: 1975.[3]

In general it is not difficult for main and reserve marine transmitters and receivers to meet these standards. In fact many will meet these levels and others could be brought within the limits with the application of only simple suppression techniques. With current equipment it is possible that much lower limits of conducted emissions could be achieved with the addition of only a simple power-line filter. However new designs of equipment incorporating new ideas and techniques may generate more interference than the equipments which they replace. Possible examples are frequency synthesizer and wideband amplifier techniques or the use of switched mode power supplies.

Transmitters, receivers, direction finders, radar and one or two other devices for shipboard use may have to meet the requirements of special Home Office or Department of Trade specifications which include maximum levels of permitted radiated emissions such as from the local oscillator in receivers and spurious emissions from communications transmitters, radar and echosounder equipment.[4-8]

4 E.M.C. Design of a Compact Radio Telephony Equipment

There is a market for self-contained, compact but powerful m.f./h.f. radio telephony transceivers for yachts, fishing boats, coasters and many other kinds of small commercial craft. Such equipments require careful design of the internal structure and layout to avoid interference problems arising between the transmitter, receiver and power supply. One example of such an equipment, having a nominal power output of 150 watts, is contained within a case measuring $119 \times 480 \times 472$ mm. For protection against interference the radio is compartmented into shielded sections which isolate the various signal sensitive paths from each other. These shielded compartments are provided with covers for additional

Fig. 1. General view of radio room showing main communications transmitter with open type aerial feeder and a communications console.

isolation and the interconnecting cabling is bypassed and shielded at each point of entry into a compartment. Earthing strips of beryllium copper are used to ensure adequate contact at critical points. The covers are also earthed to the main chassis. Behind the main board compartment a shielded section houses the modular power supply. The d.c. to d.c. power inverter operates at approximately 100 Hz. This low frequency avoids the common interference problems which occur with supplies that have switching rates of 20 kHz or more. As a result, filtering and shielding components can be common to both 50/60 Hz a.c. supplies and the d.c. to d.c. inverters.

5 Installation Measures for Minimization of Electromagnetic Interference

Modern ship transmitters may have nominal powers up to 1500 watts. Usually the more powerful equipments are located in the screened radio room and are bonded to the adjacent metallic structure by means of thick copper strip up to 300 mm wide. In most cases open feeders are used to connect the transmitter with its aerial via through-deck insulators. To reduce interference to other equipment to the minimum, careful attention has to be paid to ensuring that all equipments are earthed to the metal structure via low impedance earth leads, typically copper strip 25 mm wide, and separate earth bolts. All mains and interconnecting leads in the radio room and vicinity should be screened, usually single close-basket-weave screening having a 90% coverage factor is sufficient.

Further sources of interference arise where metallic stays, shrouds, rigging and halyards are made off to the deck via metal shackles, or in the case of halyards, loosely wrapped round some convenient metal rail or stanchion. In fact any sizeable metallic moveable or loose structure above decks may cause interference. Any variations in the conductivity to earth leads to fluctuating values of induced currents when the transmitter is

Fig. 2. Interior of radio room showing 30 cm wide copper earthing strips fixed to the bulkhead prior to installing the transmitter.

operating. This causes interference on communications receivers, distress watch receivers etc.

Metal stays, shrouds and fixed rigging can be earthed via a separate bonding wire or strip, or alternatively insulated from deck by means of compression type rigging insulators. Either method is effective in eliminating the problem of interference due to varying conductivity to earth. Metallic halyards may be replaced with non-metallic material. Conductive running wires, topping lifts etc. are best tied back close to the derrick post or mast and laid close to the deck or earthed structure. Large hinged or moveable metallic structures should be bonded to earth where possible.

To achieve satisfactory duplex operation on r.t. a signal reduction of the order of 40 to 50 dB is usually required between the transmitter output and receiver aerial input. Receiver aerials should be separated as far as possible from transmitter aerials and on some ships such aerials are located 100 metres or more from each other. In such cases the very long receiver feeders are often double-screened close-basket-weave coaxial cables with the two screens insulated from each other and joined together at the receiver end. In most cases separation between transmitting and receiving aerials is restricted to a few tens of metres or less and rejector units may have to be employed for satisfactory results. Such rejectors,

providing 40 to 45 dB attenuation to the unwanted signal, will attenuate the desired signals by no more than 4 dB. For best results the rejector unit should be fitted immediately adjacent to the receiver and connected via as short a coaxial lead as possible (usually less than 0·5 metres) to the receiver aerial input terminal. Switching of the rejector between pre-tuned frequencies normally is provided automatically by means of Ledex switches driven from the transmitter.

In the case of v.h.f. duplex operation advantage can sometimes be taken of the directional properties of the dipole aerials used. The dipole has minimal response to signals and minimal radiation along its longitudinal axis and such aerials mounted in line with each other offer a degree of isolation varying, in practice, non-linearly with separation somewhat as follows:

Aerial separation	Isolation (approx.)
$\lambda/2$	15 dB
λ	30 dB
2λ	48 dB
3λ	50 dB

At 160 MHz λ is 1·875 metres and a separation of say 4 to 6 metres for a transmitter power of 20 to 25 watts can give good results for duplex working with a minimum frequency separation of 4·6 MHz, provided that reflections from the supporting structure or nearby superstructure do not cause significant interference. If those conditions cannot be met then, irrespective of alignment, to achieve satisfactory results the separation between transmitter and receiver dipoles must be at least 20 λ and possibly as much as 50 λ.

For telegraphy operation associated receivers are automatically 'desensitized' by means of a bias voltage derived from the transmitter which effectively reduces the sensitivity to negligible proportions when the transmitter is in the key-down condition. This is necessary to prevent blocking of the detector to weak signals due to the a.g.c. delay when the key is lifted, thus permitting break-in operation.

Receivers also have to be protected from possible burnout of their signal input circuits due to the effect of high voltages induced in the receiver aerial by ship's own transmissions. Communications receivers, direction finders etc., are constructed to withstand continuously up to 30 volts acting between aerial input terminal and earth. Protection usually takes the form of the use of extra thick wire and current limiting components or semiconductor diodes connected in parallel back to back between aerial and earth. In some cases a relay, energized by the induced signal, may be used to disconnect the aerial from the input terminal and connect it to earth. On the modern design of cargo vessel this problem is aggravated due to the concentration of the superstructure at the after end of the vessel. This type of construction greatly restricts the space available for mounting aerials and, in turn, leads to less spacing and closer coupling between the transmitting and receiving

aerials. In some cases 100 to 150 volts or more of r.f. may be induced in the receiver aerial and greatly strengthened protection circuits or devices may have to be used.

6 Emissions from and Susceptibility to Interference of Electronic Navigational Aids

In an actual case an echosounder located close to a direction finder was falsely triggered by signals, induced in the direction finder vertical aerial by own ship's transmissions, in turn being coupled into the echosounder's circuits, perhaps via supply leads. Ideally one would like to site the receiving aerials sufficiently far from the transmitting aerials to keep induced voltages to relatively harmless levels. However, within the constraints of space and cost it may be necessary to tolerate relatively high levels of induced voltage and employ techniques of installation to minimize undesirable effects. Such techniques would include spacing mains supply and other leads well away from leads to other equipment, keeping susceptible equipment as far as possible from equipment connected to aerials of any sort, use of earthed screened cables for all leads, use of the shortest possible low impedance earth straps and provision of separate earth bolts for each equipment.

In one case of an older vessel a radar transceiver unit was located in the radio room and apparently performed adequately. Later a main communications transmitter was replaced by a more modern and powerful model. It was found that simultaneous operation of the new transmitter and the radar produced complete blanking of the radar display screen. Provision of extra earthing for the radar transceiver was not sufficient to eliminate this effect. In fact, the solution to such a problem is to locate the radar transceiver somewhere other than in the radio room.

If two complete radar equipments are operating simultaneously on the same ship in the same frequency band, transmissions from one equipment may be picked up directly and displayed as an interference pattern on the screen of the other. Patterning due to this cause may be overcome quite simply by arranging for the transmissions of the two radars involved to be synchronized via an appropriate circuit.

A similar situation arises where two or more ships in the same vicinity operate their radar sets simultaneously in the same frequency band. Varying interference patterns may appear on radar displays within range. This can be very serious, in, say, the English Channel, where many ships congregate and the superposition of interference patterns from other ships on a single display screen can effectively obliterate wanted target returns. However the problem can be largely overcome by painting only those received signals which are present at the same range on two or more successive sweeps of the timebase.

Modern echosounders such as those used in fishing may generate up to 10 kW, or more of power. Through the use of double screened cable and screened and earthed cabinets interference to other equipment usually can be kept to negligible proportions. However a possible source of interference with a modern recording echosounder might be the writing circuit which may use dry paper marking voltages up to 1200 V or more at a high audio or ultrasonic frequency. Where the marking oscillator produces square waves or rounded square waves multiple harmonics can be radiated through the viewing window. Also, in the process of writing, a spark is created between the stylus and platen at the surface of the paper. This spark can produce v.h.f. interference which also may radiate through the viewing window. Possible solutions include filtering out harmful harmonics, shifting frequency to avoid harmful interference on sensitive frequencies, converting the window into an earthed r.f. screen through the use of multiple wires or conductive film, or use of simple filtering in the writing circuit to shunt unwanted frequencies to earth.

Omega navigation receivers work on a basic frequency of 10.2 kHz, while some also receive on 11.333 and 13.6 kHz. In general no protection is afforded these frequencies in UK marine specifications. The timing circuits and read-out display are usually digital and the lane count operates in a dead reckoning mode, simply increasing or decreasing its reading by one unit each time the percentage of lane measurement passes through 99 centilanes and back to zero or vice-versa. Thus the equipment could be vulnerable and needs to be protected from interference pulses which may cause the lane reading to increase or decrease incorrectly. In one case a supply switch was incorporated in a paper recorder associated with an Omega equipment. The switch was seldom used but it was discovered, eventually, that often when the switch was operated the lane reading altered by one unit. This illustrates the need for susceptibility to be taken into account.

Loran navigation receivers normally have bandwidths of 20 to 25 kHz and operate on 100 kHz or 1800 to 1950 kHz. The timing circuits are usually digital and the display in the simplest type of equipment consists of an 'A' scan trace on a c.r.t. An example of a simple type of Loran receiver was rendered inoperative if supplied from a certain type of static inverter. The solution adopted at the time was to use a rotary inverter. With relatively wide bandwidth, proximity to the m.f. r.t. band and high sensitivity needed to achieve operation towards the limits of Loran coverage areas, own ship's transmissions, especially in the m.f. r.t. band, can interfere and distort the trace beyond any possibility of use. Also the timing circuits can be thrown out of synchronism with the transmitted Loran signal pattern. Possible ways of alleviating the situation include achieving the maximum possible separation between the transmitting aerials and Loran receiving aerial, good selectivity of the receiver against m.f. r.t. band signals and in extreme cases the use

of rejector or notch filter circuits. The more sophisticated types of Loran receiver may include notch filters, automatic search, synchronization and digital display, and are much less likely to be affected than the simpler types.

7 Need for Agreed and Accepted Marine E.M.C. Specifications

Generally speaking electronic and radio equipments tend to be concentrated in specific areas. Long-range communications equipment in most cases will be located in a radio room, navigational aids such as Loran, Omega, Decca Navigator and direction finder receiver may be in the chart room and v.h.f. transceivers, radar, echosounder, autopilot, loudspeaker announcement and talkback systems etc. may be located in the wheel-house. The modern trend is to enclose various equipments, in a given area, within a console. Generally a communications console and equipment contained within it will be provided by a single supplier and any problems of mutual interference identified and resolved before delivery. However, a wheel-house console may contain equipments originating from a number of different suppliers and also include electrical, engine and other controls. Since pre-delivery tests of the completed console are generally out of the question, it is important that the various suppliers can work to common e.m.c. specifications and that a suitable economic balance can be struck between levels of permitted emissions and degrees of susceptibility.

If one wishes to export electronic navigational aids or communications equipment for fitting on vessels that will sail under a foreign flag it is usually necessary for the equipment to be type approved by the flag country. Within certain limits each country is free to draw up its own specifications for equipment and some impose much more severe e.m.c. requirements than others. For example, the German requirements for conducted emissions for transmitters and receivers (VDE 0875 level K)[9] are much lower than those of the UK (BS 1597).[1] There is a need for agreed international specifications. A certain amount of work has been done towards creating an international specification covering various aspects of marine e.m.c. and a report on such a specification has been produced by the IEC as Publication 533.[10] This proposed specification is one of very few covering radiated and conducted susceptibility as well as radiated and conducted emissions.

8 Proposed IEC Specification[10]

A test for radiated interference susceptibility is proposed in which r.f. currents of 100 mA would be injected from one corner of an equipment cabinet to each of the other corners in turn, while the frequency of the injected signal is swept from 15 kHz to 30 MHz. A similar test current would also be passed through the screen of each cable attached to the unit under test.

For radar and sonar equipment a test would be made to verify that the equipment did not respond to coupling via a common earth impedance. A nominal 1 V r.m.s. at 10 to 50 kHz would be injected into the earth lead. Susceptibility via supply leads would be tested by injecting voltages into each supply input terminal, in turn, at frequencies of 10 kHz to 30 MHz and at levels between 0.1 and 1 V depending on frequency. The signal would also be amplitude modulated at 30%. Other terminals would be treated similarly except that the level would be 0.1 V. The equipment would be operating in its normal mode. Similar tests would be applied to semiconductor control equipment but utilizing transients derived from a special circuit. The transient would reach its peak in less than 2 μs and fall away exponentially. These susceptibility tests would be applied also to data acquisition and control systems transmitting signals between sensors, processors, control and ancilliary equipment. The criteria for satisfactory susceptibility performance would be no malfunction, performance degradation or change of indication.

A test for conducted interference susceptibility of receivers would involve injecting narrowband signals into the aerial input terminal and supply input terminals in turn, and noting the difference in input level required to achieve the same output. The difference, referred to as the 'mains immunity factor', should not be less than 70 dB over the frequency range of the receiver.

A somewhat similar test would be used to check the coupling between the ship's mains supply network and a 1 m reference aerial located at the site of the receiver aerial. A 1 V amplitude modulated signal would be injected into the mains network between each side and earth, at a point near to the main switch board, at frequencies chosen from each of the ship's radio navigation and radio communications bands between 70 kHz and 25 MHz. The 'aerial decoupling factor' C is calculated from the injection voltage U_g, the receiver voltage U_r, and the aerial factor F_a as follows:

$$C(\text{dB}) = 20 \log U_g - 20 \log U_r - 20 \log F_a$$

where

$$F_a = \frac{\text{known field strength in open field}}{\text{voltage at the input of the measuring receiver}}$$

C should be not less than 70 dB.

Narrowband conducted interference emissions from transmitters would be limited to 10 mV between 150 kHz and 30 MHz with the transmitter operating into an artificial aerial. The measurement would be made on the mains supply leads outside the radio room. It is likely that a substantially lower limit than 10 mV could be achieved without much difficulty.

For commutator motors, semiconductor rectifiers and regulators, data acquisition and control circuits, radar and sonar, narrowband conducted interference emissions

c

would be limited to 100 to 1 mV between 10 kHz and 30 MHz depending on frequency. Broadband conducted interference emission tests would be made with special measuring receivers meeting the requirements of CISPR 1 and 2.[11,12] The limits between 10 and 150 kHz would be 31·6 mV to 632 µV depending on frequency, in a receiver bandwidth of 200 Hz. Between 150 kHz and 30 MHz limits would be 6·2 to 1 mV according to frequency in a measuring bandwidth of 9 kHz. The broadband limits are quoted also in terms of currents.

The IEC document contains also codes of practice for marine installations.

9 Conclusions

It is hoped to be able to establish the validity and economic feasibility, for commercial equipment, of the various limits proposed. Tests on transmitters and receivers, in particular, indicate that these limits can be achieved economically with some existing commercial equipment types. Also further reductions of limits, in some areas, may be economically feasible.

10 References

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11 CISPR Publication 1, 'Specification for CISPR Radio Interference Measuring Apparatus for the Frequency Range 0·15 MHz to 30 MHz', IEC, Geneva, 1972.

12 CISPR Publication 2, 'Specification for CISPR Radio Interference Measuring Apparatus for the Frequency Range 25 MHz to 300 MHz.' IEC Geneva, 1975.

The application of mathematical modelling to e.m.c. analysis of systems

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SUMMARY

A description of SEMCAP (Specification and Electromagnetic Compatibility Analysis Program) is given. The program uses mathematical models of interference generators and receptors and of the indirect transfer mechanisms linking them. The program calculates the voltage received at the receptor through capacitive, inductive, E- and H-field coupling. The application of the program to the Orbital Test Satellite is described. The accuracy, limitations and cost effectiveness of the program are discussed.

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1 Introduction

The problem of guaranteeing compatibility has few solutions and requires time and money. In general, any of the following three methods could be employed:

(a) Do nothing until the system is assembled and sort out the problems by redesigning the hardware. This is somewhat risky as much time and money can be wasted by design changes at a late stage. It can also create a very inefficient design.

(b) During the design stage, calculate by hand the interaction of critical circuits. This suffers from man-power problems as the interactions could number several thousand. Human weakness creates short cuts which lose accuracy and tend to limit the number of models used.

(c) As above but using computer techniques to model the circuits and actions. This solution is examined in detail in this contribution.

2 The Problem

Interference is caused by a generator of electrical signals transferring energy into a receptor of electrical signals thereby disturbing the functioning of the receptor. There are three distinct areas to be defined: the generator parameters, the transfer characteristics and the receptor parameters. As illustrated in Fig. 1, the problem is complicated by the number of generators, receptors and transfer mechanisms involved in a typical application.

The generator can be a radar signal, ripple currents in power lines, command signals either within the system or part of another system. The receptors can be radio or television receivers, monitoring circuits, command receivers or command circuits. Neither list is meant to be exhaustive. Transfer mechanisms can be by wire connection, by radiated fields, capacitive and inductive coupling or by common resistance.

For a given system, the problem is:

(a) to define generators within the system and external to the system which can cause interference,

(b) to define receptors in and external to the system which are susceptible to interference,

(c) to define transfer mechanisms between each generator and each receptor (there may be more than one),
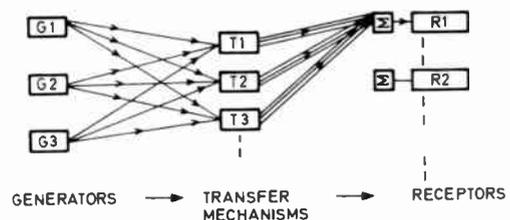

Fig. 1. Generalized interaction problem.
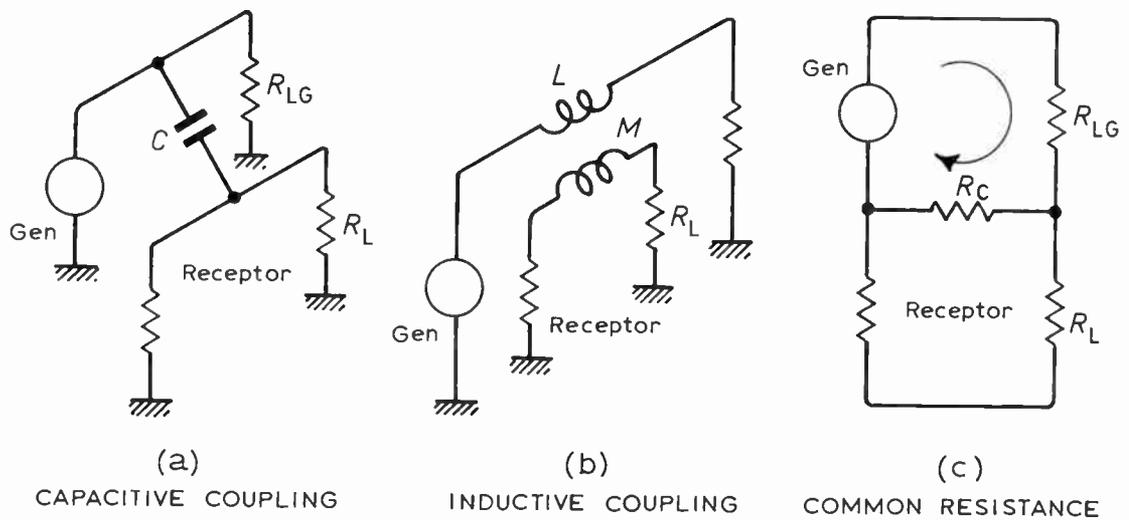
Fig. 2. Cable coupling transfer mechanisms.

(d) to calculate the effect on each receptor of each generator and to arrive at a total effect at the receptor due to all generators (not necessarily the summation since there may be some timing correlation).

For a given system, it is not unreasonable to suppose that the system engineers will ensure that wire-connected interfaces will not interfere. For example, a tele-command output from a decoder going to a command user should not affect the user except when the tele-command is sent and then only in a prescribed way. This is part of the functional design of the decoder and the command user and should be specified in the equipment specification.

However, the signals arriving at the user from other sources (E-fields coupling to the harness, return currents from other equipments causing voltages in the ground plane) cannot be foreseen as part of the functional specification.

Further, the extent of the interaction must include a consideration of each generator circuit through each type of transfer mechanism to each receptor circuit. The number of calculations becomes very large and a computer program is the only practical solution. A particular program is described below.

3 SEMCAP (Specification and Electromagnetic Compatibility Analysis Program

SEMCAP[1] is designed to analyse the interaction of generators and receptors coupling by indirect interfaces. It is assumed that there is no box leakage and that the main coupling is via the harness.

The transfer mechanisms covered by the program are:

(a) cable coupling by distributed capacitance, from voltage source generators,

(b) cable coupling by distributed inductance, from current source generators,

(c) common resistance coupling from current source generators by creating a voltage across a resistance common to generator and receptor circuit.

These three mechanisms are illustrated in Fig. 2.

(d) E-field coupling,

(e) H-field coupling.

The general generator-receptor interaction is illustrated in Fig. 3. In order to illustrate the factors accounted for in the calculation, the input data requirements will be described.

3.1 Data Requirement

Data requirements can be divided into three main sections.

3.1.1 System data

These data refer to the physical layout of the system and are applicable to most generators and receptors.

(i) The system wiring layout is divided into up to 120 segments. The length of each segment is measured and
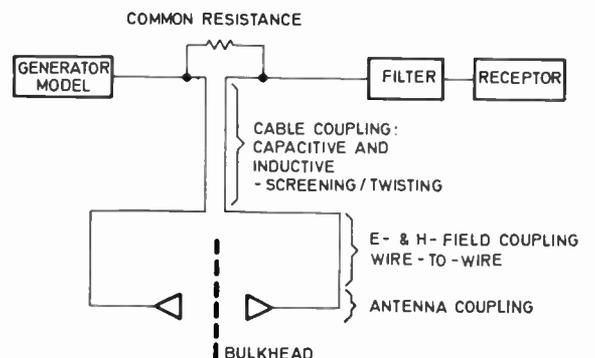

Fig. 3. Generator-receptor interaction.
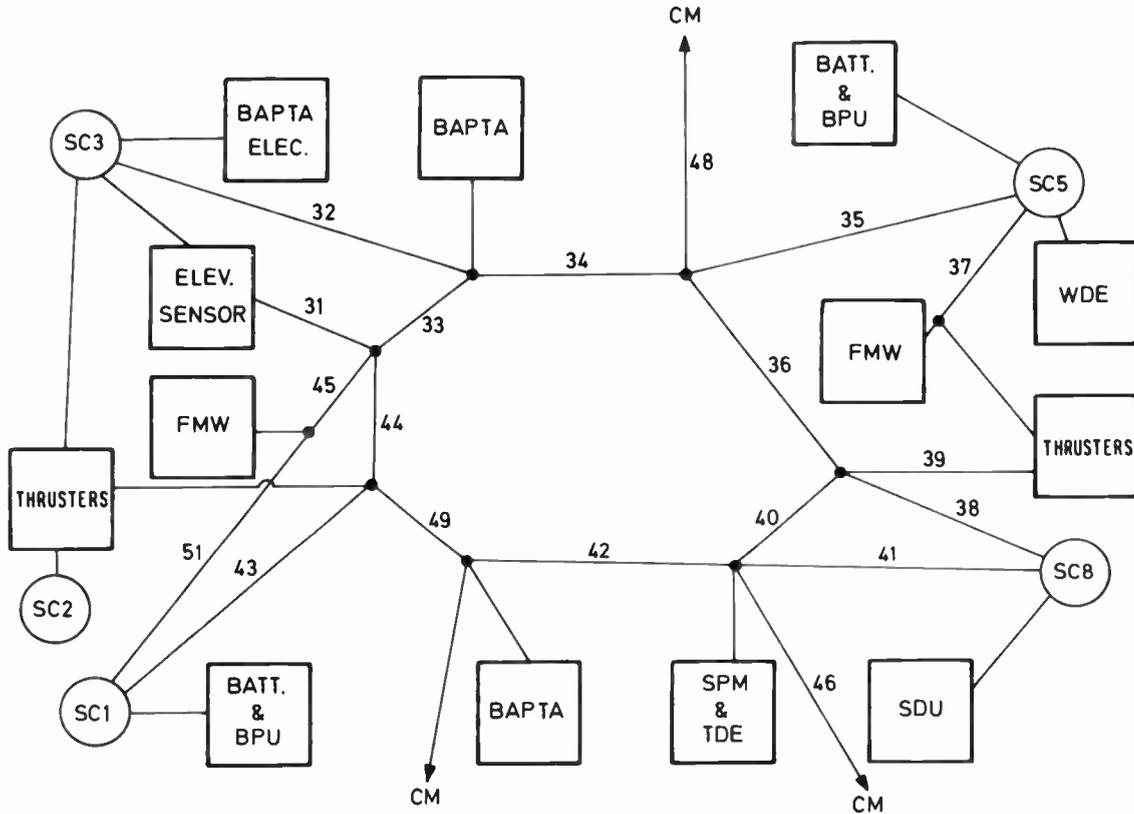
Fig. 4. Wiring map (part).

the lengths form the wire length array. A wire run for a given circuit can be nominated by choosing the relevant wiring segments. An illustration of a wiring map is shown in Fig. 4. This is part of the Orbital Test Satellite and forms only part of the complete map.

In this example, CM refers to wiring routes to the Communication Module and SC 1, 2, 3, 5 and 8 refer to access holes for wiring to route to another floor. The square boxes are electronic equipments—BAPTA (Bearing and Power Transfer Assembly), BPU (Battery Protection Unit), WDE (Wheel Drive Electronics), FMW(Fixed Momentum Wheel), SPM and TDE (Spin Phase Momentum and Thrust Driver Electronics) and SDU (Squib Driver Unit)

(ii) The separation of wires within a wiring segment is defined in a matrix for each classification of generator and receptor wiring. This matrix allows for functional separations such as power, signal, pyro-technic etc.

(iii) The classification of circuits having common resistance in their return leads is made in matrix form. The program can distinguish between common resistance in the structure, in bondstraps and in fixed resistances such as a shared battery.

(iv) The field generators and receptors—antennas and major wiring segments—are defined and the distances between them held in matrix form.

(v) The bulkhead attenuation is defined by nominating sections of the system separated by bulkheads and forming a matrix which gives the attenuation between the sections.

(vi) A list of wire types used in the system is formed giving data on the wire radius, the radius, thickness, efficiency and conductivity of the shield and the characteristic impedance of the wire.

3.1.2 Generator data

Models of generators whose signals are necessary for the functioning of the system function are identified as transient or steady state, named and numbered. Data are then required on the wiring: the length of wire, type, height above ground, shielding earths, twisting, pigtail loop area, unshielded length and the resonant length of the shield.

The relevant elements from the wiring map and the matrix elements pertaining to the generator are entered. Additionally, the load resistance may be required.

Data on the voltage characteristic of the generator include amplitude, waveform, rise-time, pulse width and p.r.f., as is relevant. More complex waveforms can be modelled directly in spectral density format. Similar parameters are required to define the current charac-teristics.

The field generating data requirements apply only to antennas. No new information is necessary for wire segments. For antennas, the field decay exponential and

the frequency characteristics of the antenna are required. Additionally, in order to compute the E-field at 1 metre (E) from information about the voltage at the antenna base (V), the computer requires the ratio E/V. This may be related to the gain of the antenna by:

$$P_D = \frac{P_T G_T}{4\pi R^2}$$

where P_D is the power density at a distance R (metres) from the antenna, P_T is the power into the antenna and G_T the gain of the antenna.

Then for antennas with 50 Ω input impedance

$$\frac{E^2}{120\pi} = \frac{V^2}{50} \times \frac{G_T}{4\pi}$$

for $R = 1$ metre.
Therefore

$$\frac{E}{V} = \sqrt{(0\cdot6\ G_T)}$$

Similar calculations can be made to determine the H-field.

3.1.3 Receptor data

Essential receptors are identified, named and numbered. Wiring data requirement is essentially the same as for generators. Additionally, both the load and source resistance are necessary.

In place of the voltage and current characteristics, receptors require data on the sensitivity, in volts, of the circuit and a frequency characterization of the sensitive terminal. Antenna receptors require the ratio of voltage received at the antenna base to the E-field at the receiving antenna. This may be related to the frequency and gain of the antenna by:

$$P_R = P_D A$$

where P_R is the power received at the antenna base, P_D is the power density at the antenna and A is the effective receiving area of the antenna.

$$A = \frac{\lambda^2 G_R}{4\pi}$$

where G_R is the gain of the receiving antenna. Then,

$$P_R = \frac{P_D \lambda^2 G_R}{4\pi}$$

and for antennas with 50 Ω input impedance

$$\frac{V^2}{50} = \frac{E^2}{120\pi} \times \frac{\lambda^2 G_R}{4\pi}$$

Therefore

$$\frac{V}{E} = 0\cdot103 \lambda \sqrt{(G_R)}$$

Similar calculations are made for H-field receptors.

Fig. 5. Computer output compatibility matrix.

Receptors receiving on wiring segments do not require any further data. It can be seen that the data requirements are demanding but the range of generator, transfer, receptor variations is wide. The effect of generators of voltage or current sources having various waveforms and either unscreened, screened, twisted, or twisted and screened wiring which reflects the system routing can be assessed on receptors taking into account the wiring characteristics, antenna characteristics and sensitivity.

3.2 Operation

With all the data for the system entered in the correct format, and after internal verification of the data, the program performs the following calculations. Starting with the first generator listed, the voltage and current data are converted to spectral density format. The interfaces between this generator and the first receptor such as common wiring segments, bulkheads and field distances are identified. For each of the transfer mechanisms described earlier, a transfer factor, as a function of frequency, is calculated. The voltage arriving at the receptor terminals is thus found.

This voltage is modified by the frequency characteristics of the receptor so that the spectral density at the receptor is calculated. This is integrated over the complete frequency range (10 Hz to 100 GHz for example) to give the received voltage which is compared with the sensitivity of the receptor.

A print-out is given of the voltage received via each of the transfer mechanisms and of the summation of these voltages, each voltage being also expressed as a ratio of the sensitivity in dB. The program proceeds to calculate the received voltage from the second generator to the first receptor. When all generators have been processed, a summation is made of all the voltage received at the first receptor.

This summation is performed both directly and as root sum square. The largest transient generator is identified and added to each summation. These quantities having been printed out, the process is repeated for the second receptor, and so on.

When the final receptor has been processed, a summary of the interactions found is printed, consisting of a matrix like that shown in Fig. 5.

The letters refer to the margin between the received voltage at the receptor: A = less than 30 dB compatibility, M = less than 10 dB compatibility, P = more than 10 dB interference. These flags also appear in the print-out for each receptor and allow problem areas to be easily identified.

Other computer routines available include the calculation of specifications based on the performance data of the system, graphical print-out of the spectral density at a receptor due to a nominated generator or all system generators and print-out of the transfer characteristic from generator to receptor.
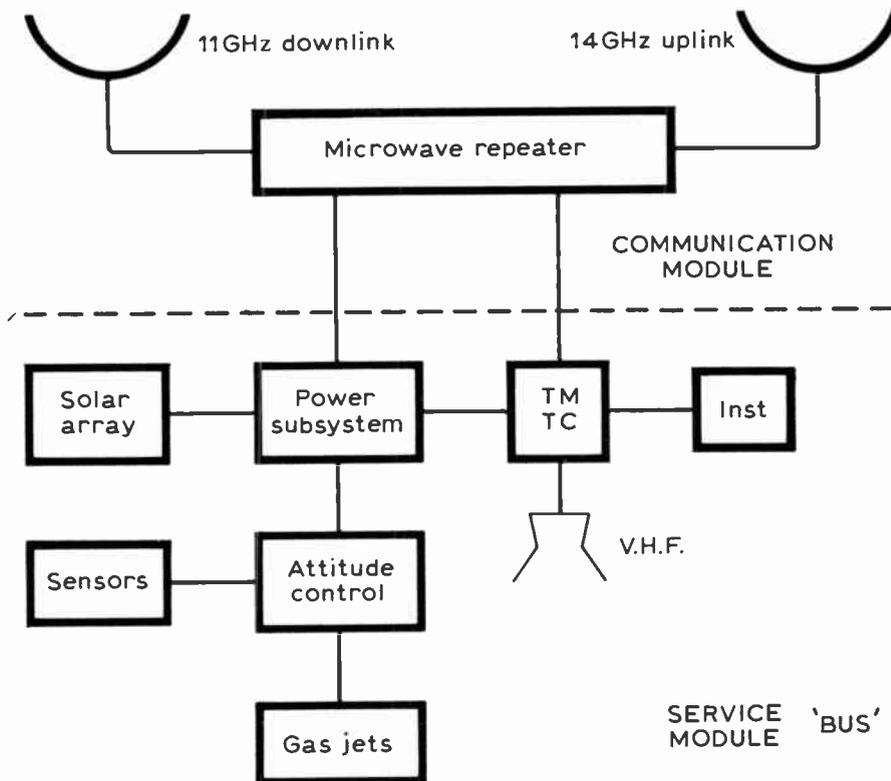

Fig. 6. System block diagram of the OTS.

4 Application to the Orbital Test Satellite

4.1 System Description

The program has been used to analyse the electro-magnetic compatibility of the Orbital Test Satellite (OTS).[2] This is a communication satellite which forms the basis of a family of spacecraft using the same basic design.

Referring to Fig. 6, the platform, consisting of power, attitude control, telemetry and telecommand and instrumentation, is designed to carry a variety of communication packages. The particular package on OTS uses 14 GHz uplink carrier to relay television and telephone channels with 11 GHz downlink at 20 W r.f. output.

Power is supplied from solar arrays regulated to give a 50 V bus. Battery power is used during launch and eclipse. Tracking, telemetry and command (TTC) is provided through a v.h.f. uplink at 149 MHz and downlink at 137 MHz. S.h.f. links can also be used through the communication module r.f. links. Attitude and orbital control systems (AOCS) use optical sensors to derive input information. Attitude change is achieved by hydrazine gas jets or by momentum wheels. An extensive network of temperature sensors give information on the thermal control effectiveness in flight. Pyrotechnics are used to fire the apogee boost motor and to unlatch the solar array.

4.2 Outline of Models

System data were found following the requirements of Section 3.1 of this paper. The wiring map was of necessity approximate because the layout was changing during the analysis period. Wire type separations used were power, signal, pyrotechnic and later, as a result of analysis, high level signals.

Generator and receptor models are outlined in Table 1, according to subsystem.

4.3 Results of Analysis

A detailed compatibility matrix was prepared showing actual margins, in dB together with an indication of the coupling mechanism. A typical example is shown in Fig. 7. This analysis used 62 generators and 66 receptors giving a total of 4092 interactions.

The matrix is formed only of generators and receptors having interactions with less than 30 dB margin (41 generators and 29 receptors) and shows 41 interactions with margins less than 15 DB about 1% of the total analysis.

The worse margin is −7 dB between the v.h.f. transmitter and the platinum resistors on the solar array. Confirmed during tests, this interference is rendered ineffectual by changes to the mission sequence: solar array temperature is monitored by s.h.f. telemetry only.

Other problem areas predicted concerned interference of platinum sensors within the spacecraft. Here, it was feasible to shield the lines to prevent the interaction. The effectiveness of this solution was calculated using the program and was found to be adequate.

In practice, it was found necessary to install ferrite beads on the wire to give extra attenuation. This implied an error in the original estimation of the sensitivity of the sensors. This error was corrected giving a more accurate model which can be used on other systems.

5 Accuracy

5.1 Sources of Error

Problems arise in attempting to represent a complex situation by a restricted set of data. The cable coupling problem varies with the size of the bundle, the relative positions of the cables and the nature of the bundle separating the two wires under analysis. The program, limited by computer store, treats all cable coupled interactions as between two cables with standard separations and no intermediate wiring. The tendency of this treatment is to predict a higher interference voltage than is the case of practice. Similar problems arise with the representation of bulkhead attenuation.

This factor depends on the materials, design, bonding, apertures etc. and varies from bulkhead to bulkhead. The input data allow for frequency sensitivity of the bulkhead but not for their individuality: all bulkheads are treated as the same. Input data used are therefore fairly pessimistic, describing low attenuation and resulting in higher interference voltages.

Inaccuracies inevitably occur in the input data. Designers cannot always supply data on an equipment's performance outside its design frequency range and

Table 1

| System	Generator	Receptor
TTC	Low and high level commands on each side of each floor	Low level commands on each side of each floor
	All clocks	Analogue telemetry lines
	V.h.f. transmitter at 137 MHz	V.h.f. receiver at 149 MHz
Repeater	S.h.f., t.w.t. amplifier output at 11·2 GHz	S.h.f. front end at 14 GHz
	I.f. channel characteristic	I.f. channel characteristics
AOCS	Thruster pulses	Sensor input characteristics
	Momentum wheel current ripple	Secondary power pickup
Power	Current transients on bus	Control loops
	Clocks and secondary supplies	Main bus pickup
Pyrotechnics	Firing pulses	Pickup on pyro and decoder lines
Instrumentation		Thermistor, platinum resistor sensors

KEY

FIGURES GIVEN ARE dB MARGIN WITH RESPECT TO RECEPTOR THRESHOLD LEVEL

C = CAPACITIVE COUPLING
I = INDUCTIVE COUPLING
E = E-FIELD COUPLING
T = SUM OF ALL COUPLING
RSS = ROOT SUM SQUARE FROM ALL RECEPTORS

SUB-SYSTEM	R	RECEPTOR NAME	OVERALL MARGIN (dB) RSS	OVERALL MARGIN (dB) TI
AOCS	3	SODERN 11V SUPPLY	8	20
	1	ELEVATION SENSOR	24	63
POWER	11	MAIN BUS PICKUP	37	-17
	12	SRA LIN DUMP FB TO PCU	18	81
PYRO	14	JB→SDU VIA SEP SW	17	5
	15	SDU TO EEOS	21	83
	16	SDU / DECODER	17	12
	17	SDU / ENCODER	28	9
REPEATER	21	SHF Rx FRONT END	25	47
	22	BEACON FRONT END	18	49
TT & C	25	DECODER M LOAD BMCU	21	57
	26	DECODER LL -Z SM	43	20
	28	DECODER LL +Z CM	54	25
	29	ANALOG I/P SM GROUP 1	-4	13
	30	ANALOG I/P SM GROUP 2	7	12
	35	VHF Rx AGC MONITOR	6	0
	36	CM ANALOGS RPS.EPC +Z	14	10
	37	CM ANALOGS Rx, Tx -Z	20	12
	38	CM ANALOGS COBO PaRAMP-Z	8	6
	49	VHF Rx OUTBAND	8	0
	50	VHF Rx INBAND	0	-8
	51	12 MHz Rx	2	-15
	52	UHF Rx / PSIU	13	16
INSTRUMENTATION	39	IEU THERMISTOR SM +Z	14	13
	42	IEU THERMISTOR SM -Z	17	-1
	43	IEU THERMISTOR CM +Z	45	30
	45	Pt COMMS ANTENNA	7	88
	47	Pt SOLAR ARRAY	-9	106
	48	IEU 2 15V POWER IN	17	17

Fig. 7. Detailed compatibility matrix.

estimations must be made based on engineering experience. Original estimates of the performance of the temperature sensors on OTS lead to a prediction of interference from v.h.f. and s.h.f. transmitters. Tests showed that only v.h.f. signals interfered and the model was changed, giving additional attenuation at s.h.f. In similar ways, other models are improved. The demand for data results in a test requirement which has the advantage of being system specific and relateable to system performance.

The computations have within them some sources of errors. The analysis of square wave pulses includes a Fourier transform to the frequency domain. In order to save computer time and storage, the time-phase reference is lost, resulting in a linear addition of harmonics rather than vectorial. The resultant voltage is higher than that which would be obtained from an exact formulation, giving more interference and pessimistic analyses.

The tendency of the program to give pessimistic answers is deliberate. It is much safer to implement a correction of a marginal problem than it is to find a problem during the late stages of system test. However, cost impacts are not to be neglected and therefore not all calculations are pessimistic. In the final addition of received voltages from all generators, the summation is performed as a root sum square on the assumption that generators are non-coherent.

5.2 Correlation with Test

The computer codes describing the transfer factors have been correlated with measurement.[1] On OTS, the correlation of the whole program calculation, including generator, transfer factor and receptor models, was attempted. Wires, about 1·5 m long, were positioned above parts of the wiring harness. These harness segments were chosen to include as much functioning circuitry as possible from all of the subsystems.

A receptor model of the wire was prepared and the computer calculated the voltage spectrum at the receiver at one end of the wire with the opposite end terminated in open and short circuits. This exercise was performed on the Engineering and Qualification models of the spacecraft. On Figs. 8 and 9, the results of the measurement are compared with the computer prediction.

The comparison shows a reasonable correlation of prediction and measurement, allowing for the complexity of the problem. The peaks in the measured signal are due to resonances in the harness, the wire probe and the connecting cable. Additionally, susceptibility signals were

Fig. 8. OTS wire probe short circuit.

Fig. 9. OTS wire probe open circuit.

injected onto the probes with no ill effects on the space-craft. The spectral density of these signals is plotted together with the effective signal on the bundle, showing a margin of some 30 dB for voltage coupling and 15 dB for current coupling.

6 Limitations of Program

Large computer programs develop an aura of infalli-bility and all-encompassing scope. It is as well to examine the limits of SEMCAP, noting some of the techniques which are necessary to enhance the scope of the program.

6.1 Data Limitations

The program described limits the number of generators and receptors to 240 of each, but this has not inhibited its use, about 60 generators and 60 receptors having been found sufficient to model OTS. Similarly a limit of 120 occurs for the number of wiring segments; the OTS model used only about 100.

For larger systems, a later version of the program exists having more capability: no restriction on the number of models and 240 wiring segments.

6.2 Operational Limitations

The mathematical models built into the program represent the vast majority of situations which occur for indirect coupling. The program does not model the hardline interactions between power supply and power users which relate voltage and current ripples in the power distribution system. These calculations are completely dependent on the character of the power system under consideration: mathematical models would be too rigid as part of a generalized interaction program. On OTS, this interface has been covered by power system engineers who are best qualified to assess the performance of the power system.

The mathematical models cannot easily represent large currents in the ground-plane caused by lightning strikes or electrostatic discharges, since the only coupling mechanisms are wire-to-wire coupling and radiated coupling. In these instances, the flow of current is virtually impossible to define and the interaction of the current with circuitry is complex. On OTS, it was found that designing to the conventional e.m.c. requirements builds in immunity to these large current pulses.

The non-standard waveforms associated with these phenomena could be modelled by finding the Fourier transform and converting to spectral density which can be used as direct input data.

A major limitation exists in the program's inability to handle non-linear elements within the modelled system. Such elements are capable of producing harmonics and frequency mixing products. On OTS, the v.h.f. link is composed of an uplink at 149·34 MHz carrying tele-commands and a downlink at 137·05 MHz carrying telemetry. The on-board receiver has an inband sensi-tivity of 0·4 μV while the transmitter output power is 5 W. Filter characteristics of diplexer and input filter ensure no direct interference but the transmitter signals mixing in non-linear elements with a signal at 12·29 MHz (the difference frequency) creates a signal at the receiver frequency. The difference occurs as a harmonic of clock signals, commands or switched power. There is no mechanism in the program to examine this effect directly. Once the problem is recognized, a model representing the difference frequency can be made which will point out the generators having high harmonic content.

The lack of non-linear analysis applies to transmitters. High power tubes usually have harmonic outputs at frequencies above the fundamental. Unless the data input specifies the amplitude and frequency of the harmonics, the program has no knowledge of them. It has no in-built experience of tubes on which to draw.

Since the program performs all calculations in the

frequency domain the time reference is lost. The output compatibility matrix assumes all generators are present at the same time. This difficulty is resolved by careful analysis of results. For example, interactions of tele-commands with analogue telemetry is only serious if it occurs during the encoder interrogation period which, on OTS, is a few milliseconds every 25 seconds. Tele-commands take only a few milliseconds to send and action. Thus, the time coincidence is rare but if the data are vital, it is well to know about the interference. Time coincidence can also refer to mission sequence. It was estimated that the current surge associated with the switch-on of the repeater would cause a pulse to appear in the line from the decoder to the pyrotechnic fire unit; no particular action was necessary since all pyrotechnics would already be fired when the repeater turn-on occurs.

Computer programs exist having routines capable of analysing problems without these limitations. Such programs are necessarily large and expensive. It may be more economical to use the medium-size program such as SEMCAP and recognize its limitations.

7 Cost Effectiveness

It is difficult to give quantitative figures to the value of the program. Its impact can be seen in many ways. Early in the development of OTS, a change of launch vehicle was made having an impact on the spacecraft design. Some of the co-contractors were dubious about the new harness design and requested extra shielding. By analysis, it was possible to demonstrate that no additional shielding was necessary. Thus no hardware was committed and time, money and mass were saved.

The analysis, by such means, ensures that only essential screening is utilized, minimizing weight and cost. This is of vital importance on spacecraft where weight is a critical factor.

Space missions have other restrictions, notably the fixed launch date. It becomes of vital importance to avoid program slippage. Thus, if units fail to meet their test requirements and modifications are necessary, it can be disastrous. By using the computer program to analyse the e.m.c. test results, it has been possible to show that the results are acceptable or at least to quantify the risk at system level. The units can proceed to inte-gration without hardware changes.

8 Conclusions

A description of a computer program capable of analysing indirect interfaces has been given. The limitations and sources of inaccuracy have been discussed and some experience on the Orbital Test Satellite has been used to illustrate the use of the program.

9 Acknowledgment

10 References

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2 Wearmouth, C. and McLaurin, D., 'The development of the Orbital Test Satellite', AIAA 76-246. Presented at CA51 6th Communication Satellite System Conference, April 1976, Montreal, American Institute of Aeronautics and Astronautics.

Superscreened cables

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SUMMARY
The fundamental phenomena involved in the screening of braided cables are discussed and knowledge of these is shown to aid in improving this screening as expressed in terms of surface transfer impedance.
It is shown how the use of magnetic materials between two braids, coupled with knowledge of the above optimization techniques, can lead to enormously improved screening which can be maintained by proper application of the magnetic tape.

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1 Introduction

There is a popular misconception in some quarters that a braided screen is like an air-tight enclosure and therefore acts as a near perfect shielding enclosure for the internal circuit. Consequently coaxial or other screened cables are not suspected when an instrument system is being considered for electrical interference immunity. Unfortunately as a screen a braid may be far from perfect but this paper is aimed at showing that, with little extra complication, we can now approach very near to this ideal without losing the essential characteristics of a braided coaxial cable.

As a background to the newly developed cables it is useful to outline the screening requirements and explain how these apply to cables and then to describe the screening performance of existing cables. Measuring methods must be described because of the greater sensitivity required over standard braided cables. The principle of braid optimization will be outlined because it is an essential feature in the design of good superscreened cables.

2 Screening Requirements

An electronic circuit is screened so that it will be unaffected by natural and man-made electromagnetic disturbance. The level of natural disturbance is normally low but can rise to very high levels during nearby thunderstorms. The more blatant forms of man-made disturbance should be controlled and this is now done, for example, in the suppression of motor vehicle ignition systems and electric hand tools. However, a source of interference remaining unsuppressed is the humble switch which at the peak voltage of a 240 V distribution system injects fast rise 8 A pulses into a mismatched 50 Ω transmission line which is a fair equivalent of a mains distribution system. The return path for this line includes conductors and metalwork other than the disturbing circuits power return wire. These conductors couple in turn to others which may include the screens of sensitive instrument circuits. Because of resonance in mismatched lines the best coupling occurs at certain indeterminate frequencies with current levels as high as 100 mA r.m.s. in the screen in question.[1] Such currents have been detected at frequencies between 100 kHz and 100 MHz and this range is substantiated when we consider the cable lengths expected in large industrial plants.

A current flowing in a coaxial cable screen will induce voltages in the screened circuit related to the disturbing current by the surface transfer impedance (Z_T) of the cable. It has been argued that electric and magnetic fields can themselves have an effect on the screened circuit without any current flowing down the screen. This is true at frequencies below 10 kHz for magnetic coupling and with very poor screens for electric coupling. For all other conditions the direct coupling effects are swamped by the surface transfer impedance of a cable.
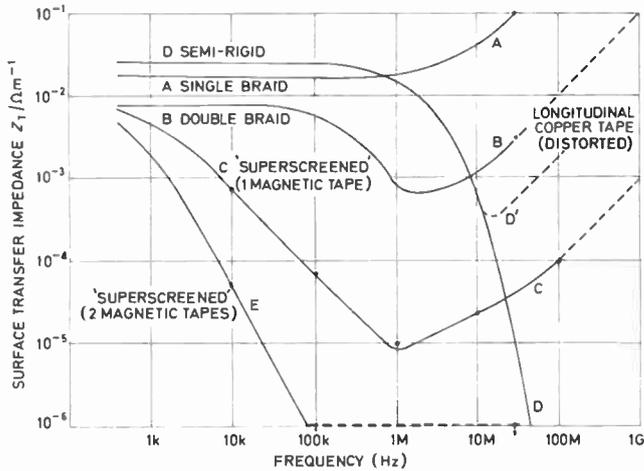
Fig. 1. Z_T of various cable classes (design limits).

Broadband instruments are used to measure signals as low as $1 \mu V$ at a frequency of 1 MHz and $10 \mu V$ at 100 MHz. Narrow band instruments may be considerably more sensitive, with 10 nV not uncommon. To reduce below $1 \mu V$ the effects of earth-coupled transients at 1 MHz would require a total surface transfer impedance less than $10 \mu \Omega$ if the whole of 100 mA flowed in an interconnecting cable screen. As normal braided cables can have a surface transfer impedance around $10 m\Omega/m$ at 1 MHz, there is much room for improvement if transient disturbance is to be kept out of sensitive circuits.

3 Classes of Coaxial Cable

Radio-frequency cables are used for signals from d.c. to microwave frequencies. While many of them have a braided screen construction there are some with homogeneous solid drawn outer conductors and others with longitudinally applied overlapped tape. The former, known as semi-rigid cables, are used in microwave applications and the latter in the frequency range of from 100 MHz to 1 GHz where their lack of flexibility can be tolerated because of low cost and lower attenuation than briaded coaxial cables. Braided cables are more flexible but suffer from serious lack of screening at high frequencies. It is to improve this screening that the incorporation of magnetic materials has been studied and exploited with such impressive results that the term 'superscreened' has been coined to describe the resulting cables.

The screening performance or surface transfer impedance (Z_T) characteristics in the frequency domain for various classes of cable are shown in Fig. 1. The curves shown are based on measurements on the classes of cable described but are actually the upper limits proposed for specification purposes. Thus for cable A (single braid) the Z_T limit at 30 MHz is $100 m\Omega/m$ while for cable B (double braid) it is $3 m\Omega/m$. Cable D (semi-

rigid) has a very low value of Z_T at frequencies above 30 MHz. Such cables with solid copper outer conductor can be bent readily to small radii but are not capable of continuous flexing because of the danger of fatigue cracking of the outer conductor. A longitudinally overlapped copper tape is popular on CATV cables. Its Z_T when plotted against frequency closely follows that for a semi-rigid cable except that bending the cable can disturb the overlap, leading to worsening at high frequency. The trend is shown at D'. A value of Z_T as high as 3 mΩ at 30 MHz has been measured on a sample found to have a small crack where it had been bent and then straightened. The remaining curves (C and E) in Fig. 1 are for braided superscreened cables and will be discussed later.

4 Measuring Methods

Surface transfer impedance relates the voltage generated inside a cable screen to the current induced to flow in that screen. There are several methods of making this kind of measurement which vary slightly in principle but greater diversity exists in the electronic equipment employed. The standard test method for Z_T currently recommended by the International Electrotechnical Commission[2] uses a jig of 'triple coaxial' form as sketched in Fig. 2(a). The screen of the cable under test forms the outer conductor of the detecting circuit which is correctly terminated in its characteristic impedance at both ends; at one end by the measuring amplifier and at the other, inside the test jig by a screened terminating resistor. The screen of the cable under test also forms the inner conductor of the drive or injection circuit. Here the test length is a coaxial line short circuit at one end which
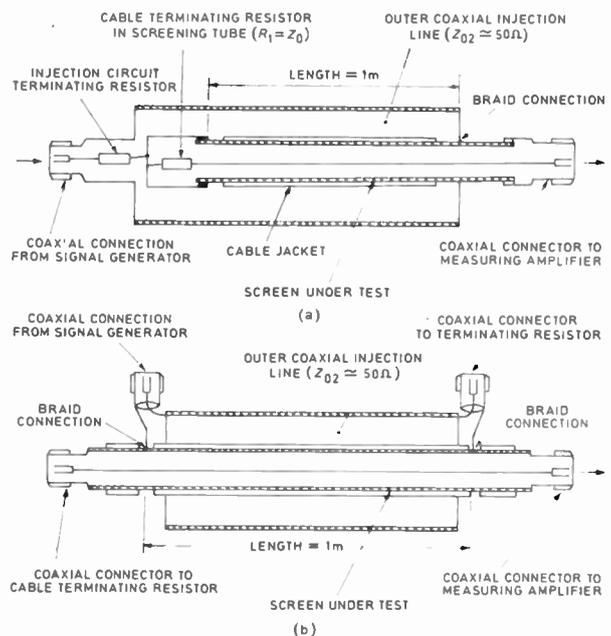
Fig. 2. Test jigs for measurement of Z_T.
(a) 'Triple coaxial' method.
(b) Alternative 'braid injection' method.
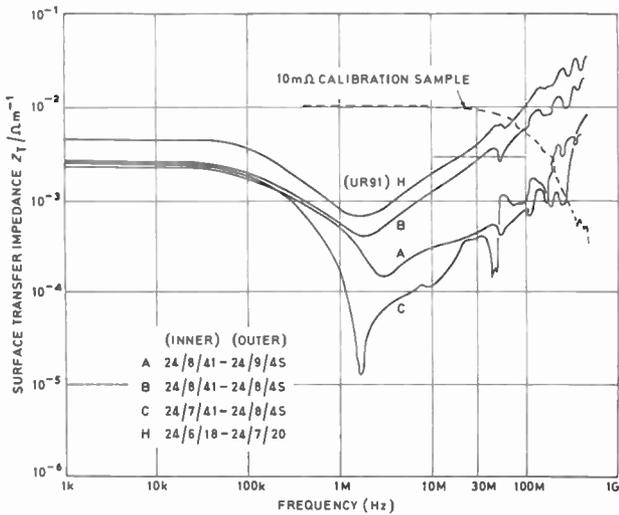
Fig. 3. Double braid cable—typical Z_T measurements. Cable type 50-7-3. Surface transfer impedance for various braid constructions.

Fig. 4. Surface transfer impedance (Z_T)—schematic of the automatic test set.

limits the useful top test frequency to about 30 MHz for a 1 m sample length. A variant of this method is to use a braid for the outer conductor of the injection circuit. This makes it possible to flex the test sample during tests or between successive measurements.

In an alternative test jig used by the author, and under consideration by the IEC, the outer injection circuit is reversed as in Fig. 2(b). This allows the circuit to be properly terminated at both ends at the expense of the outer conductor of the injection circuit being live. It is possible to work with a live outer conductor if good separation from other conducting metalwork is maintained to minimize the by-passing of high-frequency currents. Possibly more difficult in practice is the need to obtain extremely good screening in all parts of the measuring system. The basic advantage of the alternative system over the triple coaxial system is that measurement frequently is not limited by the test length. Measurements have been made successfully up to 500 MHz on a 1 m test length (Fig. 3 for example) or with a test length of 20 m at up to 100 MHz.

Using either test jig a sweeping network analyser is used to inject and detect which enables very sensitive measurements to be made over a wide frequency range without spending a lot of time with a manually-tuned detecting instrument. A network analyser can act as a frequency selective voltmeter with a bandwidth of 100 Hz. Used with a wideband pre-amplifier an input noise level as low as 10 nV is achievable. If the tracking oscillator output is amplified (in a wideband power amplifier) to 200 mA r.m.s., the transfer impedance sensitivity is seen to be:

$$\frac{10 \text{ nV}}{200 \text{ mA}} \times 2 = 0 \cdot 1 \ \mu\Omega$$

The factor 2 allows for the fact that only half the voltage
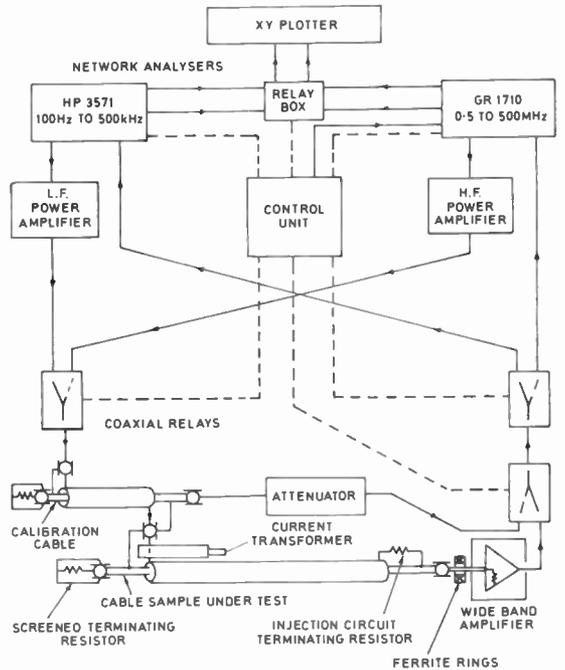
generated in the cable sample appears at the amplifier input. A complete set-up for measuring Z_T using the author's alternative test rig and two proprietary sweeping network analysers covers frequencies from 100 Hz to 100 MHz and is shown in outline in Fig. 4.

5 Braid Optimization—Single and Double Braids

A cable braid is constructed on a machine which weaves groups or 'spindles' of wire strands together to give the characteristic pattern of Fig. 5. Between each group of spindles a hole must exist and early cable specifications have been aimed at minimizing the size of these holes. If the cable braid is considered as a thin cylindrical shell
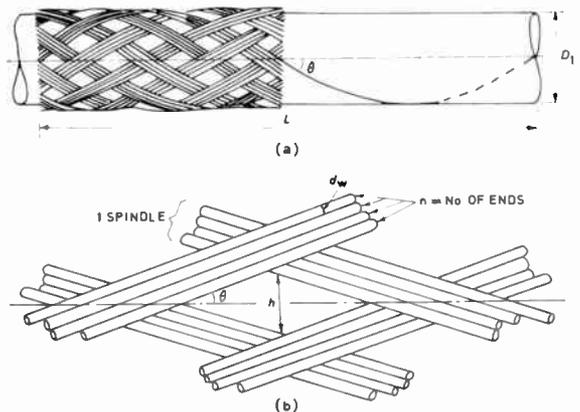
Fig. 5. Cable braid construction.
(a) Portion of braid showing weave. m (number of spindles) = 16.
(b) Detail of braid showing one 'hole'.
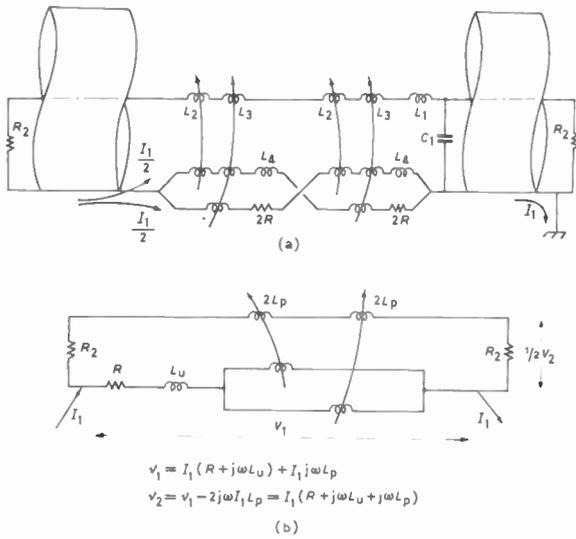
Fig. 6. Braided cable—equivalent circuit.
(a) Equivalent circuit of section of braid:
    characteristic impedance $Z_0 = L_1 C_1$
    uncoupled inductance $L_u = \frac{1}{2} L_4$
    'porpoising' inductance $L_p = \frac{1}{2} L_2$
(b) Simplified circuit.

$$v_1 = I_1(R + j\omega L_u) + I_1 j\omega L_p$$
$$v_2 = v_1 - 2j\omega I_1 L_p = I_1(R + j\omega L_u + j\omega L_p)$$

its inductance couples completely to the inner conductor as in the semi-rigid cable. Holes in this shell prevent current flowing uniformly all round it and appear as a small inductance uncoupled to the inner conductor. It was minimizing this inductance by making the holes as small as possible that was supposed to improve the cable screening.

There is a further inductive phenomenon which is equally important in a cable's screening performance. Because of the woven construction of a braid individual spindles are alternately nearer and further from the inner conductor. An equivalent circuit in Fig. 6 shows how this 'porpoising' inductance (from the action of an individual spindle in the braid) leads to coupling through the braid of opposite sign to that contributed by uncoupled inductance due to the holes. This is illustrated vividly in the oscilloscope traces of Fig. 7 which show Z_T measured on a test sample using time domain measuring techniques (which preserve the phase of the high frequency components making up the injected pulse). The three traces illustrate Z_T on cables successively larger in diameter but with the same braid so that the holes get larger. In Fig. 7(a) the porpoising inductance predominates, in Fig. 7(b) they are balanced and in Fig. 7(c) the uncoupled inductance predominates with the larger holes. An optimized cable is one in which an attempt is made to get balance between the two inductance coupling phenomena. Useful improvement in screening is possible with optimization and significant economy in copper can accompany it.

There are several parameters of a cable braid which will affect its optimization. The diameter of the braid
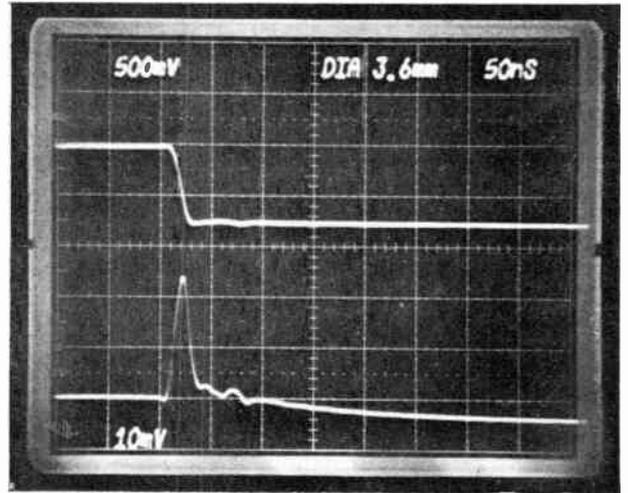
(a) D_1 (diameter over dielectric) = 3·6 mm.
Z_T − ve (overbraided). Spike is opposite polarity to l.f. level.
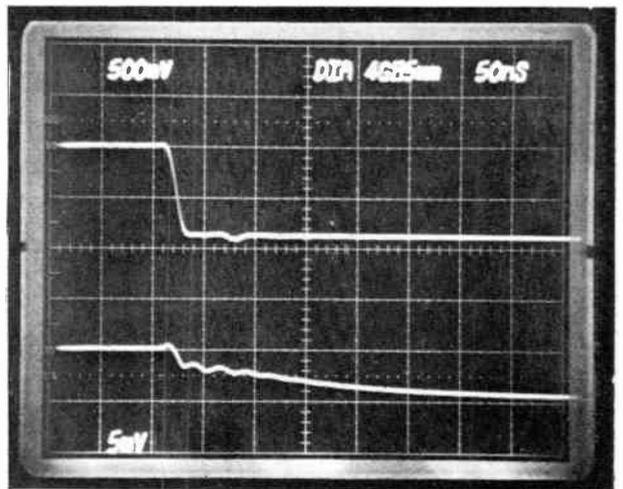
(b) D_1 = 4·85 mm. Cable jacket graphited to minimize Z_F.
Z_T (h.f.) nearly optimized.
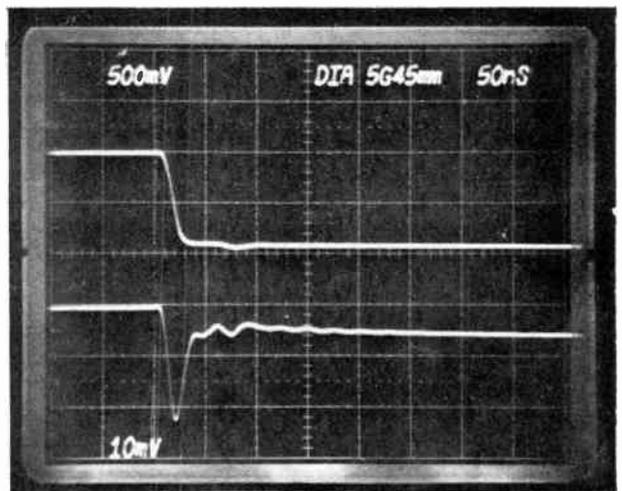
(c) D_1 = 5·45 mm. Cable jacket graphited to minimize Z_F.
Z_T + ve (underbraided). Spike is same polarity as l.f. level.

Fig. 7. Cable braid optimization—deriving sign of Z_T from pulse polarity. Braid parameters kept constant: $d_w = 0.15$ mm, $m = 24$, $n = 4$ and braid angle $\theta = 25$.
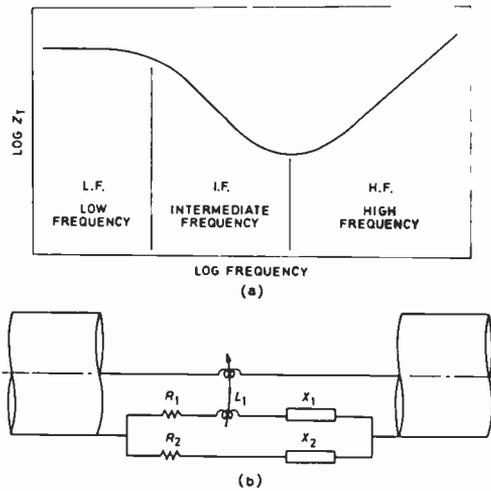
Fig. 8. The transfer impedance of a double braid.
(a) Frequency regions of Z_T
(b) Equivalent circuit.

although an obvious one and used to illustrate optimization in Fig. 7, is unlikely to be available as a variable to the braid designer. Variation can be made in braid wire diameter, number of ends and number of spindles (within the constraints of the braiding machines available). Braid angle has some effect but generally only at larger angles to which there may be objection owing to the difficulty of fitting connectors (especially crimped connectors). Aids to braid optimization[3] are available on an empirical basis but recent work has been aimed at giving this a theoretical background. Tyni[4] has obtained close agreement between measured and calculated Z_T using double helical slots in a conducting tube to simulate the braid uncoupled inductance.

Double braids in contact give greatly improved screening over single braids and the reason for this is readily apparent from a simple equivalent circuit (Fig. 8). Because of its smaller diameter the inner braid is more closely coupled to the inner conductor than the outer braid. While at low frequencies the addition of a second braid will only make a twofold improvement in screening, at high frequencies a thirtyfold improvement is readily obtained from the higher inductance impedance of the inner braid. Braid optimization (to minimize X_1 and X_2 in Fig. 8) is also important but very much more difficult to assess owing to cross-coupling between individual spindles on each braid. An empirical optimization technique has been devised and A and C in Fig. 3 illustrate the improvement.

6 The Magnetic Intersheath

It is evident from study of Fig. 8 that any increase in the value of inner braid inductance L_1 tends to improve screening. Such an increase can be achieved by increasing the space between braids. If this is done with insulating material we have a triaxial cable. Screening with triaxial cables, especially long ones leads to problems which come from intersheath resonance.[5] Briefly the intersheath is itself a transmission line improperly terminated which will resonate violently at certain frequencies. At these frequencies the triaxial cable may be no better than a coaxial cable.

Increased inductance L_1 can also be obtained by winding a tape of magnetic material over the first braid before applying the second braid. It is with cables of this class, using mu-metal as the magnetic material, that we are concerned here.

7 Construction of Superscreened Cables

Mu-metal is a high permeability magnetic material very susceptible to strain when it can lose much of its permeability. If it can be annealed after bending this permeability is regained but after bending onto a cable with polymer dielectric this re-annealing is not possible. In early cables the flexing of the mu-metal tape was minimized by winding with a gap between turns. While effective in maintaining high permeability the gap itself prevents the full potentiality of the tape being realized. Attempts to wind with successive turns butting is even worse as the mu-metal tape edge is damaged when the cable is later flexed.

It was found possible to wind the tape with an overlap between successive turns but very variable results were obtained due to the stretch applied to the tape varying markedly. Relative permeability as low as 200 was obtained on some samples with the braid pattern showing through the tape after winding. To improve the screening two mu-metal tapes were therefore sandwiched between three braids.

Many sensitive circuits were cabled using these superscreened cables but in some instances screening performance was found to be worse than expected. Investigation showed the cable to have degraded and the cause to be flexing of the cable on installation. The closely overlapped mu-metal tape was very sensitive to sharp bends as occur when the cable is pulled over an edge into a conduit. This has been reported in an earlier paper on cable screening[6] and since then a completely new method of tape application has been developed.

If a length of tape is wound, with an overlap but without stretching, onto a mandrel successive turns will be at a radius one tape thickness greater than the one before; thus the tape builds up in a cone. By winding this tape inside a cylindrical die[7] the die applies an upper limit to the tape diameter and each successive turn will press down on the edge of the turn before. The swaging process that goes on in the die compresses the previous turn sufficiently to allow the next turn in. (Fig. 9.) The process results in a lapped metal tube largely independent of the cable braid within, which can therefore have considerable flexibility. On bending, the width of tape parallel to the cable axis takes up the form of a series of chords but being initially at a greater diameter than the
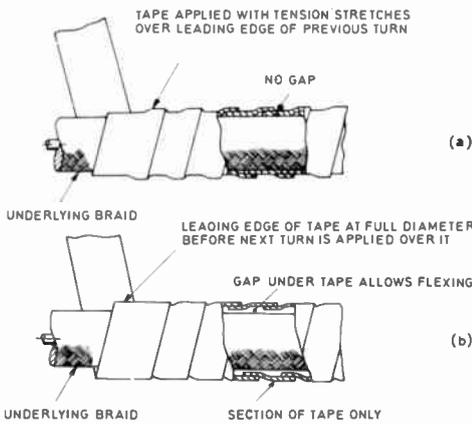
Fig. 9. Tape winding of superscreened cable.
(a) Conventional high tension winding-on of mu-metal tape
(b) Mu-metal tape wound inside a tape die.

braid below is not constrained by it. The relative permeability of mu-metal tape treated in this way has been measured as 2000, a considerable improvement over the stretched tape. The effectiveness of the technique in allowing flexing has been measured and the cable shows little degradation after bending 100 times to 50 mm diameter.[8] The screening improvement that comes from less punishment of the mu-metal is also greatly improved by the braid optimization described earlier. As with double-braided cables the calculated and confirmed optimum single braids do not make optimum superscreened cables. However, an empirical relationship has been established for appropriate braid optimization. Consequent on these improvements two classes of cable are now available. Either the improvement can be used to make a lighter and more flexible cable with good screening (cable C in Fig. 1) or the double sandwich can be maintained and cables of extremely good screening obtained (as cable E of Fig. 1).

8 Performance of Superscreened Cable

The signal handling capability and specification of a superscreened cable is in most cases similar to that of any other r.f. cable on which it may have been based. Apart from screening there are two other features to be mentioned which have come to prominence for reasons not directly connected with tape applications. The most important performance however is screening.

8.1 Screening Calculation and Measurement of Z_T

A device was made to measure the permeability of mu-metal tape after being wound onto a cable and carefully removed. Using this value and deriving a value for the optimized Z_T of each braid it is possible to calculate Z_T against frequency. This has been done for one of our superscreened cables as shown in Fig. 10, A. A calculated response for a non-optimized version is included at D and with low permeability tape at C. Measured results

are shown at B for the actual cable while curve E shows the same screen when a gap is left between successive turns of the mu-metal tape. It is evident that at frequencies up to 1 MHz the performance is completely predictable and that at higher frequencies the screening follows the trend predicted.

A double sandwich construction of three braids and two magnetic tapes is calculated to fall off at 12 dB/octave from the same frequency as the simpler cable. Calculated screening at 30 MHz is very good, over 1000 times better than the single tape construction. It is re-assuring to find that the low frequency measured performance accurately follows that predicted down to a Z_T value of 0.1 $\mu\Omega/m$ and that above 100 kHz it is not possible to detect any interference penetrating the screen. These results are illustrated at F in Fig. 10.

It is from measurements as above, supported to some extent from calculation that the value of Z_T used in specifications has been obtained. All the superscreened cable that industry has been asked to make[9] has Z_T predicted over a wide frequency range and a required level of Z_T at two frequencies.

8.2 Pulse Breakdown (V_B)

Standard cable specifications call for dielectric insulation resistance and partial breakdown tests. In this last a power frequency alternating potential is applied and the onset of small discharges ($> 10^{-12}$ coulombs) is detected. Some cables used in nucleonic instrumentation carry a d.c. (polarizing) potential of up to 3 kV and must not show small discharge pulses in excess of 10^{-13} coulombs or even smaller. With d.c. fields, surface
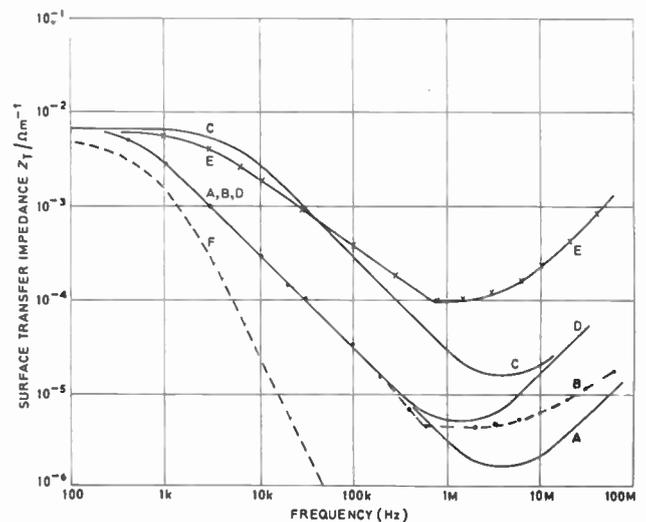

Fig. 10. Superscreened cable—calculated and measured Z_T.
A — Cable MM10/75 as designed
C — With low permeability magnetic tape
D — With non-optimized braids
B ●——● MM10/75 production batch
E ×——× Similar cable gapped magnetic tape
F ●– –● MM06/33 production cable with two magnetic tapes.
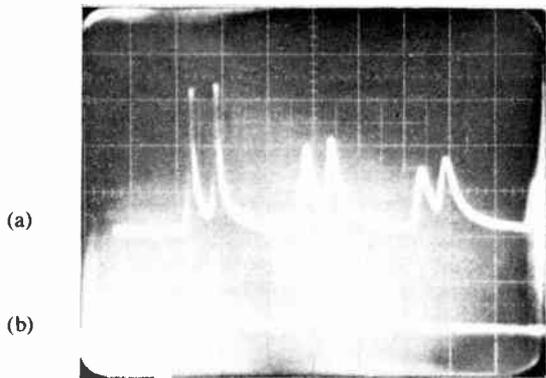
Fig. 11. Fast pulse microphony on a coaxial cable.
A 5 m sample of MM01/50 flexed by hand. Trace on a 100 MHz storage oscilloscope: 40 mV/div, 20 ns/div.
(a) Cable connected directly to oscilloscope
(b) As at (a) with matching termination (50Ω) at oscilloscope input.

leakage and relaxation can give field redistribution in the dielectric so that cables will be found suitable for this duty, when they may have failed an a.c. partial discharge test at 500 V. For this reason the V_B test is included as necessary in all these cable specifications. It is interesting to note that foam dielectric cables are very likely to fail the V_B test.

8.3 Cable Microphony

Microphony in low-level instrumentation cables has been with us for a very long time and there are several techniques employed to minimize it. Recent work has shown that it is not confined to low-frequency disturbance but can generate fast spikes (Fig. 11). Pulses in excess of 100 mV with 1 ns rise-time have been observed when a cable with solid polythene dielectric is flexed.[10]

The fast pulses in microphony do not always occur and it is thought that the batch of cable on which it was first found had been delayed in manufacture. Some tarnish could have built up on the copper braid before the cable was completed and this increased the tribo-electric effect. Micro-discharges occurring at high electric field spots when the cable was flexed could produce the pulses seen. Recent experience suggests that the effect is more prevalent than at first thought, especially in cables with PTFE or a more exotic dielectric.

9 Conclusions

There is no doubt that superscreened cables fulfil a need for flexible signal interconnections which are immune to electrical interference. It seems likely that their exceptional properties will become better known in industries other than nuclear power and they will take their place as standard cables alongside, or replacing, some existing r.f. cables. Meanwhile a group of cables has been developed to meet the immediate needs of nucleonic instrumentation. These screening properties are not confined to coaxial cables and it can be stated that significant progress is being made in the supply and application of multi-core screened cables. It must be emphasized however that few cables are complete without connectors and although coaxial connectors can have adequate screening[11] there is as yet a dearth of multi-pin connectors with anything like adequate screening potential.

10 Acknowledgments

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A case study in achieving electromagnetic compatibility for a man-portable radar equipment

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SUMMARY

Operating a man-portable radar set in a battlefield
forward area or in a civil application presents wide
variations in the frequency distribution of other services
which may affect the equipment or be affected by
it. Analysis of typical operational situations was
undertaken to quantify the problems and develop a
specification. Measurements on development models
are described, together with the solutions adopted to
meet the requirement.

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1 Introduction

Patrols and sentries often need to maintain watch in
conditions where their normal methods of observation
are interrupted by fog, smoke, darkness or noise, and a
man-portable radar system can be used as a very valuable
aid in such circumstances. The electronic environment
in which the patrol may operate can be quite stringent
and require a high performance from the radar in terms
both of radiated emission and susceptibility to inter-
fering signals. This paper describes the methods adopted
to achieve a satisfactory compromise between this
electromagnetic compatibility (e.m.c.) requirement and
equipment performance.

Figure 1 illustrates the radar in use by a patrol. It
comprises a transmitter/receiver, with an integral planar
antenna array, mounted on the operator's chest. For
sentry use the equipment may alternatively be tripod
mounted. Moving targets are detected by listening on
headphones for their Doppler frequency, and are
recognized and identified from the characteristic responses
heard by the operator. Target range is indicated by
direct reading from illuminated scales on the transmitter/
receiver, after adjustment of a range control for maximum
signal strength has been made.

Figures 2(a) and (b) show simplified block diagrams
of the two operational modes of the equipment. In the
Search Mode (Fig. 2(a)) the same J-band Gunn diode
oscillator acts as both transmitter and receiver local
oscillator. Sinusoidal frequency modulation is applied
to this oscillator and the receiver is tuned to the first
sideband of the beatnote spectrum present in the mixer

Fig. 1. The Marconi 'Prowler' Infantry Company Radar in the patrol mode.
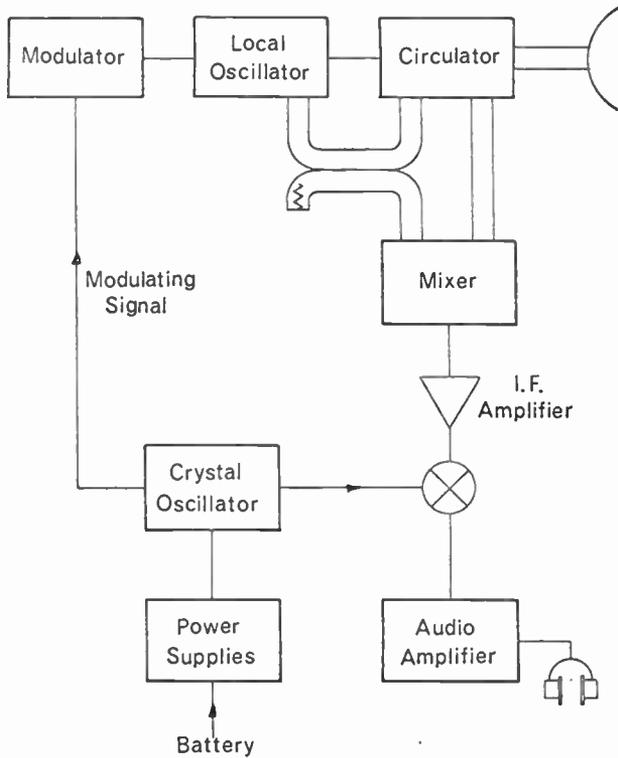
(a) Search Mode.
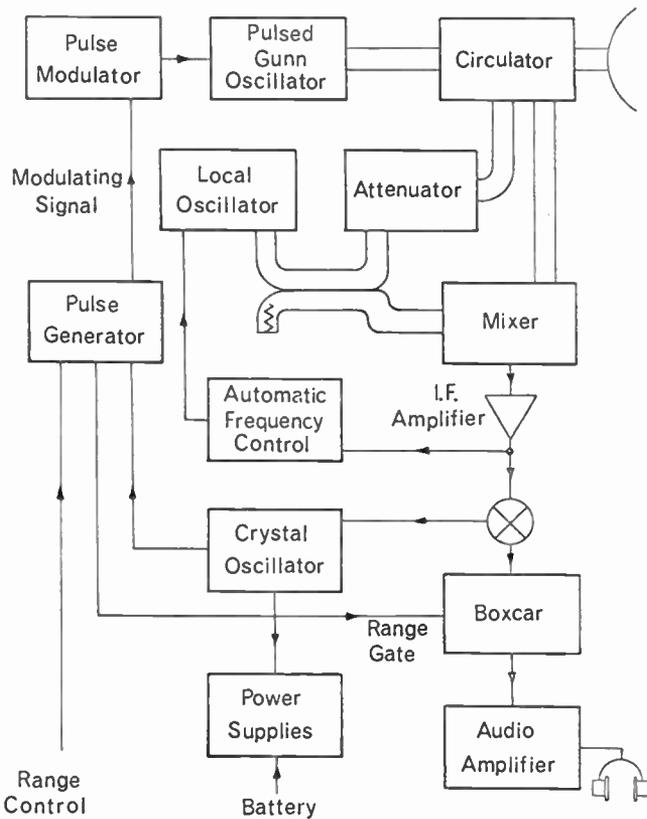
(b) Ranging Mode.

Fig. 2

output. The audio frequency output from a phase detector fed from this sideband signal is amplified and provides the output to the operator's headphones.

In the Ranging Mode (Fig. 2(b)) a conventional pulse-Doppler receiver system is used with a single variable range gate. Coherence of the pulsed Gunn oscillator used for the transmitter is achieved by the use of a phase priming technique. The pulsed receiver output is integrated and amplified before being fed to the operator's headphones. Reference 1 contains a more detailed description of the equipment.

2 Requirement Specification

The simplest definition of the electromagnetic compatibility requirement was given in the equipment design specification as:

'The radar must not suffer from interference from other r.f. and electrical sources likely to be found in the combat team area, nor must it interfere with these itself.'

This requirement implies that the equipment must be compatible with its environment in terms of radiated emissions and susceptibility to other emissions; being battery-operated there is no related 'conducted' requirement. It also implies that two similar radar sets must not interfere with each other when they are sited close together.

National and Military specifications existing at the time of development were of a general nature and it was felt that the limits available from them would not define the requirement adequately in quantitative terms. Accordingly the electromagnetic environment was assessed in terms of the likely proximity of other equipment; the case of a military user near to a patrol vehicle fitted with high-power communications transmitters was felt to be typical. This required operation of the radar in field strengths of 30 V/m over a frequency range 1·5 to 76 MHz and 1 V/m over the ranges 150 kHz to 1·5 MHz and 76 MHz to 1 GHz, and with unwanted emissions below the level at which communications were interfered with.

Problems of mutual interference were assessed by modelling a theoretical equipment deployment and the mechanisms of interference occurring in the two modes of operation. In the latter case it was not found possible to assess quantitatively the operator's ability to recognize targets in interference due to the differing signatures, and it was necessary to assume the signal/interferer level which would preclude operation. Assessing the deployment on this basis showed that the maximum use of the frequency band allocated should be made for radars in the same theatre of operations and the equipment design was based on this philosophy. The effect of variation of pulse repetition frequency (or modulation frequency in the search mode) was studied and it was concluded in this case that the improvement which would result was not worth the additional complexity which would thus be introduced.
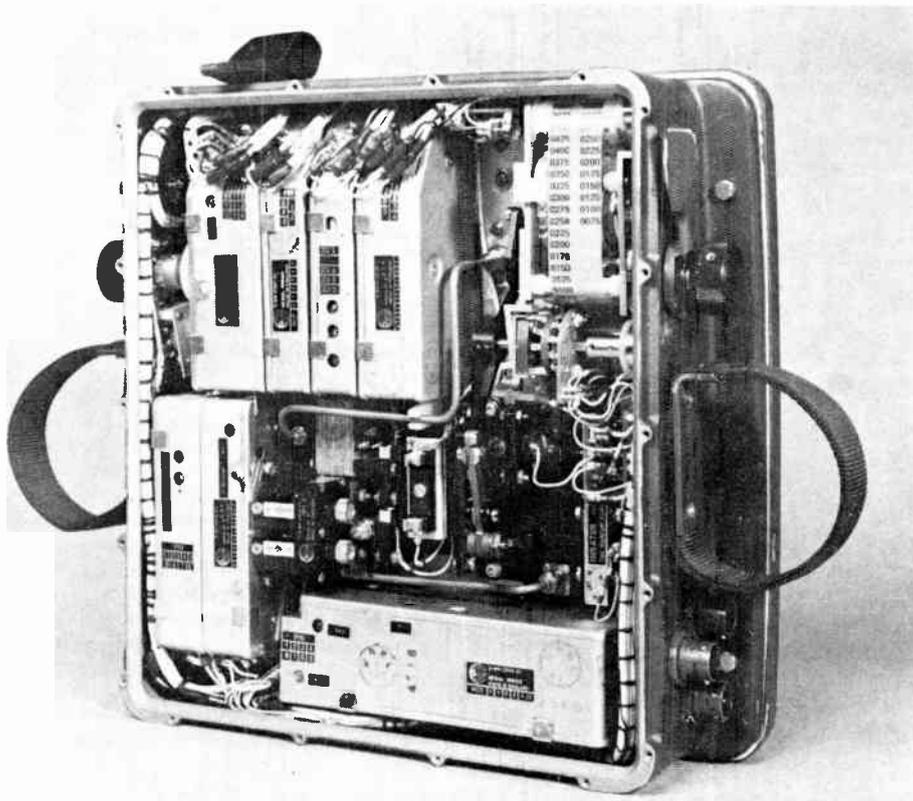
Fig. 3. Internal view of the Infantry Company Radar.

The main e.m.c. requirements influencing the design team may now be summarized as:

(1) operation without malfunction in areas of high r.f. field strength,

(2) minimizing spurious emissions, and

(3) maximum use of the allocated frequency band.

Additionally, damage to the equipment receiver could occur due to interference from other high-power radars in the vicinity. It was thought that the most likely source of interference with the radar would be from communications transmitters operating at around the ranging mode intermediate frequency of 30 MHz.

3 Equipment Development

During the development phase of the radar the e.m.c. requirements outlined were taken fully into account and the design features thought necessary to meet the specification were incorporated. Figure 3 shows the internal construction adopted, with printed circuit boards mounted in individual screened boxes. All earth connections were made by direct contact between the boxes and the outer metal container to minimize problems with induced earth currents and this policy was continued with large area earth connections between printed board and screening can. R.f. filters were added to all external leads at the point of entry into the radar container and, although there was no requirement for protection against conducted interference, these filters provided some protection for abnormal operation with other equipment connected to the same battery supply.

4 Radiated Emission Tests

Early development models were then assessed for overall performance and against the e.m.c. requirements of radiated emissions and susceptance. The electromagnetic emissions from the radar were detected using a broadband conical dipole antenna placed 1 m away and the field strengths produced by the radar were measured over the frequency range 10 kHz to 1 GHz using a sensitive field strength meter. Because of the very low level of these emissions the measurements were made in a heavily screened enclosure to exclude all other sources of interference.

Over the wide frequency range examined only three emissions were detected. Two of these were identified as being produced in the equipment and the third, a broadband emission centred on approximately 8 MHz, was not expected to be generated within the radar. To enable the source of these emissions to be located precisely the rear cover of the equipment was removed and the conical dipole was replaced by a small search coil, which could be moved around inside the equipment. The two narrowband emissions were traced to the two units generating these frequencies, as anticipated, but the broadband

emission at 8 MHz appeared to originate in the inverter used to generate the low-voltage power supplies in the radar. Further investigation with the search coil and a narrowband receiver showed the spectrum of the emission to be pulse-like with discrete spectral lines spaced at the inverter frequency; clearly the inverter was generating frequencies far in excess of those necessary for efficient operation. By reducing the switching speed slightly it was found that the emissions from the inverter could be eliminated without measurable loss of efficiency.

5 Radiated Susceptibility Tests

The susceptance of the radar to electromagnetic fields was then examined over the same frequency range (10 kHz to 1 GHz), using field strengths up to 40 V/m. Ideally, these tests should have been carried out in free space or an anechoic chamber. However, it was not possible to radiate such large fields due to the severe interference with other services which would have resulted, and anechoic chambers were not available. Accordingly, the susceptance was measured in the screened chamber with allowances being made for the field distribution that this introduced.

The required fields were generated by driving the conical wideband dipole from a high-power broadband r.f. amplifier. Various antennas were required to cover the frequency range 25 MHz to 1 GHz but below 25 MHz no efficient broadband dipole antenna was available which was small enough to fit into the screened chamber. However the man portable radar has a maximum dimension of 30 cm, and so could be fitted between the plates of a parallel plate field generator.

With the conical dipole driven at an r.f. input power of 50 W the field distribution around the chamber was measured and, as expected, the field strength varied widely with position in the chamber and with radiated frequency due to multiple reflections from the metal walls. To overcome this problem the susceptance tests were repeated several times with the radar in different orientations and different positions within the chamber. The frequency of the interfering signal was varied over the required band and recorded when signals were heard on the radar. The radar was replaced by a field-strength meter so that the levels of the interfering signals could be measured. Many of these were in excess of the specification requirement and were ignored, leaving several for further investigation. The procedure was repeated with the intefering source unmodulated, amplitude modulated and frequency modulated with an audio tone.

As with the emission tests the search coil was used to locate the sensitive areas within the equipment; however in this case it was driven from a lower-power r.f. source. Two main areas of susceptibility were located: the ranging mode i.f. amplifier at around 30 MHz, its centre frequency, and the high-gain a.f. amplifier, which responded to amplitude-modulated fields at discrete frequencies between 200 MHz and 600 MHz. Further investigation

showed the a.f. amplifier to be very non-linear at these frequencies, so that amplitude-modulated signals were being detected leaving the modulation frequency as a signal in the a.f. path.

Using the search-coil technique the methods of signal injection were determined. Interference was entering both i.f. and a.f. amplifiers by pick-up on interconnecting leads inside the radar head and not by leakage through the screening cans containing the printed boards. Changing the lengths or the positions of these interconnecting leads changed the frequency to which the equipment responded. This explained the narrowband characteristic of the susceptance responses observed. It was also found that the emissions from the radar were mainly from interconnections, especially from those made with unscreened leads.

Clearly a very significant improvement could have been made by making all internal connections with screened leads; to have achieved the full benefit of this measure soldered terminations would have had to be replaced by coaxial connectors. Space limitations precluded this and a compromise was found by screening a few additional leads and adding miniature in-line filters soldered through the walls of the screening cans. A number of leads had been screened in the initial design to ensure internal e.m.c. In some cases it was sufficient to add a series inductor and an r.f. bypass capacitor fitted directly on to the printed circuit board.

The modifications outlined were incorporated in later development models and re-tested in the screened rooms as previously described. The results obtained indicated that the modified equipment met the radiated emission requirement completely and met the susceptance requirement except at discrete frequencies in a narrowband centred on 30 MHz, the ranging mode i.f., where field strengths in excess of 2 V/m caused interference. Since this represented a separation of perhaps 16 m between the radar and a communications transmitter operating on one of the critical frequencies instead of the 1 m originally required, it was felt that the considerable additional work necessary to meet the requirement would not be cost-effective although a solution could certainly have been found.

6 Acknowledgment

7 Reference

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An amplitude-controlled adaptive delta sigma modulator

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SUMMARY

An adaptive delta sigma modulator (ADΣM) is proposed wherein the companding is done in a novel fashion. The output of a simple DΣM is differentiated, and the resulting waveform is filtered in a syllabic filter after d.c. restoration. This yields a control signal that is proportional to the average number of transitions from one to zero and zero to one that occur at the coder output. The signal so obtained is inversely proportional to the input amplitude and can then be used to control the pulse height in the feedback path. At 40 kHz, the s.n.r. is greater than 21 dB over an input range of 30 dB with a peak s.n.r. of 24 dB (the input being a 800 Hz sinusoid). The s.n.r. is almost constant over the message band and improves at a rate of about 8 dB/octave increase in the clock rate.

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1 Introduction

Pulse code modulation (PCM), differential pulse code modulation (DPCM), and adaptive delta modulation (ADM) as analogue to digital converters have all been studied in great depth.[1,2,3] Another form of analogue to digital conversion which has so far not gained much popularity is the delta sigma modulator (DΣM), the reason being the lower signal/noise ratio that a DΣM offers as compared to a DM. However, a DΣM will be useful when the input has a uniform spectrum, since a DM and ADM do not have a uniform s.n.r. in the message band while a DΣM has a uniform s.n.r. over the frequencies of interest. Even with integrated spectra like speech, this may be an asset when operating at moderate bit rates. Adaptive DΣM (ADΣM) coders have been successfully employed for speech by many workers.[4,5]

In this paper an ADΣM is proposed wherein the adaptation of the pulse height is achieved by deriving a control signal that is proportional to the average number of transitions from 1 to 0 and 0 to 1 that occur in the n.r.z. output waveform of the DΣM. At 40 kb/s the coder has a s.n.r. better than 21 dB over a dynamic range of 30 dB. The speech quality has been found to be good and the s.n.r. is more or less constant over the whole message band.

2 The Proposed Coder

The basic principle of a DΣM is understood from Fig. 1. The difference between the input and the digital output is amplified, integrated and quantized into one of two levels using a comparator and a flip-flop. The output will be a sequence of n.r.z. pulses. This leads us to conclude that the output will contain fewer transitions when the input is larger, while the number of transitions increases with a decrease in the input. Finally when the input level is zero, the output comprises alternate ones and zeros resulting in the maximum number of transitions.
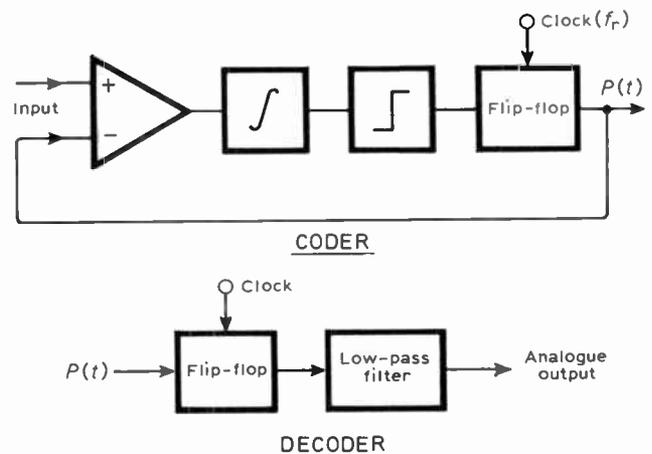

Fig. 1. Block diagram of a delta sigma modulator.

From this we find that as long as the pulse amplitude is controlled, the s.n.r. will remain constant. This will happen till A has reached the level A_1. The peak s.n.r. has been evaluated by Johnson[6] and by Cartmale and Steele[5] as

$$(SNR)_{max} = \frac{9f_r^3}{8\pi^2(3f_1^2 f_c + f_{c2}^3 - f_{c1}^3)} \tag{6}$$

where f_r is the clock rate, f_{c1}, and f_{c2} are the lower and upper frequency limits of the signal bandwidth, f_1 is
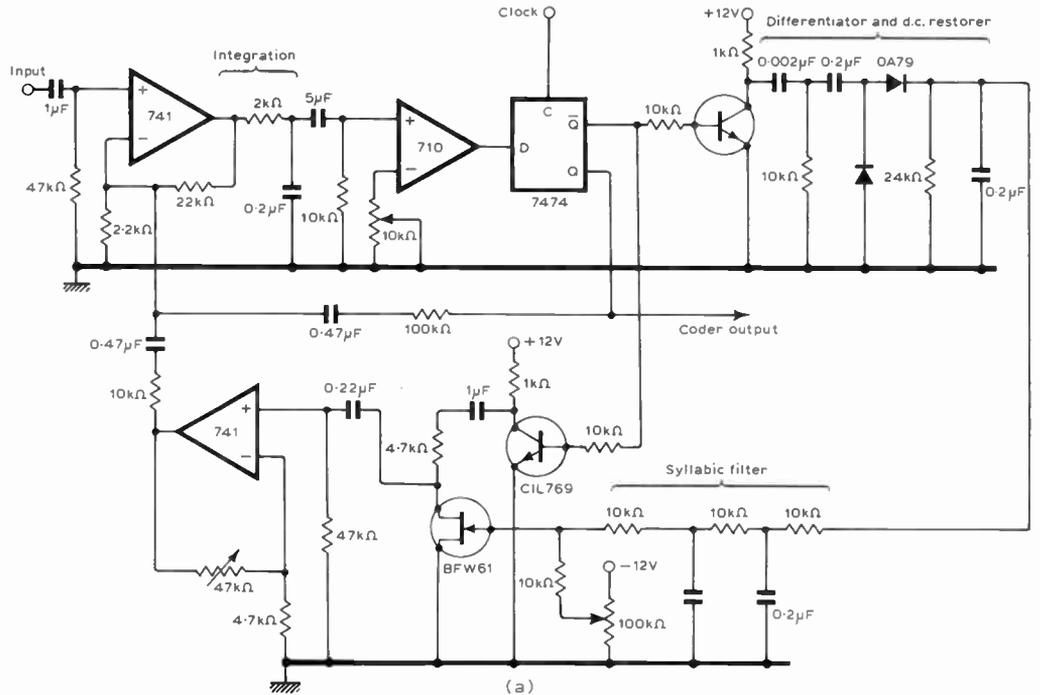
Fig. 5.

(a) Circuit diagram of the companded coder.

(b) Circuit for the decoder.
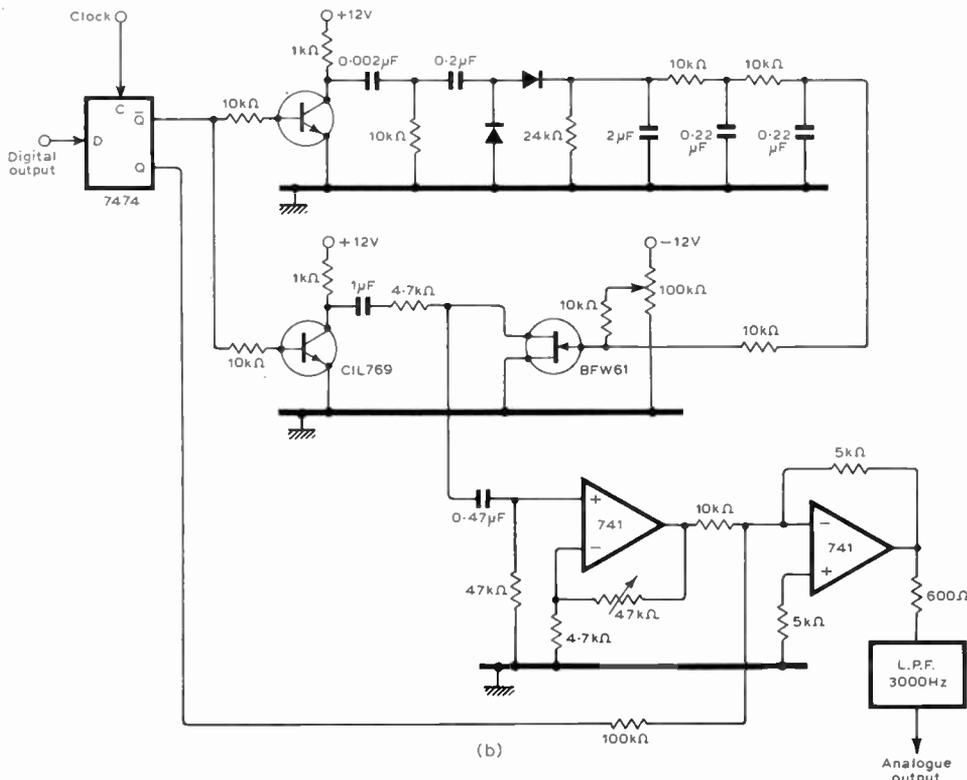
the integrator breakpoint and $f_c = f_{c2} - f_{c1}$. For $f_r = 40$ kHz, $f_1 = 200$ Hz, $f_{c1} = 300$ Hz, $f_{c2} = 3000$ Hz, $(SNR)_{max} = 24 \cdot 0$ dB.

The s.n.r. is expected to remain almost constant at this value until the adaptation of the pulse amplitude ceases and thereafter the s.n.r. will decrease with decrease in the input.

5 Implementation of the Coder and Results

Figure 5(a) shows the circuit diagram of the coder that was implemented and Fig. 5(b) the decoder. The results of the various tests conducted on the system appear in Figs. 6 to 13.

The s.n.r. of the companded and uncompanded systems are compared in Fig. 6. The peak s.n.r. obtained with a 800 Hz input and 40 kHz sampling rate is 24 dB which agrees well with the expected results. The companded system maintains the s.n.r. at better than 21 dB over an input level range of 30 dB. The improvement in the dynamic range over the linear DΣM is of the order expected on the basis of Fig. 4(b), where we expected an improvement of 28 dB in the dynamic range. At 20 kb/s the s.n.r. is about 16 dB over 35 dB input range and this result is comparable to the results reported by Cartmale and Steele.[5] From Fig. 7 the s.n.r. is seen to be constant over the range of input frequencies of interest.

If the decoder output were to be just low-pass-filtered, the resulting output would be a compressed signal and this compression characteristic is shown in Fig. 8. A 25 dB variation in the input results is only a 5 dB change in the output. Below -30 dB the output varies linearly since the pulse amplitude control has been lost.

The variation of s.n.r. with a change in the clock rate is plotted in Fig. 9. From equation (6), we expect the variation to be 9 dB per octave change in the clock rate. For the experimental coder the variation measured is about 8 dB.

The performance of the coder is highlighted further by the waveforms of Figs. 10, 11, 12, 13 and 14. The system reproduces the input faithfully as seen from Fig. 10. The variation of the control signal with the input speech envelope in Fig. 11 confirms the contention that the variation is inversely proportional to the input amplitude. Figure 12 shows the digital output and the differentiated waveform after its d.c. value has been restored. Finally the waveforms in Fig. 13 show the excellent reproduction of the envelope, while Fig. 14 shows the input envelope and the envelope of the pulse output of the f.e.t. divider.

No rigorous tests have been conducted for quality and intelligibility evaluation as recommended by the IEEE.[7] The speech quality has been found to be good even at 20 kb/s. Further testing is also needed to study the error tolerance of the coder.

6 Conclusions

An ADΣM has been proposed which adapts the pulse height by deriving a control signal that is proportional to the average number of transitions from 1 to 0 and 0 to 1 that occurs in the output. At 40 kb/s the s.n.r. is better than 21 dB with a dynamic range of 30 dB. The rate of increase in the s.n.r. is 8 dB/octave increase in the clock rate. The s.n.r. is constant over the message band,
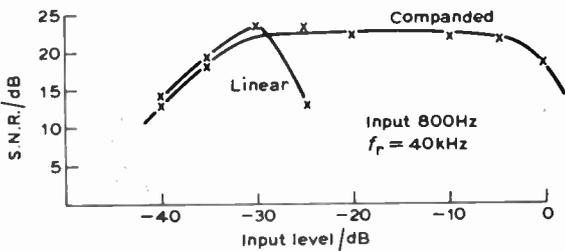

Fig. 6. Signal-to-noise ratio variation with input for a linear and companded coder.
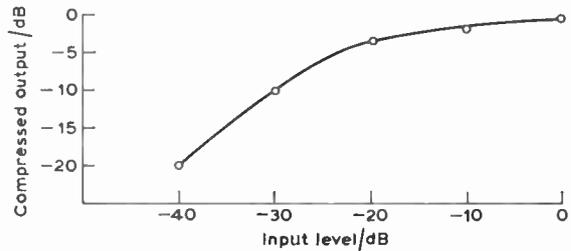
Fig. 8. Compression characteristics of the coder.
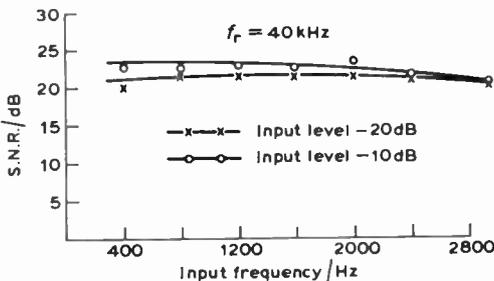
Fig. 7. Signal-to-noise ratio variation with input frequency.
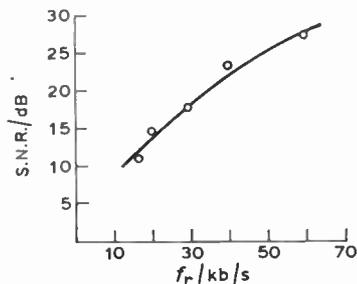
Fig. 9. Variation of s.n.r. with bit rate.
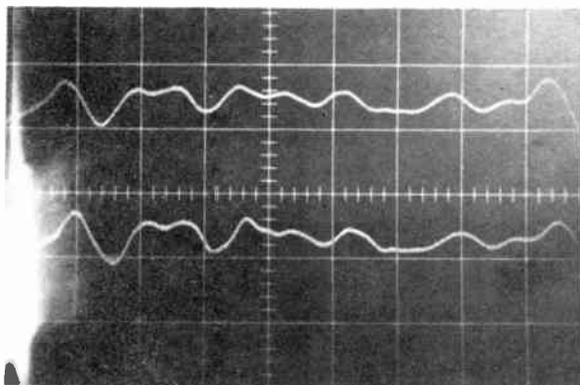
Fig. 10. Upper trace: Input to the coder; Lower trace: Output of the decoder.
Scale = 1 ms/cm; $y_1 = 0.5$ V/cm; $y_2 = 0.5$ V/cm.
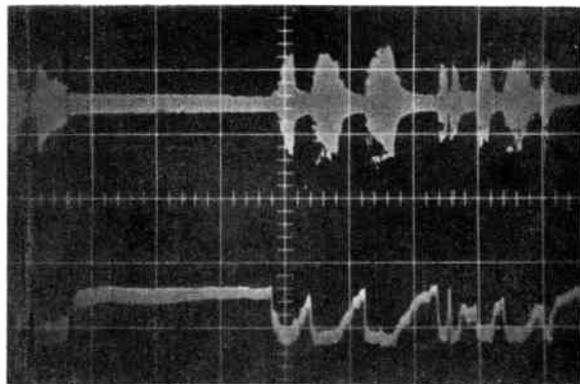
Fig. 11. Upper trace: Envelope of input signal; Lower trace: Control signal output.
Scale = 0.5 s cm; $y_1 = 1$ V cm; $y_2 = 2$ V/cm.
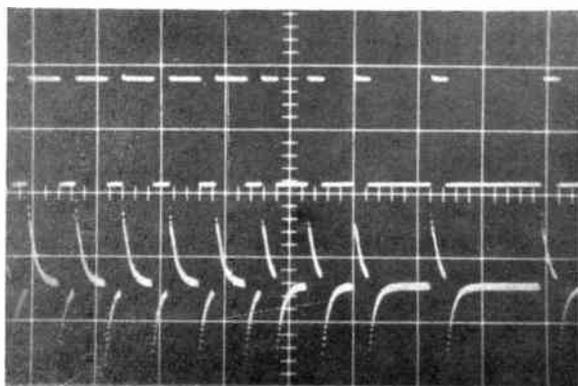
Fig. 12. Upper trace: Digital output; Lower trace: Differentiated signal.
Scale = 0.1 ms/cm; $y_1 = 2$ V/cm; $y_2 = 1$ V/cm.
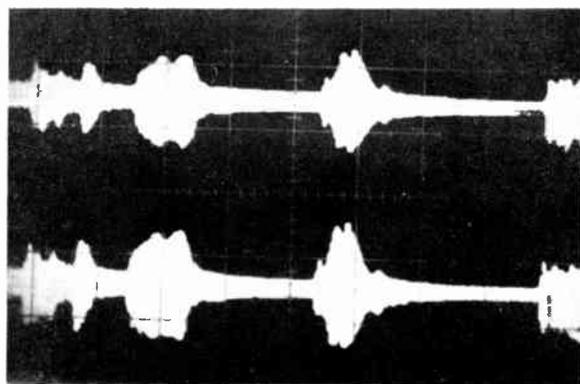
Fig. 13. Upper trace: Input envelope; Lower trace: Envelope of the decoder output.
Scale = 0 2 s cm; $y_1 = 0.5$ V/cm; $y_2 = 0.5$ V/cm.

and good quality speech is obtained. Another potential area of use for the coder is that of data acquisition systems for which DΣ systems are being used.[8]

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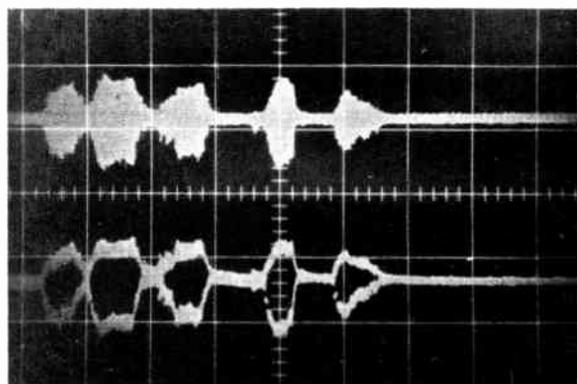

Fig. 14. Upper trace: Input envelope; Lower trace: Envelope of the pulse output of the f.e.t.
Scale = 0.5 s/cm; $y_1 = 1$ V/cm; $y_2 = 0.5$ V/cm.

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