## THE LECTURE

### Telecommunications—The Next Ten Years

Broadcasting grew out of telecommunications less than fifty years ago when engineers, largely to amuse themselves, but also as part of their experiments to transmit telephone conversation by radio means, started putting out music and talks at odd intervals. The interest these experiments aroused was immediate and widespread, and so broadcasting was born. The lecture deals with the inter-relations of telecommunications and broadcasting. It reviews past and current practices in these fields and deals with developments in radio frequency and wire communication for both types of service.
Colour television will be introduced, during the next decade, into all countries with existing networks, and it seems unlikely that by the end of the decade there will be any leading countries without a colour service.
The possible use of satellites in world communication and for broadcast coverage of large areas of the Earth's surface will be discussed in some detail. Basic requirements for the transmission and reception of information are considered, and the effect of new developments on the operational side of the industry and methods of manufacture; also the effects of these developments as they influence man-power needs and man-power training.

## THE LECTURER

### F C McLean

Francis Charles McLean CBE is Director of Engineering of the British Broadcasting Corporation. He began his career as Radio Engineer with Standard Telephones and Cables, from 1925 until 1936, working on the development of broadcasting equipment and the construction of broadcasting stations in many countries in Europe.
He joined the BBC on January 1 1937 as Head of Radio Section in the Design and Installation Department. Then he was seconded to SHAEF from 1944 to 1945 and then in 1947 he rejoined the BBC as Acting Head of Overseas Engineering Information Department. Following this his appointments were as follows: Head of Engineering Services Group in 1949; Head of Engineering Projects Group in 1950; Acting Assistant Chief Engineer in 1951 and Assistant Chief Engineer in 1952. In 1954 he left for Karachi to advise the Pakistan Government on development of Radio Pakistan. On April 19 1960 he was appointed Chief Engineer, a title later changed to Deputy Director. It was announced on January 10 1963 that Mr McLean would succeed Sir Harold Bishop as the Director of Engineering on the latter's retirement on May 10 1963. He was awarded the CBE in the 1953 Coronation Honours List. In 1965 he was awarded the grade of Fellow of the Television Society.

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*'Communication in the Modern World'*

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# THE GRANADA LECTURES 1966

Eighth Year

Three lectures given in the Guildhall, London, during October, on Communication in the Modern World.
The First Lecture:
'Telecommunications—The Next Ten Years'
by F C McLean
Chairman: Professor Sir Bernard Lovell
Monday 17 October at 8 30 pm.

Organised jointly by Granada Television and the British Association for the Advancement of Science.

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THE BRITISH ASSOCIATION/GRANADA GUILDHALL LECTURES

"Telecommunications - the next ten years"

by F.C. McLean, Director of Engineering, B.B.C.

17th October 1966

Telecommunications and broadcasting are more than related subjects. The one is communicating at a distance in general, and the other is just the same except the communication is one-way only. I would like to show that broadcasting, defined as a means of "information, education and entertainment", and often looked at as almost entirely a means of entertainment, does in fact make appreciable contributions to the science and practice of communication. This it does in two ways. Directly in the new devices and practices which it itself initiates such as those in the television field, and indirectly in the money and resources attracted to technical developments by reason of the great public interest and financial support that broadcast arouses. In its own output broadcasting can be at times superlative but it can also be futile, but in its contribution to telecommunications it is almost always very useful.

Broadcasting grew out of telecommunications less than fifty years ago when engineers, largely to amuse themselves, but also as a part of their experiments to transmit telephone conversation by radio means, started putting out music and talks at odd intervals. The interest these experiments aroused was immediate and widespread and so broadcasting was born. It was born not to meet an expressed public demand but because imaginative experimentation was to reveal a service which would appeal to the public. Something of the same kind was to happen some ten or fifteen years later when television began after a similar process, although in this case the public welcome was slow in coming.

The earliest radio transmitting equipment was naturally converted telecommunication transmitters and the first microphones were, of course, telephone microphones. The crystal receivers were those already in use in telecommunications as were also the valve receivers. Since that time broadcasting has gone on and on and continued to draw much from telecommunication practice, to make use of all new advances and to plan the developments in its own services so as to make the best use of those in related fields. On the other hand broadcasting has contributed much to communications both in the civil and the military fields. Television was started as a purely broadcasting interest, and while television did not invent either the cathode-ray tube or the use of pulse techniques, it did further the development of these very considerably, and it has added to the development of improved methods of transmission of images, data and the like. War-time radar used these television techniques, whilst the basic phenomenon of the reflection of radio waves had been noticed in observations made on short-wave transmissions from Daventry.

This interchange of ideas and developments is likely to continue indefinitely with advantages to both services.

As in most fields, developments very occasionally come spontaneously but the greater part of all developments comes from efforts to meet an envisaged or declared public need, while the recognition of a public need supplies the resources and the incentives to encourage the development.

But while they are co-operative in so many areas telecommunications and broadcasting are very competitive in others. Telecommunications serve the newspaper world and increasingly the data exchange interests, direct communication between individuals and between group interests, while broadcasting deals with the public directly. This leads to the most direct competition between the broadcasting and telecommunications' interests. Frequencies absolutely determine the kind of service that can be carried and, as for many activities telecommunications and broadcasting are interested in similar distances, both need the same bands of frequencies, because the distance to be covered largely determines the frequency band which may be needed.

Telecommunications and broadcasting both started on the lower frequencies. This was partly because these frequencies were easier on which to develop appreciable power, and hence were first used for the early work and experiments, and partly because of the properties of these frequencies. It is of interest to note however that, for some of the earliest experiments of Lodge and Hertz carried out in the latter part of the last century, many high frequencies were used - higher in frequency even than those recently bought into service for BBC-2. Development of even higher frequencies is undoubtedly the direction of many new services in telecommunication, but not all new services - at one time it appeared that interest in and the use of very low frequencies was almost at a minimum, but examination of the potentialities of such frequencies in the light of the precise measuring methods now available, led to the development of such successful devices as the Decca Navigator system which uses very low frequencies indeed. The lesson is that radio frequencies are so scarce and have such individual characteristics that none can be rejected and the telecommunication engineer must always be ready to reconsider their use and, at times, perhaps reconsider his own ideas on the best way to use them. No frequency can ever really be considered as outmoded although the use to which it is put can be very much changed. In the early days there was a fairly clear demarcation in the uses of frequencies. Low frequencies, usually speech or telegraph frequencies, were conveyed over wires, whilst any frequencies higher than this were radiated by an aerial. There are however very great advantages in transmitting high frequencies either along wires, through pipes or even along the inner and outer surfaces of a wire or tube.

Except for reflected services such as short-wave broadcasting and radar, the lower the frequency the greater the range. The tendency has been, therefore, to use the lower frequencies first and these are therefore very well filled. Subsequent developments in any field naturally are pressed more and more to use the higher frequencies. It is true to say in communications, as in other fields, that there is more than 'room at the top'. But it is equally true to say that you should get in on the 'ground floor', that is on the lower frequencies if you can. As a general rule there is an advantage in using as low a radio frequency as possible for any given service. But when the low frequencies are being fully used then the higher frequencies must be taken up. But that a band of frequencies is fully used must not be decided too lightly. That the lower frequencies were fully used was, however, the case when BBC-2 was started; although there was a little space in the lower frequency bands used for the existing BBC and ITA programmes, it was insufficient for a complete new service. The UHF band was the only suitable band available and the exploitation of UHF band frequencies for broadcasting then started with the introduction of this service.

In this band there are sufficient channels available to permit the introduction of a total of four networks, and the first of them is constructed to cover the United Kingdom for BBC-2. To give complete coverage it will need about sixty high-power transmitters, several hundred low-power transmitters, and perhaps a thousand or more very low-power transmitters to give a purely local service. All these transmitting stations will be designed and sited so that they will be suitable eventually for four programmes, and of course they will all be designed to handle colour as well as black-and-white transmission

The large number of stations required is because of the screening effects on the receiving signals which become more apparent with the higher frequency. Radio waves are electro-magnetic waves akin to light waves, although the frequency of the waves used for normal broadcasting is many million times lower than the frequencies to which the eye is sensitive, and which we know as light waves. The characteristics of the electro-magnetic waves used for broadcasting vary from those of the low frequencies such as those used in medium-wave broadcasting where the waves will bend round obstacles and the curvation of the earth, and will penetrate solid matter as long as it is non-conducting, to the characteristics of the light waves which will not bend round obstacles or the curvature of the earth, and will not penetrate solid matter unless it has the particular property that we call translucence. The waves used for UHF are in the indefinite area where they will bend a little round obstacles and over the brow of a hill, but will not bend round the curvature of the earth, and will penetrate non-conducting solid matter only very slightly. We therefore have to have many more times the number of transmitters on UHF than on VHF if we are to give a complete coverage.

In addition if we are to get the best reception we need a receiving aerial which is both unobstructed and unenclosed. If we look at a few figures for transmitter requirements, we see that in medium waves, that is frequencies of the order of 1 Mc/s, we get a complete coverage of the United Kingdom on the Home Service with 28 stations. Moving up the frequency band to VHF television, used by BBC-1 and ITA, that is from 50 to 200 Mc/s, to give a comparable coverage we need nearly 100 stations for each service. Increasing the frequency to 500 Mc/s, used in UHF, we find we need perhaps 300 stations of appreciable power and perhaps another 1,000 of very low power. This process will go on as we get to higher and higher frequencies. There are other bands up to 12,000 Mc/s and above which could be used for broadcasting, and which indeed may have to be used for broadcasting sometime, but nobody will want to use these frequencies until the possibilities of the lower bands are fully deployed, as the number of transmitters will get ever higher if we are operating from ground-based stations. These higher frequencies may, however, have to be used for broadcasting from satellites. If we ever do this there will then be a complete reversal of the trend, in that one frequency and one transmitter would give a coverage of the whole of the United Kingdom and indeed would cover a very much larger area than this. Here again it is a possibility, perhaps remote for a small area such as the United Kingdom but perhaps not so remote for a big area such as the Americas or Africa, that broadcasting can profit from the development of communication by satellite so far entirely fostered by telecommunication interests.

This question of the frequency to be used and the way it is to be used is a vital one for all forms of telecommunication, whether for broadcasting or for point-to-point services. For any communication problem the first point to be settled is whether it is better to carry out the communication by radio waves or whether to do it with wires. Wires, of course, were the first in the field, being used from the invention of the electric telegraph in the early nineteenth century, under the sea in cables - the first transatlantic cable was laid in about 1880 - and of course in nearly all forms of short distance point-to-point communication between fixed points. Radio started towards the end of the 19th century and since then there has been a continual see-saw in all aspects of the communication fields between the wire and the radio circuit. Transatlantic communication started with wire with the telegraph cable, then moved to radio for the first of the transatlantic telephone circuits, and it now seems firmly established by wire with the latest cables with amplifiers in them. It would be a foolish man however who would say that radio would never come back into such transatlantic traffic. Indeed this is perhaps already being done with the advent of communication by satellite. In the communication world we see on the one hand enormous investment in satellites and their associated ground stations, and on the other large and long-term investements in cables and in new cable-laying ships going on at the same time.

For conditions of very high density traffic between two points the wire, whether it is an actual wire or a tube conveying electric waves, seems to have an economic advantage. This advantage grows as methods are found of imposing not a single message but perhaps thousands of messages on a single wire or conducting tube. But for traffic of lower density and over difficult terrains radiated signals seem to have the advantage.

The principle is, however, not rigid, and developments of method and local conditions can and do move the balance one way or the other.

For the conveyance of messages to a widespread audience, as in broadcasting, radiated waves seem to have, except in special conditions such as densely populated areas or difficult valleys, a very definite advantage. It represents the quickest, and by far the cheapest, way of bringing messages, whatever their content, to the individual and is much cheaper than the printed word or letters. But still in special circumstances wire can still have the economic advantage, and this can apply in some areas to wire distribution for radio and television. In areas of high concentration of population, blocks of flats and so on, wire distribution can give a high-quality service, in most cases better than the radiated service, and because of the simplicity of the receiving equipment required, at a lower overall cost. We can therefore expect that, with the increasing construction of high buildings in towns, there will be an increasing use of distribution by wire of sound and television programmes within a city or a new town. The individual feeds may, however, come either by wire from a central point, or may be received on the roof of the building from a radiated signal. At least for many years, and certainly over the whole of the next decade, a greater part of the coverage, especially when measured on an area basis, must originate from radiated signals and the arrangements to provide these radiated signals must be such as to cope with the increased services to be provided. Many new towns are being fitted with wire distribution systems to bring all forms of broadcasting to the listener and viewer, with an improvement to the standard of service given and the elimination of the outdoor receiving aerial.

In some countries broadcasting programmes are transmitted to the individual over his telephone line. In time this is likely to become more widespread, or the presence of a telephone line, used in conjunction with the developing techniques of sending many simultaneous messages over one line is likely to be developed to carry many different services, and indeed different types of service to the individual subscriber. It is not impossible that at some time letters will not be delivered individually but will be transmitted electronically and delivered in facsimile to the recipient. Newspapers may follow the same line.

In the very long term we have to expect that nearly all services to and from fixed points will be by wire and that radiated services will only be used for communication to and from moving objects. It will, however, be at least 50 years before this stage of telecommunication development is reached.

What are the increased services that we can expect from broadcasting in the next few years? Well, firstly there will be colour television to be introduced in all countries into their existing networks, and it seems unlikely that at the end of this decade there will be many of the leading countries that will not have a colour service. In the U.S.A., after a slow start, colour is going ahead very rapidly and by the '70s seems certain that nearly all homes in the U.S.A. will have a colour receiver. The growth of programme exchange facilities throughout the world will tend to foster this development, and all telecommunication facilities to be provided must be such that colour signals can be transmitted. For some years now all telecommunication developments have been planned with this in mind. It means that programme links, whether they are provided by cable or by radiated signal, must be of high quality.

A black-and-white picture of reduced quality, that is, reduced sharpness and reduced contrast, can be transmitted without the viewer becoming too concerned, if the programme interest is sufficiently high. In colour transmissions, however, any reduction in sharpness of the picture often affects the colour signals, and the loss of picture quality is not only in picture sharpness but in colour fidelity or maybe even in loss of colour and is therefore much more marked. There is no doubt that the telecommunication engineers all over the world have this well in mind, and that this requirement will be fully met by the wire, cable, radio and satellite communication being built and planned.

The pictures of the World Cup were seen by 400 million viewers all over the world after transmission by every form of communication - wire, radio, cable and satellite. Within the next ten years such pictures will be seen in colour by even bigger audiences.

The problem of the worldwide exchange of colour television programmes would have been simpler had it been possible for the nations to have agreed on a worldwide basis the use of a single colour system. However, as we have seen from the results of the Oslo Conference, this has not been done: not only have we the almost inevitable split in the world between the 50-cycle power supply areas, such as Europe and parts of Asia and Africa, and the 60-cycle power supply areas, principally in North America and South America, but the nations have been unable to agree on the best colour system to be used even in the 50-cycle power supply areas. This means that the programme exchange links to be provided throughout the world must be capable of dealing with any of the various types of system used, while the facilites to be provided with the programme links must be such as to enable conversion to be made from one system to another.

This multiplicity of systems will also affect the prospects of direct broadcasting from satellites for reception in the home. This would be of particular importance in considering broadcasting to large areas of the world.

The whole of the radio frequency spectrum space can be considered as divided up into channels, the minimum width of each channel being determined by the amount of information, or picture detail in the case of television, to be transmitted; the more the detail, the greater the bandwidth - 5 Mc/s for 405 lines and 8 Mc/s for 625 lines. Hence the higher the definition of the television signal to be transmitted the less the number of channels which can be found. If, however, means can be found of some way of compressing the information or picture detail into a smaller space, then the channel bandwidth can be reduced and more channels can be accommodated and hence more services can be given. In one way this is already done in communications where it is almost universal to transmit only one sideband of a signal that basically consists of a carrier and two sidebands. One of these and the carrier is therefore omitted. In television over communication links we do the same thing but, for reception by the public, to do this would lead to a very expensive receiver. For reception in the home we therefore send not only one sideband, but also the carrier. The principle is however the same, to send no more than the minimum signal.

The ever-increasing shortage of spectrum space for all communication services is encouraging further efforts to save spectrum space. In a television service we are sending 25 complete pictures every second and each of these is complete in itself, that is, each pictures sends all the detail present in the picture. The changes in picture content from one picture to the next is however very small - for instance the background may not change at all for a relatively long period.

So, if we could transmit only information about the change in picture detail that has occurred between one picture and the next, i.e. the change in picture content that has occurred in one twenty-fifth of a second, which is usually very little, we should need to transmit very much less detail. The unchanged information is what we call redundant information and the aim of the communication experiments is to avoid transmitting "redundancies". A lot of work is going on in laboratories all over the world to try to find means of reducing the tranmission of redundancies whilst not losing picture quality. Speaking in terms of spectrum space it requires a large bandwidth to reproduce the smooth gradation from black to white that we now use. If, instead of this continuous gradation, we could adjust the brightness in a reasonably small number of steps, say 25, of brightness without seeing steps in the picture, we could achieve a considerable economy in transmission. That is if, as in some forms of communications, we can accomplish transmission of information in finite steps instead of in smoothly varying quantities, we should be able to achieve considerable simplification and hence economies. It is perhaps in some way analogous to the computer which achieves its objects by a very rapid repetition of a simple "on"/"off" or "yes"/"no" operation, and achieves multiplication by very rapid additions, each step of the addition being a very simple process. Multiplying up the number of operations is not too expensive provided that the operation itself is not too difficult. In the work that has been going on to try to avoid redundance of the transmitted information, I am not talking about lack of quality in programmes, but only of trying to avoid sending that part of the picture which is unchanging from one scene to the next and storing it up for use repeatedly until the scene changes.

You will remember that many years ago Mark Twain demonstrated the effect of reducing redundancies when in one of his short stories he inserted footnotes and references for items about the weather and the better known clichés, and hence reduced the length of the story considerably. Whilst one can hope to eliminate the redundancies in the technical aspects of broadcasting, the elimination of these from the programme content would be a serious matter, perhaps improving the programme as a mental exercise but not as an entertainment, and perhaps reducing some programmes to an unacceptable brevity.

Work to reduce technical redundancies is being done in broadcasting spheres but the greater part of the work is, of course, being done by those bodies directly concerned with telecommunication. The revenues to be earned and the resources and the amount of money available to the telecommunication authorities are so much greater than those at the disposal of the broadcasting people that inevitably most of the work must be done by such authorities. Moreover, of course, the final use of such devices is bound to be on the programme links as such devices are likely to be prohibitive in cost for the ordinary viewer, although this too may come one day. Work is being done by the broadcasting authorities to try to assess what degree of picture degeneration would be acceptable to the broadcast audience if such systems were used. This kind of work in one way means trying to put a quart into a pint pot and inevitably something must be lost in the process. The realisation of this led to the NTSC colour television system being evolved. This system in fact puts the additional information required for the colour signal into the space usually filled by the black-and-white signal and, while this is perhaps not putting a quart into a pint pot, it is certainly a pint-and-a-half. All the colour systems being considered for adoption by the world use this basic principle.

Also analogous to this choice of system is the use of stereophony in sound broadcasting, where we have the problem of sending in the frequency space occupied by a normal sound transmission two separate series of sound waves in such a manner that they can be separately reproduced and so the listener can hear separately the two series of waves and hence get his stereophonic effect. As in colour television a separate sub-carrier, located with a specific reference to the carrier carrying the main information, is used.

As far as the United Kingdom is concerned one of the most important developments required during the next decade is to solve the problem posed by the dual standard, that is, the 405-line/625-line operation in television. In 1936 the United Kingdom was the first in the world to start public television and it did it on 405-lines. It was then, and still is, a very good system.

In 1964 following the advice given by the Television Advisory Committee and the Pilkington Committee a second programme of television was started on 625 lines, to be in conformity with Europe, with the intention that in due course the two existing services should be changed over from 405 lines to 625 lines. This changeover problem is, however, one of enormous difficulty. The difficulty stems basically from two causes. Firstly that the comparatively low frequencies used for the 405-line services give a very complete coverage, and there do not seem to be any additional low frequencies available which could give equivalent coverage on 625 lines. With the passage of time this aspect of the problem becomes more difficult as more and more relay stations on 405 lines expand the coverage on this standard and increase the value of the service to be replaced. Every improvement made to 405-line service makes it that much harder for 625 lines to replace 405.

Secondly, there are some thirteen million receivers for 405-line reception on these low frequencies in the hands of the public, and the public would naturally expect to have the continued use of the receivers that they have without interruption. Any idea of modifying within a short space of time the receivers in the hands of the public from 405 lines to 625 lines is quite impossible, and the changeover can only be carried out when all the receivers are dual standard, but this is, of course, gradually being done. To modify nearly two hundred transmitters serving the 405-line public on these Band I and Band III frequencies all at the same time in such a way that there would be no interruption to the service to the public is quite impossible, but it may be that some way could be found of doing this in stages. The duplication of the service on UHF is another possibility, but here we have the difficulty that, because of the very difficult propagation characteristics of UHF waves, it is very hard to see how UHF could fully replace VHF, although it may be possible to do so on a mixture of VHF and UHF. There is a possibility that by changing the form of the sound signal modulation for VHF we might be able to make better use of the VHF channel and thus ease the changeover. Here again, however, the receiver could be somewhat more costly and discussions are going on with the receiver industry to get their views on the matter.

In one way or another this problem will be solved, and by some time in the '70s we should be able to look forward to a television standard in the United Kingdom common with that in other countries in Europe, and to the easement of the problem of programme exchange in both black-and-white and colour that this will bring. Incidentally it will also help international exports of colour transmitters and equipment as it will no longer be necessary to build special models of receiving, transmitting and studio equipment specifically for the British market.

The last decade has seen remarkable advances in the design of equipment for all forms of telecommunication, including domestic reception at home. For many purposes the valve, which had indisputably held sway in telecommunications for nearly fifty years, is now completely out of use and has been replaced by one or other of the various semi-conductor devices usually known as "transistors". These devices were first introduced in 1948 and at that time were almost scientific curiosities, although they had some affinity with the crystal detectors and the so-called oscillating crystals of the old "cat's whisker" reception days. They made rapid advances in both the applications to which they could be put and in the remarkable reduction in price that followed quantity production. Within a few years the devices that had been scientific curiosities only available to privileged bodies and at a high price were in common use in the cheapest forms of receiver. Important forms of semi-conductors were used, and are being used almost exclusively, in telecommunication equipment. The latest development of this is in the so-called "integrated circuit" which is used for a number of purposes in rocketry, satellites and most complex developments of this kind, but is also coming into use in normal domestic receivers. The first step in this direction was the printed circuit which is now in common use in all types of equipment, whether it be equipment which is made in thousands or millions, or whether it is specialised equipment of which only a few examples are made. This technique was introduced about fifteen years ago and is now widespread in both professional and domestic equipment. The connection between the various components of the circuit are formed by the deposition of copper film by a photographic process on to a suitable base. The components used, however, are quite conventional although of small size, and are soldered into position.

The second development stemming from this was the so-called "thin film technique" which used printed circuit principles, but the actual components of the circuit, that is to say, the resistors and the condensers, were formed directly by an evaporation process on to the suitable insulating base. The circuit components were thus no longer of the conventional type. This process had the great advantage that complex circuits could be built up in a very small space and by control of the devices during the manufacturing process the circuits could be made to a very high degree of accuracy.

Here then, the process enabled many small components to be formed and also enabled the high degree of accuracy of repetition essential for complex circuits to be achieved. The next step after this is the integrated circuit in which literally microscopic size circuits are formed on the surface of a semi-conductor base. This is so far a relatively expensive process but the costs are falling rapidly and for some purposes are already within the price limits for domestic equipment. The weight and space occupied by these circuits are, of course, minute even compared with other techniques, and it is hard to find a word comparing the weight and size of these with the equipment of some twenty years ago. It has been published that 95% of the electronic functions of the computer in the Minute-man are now performed by 2,144 integrated circuit chips which altogether weigh less than one-tenth of an ounce. A sliver of semi-conductor with integrated circuits formed on it can carry perhaps 40 discrete electronic components, suitably connected together and yet small enough to go through the eye of a needle. In a world of rising prices these developments have actually reduced costs in many instances. Although the equipment required for their production is expensive, the resulting product contains much less raw material and uses up much less hand work in its completion, therefore the overall cost is less.

The new developments of which I have been talking can find application in illegal as well as legal uses. The small size of printed circuit and integrated circuit components and the very small power that they need to operate them make them ideally suited for operations such as the "bugging" of various locations. It will soon be difficult to think of any hiding place so small that it cannot accommodate a little transmitter of this type.

With equipment of these kinds, and indeed it is becoming increasingly the case for telecommunication equipment of all kinds, it is becoming less and less possible to do repairs as we used to understand the word and the only possible procedure is to replace units. The reliability of these new developments is, however, of an extremely high order, as is also the accuracy. With the old-style communication equipment, assembly was from individual pieces of wire soldered at the points, and there was always a certain amount of variation due to errors in assembly, errors in wiring, differences due to manufacturing tolerances of the component and other differences in assembly making for considerable differences in performance. With the new techniques, however, errors are virtually eliminated. If the design and the margin of stability in the first place is accurate then the design can be repeated ad infinitum without change of performance. All this leads to the success, and was an essential to the development, of satellite communications.

These rapid developments in telecommunications and broadcasting have all occurred within the last twenty years and are clearly not yet finished. They have lead to a complete re-thinking of equipment design and manufacture, and operation.

The first satellite was the Russian Sputnik, which was put into space in 1957. This was, electronically speaking, a fairly simple device with a small amount of telemetry incorporated into it. It was followed by the American Explorer which had more complex telemetry. It was then followed by the first communication-type satellites, Telstar and Relay in 1962. All of these early satellites were of the so-called orbiting type, that is, they went round the earth in a series of elliptical orbits so that between various points of the world the satellite was in view for a varying amount of time.

A satellite of this type was in view from any two points of the earth's surface for only a short time, from a few mintues to an hour or more, depending on the latitude or longitude of the observing points and the orbit existing. A single such satellite cannot therefore be used to give a continuous service throughout the twenty-four hours and if this is required then a number of satellites, perhaps up to twelve or more, will be necessary.

Another type of satellite was the passive reflector type. This was a very large metallised plastic sphere that had no equipment in it and which reflected the signals directed to from the transmitting ground station for reception at the receiving ground station. This was also of the orbiting type, and characteristically went round the earth in orbits of varying heights from 100 to 500 miles.

It was estimated that it would be possible to carry out worldwide communications with a series of such orbiting satellites either of the power type such as Telstar, or even of the passive reflector type, but in communicating between any two fixed points on the earth, it would be necessary to relay the signal successively through the various satellites as each in turn came into view of the ground-based transmitting and receiving stations. This arrangment would be somewhat complicated, although the satellites themselves would be relatively cheap.

The next development, which was an improvement on the orbiting satellite and now seems likely to replace it, was the Early Bird type of satellite, first used in the Comsat satellite put up in space over the Pacific in time for the Olympic games in 1964. This type of satellite was put up at such a height and with such a velocity as to circulate synchronisingly with the earth, thus remaining stable over a fixed point on the earth's surface. As it is subject to centrifugal force the plane of rotation of the satellite must, of coure, be at right angles to the axis of the earth, and the satellite must be over the Equator. The height must be about 25,000 miles. It means that a signal received in any part of the world must go up at least 25,000 miles and down the same distance, that is, a maximum propagation path of 50,000 miles. The maximum earth-bound circuit is, of course, 12,000 miles. This puts a very great requirement on the capacity of the whole system. In spite of this, remarkable results have been obtained as has been seen by speech communication and television communication across the Atlantic via Early Bird. Black-and-white signals have been sent and radiated across as a relayed programme in Europe, while colour programmes from the United Kingdom have been transmitted to the United States and radiated across the whole of North America. This was done, for example, at the time of the General Election in March.

That this kind of development will go on is inevitable and various proposals are now being considered for the creation of new satellites, for linking all parts of the world for speech, for the transmission of computer type of data and for television. That this can be done gives added emphasis to the need to minimise as far as possible the number of principal types of television system in use in various parts of the world.

Such satellites are, of course, at the present time used only as programme links and as far as television is concerned, before it can be sent to the public, the programme must be re-radiated by a ground station. This is because the power available is far too little for direct reception by the public and so far all communications are radiated in frequency bands that are not suitable for receivers in the hands of the public. Considerable thought is, however, being given to the problem of broadcasting directly to the public from satellites.

In all forms of radio communication there is a direct relation between the power of the transmitter, the aerial used on the transmitting end and the aerial used at the receiving end, and the characteristics of the receiver itself. A small amount of power and a very big aerial will achieve the same results as a large amount of power and a very simple aerial. Power in a satellite is a very difficult and expensive matter, and hence we see that for satellite telecommunication we have very big aerials in use on the ground so that the power requirements of the satellite are minimised. At an installation such as Goonhilly, the receiving and transmitting aerial has a diameter of 85 ft., and the frequency used for the circuit is so very high that it would be unacceptable for domestic reception.

The size of the aerial is, of course, directly linked to the frequency at which it is used and the higher the frequency the greater the directivity obtained for an aerial of given size. Also for communication purposes it is possible to use special forms of receiving circuit and special components at a cost and complexity which may be out of the question in domestic reception for many years.

For satisfactory domestic reception from a satellite the frequency must come down to enable a practicable receiving aerial to be used, and the amount of energy to be picked up by the aerial must be higher than that required by the professional receiver which uses many devices which would seem to be impracticable for domestic receivers for very many years. If it is to be successful for domestic purposes, the power of the satellite must therefore be very much higher than is necessary for successful telecommunication purposes. In fact it goes up from a matter of watts to a matter of tens of kilowatts. This is assuming that the receiving aerial within the domestic band made for UHF can be as great as, say, six feet across. A few years ago power of the order of tens of kilowatts radiated from a satellite would have seemed unthinkable, and even now it still has to be achieved. The advances, however, in the construction of solar cells, that is, devices which convert the energy in the air from the sun directly into electrical energy, have been enormous, and it seems to be quite possible that this amount of power would be generated by this means. The area of cell required is, however, very large indeed and this brings in constructional problems but thought is, however, being given to the generation of electricity directly from nuclear sources and small amounts of energy have already been made in this way. With the effort which is being put into it, it seems probable that there will not be a very long delay before this required amount of power can be generated.

Various proposals for putting up such a satellite have been made, one in the United States and one in Japan, while a number of tentative proposals have been made in other countries, such as this one.

This direct broadcasting from satellites could, of course, be used either for sound or television and in areas for which this form of broadcasting is suitable it would be desirable that whatever is radiated should, as far as possible, be receivable directly by the public. Due to the characteristics of the ionosphere, which are to a great extent dependent on the time of day and the period in the sunspot cycle, frequencies lower than a certain limit are reflected and hence would not pass through the ionosphere, which is at a height of some hundreds of miles - as against 25,00 miles for the transmitter. The range of frequencies which would not pass includes all those normally used for sound broadcasting. It would, however, be possible for the services to be carried on the higher frequencies used for international short-wave broadcasting in the band of 26 Mc/s and at frequencies higher than this.

Radio research carried out by satellites has helped us to understand better what happens when radio waves pass through or are reflected by the ionosphere. Previously it had been necessary to deduce this by measurements made on the ground of signals which had or had not been reflected. By the so-called "top sounding" methods, signals are sent out by a satellite above, in or below the ionosphere and the effects on the signal then measured on the ground. This kind of work is of benefit to all telecommunication by radio means.

Television broadcasting from satellites could be carried out in Band I and Band III as far as propagation is concerned, but these bands are so congested with ground-based stations that it seems impossible to have satellite-based transmission in these bands, and we are left with the use of the UHF bands or above. In the lower parts of the UHF bands there are a number of existing ground-based stations which would make satellite broadcasting virtually impossible in Europe and it seems that satellite transmissions would have to carried out in the upper part of the UHF bands or in the higher bands.

The kind of service that would be given by such transmissions would be quite different from that given by earth-based stations. In the earth-based station we have a service area which, depending on the transmitter, site location and so on, could be over a distance of the order of fifty miles, the signal being very strong close in to the station and gradually tapering off to fringe-area reception at the outer limit. The custom in earth-based stations is therefore naturally to try to put a transmitter near to an area where there is a dense population so that they have a strong signal, whilst the fringe-area reception is in less densely populated areas. If, however, pockets of dense population receive fringe-area reception, then another station is put there to fill in the pocket. With a satellite service however the area covered will be perhaps 1,000,000 square miles and the signal from the satellite will be nearly uniform over the area, although at first this may not be very much better that what is normally considered as fringe reception. The satellite transmission could therefore, for large areas, give an improvement over a land-based transmission, but in areas of dense population it would be more subject to interference than is a normal transmission. The directivity of the receiving aerial, tilted upwards, would however to some extent help in this situation.

I have already mentioned that the aerials may have to be bigger than we use at present and they would of course have to be differently directed. The aerials that we use at present are more or less directed in a horizontal plane towards the transmitter. For reception from satellites the aerials would have to be pointed upwards. At the Equator the aerials at location on the same longitude as the satellite would be required to point vertically upwards, but upwards at a different angle for location on the earth at a different longitude to that of the satellite or at any latitude other than the Equator. At a thousand miles away from the centre of the service area near the Equator the angle would be 75° to the horizontal. Moving into higher latitudes, however, for example the latitude of London, then the receiving aerial would have to be leaning at an angle of 35° to the horizontal, and if the receiving point was, say, 50° north of the Equator, say in the United Kingdom, and, say, a thousand miles west of the longitude of the satellite, then the aerial would have to be inclined at an angle of 30° to the horizontal. The effect of this, of course, is that there could be many obstacles which could get in the way of adequate reception from receiving aerials located only a few feet above ground level. At high latitudes tall buildings, mountains and so on could cause an obstruction unless the aerial was mounted in such cases at a fairly considerable height. There is likely therefore to be quite appreciable difficulty in obtaining reception from satellites in European areas in fairly high latitudes.

The characteristics of the transmitting aerial on the satellite will be such that within reasonable limits of size it would be rather difficult to get a beam of radiation from the satellite which would result in an area as small as that of the United Kingdom being served and radiation would spill out over a much larger area.

This would mean that a channel used, for example, to give a service to the United Kingdom could not be used for another service elsewhere in Europe. This is a severe restriction on the use of channels from satellites, because the channels used by ground-based stations are used more than fifty times for different programmes in different parts of Europe. Economy in serving a large area with one channel is therefore likely to be offset by the restrictive use of channels over an area. Where such broadcasting could be applied usefully is for large areas poorly served with communications, such as Africa and parts of Asia. These areas are well situated to take the maximum advantage of the satellite in the matter of reception from directly overhead, while the prospect of adequate services being given to the whole of these areas by ground-based stations seems to be rather remote. There is therefore a real field in which direct broadcasting from satellites can give a service unobtainable by other means over large areas for many years. Such a service could be used for entertainment and news, but it is probably easier to justify such a service for educational and instructional purposes. The costs involved would, however, be very high indeed. It has been estimated that to launch a satellite capable of serving an area of one million square miles would cost something of the order of £15 million. It would, of course, have the great merit that, once launched, its operating cost is virtually nil, but at the present time it is impossible to make accurate forecasts as to how long such a device might continue to operate successfully. Calculations based on the expected life without trouble of the large number of components in such devices give rather a pessimistic picture; on the other hand the satellites which have been launched and put into operation for strictly telecommunication services have had a very good life with remarkable freedom from

interruption.

It therefore requires some country or organisation with a fairly long purse and considerable courage to launch such a device, but this is likely to come before long.

It may well be that initially such a broadcasting service would be carried out on sound only as this represents a considerable simplification of the problem. On the other hand, means for distributing sound programmes on short waves are fairly well established. Television cannot, however, be sent by short waves, and the big problem is to find means of distributing television signals.

When we come to the more foreseeable immediate future, communication by satellites will surely play a large part in making the results of the World Winter Olympics in France in 1968, and later in the year the Olympics in Mexico City, available for retransmission by local stations all over the world. Operational plans are being prepared for this and it seems highly probable that very large parts of the Olympic Games will be seen in colour simultaneously all over the world. This will represent a considerable advance over what was done for the Olympic Games in Japan in 1964 when the pictures were distributed all over the world but only a proportion of them simultaneously and a great part of them with a delay of some hours.

What other activities we shall see on the television side in the next year it is hard to say. We have already seen pictures from the moon, and doubtless at the time that man comes to land on the moon we shall be given television pictures as they approach the moon and when they land there. For weather-forecasting purposes, pictures taken from satellites are already used by the professional forecasters, and it seems quite possible that within the next decade we shall see pictures taken from the skies views of the weather over the United Kingdom as a part of the regular weather reporting.

In all forms of communication we can, as we say, exchange bandwidth for noise. "Noise" is a term originating in the telephone days and specifying the interference to the signal in various forms, hiss and so on. Now it is also used for interference to a picture, whether it be dots or the boiling porridge effect of a weak signal. We talk of white-noise when we mean noise which has all the frequencies and wavelengths of white light incorporated in it. If we want to use a wider frequency band, that is, a high definition for our signal, then we shall pick up a lot of noise and need a high-power signal to override it. If, however, we are prepared to accept less definition then we reduce the bandwidth or, if we are prepared to send the signal slowly, again we can reduce the bandwidth and hence reduce the noise so that we can operate with a lower-powered signal. This principle was used some years ago for the first transmission of television pictures across the Atlantic using the Cablefilm process and the Atlantic cable. The rule is, if the distance is too great, slow up the speed of transmission.

The same priciple has been used by the American Explorer satellite - sending pictures back from the moon - and as pictures are transmitted from ever greater distances in space, so it will be necessary to slow up the speed of transmission. The first pictures from Mars will undoubtedly be stills and it will be many years, needing intermediate relay stations, before we see moving pictures from Mars.

The money involved, the traffic to be handled and the relatively small quantities of equipment in use necessarily mean that many of the developments in telecommunication are first used and continue to be used in this kind of traffic for years until it becomes practicable to use it for broadcasting where the necessity to get millions of pieces of equipment available at prices acceptable to the public requires that economic means of manufacture will be available.

At the present time the printed circuit goes into ~~virtually~~ all receivers sold to the public, whether for sound or for television, and at whatever the price range. Integrated circuits are already going into some sets and, although there has not yet been widespread adoption, there is no doubt that within a comparatively short time they will be used in sets in the home as they are already used in the apparatus employed in the studio. We can look forward to receiving equipment which will be smaller than at present in use and more efficient, and more consistent in performance. The introduction of such devices is particularly likely in colour where the requirements of stability in operation are much ~~more~~ severe than they are in black-and-white.

All these changes in the techniques of communication are having a very important effect on the man-power requirements for telecommunication operation. Whereas in the past, for example, at the start of the transatlantic telephone by radio, it was a question of one transmitter carrying a single circuit, now transmitters carry many circuits and cable circuits carry many hundreds or thousands of circuits. The character of the equipment has changed in that, instead of being assembled from comparatively large and easily identifiable components, now the equipment consists of complex bits of equipment which it is extremely difficult or perhaps impossible to define and identify under normal service conditions. The technical demands on the men who have to operate the equipment have changed considerably. While overall the number of men engaged in telecommunications has increased enormously, the number of men required for any given service has gone down very considerably, so that in telecommunications, as in many other fields, the men engaged must have higher technical training and carry a greater individual responsibility.

While the use of automatic devices has removed a lot of the trouble from the operation of telecommunication equipment, the increased complexity of the equipment has made it necessary for the man to be more highly trained and to become more specialised in a particular field.

The first commercial use of electricity was in telecommunications, in the electrical telegraph. Even after this the use of electricity was confined to such things as the electrial generation of power, lighting and heating. In recent years, however, there has been an enormous increase in telecommunication in all forms for industry, amusement and information. Complex operations such as oil extraction, refining and distribution located in many parts of the world, are controlled centrally by computers through telecommunication networks. Increasingly complex operations are centrally controlled and the proportion of the overall telecommunication traffic represented by the necessary two-way exchange of data has increased.

Telecommunications are continually prgressing from being initially only a means of conveying messages, at first one-way, and then two-way, to broadcasting, to weather forecasting and to executive action in the control of complex operations. Broadcasting has played an important part in many of these developments, not only in the service which it gives to the public but also because of the indirect benefits to telecommunications stemming from the large diversion of money and effort to telecommunications by the public desire for broadcasting. Telecommunication in all its uses has, in the last 50 years, affected the life and thinking of the whole of the world as much and perhaps more than the printing press, and the process continues.

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