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The cover shows a small part of the screen of a colour picture tube with the red and blue guns turned off. It illustrates one of the problems of measuring the horizontal resolution of displays on the screen: the article by Noakes, beginning on page 23, describes one practical solution.

Editorial

Broadcasting is an international matter

In the previous issue of *BBC Engineering* there was an article by Urban on the international standardisation of videotape formats. In this issue there is one by Bliss about changes in the BBC's LF and MF services, closely connected with international agreements. The authority of a broadcaster is usually limited to the boundaries of his own country: what valid interest can he have outside his area of authority?

The most obvious external interest is associated with news and current affairs. Many places outside a broadcaster's own country, especially certain foreign capital cities, are fruitful sources of news. There is therefore a clear motive for sending correspondents to many of these places and camera crews to some. In other areas contributions are taken from established agencies or freelance journalists.

Many broadcasters sell some of their programmes to corresponding organisations in other countries: even more buy them. In sound-only programmes, of course, these exchanges are usually of musical programmes or take place between countries with a common language. The traffic in television programmes is more extensive, largely because of the high cost of making them: selling a programme in another country enables the broadcaster to recover some of the money spent in making it within his own organisation. When the language problem exists it can usually be solved by subtitling or dubbing at a cost which, though substantial, is a small fraction of the cost of making the programme.

Programme exchanges between, say, the USA and Canada, or between the United Kingdom and the Netherlands are easy. Films or videotapes may be sent from one country to the other; the distances are not too great and live exchanges of news items are perfectly straightforward and commonplace. The simplicity of such exchanges rests on the uniformity of the videotape formats, the television scanning standards, and – a point often overlooked because the standard has been established for so long – on the existence of a common specification for cine film. Complications arise in live or taped exchanges between the United Kingdom and her nearest neighbour, France, because one colour system is PAL and the other is SECAM.

Anyone who has studied the problems and limitations of the colour coding and decoding processes will realise that, although the programme exchange merely requires a decoder for the incoming standard followed by a coder for the outgoing one, the resulting degradation of the signal is significant. Each time transcoding takes place further degradation occurs, so it is not an operation to be undertaken lightly, and it would certainly not be a good idea to distribute international programmes on the basis of transcoding at each boundary between a country using one colour system and one using another. Discussions are taking place within the EBU to try to agree on a form of colour signal for such programme exchanges which would entirely eliminate the need for transcoding: the proposal is to adopt a form of signal which employs only aspects of the coding process which are common to both PAL and SECAM, so that nothing needs to be redone. The remainder of the coding operation is to be carried out in the destination country, and the signal which finally reaches the viewer will have been through only one coding and one decoding process, regardless of its country of origin. This is clearly a field in which international discussion and cooperation can yield real benefits, and the EBU has a commendable record in such matters.

The transcoding problem is, of course, a small one by comparison with that of television standards conversion. In the United Kingdom we have had to live with the consequences of our change from 405-line to 625-line standards: for more than ten years two national services have been transmitted simultaneously on the two standards, the former signal being derived from the latter by means of electronic standards converters. Changing the number of lines in a picture is one thing, but changing the number of fields per second is quite another: in the former case the standards converter must be able to store a whole line of the video signal, whereas in the latter a whole field must be stored. If the best compromise is to be made in the various respects of horizontal resolution, vertical resolution, and portrayal of movement, *four* fields must be stored. A new electronic digital standards converter operating in this manner has recently been introduced by the BBC.

Elegant solutions to the problems of standards conversion have thus been found, but the problems themselves would not have existed if broadcasters and governments had had the foresight to anticipate the demand for international programme exchanges and the determination to bring about international standardisation. It must be admitted, however, that it would have required a degree of foresight little short of clairvoyance. On the other hand, the lessons we have learned from the problems associated with the differences in national practice have helped to teach us all to take standardisation more seriously.

A major example of the need for international cooperation in the broadcasting field arises from the lamentable failure of transmissions to recognise national frontiers. Broadcasters use networks of transmitters to convey their domestic services to the population inside their own countries and it would not be in a broadcaster's own interests to use more power than is necessary to achieve his object. The range at which one broadcast can interfere with reception of another, however, is very much greater than the range at which it can provide a good service, and in some circumstances it is not possible to use the same channel at all in a neighbouring country: in general the allocation of channels in border regions at least must be coordinated with one's neighbours, and this often has repercussions throughout one's own country on the constraints to which planning is subject.

International conferences to deal with these problems have, therefore, been a recurrent feature of the broadcasting scene since the early days. Some have been less successful than others but, on the whole, this is a field in which the nations seem able to recognise the merits of rational discussion and to accept reasonable compromises. The 1979 World Administrative Radio Conference (WARC) of the International Telecommunication Union (ITU) is a good example of this desirable behaviour. It is unlikely that any national delegation left WARC having achieved all its aims but it is also unlikely that any participating country was completely unsuccessful.

Conferences of this type are by no means the exclusive province of broadcasters. They are essentially conferences of government representatives and broadcasting is only one of their concerns. The others include navigational aids, point-to-point communications, and mobile links, to name three broad categories, each of which has numerous subdivisions. The needs of private users (e.g. taxi and delivery services), public authorities (e.g. fire and ambulance services, police forces, etc.), and the armed services must be considered, as well as those of the communications organisations which provide telephone, telegraph, and data services. Broadcasting is, however, a very large 'consumer' of bandwidth and so a good deal of the time of these conferences is taken up in dealing with broadcasting questions.

We should not, of course, mislead ourselves into regarding such events as successful simply because there is a final document which is signed by delegates from all the participating countries. We must recognise that a delegate's signature is not an absolute guarantee of the future behaviour of his country and also that it is normal to make the document acceptable to all by writing into it appropriate reservations. Such reservations declare that a particular country reserves the right to act in a way contrary to that laid down in a specified part of the document. They are announcements by the countries concerned that they do not intend to abide by the agreement reached by others: they are essentially an admission of failure to agree on those specific issues. The immediate measure of the conference's success is the relatively small number of reservations: the long-term measure will be the ratio of honoured to dishonoured recommendations.

The gratifying fact remains that most such agreements are honoured in most respects, because it is in the general interest to do so. The successful operation of domestic broadcasting (and other) services depends on at least a reasonably reliable idea of what one's neighbours are likely to do. Industry is increasingly international in character and the higher manufacturing efficiency available through the exploitation of larger markets is one of the more obvious reasons. This search for wider markets is particularly understandable in the realm of broadcasting equipment where even a world-wide market may be uncomfortably restricted: for some of the more specialised items no manufacturer can expect to make sales which he cannot count on his fingers. Already several types of broadcasting equipment are supplied by only a very few companies, and some are the almost exclusive province of a single organisation.

All these forces of internationalism tend to encourage cooperation and standardisation. In this school, broadcasters and governments have learned to compromise and to take their written undertakings reasonably seriously. Would that such a situation existed in the broader aspects of international relations.

Re-planning and Modernising the BBC's LF/MF Networks

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Summary: The Regional Administrative Broadcasting Conference held in Geneva in 1974 and 1975 led to decisions which permitted much more reliable predictions of the long-term effectiveness of LF and MF channels. It therefore became worthwhile to draw up fresh plans for the allocation of LF and MF transmitter networks to the various radio services in order to provide coverage more appropriate to current requirements.

The extensive changes embodied in these plans provided a convenient platform from which to launch the first stage of an equipment modernisation programme which will take several more years to complete. The aims of this programme include, of course, the traditional ones of high performance and high reliability. In addition, the engineer's perennial search for economy leads to extension of the application of standardisation and to the use of transmitters with higher efficiency: this latter point becomes ever more important as the cost of energy continues to rise.

Ways of improving reception in areas where adjacent transmitters interfere have also been investigated and applied.

1 Introduction

The BBC's LF and MF transmitter networks have been in a process of continuous development since the nineteen-twenties. By the end of 1926, for example, the radio service was provided by nine transmitters covering the main centres of population, each radiating programmes originating within its region, supplemented by 11 relay stations, together with one 'national' transmitter. At the present time there are four programme networks covering most of the United Kingdom and 20 local radio stations, bringing the total number of transmitters to 111.

The developments in the United Kingdom have not proceeded in isolation and over most of the world the use of the LF and MF broadcasting bands has grown, resulting in a considerable increase in interference levels, particularly at night. Most of the expansion in the BBC's radio services took place before 1952, and between then and November 1978 only a limited amount of new transmitter plant was brought into service.

In the late nineteen-sixties it became obvious that if any order was to be brought into the LF/MF broadcasting frequency spectrum, a comprehensive international agreement was necessary and to this end an international conference was convened. It met in Geneva in 1974 to agree on broadcasting standards, and in 1975 to produce a comprehensive broadcasting plan covering the allocation of frequencies and transmitter powers. The decisions taken at the two meetings enabled the BBC to predict the long-term effectiveness of the LF and MF channels with a degree of confidence which had not hitherto been possible. As a result, following the conference, a complete reappraisal of the UK broadcasting networks was carried out with a view to reorganising the domestic radio services. At the same time a major re-equipment programme for the transmitting stations began.

The new arrangements (and many new transmitters) were put into operation on 23 November 1978.

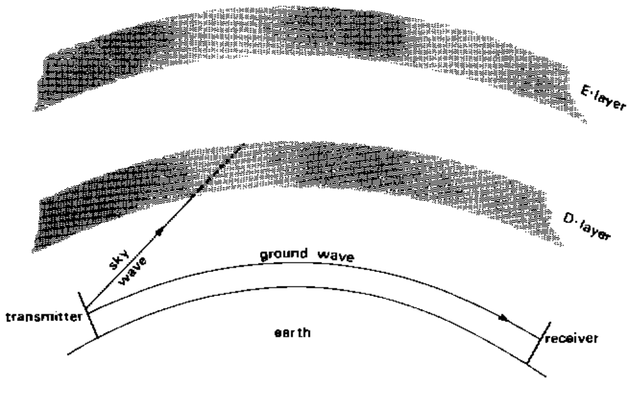

Fig. 1 During the day the D-layer of the ionosphere absorbs the sky wave and hardly any is able to return to the earth's surface.

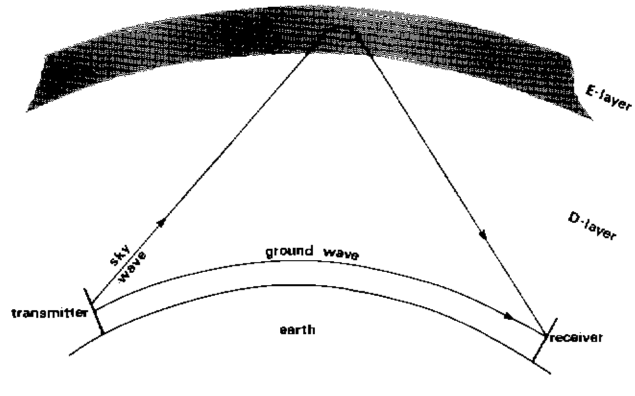

Fig. 2 At sunset the D-layer begins to fade away and allows an increasing proportion of the sky wave below a critical angle to pass through it and be reflected by the E layer. At ranges where the sky wave can return to the earth's surface the two signals interfere with each other.

2 Aims and constraints

The fundamental aim of an engineer planning a transmitter system to provide a particular programme service to a specified audience, is to ensure that in every area where that audience is to be found there is an adequate strength of the signal concerned (bearing in mind the likely characteristics of the receiving installations) to override any likely interfering signals. To work out such plans he needs to know many things, including the area in which the target audience is to be found, the channels he may use, the transmitter sites and powers available, and the magnitudes of interfering signals to be expected. In the LF and MF cases these interfering signals will vary in diurnal and annual cycles, as well as with changes in the activities of other broadcasters.

For a target audience confined within a small area (e.g. for a Local Radio station) the problem is relatively straightforward. In the absence of interference from other transmissions a modest transmitter power is usually adequate to serve the area from a single station. For larger areas, higher powers are required, but there is a size of service area beyond which it is impracticable to reach from a single station on a given channel.

An LF or MF transmission consists of two components: the ground wave which, as the name implies, follows the surface of the earth; and the sky wave, which is directed away from the surface. The effects of the sky wave are normally noticeable only during the hours of darkness and the mechanism of this type of propagation is outlined in the following simplified explanation.

As a result of the sun's radiation, ionised layers are formed in the earth's atmosphere. In LF and MF broadcasting, the layers of interest are the D layer, at a height of some 85 km, and the E layer, at 110 km. During daylight hours the sky-wave radiation is absorbed by the D layer and very little is reflected back to the earth (see figure 1). At sunset, however, the D layer disappears and that part of the sky-wave radiation below a critical angle is reflected back to earth by the E layer (see figure 2). The sky wave suffers some loss on reflection but is not attenuated by passing over the earth's surface as the ground wave is. There is thus a distance from the transmitter at which the sky wave and the ground wave have approximately equal amplitudes. Because of variations in the ionosphere, the delay suffered by the reflected signal is continuously changing so that, in this region, the combination of the ground wave and the sky wave will undergo cyclic changes of amplitude between about twice that of the ground wave alone and a very low value. The time taken to change between the two extremes is commonly a few seconds and this 'fading' is the phenomenon which, in the absence of others, limits the service area of a single station. However, because the LF/MF bands are so extensively used throughout Europe, it is more usual for night-time service areas to be limited by interference from sky waves from other transmitting stations on the same frequency.

To serve an area larger than the critical size which can be served by a single transmitting station, two or more stations are required. If they are operated on the same frequency, there are areas of mutual interference where two stations provide signals of similar strength. The nature of the degradation suffered in these areas depends on the frequency difference between the carriers of the two stations. If there is a difference of, say, 1 Hz the net signal received at a point where equal signals are obtained from two stations will vary between twice the value for one station alone and zero, and will cycle through all intermediate values every second. During the period when the net signal is reduced the noise in a receiver's output will rise due to the action of the automatic gain control.

If the two transmitters have a larger difference between their carrier frequencies the rate of variation of output will, of course, be greater; if the frequency difference is smaller the variation will be slower, and there is no difficulty in principle about eliminating the variation altogether by locking the two carriers together, in phase as well as frequency. If this is done so as to maximise the net signal at a particular point between the two stations, other points a quarter of a wavelength nearer to each transmitter will have a minimum signal strength. Now that the two carriers are locked together the minima will remain permanently in particular zones and make reception there dependent on special expedients. (See section 4.4.)

Even at times (or, for locked carriers, in zones) of additive combination of the two carrier components the modulation will be distorted because the delays experienced by the audio signal in reaching the area by two different routes will be different. (See section 4.2.)

The ideal solution to this problem is to use different channels for the two stations, when the service areas can be made to overlap without difficulty. The only snag with that approach is the basic limitation of the number of channels available for use, particularly when several services are to be radiated. Each channel will usually also be available to other broadcasters, and although the plan will not be likely to lead to interference between the services of different countries in the daytime, the night-time situation will be strongly dependent on the use made of the channels by other broadcasters.

The task of the planning engineer is therefore usually that of discovering the best way of sharing the available channels between the required services and choosing the transmitter sites, powers, etc., to maximise the coverage of the target audiences, bearing in mind the likely levels of interference. He must also, of course, keep a close watch on costs, recognising, for example, that putting a transmitter at a new site is very much more expensive than putting it at an established one.

3 Basic planning

Planning of broadcast services is, of course, centred on considerations of population coverage, and in the case of LF/MF planning it is necessary to recognise the considerable differences between the day and night conditions which were described in section 2. Furthermore, in winter in the United Kingdom, the night conditions apply to important listening periods at breakfast time and in the early evening.

There are also three VHF networks with almost complete coverage and many of the programmes in the four domestic radio services are broadcast on VHF as well as on LF or MF. Such alternative transmissions cannot be universally available, however, partly because there are only three VHF networks although there are four radio services, and partly because educational programmes and parliamentary broadcasts use one or two of the VHF networks at times. The extent to which a service is available on VHF must have a bearing on the importance of providing it with good coverage on LF or MF.

The Geneva Plan included provision for rationalising MF carrier spacings by increasing many of the carrier frequencies by 1 kHz. It was, of course, very important that all broadcasters should adopt the new carrier frequencies simultaneously: otherwise reception in darkness on the channels concerned would have been made much worse by severe heterodyne whistles. No other changes were made in the channels available to the BBC, but changes in the use of those channels by other countries would have caused serious loss of coverage in the absence of re-planning on the BBC's part. Table 1 shows the results which could have been expected.

TABLE 1

Effect on BBC radio coverage of frequency changes in other countries

Service	Principal Frequencies used (kHz)	Percentage of UK population with satisfactory reception of LF/MF services			
		Before changes		After changes in other countries but without re-planning in UK	
		Night	Day	Night	Day
Radio 1	1214	38	87	38	87
Radio 2	200	83	99	83	99
Radio 3	647	71	91	25	91
Radio 4	692, 908, 1052	75	97	72	97

Radio 1 is the BBC's programme of popular music. It attracts large audiences and it is clear from the table that its coverage left a great deal to be desired, particularly in view of the fact that it has access to a VHF outlet for a small proportion of the time only. This problem was tackled by using two channels for the Radio 1 network.

Radio 3 is based mainly on serious music and has a VHF outlet for most of the time. Certain sporting commentaries take over the MF network at times, leaving Radio 3 confined to VHF, and at other times the VHF transmissions carry educational broadcasts, leaving Radio 3 on MF only. Table 1 shows that a disastrous drop in MF coverage by night could be expected unless some change was made. The magnitude of the loss was reduced by transferring to Radio 3 the single-channel network relinquished by Radio 1. Coverage is still considerably lower during the hours of darkness than it is in daylight but it nevertheless includes the main centres of population.

Prior to the changes, the BBC's main service of the spoken word (news, current affairs, drama, etc.), Radio 4, had a three-channel MF network in England. Scotland, Wales, and Northern Ireland (known as the national regions) each had a single-channel network carrying programmes based on Radio 4 but with the substitution of locally originated 'optouts' for a substantial part of the time. A sizeable audience preferring the basic Radio 4 service (now known as Radio 4 UK) often remained when Radio Scotland, Radio Wales, or Radio Ulster was broadcasting a different programme, and unless the listeners concerned lived sufficiently near the English border they were unable to exercise that choice. (The VHF networks in the national regions always carry the indigenous programmes.) In order to make Radio 4 UK available almost everywhere in the United Kingdom the service was transferred to 200 kHz and

TABLE 2

Service	Principal Frequencies used (kHz)	Percentage of UK population with satisfactory reception of LF/MF services after 23rd November 1978	
		Night	Day
Radio 1	1053, 1089	55	96
Radio 2	693, 909	65	98
Radio 3	1215	38	87
Radio 4	200	91	99

two extra transmitting stations on that frequency were built to supplement the coverage of the established station at Droitwich.

Radio 2, which has a basis of light music, has a VHF outlet for most of the time and draws large audiences. A two-channel network has been provided which gives excellent daytime coverage. At night the coverage is reduced but the service still reaches almost two thirds of the population.

Table 2 indicates the results which have been achieved by re-planning the available channels. The large single-channel networks of Radios 3 and 4 are, of course, affected by mutual interference between adjacent transmitters, but the severity of this problem has been reduced in ways described in section 4.

4 Mutual interference between co-channel transmitters radiating the same service

The existence of an area of mutual interference between two co-channel transmitters was mentioned in section 2 and the way in which the service areas of the transmitters are limited by this effect was pointed out. It is possible, however, to reduce the degradation introduced by this phenomenon by two methods at the broadcasters' disposal and by one available to the listener.

4.1 Carrier offset

The first of the broadcasters' methods is the control of the frequency difference between the two carriers: too large a difference produces an unpleasant throbbing effect while too small a difference leads to the loss of the programme for significant lengths of time – suppressing a number of words and thus grossly impairing intelligibility. The optimum frequency difference has been found to be about 0·2 Hz, which allows a reasonable frequency tolerance before either of the above impairments gets substantially worse.

4.2 Modulation delay equalisation

The second measure which broadcasters can apply is to ensure that the audio signals derived from the two transmissions arrive in the area of mutual interference simultaneously. The propagation delays of the signals travelling from the transmitters to the affected area are small compared with the transmission times between the studios and the transmitters, where the circuits are often lines of audio bandwidth and, consequently, substantial delay. When one signal has been delayed by about 0·1 ms more than the other the combination of the two signals produces a distortion in the audio band (even in the band effectively used for modulation of LF and MF carriers). Greater differences in delay lead to more serious distortion. The equalisation of the delays of the two signals greatly reduces this particular problem.

4.3 Directional receiving aerials

Most listeners to LF and MF transmissions use portable receivers with ferrite rod aerials. Such aerials are bi-directional and if two co-channel transmissions arrive at the receiver in directions which are at right angles to each other the ferrite rod can be used to provide great discrimination against either of them. If each transmitter is producing the same field strength at such a reception point a receiver with an omnidirectional aerial will be subject to severe fading while one with a ferrite rod will probably be able to produce reception with no perceptible impairment.

At points on the line joining the two transmitters, however, a bi-directional aerial provides no benefit and the listener can only obtain relief from the effects of the interference by employing an aerial system with an asymmetrical pattern. Such a system can be produced from a combination of an omnidirectional aerial and a bi-directional one: this is easy in principle but can be very difficult in practice, particularly with receivers having no provision for external aerial connections.

4.4 Carrier synchronisation

The 200-kHz Droitwich carrier has been used as a stable frequency source by many organisations for many years. (The maximum error is 2 parts in 10^{11}.) When the 200-kHz channel was transferred to Radio 4 UK two additional transmitters were opened at Westerglen and Burghead to make the service available over almost all of Scotland. The operation of two additional transmitters, however, meant the existence of two areas of mutual interference where reception was bound to be impaired. Here, the impairment could not be reduced by the 0·2 Hz offset technique mentioned earlier (section 4.1) without destroying the value of the carrier as a standard frequency source: 0·2 Hz exceeds the maximum frequency error by a factor of 50,000. The three carriers are therefore synchronised to each other and phase locked. This produces a standing-wave pattern in the interference area such that the zones where two signals are in anti-phase are virtually stationary. At substantial distances from the lines joining two adjacent transmitters the directional properties of the receiving aerials used in the great majority of receivers permit satisfactory reception in nearly all cases. Near these lines, however, there are small areas where adequate reception cannot be obtained with ferrite aerials.

The use of receiving aerials with asymmetrical patterns can, of course, solve the problem as mentioned in section 4.3, but in this special case of the stationary interference pattern there is an even simpler solution: the use of a simple vertical wire or rod. Because the two waves that are interfering with each other are travelling in opposite directions their electric vectors will be in anti-phase at positions where their magnetic vectors are co-phased and *vice versa*. Hence, at sites where ferrite rods are ineffective because the magnetic field suffers from almost complete cancellation, an aerial which responds to the electric field will produce a strong signal because the electric vectors of the two transmissions are in phase. The only difficulty concerns users of receivers with no connectors for external aerials.

Reception in motor vehicles depends on aerials which are at least not strongly directional: furthermore it is not feasible to choose their orientation to favour reception. On the other hand, the motion of the vehicle will generally ensure that it spends only a relatively short period in the neighbourhood of a minimum.

The subjective effects arising from the phase locking of transmitters are currently being assessed and preliminary results suggest that, on the whole, impairments compare favourably with those found when the 0·2 Hz offset is used. If this impression is confirmed, the possibility of phase locking MF transmitters will be considered. The zones of anti-phase signals will be narrower and closer together with MF transmitters so that a vehicle will cross them more rapidly. Furthermore, for stationary receivers the possibility of using an aerial which responds to the electric field in areas where ferrite rods fail means that no one need be deprived of a service by the interference when the carriers are phase locked.

5 Transmitters

The adoption of standard sizes and types of transmitter has obvious benefits in reducing spares stock requirements, reducing maintenance costs, etc. An assessment of the requirements of the networks led to the conclusion that most of the needs could be met by using transmitters of 50 kW, 10 kW, and 1 kW. Higher powers than 50 kW could be provided by combining the outputs of more than one transmitter.

As the reliability of modern transmitters rises so that operational and maintenance costs fall (in real terms) and energy becomes more expensive, the cost of operating the transmitters becomes more closely connected with the cost of the energy. Consequently the efficiency of the transmitter becomes even more important than it was.

5.1 Combination of transmitters

Methods of interconnecting a pair of transmitters to feed a common aerial have been known and used for a long time. Besides permitting the use of standard transmitter units, this type of operation has the advantage that it provides an automatic standby in case of failure of one of the transmitters, thus reducing the risk of complete failure – a particularly important consideration when transmitters operate unattended.

The interconnection of three or more transmitters is a relatively novel technique, however. The system adopted provides for any number of identical units to be used, each of which can (ignoring losses) deliver its full power to the common load. When all units are operating at equal power there is no dissipation of energy in the balancing resistors, and when one fails the voltage at the output of that unit due to the other transmitters is zero, so no power from the working units is transferred to the faulty one.

Taking the normal example of three units of 50 kW each, the output power when all three are working is 150 kW. When one unit fails, the output power falls to 66⅔ kW and the remainder of the 100 kW (33⅓ kW) is dissipated in the balancing resistors. If two units fail the output power falls to 16⅔ kW and the power into the balancing resistors remains at 33⅓ kW.

Details of the arrangement are given in Appendix 1.

5.2 Modulation

The efficiency of an amplitude-modulated transmitter is heavily dependent on the method of modulation employed. Both the high-power (50 kW and 10 kW) and the low-power (1 kW) types use high-efficiency methods which are described below.

5.2.1 The Doherty system

The 50-kW and 10-kW transmitters are both amplitude modulated using the Doherty system.

The Doherty system was devised in the thirties as a means of producing linear amplification with high efficiency. Two output valves are used, biased so that below carrier level only one conducts while for higher outputs both come into operation. The method of interconnecting the two valves provides for an automatic change of load resistance presented to the first valve when the second one comes into operation. This ensures that the total power which can be delivered by the two valves at the modulation crests is four times that of the single valve at carrier level, as required. Appendix 2 describes the system in more detail.

The 50-kW transmitters employ a screen-grid-modulation Doherty system giving up to 10% higher efficiency than conventional anode-modulation equipment. The Doherty method also has the advantage that it requires no heavy iron-cored modulation components and thus permits the construction of smaller and less expensive transmitters.

5.2.2 Pulse-duration modulation

The 1-kW transmitters use a pulse-duration method of modulation.

The modulating signal is first sampled and the amplitude of each sample is used to control the duration of a pulse in a linear manner. Amplification of the pulse train can be very efficient because the signal spends a very low proportion of the time at intermediate levels. The amplified result is filtered (thus reducing the pulse train to the modulating signal once more) and used to control the power supply to the RF amplifier in the conventional anode-modulation manner.

More information about the system is given in Appendix 3.

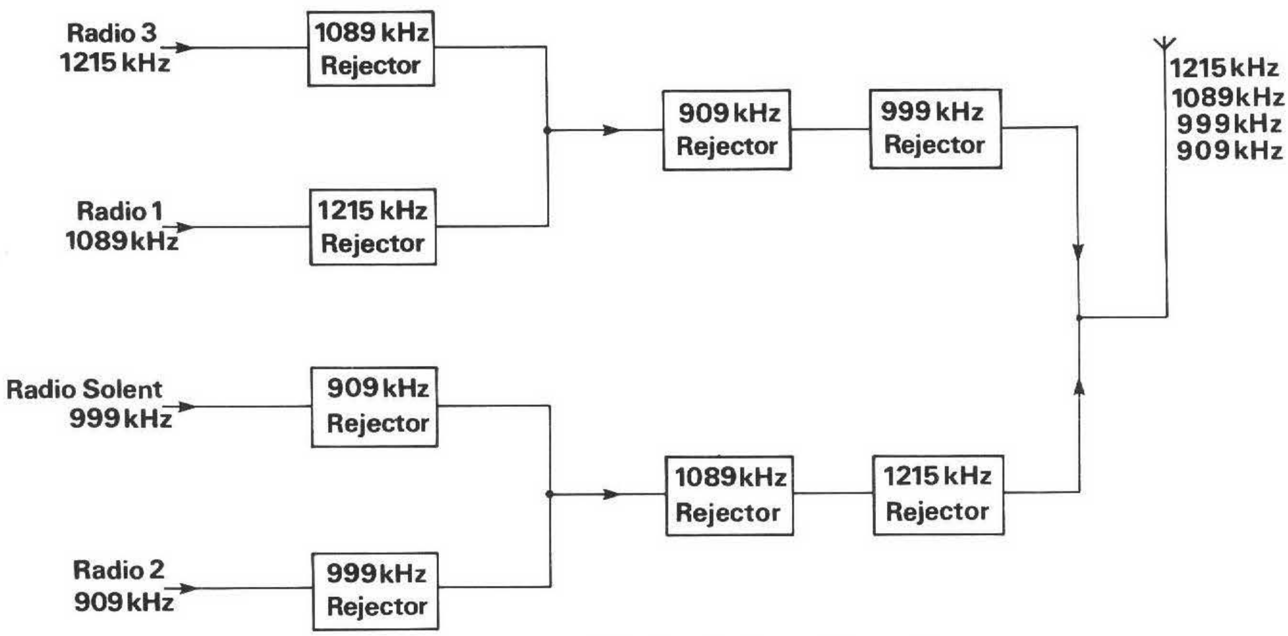

Fig. 3 The arrangement of rejectors used at Fareham for combining four closely spaced frequencies.

6 Combining units

At some stations it was necessary to radiate as many as four MF services from the same aerial. This gave rise to the requirement for a combining unit to connect the outputs of four transmitters on different frequencies to a common feeder. Where the channels were closely spaced the problems were, of course, particularly difficult. Fareham, in Hampshire, is an example of a station with closely-spaced frequencies: 909, 999, 1089, and 1215 kHz. Each service uses a 1-kW transmitter.

The essence of the combining-unit problem is to obtain adequate widths of the pass bands while at the same time providing sufficient isolation between transmitters to avoid perceptible intermodulation – all, of course, without significant losses. The technique adopted was to combine the transmitters in pairs, with the output of each unit connected through a rejector for the paired unit (see figure 3). In the output of each pair, rejectors for each unit of the other pair are connected and the two pairs are then combined to produce a single feed.

At Washford the Radio Wales service on 882 kHz is combined with the Radio 3 service on 1215 kHz by a unit using a similar screened-compartment technique. This technique permits the design of a compact and easily set-up arrangement. The problem here was much simpler in that only two transmitters were involved and the frequency spacing was much greater, but more difficult as far as the power is concerned – 70 kW and 60 kW respectively. Figure 4 is a photograph of the equipment, which has been developed by the BBC to satisfy these stringent requirements.

Current matching and combining equipment benefits greatly from the use of modern insulating materials and reliable ceramic and vacuum capacitors.

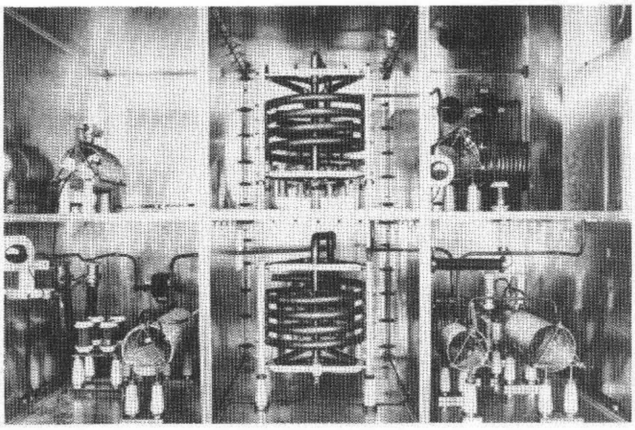

Fig. 4 The combining unit at Washford.

7 Aerials

Once the basic planning of the networks had been done, the requirements for the individual stations could be deduced, including in particular those for the directional characteristics of the transmitting aerials. Nowhere, as it turned out, were these directional requirements onerous, for there was already an extensive network of transmitting sites. The most difficult aerial problems were associated with the need to radiate up to four MF services from one aerial, especially where site conditions permitted aerials of only limited height, and with the provisions of LF aerials at Burghead and Westerglen.

Where new aerial systems have been provided at low-power stations a 'T' aerial has been used, supported by insulated masts. The virtue of this arrangement is that the masts can be brought into use as mast radiators in the event of a failure of the normal aerial.

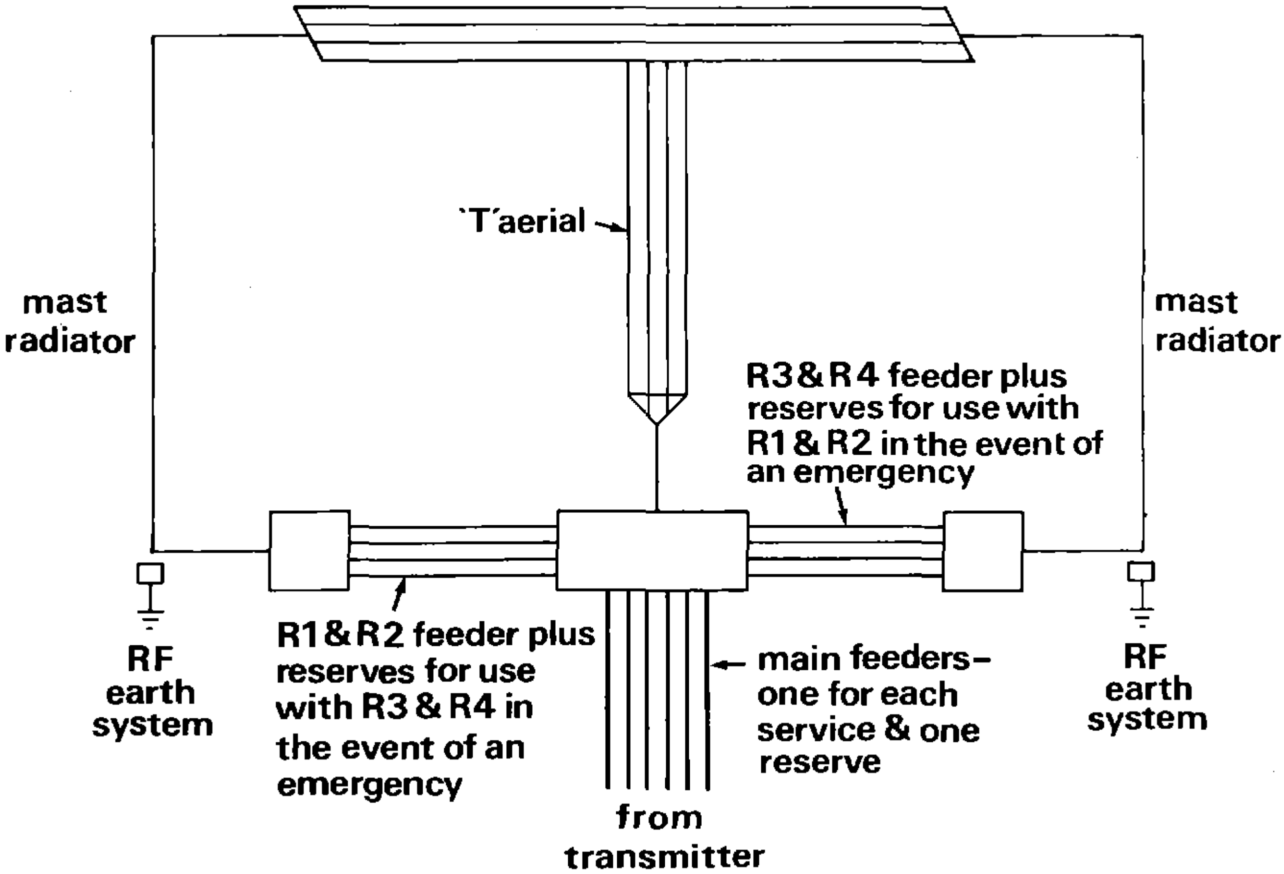

Fig. 5 The Burghead transmitting aerial system.

Many different types of aerial were in use at the high-power stations and, in general, they have been retained: only the combining systems were replaced to suit the new channels. At the two stations where LF transmitters were to be installed, however, completely new aerial systems were required. Burghead, for example, now radiates four MF services and one LF service.

The LF aerial at Burghead is a multi-wire 'T' supported by two 500-foot masts. Both masts are insulated and either can be used to radiate all four MF services with the other as a standby. The arrangement is illustrated in figure 5.

8 Feeders

The transmitting stations had used aerial feeders of two types: some had multi-wire systems and some had solid 80-ohm coaxial feeders. Although the multi-wire feeders were reliable their electrical characteristics were affected by snow and ice and at coastal sites frequent insulator maintenance was required because of salt contamination. The impedance of the coaxial feeders was suitable for the old equipment but not for new and, because the feeders were installed above ground, they, like the multi-wire systems, were vulnerable to accidental damage.

All new installations now use 50-ohm coaxial feeders in underground ducts.

9 Buildings

The high-power transmitting stations were designed in the thirties when the transmitters themselves were quite large. Additional space was required for the rotating machinery which provided the high voltages the transmitters required. Power generating equipment and bulk storage for diesel fuel added to the demands on space. (This was not merely a safeguard against mains failures: some of the stations were not originally connected to the mains supply at all.)

All this equipment needed regular maintenance and skilled operation and so an engineering staff of substantial size was required, thus further extending the accommodation needs. In 1930 Brookmans Park had two transmitters with a combined power output of 112·5 kW. Figure 6 shows a plan of the original station together with those parts now in use for eight 50-kW transmitters and their associated equipment. Modern equipment has permitted a compact and operationally convenient arrangement.

10 Programme circuits

Because many new transmitters have been installed and because the broadcast services have been re-planned to use different transmitting stations, extensive changes have been required in the programme distribution system between the

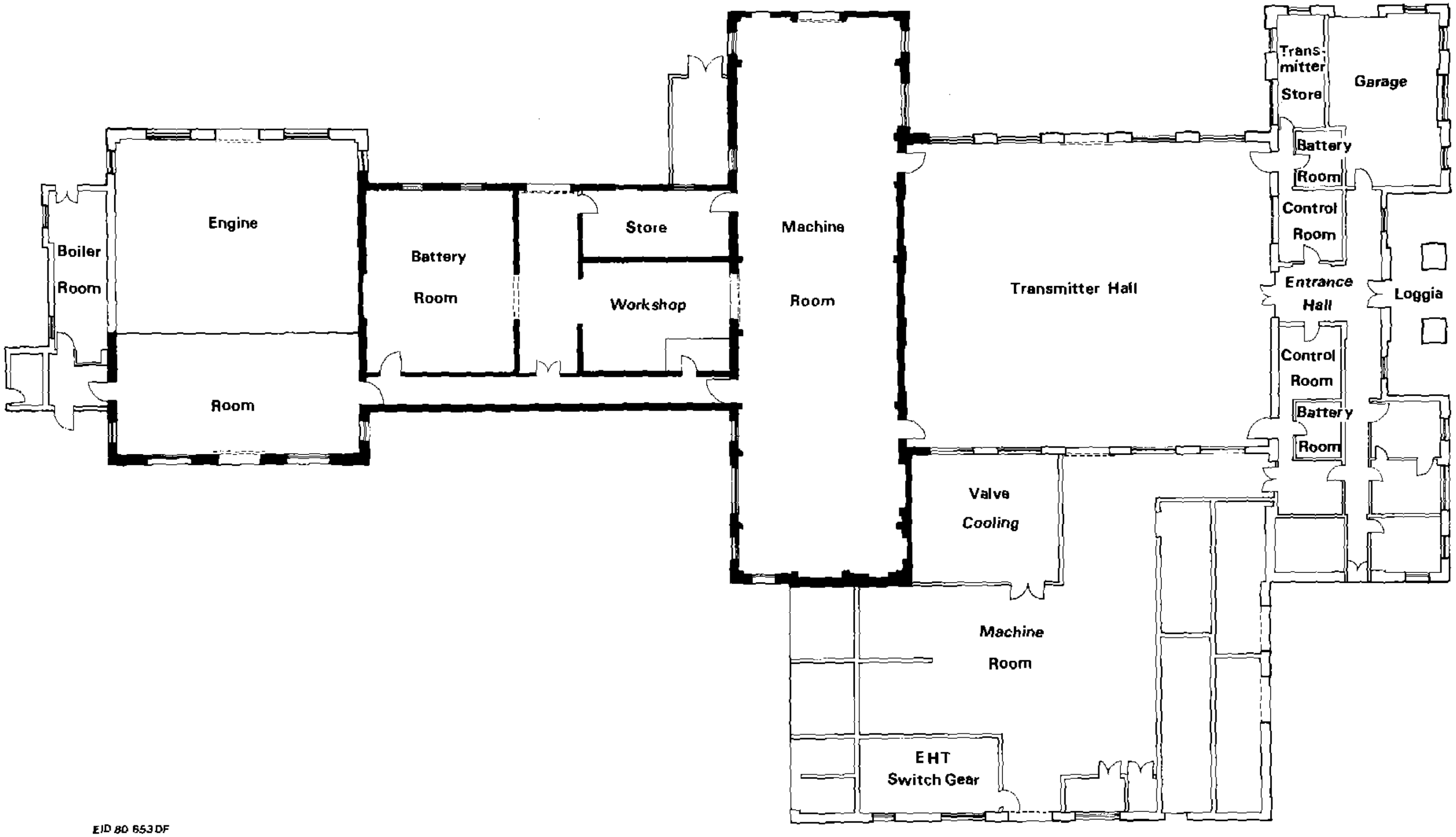

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Fig. 6 Brookmans Park transmitting station plan. The area outside the heavy boundary is not required for the eight 50-kW transmitters currently in operation. The area descriptions shown on the plan indicate the original uses of those areas: the eight transmitters now in use are housed in what was a machine room and only part of the original engine room still serves the same purpose.

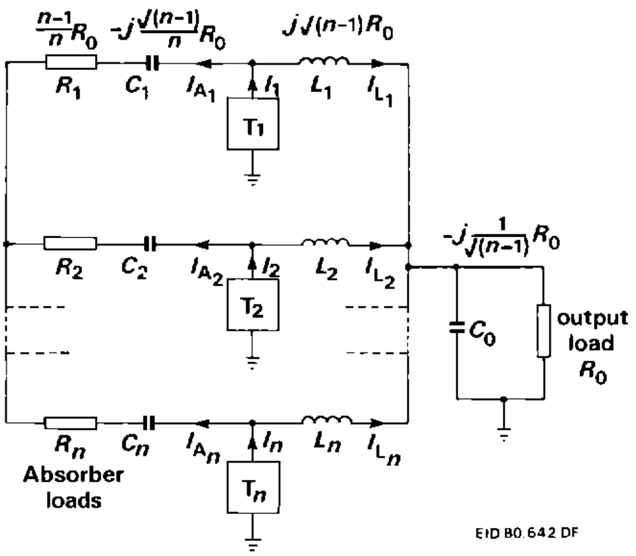

Fig. 7 The general arrangement for operating n transmitters into a common load. When, as is normal, the transmitters are identical the components have the resistances and reactances indicated above the top row.

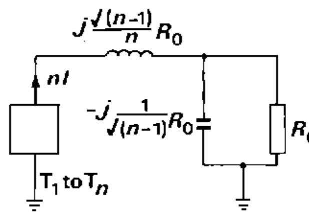

Fig. 8 Equivalent circuit to figure 7 for identical transmitters operating normally. No current flows in absorber loads, which can therefore be ignored.

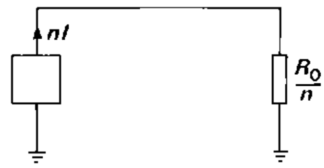

Fig. 9 The circuit of figure 8 further reduces to this, which is equivalent to a load of R_0 on each transmitter.

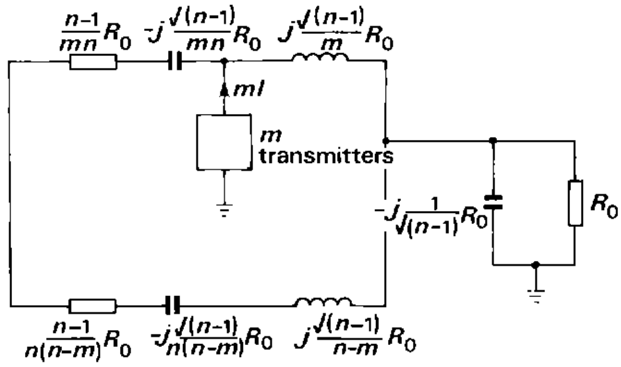

Fig. 10 The circuit of figure 7 reduces to this when m identical transmitters are operating normally and the remainder have failed to zero output.

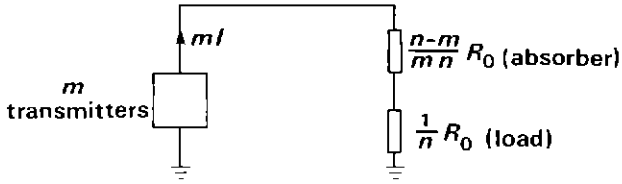

Fig. 11 Equivalent circuit derived from figure 10 to show the division of power between the absorbers and the load.

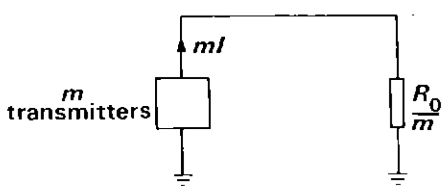

Fig. 12 Equivalent circuit derived from figure 10 to show the matching of the operating transmitters.

studio centres and the transmitting stations.

Four additional channels were brought into use on the BBC's main PCM distribution network and 64 new music lines were provided by the Post Office. The programme distribution systems within the main London Continuity and Control Room areas were also extensively modified to deal with the new arrangements.

11 Conclusion

The Regional Administrative Broadcasting Conference at Geneva in 1974 and 1975 provided a focus for the first phase of the modernisation of the BBC's LF and MF transmitter networks. Several more years will be required for completion of the work.

Advantage is being taken of modern equipment and new techniques to reduce running costs and improve services wherever possible. When the modernisation is complete the entire network will be capable of automatic unattended operation.

Appendix 1

Parallel operation of transmitters

Any number of like transmitters can be operated in parallel by means of the circuit of figure 7 where all the n transmitters are designed to operate into a load of R_0,

$$R_i = R_0\,(n-1)/n$$
$$X_C = -jR_0\,\sqrt{(n-1)}/n$$
$$X_L = jR_0\,\sqrt{(n-1)}$$
$$\text{and } X_{C_0} = -jR_0/\sqrt{(n-1)}.$$

When all the transmitters are operating normally, i.e., identically, the symmetry of the arrangement precludes any

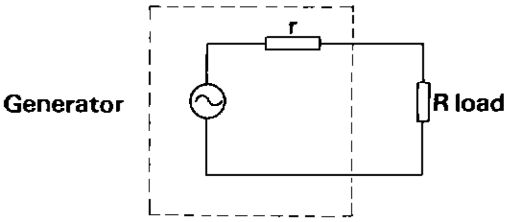

Fig. 13 Generator connected to load.

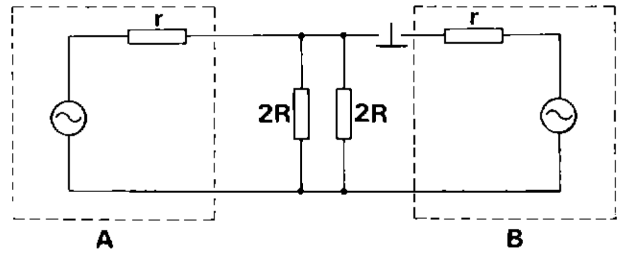

Fig. 14 Identical generators connected to identical loads in parallel.

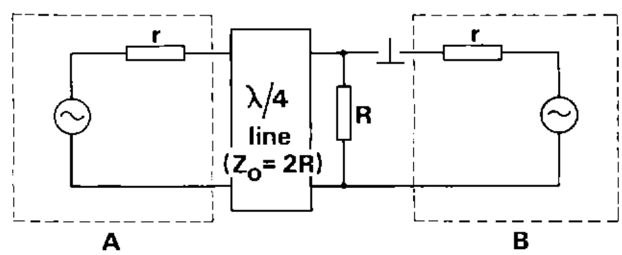

Fig. 15 The use of a quarter-wave line to produce an impedance *rise* when switch is opened.

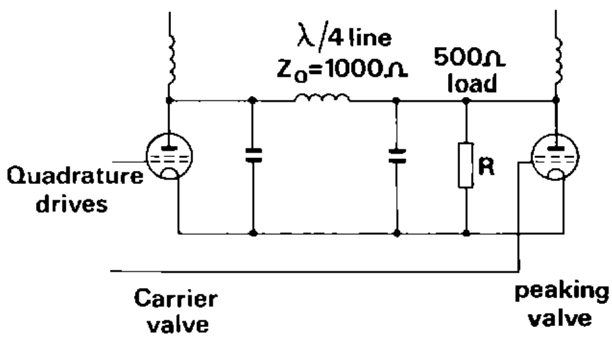

Fig. 16 Simplified practical Doherty circuit.

flow of current through the absorber load circuits. The circuit reduces, therefore, to that of figure 8 which further reduces to that of figure 9. This is equivalent to a load of R_0 on each transmitter.

Analysis of the circuit shows that when one transmitter fails the others produce no voltage across its output and therefore its output impedance in the failed condition is of no importance. In fact the same conclusions can be drawn for any number of failed transmitters, and for the general case of m operating transmitters out of the total of n, all others having failed to zero output, we can derive the following formulae:

$$\text{Power into load} = Pm^2/n^2$$
$$\text{Power into absorbers} = Pm\,(n-m)/n^2$$
$$\frac{\text{Power into load}}{\text{Power into absorbers}} = \frac{m}{n-m}$$

where P is the full power of n transmitters, i.e. n times the power of one transmitter.

The results given in section 5.1 can be deduced from these formulae.

Figure 10 shows the equivalent circuit for m operating transmitters. This can be reduced to figure 11, showing how the power is divided between the absorbers and the load, and to figure 12, showing how the working transmitters are properly matched.

Appendix 2

The Doherty system

When two identical generators supply power to the same load the resistance presented to each generator is twice that offered to either of them when the other is absent. Thus, in figure 13 the value of the load resistance is clearly R whereas the effective value of load resistance presented to each generator in figure 14 is $2R$ (providing that the generators are identical in amplitude and phase of output and in internal impedance) althought the actual common load resistance is still R and this is what generator A will 'see' if the switch is opened.

If, however, we connect a quarter-wave line between generator A and the load (and change the phase relationship between the two generators to quadrature so that they deliver co-phase voltages to the load) as in figure 15, the load presented to generator A will *rise* when the switch is opened because of the impedance-inverting property of a quarter-wave line.

In a practical circuit we might use an actual load of 500 ohms which with the peaking valve off (see figure 16) would appear to the carrier valve as 2,000 ohms because the lumped-constant quarter-wave line has a characteristic impedance of 1,000 ohms. Biasing arrangements are such that at carrier level the carrier valve saturates and the peaking valve just begins to conduct. For levels above the carrier, therefore, the peaking valve also supplies power to the load and raises its effective value to 1,000 ohms which *reduces* the value seen by the carrier valve to the same figure. Without any increase of voltage, therefore, the carrier valve can now deliver twice the power and the peaking valve can deliver a like amount. Thus, four times the carrier power is available to supply modulation peaks, as required.

Early versions of the Doherty circuit used grid modulation, requiring linear valve operation (class A), but using tetrodes with screen modulation permits class C operation and greatly improved efficiency.

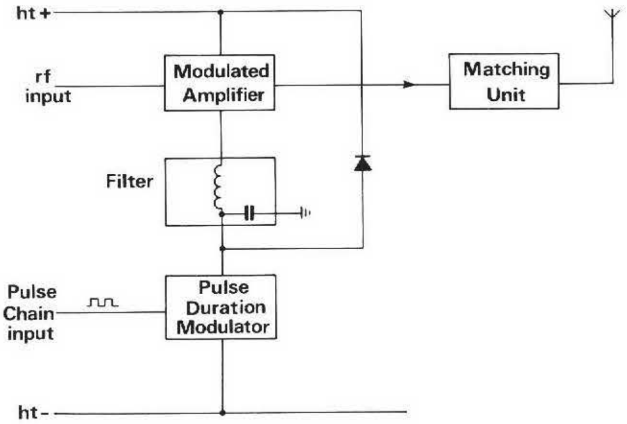

Fig. 17 Pulse-duration modulator.

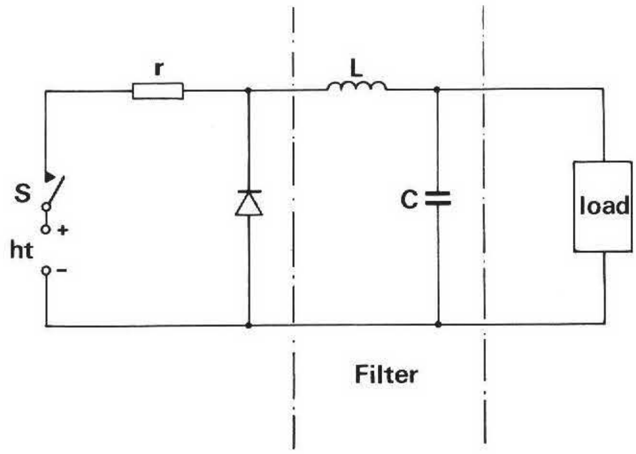

Fig. 18 Equivalent circuit of pulse-duration modulator.

Appendix 3

Pulse-duration modulation

The high efficiency of pulse amplifiers is due to the fact that the active amplifying device dissipates very little power when *either* the voltage across it *or* the current through it is small. Provided the pulses drive the device from one end of its range to the other very rapidly, therefore, it only dissipates significant power for very small intervals of time.

This phenomenon can be exploited even for audio signals by converting the signal to a train of pulses, the duration of each of which is made to have a linear relationship to the correspondiong audio sample. The sampling rate, and therefore the pulse repetition frequency, must, of course, be made at least twice the highest audio frequency: in some designs of equipment 50 kHz has been chosen; in others, 70 kHz. The pulse train so produced contains in addition to the higher-frequency components in the range of the sampling frequency and its harmonics, the audio signal, which can therefore be recovered by means of a low-pass filter.

Figure 17 shows how this device can be applied to a transmitter modulator, and figure 18 shows the equivalent circuit. The modulator valve is virtually always either fully on or fully off and is therefore represented in figure 18 as the switch 'S'. When the switch is closed, current is drawn from the power supply and when it is open the current is sustained through the diode.

The system permits very high efficiency over the entire cycle of modulation.

Roy Bliss joined the Transmitter Department of the BBC in 1956, and in 1961 transferred to Transmitter Capital Projects Department (at that time Planning and Installation Department) where he has remained ever since. At first he was responsible for the planning and installation of several television/VHF radio relay stations and later he was closely concerned with the development of the high-power UHF television transmitting station scheme. In 1970 he was appointed Project Manager, Radio Development, and became responsible for the engineering aspects of local radio expansion.

He took over as Head of External Services Section in 1972, taking charge of the Caribbean relay station scheme, the FERS project in Singapore, and capital work at domestic MF transmitting stations. In 1977 he was given responsibility for the project management of the LF/MF transmitter network changes, and is currently responsible for all the department's power and LF, MF, and HF transmitting station projects.

Broadcasting Facilities in Wales: Development at Llandaff

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Summary: The most recent stage in the development of the BBC's Llandaff site has been the completion of a 590-m^2 television studio, together with the associated rooms and technical installations to provide comprehensive production facilities. The modern, purpose-built building, with up-to-date equipment replaces adapted accommodation housing older installations and greatly improves the standard of television production facilities in Wales.

1 Introduction

The BBC site at Llandaff was bought in 1952 and an initial development of six sound studios, concert hall, technical block, offices, and staff restaurant was completed in 1966. A 140-m^2 television studio, known as Cardiff Studio C2, together with associated production and technical areas, was subsequently built on the site and came into service in 1974. This was followed in 1977 by the completion of an office block extension, to which further additions were subsequently made and completed in early 1979.

The latest development, which makes provision primarily for a 590-m^2 television production studio was brought into service in December 1979. It completes a further stage in the development of the Llandaff site and in the centralisation of the BBC's television broadcasting facilities in Cardiff. An outline of the new building is shown in figure 1.

Further projected developments at Llandaff include the provision of a multi-storey car park and a television OB base.

The new studio, known as Cardiff Studio C1, replaces a smaller production studio housed in adapted premises at Broadway and is associated with the following ancillary areas.

	Area (m^2)
Studio control suite	148
Studio and VT technical apparatus rooms and VT storage area	319
Production lighting dimmer room	42
Scene dock	208
Artists' dressing rooms and assembly area	330
Make-up room	38
Quick-change area	24
Wardrobe area	56
Technical equipment store	48
Ventilation plant room	90
Miscellaneous office accommodation	402
Electrical substation	50

Associated with and as part of the new development, the following technical facilities (some of which were formerly housed at Broadway) have now been provided at Llandaff.

— A television continuity suite now housed in newly adapted accommodation in the existing technical block.

— Existing videotape machines have been reinstalled in accommodation provided as part of the new studio development.

— Local vision and sound source-to-destination routeing facilities serving the whole station together with SB switching have been provided in the existing Communications Centre in the technical block. External

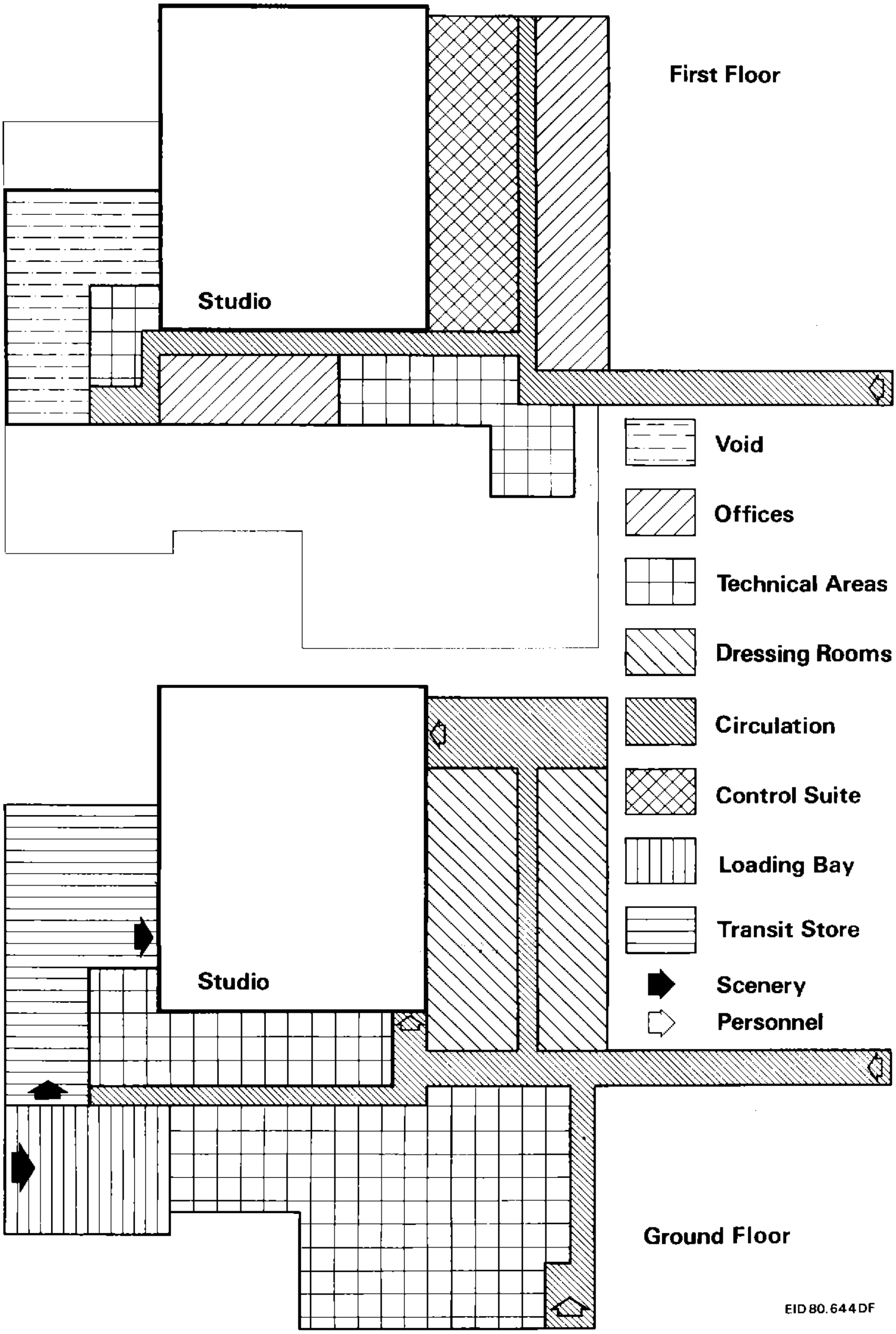


Fig. 1 Outline floor plans of the new building at Llandaff

network contribution and distribution circuits, formerly terminated at Broadway now also terminate in this area, which has been extensively reorganised to accommodate both television and radio broadcasting central facilities.

To meet the increased electrical load created by the additional facilities now available at Llandaff, a new electrical substation, with a capacity of 800 kVA, has been established.

As a result of this further development of the Llandaff site, the premises at Broadway have now been vacated.

Building work for this development began in January 1977. The total cost of the project was £5M divided nearly equally between building work and technical plant costs.

2 The building and its services

2.1 The plan

The dominant feature of the new building is the studio itself, but ancillary accommodation is grouped round three of its sides on two floors. The new structure adjoins the technical and scenery areas of the pre-existing studio C2. The technical area, which has been enlarged as part of this development, now accommodates additional studio and videotape technical apparatus and provides videotape storage.

To the west of studio C1 are the scenery storage area and a vehicle-loading bay shared with C2. To the east of the studio the artists' assembly area, dressing rooms, and make-up and quick-change areas are on the ground floor, while the production control suite, wardrobe area and offices are to be found on the first floor. The control suite is divided into three main areas – production control, lighting and vision control, and sound control. Windows are provided to enable staff in any of the three areas to observe the activities in the studio. Figure 1 gives an overall view of the arrangement.

2.2 Construction

The internal walls of the studio are of 370mm reinforced concrete cast *in situ*. The external facing of 103mm black brickwork is separated from the concrete by a 75-mm cavity. Another cavity separates the other studio walls from the adjoining accommodation: its purpose is acoustic insulation. Steel trusses, 3·5m deep, support a roof of pre-cast concrete slabs with a poured topping to a total thickness of 200mm.

The technical area is a single-storey structure of reinforced concrete columns and flat slabs. The scenery bay has a steel frame and rises to a height of about 7m: it is lined internally with a wall of fairfaced blockwork and clad externally with lightweight panels. The roof steelwork, which is exposed internally, supports a profiled-sheet roof deck.

2.3 Interiors

The walls of the studio are lined with an acoustic treatment to a depth of 250mm. Timber frames enclose cavities within

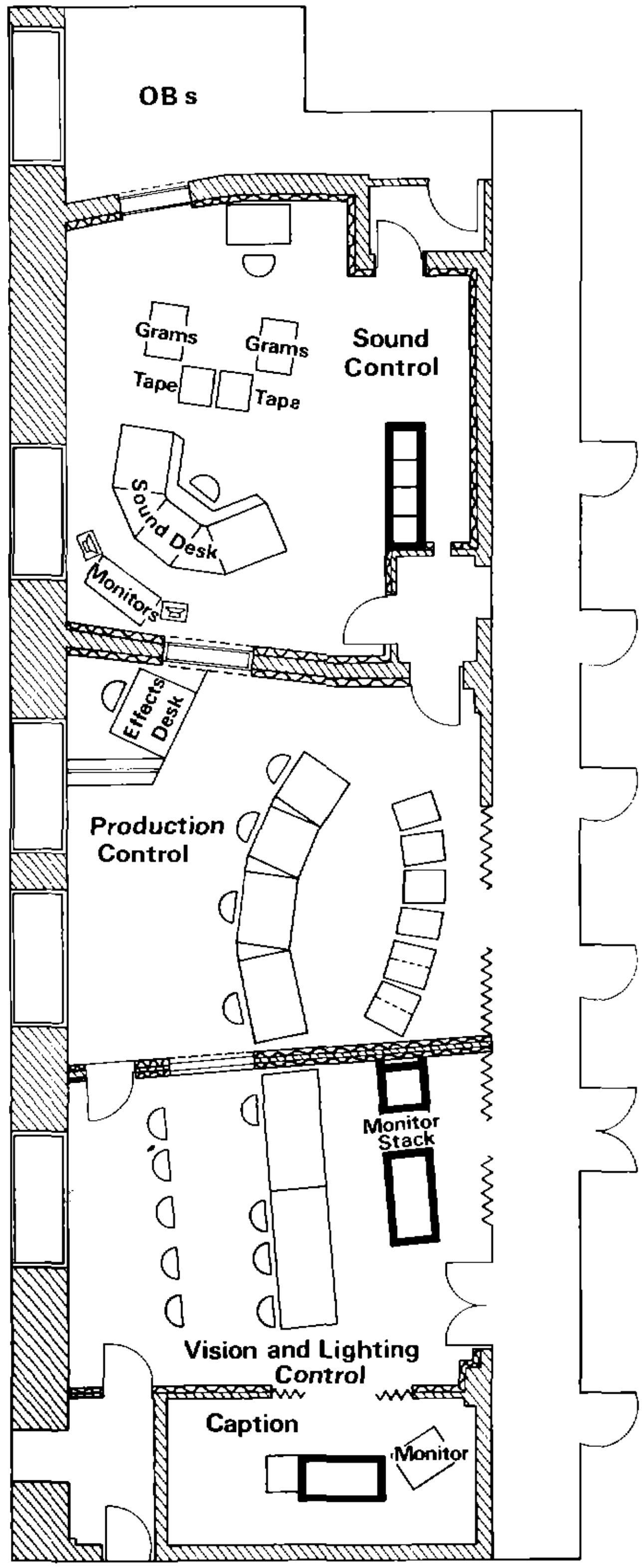


Fig. 2 Production control suite

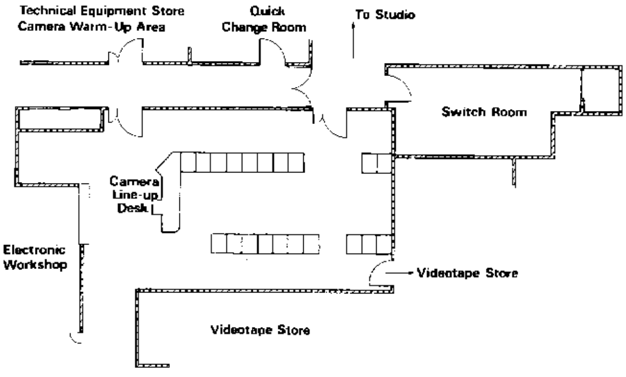


Fig. 3 Vision apparatus room

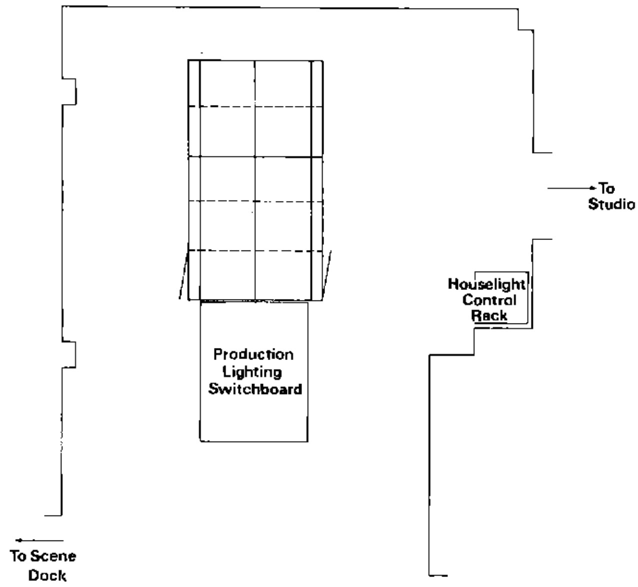


Fig. 4 Dimmer room

this depth which are faced with fibreglass, covered with hessian, and finally protected by a steel mesh. The treatment achieves the reverberation-time characteristics specified for the studio. Where it was required to fix technical equipment, gaps were left in the acoustic treatment to permit pattresses to be fixed directly to the concrete wall.

The door between the studio and the scenery transit store has to be big enough to permit the passage of large scenic pieces: it is, in fact, 4·8m high and 3m, wide (i.e. big enough for a double-decker bus). When closed, the door is required to provide considerable acoustic isolation. Its seal design is based on those commonly used for cold-store doors. The simplicity of the design minimises maintenance problems, but the acoustic performance is very good. When measured with one-third octave bands of noise the average loss between 100 Hz and 3·15 kHz is 51 dB.

The studio roof trusses, besides supporting the roof, carry the open-mesh lighting grid and a lighting gallery of width 1·25m running round the studio walls. The grid is about 9·1m and the gallery some 6m above the floor.

The studio floor has to meet an exacting specification, including being level within extremely close limits. At the time of installation it was not possible to construct an asphalt and lino floor such as is usual in BBC television studios because the requisite high-quality linoleum was not available. Experiments were therefore conducted with alternative types of floor and the final choice was a chemical composition similar to that commonly used in gymnasiums. Although widely used in television studios in the USA, such floors have not previously been so used in the UK. One of their advantages is the ease and speed of repair in the event of damage.

The technical area has an acoustically treated suspended ceiling with roof lights, and also metal-faced acoustic treatment on the walls. In the control suite the acoustic treatment on the walls has a protective hardwood (ramin) slatted surface, giving a pleasing, light-coloured appearance.

Both the technical area and the control suite have modular floors to provide convenient access to the cable runs between the various items of equipment.

2.4 Heating and air conditioning

There are two purpose-built air-handling plants, each individually mounted on its own isolating floor. One serves the studio and the other serves the ancillary accommodation.

Supply of air to the studio is controlled by distribution dampers operated automatically from a control panel in the plant room, where a mimic diagram indicates, by means of illuminated sections, where air is distributed.

Technical and dressing room areas are air conditioned and served by means of a dual-duct system blending in each room to provide the required conditions.

The cooling medium is chilled water distributed via new site mains from two refrigeration machines, one of which is a steam-driven absorption unit, while the other is an electrically driven centrifugal type. The total cooling capacity is 400 tons of refrigeration.

Heating is provided from a new medium-temperature, hot-water, site distribution system from the existing boiler house to heat exchangers in the non-air-conditioned areas as well as air-heating batteries in the air-handling plant rooms.

3 Studio C1: technical facilities

Technical plant directly associated with Studio C1 is housed in the following primary areas:–

	Area (m^2)
Production control room	47
Lighting and vision control room	45
Sound control room	56
Vision apparatus room	66
Dimmer room	42

The layout of technical facilities in these areas is shown in figures 2, 3 and 4.

3.1 Vision

Provision is made to operate up to five Link type 110 camera channels in the studio with the option to change any two camera heads to the lightweight type 120.

The type 110 camera heads are operated with Schneider 15 × 12·5, F/1·7 zoom lenses. The type 120 heads are operated with Angenieux 15 × 12·5, F/2·5 zoom lenses.

Comprehensive camera line-up facilities are provided at a desk in the vision apparatus room.

In accordance with common practice, camera remote control facilities are provided in the lighting and vision control room in association with production lighting control facilities.

Slide caption facilities including Tarif, with provision for the random selection of up to 60 slides, are provided by a Rank Cintel MK 8B slide scanner.

Vision mixing facilities are provided by a BBC-designed unit type EP5/512. This provides for 'knob-a-channel' cutting and mixing on two eight-channel units, the outputs of which feed a common two-channel group mixer.

Cameras 1-4 are permanently allocated to channels 1-4 of both eight-channel units. Camera 5 and other local and remote vision sources are routeable to channels 5-8 of both eight-channel units individually.

The vision mixer makes provision for mixing, cutting, CSO, and wipe effects at group level between the two eight-channel bank outputs.

Multiple CSO effects generated from up to three interconnected electronic switchers are also available as a source to the mixer. Colour overlay effects processing is included in the RGB feeds from each camera channel. This provides for key-axis switching and key-colour suppression. Other local sources include pictorial and colour-synthesised captions.

Feeds of telecine, videotape and any other locally or externally generated programme sources are made available to the vision mixer via the centralised television local router in the communications centre.

In the production control room, permanent monitoring is provided of the vision inputs to channels 1-4 of the vision mixer (common to both mixer banks) and of each of channels 5-8 individually on both eight-channel banks.

Monitoring is additionally provided of studio and network outputs and, on two switchable monitors, of all available vision sources.

In the lighting and vision control room permanent monitor displays are provided of all camera channels. Monitoring is additionally provided on seven switchable monitors serving the operational requirements of the vision operator and lighting supervisor as well as of engineering.

3.2 Production lighting

Production lighting in Studio C1 is provided by dual-source lanterns controlled from a lighting memory system. The total lighting load is 210 kW. The lanterns are suspended on pantographs from 88 motorised winches. The studio single-phase lighting power is fed via self-regulating thyristor dimmers to each production lighting socket in the studio.

The principal production lighting comes from 170 dual-source Kahouteck lanterns fitted with 3¾ kW lamps. The single lamp in each lantern is used for both hard and soft lighting and has two switchable filaments to provide three lighting powers (i.e. 1¼ kW, 2½ kW or 3¾ kW).

Cyclorama lighting is provided by 50 four-colour ground row lights. Other lanterns include ten single hard and ten single soft sources, two follow spots, four effects spotlights, two 10-kW and miscellaneous smaller spotlights. Camera headlamps, as double and single sources, are also available. The dual-source lanterns may be used with twin-filament 5-kW lamps if necessary. The lighting is designed to produce about 800-1000 lux normally, which is suitable for the Link 110 camera.

There are 310 lighting channels in the studio and five camera headlamp channels. Each channel has an individual dimmer controlled from the main lighting control desk. Production lighting control is by a Thornlite control system which is based on the use of microprocessors. This primarily comprises a channel controller, six group controllers, four playbacks and a long-term memory with two visual display units for presentation of lighting group and level information.

A geographic mimic diagram in the lighting and vision control room monitor stack gives instant display of which studio lights are on.

Lighting dimmers, normally controlled from the lighting desk, may be turned on at a preset level from a lighting test panel on the studio floor. There are three hundred 5-kW dimmers supplying lighting outlets on the winches, at floor level, and at gantry level. Of the ten 10-kW dimmers, six supply outlets in the lighting grid and the remainder supply outlets at gantry level. Camera headlamp outlets are supplied from 5-kW dimmers and disposed adjacent to camera boxes at floor level.

Studio houselighting is supplied by tungsten-filament or mercury discharge lamps depending on circumstances. The tungsten lamps produce 400 lux at floor level and the mercury lights 800 lux.

3.3 Mechanical services

In addition to the 88 motorised lighting winches, there are 39 motorised scenery support hooks in the studio. Control consoles are situated at floor level for operation of both lighting and scenery winches. All lighting winches also have independent local control and isolation facilities. The scenery winch system consists of thirteen groups of three supporting hooks. Each group traverses the length of the studio in one of thirteen runway tracks. The hooks are supported by traversing trolleys which run within the enclosed track on rubber tyres.

A twin cyclorama curtain support track is provided at high level in the studio and a single low-level track is situated under the gantry at one end of the studio. A lighting track is also mounted under the gantry and extends all round the studio.

The major lighting support system consists of scaffold barrels 2·5m long. These are suspended by twin wire ropes from motor units mounted at grid level. Power sources to lanterns are routed from the grid to the lighting barrels using flip-flop trays, and terminated at the barrel position on individual sockets. Other circuits, similarly routed and terminated, carry video, microphone, and loudspeaker facilities as required.

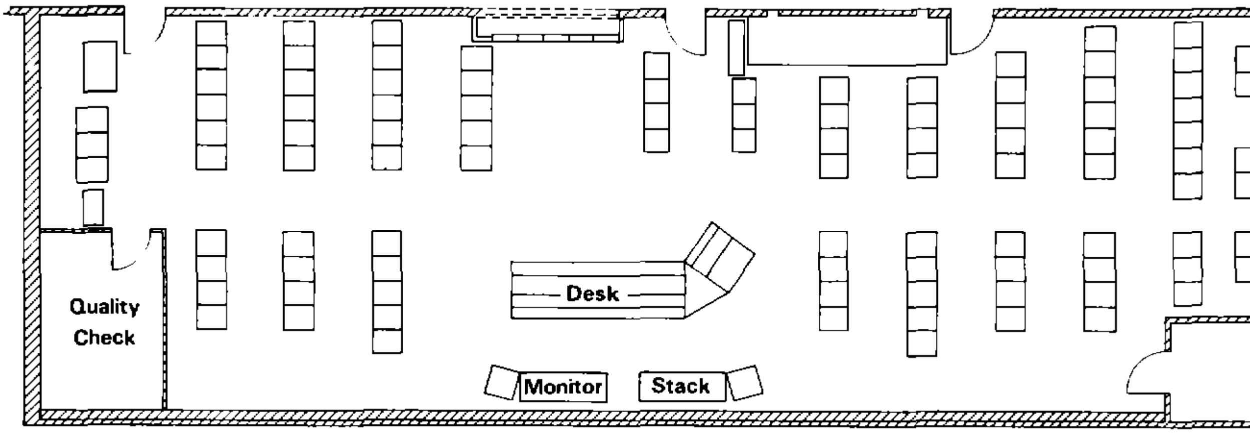


Fig. 5 Communications Centre

3.4 Sound

The programme sound installation is centred round a custom-built 44-channel, eight-group Neve sound desk. All channels have preset gain controls and full equalisation. Four echo-send, four foldback, and two PA busbars are accessible to channels or groups or via controllable direct inputs. To minimise the risk of overload in emergencies in the channel preamplifiers, the latter have output stages capable of delivering +36 dB before clipping. Apart from these output stages, the desk is designed around integrated circuits.

The installation is required to handle both stereo and mono signals. All 44 mono input channels are, therefore, equipped with pan-pots feeding the eight stereo groups. Built-in A+B mixing amplifiers provide mono signals for the echo-send, foldback, or PA feeds from groups: levels are automatically controlled.

A comprehensive push-button logic-controlled solid-state matrix provides stereo/mono monitoring via a pair of LS3/7 loudspeakers and three stereo PPMs. It is possible to use the loudspeakers independently to monitor two different stereo (or other) sources via A+B mixing arrangements for each loudspeaker, overall acoustic output being maintained sensibly constant.

Stereo outputs are also available from main clean feed, group separate outputs, an eight-way group recording matrix and a ten-input auxiliary mixer for signals from the audience area.

Pluggable devices include width/offset controls, a ten-way clean feed network, eight compressor limiters, and seven telephone effects filters which can be switched in automatically by the vision mixer channels.

Other peripheral desk facilities are a nine-way mix for the music director, channel separate outputs, and remote control of six tape machines and four echo plates.

Four sound bays provide comprehensive jackfield access to line circuits, special desk outputs, monitoring feeds to studio wall boxes, production and lighting control rooms, dressing rooms, phone-in facilities, etc.

The installation includes also a bay-mounted 120-way push-button-controlled solid-state monitoring matrix. Communications systems cover telephones, talkbacks, intercoms, radio communication and logic for transmission rehearsal signalling and associated facilities interlocking. The basic communications system uses the BBC design of logic-controlled pulse-switched solid-state matrix together with high-quality microphones and 6½" loudspeakers.

The EMX system is self contained in the main desk panel and caters for fourteen lines to five subscribers together with line injection of programme or talkback or clean feeds. Auxiliary telephone systems are provided for electricians and make-up staff.

A UHF radio communications link is provided between producer and floor manager. All the studio control rooms and the vision apparatus room are stations on a Philips M100 intercom system connecting to other remote areas.

4 Communications Centre

This area, located in the existing technical block, was originally built as a central technical area serving radio broadcasting only.

Under this project, the area has been extensively reorganised to accommodate both radio and television central facilities.

The original radio equipment has been rebuilt and integrated with new equipment for television sound. A new layout of equipment in the area (figure 5) has been made to give higher equipment density and improved access. This also gives space to accommodate central vision equipment associated with the new and existing television facilities now available at Llandaff.

A new control desk has been installed which provides for integrated central operations for both television and radio. These include video and audio monitoring, measurement, and routeing, together with EMX positions. A three-channel television cut position is also included. This is used to carry trade test transmissions and as an emergency control position.

The comprehensive television and radio routeing facilities in this area serve the whole station.

The television local router, based on uniselectors driving BBC video matrices MA2M/505, provides for routeing 50 sources to 50 destinations. The following facilities are routed:– vision, sound, cue programme, talkback, reverse talkback, telephone, colour phase error correction, plain-language indication. A facilities lockout system limits selection of full facilities to one destination at a time. The basic selection of vision, sound, and telephone is available to any number of destinations. Self-operated selection is provided in television studios, videotape areas, and television continuities.

The radio local router, also based on uniselectors, provides for routeing 100 sources (50 stereo capable) to 60 destinations (36 stereo capable). The facilities routed are:– stereo A and B or mono programmes, telephone/cue line, transmission signalling, plain language indication. Self-operated selection is provided in three radio sports/current affairs studios and in radio continuities.

Television SB switching facilities in this area provide for Post Office line routeing, local source selection, and optout facilities. Control of optout is extendable to the television continuities, the cut position, or to master control in the communications centre.

Comprehensive monitoring facilities are provided of the following separate signal groups: television local router, television SB switcher, television lines, television OFF AIR, radio local router, audio lines (mono), stereo sources, lines, and OFF AIR. For groups with multiple audio levels the individual levels are switchable. Vision and sound are separately selectable. Group selection facilities are provided at four points on the communications centre main desk, the facilities available depending on the function of the desk location. All positions feed a 22-inch colour monitor, PPM, and loudspeaker. Video positions feed an oscilloscope and vectorscope; audio positions feed noise-measurement equipment and stereo monitoring facilities.

The engineering manual exchange (EMX) provides for 120 subscribers selectable to six positions within the area, each with four answer circuits. On the main desk answer circuits, multiple subselection is possible for conference working. Through calls can be selected with or without through ringing.

A communications router provides facilities for routeing twelve two-wire or four-wire communications circuits to 200 internal cue-programme, talkback or telephone sources and destinations. The router is integrated into the EMX, PABX and monitoring systems.

The main station intercom is provided by a Philips M100 microprocessor-controlled system. This offers a number of special features such as queueing with automatic recall, number transfer, break in, group calling etc. The wiring pattern is simple, stations being linked by a ten-pair cable. The disadvantage of the system is that traffic is limited to four simultaneous calls within specified station groupings.

The distribution of three existing television pulse chains has been extended to accommodate the additional vision facilities on the station. Control of these chains is now exercised from the main control desk.

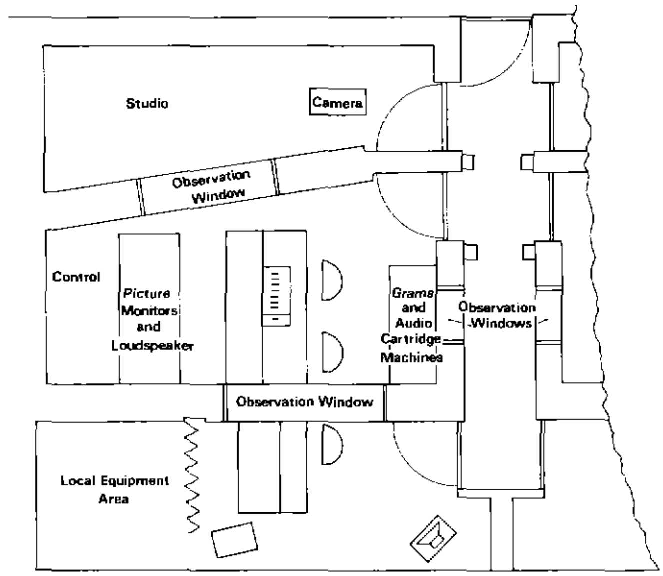


Fig. 6 Continuity A: the accommodation for Continuity B is on the right and is a mirror image of the arrangement shown.

5 Continuity suites

Provision has been made under this project to build two television continuity suites. One of these, normally serving as the continuity suite for BBC 1 optouts, has been equipped and was brought into service in September 1979. The second, which was originally left in carcase form and will normally serve as the continuity suite for BBC 2 optouts, is currently being equipped.

Each suite consists of three areas, as indicated in figure 6, and comprises a small studio capable of later equipment with a single television camera, a control room housing a video/audio mixer and monitoring facilities, and an engineering area/local VTR room. The control room is also capable of sound continuity announcements.

Caption facilities for the continuity suites are housed in an adjacent caption area ultimately to be equipped with three opacity scanners and a BBC-designed twin-port colour slide scanner for each continuity suite.

The control desk in the continuity control room contains control facilities for an EMI audio/video mixer, caption selection, channel-source indication, optout controls, audio and video monitoring controls and emergency cut. To the rear of this operational position is a combined grams, cartridge, and electronic captions unit, the facilities of which are remotely controlled from the desk. This area is normally operated by production staff who give continuity announcements in sound only.

At an additional operating position in the engineering area, facilities are provided for more complex use of the continuity suite whereby the announcer can be relieved of some of his normal duties, permitting him to concentrate on making announcements and on mixing operations.

The equipment controlled from the continuity suite is housed in equipment racks in the Communications Centre.

The continuity audio/video mixer gives audio mixing on eleven channels and video mixing on seven channels. Five channels are married sound and vision sources. A downstream keyer is incorporated with superlock facilities, colour edge, and infill. Married channels may be used in 'bypass to transmission' mode if required leaving the mixer free for closed-circuit recording or rehearsal.

6 Conclusion

Studio C1 and the associated areas have provided BBC staff in Cardiff with far better television production facilities than ever before. Many programmes which have been broadcast throughout the UK have been made there (e.g. *The Enigma Files*) and no doubt many more will follow.

Appendix

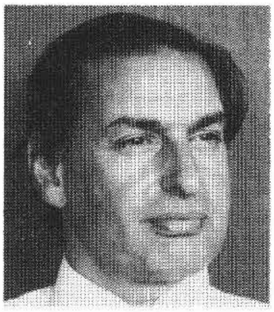
In any large undertaking many individuals and groups of people are concerned. The following indicates only the major groups.

BBC Departments

Studio Capital Projects	Overall responsibility for the project. Detailed technical plant system design and installation.
Transmitter Capital Projects	Additional intake facilities
Architectural and Civil Engineering	Architecture (Chief Architects' Group). Structural, heating and air conditioning, and other specialised work.

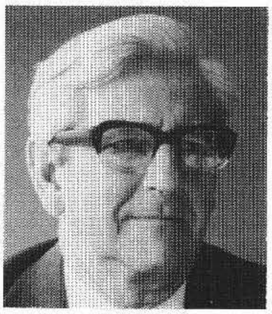
Other organisations

W. S. Atkins and Partners	Initial structural design
Espley Tyas Group Ltd.	Main building contractor
M. K. Boyden and Co.	Quantity surveyor



John Courtney has been in the Architectural and Civil Engineering Department throughout his service with the Corporation. He joined the Department (then known as Building Department) in 1964 on a two-year contract but subsequently obtained a permanent post as an architectural assistant. He became a qualified architect in 1972.

The projects in which he has been concerned are many and various, and include accommodation for Radio London, new local radio stations, refurbishments at Lime Grove, and regional developments in Bristol as well as those in Cardiff described in this issue.



Dan Rattle joined the BBC as a junior maintenance engineer at Daventry transmitting station in 1941. After three years of service with the RAF he returned to the BBC in 1947 as a technical assistant in Research Department. In 1950 he transferred to Television Operations and Maintenance Department and in 1953 to Studio Capital Projects Department (at that time Planning and Installation Department) where he has remained ever since. As a senior planning engineer he has been involved in many major television studio development projects both in London and in the Regions.

Measurement of the Horizontal Resolution of Picture Monitors

J. E. Noakes

Television Engineering

Summary: A prototype instrument has been built to measure the overall amplitude/frequency response of a picture monitor from video input to displayed pattern on the screen. A microscope and slit are used to select the parts of the pattern for measurement and the relative brightnesses are assessed by means of a photomultiplier. The instrument is capable of fairly rapid and semi-automatic operation, and the results are repeatable and consistent with the judgments of experienced staff.

In conjunction with conventional measurements of amplifier performance the new procedure has helped to establish which parts of monitors are principally responsible for limiting their resolution and, hence, where efforts to bring about improvements might advantageously be directed.

1 Introduction

Objective assessments of the resolution of a picture monitor have traditionally consisted of measurements of the gain (as a function of frequency) from video input to picture tube drive. This method of test is fairly easy to apply, provided that due care is taken to ensure that the shunt impedance of the probe does not significantly affect the drive.

A particular type of monitor in use in the television service received a good deal of adverse criticism from operational staff on the score of its lack of sharpness, but measurements of the above type failed to provide support for the complaints. The only explanation appeared to be that the suspect monitor had some serious flaw in its ability to produce the appropriate display in response to the measured electrical drive of the tube, assuming that the operators' opinions had not been affected by other features of the monitor.

What was required was a means of measuring the 'optical transfer factor' which we may define as the ratio of the amplitude of the displayed pattern to the amplitude of the electrical drive which produces it. The 'optical transfer *function*' will be the same thing considered as a function of video frequency. What we mean by the amplitude of the displayed pattern is considered in the next section.

2 The basic problem

The 'obvious' way to measure the optical transfer factor is to proceed as follows.

A video waveform is generated with a sinusoidal oscillation in the picture period. The sine wave is phase locked to the line scanning rate so that every picture line is identical and the waveform produces a display of stationary vertical striations. A travelling microscope is focused on the screen and the image falls on a narrow vertical slit (narrow in relation to the distance in the image between lines of maximum brightness). The light passing through the slit illuminates a photomultiplier and the brightness of that particular part of the image is measured by the current produced. Moving the microscope horizontally by a small amount permits a measurement of the brightness to be made at another part of the cycle. Repeated movements and measurements provide the information for a plot of brightness against horizontal displacement. The amplitude of the cyclic variations on the graph can now be related to the amplitude of the sine wave in the driving video signal in order to yield the optical transfer factor.

It is convenient to measure the peak-to-peak amplitude of the cyclic variations on the graph, which could be recorded in terms of the maximum and minimum currents in the photomultiplier or the voltages produced by those currents in a load. Whatever the units used, however, the figures represent the brightness of small areas of the screen and it is therefore clear that the optical transfer factor cannot be a dimensionless ratio. Fortunately the units in which we express the factor are unimportant because we are not interested in its actual magnitude but in the way in which it varies with frequency – i.e. in the shape of the optical transfer *function*.

Another aspect of the graph has some theoretical interest:

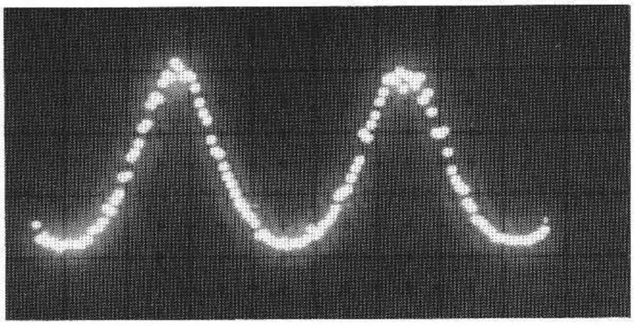


Fig. 1 An example of the display on a storage oscilloscope. The separate points in the waveform correspond to successive pictures on the screen of the picture monitor. The elongated peaks and broad troughs indicate the non-linearity of the relationship between the brightness of the screen and the drive voltage.

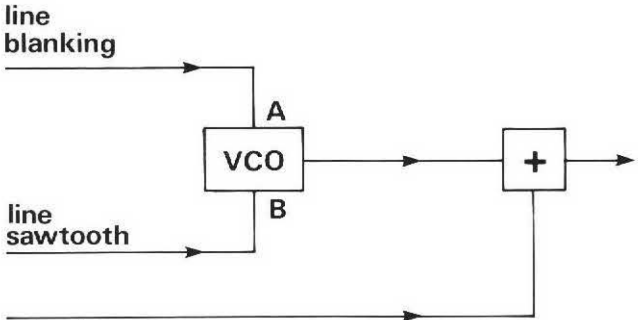


Fig. 2 Normal method of operation of line sweep generator.

its shape is by no means sinusoidal because the picture tube's transfer characteristic is far from linear. Consequently the choice of which feature of the graph to measure is to some extent arbitrary. If the shape of the graph were sinusoidal (like the input waveform), or if it were independent of input frequency, it would be equally valid to choose any measure of its amplitude. In practice, however, the magnitude of the graph decreases as the input frequency increases and, because of the reduction in size, the shape changes, becoming more sinusoidal.

Apart from the problem of deciding what constitutes the appropriate measurement to make on the graphs, the above method suffers from very serious drawbacks. The whole procedure is very slow because of the time taken in adjusting the microscope for each reading, which only produces one point on the graph, and a graph is required for each frequency of input signal in order to obtain the graph we are really trying to determine – that of the optical transfer function.

In addition, and even more seriously, any variations in the effectiveness of the phosphor between the area observed in one measurement and that used for the next, constitutes a limitation of the validity of the result and makes it necessary to cover more than one cycle to reduce such effects. These problems are particularly intractable when measurements are being carried out on colour tubes which, of course, have three different phosphors in arrays of very small individual areas separated by spaces where there is no phosphor at all.

What is required is a method which is as nearly automatic as possible and which provides solutions to, or avoids, most of the above problems.

3 Method

A microscope with a narrow vertical slit is focused on a convenient area of the monitor screen, just as in the 'obvious' method described in section 2, and the light passing through the slit falls on a photomultiplier, so that the light output of that small area of the screen can be assessed. The microscope is not, however, moved to a new position to determine the brightness of an adjacent area of the screen; instead, the pattern displayed on the monitor is shifted across the screen.

This approach, by using the same small area of the screen for all measurements, avoids the problems of finding that different proportions of the slit area are illuminated by phosphor. At the same time it avoids the need for traversing the microscope and suggests straightforward means for making the measurements automatically. All we need to do is to ensure that the shifting of the monitor display is done at a more or less constant rate and that a voltage derived from the current in the photomultiplier is applied to the vertical deflection system of an oscilloscope; the required graph will then be traced automatically. There are still some practical problems to be examined, however, before a working system can be built.

Consider first the nature of the image segment selected by the microscope slit. It is *not* continuously illuminated: to avoid blurring of movement the afterglows of the phosphors must be short, and the current in the photomultiplier must, therefore, consists of pulses at field rate. Because only a very small area of the screen is being examined, there will also be a significant difference between the lace and interlace fields because the areas of phosphor scanned in two fields and imaged onto the slit are most unlikely to be the same. This problem could be overcome by suitable smoothing circuits. The fact that a smoothing circuit would have to suppress a component at 25 Hz draws attention to the very low frequency which the output of the photomultiplier must have.

For the current in the photomultiplier to represent the brightness of the area imaged onto the slit for a particular sample of the displayed pattern, at least 40 ms must be devoted to the observation; i.e. a lace and an interlace scan must occur before we turn to the next sample from the pattern. If we decide that at least 25 'points' are required to define the shape of one cycle of the pattern, then at least one second will have to elapse before that cycle is completed. Thus, we see that the frequency of the output of the photomultiplier must be about 1 Hz or below. An ordinary oscilloscope is not a very suitable instrument for displaying such a waveform. In the experimental equipment a storage oscilloscope was used, but a pen recorder would also be suitable.

As mentioned in section 2, the shape of the waveform displayed (see figure 1) indicates the non-linearity of the picture tube's transfer characteristic and gives rise to the problem of deciding which feature of the waveform should be used to define the optical transfer factor. The shape also depends on the way in which the brightness and contrast controls are set, so the question arises of what is the most appropriate adjustment procedure: it is particularly important to use the same procedure for different monitors which are to be compared with each other.

Both decisions were taken on the same basis, i.e. that the technical purpose of television is to satisfy the human eye. Consequently, the setting up of the picture monitor controls is done in the standard manner which has long been established in the television service, and the feature of the waveform which is recorded is that which is judged to be at least as good an indication of the eye's appreciation of detail as any other – the peak-to-peak value.

The problem of choosing the criterion of amplitude can be approached in other ways. We could, for example, pass the test signal through a gamma corrector, so that the sine wave would be subjected to a pre-distortion process to yield, in principle, a sinusoidal output from the photomultiplier. Another approach would be to replace the sine wave in the test signal by a square waveform which, of course, can be effectively measured only by its peak-to-peak value. Either of these methods would be expected to produce valid results for low-frequency test signals but the shape of the output waveform from the photomultiplier would deteriorate progressively as the frequency was raised and fewer harmonics were accommodated by the system. It is in this higher-frequency region, where they are most needed, that the results would be most in doubt.

The value of adopting such expedients is therefore far from clear and the results obtained using a sinusoidal signal have provided a good deal of useful information. In consequence, no need has yet been felt to pursue any more complicated approach.

The standard practice has been to observe the green phosphor elements only and to turn off the other guns.

The procedure outlined in this section allows each point on the graph of the optical transfer function to be determined in a few seconds.

4 Equipment

4.1 Picture monitor display

The equipment which produces the shifting display is a modified form of a commonly used test device. In its unmodified state it generates a normal video waveform with a test signal in the picture period: the test signal produces a display on a picture monitor consisting of variable-pitch vertical striations which are coarser on the left and finer on the right. Figure 2 shows the way in which the generator works, in as much detail as is required for the present purpose.

The voltage-controlled oscillator (VCO) is inhibited during the blanking period by the waveform at its input A, so that it starts to oscillate at the beginning of each picture line. The frequency of the oscillation is controlled by the voltage at input B and the use of a line sawtooth at this point produces the gradation of the striations across the picture width.

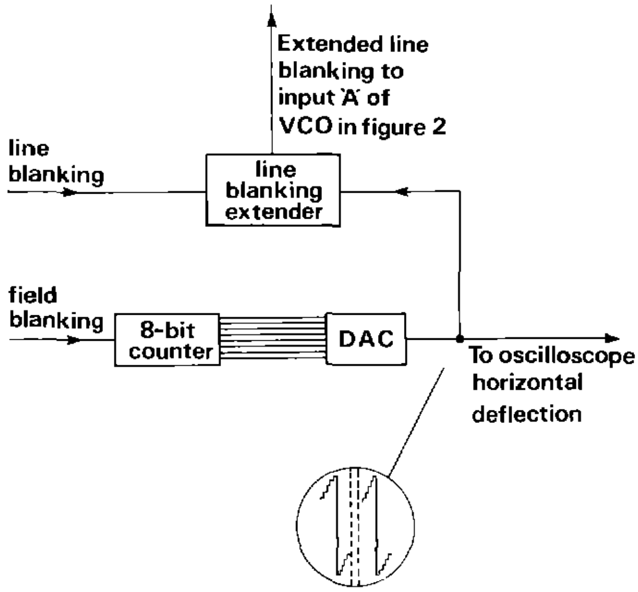


Fig. 3 Generation of oscilloscope sweep drive and modified line blanking.

To make this equipment suitable for the measurement of optical transfer functions two modifications were carried out. The line sawtooth waveform was disconnected from the control input (B) of the VCO and its place taken by a switch connected to a number of different DC supplies; and between the blanking signal and the inhibit input (A) of the VCO a delaying system is inserted. The first modification provides for the use of a selection of pre-determined constant frequencies instead of the variable-frequency picture signal of the unmodified equipment, and is easily achieved: no further discussion of it is required here.

The second modification is more interesting. Figure 3 shows how the field-blanking signal drives an eight-bit digital-to-analogue converter (DAC) to produce a 256-step staircase which is used to drive the horizontal deflection system of a storage oscilloscope (or chart recorder). The same stepped waveform is used to extend the line blanking waveform, the timing of the trailing edge of which is determined by the voltage reached by the step waveform. Thus the width of the modified line blanking delivered to the output increases by one step at each field until the maximum width is reached and the process is automatically repeated, starting again from the normal blanking width. This is the signal connected to the VCO at point A in figure 2, so that the pattern is stepped across the screen by one very small increment at each field.

It is interesting to note that no filtering is necessary at the output of the DAC: there is no need to convert the stepped waveform into a smooth sawtooth. Because the waveform is used unfiltered the timing of the trailing edge of the line blanking signal delivered from the output (C) is constant throughout any given field and the pattern displayed is truly vertical. If filtering were employed to give a smooth sawtooth waveform the duration of the modified line blanking signal would increase slightly from one line to the next so that each line would carry picture information displaced a little to the right of that conveyed by its predecessor. The

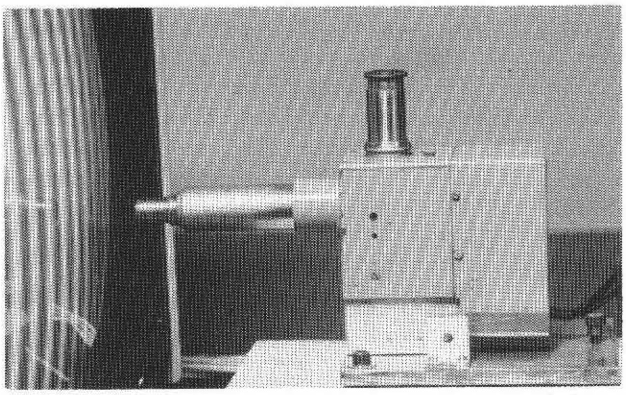


Fig. 4 Prototype microscope unit focused on screen of picture monitor. The eyepiece for setting-up purposes protrudes from the top of the case and the photomultiplier is housed in the compartment at the back.

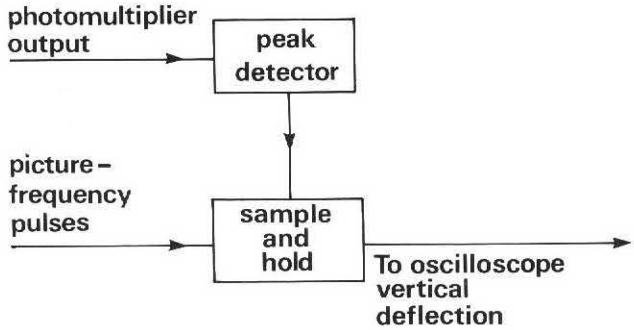


Fig. 5 Signal processing.

'vertical' lines would therefore be inclined slightly. The difference between the two types of display would be undetectable to normal observation and also to the type of measurement considered here where only a few consecutive lines in only one field of the pair are used.

4.2 The microscope

The function fulfilled by the microscope is the selection of a small area of the screen for the purpose of assessing its light output. The essential aspect of this requirement is clearly carried out by the slit: magnification is needed only to a degree sufficient to permit the slit to perform its function effectively. The vertical extent of the slit is unimportant, but the horizontal extent must be small compared with the distance between lines of maximum brightness on the screen, *referred to the plane of the slit.*

In setting up, the microscope is aligned on a suitable part of the screen by checking the image visible through the eyepiece (figure 4) but in operation the light is directed instead to the photomultiplier at the back. It is important to align the microscope so that the maximum area of illuminated phosphor is imaged onto the slit. Clearly, this will increase the sensitivity of the system, but there is another reason why it is undesirable to allow the slit to select the edges of illuminated phosphor elements: if this happens, the arrangement is particularly sensitive to mechanical disturbances. Very small movements of the microscope relative to the screen result in substantial changes of the area of illuminated phosphor 'seen' through the slit and thus in marked variations of current flowing through the photomultiplier. In such circumstances it is very difficult to make reliable measurements.

4.3 Signal processing

The light passing through the microscope and falling on the photomultiplier produces a current which, in turn, yields a

TABLE 1

f (MHz)	Screen Pattern				Video Drive				Optical Transfer Ratio	
	Peak	Trough	P-P	Relative Level % (X)	V_k	Cross-talk	Net	Relative Level % (Y)	(X/Y) %	
0·5	3·5	0·25	3·25	100·0	7·0	0·1	6·9	100·0	100·0	Monitor A
1·0	3·3	0·3	3·0	92·3	7·0	0·23	6·77	98·1	94·1	
2·0	2·9	0·4	2·5	76·9	7·0	0·36	6·64	96·2	79·9	
3·0	2·6	0·6	2·0	61·5	7·0	0·49	6·51	94·3	65·2	
4·0	2·2	0·8	1·4	43·1	7·0	0·62	6·38	92·5	46·6	
5·0	2·0	0·85	1·15	35·4	7·0	0·75	6·25	90·6	39·1	
0·5	3·5	0·2	3·3	100·0	10·0	0·15	9·85	100·0	100·0	Monitor B
1·0	3·5	0·2	3·3	100·0	10·2	0·3	9·9	100·5	99·5	
2·0	3·3	0·2	3·1	93·9	10·2	0·5	9·7	98·5	95·4	
3·0	2·9	0·3	2·6	78·8	10·2	0·8	9·4	95·4	82·6	
4·0	2·6	0·4	2·2	66·7	9·5	0·9	8·6	87·3	76·4	
5·0	2·4	0·5	1·9	57·6	9·0	0·9	8·1	82·2	70·0	
0·5	3·5	0·2	3·3	100·0	8·4	NEGLIGIBLE	8·4	100·0	100·0	Monitor C
1·0	3·4	0·2	3·2	97·0	8·2		8·2	97·6	99·3	
2·0	3·2	0·3	2·9	87·9	8·2		8·2	97·6	90·0	
3·0	3·0	0·4	2·6	78·8	8·2		8·2	97·6	80·7	
4·0	2·6	0·5	2·1	63·6	8·3		8·3	98·8	64·4	
5·0	2·4	0·6	1·8	54·5	8·6		8·6	102·4	53·3	

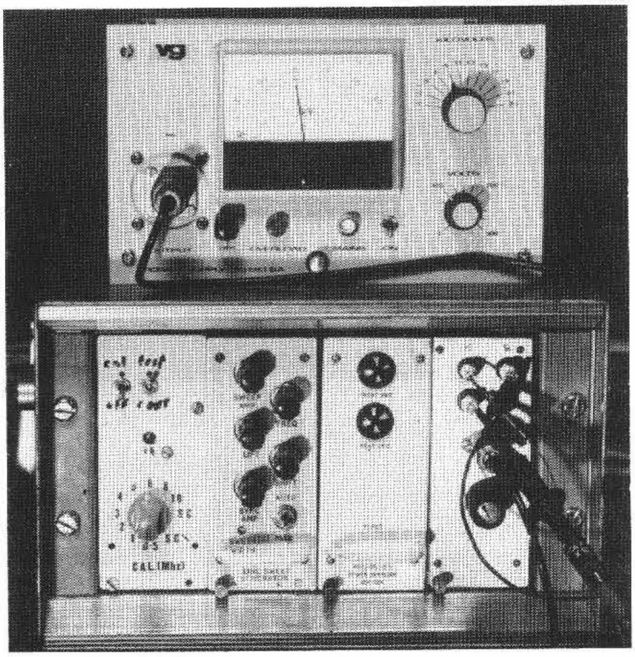


Fig. 6 The prototype electronic unit.

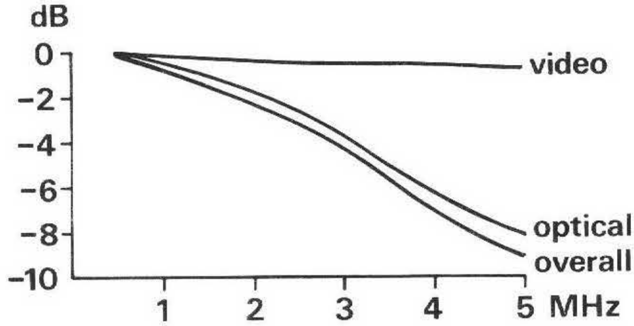


Fig. 7 The performance of monitor A.

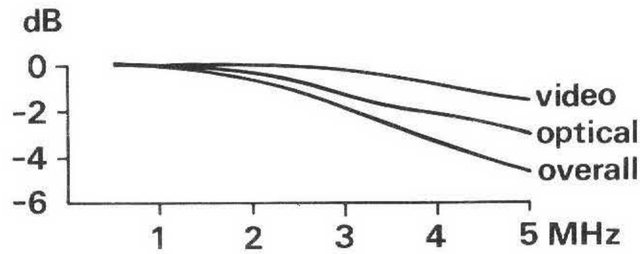


Fig. 8 The performance of monitor B.

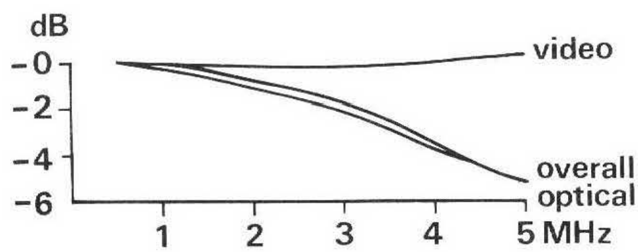


Fig. 9 The performance of monitor C.

voltage in a suitable load. This voltage is fed to a peak detector (see figure 5) the output of which is connected to a sample-and-hold circuit driven by pulses at picture rate. Immediately after each sample is taken, the capacitor which is charged by the detector is automatically discharged, ready to accept the new charge during the new picture period. Each sample therefore represents the peak light flux through the microscope slit during that picture period, regardless of whether that flux was produced by the first or the second field. It is therefore unnecessary to arrange that the area of illuminated phosphor imaged onto the slit in one field is the same as that in the other.

Each discrete sample produces its own point on the display device, giving a 'dotted' representation (see figure 1) of the required trace of brightness of the picture monitor screen against horizontal displacement. The photograph shows the slight irregularity of the curve produced by noise and other disturbances, but the number of points is quite large enough to give, as a rule, a clear idea of the shape of the curve and, in particular, of its peak-to-peak amplitude. Occasionally there is sufficient irregularity near the peaks to leave significant doubt about the correct value. When such confusion arises, another sweep quickly clarifies the position. Figure 6 is a photograph of the prototype electronic unit.

5 Results

The experimental equipment described in the preceding sections was used to investigate the overall performance of the type of monitor referred to in section 1. Two other types of picture monitor were also tested and the observations on the three types are set out in table 1. The type which had been criticised for poor definition is referred to as type A and the other two types as B and C.

The amplitude of the input sine wave is independent of the frequency and so the figures under the heading of 'Screen Pattern', which are straightforward linear measurements of such displays as are shown in figure 1, can easily be normalised and expressed as percentages (column X) to give an indication of the overall performance of the monitor. The figures in the section of the table headed 'Video Drive' are voltage measurements at the picture-tube electrodes, measured by the traditional method of connecting a probe to the appropriate pins. Allowance is made for cross-talk picked up on the grid of the tube, so that the normalised result in the last column of the section (Y) accounts for all factors except the conversion of the electrical drive of the picture tube to its optical output. The normalised optical transfer factor is therefore easily found by dividing the figure in column X by that in column Y. The result (expressed as a percentage) is given in the final column of the table.

Plots of the optical transfer functions of monitors A, B and C are given in figures 7, 8 and 9 respectively. In each case the performance of the video amplifier and the overall characteristic are also shown and it is immediately clear that for monitors A and C the optical transfer function is the main influence on the overall performance. The same

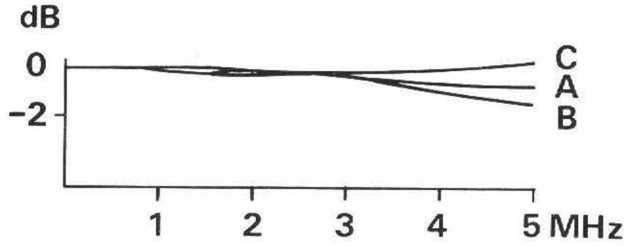


Fig. 10 The overall performances of the three monitors.

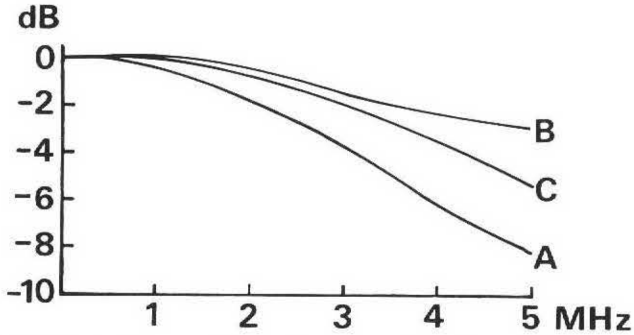


Fig. 11 The video amplifier performances of the three monitors.

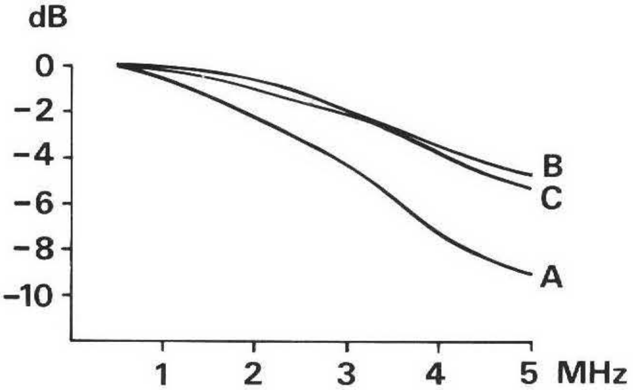


Fig. 12 The optical transfer functions of the three monitors.

curves are re-grouped in figures 10, 11 and 12 with the overall performance curves in figure 10, the video amplifier characteristics in figure 11, and the optical transfer functions in figure 12. These groupings show at once that monitor A is significantly worse than either of the others both in optical transfer function and in overall performance. They also show that monitor B, which is marginally better overall than C, achieves this position, in spite of having the poorest amplifier performance, by means of an optical transfer function which is by far the best.

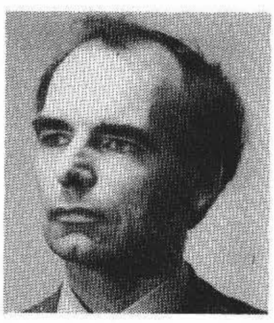
The results show differences between types of monitor which are substantially greater than the differences between speciments of one type. They indicate ways in which existing types might be improved: type B, for example, might be made even better by relatively simple modifications to its video amplifier; type A might be improved by precorrection in the video circuits to compensate for the shortcomings of the optical transfer function. (This last possibility could only be a partial solution if, as seems likely, the poor optical transfer function is a result of an excessive spot size, unless vertical aperture correction techniques were employed as well as ordinary equalisation or amplifier modifications).

The differences between the type B and type C monitors are also interesting. These monitors use the same picture tube but have different voltages on the first anode. Possibly better results could be obtained from type C monitors with a modified first-anode supply.

6 Conclusions

The system described in this article is capable of measuring the detail-resolving performance of a picture monitor right up to the screen. The method is reasonably quick and semi-automatic, and avoids difficulties with the screen structure of colour monitors. The objective results it gives correlate well with the subjective impressions of experienced staff.

It is possible to distinguish between different effects that limit resolution and hence to draw useful conclusions about the types of remedial action most likely to lead to improvement.



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From 1964 to 1971 he was involved in providing on-station training for technical assistants and direct-entry engineers. Since that time he has been concerned with technical investigations in Television Engineering.