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**ENGINEERING
ADVISORY COMMITTEE
SIXTH REPORT**

BRITISH BROADCASTING CORPORATION

APRIL 1968

ENGINEERING ADVISORY COMMITTEE

SIXTH REPORT

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SIXTH REPORT OF THE
ENGINEERING ADVISORY COMMITTEE
TO THE CHAIRMAN OF THE BOARD OF GOVERNORS OF THE BBC

We were appointed in May 1948 with the following terms of reference:
"To advise on the BBC's scientific research and its correlation with
external activities in the same field."

Our Fifth Report was submitted to the Corporation in December 1964.
The following changes in membership of the Committee have occurred
since that date:-

Sir Edward Appleton died on the 21st April 1965.

Professor J. Brown was appointed to the Committee in August 1965.

Professor A. L. Cullen was appointed to the Committee in August 1965.

INTRODUCTION

When our fifth Report was issued in December, 1964, BBC-2 had only just started, and BBC-1 continued to be originated and radiated on 405 lines. The bases of colour television were still under investigation. Various methods of changing over the television services in the United Kingdom from the two standards of 405 and 625 lines to a uniform 625-line service were under discussion and examination. Important developments for radio broadcasting, including stereophony for the home services, were also under consideration for both domestic and external coverage. On most of the important factors no decision had then been taken or appeared at that time likely to be reached at an early date. In the intervening years, however, basic decisions have been taken, both domestically and internationally, on important technical developments affecting all the services.

These decisions will influence over many years the rate of development and the kind of work to be carried on in the Engineering Division of the BBC. In these circumstances, therefore, we think it is desirable to issue a further report.

We shall record the basic work that has been completed leading to the decisions which have now been taken; we shall refer to the increased facilities and services which have been and are being made available; we shall refer to the economies in staff and equipment that have resulted from design and development work; and we shall outline the kind of equipment that has been developed in the last few years.

We shall deal also with those factors both internal and external which will influence the course of work in the Engineering Division over the next few years.

We shall then give our interpretation of what effect we think this will have on research, design and staff recruitment and training within the Engineering Directorate.

PART 1 SYSTEMS : DEVELOPMENTS

1.1 Position at December 1964

When our last report was published in December 1964, the B.B.C. was providing the following services:-

1.1.a Television

BBC-1

A nation-wide service was being provided from 23 main stations and 29 relay stations radiating the BBC-1 programme and giving a service to approximately 99% of the population.

BBC-2

The BBC-2 programme was being radiated on 625-line from transmitters at Crystal Palace and Sutton Coldfield, giving a coverage of 23% of the population.

1.1.b Radio Broadcasting

Medium and Low Frequency Services

The BBC was radiating three programmes - Home, Light and Third - from 43 medium frequency (mf) transmitters and one low frequency (lf) transmitter, which gave near national coverage, except for the Third for which the coverage was 69% of the population.

VHF

A chain of very high frequency (vhf) stations had been constructed and was radiating three programmes - Home, Light and Third - from 39 transmitters, giving a coverage of 99% of the population.

1.1.c External Services

A total of 40 high frequency (hf) transmitters was in service in the United Kingdom and provided 626 transmission hours of programmes, which were radiated to overseas countries.

1.2 Present Position

Since our last report was published there has been a considerable expansion of the services provided and we would like to express our appreciation of the help and co-operation that has been received from Industry, which has assisted in making the expansion possible.

The following main developments have taken place:-

1.2.a Television

Expansion of BBC-1

Relay Stations

The BBC has continued to expand its BBC-1 service and 30 new stations, sometimes combined with very high frequency/frequency modulated (vhf/fm) relay stations, have been built. The new stations have provided a service or an improved service to about 730,000 people, making the total coverage of BBC-1 some 99.5% of the population of the United Kingdom.

The expansion of coverage, in terms of cost per head of population, has been expensive. This, in most cases, arises because the additional areas covered have been sparsely populated. The capital cost of the transmitter installation for providing a television service to a densely populated area works out at a very few shillings per head of the population served. Because of the nearness of such transmitters to programme originating points and the fact that the running costs are shared over a service to so many people, the annual cost of these per head is very low. The costs rise very considerably, however, when providing transmitter facilities to the outlying areas, particularly mountainous areas such as North-West Scotland and Wales or island areas such as the Orkneys and Shetlands. The transmitters in general serve only a very small number of people, while the remoteness from the programme source means that special programme links have to be provided that can be as expensive as the transmitter. The result is that the overall cost of providing the facilities can come to some tens of pounds per head of population served. Television in the more remote areas is, therefore, very expensive and can cost more than any possible licence revenue.

BBC-2

Fourteen additional main and twelve additional relay stations have been constructed, giving a coverage of about 70% of the population. In addition, production facilities have been provided including two large production studios in London, studios for presentation and News, additional Outside Broadcast units, and video tape recording (VTR) machines, recording channels and film cameras.

Colour Television Service

A colour television service, using the Phase Alternation by Line (PAL) system, was started on 1st July 1967. The service, which is radiated on the BBC-2 network, is now (April 1968) being transmitted by sixteen

main and twelve relay stations. The programme origination facilities provided include two large studios, a News studio, a presentation studio, three 4-camera mobile control rooms and an adequate number of colour tele-cine and VTR equipments.

About thirty hours of programme per week are being transmitted in colour and facilities are being provided so that all BBC television programmes will eventually be radiated in colour. Plans have been made and work is in hand to expand the output in colour to about 65 hours per week by the end of 1969.

Duplication of BBC-1 in UHF

It is intended to build a network of ultra high frequency (uhf) transmitters which will radiate the existing BBC-1 programme using the 625-line standard. The transmitters will be installed in the existing BBC-2 uhf buildings and will utilise the same aerial systems. The first five stations are expected to come into service towards the end of 1969/beginning of 1970. The existing vhf 405-line service will be maintained in parallel for many years until Band 1 and Band 3 receivers become obsolete, after which it will be closed down. The channels in Bands 1 and 3 will then be available for re-engineering for 625-line working for further programme requirements.

1.2.b Radio Broadcasting

Expansion of VHF/FM Relay Stations

The BBC has continued to improve the coverage provided by vhf/fm stations and a total of 28 new relay stations has been built since our last report was issued, making a total of 45 out of a total of 56 relay stations so far approved. The new stations provide a service, or an improved service, to about 1,200,000 people, making the total coverage some 99% of the population.

Popular Music Programme

The Popular Music Programme was introduced on 247 metres on the 30th September 1967. It is being transmitted from stations which were previously used to supplement the Light Programme (Radio 2). To improve reception in areas where stations on 247 metres were formerly not well received, it has been necessary to modify and bring into service three reserve transmitters at existing BBC stations and to install new transmitters at three other BBC stations. Further improvements to the service are under consideration.

Local Radio

To permit an experiment to be carried out in local broadcasting in accordance with the Government White Paper (CMND 3169 (1966)) eight vhf/fm stations are in service or under construction. Each station consists of a transmitter, a main studio, which may be used independently or together with an operations room, and an educational studio. Supporting facilities include a radio car, which, as well as being equipped for recording programmes, is capable of transmitting programmes to and receiving instructions from base.

Stereophony

The BBC has adopted the pilot tone system, which is one of the two systems recommended by the International Radio Consultative Committee (CCIR). The music programme and Radio 3 started broadcasting stereophonically in July 1966 from a suitably modified transmitter at Wrotham, and the relay stations at Swingate and Brighton. It is intended to extend the service to the Midlands and to part of the North of England in Summer 1968, when the BBC has installed the necessary radio links to carry the programmes to stations in these areas. Further extension of the services awaits the availability of funds.

1.2.c External Services

Work has continued on the replacement of transmitters by equipment of higher power and aerials and feeders at External Services stations. Phase 2 of the work is now in hand and two more 250 kW transmitters, at both Daventry and Rampisham, have been installed making a total of four at each of these stations. The installation of six 250 kW transmitters at Skelton was also approved and work is nearing completion.

Overseas, the BBC Atlantic Relay Station has been built on Ascension Island. As few facilities have been developed on the island, as well as constructing the station, in which are installed four 250 kW high frequency transmitters, it has been necessary to provide power generating plant, plant for water treatment, fuel oil handling and storage facilities, domestic services, and staff recreation facilities. The building work and the provision of the related facilities have been undertaken by the Ministry of Public Buildings and Works, while the BBC has been responsible for the installation of the transmitters and associated equipment and aerial arrays. This station relays programmes from the United Kingdom and serves Africa and South America.

The External Services benefit from the techniques and developments that result from work undertaken for Home Radio Broadcasting but do not contribute financially to such work if it is being undertaken to meet a basic need in the Home Services.

1.3 Staff Requirements

Transmitter Service Productivity

The first unattended stations were low-power mf stations which went into service from 1946 onwards and are still operating successfully. By 1951, the techniques which had been developed permitted an unattended mf high-power station of 150 kW to be commissioned and since that date other automatic mf stations have been put into service. In conjunction with this, development work was put in hand to solve the much more difficult problem of unattended television station operation. The first of these stations for Band 1 television went into service in 1958. Since that date, over 60 automatic and unattended installations for Band 1 television broadcasting have been commissioned. To achieve the same results in the uhf band and to ensure that satisfactory performance could be maintained within the even more stringent conditions of colour television, further work was carried out. The whole of the BBC-2 network was designed with unattended operations in mind. Unattended uhf stations suitable for colour television transmission have been designed up to the highest powers and all future installations which will carry BBC-2 and BBC-1 in colour will be constructed on this basis.

In 1955, the BBC operated 134 transmitters using a total of 994 staff at these stations; in 1967, there were 419 transmitters and the number of staff had only increased to 1,062. The gain of this development, giving an increase in output of over three times for a staff increase of less than 7 per cent is quite clear. There is a large saving in operating expenditure and there has also been a saving in the size of the buildings required, as only minimal office and canteen facilities are needed at unattended stations. The nature of the work for the men concerned has become much more rewarding and without these developments it would have been almost impossible to recruit and train sufficient staff to man the BBC transmitter service from the already overstrained technical manpower resources of the country. At the present time, we believe that the BBC leads the broadcasting world developments in unattended transmitter working and in its record of continuing improvement in productivity in this field.

PART 2 RESEARCH AND DEVELOPMENT

2.1 General

This part of the Report refers to the work of the Research and Designs Departments. The principal function of the former is to undertake scientific and engineering investigations on all aspects of sound and television broadcasting, whereas the main function of the latter is the development and design, with a view to manufacturing in quantity, of a significant proportion of apparatus needed by the BBC for its broadcasting services, particularly in those fields where the BBC's requirements cannot readily be met from Industry; for example, where it is necessary for equipment to meet specific BBC requirements in terms of facilities, performance and layout. It is important that equipment developed by either Department must meet not only the required standard of technical performance but also be of the right type to fulfil adequately the operational needs of the Programme Departments. Although the basic functions of the two departments are different, there are important areas of overlap and co-operation and for this reason their work is considered jointly below. Only the major activities of the departments are dealt with: other significant items of research and development are included in an appendix.

Before describing the purpose and performance of a few of the more important developments which have taken place, it may be helpful to refer to the broader principles on which the design of apparatus for broadcasting purposes must be based. The engineering of a broadcasting system is essentially an exercise of an advanced type in the field of communication engineering, in which the electrical signals generated from the original visual and aural information are passed through a large number of processes, some of them very complex, occurring in tandem. Clearly, each individual item of equipment must introduce some impairment of the signal quality, however slight; consequently, it is desirable that the number of individual characteristics which can affect signal quality of each piece of equipment in the chain should be known, so that for a particular item of apparatus the performance requirements can be set down clearly. Moreover, the particular amount of any distortion causing degradation in the quality of the signal at the end of the most complex broadcasting chain needs to be defined if individual amounts of this distortion are to be allocated to the many separate pieces of apparatus. This situation is made even more complicated by the necessity to allow for the inevitably rather large distortion which must be permitted for the viewer's or listener's receiver, for the obvious reason that these receivers, existing as they do in millions and representing an investment many times that of the broadcasting systems, must be designed as economically as possible.

An exact scientific solution to the problem of allocating permissible amounts of distortion to each item of equipment is not yet in sight, either here or anywhere else, with the inevitable result that designers of professional equipment are, in most cases, striving to obtain the best possible performance within the limits of economic commonsense, and are therefore working at the boundaries of present day techniques. This has been particularly the case during the last four years, during which much of the effort on television has been devoted to the design of apparatus to handle, in one way or another, a colour signal.

In all fields of science and engineering in which advances are being made, progress is dependent upon the ability to make measurements which are significant and accurate. Accordingly, in the work to be described below and in Appendix A, it will emerge that considerable effort is being put into the devising of the necessary means of measurement and the development of the apparatus with which to make the measurements. Of course, too, such measuring apparatus is needed in quantity throughout the broadcasting system, to check the level of performance of the apparatus and to bring assurance that the quality of the signals broadcast from the BBC's transmitters is at the desired level.

We describe below a few of the major research and design projects which have contributed to the achievement of the developments described in Part 1.

2.2 UHF Planning

The opening of the BBC-2 service on 625-lines in the uhf bands in 1964 and the fact that the bands were going to be used for a compatible colour service involved much planning, which will continue until the great majority of the population of the United Kingdom is served with uhf 625-line colour programmes. The technical standards for the 625-line signal had been discussed for many years and had already been agreed, as had those standards of the colour signal that were independent of which of the three competing colour systems (see section 2.3) would be adopted. Although uhf stations generally have an effective service radius of not much more than 50 km, they can, depending on weather conditions, propagate much farther than this and the allocation of channels to a nation is thus an international problem. A basic plan for the European broadcasting areas was agreed in outline form at the 1961 European vhf/uhf Broadcasting Conference in Stockholm. It is on this plan that the United Kingdom uhf service is based. In Appendix A, the main aspects affecting the planning of the uhf service are discussed.

2.3 Colour Television - Choice of a system and preparation for its adoption

Work on colour television occurred in two distinct phases, the first covering the investigation of the performance of the three colour television systems which, by 1964, were competing for standardization in the European broadcasting area for 625-line television, and the second, the development and design of apparatus for the chosen system in time to allow its manufacture and installation on the extensive BBC-2 network for the opening of the colour service in July 1967. The systems were:

- (i) the National Television Systems Committee (NTSC) system, at that time favoured by a majority of engineers in the United Kingdom and already in full public exploitation in the U.S.A.
- (ii) the SECAM system (from the French "Séquentiel Couleur à Mémoire"), which was still going through many quite serious modifications.
- (iii) the Phase Alternation by Line (PAL) system, which was well established from the theoretical aspect but went through some modifications with regard to the method of colour synchronization.

BBC Research and Designs Departments made a considerable contribution to the work of comparing the three systems, work which was shared by France, West Germany, Italy, Holland and Switzerland. The appraisal of the systems was very time-consuming and, since 1964, 17 Research Department reports have been issued on this question alone. The performances of the systems had to be investigated in detail in the laboratory and in field trials.

The number of parameters which have to be examined in respect of the performance of any one colour system, with a view to its use for practical broadcasting, is formidable. The work involves not only investigation of the inherent quality of the colour and compatible black/white pictures and the ability of the system to withstand the inevitable distortion encountered in transmission, but also its performance in the field after broadcasting, the possibilities of magnetic recording and other factors affecting performance right back to the colour camera used in the studio. All this included the design and a good deal of construction of a wide range of equipment with which to make the tests, observations and measurements. Although much of this equipment had an ephemeral existence, partly due to frequent changes in the parameters of many of the systems,

design requirements could not be reduced, since a weakness in the instrumentation would have defeated the objective of assessing the performance of the system per se.

Many large scale demonstrations were mounted for the European Broadcasting Union (EBU), the International Radio Consultative Committee (CCIR), the Postmaster-General, Members of Parliament, the British Radio Equipment Manufacturers Association (BREMA), etc. In the winter of 1964/65, BBC engineers visited the Soviet Union on two occasions, taking with them a large quantity of colour equipment, some of it specially designed for the purpose, with which to make comparisons between the performance of the various colour systems over the very long transmission circuits between London, Paris and Moscow and within the Soviet Union itself. The knowledge of the behaviour of the systems during long distance transmission so obtained was of considerable value in the eventual choice of the colour system for use in the U.K. After the conditional decision, in March 1966, to adopt the PAL system for use in the U.K., confirmed after the Oslo Conference in the same summer, the Designs Department's efforts in colour television were concentrated on the design of the necessary apparatus to enable the Colour Service to start on an appreciable scale in July 1967, and to open officially on a full-scale in December 1967. The experience gained during the investigation period previously described was of great value in approaching this task with a system not yet used for the practical business of day-to-day broadcasting. The work covered the design of equipment for use from the point at which the colour signals emerge from the source prior to coding to the delivery of the signals in good shape to the broadcasting transmitters in all parts of the U.K. Many different items of equipment have been designed, subsequently manufactured and installed. To the best of our knowledge, the quality of the colour pictures received from the transmitters, including those most remote from London, is, for all practical purposes, indistinguishable from that at the source.

Some of the projects discussed separately in this part of our report are also relevant to colour television but are of sufficient importance to justify consideration in their own right. Other significant colour developments are included in Appendix A.

2.4 Television Standards Conversion

In Part 1, we have referred to the introduction of broadcasting on the 625-line standard and the plans laid for the broadcasting of all existing programmes on this standard by the duplication of the existing BBC-1 and Independent Television Authority (ITA) programmes on 625 lines, while continuing radiation simultaneously on the present 405-line standard. Some years ago, it was clear that a change would have to be made from the then existing 405-line standard to the

625-line standard used in most other European countries and elsewhere in the world. It was also clear, however, that whatever the detailed plans adopted, there would inevitably be a long period during which the simultaneous radiation of the same programme would be necessary on the two scanning standards. Work was therefore begun on the development of a converter capable of high quality, reliable and unattended working, based on an original idea from which a continuous series of developments has flowed. The result was the achievement of a laboratory prototype of the solid-state "line-store" converter, capable of converting between 625 and 405-line standards in both directions. A number of converters of this type have been installed and they are in continuous use both in the BBC and other broadcasting organisations and a large-scale use is about to occur for the forthcoming duplication of BBC-1 and ITA programmes.

The performance of these converters is such that the quality of the picture offered on 405 lines is not significantly worse than that which would have been obtained by direct generation on this standard. But for their existence, the adoption of the duplication programme, with all it means to the future of British television, could hardly have been contemplated.

An outstanding problem which had not been solved at the time of our last report was that of providing facilities for changing the scanning standards of colour pictures between the American 60-field/525-line system and the European 50-field/625 line system. At that time, a means existed of converting between these systems for black-and-white pictures by means of the so-called "image" type standards converter which displayed a picture on the incoming standard and regenerated it on the outgoing standard by means of a television camera.

The "image" converter technique is unsuitable for use with colour television pictures; accordingly, an intensive theoretical study was made to find means of providing this facility in a wholly electronic form. Two possible solutions were proposed, one by the Research Department and the other by the Designs Department. They had a number of common features, in particular both proposals required a total delay for storage purposes equivalent to the duration of one field of the television system concerned. Hence the name subsequently given to these converters, "field-store". At the time, it was clear that the Research Department converter would be an extremely complex and sophisticated piece of electronic design, whilst the Designs Department type would be capable of being brought to the stage of a working laboratory model much more quickly. The price paid for the simpler conception of converter lay in the presentation of a picture in a non-standard format together with certain other technical difficulties which, while a nuisance to the broadcasting authorities, would not affect significantly the pictures as seen by the viewers.

It was decided to proceed with both, based on the long-term requirement, on the one hand, for a converter producing an absolutely standard picture, i.e. the Research Department type and, on the other hand, the requirement for standards conversion facilities as quickly as possible, i.e. the Designs Department type. An additional most important reason lay in the fact that, at the time, it was not known whether either would be satisfactory, nor could it be determined in any other way than by constructing a converter that a satisfactory conversion could be obtained using a storage time equivalent to the duration of one field. The chief doubt lay in the portrayal of motion, because systems which inherently have a different number of fields and pictures describe motion in different ways. There were other doubts about such points as the visibility of flicker on edges and overall picture flicker at the low and very visible rate of ten per second, due to the difference between the 50 and 60 field rates of the two television systems. It was important to settle these doubts as quickly as possible in order to reduce to a minimum what might have been wasted engineering effort.

It was decided, therefore, to proceed with both projects in close collaboration. In the event, the Designs converter was sufficiently developed to answer these questions, happily in the positive sense, by the end of 1966, in time to justify the continued development of the more advanced type of converter and also to answer a number of important programme planning questions, not the least those concerned with whether or not colour pictures could be derived by conversion from the American type pictures of the Olympic Games in Mexico in 1968. In the summer of 1967, the laboratory prototype of the Designs Department converter was available for the conversion of colour pictures originating on the American standard. It is in regular use to convert programmes from North American sources, both live and recorded on magnetic tape, for broadcasting in the BBC-2 colour programme. Work continues to develop the instrument to convert in the other direction, from the European to the American standard, whilst manufacture has begun on two further models each of which will be capable of conversion in either direction to provide permanent facilities for the Television Service.

It is interesting to note that the line-store converter is an important part of both types of field-store standards converters. This demonstrates how a continuous flow of developments can arise from the production of a single basic original idea. Further exploitation of this idea has led to a proposal for a single tube colour television camera on which some promising practical work has already been done. The importance of providing the right environment in which ideas of this kind can be generated and subsequently exploited cannot be over-emphasized.

2.5 New Systems of Sound and Television Broadcasting

2.5.a Stereophony

A great deal of work was done by the Research Department on the audio-frequency and radio-frequency aspects of stereophonic broadcasting. Several systems of transmitting stereophony have competed in the international field for world-wide standardisation, the system finally chosen coming from the U.S.A. - the "pilot tone" system. An examination of proposals made by Electric and Musical Industries Limited and by the Swedish Post and Telegraph was also made.

While stereophonic broadcasting in the BBC is as yet on a comparatively restricted scale, much design work has been necessary. The coded stereo signal has many points of similarity with the coded colour television signal. Both signals carry information additional to their respective monophonic and black-and-white forms on a so-called "sub-carrier". The difficulties attendant on the sub-carrier technique have made obsolete much of the monophonic transmission equipment which was designed some years ago. One example is the re-broadcasting receiver referred to in section 2.6 of this part of the Report; others are the modulating equipment for the broadcasting transmitters, pick-ups for the reproduction of stereophonic records and provision of facilities on studio control desks. A stereophonic decoder for monitoring and measuring purposes has also been designed. A different aspect of the work required for stereophony is to be found in the modifications to the complex facilities in Broadcasting House Control Room and associated Continuity Suites. At this point in the broadcasting chain, the stereophonic signal is not coded and therefore is in the form of two separate signals. Providing the necessary two routes through the complicated switching, controlling and monitoring system required painstaking attention to detail to effect a sensible, practical modification. This example draws attention to an aspect of design work which is all too easily overlooked but which enters into every project to a greater or less degree.

2.5.b Compatible single sideband (CSSB) for high frequency, medium frequency and low frequency sound broadcasting

An American proposal for a change from the present-day double sideband amplitude-modulated broadcasting standard to an asymmetric sideband transmission was given world-wide consideration. The advantage claimed was that either radio broadcasting in the hf, mf and lf bands could be done with less adjacent channel interference or more programmes could be fitted into the present bands. Some field trials were carried out by the BBC on the system. Engineers of the Philips Company proposed a slightly different method, claiming to achieve the same results. This proposal was submitted to very searching laboratory tests by Research Department and these were followed by field trials at hf over

the Rampisham to Singapore circuit, which were supplemented by further field trials over a "twilight" path from Rampisham to Ghana. All the tests showed that, while CSSB can give satisfactory reception, the overall advantage it can offer when received compatibly by existing receivers is slight, while more skill is needed in the operation of the receiver.

2.5.c Transformation of Sound and Television Signals into Digital Form : Pulse Code Modulation

The use of transistors, solid state diodes, as well as integrated circuits, has enabled large sections of electronic engineering to depart from the processing and transmitting of analogue type signals and permitted the introduction of digital forms of signal that can be more efficiently matched to the channels through which they have to be transmitted. The signal to be transmitted is sampled at frequent intervals and the magnitude of each sample is expressed in arithmetic form as a binary number. This is then converted into a group of short pulses which are very resistant to noise arising in the transmission circuit. The response time of modern circuit elements is so short that the basic methods of pulse coding can also be applied to the television signal and, because many of the processes which a television signal must undergo can be described in quite precise mathematical terms, the advantages of converting the television signal into an arithmetic form are many.

To enable existing receivers to be used, the signals must be converted back to analogue form before being broadcast. Research Department is now devoting considerable effort to analogue-to-digital conversion and vice versa, and to binary and other methods of pulse code modulation. A first useful application will, it is hoped, be the transmission of the sound signal accompanying the BBC-2 programme in pulse code form within the synchronising pulse period of the BBC-2 625-line television signal. Such a proposition will allow the networking of a composite BBC-2 sound and television signal throughout the United Kingdom with no loss of sound quality.

2.5.d Broadcasting from Satellites

Direct television broadcasting from satellites to the viewer's own home aerial is not yet feasible, as satellite broadcasting transmitters of sufficient power are not at present available. Probably, this difficulty will be overcome as research and development work proceeds. There will remain, however, the problem of the availability of suitable frequency channels. At present, it is possible for a number of countries in Europe to use the same channels in the uhf and vhf bands without mutual interference. The area covered by a satellite broadcasting transmitter would be so extensive as to make this no longer practicable. The requirement for rather high power in the satellite

transmitter depends directly on the type of modulation used for the television broadcast and the use of a pulse code system, whilst requiring a new type of television receiver decoder, would permit a much lower power satellite transmitter.

2.6 Transmission

The majority of long-distance transmission circuits are rented from the Post Office with whom close technical collaboration is maintained in specifying performance and in the adoption of common methods of measurements so that both sides "speak the same language" for both picture and sound transmission. However, the technique of receiving a broadcast signal to provide the programme for transmitters which would otherwise need a point-to-point link is employed as much as possible to avoid the expense of such links. This technique may be used for two such "pick-up" links in series so that the performance required of the receivers is high; moreover, the receivers are usually installed at unattended sites and must therefore be highly reliable and maintain a consistent performance. Receivers of this kind have been developed for both television and sound reception including stereophony on the vhf service. Particularly for colour television, it has been necessary to use solid-state devices to the limit of their performance by meticulous circuit design to provide the necessary standard of performance without introducing difficult manufacturing techniques and undesirable adjustment after manufacture of each individual receiver. In a modified form, the television re-broadcasting receiver is used as a monitoring device to provide a signal for the measurement of the performance of the broadcasting transmitter.

With a studio complex, such as the Television Centre, coaxial cable circuits are used in some hundreds and the same type of circuit is used between BBC premises up to about five miles apart. All but the very shortest, a few feet in length, must be carefully corrected to provide nearly distortionless transmission, particularly since many such circuits may occur in tandem in a broadcasting chain. A technique for providing correctors for permanent circuits has been developed, whilst adjustable correctors have been designed for the correction of circuits used for outside broadcasting including a version for use with the permanent coaxial cable network which is available from many points in Central London.

2.7 Measurement and Monitoring Techniques

In this part of the report, we describe the measurement techniques and other techniques closely allied to measurement, without which none of the work previously described could have been possible. From its earliest days the BBC has been a pioneer in the development of measuring and testing methods to sustain the quality of the signal as broadcast from its transmitters.

With the advent of colour television, which is affected by more types of distortion than its black and white counterpart, measurement techniques have been extended and have employed novel methods, leading to proposals for automatic monitoring and automatic correction. For many years the technique of television measurement for the majority of equipment and the whole of the transmission network has been based on the use of electrical signals on which objective measurements can be made. These measurements are related to the subjective impairment of television images due to the presence of the known types and amounts of distortion. By inserting these measurement signals in a part of the waveform not used for picture information, a means of making measurements at any desired time during the transmission of pictures can be provided although, because the test signals are present for only a small percentage of the total period of the waveform, the accuracy is necessarily less than that obtained when measurement signals completely replace the transmission of pictures at times when this is possible. Since the inserted test signals may be arranged to be always present in the waveform, continuous automatic methods of monitoring the picture quality have been developed.

A considerable effort has been expended in determining the most appropriate waveform of test signals to provide all the information thought to be necessary for assessing the quality of colour pictures. The provision of measuring equipment has allowed daily measurements to be made of the whole distribution system of the BBC-2 programme as it has become suitable for colour transmission. This has had a number of important consequences; it has disclosed any weaknesses in the system due to inherent poor design or maintenance, most of which have been readily reduced in significance; it has enabled an assurance to be obtained that the quality of the colour picture put out by all transmitters in the U.K. is satisfactory; and it is providing a body of data on the behaviour of the whole system which it is hoped will enable more realistic specifications of the performance of individual items of equipment to be drawn up. The latter is important economically if a specification is too stringent; and on the other hand, important from the point of view of picture quality if not stringent enough. It has also enabled a start to be made in the allocation of working limits of distortion to each point in the chain.

Automatic monitoring for both picture and sound transmission has been applied on an increasing scale in a variety of ways. This technique is of importance by reason of the large savings of staff which can be achieved. An even more useful technique is beginning to emerge from the work on measurements in the application of automatic correction of transmission impairments. The continuous availability of the "insertion" measurement-type signal enables information to be obtained at any point in the network on the nature and amount of any impairments which have occurred on the accompanying picture signal.

The information can be made available in the form of an error signal, which in turn may be used to operate automatic correction with a subsequent reduction in the degree of the impairment. This automatic correction technique can be applied for the varied types of impairment to the signal as it leaves the broadcasting transmitter so that the behaviour of the whole distribution network is taken into account. The amount of correction which can be applied is limited, however, since it would be unwise to apply so much that a serious fault condition which could lead to breakdown of the service, could be obscured. Nevertheless, it is a simple matter to give an alarm when a prescribed maximum degree of correction is being approached. It is clear that, if the present experiments are successful, this technique is a powerful tool for the further expansion of automatic working and consequently of staff saving.

2.8 Miscellaneous Items

2.8.a Vertical Aperture Correction

Provided the level of random noise generated in a source of television pictures is low enough, it is not difficult to improve the sharpness of the image displayed on the viewer's receiver by the use of circuits that accentuate the higher frequency components of the picture signal. This is termed "horizontal aperture correction" and has been used for many years. Until recently, however, the sharpening of the displayed image in the vertical direction, that is to say the sharpening of the edges of horizontal bars in the picture, known as "vertical aperture correction", has not been applied. Although a means of achieving vertical aperture correction was published many years ago in an American journal, Research Department has pioneered the development of such methods. Vertical aperture correctors have now been incorporated in colour television cameras by the manufacturers.

2.8.b Loudspeakers

The BBC's requirement for loudspeakers for monitoring purposes is stringent and the manufacture of loudspeakers using the standard cones made from jute and esparto grass results in variations in the finished product that are undesirable. Research Department has developed a quick and simple method of making loudspeaker cones of uniform performance from a plastic material, and such cones have been included in a new design of loudspeaker developed by the Department. This loudspeaker went through searching field trials and has met with very general approval.

2.8.c Sound Programme Level Control

Compondors compress the range of signal magnitude at the transmitting end of the chain and expand it at the receiving end. Such devices are used in certain networks for reducing the effect of noise in a transmission circuit. Research Department has studied various commercial compandors with a view to their possible use in the sound network in order to render useful certain Post Office circuits having an intrinsic signal-to-noise ratio that is scarcely adequate for high-quality broadcasting. In studying these problems, a new type of limiter has been developed which can be used to permit small speech studios to be operated in an unattended mode, thus allowing a considerable saving in staff. Work is now proceeding to apply the principles of compansion to signals that are in digital form and, to date, very encouraging results have been obtained in the laboratory using a novel method.

2.8.d Studio Acoustics

With the building of new studios and the introduction of new building materials, measurements of sound insulation of partitions and walls, and of the performance of sound absorbers made of sandwiches of various suitable materials must continue. Acoustic surveys of studios, that is to say, the excitation of a new studio by specially chosen audio test signals and the measurement of the consequent response, are now made by automated methods, obviating the necessity for research workers to visit studios in widely separated areas of the U.K. The measurement results are recorded on magnetic tape, which Research Department transcribe in digital form on to paper tape which is then fed into a computer. The computer programme is arranged so that reverberation times are automatically calculated.

2.8.e Transmitting Stations in Bands I (TV), II (FM VHF Radio) and III (TV)

The planning of service areas and transmitter siting, as well as the specification of transmitting aerials for uhf television are described in Appendix A, sections 2.2 and 2.3, but the same jobs, on a diminishing scale, continue in the vhf bands. The work is of a less exacting nature than it is for uhf and the number of relay stations in these bands is approaching the maximum that it is possible to accommodate.

2.8.f Propagation and Transmitting Aerials for the HF, MF
and LF Bands

The External Services of the BBC use transmissions in the hf and mf bands and the advice of Research Department on the siting of overseas stations is sought from time to time.

This sometimes requires quite lengthy studies of a mathematical nature in order that the advice shall be based on sound knowledge, both theoretical and practical, of the behaviour of the ionosphere and of the ground conditions at the transmitting site. The overcrowding conditions in the mf and lf broadcasting bands exert pressure on the BBC to arrange its amplitude-modulated radio broadcasting so as to maintain a service which is as attractive as possible to the listener. New permutations of the present transmitters, aerials and frequencies that are allocated to the BBC are continually being put forward and reviewed.

2.8.g Re-engineering Television Transmission from 405 lines to
625 lines

When the Government, advised by the Television Advisory Committee, decided to introduce the 625-line standard into the U.K. it stated that the ultimate objective was the attainment of a single 625-line standard and that the present 405-line service should be changed to 625-line standards when this became possible. At the time this advice to the Government was given, it was thought that it would be possible to duplicate the present 405-line BBC-1 and ITA programmes in the uhf bands on 625 lines. Subsequently, fears were expressed that uhf propagation was so inferior to vhf propagation that, in some areas, the time when all viewers could receive BBC-1 and ITA on 625 lines in uhf would never arrive. Many proposals for effecting the change from 405 to 625 lines partly, mainly or wholly, in vhf bands were put forward to the Technical Sub-Committee of the T.A.C. One Research Department contribution to these studies went as far as inventing, investigating, laboratory testing and proposing a method of transmitting the television sound signal in the line blanking intervals of the picture signal. The method of modulation was known as "pulse position modulation", not to be confused with pulse code modulation. The decoder circuits required for the reception of such a "pulse sound" system were simple and cheap. The object of the proposal was to eliminate the sound carrier that accompanies each broadcast television signal thereby saving channel width and assisting in the possible re-engineering of BBC-1 and ITA within the vhf bands. To our disappointment, the system was rejected mainly because the Television Industry was unwilling to face what was called "yet another change in broadcasting standards".

2.8.h Economies resulting from Research and Development Work

In Part 1, section 1.3 of the Report, we referred to the considerable staff economies that had resulted from the study and adoption of automatic and unattended techniques at transmitting stations. Considerable savings have also been made possible in many other fields as a direct result of research and development work.

We record below some examples of ways in which the work of Research Department has resulted in financial savings, either directly or in terms of staff time:-

- (i) The use of Technical Apparatus for the Rectification of Indifferent Film (TARIF), referred to in Appendix A, has resulted in the retrieval of colour film which would otherwise have been unusable.
- (ii) Research on camera head-amplifiers (Appendix A, section 1.1) has improved the sensitivity of colour cameras, thereby enabling the level of studio lighting, and hence the cost, to be reduced.
- (iii) Some equipment is purchased at a reduced price which takes into account the help that has been given by the Specialist Departments during development.
- (iv) The new sound-level limiter (Part 2, section 2.8.c) is being used on an increasing scale and reduces staff costs by permitting the unattended operation of small speech studios.
- (v) The time spent on assessing the quality of magnetic tape used for television recording has been greatly reduced by the development of a "drop-out" meter.
- (vi) A device invented and developed in Research Department, called Camera Line-up Equipment (CLUE) Appendix A, section 1.1) has brought about a very considerable reduction in the time taken to line up colour cameras and to match their performance.
- (vii) It is envisaged that the work on pulse code modulation (Part 2, section 2.5.c) applied to the distribution of television sound will save the rental of separate sound distribution circuits.

- (viii) There is an appreciable income from royalties on the manufacture for general sale of equipment made in accordance with BBC design and developments.

The major part of the work in Designs Department has as one of its principal aims the objective of providing equipment which will give fully adequate performance and requires the minimum maintenance and attention. It is not possible to estimate accurately the savings that result since the BBC are never in a position of having the situation without such apparatus with which to compare the manpower position. As an example, it is clear that if the BBC had had to rely on image-type standard converters, it would have been faced with substantial manpower requirements in connection with the forthcoming duplication of BBC-1. A large range of equipment in the transmission field now requires a very small degree of attention by comparison with the standard of the past, e.g. solid state re-broadcast receivers and transposers. In addition, the BBC are expecting to move into the field of automatic correction during transmission over the distribution network of BBC-2 and, in due course, BBC-1 colour programmes. The practical realisation of a major part of the plans for unattended working will depend greatly on the success of this technique. It could lead to the abolition of much of the routine testing of the distribution system, and reduce manpower required for this purpose.

For many years the Designs Department has provided equipment in television and sound to utilise the technique of reception by radio to provide programme feeds at many BBC transmitting stations, thus saving a very large sum which would otherwise be paid to the General Post Office to provide the equivalent programme links.

PART 3 INTERNAL AND EXTERNAL INFLUENCES ON FUTURE DEVELOPMENTS

The programme of BBC research and design is set partly by national decisions, partly by the BBC's needs in the development of its services, which are affected by these decisions, and partly by the reflection of international developments. The decisions that have been taken within the first two categories and other factors are to:

- (i) implement colour as quickly as possible on 625 lines only and using the PAL system.
- (ii) take positive steps to replace the 405-line system by duplicating BBC-1 and ITA-1 in uhf, starting at the end of 1969 or early 1970, and eventually to re-engineer the vhf channels then left unoccupied for 625-line television.
- (iii) ensure that by the end of 1969 a high percentage of BBC-1 and BBC-2 will be available in colour.
- (iv) achieve complete programme interchange on a world-wide basis in colour both in the live, taped and film media.
- (v) expand the stereophony service with a view to ultimate use over the whole country in the three main programmes.
- (vi) start a popular music programme with consequent effect on the BBC's wave-length allocations for the radio programmes.
- (vii) start local broadcasting on a trial basis on eight stations but to be so planned that, if successful, it could be expanded to a total of perhaps two hundred stations.
- (viii) improve the effectiveness of the BBC's External Services in both the mf and hf bands.
- (ix) keep under review the further uses that can be made of computers both in relation to the direct work of Research and Designs Departments and in systems which can be developed for operational use.
- (x) provide facilities for the "Open University".

- (xi) study video film recording, particularly in relation to colour, and the problems of film processing.
- (xii) maintain interest in the Pay TV experiments, on which a report and decision are awaited.
- (xiii) study the possibility that the Electron Video Recording System may provide an effective means of recording in colour and the implications of the use of the system by the public.

External factors which could affect the BBC's developments to a very material extent are:

- (i) The continued increases in the power and the improved aerials used in mf and lf European broadcasting stations could lead, in the near future, to a revision of the Copenhagen Plan and to a very considerable expenditure of money and design effort in the provision of much more efficient and higher-power stations in this country. Possible changes in the form of the signal transmitted must also be decided upon prior to the international consideration of such a revision.
- (ii) The External Services, both in their mf and hf facilities, are affected by the same factors. This will also need considerable expenditure and engineering effort.

A number of economic factors also have an influence on the programme of work. These are:-

- (i) The provision of additional facilities at a time when technical manpower is becoming scarcer and more expensive increases the pressure to automate further the BBC's operations. Also, the use of thin film devices, integrated circuits and the like will undoubtedly enter more into new developments.
- (ii) As the equipment coming into use becomes increasingly complicated, staff need to be trained to a higher standard. A start has already been made on the introduction in the Engineering Training Centre of programmed learning and teaching machines and this trend will undoubtedly continue.

PART 4 CONSEQUENTIAL DEMANDS ON RESEARCH AND DEVELOPMENT WORK

Arising from the matters discussed in Part 3 of our Report, the work required to be carried out by the Research and Designs Departments will understandably increase, with a consequential need for increases in staff.

4.1 Research Department

We consider that it would be necessary to concentrate research effort on the following fields of work:-

- (i) The planning of the uhf distribution networks (BBC and ITA) will continue and the need to consider the re-engineering of the vhf television Bands I and III for 625-line services will call for additional planning work in later years.
- (ii) Conversion between television signals having different frequencies of field scan requires further work which will lead to means of achieving a completely error-free converted signal, identical in all technical aspects to those of the television standards of the receiving country.
- (iii) Consideration must be given to suitable proposals for the U.K. to put forward at a new "Copenhagen" wavelength conference which may take place within the next few years. Technical studies will have to be made of the effects on present-day mf and lf domestic broadcast receivers of a change in channel bandwidths and channel separations, in case advantages might accrue from such modifications.
- (iv) Investigations and studies are needed into many aspects of digital coding of sound and television signals. This work should have three main objectives:
 - a) Signal distribution problems or "networking" applications for both terrestrial and satellite chains, including "long-hop" links and short distance outside broadcast work.
 - b) Signal processing applications such as standards conversion, colour signal correction, coding and other processes affecting the television signal, also "compansion", limiting, pre-emphasis and similar processes that may be applied to the sound signal.
 - c) Television signal recording on optical film and on magnetic tape.

The transformation of television and sound signals into groups of numbers (digits) by techniques (iv.b) and (iv.c) would render them much more amenable to the application of automation and therefore introduce the prospect of reductions of operating staff and increase in reliability, with consequential diminution of breakdowns and maintenance.

Item (iv.a) may lead to longer-distance "single-hop" links and, again due to the conversion of analogue signals into digital form, provide the BBC signals in a form suitable for the data-transmission circuits that the Post Office are planning for the future.

- (v) The decision in favour of the PAL system of colour television will relieve the Research Department of the earlier need to compare the performances of the competing systems. There will remain many new problems to investigate and new devices such as new forms of colour cameras and camera tubes, colour film and scanners to be examined.
- (vi) Some work for the Corporation's External Broadcasting Services will continue to be required. Long-distance propagation on mf and hf and transmitting aerial systems suitable for high-power stations will require to be investigated.
- (vii) The problems of the use of satellites for programme exchange, programme distribution and even direct broadcasting, will entail considerable work over several years.

With little or no increase in staff, the above work will inevitably "squeeze out" or reduce some of the work concerned with the maintenance of the quality of audio frequency signals in both their electrical and acoustic forms.

4.2 Designs Department

During the next few years, the work of Designs Department will be characterised by an increasing emphasis on the design of equipment for the automatic operation, in the broadest sense, of the broadcasting systems. This work will aim at saving operating manpower and effort whilst simultaneously having the objective of maintaining the quality of the broadcast signal at a higher level than appears to be possible by the present manual methods. This will be particularly true of the colour television signal which has a number of parameters additional to those met with in monochrome television, the quality of which must be controlled to quite fine limits. Also, some of the familiar parameters which affect quality in monochrome, such as signal level, have an added importance in colour and must be similarly automatically controlled.

During the next few years, it is expected that full automatic control of the quality of the signal will be achieved from the output of a studio, or other picture sources, to the output of all broadcasting transmitters at whose input a signal in video form is applied.

Such automatic control equipment will also be able to fulfil some of the functions of automatic monitoring by sounding an alarm when the pre-set limit of automatic correction is approached. Automatic monitoring of the various forms of interfering signals which may occur during transmission will continue to be necessary and will require further development to approach nearer to the intelligent discrimination of an observer in this task. Automatic control of the quality of the sound signal in its present analogue form is not easy; it will probably be necessary to rely on further refining of present automatic monitoring methods, coupled with automatic selection of alternative routes, if quality deteriorates.

Work on the automatic assembling, routing and switching of sound and vision, both at studio centres and in the distribution system, will be necessary, leading to the control of such operations by computers. Much of this work on automatic methods must be extended into the international field if the very long-distance exchanges of colour pictures, which are obviously necessary and rapidly becoming more possible, are to be of the desired quality.

Among the more important of particular lines of development are:

- (i) Standards conversion leading to greater reliability and better performance.
- (ii) Automatic measurement techniques and apparatus for sound and vision producing results suitable for processing by computer.
- (iii) Automatic picture timing and "slaving" in studio complexes and throughout the national networks.
- (iv) Solid-state switching for sound and vision.
- (v) Transcoders.
- (vi) Very low-power uhf transposers.
- (vii) Radio links for mobile colour cameras.
- (viii) A light-weight portable colour camera possibly employing standards conversion techniques.

- (ix) Economical 16 m.m. colour film recording of acceptable quality.
- (x) Studio mixing equipment for stereophony.
- (xi) Switching systems suitable for the application of automation or automatic methods.
- (xii) Improved demodulators for rebroadcast professional receivers, to enable more links based on "pick-up" techniques to be connected in tandem.

In addition, there will be design work to exploit the results obtained by the Research Department in, for example, such fields as p.c.m. for sound transmission and, possibly within the period considered, digital methods for various purposes in television.

Activity will decline in the field of sound recording, thus releasing a small amount of effort, but in Designs Department, too, the situation could be eased if some increase in staff could be granted and if some appreciable revenue could be earned from outside sources.

PART 5 ENGINEERING DIVISION STAFF

5.1 Staff for Research and Design Work

5.1.a Type of staff needed

The essential staff required in specialist departments are professional engineers, and these are provided from trainee graduates who are recruited each year from the universities, from staff who have achieved professional status while working for the BBC, and also by recruitment direct from Industry.

5.1.b What contributions the BBC is making to their development

The BBC provides training for staff in specialist departments by means of courses designed to meet needs as they arise. It also assists unqualified staff to achieve professional status by awarding a number of scholarships for participation in sandwich courses and helping others to study by day release for a variety of qualifying examinations.

Arrangements have been made whereby graduate employees may qualify for higher degrees of the University of London on work carried out wholly within the BBC, subject to an approved amount of attendance at advanced courses within the University. It is hoped that similar arrangements may be arrived at with other universities in respect of their own graduates.

5.1.c BBC Research Scholarships

The BBC Research Scholarship system was instituted in 1956, with the object of providing an opportunity for selected graduates to work for a higher degree of Physics or Engineering at any university in the United Kingdom. The scheme had originally been based on the concept that as Engineering Division recruited a proportion of its staff directly from the universities, so it was morally right to make some contribution to the financing of research at the universities in return. However, in 1965, because of increasing difficulty of recruiting research engineers, there was a change and it was decided to use the scheme to attract Honours Graduates who were interested in the type of problems dealt with in Research Department and would therefore be more likely to join the BBC's staff. Two Research Scholarships are offered each year to selected graduates.

Since the scheme was introduced, twenty Research Scholarships have been granted, and of these, twelve scholars have been awarded a degree of Doctor of Philosophy, one has been awarded a degree of Master of Science, and one has been awarded a Diploma of Imperial College.

The remaining six are expected to complete their studies by 1971. Three of those who obtained their Ph.D. joined the BBC Research Department, but one has since resigned. Two of the scholars who have not yet completed their studies are to join the BBC later this year, one the Research Department and the other the Design Department.

5.1.d Links with the Universities

The need to achieve closer collaboration between the universities and the Engineering Division of the BBC has been recognised as highly desirable for a number of years and, in order to strengthen these links, a symposium on scientific collaboration between the universities and the Engineering Division of the BBC was held in London on the 21st September 1966. The objects of the programme were:

- (i) To acquaint the university world with the policy of the BBC on research and development - the scope of the work, the nature of the problem, the approach to a solution and the type of man needed to deal with it.
- (ii) To consider whether there would be any possibility of university staff participating in the work during vacation periods or at other times.
- (iii) To study the short and long term research and development being undertaken and under consideration in selected fields, and to discuss whether this would afford suitable subjects for research in the universities.
- (iv) To consider whether there was any possibility of providing means whereby students could, as a result of work within the BBC, proceed to a higher degree.

The Symposium has been responsible for increased contact between the universities and the Research and Design Departments. University staff have visited Research Department to discuss items of that department's work which they have found of interest. Specific items which have been the subject of visits from a number of universities have included:

- (i) Bandwidth compression.
- (ii) Narrow-band f.m.
- (iii) Vhf propagation and co-channel interference problems.
- (iv) The theory of "sea-gain".
- (v) Physiological aspects of colour television.
- (vi) Acoustics.

A notable example of action resulting from contact between Imperial College and Research Department has been the setting up of a laser by the former to study uhf propagation over irregular obstacles, having heard of the latter's own scaled experiments using a laser beam.

There has also been co-operation between the universities and Designs Department in two cases. The first was in connection with the arrangement of a programme of research at Hull University into the fundamental causes of the interference with microphone circuits by thyristor-controlled lighting circuits. The second was with the University of Surrey, the staff of which visited Designs Department to discuss the study of "Systematic Methods of Synthesising Equalising Networks".

5.2 Technical Staff in Operations and Maintenance Departments

The formal training of this category of staff is undertaken at the Engineering Training Centre which is fully residential and is capable of accommodating about 200 students at one time.

The training facilities have kept pace with the increased training requirements of the Engineering Division and the most recent development, completed in March 1967, has been the Colour Television Training Area.

Courses provided by Engineering Training Department are of two basic types - those designed as part of a training programme, which are referred to as Statutory Courses and those which are run to train certain chosen staff in specific techniques, known as Special Courses.

In the Engineering Division, staff attending Statutory Courses fall into one of two categories - Operators or Maintainers.

At present staff are recruited into Technical Operations as Technical Operators (T.O.'s) and into Engineering Maintenance as Technical Assistants (T.A.'s). T.O.'s and T.A.'s are drawn largely from the Sixth Form of Grammar Schools at the age of 18 years. For each category there is a statutory training programme.

The BBC has been examining the technical requirements of the various categories of work in Operations and Maintenance Departments, to ensure an efficient matching of technical manpower to job definition.

Two levels of technician are envisaged:-

- (i) The Technician who would have the academic standard of the 3rd year of the City and Guilds Telecommunication Certificate (Syllabus 49) and be trained in the maintenance and performance checking of electronic equipment and installations.
- (ii) The Technician Engineer who would have the academic standard of the Full Technological Certificate (Syllabus 49 - 300) of the City and Guilds of London Institute or the Higher National Certificate in Electronics, and who would hold the academic qualifications necessary to be a member of the Institution of Electrical & Electronic Technician Engineers. He would be a man who could apply in a responsible manner proven techniques which were commonly understood by those expert in the field of broadcast engineering in which he would work.

It is considered that, with further vocational training and experience, the present Technical Assistant would fulfil the requirements of the Technician level and should have useful promotion prospects in this category, whilst the present Grade C Engineer would meet the qualifications thought necessary to justify inclusion in the Technician Engineer category.

The BBC has examined with representatives of the I.E.E.T.E. what steps would be necessary to secure recognition of the 'Grade C' examination by I.E.E.T.E. and it was recommended that the BBC should first secure City and Guilds of London Institute (CGLI) recognition of the 'Grade C' course.

The BBC accordingly made proposals to the CGLI for the recognition of the two parts of the Grade C examination as exemptions from the two Advanced Subjects (Syllabus 300) required for the Full Technological Certificate. The CGLI Syllabus Sub-Committee were of the opinion that such a major change in CGLI examination policy would be unacceptable to their advisory Committee but suggested a possible compromise solution in which BBC staff would take one Advanced Subject as set by the CGLI and would be exempted from taking the second CGLI Advanced Subject if they had passed the BBC Grade C Part II examination. The matter is being considered within the BBC in the light of these developments.

5.3 Details of Engineering Division Staff

The following sets out the present staffing position in the Engineering Division:-

	<u>Approximate Number of Staff at 1st April, 1968</u>
Professional Engineers (Corporate Members of Chartered Institutions)	320
Technician Engineers (BBC Grade C pass or equivalent)	2,130
Technical Assistants (Operations Departments)	670
Technical Operators (Operational Departments)	1,080
Technicians (supporting staff mainly in Specialist Departments)	280
Skilled craftsmen	870
	<u>5,350</u>

The total number of staff in the Engineering Division is about 7,410.

PART 6 RELATIONS WITH THE ITA AND INDUSTRY

6.1 Co-operation with the ITA in Research and Development

There is pressure from the ITA for participation or collaboration in the formulation of BBC Research and Designs programmes and also for them to share the results of this work.

Although in the Fifth Report (paragraph 94) we advised against co-operating with the ITA, in the changed circumstances of the joint development of 625-line uhf and the extremely competitive situation now existing for the services of technical staff we believe that it would be in the BBC's interest to invite the ITA to participate, in some limited form, in the framing of the programme of work for the Research and Designs Departments and to find means of making the results of the work available to the ITA. It would neither be in the national interest nor in the BBC interest that there should be competing Research and Development organisations in the broadcasting fields.

6.2 Co-operation with Industry

The BBC maintains very close relations with Industry in the following respects:-

- (i) During both the initial design period and the introductory period of new equipment originating from Industry, information is fed back to make the equipment as suitable as possible for operation and to obtain the optimum performance. Frequent discussions take place between specialists in the BBC and designers in Industry.
- (ii) The BBC makes available to any qualified British manufacturer information on specific equipment or methods that have been developed in our laboratories or workshops.
- (iii) As far as possible, the BBC keeps Industry advised of foreseen requirements for new equipment and gives forecasts of expected demands over a period of time, but there could be an improvement in the situation if, in many cases, Industry consulted the BBC at an earlier date in the development of equipment.

Despite the liaison mentioned above the BBC experiences difficulty in some fields in getting supplies from British Industry; examples are, film equipment, video tape recording equipment and certain types of test equipment.

PART 7 CONCLUDING REMARKS

The period under review has been one of very important policy decisions profoundly affecting developments and new enterprises in the engineering work of the Corporation. The next phase is likely to require close attention to the detail of technological application, including increasing rationalization of equipment and the extension of automatic processes directed towards greater economy in operations, side by side with the exploration of new techniques which offer promise for the future.

The Committee envisages that the Engineering Division will be faced, in the period ahead, with major developments in providing even more sophisticated and even more reliable services and in extending the valuable work which has already been completed in relation to unmanned operation of the broadcasting and television network. These developments make increasing demands on the staff of the Division at all levels and will be fully met only if the Division retains its present acknowledged position as one of the world's leading authorities on broadcast and television engineering.

The Committee therefore attaches great importance to the support of the Division by the Corporation, particularly in relation to the activities of the Research, Design and Training Departments. The continued strength of these three departments, interacting as they do at present with virtually every facet of the engineering activities of the Corporation, is essential to maintain the possibility of improvements, both technical and economic, which continue to arise as technology develops. The breadth of technology relevant to the work of the Corporation makes it quite impossible for the Engineering Division to fulfil its responsibilities in isolation, and the Committee welcomes the close collaboration between the Division and Industry, the Post Office and the Universities. The Committee regards the furthering of such collaboration as one of its main duties.

The independent members of the Committee feel it a great privilege to be given the opportunity of participating in discussion of the changing problems with which the Engineering Division is faced. They have formed the highest opinion of the senior staff of the Division, and would like particularly to record the esteem in which they hold Sir Francis McLean, now about to retire after a long and distinguished period of service and a most successful term as Director of Engineering from May 1963 to May 1968.

- Chairman

APPENDIX 'A'

Significant Items of Research and Development work, in addition to those mentioned in Part 2 of the Report undertaken since December, 1964

1. Colour Television

In section 2.3 of Part 2 of the Report the factors which affected the choice of a colour system and the preparations for its introduction are discussed. We give below information about important considerations affecting the establishment of a colour service.

1.1 Cameras

In the United States, colour cameras relied upon the image-orthicon tube of the same type as is used for monochrome television, and to a limited extent still do. These tubes rely upon the bombardment, by electrons emitted from a photo-emissive surface, of a glass target which retains an electron-charge image that is discharged by a scanning beam, thus giving rise to the television picture signal current. The Philips Company in Holland developed a camera tube based on the photo-conductive effect and, unlike the rather similar vidicon tube, the new plumbicon tube, using a lead-oxide target, suffers very much less from the phenomenon of "lag" than does the vidicon. Plumbicon tubes are much smaller than image-orthicon tubes, are more sensitive and do not suffer from "shading" signals. Even although Research Department had discovered, by a careful study of the optics and colour analysis of three-tube 3' image-orthicon cameras, a way of increasing the sensitivity very appreciably, the plumbicon camera was such an advance over previous types that all our energies were devoted to it.

For some time, Electric and Musical Industries Limited had been proposing a modification to the equations describing the formation of the composite colour television signal, in order to improve certain features and derive the benefits obtainable from the full use of the constant-luminance principle. A constant-luminance working party was formed to advise the Technical Sub-Committee of the Television Advisory Committee. This working party was chaired by a member of Research Department which resulted in the Department making the principal contribution to this not inconsiderable subject. In the end, the proposal was rejected, but it had some influence on the introduction of the four-tube plumbicon camera such as is now being manufactured by Electric and Musical Industries and by The Marconi Company. A great deal of work was contributed by Research Department to assist in the appraisal of the relative merits of

three-tube cameras. The subject is still being debated and a definite choice will not be possible until more studio and outside broadcast experience has been obtained.

A major contribution was made, as mentioned, to the three-plumbicon camera and, by careful colorimetric analysis involving a computer optimization programme, the best combination of rather wideband colour analysis filters, coupled with an appropriate 3 x 3 matrix circuit, was determined; it was fitted to these cameras to improve the fidelity of colour reproduction without sacrificing signal-to-noise ratio. A new head amplifier, using field effect transistors, based on work that had been done in the Designs Department, was developed. These head amplifiers, three per camera, one for each primary colour plumbicon tube, enabled the cameras to operate in a studio lighting level that was half that hitherto required. Since the colour service started in 1967, our efforts in the colour camera field have been concentrated on assistance and advice urgently required by our colleagues in the studios and in the mobile control rooms of the Outside Broadcasts Department. One of the serious problems with regard to colour television is the complexity and length of time required to align camera and monitors so that a satisfactory colour programme can be broadcast. Various means, none of them entirely satisfactory, have been devised for the alignment of colour monitors and one of the great difficulties was that the alignment of colour cameras relied upon the production of a satisfactory picture on the colour monitor. Camera alignment was thus dependent on the stability and accuracy of monitor alignment. Quite recently, Camera Line-Up Equipment (CLUE) has been devised, which enables a colour camera to be aligned using a black-and-white monitor. The system, although still making use of the eye, is almost objective in the same sense that the reading of a meter is usually regarded as objective. The major property of the eye being used is that of its sensitivity to flicker.

1.2 Film, Telecine and Telerecording

The principles, and a good deal of the practice, regarding the development and design of colour analysis applied to colour cameras can be applied to colour film scanners or telecine machines, but here there are two different philosophies. The first is that the scanning of a colour film should produce a picture on the colour viewer's screen identical with that which he would see had the film been optically projected. The second to which the Research Department moved, notes that even when optically projected many colour films are far from faithful reproductions of the scenes that they claim to portray. Whilst this infidelity is of perhaps minor importance in the cinema, it is immediately revealed if a television programme contains a mixture of scenes originating from a colour camera and others obtained by means of film inserts. The philosophy then goes on to note that if the

sensitometric and colorimetric characteristics of a given type of colour film are known, then it should be possible, when this film is scanned in a telecine machine, to compensate or correct for the known film errors and reconstitute the original scene with greater fidelity.

This has given rise to the development of two very important devices. The first (TARIF), enables an operator on preview of a length of film, to adjust black levels and gains so that inadequacies of the film in these respects can be corrected. For example, if a length of film has a permanent colour cast this can be eliminated. Another typical fault which can be much reduced is that of the colour cast in black parts of a scene. Many films have a tendency to turn magenta instead of dark grey in the darker areas. This TARIF device has been made in some numbers and many other organizations have expressed an interest in it. The device is being made commercially and is being sold on a world wide basis. It enables the Corporation to broadcast available colour films that would have been rejected because of inferior colour fidelity.

Another lack of fidelity in colour film is the general tendency to desaturate colours that are close to the three positive primaries, red, green and blue. This is due to the fact that the film process uses negative primaries, cyan, magenta and yellow, and the colour analysis characteristics of the dyes used tend to be too wide and overlap one another. This kind of error can be corrected by the use of 3×3 matrix circuits operating upon an appropriate mathematical form of the three primary-colour signals. The device is known as masking and, as with TARIF, units are being sold commercially.

The BBC has at present no means for recording colour programmes on to film. This could be a method of exchanging programmes with other organizations and countries. It has the advantage of not requiring standards conversion in the case of exchange between countries having television standards in which the numbers of lines and/or fields are different. With the combined existence of colour video-tape recording and colour standards conversion the need for colour tele-recording is less than it would otherwise be, but it might still be useful for distribution of colour programmes to those less developed countries which could afford colour film scanners, but not necessarily colour video-tape recorders. Some time ago it was decided to develop a colour telerecorder and the work was split between Research and Designs Departments. Research Department's contribution, which consisted of colorimetric studies and investigations into random fluctuation noise arising from the scanning of unexposed film, has been completed and the obtaining of good colour fidelity can be guaranteed. The noise level and sharpness of the colour images resulting from the scanning in a film scanner of such a colour tele-recording might, however, still not be entirely satisfactory.

1.3 Colorimetry and Optics

The Research Department's Optics Section has been kept very busy supplying the colorimetric background for the work on cameras and film scanners and, in this connection, it had to standardize a set of test colours so that the colour fidelity of the various devices already mentioned can be assessed.

A tristimulus spot colorimeter developed in the Research Department has been taken up commercially. A colour temperature meter has also been developed and this was of assistance during some research aimed at deciding which tint of white would be appropriate for the alignment of colour cameras in the studio and for outside broadcasts, assuming that the viewer's receiver had been set up to the standardized white of the colour television system, namely Illuminant C.

The colour analysis or the separation of the light in the optical image of the studio or outside broadcast scene into the three primary colours is invariably done by means of optical interference filters, sometimes called dichroic mirrors. Although these have been well known for many years and commercially available it was found that for research purposes it would be desirable for Research Department to set up a small facility for manufacturing them. The equipment, which is little more than a vacuum bell jar, has enabled Research Department to increase the utility of its specifications and to persuade manufacturers that what they thought was barely possible was in fact not difficult. It has also enabled Research Department to satisfy urgent requirements coming from the Television Service. It has, of course, greatly extended the capacity for experimentation in this field.

1.4 Reception

It is interesting to note that not all important matters result from lengthy research programmes. A short investigation, concerning the production of a visible "beat" pattern resulting from the interaction between the sound and chrominance carriers in a receiver receiving a colour transmission, revealed that rather accurate tuning of the receiver would be necessary. The engineers concerned with this investigation wondered whether a quite small change in the unmodulated sound carrier frequency would mitigate this effect. This was found to be the case and, although the internationally-agreed spacing between the sound and vision carriers for the United Kingdom television Standard I was 6 MHz, plus or minus an internationally-agreed tolerance, it was found that a spacing only 400 Hz less than 6 MHz, again plus or minus the internationally-agreed tolerance, gave an advantage of 3 dB in terms of the ratio between the powers of the sound and vision carriers.

In other words from the point of view of interference, by this very small change, we gain the advantage equivalent to halving the power of the sound carrier but without in fact reducing it, and, therefore, preserving the signal-to-noise ratio.

2. UHF Planning

In Part 2, section 2.2 of the Report, reference is made to the general considerations that affect uhf planning in the United Kingdom and attention is drawn to the international aspect of such planning. We give below details of the various factors which have entered into the planning of the uhf network.

2.1 Propagation

Since long-distance propagation depends upon weather conditions, it follows that the length of time during which a viewer will suffer from co-channel interference from a distant station will itself depend upon the weather. It is necessary, therefore, before setting up the transmitters for a new television service, to have made measurements, lasting over as many years as possible, of the field strength received at various distances across various types of propagation path (over land, over sea and mixed). This work has formed a part of the Research Department's programme for many years. Receivers that can record on paper the field strengths received at various fixed sites up and down the country have been installed and the recordings have been analysed in statistical form. The result is plotted in the form of curves showing that field strength which is exceeded for a given percentage of time (50%, 10%, 5%, 1%) as a function of distance in kilometres from the originating transmitter. The topography in the neighbourhood of the transmitter and in the neighbourhood of the receiving site is important, as is the proportion of the propagation path which lies over the sea compared with that over land. Various empirical formulae have been established and these, along with the propagation curves mentioned earlier, have been submitted to the CCIR where they ultimately received international advisory status. It will be realized that the foregoing discussion is in relation to the propagation over long distances of an unwanted signal.

The other half of the problem relates to the propagation over short distances of the wanted signal; that is to say, given a certain transmitter site and the topography lying within a circle of say 50 km radius around this site, what will be the field strength at any given point within the area encompassed by the circle? The solution to this problem is very dependent upon the topography lying along a radius from the transmitter to the hypothetical receiving site, as it is upon the heights of the transmitting and receiving aerials.

Again, empirical formulae have been developed and these have been given international advisory status. Research Department has been in the forefront of these propagation studies for many years and has been the major contributor to these problems in the CCIR.

Computer programs have been developed, and are in process of being improved, that make use of the above-mentioned empirical formulae both for the calculation of interference coming from great distances and for the calculation of wanted field strength arriving from relatively short distances. It will be evident that the groundwork for planning a uhf television broadcasting service has been laid, but one further empirical/theoretical study is required. This relates to the incidence of multiple co-channel interference; that is to say, the estimation of the importance of interference coming from many distant transmitters, each one of which is known to give rise to interference for a certain proportion of the time. First, it is necessary to decide how to add simultaneously-occurring interferences; what is the allowance, in decibels, to be made when two long-distance transmissions of equal field strength at the receiving point are simultaneously present? The same question must be answered when three, four, five n transmissions are simultaneously present. Again the question is not yet completely answered because we also need to know what allowance should be made when these transmissions are not simultaneously present. Partial answers to these questions have been obtained by laboratory work. The results of this work are then used in an empirical/statistical study, the formulae from which are then incorporated into a complicated computer program. The computer program is arranged to calculate the "protected field strength"*required when up to as many as 30 or 40 distant transmissions using the same channel have to be accounted for.

- * The protected field strength is the field strength required at a hypothetical receiving site from a wanted transmission in order that the viewer at that hypothetical receiving site shall not suffer interference more visible than a specified figure for more than a specified percentage of time.

2.2 Service Planning

Since the opening of the BBC-2 service in 1964, 44 high-power uhf transmitting stations and 75 medium-power uhf relay stations have been planned by Research Department; 16 and 12 of these respectively are in service.

The Stockholm Plan for the United Kingdom uhf network assumed four separate television programmes and detailed planning has continued on this basis. Thus the Service Planning Section has had to plan not only for the BBC but for ITA as well.

The task of service planning consists in planning the major uhf transmitting stations throughout the U.K. and simultaneously planning the major relay stations inside and around the edges of the service areas of the main stations. The sites for the main stations have been chosen (within a radius of about 25 km) by a combination of expediency and optimum geography. It is expedient to put a main station at the same site as an existing vhf television station. It may sometimes, however, be geographically more suitable to site a uhf station away from the site of a vhf station. These considerations had already been taken into account before the Stockholm Conference in 1961.

The horizontal radiation patterns of the main station aeriels are, in general, omnidirectional, whilst those of many of the relay stations are partly directional, although on occasion the horizontal radiation patterns of the latter may be tailored to a precise geographical situation.

Having chosen a likely site for a main station, the suitability of the choice must be checked by experiment, thus a small transmitter with an aerial affixed to an existing mast, if any, or to a balloon, is used to radiate a low-power signal whose penetration into the surrounding countryside is examined by means of a field strength measuring set incorporated into a vehicle. This is termed a site test. It will show the pockets of low field strength within the nominal service area of the main station that will require a relay station. The extent of the service area is defined in two ways; (i) in the absence of co-channel interference and (ii) in its presence. In the absence of co-channel interference the factor that will determine the lowest value of field strength considered to be serviceable is the random fluctuation noise occurring in the input circuits of the viewer's receiver.

A figure of 70 dB above $1\mu\text{V/m}$ is the standard field strength used. This figure was agreed in co-operation with the Post Office and the Radio Industry. The lowest field strength considered to be serviceable in the presence of co-channel interference will depend upon the latter, but in certain circumstances a value of 80 dB above $1\mu\text{V/m}$ has been fixed. The site test will indicate, therefore, the actual service area for the main transmitter at its full power rating when co-channel interference and the "protected field" have been taken into account. Finally, when the main station is in service a survey is carried out, the survey being necessary to supply information for Engineering Information Department and radio and television dealers and also to find the relatively small unserved pockets within the nominal service area so that the positions for minor relay stations can be determined.

The choice of sites for relay stations is sometimes carried out by the same methods as above, but sometimes no site test is undertaken if the topography in the proposed service area is such as to warrant adequate confidence in predictions made on the basis of the computer programs based upon the CCIR information, as up-dated by Research Department.

2.3 Transmitting Station Aerials

The design of uhf transmitter aerials is complex. They are regarded as discontinuous apertures excited by panels of dipoles, or Yagi-type combinations of these. The fact that the aperture of a uhf transmitting aerial is discontinuous gives rise to a vertical radiation pattern that is not a smooth curve of field strength as a function of direction in which the energy is radiated. This results in a cyclic variation of field strength as a function of distance outwards from the base of the transmitting aerial mast. Viewers living within a narrow annulus at a mile or so from the transmitter can suffer from weak signal strength, even distorted signals, if care is not taken in the design of the transmitting aerial. Several theoretical studies, theoretical because this problem is amenable to advanced mathematical treatment, have been made which have led to methods of feeding power to the various tiers in such a way that these annuli of low and distorted signal are rendered insignificant. The technique is known as gap-filling.

Research Department has supplied Transmitter Planning and Installation Department with the necessary information for the establishment of specifications for high-power uhf transmitting aerials that are both satisfactory and realisable. Mathematical studies by Research Department enabled various improvements to be made to the uhf aerial at the Crystal Palace and other BBC-2 transmitters. The Department developed and, in conjunction with Transmitter Planning and Installation Department, designed a standard aerial for relay stations, having effective radiated powers of the order of 10 kW.

This aerial has a horizontal radiation pattern conforming to a templet that satisfies service planning requirements, a satisfactorily gap-filled vertical radiation pattern, a bandwidth adequately wide to permit the emission of four uhf programmes simultaneously; it is 36 ft. in vertical dimension and is enclosed in a glass-fibre cylinder of 15" diameter.

2.4 Transmitters

The radio astronomers have been allocated some channels in the middle of the uhf television broadcasting bands and as they are trying to measure random fluctuation noise arising from distant parts of the Universe it will be apparent that their requirements with regard to interference from man-made equipment, for example television transmissions, are very stringent indeed. In spite of the various filtering elements in uhf transmitters and their aerials, a very small part of the energy in the television signal escapes both into neighbouring channels and, in harmonic form, into channels at very much higher frequencies. This unwanted interfering energy is generated in the output amplifier valves of the uhf transmitter. Klystron tubes are used in all the high-power transmitters and like other types of valve suffer from some non-linearity when operated in high-power modes.

Research Department carried out an investigation into the non-linearities of a klystron tube and the results give an idea of the amount of unwanted energy that may be radiated and point to ways of reducing it as far as possible by the use of filters.

3. Miscellaneous Items

3.1 Picture Source Synchronising System (NATLOCK)

Earlier studies of "genlock" techniques led to the development of a new system which permitted the nationwide synchronism of picture sources (NATLOCK). This system has now been further developed to provide similar facilities for colour signals. The equipment required to generate the PAL colour subcarrier and to synchronise pulse generators has been developed and successfully demonstrated in service.

3.2 Specialised Colour Measuring Equipment

To assist the introduction of a colour television service it has been necessary to devise a number of new test waveforms which have now been widely accepted as standard measurement techniques. A comprehensive range of colour test equipment has been developed which should help in maintaining a high standard of performance with a minimum capital expenditure.

3.3 Specialised Colour Equipment e.g. Coders and Decoders

Development of coders and decoders for the proposed colour systems such as SECAM 4, NIR and the earlier PAL systems culminated in the production of equipment now in use throughout the Corporation. In addition to providing new facilities it has been necessary to bring up to date existing monochrome facilities. The monochrome studio mixers have been converted to colour operation and include a novel burst stabilization system which permits cross fades and similar facilities on colour signals. In addition, a colour caption synthesiser has been developed and the design of colour overlay equipment is being considered.

3.4 Vidicon Telecine

A telecine equipment was designed to produce high-quality pictures and had a number of special features of particular value for News Programmes and similar applications.

The production of this machine has now been handed over to industry who are modifying it to provide colour facilities.

3.5 Vision Mixers

A range of semi-conductor modules had been designed to provide vision mixer facilities in BBC studios. The range has been extended in the last three years to include a variety of special effects and mixers for special applications such as in Mobile Central Control Room, Sound and Vision Continuity, and in Video Tape Recorders.

3.6 Transcoders

An investigation has been completed of the problems of exchanging signals between the PAL and SECAM coding systems. A transcoder which produces a PAL signal from a SECAM input has been designed and prototypes are being constructed.

3.7 Automatic Correction of Video Signals

Apparatus has been constructed to remove automatically some types of waveform distortion by reference to the vertical interval test signal. Prototype equipment to correct the amplitude and luminance/chrominance ratio of the video signal are already on field trial and further equipment to correct automatically for differential gain and differential phase distortion is under development.

3.8 Programme Effects Generator

Equipment of novel design for inserting "spot" sound effects into Sound and TV programmes has been developed by Designs Department and is undergoing field trial.

3.9 Transposers* for Television and Sound

Many of the transposers used at BBC-1 television and vhf/fm relay stations are BBC designed. These transposers have a maximum output power of about 10 watts and of recent years have employed solid state techniques. The first four uhf transposers put into service were designed by the BBC and were the first to use solid-state techniques other than for the power output stage which employed electronic beam devices of commercial origin.

- * A transposer is a relay station that takes sound and vision signals, or sound signals alone, by direct radio reception from a parent station and rebroadcasts them on another channel without first demodulating them.

APPENDIX 'B'

List showing the number of books, papers, articles, etc., published since December, 1964.

1. Books and Monographs

Books	4
Contribution to books and encyclopaedias	7
BBC Engineering Division Monographs	15
Contribution to EBU Technical Monographs	4

2. Papers and Articles

Proceedings of the Institution of Electrical Engineers	13
Electronics and Power	4
Institution of Electrical Engineers Conference Publications	3
IEE News	1
Conference Proceedings of the Institution of Electrical and Radio Engineers	9
Proceedings of the Institution of Electronic and Radio Engineers	1
Radio and Electronic Engineer	2
Electronics Letters	6
Journal of the Royal Television Society	4
British Communications and Electronics	1
Journal of the SMPTE	4
Design Electronics	1
Journal of the Royal Photographic Society	1
Control	2

Journal of the British Kinematographic Society	1
Journal of the Society of Film and TV Arts	3
British Kinematography	2
SERT Journal	1
CETO News	3
Modern Science	1
Spectrum	3
B.S.I. Journal	1
Mathematical Gazette	1
Taba	1
Bulletin of the Institute of Physics and the Physical Society	2
Journal of Sound and Vibration	2
PA Engineers Journal	1
Rundfunktechnische Mitteilungen	1

3. Premiums:

Two papers by BBC authors were awarded premiums:

The IEE J. J. Thomson Premium, 1966, was awarded to P. Rainger and E.R.Rout, for their paper, 'Television standards converters using a line store'.

The Royal Television Society's Pye Premium, 1966, was awarded to J. E. F. Voss and C. J. Paton for their paper 'Olympic Games : Tokyo 1964'.

