FIRST EDITION

AERIAL HANDBOOK

BY
G. A. BRIGGS

WITH
R. S. ROBERTS


Technical Editor
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R. S. ROBERTS

as Technical Editor

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Other books by
G. A. Briggs

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Sound Reproduction *
Pianos, Pianists and Sonics
Amplifiers *
High Fidelity *
Stereo Handbook *
A to Z in Audio
Audio Biographies
Cabinet Handbook
More About Louppers
Audio and Acoustics
(* Out of Print)
INTRODUCTION 1

THE RE-WRITING OF Sound Reproduction is going on—but not quite according to plan. The first section was published in November 1963 under the title of Audio and Acoustics.

In the next part, I ran into the subject of Aerials and soon realised that it was too vast to be covered in a single chapter, so a separate handbook was decided upon. After all, the aerial performs in radio and television the part played by the pickup in record reproduction, so it is a relevant subject.

When struggling with the many aerial problems, I was fortunate in running into Mr. R. S. Roberts who is an acknowledged expert and is Technical Consultant to Antiference Limited, and also Principal Lecturer, Department of Telecommunications, Northern Polytechnic, London. I was delighted when Mr. Roberts agreed to act as my Technical Editor. (If this were a pop record, the critics would no doubt describe the backing as superior to the solo performance!)

As to the contents of the book, I would say that Mr. Roberts is the chef who has provided the main dishes, whereas I have supplied the hors d’oeuvres and the coffee. Even so, we have vetted each other’s work and we are jointly responsible for statements made. (This is just a cover in case of libel actions.)

I had a go at the Relay chapter because I used to visit relay companies regularly during the 1932–1952 period, but we have had valuable help from various authorities, with the overall guidance of Mr. R. J. Milwidsky of Rank Relays.

We called in Michael Foster of the BBC Engineering Information Department to tackle the chapter on Transmitters and I am sure readers will agree that it was a good call which resulted in a first-class tackle.

Before passing the reader on to Introduction 2 by Mr. Roberts, I should like to thank the various aerial manufacturers who have
provided information and illustrations, particularly Mr. R. Stallworthy of Antiference Limited, and Mr. G. F. Redgrave of Belling & Lee Limited, who have been most helpful. I should also like to thank my secretary, Mrs. D. Dawson, who, in addition to juggling manfully with stacks of MSS, blocks and galley proofs, has also contributed substantially to the art-work involved and now knows the difference between a corkscrew and an inductance coil, and can actually draw a dipole from memory.

August 1964

G.A.B.

INTRODUCTION 2

AERIALS ARE OFTEN regarded as being something of a mystery to many in the field of communications. The “piece-of-wire” is, in fact, a highly complex device with a wealth of technical literature available. If all the technical information that has been published were placed end-to-end, I am sure that the line would reach from here to SYNCOM!

This book is an attempt to put the aerial story into an easily-understood context. The aerial engineer may smile at some of our naïve explanations, and even be indignant at certain liberties we have taken with the truth when explaining some particular point; but I make no apology for this. The book is not for the expert, but for the reader who would like a little of the mystery taken out of that piece of wire.

We have endeavoured to show some of the basic principles underlying the operation of the domestic aerial. Many theoretical designs of considerable technical interest have not been mentioned, because they would be too costly to manufacture and have no commercial value in the domestic field.

Some of the writing has been difficult (the mandate from Mr. Briggs was “No mathematics; layman’s language”), but it has been an interesting and pleasant task nevertheless. It is my sincere hope that the reader will obtain as much interest from the book as I did in writing my contribution.

I must associate myself with Mr. Briggs in thanking the many firms in the aerial industry who helped with information on their products. In particular, I must thank the Directors of Antiference Ltd. for their permission to do the work, and for their whole-hearted co-operation.

August 1964

R.S.R.
GENERAL PRINCIPLES

The important role played by the aerial in the quality of radio and television reception and reproduction is not always appreciated. As higher frequencies and shorter wavelengths are used for transmission, the importance of the aerial is intensified.

The purpose of this book is to explain—in layman’s language—the principles involved, supported by practical advice on the minimum type of aerial equipment required for good results in different reception areas, where conditions can vary almost as much as the scenery.

Most listeners are aware of the excellent sound quality now available from the VHF/FM transmissions, especially if received direct from Wrotham. When long land-lines have to be used, there is unfortunately a cut in the band-width from 15 kc/s to 10 kc/s, and line distortion is sometimes evident. Nevertheless, the overall results justify a really adequate aerial system.

With TV, the effect of aerial input on the picture is self-evident, but it also affects the sound quality, which can be very good indeed. For instance, the quality of speech put out by the BBC and ITA is usually excellent, and the musical standards are far superior to the performance of the small elliptical speakers now fitted to the average TV set. But even these little fellows require adequate aerial support for best results.

Historical Dates

In view of the many developments which have taken place during the last 40 years, all involving the use of some sort of aerial, we give in Table 1 a list of the dates of inauguration of important service or test transmissions.
TABLE I

Opening Dates, Radio and TV Services or Tests

1922  British Broadcasting Company, (2LO) Medium waves.
1925  BBC Daventry, Long waves. Replaced in 1934 by Droitwich.
1927  Chelmsford, Short waves.
1936  Alexandra Palace, TV on Band I (closed down 1939 to 1946 by war conditions).
1945  Light Programme introduced.
1946  Third Programme introduced.
1953  Colour TV (RCA system) adopted in U.S.A.
1955  Wrotham, first VHF/FM Service. Band II.
      Croydon, first ITA transmissions, Band III.
1956  Colour TV tests from Alexandra Palace.
1958  Stereo tests by BBC using two separate transmitters.
1961  Multiplex stereo service inaugurated in U.S.A.
1962  Occasional Multiplex tests put out by BBC from Wrotham on VHF.
      Telstar live transatlantic exchanges, including colour TV.
1964  625-line TV by BBC, UHF Bands IV and V.

Fig. 1/A  The original 2LO Transmitter at Marconi House, Strand,
London W.C.2. Power: 1·5 kW.
The importance of 2LO in setting the pattern for the enormous strides made in subsequent decades cannot be over-emphasised; we therefore have pleasure in opening the illustrations with a view of the transmitting station taken in 1923. It is interesting to compare this with the modern Droitwich station shown in the chapter on Transmitters, Fig. 10/2.

Future Plans

As to the future, the next new service to be started will probably be colour television on UHF. It seems unlikely that there will be regular multiplex stereo programmes before 1966—if then.

In any event, it is gratifying to know that the introduction of either of these new services need not involve the erection of a new aerial, although the area covered by multiplex stereo would be less than the present FM mono transmitter range.

It is also gratifying to know that a complete aerial array to cover Bands I to V in an average reception area need not look really unsightly. This is illustrated in Fig. 1/1.
GENERAL PRINCIPLES

The connecting cables from each aerial can be separate, or combined into a common cable by suitable units. These are known as diplexers, triplexers or multiplexers and are dealt with in a separate chapter.

No doubt aerials could be made to look quite attractive with a free hand in styling, as the following drawing indicates, but I doubt if our Technical Editor would approve of their efficiency.

"I AM A RETIRED AERIAL ENGINEER."

Transmission Channels

All radio frequencies are classified into bands. These classifications are the result of international agreement and are shown in Table 2.

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLF</td>
<td>Less than 30 kc/s</td>
</tr>
<tr>
<td>LF</td>
<td>30—300 kc/s</td>
</tr>
<tr>
<td>MF</td>
<td>300 kc/s—3 Mc/s</td>
</tr>
<tr>
<td>HF</td>
<td>3—30 Mc/s</td>
</tr>
<tr>
<td>VHF</td>
<td>30—300 Mc/s</td>
</tr>
<tr>
<td>UHF</td>
<td>300—3,000 Mc/s</td>
</tr>
<tr>
<td>SHF</td>
<td>3—30 Gc/s</td>
</tr>
<tr>
<td>EHF</td>
<td>30—300 Gc/s</td>
</tr>
</tbody>
</table>

N.B.:
1 kc/s = 1,000 c/s
1 Mc/s = 1,000,000 c/s
1 Gc/s = 1,000 Mc/s.
For broadcast entertainment purposes, only parts of these bands are used. No broadcasting takes place on the VLF bands, or on frequencies higher than UHF. Table 3 shows the sections of the other bands which are in use or allocated.

### TABLE 3

<table>
<thead>
<tr>
<th>Frequency bands used in broadcasting, with approximate wavelengths in metres.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Band</strong></td>
</tr>
<tr>
<td>LF</td>
</tr>
<tr>
<td>MF</td>
</tr>
<tr>
<td>HF</td>
</tr>
<tr>
<td></td>
</tr>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

The VHF and UHF TV bands are further classified with channel numbers as shown in Table 4.

### TABLE 4

<table>
<thead>
<tr>
<th>Television Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Channel Numbers</strong></td>
</tr>
<tr>
<td>Television Band I</td>
</tr>
<tr>
<td>FM Sound</td>
</tr>
<tr>
<td>Television II</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

*N.B.: Band III channel numbers will eventually be re-allocated, when the present standard 405 will be changed to 625. It is possible that, ultimately, Band I may cease to be used for TV broadcasting; by that time, the programmes will have been duplicated in Bands III, IV or V where channels are more numerous.*
GENERAL PRINCIPLES

Coverage

It is of course well known that the longer wavelengths cover a greater area for a given power. For instance, at 1,500 metres, the radio wave from Droitwich is nearly a mile long and can reach Scotland by repeating itself 300/400 times. A similar wave in Band II, about 3½ yards long, would cover less than a mile with 400 repeats and the same repeats in Band V would just about reach the end of the street.

This boils down to more transmitters at higher frequencies with less interference between stations, but more and more obstruction and reflection effects as the wavelengths are shortened. At VHF and UHF we are in fact down to the wavelengths of sound and the analogy is examined in a later chapter.

It also follows that aerial requirements vary enormously according to locality and frequency band involved. We have shown in Fig. 1/1 an array to cover Bands I to V in an average reception area, and we now show in Fig. 1/2 an assortment of aerials in the same bands but related to distance from transmitter, field strength, etc.

<table>
<thead>
<tr>
<th>BAND</th>
<th>INDOOR AERIALS</th>
<th>OUTDOOR AERIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAND I</td>
<td>Channels 1-5 VHF/405 line TELEVISION (BBC I)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>'Vantenna' (room aerial)</td>
<td>4 rod type with telescopic rods</td>
</tr>
<tr>
<td></td>
<td>'Vantenna' (room aerial)</td>
<td>Single Dipole</td>
</tr>
<tr>
<td></td>
<td></td>
<td>'Antex 'X' (or 'Hilo' type)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 element type</td>
</tr>
<tr>
<td>BAND III</td>
<td>Channels 6-13 VHF/405 line TELEVISION (ITA and new BBC I Stations)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>'Veemaster' (room aerial)</td>
<td>5 element aerial for loft mounting</td>
</tr>
<tr>
<td></td>
<td>'Hilo' V + 5 for loft mounting</td>
<td>3 element</td>
</tr>
<tr>
<td></td>
<td>'Hilo' 1 + 3</td>
<td>5 element</td>
</tr>
<tr>
<td></td>
<td>'Hilo' N + 5 with rotatable reflector</td>
<td>Double 5</td>
</tr>
<tr>
<td>BAND V</td>
<td>Combined aerials VHF/405 line TELEVISION (BBC I &amp; ITA)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>'Vantenna 625' (Set-top)</td>
<td>6 element for window mounting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 element for window mounting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9 element (Broadside model also used)</td>
</tr>
<tr>
<td>BAND IV</td>
<td>Channels 21-34 VHF/FM (BBC Sound)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 rod type with telescopic rods</td>
</tr>
<tr>
<td></td>
<td></td>
<td>'Vantenna' or 'Veemaster' may also be used</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 element for loft mounting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SINGLE DIPOLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>'W' type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 element type</td>
</tr>
</tbody>
</table>

Fig. 1/2. Aerial types related to reception conditions in Bands I to V.
The rest of this chapter is devoted to a semi-technical explanation of the principles involved in the design and use of aerials in general. Subsequent chapters are basically non-technical and are intended to clarify practical requirements for best results.

Basic Theory

What happens at the transmitter that will produce a display of energy in a piece of wire many miles away?

In order to set an electron in motion, energy is required. If the moving electron has its velocity reduced for some reason, energy is generally dissipated in some form of radiation. A familiar example of this phenomenon takes place in the domestic television receiver. Electrons are accelerated down the cathode-ray tube and brought to an abrupt halt when they hit the screen. The resulting radiant energy release takes a complicated form and includes heat, X-rays and light. The latter form of energy is encouraged in the case of the cathode-ray tube, by the choice of suitable materials for the screen. (The X-rays and heat generated are very small indeed, and quite harmless.)

When a wire carries an alternating current, the electrons in the wire are moving with a varying velocity and, hence, some radiation of energy can be expected to take place as the velocity changes—as, in fact—it does.

The form the energy takes is what is known as electro-magnetic radiation, more familiarly known as radio waves. The energy is manifest as electric fields and magnetic fields moving away from the wire with the speed of light. The fields will vary in strength as the velocity of the electrons in the wire varies, thus the field strength characteristics will be the same as those of the current in the wire and they will vary in the same manner; i.e. the frequency of field variations will be the same as the frequency of the current in the wire.

From above it would appear that, if the frequency of the current in the wire is increased, the changes in electron velocity become greater and more energy should be radiated. This is indeed the case.

It may come as a surprise to realise that a wire carrying a 50 c/s supply is radiating some energy into the space around it!—but it is true, although the amount of energy radiated at such a low frequency is very small indeed.

A distinction must be made at this stage between the radiated field and the induction fields. We are all familiar with the effects of induction where an electric or magnetic field can “induce” voltages in nearby conductors. The induction field strength varies inversely as the square of the distance from the source. That is, if we double the distance, the field strength falls to a quarter; increasing the
distance by five times reduces the field strength to one twenty-fifth. The radiated field, on the other hand, varies inversely as the distance. That is, increasing the distance by five times will reduce the radiation field to one fifth. It is seen that, at distances remote from a conductor carrying an alternating current, the radiated field is the only one of importance, the induction field having fallen to an insignificant value.

**Original Designs**

The first person to produce an efficient radiating system was Hertz in 1887. The radiation is identical with light, travelling through space with the same velocity and obeying the same laws. The only difference is that the radio wavelengths are longer.

The radiating system has an optimum overall length for maximum efficiency and this is half a wavelength. It so happens that the inductance and capacitance of the system tune it to resonance with the energising supply frequency when the overall length is the optimum half wavelength.

The practical realisation of the system as a means of communication was due to Marconi, who in 1896 realised the importance of the presence of the ground—that immense mass of near perfect conducting surface. He also realised that if a conducting plane were passed through the centre of a system, as shown in Fig. 1/3 (b), it would not change its mode of operation and at (c) the conducting plane has become the surface of the ground. The Marconi modification resulted in a vertical radiator only a quarter wavelength high and the ground has become an integral part of the system. The electric field is set up between the ground and space.

![Diagram](image)

\( \lambda = \text{WAVELENGTH} \)

**Fig. 1/3.**

(a) Aerial transmitter tuned to half wavelength.

(b) Conducting plane passing through centre of aerial without affecting operation.

(c) Ground used as conducting plane with aerial tuned to quarter wavelength.
It is a very interesting fact that all aerials, however exotic in design they appear to be, are derived from either the Hertz or Marconi type. There are no others. (Even the Ferrite loop aerial in transistor receivers is a Marconi type.)

The transmitting radiator systems in general use today are of the Marconi type for LF and some MF stations, but the Hertz is used for some MF transmitters and for all those that operate on higher frequencies.

So much for the process whereby electro-magnetic radiation takes place. How does it develop a voltage in the receiving aerial? The process is surprisingly simple, and is shown in Fig. 1/4. A thin slice of the field is shown advancing along a line from a radiator towards a vertical conductor that is elevated above ground. The electric field may be considered vertical, and the magnetic field horizontal if the location is sufficiently far from the radiator. Note that the two fields and the direction of propagation are mutually at right angles to each other.

![Diagram](image)

**Fig. 1/4. Energy from radiating aerial intercepted by a Hertz or Marconi receiving aerial.**

It is seen that, as the magnetic field sweeps past the conductor, a voltage is developed in the conductor and, as the field is continuous (i.e. not the thin slice shown in Fig. 1/4) and varying with the frequency of the transmitter source, the voltage developed will be a miniature copy of that in the transmitting aerial. An alternating current will flow in the conductor and, if the conductor is broken at any point, the current can be made to pass through the input terminals of a receiver.

One very important point should be noted from Fig. 1/4. If the receiving aerial is not in the same plane as the electric field, the received voltage will not be a maximum. If, in fact, the conductor lies in a plane at right angles to the electric field, no voltage will be developed in the conductor. This point is fundamental and of considerable importance when considering receiving aerial performance.
Polarisation

The term "polarisation" is used to denote the plane in which the radiated electric field lies, and it will be seen that a Marconi-type radiator can only be vertically polarised whereas a Hertz can be polarised in any plane. For broadcast purposes in the VHF and UHF television bands, the polarisation used may be vertical or horizontal, depending on the part of the country and the channel in use. The VHF FM transmissions are horizontally polarised, but the medium wave and long wave broadcasts are vertical.

Directivity and the Polar Diagram

When the transmitting aerial is energised, radiation takes place into the space surrounding the aerial. However, the radiation is not of uniform intensity in all directions. Consider the electric field of the Marconi radiator shown in Fig. 1/5.

![Electric field produced by Marconi radiator.](image)

The field is set up between the aerial and the ground and, from whatever direction we viewed the system at ground level, the general field picture would be as shown. If we were to walk round the system at a constant radius with a field strength measuring set, and take field strength readings at various positions, they would be constant in value. If we halved the radius and repeated the experiment, the readings would be twice as great but gain the same value at all points. If we looked down on the system, we could visualise "contour" lines of constant field strength and they would all be concentric circles with the aerial at the centre. Any one of these circles shows the manner in which radiation takes place over the surface of the ground, and we see that it is uniform in all directions. The radiator has no directional discrimination in the horizontal plane.

If the experiment were to be repeated in the vertical plane, a different shape of "contour line" would be revealed. If the field strength set were taken out to some distance remote from the radiator and moved vertically through an angle θ, as shown in Fig. 1/6 (a), the field strength will fall and, for a constant field strength reading, the radius would have to be continually shortened. Fig. 1/6 (b) shows how the radius would be reduced for three values of θ.
If the points so plotted are joined by a continuous line, a “contour” (or polar diagram) is drawn, as shown in Fig. 1/6 (c), which shows the complete field strength variation for a vertical angular traverse of 180°. It is seen, for example, that the Marconi system of Figs. 1/5 and 1/6 radiates most strongly over the surface of the ground, and has zero field strength immediately above the top of the system.

Hertz Radiator

The previous two diagrams have dealt with the Marconi type of aerial which is, so to speak, down to earth.

If we now consider a Hertz radiator in free space, the polar diagrams are as shown in Fig. 1/7.

At (a) is shown a vertical Hertz and its associated vertical polar diagram, with, below, a plan view of the same aerial and its
GENERAL PRINCIPLES

horizontal polar diagram. At (b) and (c) are shown similar diagrams for the Hertz aerial in two possible horizontal positions; radiation patterns for the vertical plane are shown at the top, and the horizontal radiation patterns at the bottom. These fundamental polar diagrams are of the utmost importance, particularly when considering VHF and UHF receiving aerials.

Modulation

In order to convey intelligent information from the transmitter to the receiver it is necessary to carry out, at the transmitter, a process known as modulation. This consists of varying the transmitted wave in some manner that can be interpreted at the receiver as information. The original, unmodulated wave is termed the carrier wave or carrier.

There are many ways in which a carrier may be modulated. The first was to break up the radiation into short and long bursts, corresponding to the telegraphy code developed by Samuel Morse. At the receiver, by using a process termed demodulation (sometimes detection), the bursts of received voltage were interpreted as appropriate characters of the alphabet.

However, we are interested in conveying speech or music between the transmitter and the receiver, and there are many methods that can be used to modulate the transmitter with audio-frequencies, but only two are used for broadcast entertainment purposes. These are amplitude modulation (AM) and frequency modulation (FM).

AMPLITUDE MODULATION

If the transmitter output is maintained constant, the ac current flowing in the transmitting aerial will be of a constant amplitude and, at the receiving aerial, a miniature version of the transmitter aerial current will be flowing. The receiver circuitry will develop a steady dc voltage at the detector stage, and the magnitude of this voltage will be determined by the strength of the input signal developed in the receiving aerial.

If the transmitter output power is varied, the dc voltage developed in the receiver will vary in sympathy. Thus, by varying the transmitter output at audio frequency by speech or music, the voltage developed in the receiver will vary in a manner reproducing the original speech or music modulation.

Fig. 1/8 (A) shows the manner in which the amplitude of the current in the receiving aerial may vary as the result of modulation at the transmitter; it should be noted that the radio frequency remains unchanged during the modulation process. Fig. 1/8 (B) shows how the voltage at the receiver detector will vary due to the transmitter modulation; the modulating signal has been recovered or demodulated.
GENERAL PRINCIPLES

Fig. 1/8.
Amplitude Modulation.
A Modulated carrier,
B Signal received.

FREQUENCY MODULATION

The transmitter may be modulated by keeping the power constant, and arranging for the modulation to vary the frequency.

Fig. 1/9.
FM Signal

Fig. 1/9 shows how the frequency is changing during modulation. There is no carrier frequency as in the AM system. The frequency swings about a mean value, and the absence of modulation would cause the transmitter to radiate a steady signal on the mean frequency.

There are many advantages to be obtained by this system, the most important being a considerable improvement over AM when interference and noise are present at the receiver location. Ranges are short, however, but this makes the system very suitable for broadcasting. Risks of interference with other transmitters on the same frequency are minimised by suitable geographical spacing of the transmitters, and the use of the correct type of aerial at the receiver.

Band-Width

Another result of modulation is less obvious and will not be explained in detail, but it is extremely important when considering aerials and tuners. We refer to the production of side-bands.

If a transmitter is amplitude modulated with a pure tone of, say, 1,000 c/s, side frequencies will appear spaced 1,000 c/s on either side of the carrier frequency. Three frequencies will be radiated by the transmitter; one will be 1 kc/s below the carrier frequency, one at 1 kc/s higher, and the carrier frequency. If the modulating frequency is 10 kc/s, the three radiated frequencies will consist of the carrier, and the upper and lower side-frequencies spaced 10 kc/s on either side of the carrier. If the modulation is produced by the range of frequencies represented by speech or music, side-bands will extend on either side of the carrier frequency.
GENERAL PRINCIPLES

In order that the receiver's demodulator can reproduce the original modulation as faithfully as possible, it is necessary for the frequency band-width of all the circuits preceding the demodulator (including the aerial) to be wide enough to pass not only the carrier frequency, but the upper and lower side-bands as well. Any restriction on band-width will attenuate the higher modulating frequencies, and the demodulated signal will suffer a loss of the higher frequencies.

Assuming that an audio-frequency modulation can go up to 15 kc/s, the overall band-width required for distortion-free demodulation is 30 kc/s. In the case of television signals, where the highest modulation frequency may go up to 5 mc/s, the required band-width would appear to be 10 mc/s, but a special system is used which cuts one side-band down to about 1 mc/s. This still leaves a large band-width requirement which must be met by the television receiving aerial.

Frequency modulation is very extravagant in band-width. For distortion-free reproduction of an AF modulation extending up to 15 kc/s, it is necessary to have an overall band-width of about 230 kc/s for each FM transmission. In each area of the country there are at least three transmitters and, as these have to be spaced well apart in frequency to avoid mutual interference, the aerial for FM must have a very wide band-width. In fact, it should be as wide as that of a television aerial.

AM, as used on medium and long waves, suffers a special restriction on band-width. Due to the congestion caused by crowding a large number of stations into a restricted frequency range, it is necessary to space station frequencies (by international agreement) 9 kc/s apart. It is seen that modulation of hi-fi quality (i.e. up to 15—20 kc/s) would produce side-bands which would interfere with stations operating on the adjacent channels. For this reason, the highest modulating frequency should not exceed 4·5 kc/s, and this is one of the reasons for the restricted quality obtained from these bands.

It has been shown that television and FM require large band-widths. This is one reason why these transmissions are found in the VHF and UHF bands; the required radio-frequency "space" is available at these frequencies.

Noise

"Noise" takes many forms and, in radio or television reception, becomes very obvious when a neighbour's unsuppressed hair dryer goes into action, but it is not always realised that when we are enjoying a programme, the set is receiving noise signals as well. This will be more obvious if the receiver is switched on at a time when the transmitter is not working, or if it is tuned to a vacant channel.
Signal-to-noise ratio is, probably, the most important single factor common to all forms of radio reception. It will be realised that, if a receiver is capable of producing an excellent output from an input signal of, say, 20 μV, such a receiver would be quite useless if conditions are such that 30 μV of noise is fed to the receiver together with the 20 μV signal.

Noise accompanying sound reception is well known and, if the interference is small in value (i.e. a large signal-to-noise ratio) it may not be offensive. The ear can also exercise an ability to reject what it does not want to hear, as many ex-service radio operators well know; they will remember the times when they had to read signals through noise levels so high that the signal-to-noise ratio was 1 : 1 or less.

Television requires relatively high signal-to-noise ratios because the eye is particularly sensitive to visual disturbance, and cannot—without dropping its lid—reject what it does not want to see.

We shall be referring to noise many times in this book but, at this stage, it will be clear that the aerial plays the most important part. The polar diagram of the aerial exercises discrimination in its ability to receive signals from the required direction, as against undesired interference from other directions. Aerial gain is, obviously, also of importance and it is generally the case that directivity provided by the polar diagram is accompanied by gain. The more directive the aerial becomes, the greater is the gain that the aerial will provide, thus yielding a two-fold benefit in signal-to-noise ratio.

**Lightning**

*During a thunderstorm, it is often possible to see flashes of disturbance on the TV screen. Should the aerial be disconnected as a safety measure?*

The answer to this question is as follows:

Any metal elevated above ground—such as an aerial or fall pipe—constitutes a lightning hazard, but the aerial plug is best left connected. The accumulation of static charge on an isolated aerial would be a serious hazard and all receiver designs are obliged to maintain a d.c. path between the aerial terminal and the chassis in order to drain off such a charge.
MEDIUM AND LONG WAVES

As these radio services have been in use forty years or more, there is little that need be said here about reception. The biggest trouble is interference from foreign stations, particularly at night, and the improvement with the VHF/FM service is in most districts quite phenomenal.

On long waves, the Droitwich 400-kW transmitter serves the whole of the British Isles with the Light Programme.

On medium waves, the stations vary in power from 150 kW down to 0.25 kW, with 28 for the Home Service, 18 on the Third and 10 on the Light. (Full details are to be found in the *BBC Handbook*, published annually.)

For best reception, the plan is to use the highest aerial possible, one advantage being that ordinary wire is suitable and there is no need to bother about impedance matching with coaxial down leads.

In most parts of the country, the signal strength is high enough to permit working with built-in aerials, as witness the small portable transistor sets which can be such a nuisance when used in public. Indoors, the placing of the set and aerial is not so critical as it is with VHF. A telescopic aerial, as depicted by our cartoonist Holmes in Fig. 2/1, can often make a considerable difference to results.

"—and when the aerial is opened to its fullest extent, the Japanese flag is unfurled . . ."

Fig. 2/1. Telescopic aerial.
AM Signals

The medium and long waves are of course amplitude modulated, as explained in Chapter 1.

The sound quality of the signal will be determined by two considerations: (1) the band-width of the AF response, and (2) the signal-to-noise ratio. These two factors are, to some extent, interdependent, but the aerial system becomes an important consideration in the determination of signal-to-noise ratio.

Noise is a term that includes interference from adjacent stations, and this type of noise is very prevalent on medium and long waves. Two methods of combating it are possible and both, in fact, are used. One is to restrict the band-width and exclude the offending interference; this is generally necessary anyway due to the very close spacing of stations—and it results in a loss of the higher modulating frequencies.

The second method is to deliver a large signal voltage to the receiver so that the Automatic Gain Control (AGC) is fully operative; the gain of the receiver is then reduced and the interference suppressed, to a degree determined by the strength of the desired signal. Clearly, the aerial is the most significant device one can use to provide the required large signal input.

Propagation

Propagation conditions vary for each waveband, but long waves provide the opportunity for nation-wide broadcast coverage. With the use of high transmitter power, a signal of useful value is established, and it does not vary in strength appreciably.

Medium-wave broadcasting, however, is zonal in character and intended to provide a useful signal over a restricted range. Within the service area, the signal strength is steady and unvarying but, after sunset, interference effects may be experienced from stations at considerable distances. It is possible, at night, to receive stations over long distances, but such long-range reception is generally accompanied by variations in signal strength known as fading.

FADING

In brief, the reason for this effect is as follows:

The transmitter radiator system is designed to direct the radiated energy over the surface of the ground, but quite a large proportion is sent towards the sky. The upper atmosphere is heavily ionised during the day and, at a height of about 100 kms, medium and long-wave signals are absorbed. The ionisation is produced by radiations from the sun, and when the sun has set, the changed conditions result in a state of ionisation which will return medium-wave signals back to the ground. The ionised atmosphere is
Medium and Long Waves

continually changing its character and, hence, the strength of the returned signal is also continually changing.

The listener situated at the fringe of his local station's service area will experience severe fading after sunset from this station, due to interference effects between the ground-wave signal and the sky-wave signal, when both are being received from the same station. The phase of the two received signals will be continually varying.

AGC helps to combat fading but cannot eliminate it in severe cases.

The Aerial

The best possible aerial here would be a Marconi, consisting of a wire erected vertically with a height of a quarter wavelength, and a connection to ground. As the wavelengths involved are 187 metres upwards, such an aerial is obviously out of the question for domestic use.

The next best is to use an aerial of the type shown in Fig. 2/2.

![Fig. 2/2. Typical medium or long-wave aerial tuned to a quarter wavelength, with coil in receiver.]

The height is made as large as possible, and the combination of capacitance resulting from the horizontal top, and the series inductance at the bottom (usually included in the receiver input circuit), assists in tuning the aerial to an electrical equivalent of a quarter wavelength. It is important to realise, with this type of aerial, that the vertical height is the most important feature.

Ferrite Aerials

The previous section describes the best aerial for use on medium or long waves, but the most widely used systems today are the small Ferrite aerials, as fitted to portable transistor receivers. These operate in a rather different fashion, as described below.

The loop or frame aerial has long been used, but is not very efficient. The design is on the lines of Fig. 2/3 and the efficiency can be improved by (a) increasing the number of turns in the loop, (b) tuning the loop, and (c) increasing the area of the loop. Treatment (c) could obviously prove difficult and in some cases would be like fitting a horse saddle on a greyhound.
The Ferrite aerial has many turns and is tuned, and the effect of the core is to concentrate the magnetic field through the coil, as shown in Fig. 2/4. In this manner the small-diameter coil is extracting its energy from a field area which would otherwise be very large and many times the area of the coil.

The Ferrite aerial is very directional because it will deliver its strongest signal only when the core is aligned along the radiated magnetic flux lines. If the core is at right-angles to the field, the signal will be zero. It may not be generally realised that the directional effects are highly accurate, and many people use a transistor receiver for position-finding when at sea on their own craft. It is only necessary to tune to one or two known stations, aligning the receiver on a compass bearing each time.

A typical aerial of this type is illustrated in Fig. 2/5. The spaced winding is for medium waves and the fine wire coil on right covers long waves, the small coil on left being coupled to external aerial, when used.
Finally we see a Ferrite aerial in situ in Fig. 2/6. This is part of a rear view diagram of the Bush VTR103, a portable set which covers LW, MW and VHF, the illustration being taken from the Trader Service Sheet. No. 1549.

![Fig. 2/6. View of chassis with internal ferrite aerial.](image)

Coils from left to right:
- $L8$ = coupling coil to coaxial socket for external aerial on MW and LW.
- $L9$ and $L10 = LW$.
- $L11$ and $L12 = MW$.

The Ferrite aerial is not used on VHF. This is picked up by an external telescopic aerial (not shown in diagram) and the FM tuning uses a separate section with two transistors VT1 and VT2. These are switched out of circuit on AM, and VT3 then operates as a self-oscillating mixer.

Tests with one of these sets showed that the directional effects with the Ferrite aerial are quite strong, the point of no reception being narrower and more pronounced than the direction of reasonable signal strength. This agrees with the angle of zero signal strength mentioned in relation to Fig. 2/4.

Connecting an outdoor FM aerial to the coaxial AM socket removed the silent zone at right-angles to the Ferrite rod, but did not appreciably increase the signal strength in other directions.

A jack socket for external speaker is fitted to one side of the set, which has an output of 250 mW. When a speaker in the £15 to £20 class is connected up, the results are greatly improved and the benefits of FM can be clearly heard, but this is a subject for Chapter 4.
MEDIUM AND LONG WAVES

Car Aerials

These aerials are of the Marconi type. The car body forms the "ground plane", and is capacitance-coupled to the earth as shown in Fig. 2/7. The aerial generally consists of a rod (of a fixed length, or telescopic), secured to the car body by means of an insulating fixture. A screened connecting lead from the aerial terminates at a convenient position in the car, with a plug-in connection to the receiver.

On medium and long waves, the aerial is obviously much less than a quarter-wavelength high and, as a consequence, is very inefficient. The efficiency improves when the receiver is tuned to short waves, and is seen at its best on the wavelengths used by police and ambulance services, where the aerial is a true quarter-wavelength high.

NOISE

The car's entire electrical system is a powerful source of noise, particularly the ignition system. Fortunately, new cars are obliged to have interference suppression fitted to the ignition system, but older cars will need this treatment before a receiver can be used in the car. It is quite simple and reasonably cheap, and consists of fitting a specially-designed resistor in the main e.h.t. lead from the coil. Any garage can carry out the fitting in a few minutes.

Other sources of noise are the dynamo, screen-wiper, fuel pump (if electric) and, in fact, any electrically-operated device on the car. It is possible to suppress noise generated by all these, but it can prove expensive and may not be so effective as choosing the best position for the aerial.

AERIAL POSITION

Undoubtedly, the best position for a car aerial is on the roof. The screening provided by the roof minimises the pick-up, by the aerial, of noise generated by the electrical system.

Less satisfactory but, perhaps, more elegant positions for the aerial are shown in Fig. 2/8. The object is to place the aerial as far away from the engine as possible. If it is in the usual front position,
the best place for the aerial (excluding roof-mounting) is that marked A. Here the aerial is well exposed, and a lot of screening exists between the aerial and the engine compartment. B is the next best position, with C the worst because the effective aerial height is being reduced by proximity to the car body.

Some cars have the engine at the rear. In these cases, the aerial should be mounted forward in positions D or E, the most forward position E being the best.

RECEIVERS

It is often found that when a car aerial is plugged into the ubiquitous transistorised portable receiver, very little increase in signal strength takes place; the built-in ferrite aerial is doing most of the work. However, the car aerial connection will offset to some extent the directional effects of the ferrite aerial which, of course, can be a very useful feature as the car turns during normal traffic manoeuvres.

The receiver specifically designed for use with a car aerial will, generally, give a better performance than the portable with a socket marked "car aerial". Some portable receivers have a switch whereby the input circuit can be changed to take full advantage of the car aerial when it is used.

Actually, results today from car radio can be very good and amply justify the fitting of a sensitive 8" speaker facing upwards near the rear window, using the boot as the enclosure mounting. The main electrical interference comes from overhead cables used by trolley buses and this, fortunately, is limited to comparatively small areas of travel.
3

SHORT WAVES

Although known as short waves, it can be seen from Table 2 in Chapter 1 that the wavelengths here are about ten times as long as VHF. The modulation used is AM, so it follows that a good medium-wave aerial is also suitable for short-wave reception.

Many radio sets sold in this country are fitted with a short-wave tuner and a panel displaying as many as 18 names of foreign stations, but it is difficult to imagine who listens to them this side of the Channel or Atlantic Ocean.

Distortion

Reception on these bands covers a frequency range from about 3 Mc/s to 25 Mc/s or so, and is characterised by three forms of distortion:

(a) Noise, in which interference from other stations is most prevalent;

(b) Fading, i.e. a continual variation of signal strength;

(c) Selective fading. This is a term for a form of frequency distortion, usually accompanied by fading. Nothing can be done about this distortion by the ordinary listener. A professional aerial of a special type requires a site quite flat over a distance of some two miles and, with associated equipment, costs about a quarter of a million pounds!

Propagation

The method of propagating a signal between transmitter and receiver on short waves is quite different from that used for the longer wavelengths. Ground-wave propagation is characterised by an increasing attenuation as the wavelength is reduced and therefore does not result in useful ranges on short waves.
SHORT WAVES

The transmitting aerial is designed to direct its energy towards the sky, where the wave meets a heavily ionised region in what is known as the ionosphere. In this region, the wave is refracted, or bent, out of the path it started to follow and eventually is returned to the ground, as shown in Fig. 3/1.

As frequency increases, penetration of the wave into the ionised region becomes greater, and at about 25–30 Mc/s penetration is complete and the wave is lost into space. (See appendix at end of chapter.)

Any wave returned from the ionosphere finds that the ground is an excellent reflector; the wave is again returned to the ionosphere. The process is depicted in Fig. 3/2, from which it is seen that, by “multiple hops” as they are termed, world-wide ranges can be obtained. Under favourable conditions, the attenuation that the wave experiences with each hop can be quite small, and long ranges are possible using only modest power at the transmitter.

The ionisation is caused by radiation from the sun. Thus, favourable conditions will be variable and will depend on a number of factors such as whether it is daytime or night, whether it is summer or winter, and a number of other variables.

Reception

The net result of the propagation conditions, so far as the received signal is concerned, is considerable unreliability. The signal strength is continually varying, and distortion referred to at the beginning of the chapter is difficult to overcome.

The bands allocated to short-wave broadcasting are very congested, and heavy interference can take place at times, even from very low-powered stations situated at remote distances.
Broadcast authorities have to change frequencies as the day progresses, in order to maintain a service intended for some part of the world remote from the transmitter. In general, the "longer" short waves would be used during the day, and the higher frequencies at night.

Finally, there is "jamming" where, for reasons usually political, a country wishes to prevent its listeners from hearing certain programmes of foreign origin. This is accomplished by locally transmitting a powerful and specially modulated signal on the frequency that it is intended to jam. The resulting interference level is very high within the country of origin but, unfortunately, it can have a world-wide range.

The Aerial

Another effect of propagating signals via the ionosphere is that, due to the "bending" process, the returned signal is polarised both vertically and horizontally. This means that it does not matter whether the receiving aerial is vertical or horizontal, particularly on "multiple hops", i.e. very long range.

Vertical Marconi quarter-wave aerials can be used very successfully, but the wavelengths involved are so short that the half-wave Hertz is a possibility for the higher frequencies. The Hertz is the most efficient simple aerial one can use and it can be mounted vertically or horizontally, whichever is the most convenient. It should be noted, however, that the horizontal aerial is directional whereas the vertical will receive equally well from any direction. (See Fig. 1/7).

Table 1 shows the short-wave bands and the Hertz aerial length for optimum performance on each band.

<table>
<thead>
<tr>
<th>Band (Meters)</th>
<th>Frequency Band (Mc/s)</th>
<th>Aerial Length (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>2.3 — 2.5</td>
<td>190</td>
</tr>
<tr>
<td>90</td>
<td>3.2 — 3.4</td>
<td>139</td>
</tr>
<tr>
<td>75</td>
<td>3.95 — 4.0</td>
<td>115</td>
</tr>
<tr>
<td>60</td>
<td>4.75 — 5.06</td>
<td>91½</td>
</tr>
<tr>
<td>49</td>
<td>5.95 — 6.2</td>
<td>75</td>
</tr>
<tr>
<td>41</td>
<td>7.1 — 7.3</td>
<td>63½</td>
</tr>
<tr>
<td>31</td>
<td>9.5 — 9.75</td>
<td>47½</td>
</tr>
<tr>
<td>25</td>
<td>11.7 — 11.975</td>
<td>38</td>
</tr>
<tr>
<td>19</td>
<td>15.1 — 15.45</td>
<td>30</td>
</tr>
<tr>
<td>16</td>
<td>17.7 — 17.9</td>
<td>25½</td>
</tr>
<tr>
<td>13</td>
<td>21.45 — 26.1</td>
<td>21</td>
</tr>
<tr>
<td>11</td>
<td>25.6 — 26.1</td>
<td>17½</td>
</tr>
</tbody>
</table>
SHORT WAVES

Unfortunately, the Hertz is most efficient for use on the frequency for which it is a half-wave long—and this means a separate aerial for each of the short-wave bands! As a result, one must compromise, and a good general-purpose aerial can consist of about 20 ft. of wire, erected as near vertical as possible. If necessary, one could supplement this arrangement with a half-wave aerial for a band of special interest.

APPENDIX

The highest frequency that can be returned varies on an eleven-year cycle, coincident with the sun-spot cycle. At times of high sun-spot activity, the highest returned frequency can reach 50–55 Mc/s. It is at these times that reports are received, detailing reception of BBC television in distant places such as South Africa.
VHF, Band II

This chapter and the next cover the VHF band (or brand) of frequencies, including the FM sound services in Band II and the television services of Bands I and III.

We begin by outlining the general principles of VHF propagation, and although the chapter is headed VHF, Band II, these principles apply with equal force to Bands I and III.

The second part of the chapter deals specifically with Band II FM, and the requirements for optimum results.

VHF Propagation

It is explained elsewhere in the book that frequencies in excess of 30 Mc/s or so are not normally returned from the ionosphere, but are lost into space. Also that ground-wave signals become heavily attenuated as the wavelength becomes shorter. In the VHF band (wavelength range 1–10 metres), this ground-wave attenuation becomes very severe indeed. How, then, do signals arrive at the receiving aerial?

The wavelengths are so short that the basic aerial element can now be the efficient half-wave Hertz and, with this type of aerial used at both the transmitter and the receiver, a different method of propagation is used. The system adopted is similar in every way to the manner in which a lighthouse can cast its beam over a considerable distance. The transmitting aerial is sited at the top of a high mast and the radiation is directed towards the ground, as shown in Fig. 4/1. The mast is not part of the radiation system, and serves only to raise the radiator above the ground.

Fig. 4/1. Direction of radiation from VHF transmitter.
The maximum range is no longer determined simply by the transmitter power but, as shown in Fig. 4/2, by the height of the radiator and the curvature of the earth. Transmitter power only determines the signal/noise ratio within the service area. These short wavelengths are easily obstructed by objects of a size comparable with the wavelength—and the earth is a massive obstruction!

**Fig. 4/2. Showing how the earth casts a “shadow” beyond the point of maximum range.**

**AF Analogy**

It is interesting to note here that we are actually down to audio wavelengths, the range covered in Bands I to V being about 24 ft. to 1\(\frac{1}{2}\) ft. This corresponds to a frequency range of approximately 50 to 1,000 c/s.

In sound reproduction, directional effects are more pronounced at high frequencies than at low, with stronger reflection from obstructing objects and poor diffraction around them. For instance, in a listening room, the sound waves begin to bend round an object in their path when its dimensions are less than half a wavelength. This is illustrated in Fig. 4/3, where the chair would begin to obstruct the passage of frequencies above about 250 c/s and produce a shadow similar to the one produced by obstructed rays of light, growing stronger as the frequency rises.

**Fig. 4/3.**

Obstruction of sound waves by object 2" 2" wide.
Negligible at and below 250 c/s.
Severe at 500 c/s upwards.
Anyone sitting in the chair with its back between his ears and the loudspeaker would hear only reflected sound waves at high frequencies.

**Effective Range**

The useful VHF range is, in fact, slightly more than indicated in Fig. 4/2 because the radiated field does not travel in straight lines, but along lines curving slightly downwards towards the earth, thus reaching beyond the horizon. The amount of curvature depends on atmospheric conditions such as temperature, pressure and moisture content and, with favourable values of each, very considerable ranges can be experienced at times.

**Reflection Effects**

Another fundamental and important fact concerning propagation is best understood by considering the lighthouse once again. If we were actually looking at a lighthouse beam across a calm sea, we would observe its reflection in the water. Precisely the same thing happens with the radio wave, as depicted in Fig. 4/4. Signals arrive at the receiving aerial system R from the radiator T by the two paths P₁ and P₂. This looks, at first glance, as though we are receiving twice the field strength. Unfortunately, signals arriving along the P₂ path are out of phase with those that arrive along the P₁ path and thus, the two signals tend to cancel each other. The aerial at R "sees" two fields, roughly equal in strength but of opposite phase and, if the two path lengths were equal—which normally, they are not—there would be no voltage at the receiving aerial. It is only the fact that P₂ is longer than P₁—and thus ensures that the phase difference is not 180°—that provides a signal at the receiving aerial. An important conclusion results. In order to make the signal at R as large as possible, P₂ must be as much longer than P₁ as we can make it—and this means raising the receiving aerial height as much as possible.

![Fig. 4/4. Showing how signals arrive at the receiving aerial R by two paths.](image)

At short ranges it is possible to produce such a large difference in path length that the two fields cannot cancel each other, and no signals are delivered to the receiver. The remedy is to change the path length by either raising or lowering the aerial by a small amount.

Signals can also arrive at the receiving aerial by other paths in the form of reflections from large buildings and metallic masses, such as cranes and gas-holders, or even aircraft. See Fig. 4/5.
The reflected signal obviously travels over a longer path than the direct signal and arrives later. The effect on television is to produce a second image, displaced to the right by an amount depending on the time lag between the two signals. These reflected signals are termed "ghosts", and the only way to avoid them is to use an aerial with a polar diagram that has the required directional discrimination—and to erect it carefully.

The effect of ghosting on FM reception in Band II is known as Multipath Distortion and is dealt with later in the chapter.

**SIGNAL STRENGTH**

This increases at the receiving aerial as the height of the aerial is increased. Another method for increasing the signal strength is, of course, to increase the transmitter power. Doubling the receiving aerial height will double the strength of the received signal—an effect that, in terms of transmitter power, would require a four-fold increase. It is seen that aerial height is, probably, the most important single factor that can contribute to a high signal/noise ratio at VHF.

**VHF Aerials**

The wavelength is so short that all VHF (and UHF) aerials are of the Hertz type. The signal yield from a single Hertz aerial element is generally increased by the addition of further elements, the whole constituting an Array. The resulting increase in signal level is accompanied by a change in the polar diagram which confers better directivity to the system.
There are many ways of combining aerial elements into an array, but the method used for domestic aerials is the system known as a Yagi, named after the Japanese engineer who first produced it nearly 40 years ago.

Yagi found that another element, spaced about a quarter-wavelength (and suitably mis-tuned by making it longer than a half-wavelength) as shown in Fig. 4/6A, can enhance the forward gain and improve the directivity. An element used in this manner is termed a reflector.

![Diagram of Yagi array](image)

**Fig. 4/6. Vertical Hertz aerial with A reflector and B reflector and directors.**

By placing another element in front of the aerial—this time shorter than half a wavelength—the gain and directivity are still further improved, as illustrated in Fig. 4/7. This shorter element is termed a director, and the fitting of additional directors (as shown dotted in Fig. 4/6B) can further increase the gain and sharpen the polar diagram.

![Polar diagrams](image)

**Fig. 4/7. A Horizontal polar diagram of vertical Hertz aerial. B Effect of reflector on polar diagram, and the relative gain. C Effect of adding one director to B.**
FM RECEPTION, BAND II

There is no doubt that the VHF transmissions of the Home, Light and Third programmes are the most satisfactory source of good quality sound reception. Interference from foreign stations and electrical equipment is virtually eliminated. The FM system covers a much wider frequency range than the normal AM of medium waves, and those who are situated within striking distance of Wrotham can enjoy response up to 15 kc/s. Further afield the range is often restricted by GPO land lines, as explained in the chapter on Transmitters. Even so, the FM programmes usually sound better than AM after travelling 200 miles to the north of England.

Aerial Systems

The basis of frequency modulation has been illustrated in Fig. 1/9, and as these transmissions are horizontally polarised, the FM aerials are mounted so that the elements are also horizontal.

The simplest type of aerial that one can use is a Hertz half-wave, mounted horizontally as shown in Fig. 4/8. In order to tune to the centre of the FM band, the overall length needs to be about five feet.

Fig. 4/8.
Simple dipole FM aerial, suitable for strong reception areas.

The band-width of the aerial must be adequate to receive all three stations and, to ensure this, the diameter of the elements must be not less than \( \frac{3}{8} \) in. The feeder from the aerial to the receiver should be of the 70-80 ohm coaxial type, as shown in Fig. 11/10. The feeder should be connected at the centre of the dipole; the inner conductor to one side and the outer braid to the other.

A horizontal "H" type of aerial, as illustrated in Fig. 4/9, is to be preferred however, because it confers some directivity to the system and tends to suppress any interference signals (such as car ignition noise) that might be picked up from the back of the aerial.

Fig. 4/9.
Horizontal "H" type aerial, giving better results than the simple dipole.
VHF, Band II

Band-width

The band-width of the aerial is important. The FM band extends from 87.5 to 100 Mc/s, and the aerial must operate with uniform efficiency over the band. The three stations in any one area are spaced 2.2 Mc/s apart so that, for local reception alone, the required band-width is nearly five megacycles. (In some parts of the country, the spacing between local stations is even wider). When stereo transmissions become fully operational, they will certainly use some system of sub-carrier modulation to transmit the stereo information; the band-width of each transmission will then be fully utilised, and any deficiencies in the aerial in this respect will become obvious. One need have no misgivings with respect to band-width if an aerial of reputable make is obtained in the first place.

Multipath Distortion

Reference has already been made to this delayed signal effect. The two signals constitute a phase modulation and, unfortunately, the receiver demodulates this and produces a rather unpleasant AF noise as a result, not unlike the buzzing sound made by a moving coil speaker which is out of centre.

The aerial provides the only real solution to this problem. The stacked "H", illustrated in Fig. 4/10, offers considerable reduction in multipath effects. The aerial gain is increased and the signal discrimination improved, compared to a single H.

![Stacked "H" aerial for reducing multipath distortion on Band II and improving signal strength.](image)

Signal/Noise Ratio

One of the most important reasons for the high signal/noise ratio of FM is due to the fact that noise impulses are largely AM in
character. The FM tuner embodies in its circuitry an amplitude limiter, which has the laudable object in life of suppressing amplitude variations—or noise—in the signal presented to the discriminator (i.e. detector). The amount of noise suppression obtained is dependent on the signal strength, becoming greater as the limiter is driven harder.

If the signal is too weak to operate the limiter properly, the noise level will be high and turning up the gain control will merely intensify the aural agony.

It is possible to obtain the local stations on a very elementary aerial system; but, however good the programme may sound under these conditions, it will be better if a good aerial is used, due to the lower noise level that will be obtained.

Most FM receivers employ some form of AGC which should be driven hard with a strong signal in order to contribute optimum noise reduction.

**CAPTURE EFFECT**

Of the many characteristics of FM reception, one of the most interesting is what is known as “Capture Effect”.

The receiver will discriminate between two signals operating on the same frequency by accepting the stronger and rejecting the weaker. (This is of great value to the transmission engineer who faces the problem of providing national coverage with a lot of stations and a limited number of channels.)

In the presence of a high noise level, the receiver is in no position to distinguish between “noise” and programme; it will “capture” the noise signals and reject the programme. This behaviour sets a fairly clear limit to the service area of an FM transmitter. These areas are more clearly defined than they would be with AM transmissions.

**Tuning**

As a result of the deviation produced by the modulation process, the band-width of an FM channel is not 150 kc/s as might be imagined. It is, in fact, infinitely wide but, fortunately, the outermost side frequencies contain so little energy that they can be ignored. For good quality it is necessary to contain the side frequencies within a band 220-240 kc/s wide. If the receiver is not accurately tuned there will be distortion caused by the signal being “off centre” in the band.

**BBC Coverage**

As will be seen from Fig. 4/11, most of Great Britain and Northern Ireland is covered by the large number of main and relay stations now in use.
Fig. 4/11. VHF/FM. BBC coverage, June 1964.
TELEVISION, BANDS I AND III

IT IS SAFE TO SAY that the main residential areas of Great Britain and Northern Ireland are now well covered by the TV services. The BBC have 86 transmitters at 41 stations, and ITA operate 40 transmitters at 22 stations.

The number of licences in 1963 reached a total of 15,698,991 made up as follows:

- Sound and TV — 12,442,806
- Sound only — 3,212,814

Reception conditions are usually very good, and the menace of electrical interference has been greatly reduced during the last few years by regulations covering suppressors fitted to various types of electrical equipment. The worst period is in the early summer when atmospheric conditions at times produce visual and noisy interference in Band I from continental stations. As these effects are due to laws of nature, and periods of high sunspot activity, it is not possible to control them by regulations, no matter which party is in power.

Aerial System

It has been said that if you live within sight of the transmitter, you can see a TV picture on the door of a refrigerator without the use of an aerial, or pick up an FM programme on a shoe string. It is no doubt true that those who live in such localities do not need to worry much about aerials, but they form a very small percentage of the 15-million odd subscribers (the adjective here referring to the number only).

As a rule, a good aerial improves both sound and vision. A typical array for Bands I and III is shown in Fig. 5/1A, used with single coaxial feeder.
The X Aerial

This is a modification of the H for use on Band I, and is a method of simplifying the construction by eliminating the spacing bar which is necessary between the dipole and reflector in an H array. Fig. 5/1B shows a “bent” dipole and reflector, their equivalent mean positions being shown dotted. The junction point of the elements becomes a relatively small housing for attachment of the feeder cable. The performance is virtually the same as an H.

Special Yagi

A variant of the Yagi for Band III which has been used is illustrated in Fig. 5/1C. Apart from the fact that this looks like a fish-bone, it is basically the same as the ordinary Yagi dipole.
TELEVISION, BANDS I AND III

These aerials were produced about the time when the customer might have been attracted to an aerial that looked different, the performance being normal. They are illustrated here in case the reader has seen them in use and wonders what they are.

As we are in the VHF region, the installation of the aerial is usually a job for the expert, but we will consider some of the principles involved and the main requirements for good results.

**Signal Strength**

The best aerial to provide a good signal is some form of Yagi, where the gain increases as more directors are added. The yield of gain-per-element goes up quite fast to five or six elements. The yield then falls until, at about nine or ten, the addition of further elements adds very little to the gain but increases the mechanical problems of mounting and securing a very long boom.

Where maximum gain is required, it is customary to use a pair of five or eight-element Yagis suitably connected, rather than one long array, thus reducing the mechanical problems. The two aerials may be stacked one above the other, or arranged side by side in a "Broadside” array as shown in Fig. 5/2.

![Fig. 5/2. Yagi aerial arranged in broadside array to improve directivity and signal strength. Band III.](image)

Stacking one above the other would only be used with horizontal aerials and is illustrated in the next chapter, Fig. 6/7.

The stacked pair raises the gain over the single unit by about 3 dB, tends to reduce reflections from aircraft (i.e. “flutter”), but contributes nothing to directivity. The broadside pair raises the gain by the same amount, is of no help where aeroplane “flutter” is concerned, but improves the directivity. Owing to wavelengths and dimensions involved, these arrays are not really practical in Band I.
Band-width

If the band-width is inadequate either the sound signal will be down in strength, or the picture detail will be lacking, or both! Television channels are wide, and include the sound channel. The 405-line channels are 5 Mc/s wide, and the 625-line channels are 8 Mc/s in width. Aerial manufacturers are now producing single aerials that will cover several channels, and combined Band 1/III aerials have been available for some time, as shown in Fig. 5/1A.

Directivity

Again, the Yagi is the best solution, but a problem exists on Band I. A Channel I dipole is over 11 ft. long, and a multi-element Yagi becomes a formidable mechanical structure. Fortunately, careful siting of simple arrays can often yield high signal/noise ratios.

Directivity problems are frequently concerned with obtaining a good signal where a noise source (such as car ignition noises from a busy road) is fairly well defined with respect to direction. A simple vertical “H” (or better, an “X”) type aerial has a very good front/back ratio which can be turned to good account in such a situation. Fig. 5/3 shows the polar diagram looking down on such an aerial which has been erected in a position to provide a maximum signal. If the aerial is rotated to the position shown dotted, the noise arrives at a (theoretically) zero point in the polar diagram, whilst the signal strength has fallen very little.

In practice, there is never quite a zero in the polar diagram, but it can be very small indeed and thus result in a high signal/noise ratio.

Noise

This name is inherited from the audio field and when applied to a visual display describes the effect of interfering signals on the picture. Noise on the sound channel still has its usual meaning.
TELEVISION, BANDS I AND III

It is difficult to say what constitutes a satisfactory signal/noise ratio where television reception is concerned, because the eye exhibits a varying sensitivity to different types of interference, and receivers embody circuitry—of varying effectiveness—that minimises noise effects.

A general, random type of noise (that would give rise to hiss on an AF channel) would be seen as a grainy background to the picture, usually referred to as “Snow”. This is often produced by inadequate signal strength, and occurs as much in summer as in winter.

An interfering radio signal (of a type that would produce a whistle on a sound channel) gives rise to stripes across the picture. The stripes generally move in angle between vertical and horizontal and may be of varying width, often referred to as “herring-bone” interference. It is difficult to assess in terms of annoyance value because the offensiveness depends on the frequency of the interfering signal as well as its strength.

Interference from the ignition system of motor vehicles (and some domestic appliances) is characterised by the fact that it extends over a very wide frequency band. Car interference tends to peak in the 40–70 Mc/s range, corresponding to Band I. It is less offensive in Band III and almost negligible in the UHF bands. This type of noise, termed impulsive interference, produces large visual splashes across the picture and, when severe, can affect synchronism and unlock the picture.

It will be appreciated that annoyance value cannot be measured. Various authorities have made tests on groups of viewers—often inconclusive. As a very rough guide, a minimum signal/noise ratio for the snow type of interference may be taken as 25–30 dB, but the other types require at least twice this value.

Correct Impedance

The half-wave dipole has an impedance of 70–75 ohms and, with a signal, looks like Fig. 5/4 so far as the aerial terminals are concerned.

It is well known that, in order to transfer maximum power from a source, the load must match the source impedance. This is one of
the reasons why the aerial feeder cable has an impedance of about 75 ohms.

When other elements are added to form an array, as with the Yagi, one of the effects is to reduce the dipole impedance; it can fall to as low as 15 ohms. A folded dipole, as shown in Fig. 5/5, is generally used in arrays. It is still a half-wavelength long, but the impedance is increased by a factor of four to about 300 ohms. When used in an array, the folded dipole experiences the same ratio of impedance reduction due to the other elements and can finish at 75 ohms—the required value to match standard coaxial cable.

![Fig. 5/5.
Folded dipole, half-wavelength long, as used in Yagi arrays.](image)

In the cable generally used hitherto for VHF, the overall diameter is about \( \frac{1}{4} \)" with a centre wire of 24 g copper, \( \cdot022\)" diameter. It may be necessary to use a thicker cable on UHF to avoid undue loss of power, as line losses increase rapidly as the frequency goes up and wavelengths are reduced.

When fitting coaxial leads at VHF between receiver and aerial input sockets, it is most important to use the correct plugs and to avoid any leaks or joints which would upset the impedance of the line. I can vouch for this from personal experience. (G.A.B. speaking—not R.S.R.). About five years ago I decided I must have VHF radio, in spite of living in a difficult reception area. A good, lofty, outside aerial was duly erected and I bought a Quad FM tuner to work with the rest of my hi-fi equipment.

Unfortunately, I could not find a coaxial lead long enough to reach the tuner, so I connected two short ones by twisting the exposed ends together as per loudspeaker-lead practice followed during 30 years. Results were dreadful. A few days later I met Peter Walker at a rehearsal in London and told him what I thought about his tuners. When I described my ingenious, semi-coaxial input lead arrangement, he told me what he thought about my VHF gumption! A correct lead was in due course fitted and made a vast difference to results.

Even stricter attention to rules will be necessary at UHF.

**Ferrite Rods**

Some readers may wonder why the ferrite aerial mentioned in Chapter 2 is not used for the TV bands. The answer is that the losses in ferrite material go up with frequency and so far, in this country, there are no suitable materials available. Band II ferrite aerials are, however, in use in Germany.
TELEVISION, BANDS I AND III

Sound Quality

The possibilities for excellent reproduction of the sound channel that accompanies the vision programme are not fully realised. The sound transmissions are amplitude modulated, as are the long, medium and short-wave transmissions, but they do not suffer from fading, and their range is short so that they do not experience interference from other stations.

The steps taken by the BBC to improve the quality of serious music transmissions from large TV studios by Ambiophony were fully explained in our last book Audio and Acoustics.

EXTERNAL SPEAKER

The usual domestic television receiver uses a small loudspeaker that reproduces a very restricted frequency range compared with that transmitted.

The simplest way to improve results is to fit an isolating transformer inside the set and connect to an external speaker up to about £20 in price. As the existing (limited) output stage is still in use, it is hardly worth while going up to a really expensive speaker system.

To ensure complete safety, the fitting of the isolating transformer should be done by a qualified dealer.

Separate Sound System

A well designed and sited aerial of reliable manufacture is well suited for excellent sound reproduction. Its band-width will be adequate, and its directional properties will be such that the signal/noise ratio will be high. The one shown in Fig. 5/1 is quite suitable for medium range operation.

For optimum results, the best plan is to route the sound through one’s own amplifier system. There are two ways of doing this.

It is possible to obtain access to the audio output from the television receiver’s demodulator circuit; but this is not recommended for two reasons: it requires some painstaking circuit tracing and, of course, will invalidate any guarantee on the receiver; secondly, these receivers obtain their h.t. by rectifying the mains supply, and this results in a need for isolation between the receiver and the amplifier; with a serious risk of hum appearing with the sound.

The other, preferred (and safer!) method is to use a separate tuner to feed the amplifier system. Suitable tuners can be obtained and are also available as “do-it-yourself” kits.

In Fig. 5/6 we illustrate the Jason tuner which can be used on the FM broadcasts in Band II and also on the AM Sound of the BBC and ITV programmes in Bands I and III.
We have tested this with a high class amplifier and speaker system on BBC and ITV programmes. The improvement in sound quality compared with the average TV set is quite remarkable. The loudspeaker should be placed reasonably close to the TV set to avoid disembodied effects.

In order to feed a separate tuner as well as the television receiver, it is necessary to split the feed cable with a suitable unit to provide the two cables. These units can be ordered through dealers.

**Indoor Aerials**

Although a separate chapter is assigned to this subject, we will examine here the main points in relation to TV reception.

Where the field strength is very high, it is possible to dispense with the outdoor aerial and use one of the indoor versions. There are two varieties. One is a compact version of the outdoor aerial intended to be erected in the roof space; the other is the popular V-type for use in the same room as the receiver, similar to the Antiference model illustrated on the front cover of this book.

Although the best of indoor aerials can never be as good as a well-sited outdoor unit, it has one advantage in that it is easier to make a test.

There are many versions of the "V" aerial, and all are variants of the Hertz intended for operation on Bands I and III. The two halves of the Hertz are arranged to swivel, thus providing for horizontal polarisation when extended horizontally, and for a compromise when receiving vertically polarised transmissions. When the arms are in a "V" position for optimum performance with vertical polarisation, some small measure of directivity is afforded by rotating the aerial. A good example of modern practice is illustrated in Fig. 5/7.
The elements of most "V" aerials are telescopic to permit a degree of tuning to the Band III station. Many of the cheaper "V" aerials do not have provision for tuning the Band I signal, but rely on this being so much stronger than Band III that it will provide an adequate signal. Quite large differences in signal strength between the two would not be noticed on a modern receiver due to the operation of AGC when changing from one channel to another.

The "V" aerial has certain disadvantages, and a careful trial should be carried out before finally deciding to use one. The best position for the aerial is not necessarily the top of the receiver; in this position it may pick up a lot of noise generated by the time-base circuitry. To obtain the best performance it is necessary to carry out some experiment with the telescopic rod lengths, angular position of the rods, and position of the aerial in the room.
TELEVISION, BANDS IV AND V

These UHF bands offer exciting possibilities for the future. They are very wide and 64 main stations in the U.K. are planned, each allocated with four channels out of the 44 which are available.

We are now involved in no less than five Bands. According to our artist Holmes, complaints may arise if further bands open up.

"and you can hear Band VI next door—the local colliery rehearsing!"

Fig. 6/1. Local reception conditions.

The TV transmissions are to be accompanied by FM sound, so it will be possible to obtain the same audio frequency range as that put out in Band II. With a second TV programme there should be more time available for serious music, and this would make a separate tuner—when available on UHF—an even more worth while acquisition than it is on Bands I and III which are AM.
TELEVISION, BANDS IV AND V

The ultimate plan for UHF is for four channels to be operational in any one part of the country. Only one station will be in service initially, and some time will elapse before the other three come into service. The reputable aerial manufacturers have allowed for this, however, and the UHF aerial is designed to cover all four channels. As the transmitters will be co-sited, the varied reception conditions which now often occur between Bands I and III will not arise.

The provisional allocation of channels for the 64 main stations is outlined in Table 1.

<table>
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<tr>
<th>TABLE I</th>
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<tbody>
<tr>
<td>Belfast</td>
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<td>Caithness</td>
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<td>Cardiganshire</td>
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<td>East Lothian</td>
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<td>Huntingdon</td>
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<td>Isle of Wight</td>
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<td>West Yorks</td>
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<td>Lewis</td>
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<td>London</td>
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<td>North Yorks</td>
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<td>Isle of Man</td>
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<td>Northumberland</td>
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<td>Birmingham</td>
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<td>Dorset</td>
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<td>Lanarkshire</td>
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<tr>
<td>North Kent</td>
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<td>North Lancs</td>
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</tbody>
</table>

_UHF Transmitters in the U.K._

_Band IV_ 470-582 Mc/s. Channels 21-34.


BBC 2 plans for 1964/7 are outlined in Fig. 6/2. Channels will of course be allocated to ITA.

It is also a reasonable assumption that colour television will eventually be introduced. The system to be used still has to be decided, but whatever system is finalised, it poses no particular problem. If the UHF aerial is well sited and the received signal is free from ghosts, colour reception should be quite good.
The first eighteen BBC-2 UHF stations and the dates for the extension of BBC-2 to other parts of the United Kingdom. The service areas must be considered approximate since in several cases sites and other technical details are not yet decided.

FIG. 6/2.
Simple Aerial

Because the wavelength is short, the half-wave aerial is small and a multi-element, high-performance array is of modest dimensions. (Fig. 6/3). Band-width is no problem, car ignition and similar noises are much reduced, and ghost signals more easily avoided by directivity of aerial.

The horizontal polarisation also helps the enthusiastic cleaner, as shown in Fig. 6/4.

National Coverage

Bands I and III have been thoroughly exploited in order to obtain national coverage. The BBC have, indeed, achieved remarkable results using the five channels of Band I to give a useful service to nearly 95% of the population. The ITA, using Band III channels, have also obtained extensive coverage. Now that consideration must be made to providing alternative programmes (such as BBC 2), it is apparent that not enough channels exist in Bands I and III.

The UHF bands have been closely studied by various authorities over many years. (The first UHF broadcast station went into operation as long ago as 1950, on 530 Mc/s, in the U.S.A.). As a
result of these studies, a European plan has been agreed, of which the U.K. channel allocations form an integrated part. The frequency ranges and channel numbers have been given in Table 1.

The 44 channels are 8 Mc/s wide (as against the 5 Mc/s channels already in use on Bands I and III) to allow for the use of 625 line standards and any possible colour system that may be adopted.

TRANSMITTER PLANS

Channel allocations were not made in a random fashion. Planning of a national service must take every possible cause of interference into account. In each area there will be four high-powered transmitters; adjacent receivers may be tuned to any one of the four channels—and interference effects from receiver oscillators must be avoided. Service areas will be small, and with 64 main stations each using four channels there will be 256 transmitters; receiving aerials must not experience any interference effects from other groups of high-powered transmitters surrounding the area, not so very far away.

It is possible to do the arithmetic posed by these problems, but it would prove a very formidable task. In fact, many thousands of calculations were made by computer to determine the channel allocations which would result in the minimum of interference effects.

The plan also recognises the existence of regions within the service area where deep shadows of poor field strength will exist. These will be covered by low-powered "fill-in" stations which will operate on different channels from the main stations, and will be vertically polarised.

Propagation

The most interesting feature of UHF operation is that, because the wavelengths are so short, the radio waves closely resemble light waves in their behaviour and the effects of shadows, reflections and refraction are much more pronounced than on the VHF bands. The wavelength for the lowest channel in Band IV (Channel 21) is about 25 inches, and for the highest channel in Band V (Channel 68) is about 14 inches. As already explained in Chapter 4, objects of quite modest dimensions will constitute an obstacle in the propagation path, and will cast a "shadow" region of low field strength.

Useful transmitter ranges depend very largely on a clear path between the transmitting and receiving aerials and, within the service area, very large variations in field strength are to be found. The service area is more clearly defined than on VHF, because the UHF signal strength falls very rapidly beyond the radio horizon. (See Fig. 4/2). Many regions of elevated ground outside the main service area can experience a good signal.
Taking the London district as an example, the service areas of Bands I, III and IV are compared in Fig. 6/5.

![Diagram showing service areas of Bands I, III, and IV in London district]

**Aerial Design**

The receiving aerial poses a special problem. The dipole is so short that a high field strength is required to develop a useful voltage, as the following example will show:

- **Field strength**: 1 mV/m.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Voltage developed in dipole</th>
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<tbody>
<tr>
<td>50 Mc/s</td>
<td>2 mV</td>
</tr>
<tr>
<td>200</td>
<td>500 μV</td>
</tr>
<tr>
<td>800</td>
<td>110 μV</td>
</tr>
</tbody>
</table>

Fortunately, field strengths can be high at the higher frequencies, as explained towards the end of Chapter 10. The transmitters will be using ERP's in the region of 500 kW, with 1 MW (1000 kW) in a few areas.
In spite of this radiated power, aerial requirements are stringent and may be summarised under three headings as follows:

1. The UHF aerial must have an unusually large band-width. The channels allotted to the London area, for example, are 23, 26, 30 and 33, whilst those for Birmingham are 40, 43, 46 and 50. The first channels to be operational (with BBC 2) are numbers 33 and 40. It will be necessary that an aerial erected to receive BBC 2 must also be able to receive the other three channels when they come into operation. The overall band-width for most of the groups is 88 Mc/s, but some special groupings are much wider than this. Over this wide band, the aerial must maintain its correct impedance and all its other characteristics as closely as possible.

2. The directivity (i.e. the polar diagram) must meet the requirements of the plan. This is a very important and essential requirement. It means that, even in regions of high field strength where a simple dipole could provide an adequate signal, the aerial would be unsuitable because its directivity is not satisfactory. A three or four-element Yagi would have to be used.

The front/back ratio has to be much higher than is general on VHF. Most UHF aerials have an extensive reflector design which helps to raise the front/back ratio. The reflector element varies from multiple rods to a fairly solid mesh screen, depending on the make of aerial.

3. The aerial must have gain figures higher than the VHF aerial. Over most of the service area, the yield from a simple dipole would be inadequate despite the high field strength, as shown by the example earlier. UHF tuners are less sensitive than VHF tuners; also, they are more noisy. Hence, to obtain a good signal/noise ratio, a much higher signal input is required. This situation will change as tuner design improves but, at this time, a minimum signal input of the order of 400–500 µV is required. This calls for a gain over the dipole of 9 or 10 dB, and a Yagi of about nine or ten elements is required. For optimum results, stacked or broadside arrays, similar to those illustrated in the next section, would be used.

Fortunately, the short wave length results in an aerial design of compact dimensions and low weight. A typical nine-element Yagi aerial, with a gain of about 10 dB, is less than three feet long and has a weight of only one pound. Another aspect of the use of such short wave lengths is that more exotic designs than the Yagi can be considered. The photograph in Fig. 6/6 shows a design using a single broad-band dipole mounted in what is known as a “corner reflector”.
Erection of Aerial

In Chapter 4 it was shown how important height can be on VHF. The same general principles apply to UHF, with the difference that we are now dealing with wavelengths that more closely resemble light in their behaviour. The aerial should generally be sited as high and clear as possible. This is the place to point out that Fig. 1/1 shows the aerials mounted in the wrong order; the aerial at the top of the mast should be the UHF aerial! The chronological order of the appearance of television in this country has, for most people, dictated the position of aerials on a mast, and it is probable that the addition of the UHF aerial to a mast will be as in Fig. 1/1—unless some large-scale dismantling and re-erection is carried out.

SHORT RANGE EFFECTS

It was also pointed out in Chapter 4 that, at short ranges, it is actually possible for the aerial to be too high. This effect may be much more pronounced on UHF. A difference in path length of only nine inches or so can produce 180° difference in phase (see Fig. 4/4), and the aerial should be raised and lowered a foot or two before being finally secured in position.
RIGIDITY

The aerial must be rigidly mounted, and the mast should be free from whip. At UHF an aerial sway of an inch or two due to the wind may cause picture "flutter", similar to the effect produced by reflections from an aircraft. Fortunately, the size and weight of the aerial do not make this a severe problem, but where the aerial is to be mounted on an existing structure carrying other aerials, the overall rigidity may require attention. The question of rigid mounting will be particularly significant when colour transmissions take place; it will be found that an aerial sway of an inch or two may change a colour from, say, red to blue!

STACKED ARRAY

Fig. 6/7 shows a good example of a stacked array. The basis of design and fixing is explained by the makers in the following terms: "When it comes to stacking large multi-element arrays, two main problems have to be overcome. The first is the method of electrical connection and the second is that of mechanical support. The aerial shown in the photograph shows the particular way in which Aerialite Limited have solved these two problems.

1. To obtain the maximum benefit from stacking of such large arrays, the arrays should be widely spaced. A substantial H-shaped tubular frame has been adopted to give a wavelength physical spacing.

2. The electrical connections are by a parallel feeder transmission line made from 3/" aluminium tubes, instead of co-axial cable. Such transmission lines are rigid, for consistent performance, cut cable junctions down to a minimum, which cuts down the need for carefully waterproofed connections, and supply a convenient transition from balanced connections to the co-axial downlead connected at the centre."

Fig. 6/7.
UHF stacked array with centre tube to facilitate mounting above existing VHF arrays.
Aerialite 45/D18

N.B. For a real display of stacked arrays, see Fig. 11/6.
BROADSIDE ARRAY

In this arrangement, the two aerials are mounted side by side and a good example is illustrated in Fig. 6/8, with diagrams showing the improved performance compared with a single array—Fig. 6/9.

Fig. 6/8.
Antiference UHF “Broadside Explorer”.

Fig. 6/9.
Diagrams showing increase in gain (centre panel) and improved directional properties with broadside arrays of the type illustrated in Fig. 6/8.

Aerial Balance

The dipole is a balanced device, i.e. neither of its terminals is at ground potential, but a coaxial cable is unbalanced in that its outer braid is at earth potential.

The problem is to connect the cable at UHF without unbalancing the aerial. (This is not so important at VHF because the wavelengths are much longer.)
Various methods exist for tackling the problem. One would be to use an auto-transformer (ratio 1 to 2) connected according to circuit of Fig. 6/10, between coaxial lead and aerial.

Another method is to use a shorter quarter-wave line. The end of the coaxial cable carries a \( \lambda/4 \) sleeve shorted to the outer conductor, which raises the impedance so that both sides are working above ground potential.

Yet another device is the BALUN used by Antiference. If a half-wavelength of line is connected between two points, it has the property of transferring an impedance value from one end to the other. The \( \lambda/2 \) line used in the Balun is a twin-conductor formed into a spiral, as shown in Fig. 6/11. The effects of unbalance are thus offset to ensure maximum performance.

Colour TV

It seems likely that this will be our next major UHF development, and as they have had a colour service in the U.S.A. for some time, we wrote to Norman H. Crowhurst for details about date of inauguration and rate of progress.

We received a typical N.H.C. reply which is reproduced here in full.

Your question about the year in which color TV (we don't have any colour TV here!) started service in the United States is an interesting one.

In 1950, it looked as if the CBS system, which primitively used a color wheel and was called the field-sequential system, because a whole picture was transmitted in each color in succession, was certain to be accepted by the FCC. In 1952, the then Radio
Manufacturers' Association (which has since changed its name to Radio and Television Manufacturers' Association and finally to Electronic Industries Association—still same bunch) set up the National Television System Committee (NTSC), which in 1953 adopted and recommended what was a system developed by RCA, the “dot-sequential” or color-gun system now used. The FCC adopted it as standard, giving the green light to go ahead, in 1953.

But as late as 1960, even the big cities had no color TV programs on the air. At every show, closed-circuit TV programs would be demonstrated—usually of such lousy quality that anyone but a millionaire who had money to throw away would comment, “I'll stick with b & w a little longer”. Some stations would transmit the occasional “special” in color, so the fanatics who had spent over $1000 for a color set could see something (?). But the manufacturers have been whittling away at the problems, and color quality has been improving, until now even local stations like Eureka, California, transmit color some of the time, for out of the way spots like this. We don't have it, but people with favorable reception spots in town do now have color TV.

That's the picture in US color TV. Now you tell me when service started! It's been pushed and pushed and pushed. Only the enormous amount of money that Americans will put into things ever got it started, but that very much more slowly than any other American enterprise anyone ever saw.

March, 1964.

Gold Beach, Oregon.

We can see from N. H. C.'s entertaining story that colour TV has had a somewhat chequered career over there, and we can assume that it will not be all plain sailing over here. There is however one consolation: it will not involve a new aerial in addition to the UHF array.
7

INDOOR AERIALS

It is obvious that aerial requirements depend on field strength, which in turn depends on locality, effect of hills, etc.

There are some people who live in a position of high field strength and may be able to receive VHF and UHF with a set-top aerial similar to those shown in Figs. 7/1 and 7/2.

**Fig. 7/1.**

_Telerection “Double Top” aerial with telescopic elements for Bands I, II and III and adjustable dipole for UHF._
INDOOR AERIALS

One convenient aspect of the indoor aerial is that it can be tried without any building or plumbing operations. A qualified dealer would help in the reception tests and arrange to fit outdoor equipment if found to be necessary to get rid of ghosts.

"—and some people said we'd get 'Ghosting' with an indoor aerial"

FIG. 7/3.  Drawing by Holmes.
It is unlikely that all bands will be of equal power and some movement and special orientation of elements will be necessary to suit conditions.

Then again, an outdoor or loft aerial may be necessary on one station, with a room set-up for the others.

This chapter is in fact intended for the few rather than the many, as it is easy to show that the majority of people do not live in areas of high field strength. If we assume an even population rate within 20 miles of a transmitter, with say 10,000 people living inside a five-mile radius, there would be about 30,000 in the next five-mile area, with a further 120,000 in the region between 10 and 20 miles away. The effects of distance and obstruction become more severe as wavelengths are shortened, and the importance of the aerial increases accordingly.

As to locality, reception conditions around Bradford are very good on the high ground but very variable in the valleys. Only yesterday a friend of mine—who lives in a valley—was complaining of snow on his BBC television picture, whereas the ITV picture was clear. It transpired that he was using an outdoor aerial for ITV, Band III, with a loft-mounted aerial for BBC reception on Band I. Fitting a King TV Booster removed most of the snow, but the picture was not quite so good as that given by an outside aerial expertly mounted.

On the other hand, a friend of his, living half a mile away—but on high ground—receives both TV programmes without difficulty using the set-top aerial illustrated in Fig. 5/7.

FERRITE AERIALS

Indoor aerials usually relate to TV and FM reception. Medium and long-wave receivers nowadays have a built-in ferrite aerial, or can be connected to almost any type of aerial system without worrying about coaxial joints and 75Ω impedance matching. The ferrite rod techniques have not yet become applicable to the VHF bands.

RESTRICTIONS

A lot of people are obliged to use indoor aerials. In many cases, the flat dweller has restrictions to observe that forbid the use of outdoor types. In some cases the reason is purely aesthetic, in that outdoor aerials would look unsightly in surroundings of artistic or architectural merit.

Loft Aerials

There are two types of indoor aerial; those for mounting in the roof space and those for use in the same room as the receiver. The loft-mounted aerial is, generally, a light-weight version of a standard
outdoor type, shorn of its costly outdoor fixings and waterproof junction box. A house usually has conveniently-placed wooden beams to which an aerial can be secured, but it is obviously of no use expecting it to perform properly if the roof has been lined with aluminium foil for heat conservation!

The Band I aerial may be a problem when vertically mounted in a roof space. For example, a Channel I dipole, which is over 11 ft. tall, will not go into a roof with a 9 ft. apex. For this reason, the Band I Hertz often takes the form shown in Fig. 7/4.

The horizontal section may be used as a boom for carrying Band III elements. Sometimes the horizontal section is in the form of a flexible “tail” that can be laid on the floor of the loft. By moving the tail around, a small measure of directivity can be applied to give some discrimination when interference is present. The aerial shown in Fig. 7/5 covers Bands I and III and can be tilted or rotated after fixing, to improve directivity. Also, the length of the top half of the Band I dipole is adjustable for optimum tuning.

In the version for horizontally polarised signals, both halves of the Band I dipole are rigid, but of adjustable length.
Band III aerials are so small that they present no difficulties. The elements are of light weight and offer no fixing problems.

The Band II aerial, being horizontal, may be even less of a problem. It often requires no securing and may be laid flat on the loft floor. This is such a convenient arrangement that one should use an "H" rather than a simple dipole; the extra gain (about 3 dB) and directivity are well worth having for so little trouble and expense.

The small size and weight of the UHF aerial make it an attractive model for loft mounting. But, as will be seen later, it may still have to be mounted outside for satisfactory results.

PLACEMENT

Siting of the loft aerial is, surprisingly, a very important and critical operation and should not be undertaken lightly. The loft space probably contains a water tank and various plumbing, gas and electric-wiring runs, all of which will be near to the aerials and will influence their polar diagrams and general performance. Gutters and fall-pipes outside the roof-space can, also, be very near to the aerials. As a result, the performance of a loft aerial is something that even the designer of the aerial would not predict; it must be the result of careful experiment, using various positions until the most satisfactory site is found.

Power Loss

What loss of signal strength results from mounting the aerial in the loft space instead of outdoors? Excluding the effect on performance of other objects in the vicinity, the attenuation due to the roof is negligible on Band I and quite small on Band III. (Incidentally, rain does not seem to have any appreciable effect at these frequencies.)

The UHF aerial requires special consideration before fitting in the loft space. The signal loss on these short wavelengths is no longer negligible, and varies from house to house. The attenuation is at a minimum when the field has to traverse one roof, but if it has to travel down a line of terraced houses before reaching the aerial, the loss will be severe. It is not possible to quote a firm figure for the difference between indoor and outdoor mounting, but the result of a large number of measurements at UHF indicates that, on the average, the difference will be of the order of 6 dB. In some cases it will be less than this, but in others it can be a great deal more.

It is clear that, before fitting a UHF aerial into the roof space one must be sure that the field strength is large enough to tolerate the possible heavy attenuation. Even then, siting in the loft must be carried out with even greater care than is necessary on VHF.
INDOOR AERIALS

Down Leads

It is possible to run one feeder cable from various aerials in the loft by using a Combining Unit to connect them together. A Dividing Unit may then be fitted in the listening/viewing room to separate the Bands as may be required. At UHF, the cable should be of the low loss calibre, say $\frac{3}{8}$" or $\frac{5}{16}$" coaxial as against the $\frac{1}{4}$" generally used for VHF leads.

It is a good plan, in a new house or when re-wiring, to run the cable in conduit as is done with electricity cable.

Room Aerials

We can now leave the attic and come down to home comforts.

One type of room aerial is a straight rod, resembling a dipole, useful for Bands I and III, and possibly Band II. It is usually a special form of dipole yielding a few dB's of gain on Band III, but being less efficient than a full-sized dipole on Band I. Where the field strength is high, a convenient position can usually be found in the room where the aerial can stack or lie.

The popular type is undoubtedly the more elegant "V" or "set-top" aerial. As explained in Chapter 5, these are variants of the Hertz aerial in which the two halves form the V. Tuning for Band III is generally possible by changing the length of the telescopic arms, and many aerials embody auxiliary tuning arrangements in the base for obtaining optimum performance on Band I. A number of makes now incorporate features for tuning to any Band, but such an aerial may require a Dividing Unit to provide the two inputs to the modern VHF/UHF receiver. (The model shown in Fig. 7/2 is fitted with two output leads.)

All set-top aerials suffer to some extent from the effects of anyone walking in the vicinity of the aerial. Shadowing and reflections cause the signal strength to vary. These effects are much more severe at UHF and, for this reason, the UHF aerial is generally in a form resembling a dipole and reflector. This gives the aerial some directivity which, together with suitable siting in the room, can be used to minimise the effects.

Many set-top aerials are now available for the UHF Bands only. This can prove convenient for anyone already in possession of a VHF aerial; the modern receiver has two input sockets. An interesting example is shown in Fig. 7/6. This consists of two metal rings about 8" in diameter, mounted on an anti-scratch base.
Safety Measures

Before fitting a set-top aerial, it is necessary to be certain that it conforms to certain safety requirements. Any room aerial must be so constructed that it is not possible to make direct physical contact with the input socket of the receiver. This is a safety precaution that, in practice, is carried out by either (a) a plastic coating over all exposed metal parts, or (b) connecting isolating capacitors in series with the exposed parts.

Final Word

Although very good results are possible on TV with indoor aerials in some districts, the fact remains that poor quality will result if an indoor aerial is adopted under conditions where an outside array should be used. This applies with particular emphasis to UHF.

It is reported that the GPO and the BBC are very concerned about the harm to the advent of BBC2 which is caused when a set is obtained and an inadequate indoor aerial is used in the interests of cheapness and convenience. The customer is in no position to know that he is not getting the best results, and considers that the poor picture quality he sees is one of the characteristics of the new UHF programme. In short, the high standards at 625 lines UHF are more exacting all along the chain than at 405 lines VHF.

The difference between the line density at 405 and 625 lines is clearly shown in Fig. 7/7, which is taken from the Mullard leaflet No. 7 dealing with BBC2 quality. It is clear that, with this greater line intensity, the detail for a given size of screen and viewing distance must be greatly improved if the required standards are maintained throughout.
Fig. 7/7. Diagram to show comparison between 405 and 625 lines.
DIPLEXERS AND MULTIPLEXERS

The need for diplexers first arose in 1954, when it was known that the new Independent Television Authority was soon to commence service on a new frequency range in Band III. The industry made aerials available, but it was necessary to combine the Band I and Band III aerials in a single feeder cable to plug into a common input at the receiver.

The design of a suitable filter appears, at first glance, to be fairly straightforward but it is, in fact, quite complicated. It has to isolate the effects of connection between the aerials, so that performance in each Band is not affected by being connected to each other via the diplexer. Also, above all, the impedance match on the coaxial cables must be maintained on the whole of the system.

The first commercially available diplexer to be produced in this country was designed by the Technical Editor of this book. The circuit arrangement is shown in Fig. 8/1. It is seen that the Band I input is taken through a low-pass filter, and the Band III input is applied through a high-pass filter. Fig. 8/2 shows the frequency response of the two filters; the diagram also indicates how the isolation between the Bands is achieved. (Note: The shape of the two response curves originally gave the name "Crossover Unit" to the device.)

![Diplexer Circuit Diagram](image)

**Fig. 8/1. Diplexer circuit designed by R. S. Roberts in 1954.**

Values:
- \( C1 \) 33 pfd
- \( L1 \) 0.06 \( \mu \text{H} \)
- \( C2 \) 8.2 "
- \( L2 \) 0.13 "
- \( C3 \) 12 "
- \( L3 \) 0.08 "

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Incidentally, I was more than a little interested in this design by Mr. Roberts because it so happens that we (at Wharfedale) were the first to offer a loudspeaker crossover to the general public in 1947, and Fig. 8/1 is as near to a full section speaker network as makes no matter. The main difference is that at VHF you are dabbling in microhenries and picofarads (µH and pF) whereas at audio frequencies we have the larger millihenries and microfarads (mH and µF). Anyway, so far as crossovers are concerned, we can claim to have been seven years ahead of our Technical Editor. (I am ordering a larger hat!)

All diplexers follow the same general principles. In many cases, the filter circuits have been simplified to something similar to Fig. 8/3 which is a half-section network.

It was realised that it is unnecessary to put the entire burden of isolation on the filters, because the receiver input circuits discriminate considerably when selecting the Band required.

An actual diplexer unit is illustrated in Fig. 8/4, complete with mounting bracket.

TRIPLEXERS

The addition of Band II to the Diplexer created the Triplexer (or Multiplexer). This addition often takes the form of a series circuit, frequency-centred on Band II. Fig. 8/5 shows the filter of Fig. 8/1, with the Band II addition down the centre.
DIPLEXERS AND MULTIPLEXERS

Fig. 8/4. Outdoor diplexer unit made by Antiference Ltd.

All multiplexers are reversible. That is, those so far discussed have combined signals into one output, but the same device can divide a number of signals on one cable into separate outputs. The differences between a combining unit and a dividing unit are usually concerned with construction. Combining units are used outdoors for taking aerial outputs into one feeder, therefore they have to be rugged and weather-proof. (See Fig. 8/4.) Dividing units

Fig. 8/5. Triplexer circuit, including FM Band II feeding into a common lead with Bands I and III.

Fig. 8/6. Triplex dividing unit for indoor use with provision for three coaxial output leads.

Antiference Limited
DIPLEXERS AND MULTIPLEXERS

are used indoors to feed the receiver and, consequently, are more elegant in design and do not require a weather-proof finish. A typical three-way dividing unit is illustrated in Fig. 8/6.

UHF

UHF filters are the latest multiplexers to appear. Their design is, again, following the same general principles shown in Fig. 8/1. The low-pass section passes the entire VHF Band, and the high-pass section covers the UHF Band; the crossover frequency occurs at about 300–350 Mc/s, as shown in Fig. 8/7.

![Relative Response Graph](image)

**Fig. 8/7.** Response of dividing network for VHF and UHF aerials.

When the TV signals at VHF and UHF reach the viewing room, they are divided by a splitter similar to the one shown in Fig. 8/8. This is small and light and is carried by the leads, requiring no fixing.

![Splitter for VHF and UHF signals](image)

**Fig. 8/8.**

**Complete System**

Finally, we show in Fig. 8/9 a block diagram of a complete system providing the two outputs for the modern television receiver, and a separate feeder cable for the FM tuner. (Maybe multiplex stereo one of these days.)

It is appreciated that these installations would be made by professionals, but it is useful to know how things work and what the future may have in store for us.
The insertion loss with combining and dividing units is about 6 dB.
BOOSTERS AND ATTENUATORS

THE TITLE OF THIS CHAPTER contains a pair of opposites. Boosters—or amplifiers—are used to raise the signal level, but attenuators are inserted to reduce it.

Nevertheless, the purpose is the same, and that is to ensure a reasonable voltage level at the input to the receiver, and this is why the two devices are dealt with in the same chapter. We will however tackle them separately.

BOOSTERS

At extreme range or in a region where signal strength is poor, a line amplifier can often be used with advantage. Where it is necessary for the cable run to be lengthy, a mast-head amplifier is useful to offset cable losses.

Early this year (1964) TV and FM boosters received a tremendous boost from the lay press, where they were described as a novel kind of magic box, instead of a convenient form of preamp. Such devices have in fact been in use for several years, particularly as mast-head amplifiers in coaxial relay systems. At least eight manufacturers are now in production with various TV and FM types.

The ideal amplifier will raise the signal level and add no noise of its own to the output. The practical amplifier will generate some noise, and the good amplifier will provide a lot of gain and very little noise. A figure for gain alone is no criterion of amplifier performance; it is necessary to know the noise performance as well.

Valve Amplifiers

These are available for use on the VHF bands. They are of two types; one for mast-head operation, and the other for use near the receiver (often secured to the back of the set). Both follow the same basic circuit, but the mast-head unit is rugged in design and weather-proof.
In order to keep amplifier noise to a minimum, triode valves are used either as grounded-grid stages, or in pairs as a “cascode” stage. (Pentodes or multi-grid valves are more noisy than triodes).

Power supplies for heaters and h.t. are fed to a mast-head amplifier in a number of ways. In some cases, an a.c. supply is fed up the coaxial cable (down which the amplified signal is fed to the receiver), to a small power unit in the housing of the amplifier. A statutory maximum voltage of 65 V must not be exceeded on the cable, and a transformer is required to supply this voltage. It is then necessary to filter the power supply and signal-frequency voltages on to, and off, the cable. Fig. 9/1 shows A how the a.c. and r.f. supplies are filtered at the amplifier. At B is shown a diagram of the unit at the receiver end of the cable.

**Fig. 9/1. Power supply from a.c. mains being fed via coaxial cable to mast-head amplifier.**

- A Mast-head filter unit.
- B Indoor filter unit.

In simple terms, the capacitors keep the 50 c/s voltage out of aerial and receiver, while the RF chokes keep the VHF signals out of the a.c. supply to the booster.

There are other, and more complicated, methods in use whereby d.c. and a supply for the heater can be fed up the cable from a power unit located at the receiver end.

Valve head amplifiers have some disadvantages. The valve life is finite and, at some time, a replacement will be required, and this can be an inconvenient operation. At UHF, a further disadvantage arises; the signal/noise ratio is worse than when the valve is operated at VHF.

**Transistor Amplifiers**

During the last two or three years, transistors have become available that will operate up to the highest frequency in Band V, with a lower noise level at UHF than can be obtained with valves. As a consequence, transistors have tended to replace valves for
mast-head use, and also for all other booster applications because of their compact size.

Transistors have many advantages and some disadvantages. It is no longer essential to feed l.t., h.t. or a.c. up the cable; the only power supply required is a modest voltage (6—18 V) at a few milliamps, from small batteries or a small power unit. The life of the transistor can be very long (how long is not yet known), but careful design of the amplifier is necessary if the performance is to be maintained over temperatures ranging from the sub-zeros of winter to those of a hot summer. Transistors are notoriously more non-linear than valves and, although they are now being used for a single UHF channel, their cross-modulation performance when all four stations are in operation may be poor, and there is no protection from the wide-band aerial. However, it is reasonably certain that, as transistors improve in performance, they will be the standard method for preamplification of signals before they reach the receiver.

UHF ADVICE

A few notes of caution on the use of transistor amplifiers at UHF would not be out of place, so here they are:

1. Some transistor amplifiers have a tendency to instability, and any resulting oscillation can create a disturbance over a considerable area. Oscillation may be taking place on a frequency where other channels may appear at a later date, or even out of the UHF band altogether.
2. It is essential that the amplifier, once installed, shall cover the full band-width necessary for all four channels.
3. At extreme range, one might be tempted to use a modest aerial with an amplifier. It should be remembered that the directivity of the combination will be that of the aerial, and any interference effects due to inadequacies in aerial directivity will be amplified.
4. Excessive transient voltages of very short duration can destroy transistors. So, do not be surprised if the amplifier is not functioning after a nearby thunderstorm!

Having covered the general principles behind the booster device, we will complete this section with a brief account of the performance of actual units.

FM Booster

It is well known that distortion is produced in an FM receiver if the input signal is too weak. Under such conditions, a booster could be a most valuable asset.
In Fig. 9/2 we illustrate the King FM Booster, which is battery operated with transistor and printed circuit, and is designed for indoor use.

The input and output impedances are 75 ohms but the booster can be used in any circuit between 50 and 350 ohms impedance. It also covers the whole of the FM band.

This unit has been tested in Ilkley on one side of a hill where the VHF reception is difficult even with a very good aerial. The booster gave a much stronger signal with an improvement in quality on FM.

**TELEBOOSTER**

Made by the same firm, the Telebooster covers Bands I and III, and has already been referred to in Chapter 7 in relation to a loft aerial used for BBC1. One of our directors (Mr. W. E. Escott) has a flat in Filey with outside aerials which are satisfactory for BBC1, but produce only sound on ITV. The insertion of a Telebooster improved the sound and also provided a watchable ITV picture.

It should be added that these results were obtained with a rather old receiver. A modern set used with the same type of aerial in a similar locality picks up the ITV transmissions very well. In our Mr. Escott’s case—being a Yorkshireman and using the flat only occasionally—it suited him better to buy a Telebooster at less than £4 than a new set at about £60!

By the time the UHF service is in general use there will be plenty of boosters available. In fact, Television Installation Service already have a battery-operated model pre-tuned to one channel in Band I, a channel in Band III, plus a 30 Mc/s band-width on UHF.

**Mast-head Mounting**

As already mentioned, this is rather more efficient than back of set or skirting-board mounting, as it operates before the down lead losses occur and avoids amplifying any noise on the down lead.
BOOSTERS AND ATTENUATORS

Installation would be carried out by professionals as no amateur should risk breaking a leg trying to do work which calls for skill and experience as well as technical knowledge.

The battery or mains unit to power the booster would of course be placed at the set end and fed via the aerial down lead, a simple LC filter being used to separate the d.c. and signal components, as already explained.

In Fig. 9/3 a Belling-Lee VHF Booster is illustrated.

The amplifiers are generally tuned for operation on one particular TV channel. The Band II variety covers the three BBC FM services.

The makers will also produce a UHF version, as suitable transistors are now becoming available. The method of use is neatly described by Mr. G. F. Redgrave as follows:

**UHF Mast-head Booster**

Again, there are likely to be two versions; the lower gain model for general use will be a wide band model (88 Mc/s) covering all four local channels that will ultimately be used in each area, and the higher gain type for distribution systems will be tuned for one particular channel to obtain maximum performance on each, in line with the requirements of all public utilities.

Initially there will be, in fact there already is, a considerable demand for these UHF boosters for use in relatively high signal areas because the present generation of sets requires a fairly large signal input, of the order of 600 μV minimum (c.f. the 200 μV or less required by contemporary VHF receivers), to produce a
good picture. This is due to the amount of self-generated noise in the valve equipped tuners.

By the use of a low noise pre-amplifier, a signal of only 250 \( \mu V \) from the aerial will produce an equally good picture and, at levels of this order, noise picked up on the down lead is not usually a problem and so the pre-amplifier can be installed anywhere along the line, even adjacent to the set. Later on, as the performance of sets is improved, the UHF pre-amplifier, like the VHF type, will only be required for boosting very weak signals, and then it will normally be desirable to mount it at the mast-head.

I am sure it will be obvious to you that, for people who live in areas of very weak signals, it is more practical and economical to raise the gain of an installation by an amplifier than to try to do so by making a more elaborate aerial, provided the existing one has adequate directivity. Beyond a certain point, the complexity of an aerial increases out of all proportion to the improvement in its gain.

G.F.R.

Other firms producing mast-head devices include Aerialite, Labgear, Transpeater Ltd. of Worthing, and B.H.L. Aerial Installations Ltd. of Northampton.

**INDOOR AERIALS**

In fringe reception areas where an outdoor aerial would normally be required, a booster could make it possible to work with an aerial mounted in a loft or attic.

The booster could also be used with a set-top aerial, although there might be a tendency to instability in some cases. To avoid this, the King Telebooster is available in a patented integrated form with aerial, described as a “Powered Set-Top Aerial”.

**GHOSTS**

In hilly districts where ghosting is troublesome, an improvement can be effected by orienting the aerial to avoid the ghosts, even at the cost of signal strength, which is then augmented by the booster. Similar tactics could be tried with aerials in loft or attic.

**ATTENUATORS**

We now leave the more barren fields of TV and FM reception, where local assistance may be necessary to maintain reasonable standards, and we turn to the land of plenty where too much of a good thing may result in severe indigestion, so to speak.
A signal which is too strong is very evident on a television receiver. With the contrast control turned right back, interference of “vision-on-sound” and/or “sound-on-vision” may be experienced. In an extreme case, contrast may be lacking or, even, the picture may go negative (i.e. whites go black and blacks, white). Undoubtedly, the best method of dealing with the strong signal is to introduce an attenuator into the feeder cable lead, and if the correct value of attenuator has been used, the resulting picture quality can be superb.

With a few exceptions, it is seldom possible to have a signal which is too strong on Band II. As explained in Chapter 4, the harder the limiter stage is driven, the better is the signal/noise ratio. This generalisation presumes that the circuitry of the receiver includes an efficient AGC system. The exceptions are a few receivers and tuners in which AGC is not applied to the first stage. A strong signal can overload this first stage, resulting in many effects ranging from cross-modulation (where interference from one or both of the other channels may be experienced), to a situation where the local stations can be tuned at several positions over the band. The remedy is to use an attenuator.

The usual method for reducing signal levels is to insert a form of “Pi” or “T” attenuator network in the feeder line. It is essential that the feeder-cable terminal impedance is undisturbed by the use of an attenuator; also, the receiver input socket must still “see” 75 ohms.

A convenient way of reducing the level is to unplug the feeder from the back of the set, and plug in a unit such as the one shown in Fig. 9/4. A socket at the end of the unit is provided for the insertion of the feeder plug.

![Fig. 9/4. Belling-Lee π pad Attenuator for plugging into receiver socket.](image)

The circuit of the “T” attenuator is shown in Fig. 9/5. Typical values of $R_1$ and $R_2$ for various degrees of attenuation are given in the table.
The circuit does not show stray capacitances and inductances. The reactances provided by these strays are not significant if the frequency is low, but they can make nonsense of the values shown in the table if the frequency is made sufficiently high.

Fortunately, UHF problems are more concerned with obtaining a strong enough signal, and attenuation problems that cannot be dealt with by the receiver's contrast control seldom arise.

**Signal Strength Meters**

When playing around with aerial orientation, signal boosting or attenuation, etc., the benefits of a calibrated meter for checking results are self-evident. A typical unit for UHF is illustrated in Fig. 9/6.

This is quite a complicated piece of equipment, as the following technical details, supplied by the makers, clearly show.

The instrument is a.c. mains powered, and comprises a standard commercial UHF tuner with a frequency coverage from 470 to 860 Mc/s, i.e. channels 21 to 68 inclusive, in one range (this is the whole of Bands IV and V at present allotted to television broadcasting in the U.K.); the output from this is fed to a stabilised i.f. amplifier, signal rectifier and range expansion circuit, and thence to a calibrated meter which gives a direct reading of signal strength in the range 100 μV to 10 mV, without switching. The instrument may be used for comparative measurements in determining the optimum position for an aerial, or it may be used for actual signal

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**Fig. 9/5.** Circuit for VHF attenuator. Resistors $\frac{1}{4}$, $\frac{1}{2}$, or $\frac{1}{10}$ W, cracked-carbon type of low self-inductance.
strength measurement, the calibration accuracy being ± 3 dB; an in-built mid-band calibration source (stabilised) is incorporated. The band-width is 1 Mc/s at ± 1 dB points, so that signals in the sound and vision channels can be separately measured, and an audio output socket is provided.

After this excursion into the realms of signal strength, we will move on to the next chapter and take a look at Transmitters—without which we should have no signal strengths to measure.
TRANSMITTERS

WHEN DEALING WITH THE SUBJECT OF AERIALS, it is obviously im­
possible to overlook or over-emphasise the importance of the
transmitter.

We are therefore pleased to have a contribution from Mr. M. G.
Foster of the BBC Engineering Information Department, who will
now take over and transmit on his own wavelength.

Transmitters and How They Work
by M. G. Foster, A.M.I.E.E.

After that introduction it might be said, in the words of the late
Professor Joad, “It all depends on what you mean by a transmitter”.
Most electrical devices, thermostats, vacuum cleaners, even motor
car ignition systems, act as transmitters, often interfering with radio
reception, and they do this for the very good reason that they cause
“an electromagnetic disturbance” to which an adjacent radio set or
television receiver will respond.

The theory of electromagnetic waves—of which the radio wave is
one—was originated by the British physicist James Clerk-Maxwell
in 1864. The equations he formulated showed that electrical and
optical phenomena in space are essentially similar in character and
that if the wavelength is sufficiently short a light wave results
whereas longer wavelengths are radio waves. They travel in free space
at a speed of 300,000,000 metres per second—about 186,000 miles
per second—the same speed as light waves.

A transmitter then is a device whose primary function is to
generate high-frequency oscillations which, when amplified and fed
to an aerial system, will set up electromagnetic waves in space.
Its second function is to provide some means of “modulating”
these waves so that they can be made to carry the information it
is desired to transmit.

If the speed of oscillation, or frequency, is low, the wavelength is
long, and the higher the frequency the shorter the wavelength.
TRANSMITTERS

Wavelength
The relationship between wavelength and frequency is quite simple and can easily be calculated from the formula:

\[ \lambda = \frac{c}{f} \]

where \( \lambda \) = wavelength
\( c = \) speed of light
\( f = \) frequency

or in plain language:

wavelength, in metres = \( \frac{300,000,000}{\text{frequency in c/s}} \)

Taking one example in long waves, and one at VHF in Band I we get:

\[
\begin{align*}
\text{Frequency} & \quad \text{Wavelength} \\
200 \text{ kc/s} & \quad \frac{300,000,000}{200,000} = 1,500 \text{ Metres} \\
50 \text{ Mc/s} & \quad \frac{300,000,000}{50,000,000} = 6 \text{ Metres}
\end{align*}
\]

The wavelengths internationally allocated to broadcasting in the United Kingdom are shown in Table 3, Chapter I, and it is this variation in wavelength or frequency which enables the receiver to sort out the desired transmission from all the others, by being tuned to the specified frequency.

Resonance
All readers are familiar with resonance and will know that when certain bodies are vibrated, either mechanically or by sound waves, they resonate at a spot frequency or over a frequency range according to their constitution, size, shape, etc.

Similarly, electrical circuits made up of inductance and capacitance each have their own individual resonant frequency. At this particular frequency the circuit will pass its maximum current and if it is “excited”—this time by electrical oscillations (not by the programme!) at or very near that resonant frequency—it will respond readily, whereas it will be almost unaffected by oscillations of a different frequency.

Transmitters therefore consist basically of electrical circuits which are arranged to set up an alternating current of a particular frequency and to maintain that frequency very precisely. This “drive” as it is called has its output amplified to produce the required
output power which may be a few watts or several hundreds of kilowatts.

To pass on information, the transmitter carrier must be modulated and the receiver provided with means to sort out the information from the carrier. The two methods now used are known as amplitude and frequency modulation and have been described in Chapter 1.

**Tuned Circuit**

First let us consider the production of the carrier wave whose frequency is all important in ensuring that the broadcast operates only those receivers which are tuned to it. Of the various possible methods of producing the required oscillations, the one almost exclusively used until recently was that employing the thermionic valve. Today, in many cases, transistors are replacing the actual valves, but the principle remains the same. A very important property of the three electrode valve is its ability to create and sustain electrical oscillations as well as amplifying them.

If we construct a circuit such as that illustrated in Fig. 10/1, having a tuned circuit consisting of an inductance L and a capacitance C in the anode circuit of a valve and having grid and aerial coils connected in the grid-filament circuit and between the aerial and earth, we have a very simple transmitter.

A continuous oscillating current is produced by the oscillatory circuit and is coupled to the aerial-earth circuit by transformer action. The arrow shown in Fig. 10/1 is the normal indication that the degree of coupling between the three coils is variable.

In practice the frequency is determined by L and C. The aerial is tuned to the frequency of the LC circuit by its capacitance, inductance and the coil in the aerial circuit, thus ensuring the maximum energy transfer between the oscillatory and aerial circuits.

This arrangement represents one of the simplest forms of transmitter but modern broadcasting stations employ far more complicated circuits to ensure the precise stability of their transmitted carrier frequencies.
TRANSMITTERS

Frequency Control

Various devices have been used at different times to control the carrier frequencies of transmitters, including tuning forks whose vibrations were electrically maintained. By far the most common form of high-stability drive used today, however, is the crystal controlled oscillator.

Certain crystals including natural quartz, tourmaline, Rochelle salt and others have Piezo-electric properties. This means that if the crystals are subjected to tension or compression they produce tiny electric potential differences across certain axes. This property, incidentally, is made use of in crystal microphones, and crystal pickups for disc reproduction. Conversely, if an alternating voltage is applied to such a crystal it will vibrate. Further, if the frequency of the applied voltage is at or near the natural frequency of the crystal—a frequency determined largely by its physical dimensions—something like mechanical resonance occurs. The vibrations induced in the crystal in this way set up a corresponding oscillatory voltage across it which, in turn, is applied to a valve circuit and used to maintain the frequency of oscillation in the circuit.

Since the crystal frequency is almost entirely dependent upon its dimensions, very precise grinding and polishing techniques can be used to produce crystals giving a high degree of frequency stability. Other very important factors governing the stability of crystal controlled oscillators are temperature variation and voltage supplied to the valve circuit. Crystal drives are therefore usually fed from the mains via a voltage regulator which automatically compensates for changes in the incoming supply pressure, whilst the actual crystal unit is contained in a thermostatically controlled oven which maintains its temperature as nearly constant as possible. Temperature changes within the oven of BBC drive units are of the order of 0.01°C for ambient temperature changes of 5°C. The whole equipment is often installed in a room where the temperature is thermostatically controlled, which still further reduces the possibility of frequency changes due to ambient temperature variations.

As a case in point, it is interesting to note that the Droitwich Light Programme Transmitter has a long-term frequency stability which is maintained to within 5 parts in 10\(^9\). The diurnal rate of frequency change of the 200 kc/s carrier frequency is not greater than +1 part in 10\(^10\), and the resultant error is corrected on the first Sunday in each calendar month.

Transmitting Stations

Following on the drive unit are amplifying stages to provide the required carrier output power. Similarly, amplifiers are employed to raise the power of the incoming speech or music signals to such a value that they can be used to modulate the transmitter carrier
with the information it is desired to radiate. A typical AM installation, at Droitwich, is shown in Fig. 10/2.

In the foreground is the desk from which the transmitters are controlled. On the right can be seen part of the two medium-wave Home Service transmitters each having an output power of 150 kW; only one of these is in use at a time, the other acting as a standby. On the left are the two long-wave Light Programme transmitters which are operated together to give an output power of 400 kW.

**Stages of Development**

So far we have considered only amplitude-modulated medium-frequency transmitters, but before going on to discuss other types let us take an excursion back in time and examine the growth of broadcasting as we know it today and some, at least, of the reasons for changes which have occurred over the years.

The BBC’s first 2LO transmitter, which started service on 14th November 1922, has been illustrated at the beginning of Chapter 1. This was replaced on 6th April 1925 by a more powerful one on the roof of Selfridges in Oxford Street, shown in Fig. 10/3.
Other stations in Newcastle, Cardiff, Glasgow, Aberdeen and Bournemouth came on the air during 1923, and a station in Belfast was opened in 1924. Each of these stations had a transmitter power of 1.5 kW and could be heard on crystal sets over a range of some twenty miles during the day and much further at night. Ten low-power relay stations were also opened during 1924. Each was linked to a main station and between them they brought some 60 to 70% of the population of Great Britain within range of a transmitter.

**Interference**

Up to the 1939–45 war, sound broadcasting in this country was confined to the medium and long-wave bands, with the Empire Service as it was then called on the short-wave bands and the Television Service from Alexandra Palace in the VHF band. At that time the service given was reasonably satisfactory in most parts of the country and, provided a fairly selective receiver was used, interference between stations in the United Kingdom and on the Continent caused comparatively little trouble.

After the war, however, the picture had changed; more and more stations were competing for a limited number of long and medium wavelengths and transmitters of higher power were coming into service with the result that interference between them became more and more general.
VHF/FM

After careful laboratory tests had indicated that a change to the VHF band would be likely to provide a generally improved service, the BBC opened an experimental VHF sound broadcasting station at Wrotham in Kent in July 1950. It was equipped with two 20-kW VHF transmitters and began a series of test transmissions using both amplitude and frequency modulated signals.

This work culminated in a proposal for a VHF broadcasting chain using frequency modulated transmitters and providing substantially National coverage with three programmes.

The advantages of such a scheme were, firstly, that the service areas of stations operating in the VHF band, between 88 and 100 Mc/s, would extend only to a distance approximating to the horizon, thus largely overcoming the problem of interference between stations in fairly close geographical proximity. Secondly, that such frequencies are relatively insensitive to interference from man-made sources except in areas of low field-strength. Thirdly, these frequencies, coupled with the FM system of modulation, permit a much wider audio frequency band-width to be transmitted and could therefore offer a much higher quality of reproduction from the receiver provided the latter was designed to handle the greater frequency range of the incoming signal and was fitted with a good quality loudspeaker.

To return once more to our transmitters, it can be seen from Fig. 1/9 that we now have another problem, namely to provide a drive unit which will maintain a highly stable mean frequency but which can be varied instantaneously by the modulating signal. One such unit is known as the Marconi FMQ drive. In this a crystal controlled drive oscillator is used, but the frequency it generates is 1/24th of the required carrier frequency. The actual crystal is specially cut to prevent it from producing any spurious resonances in the modulating frequency band. The output from the oscillator unit is fed through a series of frequency multipliers to produce the final carrier frequency. Now it follows that in multiplying the oscillator frequency by 24 any deviation in the original frequency will also be multiplied by 24. Thus, if the required deviation in carrier frequency is to be ± 75 kc/s, the deviation in the original oscillator frequency needs to be 75/24 or ± 3.125 kc/s. This system has the advantage that the mean carrier frequency stability is high due to the crystal control. Also, because of the special way in which the crystal is cut, it is possible for the modulator circuits to swing the fundamental frequency which it generates by the comparatively small amount of ± 3.125 kc/s which would not be practicable with conventionally cut crystals used in other forms of drive.
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Equipment

It has been attempted, very briefly, to give an idea of the method of operation of amplitude and frequency modulated transmitters but it must be borne in mind that a transmitting station needs to contain a lot more equipment besides the actual transmitter, and requires elaborate distribution facilities.

LAND LINES

It is common practice to site a transmitting station in the place most suitable to serve the particular area concerned. Therefore it is necessary to pass the programme material from the studio centre—usually in a large town or city—to the transmitting station: usually in a remote spot. In most cases this is done using a land-line or telephone-type cable.

Since the responsibility for providing point-to-point communication links in this country is vested in H.M. Postmaster General, the broadcasting authorities rent the lines and television circuits between their various premises from the Post Office and the actual lines themselves are owned and maintained by the Post Office, just as one's private telephone is owned by the GPO but is used exclusively by oneself. To attempt an accurate diagram of the distribution of the domestic sound and television programmes within the compass of one, or even two, pages of this size would be impossible, but Fig. 10/4 shows the main distribution circuits of the Home Service from Manchester which receives its feed from London via Birmingham; this is typical of the circuits radiating from BBC main Regional Centres.

![Diagram showing distribution circuits for Home Service from Manchester Centre, using eight cable lines and four radio links.](image)

As a contrast Fig. 10/5 shows the main television distribution circuits in the London area between the various BBC premises concerned with the origination or control of television programmes.
LINE QUALITY

Most of the music circuits provided by the GPO for BBC use will carry audio frequencies up to 8 kc/s; many will handle frequencies of 10, 12 or even 15 kc/s. A great improvement has taken place over the years in the frequency characteristics of these circuits and more is being done each year.

Nevertheless, complaints are received from time to time from folk who evidently consider that no line incapable of passing 15 kc/s should be used anywhere in the distribution system. Perhaps, ideally, this would be a good thing, but such a contention completely overlooks the fact that in many cases such circuits just do not exist over the routes needed. Even if they did, their use would mean a large increase in rental costs. To offset such increases in rental, however, and also to improve the frequency characteristics of the...
programme links, broadcasting authorities are making more and more use of re-broadcasting techniques.

It is frequently possible, by using aerials specifically designed for the purpose and mounted at an adequate height on a tall mast, to receive the programmes radiated by a fairly distant station and to use these programme signals to modulate a transmitter serving a completely different area. By this means line rentals are saved and the frequency response of the “link” is not restricted by line characteristics. Care has to be taken when using this arrangement to ensure that any deterioration, such as severe fading, due to abnormal propagation conditions is not likely to impair the programme to a greater extent than would be occasioned by line faults.

BBC Stations

Quite apart from the distribution of the programmes themselves a corresponding communications network is needed to support the sound or television services. Fig. 10/6 shows a general view of the Communications Room at Broadcasting House, London.

Fig. 10/6. Main Control Desk, in Communications Room, Broadcasting House, 1962.
Once the programme has arrived at the transmitting station it is connected to the "Programme Input Equipment" which comprises equalizers, to restore the correct balance between high and low frequencies in the incoming signals, amplifiers to make good the losses in signal level occurring in the line and equalizers, and limiters. Limiters are in effect amplifiers so designed that, if the input signal increases beyond a predetermined level, the output remains constant. Their purpose is to prevent distortion due to over modulation and possibly damage to the equipment which might result. Fig. 10/7 shows the programme input and lines test equipment at the VHF transmitting station at Pontop Pike, together with the automatic monitors which give an alarm if a fault occurs in the programme feeds or transmitters.

Fig. 10/7. Pontop Pike VHF/FM Transmitting Station, 1956.

Nowadays stations are designed from the outset for a.c. mains operation, the d.c. supplies for the actual transmitters and associated equipment being derived from rectifiers. These range from small metal rectifiers, similar to those used in car battery chargers, supplying small amplifiers and similar apparatus, to the large steel-tank mercury-arc type delivering 11,000 to 15,000 V and rated at up to 450 kW, which provide the main H.T. supplies for high-power transmitters. Silicon rectifiers also are now coming into use at broadcasting stations.
Transmitter Systems

Since this is a handbook on aerials this section would not be really complete without a few words on transmitter feeder and aerial systems and these fall into a number of different classes.

Short-wave transmitters are intended to put down their signals at points hundreds or even thousands of miles distant and it is therefore desirable to direct as much of the radiated energy as possible towards the destination. The aerial must impart the correct horizontal and vertical angles to the radiated wave to take advantage of the reflections referred to earlier and the “beam” width must be kept as small as is practicable to prevent losses by spreading the signal over too large an area at the receiving end.

These conditions are fulfilled by using what are known as “curtain arrays” which are aerials comprising a large number of small radiating elements each approximately half a wavelength long suspended in a horizontal and vertical stack rather like the beads

Fig. 10/8. Short-wave transmitting aerials at Daventry, 1937. By using one curtain as radiator and the other as reflector, the beam may be directed in either of two reciprocal directions.
TRANSMITTERS

on a Victorian bead curtain. Each radiator is fed from the main feeder of the transmitter using the aerial. If only a single aerial of this type were used it would radiate in two directions, one to its front like the beam of light from a searchlight and one from its back in precisely the opposite direction. It is therefore customary to suspend a second similar curtain behind the array which acts as a reflector (as already explained in Chapter 4, Yagi principle), suppressing radiation to its back and directing all the suppressed energy in the desired direction. This halves the transmitter power that a bi-directional system would require and avoids interference with other services as far as possible. Fig. 10/8 shows such an array and reflector curtain at a high power short-wave station.

AERIAL SWITCHING

As different aerials and transmitters have to be used at different times of the day and seasons of the year it is essential to provide a very flexible arrangement for connecting transmitters and aerials at short-wave stations. Figs. 10/9 and 10/10 show the early, hand-operated, and the modern, remotely controlled, feeder switching systems used at short-wave transmitting stations.

Fig. 10/9. BBC short-wave aerial-switching and distribution frame, hand operated, as used in 1937.
MEDIUM AND LONG WAVES

At stations radiating in the medium and long-wave bands completely different types of aerial are used. Some are wire aerials supported by masts such as that used for the long-wave Light Programme transmitter at Droitwich and shown in Fig. 10/11. Others are of the type known as mast radiators, in which the structure of the mast is insulated from earth and is used as the actual radiating element. An aerial of this type is also seen in Fig. 10/11 and a view of the MW Third Programme aerial at Daventry is seen in Fig. 10/12. Such aerials provide approximately equal radiation in all directions.
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Fig. 10/11. BBC Transmitting Station, Droitwich, 1946. Transmitting aerials supported by two 700 ft. masts radiate long-waves at 400 kW. In the foreground is a 350 ft. tower used as mast-radiator on medium-waves, 150 kW.

VHF

In the VHF bands many different types of aerial can be used depending on the required transmission characteristics. Various names which are frequently seen are the dipole, folded dipole, slot, vee, turnstile and batwing.

At high-power VHF stations the most commonly used are the folded dipole and the slot. Fig. 10/13 shows the upper section of the mast at a high-power television and VHF sound transmitting station. The folded dipoles used for the Band I television aerial can be seen mounted on the short topmast above the cylinder. The cylinder itself with the slots seen in the vertical face forms the slot aerial used for the VHF sound programmes. One advantage of this type of aerial is that by arranging the slots in tiers one above the other the effective strength of the radiated signal is increased. Thus a slot aerial having, say, eight tiers of four slots each will
produce an effective radiated power—allowing for losses in the feeders, etc.—about six times greater than the rated output of the transmitter feeding it. This represents a considerable saving in power as it means, for example, that a transmitter of, say, 10 kW output connected to the aerial would have an effective radiated power of 60 kW.

M.G.F.
Many thanks to Mr. Foster for his high-power contribution and also to the BBC Engineering Information Dept. for some excellent photographs.

*   *   *

We will now take a brief look at the position in relation to commercial television, followed by a glimpse at Eurovision, Satellites, and the new Post Office Tower.

The number of TV transmitters in use by the BBC at the end of 1963 was 86, located at 41 stations, of which 9 are translators.
TRANSMITTERS

The number in use by the Independent Television Authority was as follows:

<table>
<thead>
<tr>
<th>ITA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Television transmitters</td>
</tr>
<tr>
<td>Transmitter stations</td>
</tr>
<tr>
<td>Translator equipments</td>
</tr>
</tbody>
</table>

When I received this information I was rather intrigued by the translators, as I thought they must be new devices for use on foreign transmissions and translating Russian into English—or vice-versa.

However, their true function is described by Mr. P. C. D. Dann of ITA as follows:

A television translator is essentially a frequency changing device in which the signal is received from the parent station, frequency changed to another channel, amplified and re-radiated at a higher power. This applies, of course, to both sound and vision signals.

A typical translator station is at Selkirk. It receives signals from the parent station at Caldbeck which is approximately fifty-six miles away in a direct line. The signal level at the input to the translator in this case is approximately 300 $\mu$Vs and is on Channel 11. The corresponding output power of the translator is 1 kW and the maximum effective radiated power of the station is 25 kW on Channel 13.

Translator stations are unattended; a maintenance team visits them after periods lasting several weeks. In order to be sure of maintaining a continuous and high quality service to the public, precautions are taken to ensure that at least three major faults are necessary before the station is forced to reduce power and four major faults before it is off-the-air in either sound or vision. There are in effect four of these equipments. Automatic change-over facilities are provided and in addition the signal from Selkirk is monitored and indication facilities also exist.

P.C.D.D.

The next three photographs give a good impression of the type of equipment involved in ITV activities.

The first is an aerial view of the transmitting station at Fremont Point on the north coast of Jersey, serving 100,000 people living in Jersey, Guernsey, Sark and Herm. This transmitter is, to say the least, nicely situated. The mean aerial height is 760 ft. above sea level with a radiated power of 10 kW on vision and 2.5 kW on sound.
Fig. 10/14. ITA Transmitting Station, Jersey. Band III, Channel 9, horizontally polarised.

Fig. 10/15. A view of the station building at the ITA Transmitting Station, Caradon Hill, Cornwall.
TRANSMITTERS

The Caradon Hill station in Cornwall uses Channel 12 in Band III, vertically polarised, and a view of the building is given in Fig. 10/15. The mean aerial height here is 1,925 ft. above sea level, and radiated power is 200 kW vision and 50 kW sound.

Moving further north we come to Pembrokeshire in the principality of Wales. A view of the control room at Presely is in Fig. 10/16. The effective radiated power is 100 kW on vision and 25 kW on sound, with a mean (and generous!) height of 1,875 ft. above sea level.

![Image: A view of the Control Room and Transmitting Hall at the ITA Station, Presely, Pembrokeshire.]

Radiated Power

It is fairly obvious that this must be determined in accordance with the wavelength in use and the area to be covered. For instance, we see from the BBC Handbook that on medium wavelengths Droitwich has a power of 150 kW whereas Londonderry is served by 0.25 kW. On TV we find 500 kW from Crystal Palace in Band I, with a mere 0.002 kW for Hastings via BBC relay station to serve a secluded area.
This is understandable, but when browsing through one of the interesting ITA Handbooks* I noticed that they quote transmitter power and effective radiated power, the latter being as much as 40 times higher from the largest stations.

To cite Jersey and Cornwall—already illustrated—and the large Croydon transmitter, we have the following figures:

<table>
<thead>
<tr>
<th>Station</th>
<th>Transmitter Power</th>
<th>Effective Radiated Power</th>
<th>Radiated Increase Times</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freemont Point, Jersey</td>
<td>Vision 2×0-5 kW</td>
<td>10 kW max.</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Sound 2×0-125 kW</td>
<td>2-5 kW max.</td>
<td>10</td>
</tr>
<tr>
<td>Caradon Hill, Cornwall</td>
<td>Vision 2×5 kW</td>
<td>200 kW max.</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Sound 2×1-25 kW</td>
<td>50 kW max.</td>
<td>20</td>
</tr>
<tr>
<td>Croydon, Surrey</td>
<td>Vision 10 kW</td>
<td>400 kW max.</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Sound 2-5 kW</td>
<td>100 kW max.</td>
<td>40</td>
</tr>
</tbody>
</table>

As the BBC Handbook gives only one rating for power, and the original 2LO transmitter was rated at 1-5 kW, I was curious to know if this was transmitter power or effective radiated power. (Although I am a simple soul, I found it hard to believe that ITA had discovered a magical method of changing 10 kW into 400 kW, which the BBC engineers knew nothing about!)

I therefore wrote to our old friend Michael Foster to ask for an explanation, at the same time suggesting that a TV relay station like the one at Fort William, with 1-6 kW radiated vision power, was in fact driven by a 35/40 watt amplifier.

Mr. Foster's reply clears the air and here it is:

In general it can be said that in the medium and high frequency bands radiated power is virtually the same as transmitter power, as it is impossible, for mechanical reasons, to use the techniques adopted in VHF and UHF aerial design and this is one of the reasons why the BBC Handbook quotes radiated powers.

In the VHF or UHF bands, it is possible by suitable aerial design to concentrate the power radiated from the aerial into useful directions and to suppress radiation in others to a much greater degree than is practicable in the lower frequency bands.

Suppose a station is transmitting using an aerial which radiates equally in all directions. Then the field strength it provides at a certain receiving point will have a given value. Suppose now we replace this aerial by one which concentrates all the available energy from the transmitter into a horizontal direction instead of allowing some to go upwards or downwards as well. We should

*The Authority's Stations, ITA, 70 Brompton Road, SW3.
then have all the energy being radiated in an area of space rather like a gigantic washer centred on the aerial instead of an area like a great globe supported at its centre by the aerial. Thus, since the total energy is the same, the field strength at our receiving point will be increased.

However, if the original field strength at the receiving point was adequate, we can now reduce the transmitter power and yet still achieve the original field strength at the receiving point. Nevertheless the *effective* radiated power, i.e. that needed to produce the given field strength at our receiving point, remains the same so we can rightly say that the e.r.p. of the station is unchanged, although the actual output power of the transmitter is less.

It follows that the precise e.r.p. which can be obtained from any given size of transmitter depends on the “gain”, or multiplication factor, of the aerial—neglecting feeder losses, etc.—and this in turn depends on the design and construction of the aerial itself.

Very approximately it can be said that the gain of an aerial in the horizontal plane is proportional to its vertical length in terms of wavelength. Thus an aerial consisting of two tiers of vertically mounted dipoles occupying a vertical length of two wavelengths would have a gain of two. If, therefore, a power of 50 kW were applied to such an aerial, the effective radiated power—i.e. the power which would have to be applied to a single simple dipole suspended in free space in order to produce the same field strength at a given receiving point—would be 100 kW. It is obviously easiest to do this at the shortest wavelengths.

Practical considerations of design (e.g. the fact that the aerial needs a support structure and that this will obstruct radiation in some directions) usually mean that each tier will in fact contain say four dipoles on the faces of a square section mast to provide equal radiation all round the mast.

The 2LO transmitter power was 1.5 kW and the radiated power was approximately the same. As it was a medium frequency aerial it would not have been possible to achieve an increase due to aerial design.

As regards Fort William, although this is VHF with a wavelength in the 5 metre region, the position is controlled by the taskmaster of economics. It would be just about possible to produce an effective radiated power of 1.5 kW from a 35/40 W amplifier, but the cost of providing and maintaining an aerial to do this would more than outweigh the savings resulting from the reduction in the size of the transmitter and the lower power consumption. In low-power stations such as Fort William, therefore, the radiated power and the transmitted power are usually near enough identical.

M.G.F.
Thanks once again to Mr. Foster for taking us aloft. The system could be described in a nutshell as making optimum use of directional effects. It has been shown in Chapters 5 and 6 that this is applied to the design of receiving aerials, and it is also done at audio frequencies in certain loudspeakers where horn loading may increase efficiency by a factor of two or three over a certain area. In cinemas, for example, the treble speakers are horn loaded and arrayed to project the sound over the entire listening area.

EUROVISION

Fig. 10/17. Eurovision reception and transmission station in the Black Forest.

Courtesy Telefunken AG, Berlin
TRANSMITTERS

Optimum directional effects are achieved by concave reflectors and very high frequencies.

These qualities are made use of in the Eurovision Network—one of the most interesting developments in TV during the last ten years. During a Eurovision programme, Western Europe is a unified area for some hours, with eighteen countries interconnected with 1,400 TV stations covering a total distance of some 70,000 kilometres. The photograph in Fig. 10/17 was taken on Mount Hornisgrinde, which is the highest mountain in the northern Black Forest with a height of 1,164 metres—about 3,850 ft.

The parabolic aerials are to receive and re-transmit the transmission from one link station to the next. The frequencies used for these link transmissions are very high, (4-8 Gc/s) and the parabolic aerials produce very concentrated beams at such short wavelengths. The masts in the background are holding up the power lines which feed the power to the link station building at the left of the picture.

SATELLITES

Even more ambitious than the Eurovision network is the transoceanic artificial satellite communication service.

Telstar One was launched by the U.S.A. in July 1962, followed by Relay One in January 1963 and Telstar Two about four months later.

These artificial earth satellites have already been used for relaying live television pictures across the Atlantic. As previously explained, radio waves of the highest frequencies normally pass right through the ionosphere and are lost. If, however, they could be reflected back to the earth they could be made to traverse very long distances. It was this fact that prompted the idea of artificial earth satellites for relaying telegraph, telephone and television traffic across the world's oceans and other difficult terrain where the provision of cables, relay stations etc. would be impracticable or uneconomic.

In the very simplest terms, the transmitting aerial can be likened to a searchlight trained on the satellite when it is in a position above the horizons of both the transmitting and receiving sites. The receiving aerial may then be regarded as a telescope trained on the satellite and seeing it illuminated by the light from the distant source, which normally would be invisible due to the curvature of the earth's surface.

Naturally it is not quite as simple as that. Fig. 10/18 shows the arrangement diagramatically. The transmitting aerial is located in a large reflector dish which is capable of horizontal and vertical movement and can be set to "track" the satellite—i.e. keep it "in view" of the aerial—just as a large astronomical telescope can be set to track a star, when it is above the horizon. The receiving aerial is similarly mounted.
TRANSMITTERS

Fig. 10/18. Diagram showing limits of useful part of satellite's orbit. Beyond the outer positions shown, the satellite is below the horizon of one or other of the link stations and therefore unusable.

The satellite contains receivers and transmitters and thus picks up the signals from the transmitter on the earth's surface, amplifies them and re-transmits them to be picked up by the distant receiving station. The power for operating the equipment is derived from batteries charged by "solar cells"—devices which generate electricity on exposure to sunlight. As will be seen from the diagram this system only works when the satellite is "visible" above the horizon at both sites and thus Telstar and Relay, which have a maximum height of some 3,000 miles and an orbital time of approximately 2½ hours, offer a period of mutual visibility between the U.S.A. and U.K. stations of about 30 minutes in each orbit. Frequencies for ground to satellite signals are of the order of 6 Gc/s and 1.75 Gc/s respectively for Telstar and Relay, and satellite to ground frequencies for both are around 4 Gc/s.

The Syncom project is intended to launch a satellite which, by virtue of its distance of some 22,000 miles from the earth above the equator would have an orbit time of 24 hours and would therefore, when travelling in the direction of the earth's rotation, appear stationary. Such a satellite could be used at all times of the day and night.

Since the above SYNCOM report was written, the satellite has been launched and Michael Foster reports as follows, under the date of 15th September 1964:

The satellite has now been successfully stopped in its correct position above the Equator over the International Date Line. We understand here that test signals have been passed through the satellite, and it appears to be functioning correctly.
Leaving the field of Eurovision and the sphere of Satellites, we return to London to inspect a recent development of comparable ingenuity and technical achievement. This is the Post Office Tower situated near Tottenham Court Road, from which the first test transmissions are scheduled to be made in November 1964. The essential purpose of the Tower is to provide micro-wave radio channels to carry telephone and television traffic between London and all parts of the country, with an ultimate capacity of 150,000 telephone circuits and 40 television channels.

The Tower rises to a height of 580 ft. above street level and is surmounted by a 40-ft. trellis mast which supports a weather radar aerial to improve short range weather forecasting. Fig. 10/19 gives a good outline of the various sections and the purpose for which they are to be used.

There are three interesting articles* about the Tower in the Summer 1964 issue of the Post Office Telecommunications Journal, commencing with a very apt quotation from Tennyson:

"We needs must love the highest when we see it."

On the strength of this, we will complete our Transmitter chapter with further details of the Tower taken from these articles*, and a few illustrations, including the novel horn-parabolic reflector aerials which have been developed. The photographs from which Figs. 10/20, 21 and 23 are reproduced, were sent to us by the editor of the above journal and are used by permission of the GPO.

There were two main reasons for the development of the Tower:

1. The growth of telecommunications services and the popularity of television, with a prospect of a further need in the future for 625-line colour signals, has created a demand for more channels.
2. Additional telephone channels are necessary because of the considerable increase in trunk traffic—some 14 per cent annually. Micro-wave radio circuits were chosen to offset the vast cost and difficulty of providing underground cables out of London.

The public will be able to view London from the galleries near the top of the Tower. Additionally, a public revolving restaurant and cocktail lounge are to be provided near the summit; the restaurant making one complete revolution every twenty minutes.

The cost of the Tower and associated four-storey extension, part of which houses the Museum telephone exchange, is expected to be £2 million.

TRANSMITTERS

Lift Motor Room
Tanks & Vent. Plant
Pulley Room
Kitchen
Cocktail Bar
Restaurant (REVOLVING FLOOR)
Observation
Open Observation

Aerial Galleries

Transmitting Apparatus Floors

Ventilation Floors

Fig. 10/19. Post Office Tower, London, completed 1964.
The photograph, Fig. 10/20, gives a fine view of the Tower and the telephone exchange associated with it.

Fig. 10/20. General view of the Tower.
TRANSMITTERS

MICRO-WAVES

The main reason for the height of the Tower (which is about twice the height of the new Hilton Hotel) is that the micro-wave transmissions must be clear of obstruction. We have already mentioned several times in this book the relationship between wavelengths and directional effects. The frequency bands to be used in the new service are outlined in Table A and the wavelengths are down to approximately 3–12 centimetres.

TABLE A

Details of the six frequency bands to be used at the Tower in the early years.

<table>
<thead>
<tr>
<th>No.</th>
<th>Frequency Band Me/s</th>
<th>Probable number of aerials for each of four main routes</th>
<th>Number of Carrier waves for each route</th>
<th>Probable maximum number of telephone circuits per carrier wave as alternative to television</th>
<th>Probable use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3800-4200</td>
<td>4 Horn type</td>
<td>Transmit 6</td>
<td>1800</td>
<td>Main Route</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Receive 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5925-6425</td>
<td></td>
<td>Transmit 8</td>
<td>1800</td>
<td>Main Route</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Receive 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6425-7110</td>
<td></td>
<td>Transmit 16</td>
<td>{alternative 960 arrangement 2700}</td>
<td>Main Route</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Receive 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>10700-11700</td>
<td>2 dish paraboloids</td>
<td>Transmit 12</td>
<td>960</td>
<td>Main and/or Spur</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Receive 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1900-2300</td>
<td></td>
<td>Transmit 6</td>
<td>{alternative 960 arrangement 120}</td>
<td>&quot;Spur&quot; direc-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Receive 6</td>
<td></td>
<td>tion only</td>
</tr>
<tr>
<td>6</td>
<td>1700-1900</td>
<td></td>
<td>Transmit 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Receive 6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Directional Aerials**

The main type of aerial is the highly efficient horn-paraboloid illustrated in Fig. 10/21. The design of these units is extremely interesting, as it is rather like a huge cinema speaker in reverse. The aerial consists of a parabolic reflector fed by a pyramidal horn with its axis vertical and its apex coincident with the focal point of the reflector. Thus the radio energy is concentrated and that received from unwanted directions is very small.

The horn is truncated at the bottom and connected to a circular hollow pipe waveguide feeder.

The horn aerial will transmit and receive many carrier waves simultaneously in several different bands, and each carrier wave will take a large number of telephone circuits. Dish-type paraboloid reflectors are also used for TV in Band 5. The diagram of Fig. 10/22 shows the general lay-out of one section of the aerial galleries.
Mr. P. J. Edwards points out that the concentration of microwave power in the beam of the aerial is such that the beam power density exceeds that of a theoretical omni-directional aerial by 40,000 times.

**Power Supply**

It is anticipated that after 1966–67 most of the equipment, including travelling wave amplifiers, will be solid-state with power derived entirely from 24 and 50-volt batteries, installed in an upper floor of the Tower. This will include the 6,000 Mc/s equipment to be used for exchanging 625-line programmes with the Continent.
Repeater Stations

In view of the very short wavelengths, repeater stations are usually located on hilltops about 26 miles apart, but a chain of them can span hundreds of miles. The radio signals travel in substantially straight lines and are concentrated into narrow beams by dish-shaped reflectors, similar to those used in the Eurovision service.

The path of the beam must be clear of all obstructions such as hills, trees, buildings, etc., if adequate quality is to be maintained. For this reason the aerial reflectors are usually built on steel towers at a height of 50 to 300 ft. similar to Fig. 10/23.
Fig. 10/23. Repeater station with micro-wave radio equipment housed in single-storey building at foot of aerial tower.

* * *

Incidentally, the Tower is not far away from Broadcasting House and is visible from Michael Foster’s office window. He informs me that foreign visitors looking for the new structure are already asking to be directed to the Tower of London!
RELAY AND COMMUNAL SYSTEMS

An obvious way to improve reception in difficult areas, and to simplify conditions in large blocks of flats, is to provide a communal service with specially sited aerials, plus amplifying equipment and distribution by cable. Either coaxial or balanced multi-pair cable systems may be used.

The purpose of this chapter is to take a look at the services now available and the history of their development, without going into technicalities beyond the scope of the average reader.

Mountainous districts present the most direct interference with transmission—especially at VHF and UHF—and Fig. 11/1 shows a black spot in a valley where the ordinary aerial would, so to speak, be working in a silent zone.

Fig. 11/1. Signals from transmitter on left, picked up by relay aerial in centre for line distribution to houses in valley.
This represents an extreme case; there are, in fact, many degrees of interference and reflection effects.

Radio Relay

Wire Broadcasting (or Relay) was first tried in this country in the village of Hythe near Southampton in 1924\(^1\), the idea being to use a number of extension speakers so that one good aerial and wireless set could be shared among several listeners. Over a period of two years the system expanded to some 20 neighbours, and eventually to as many as 150 subscribers, the most distant connexion involving no less than 10 miles of wire!

In 1926 this first exchange received some publicity as a result of which the Postmaster-General licensed the Proprietor to continue its operation, which he did until 1941. Other relay exchanges obtained licences and started up as the commercial possibilities of wire broadcasting were appreciated.

In pre-television days the situation was comparatively simple, as it was fairly easy to erect a good aerial for medium and long waves, install large amplifiers and distribute by cable at audio frequencies at a high impedance, say 5,000 ohms, to avoid undue line loss.

The subscriber paid as little as 7½d. a week for a single BBC programme, rising to perhaps 1/- when a second programme, usually Radio Luxembourg, was added. (The Light Programme did not begin until 1945, followed by the Third in 1946.)

The programme selector switch would be mounted near the window, and all the customer had to buy was the loudspeaker fitted with matching transformer and volume control. One 1,000 W amplifier would drive about 1,500 loudspeakers, which in those days would be fitted with magnets of around 7,000 oersteds. Today, speakers of 12,000 oersteds are often used and the 1 kW amplifier will then give adequate volume for up to 4,000 speakers.

I recall that in 1938 we had the relay service installed in our small factory in Brighouse, and we found that we could get 10/15 watts into a 15 ohm speaker for test purposes by dispensing with the transformer. But when the relay engineers found out, we had to promise not to do it again because it silenced all the other relay speakers in the vicinity!

Today, television forms a major interest of relay systems and involves operating at HF or VHF, but sound radio is still often distributed at AF on 65-volt lines, which may also carry the HF or VHF signals.

Reference

A modern version of the relay amplifier is illustrated in Fig. 11/2, with frequency and distortion curves in Fig. 11/3 from which it will be seen that the total distortion at 1,000 watts does not exceed 1% between 80 and 10,000 c/s.

**Fig. 11/2.**
Output: 1,000 watts, at 28.75, 57.5, 115 or 230 volts.
Size: 78" x 23" x 21".
Weight: 500 lbs. approx.

**Fig. 11/3.** Amplifier of previous figure:
Response curve at 250 W.
Distortion % at full output.
Incidentally, amplifiers with 2½ kW output are now often used by relay companies.

**Burnley Leadership**

The Lancashire town of Burnley—more famous for football—became a pioneering relay centre around 1926 and the local council gave planning permission to virtually all and sundry, with the result that 15 relay firms eventually set up in business. Each covered a limited area of the town and suburbs, but often with considerable overlap and two networks in one street.

Today, nearly 80% of the relay services in this country are in the hands of the following four major companies, arranged in alphabetical order:

- British Relay Limited
- Rank Relay Services Limited
- Rediffusion Limited
- Relay Exchanges Limited

For Burnley, with a population of just over 80,000, 15 companies were a bit much and around 1938 the town council ordered them to amalgamate and form one company. This had some rather amusing results as each operator or partner insisted on being a director and the first letter paper of the Amalgamated Relay Co. Ltd. was an imposing document with the names of 22 directors listed in alphabetical order down the left hand side!

The Burnley service is now run by Rank Relays and the subscribers number about 7,000, (including 5,000 on TV) with a further 8,000 in the offing. This represents a fairly high percentage, and as all the old wire is being removed and replaced by an entirely new network, we might say that Burnley is still near the top of the Relay League.

**Aerial Site**

The aerial is located on Crown Point Moor, some four miles from the town, and as this is typical of good relay practice a photograph is reproduced in Fig. 11/4.

The line amplifiers in the run down from Crown Point are spaced at approximately 2,000 yd. intervals and are fed by direct mains power derived by separate underground mains feed.

It is worth noting here that in some installations the line repeater amplifiers are powered by 60 volts a.c. fed back through the same cable, or low-voltage d.c. (12—18 v) for transistor amplifiers.
Fig. 11/4. Relay Receiving Station, Crown Point Moor, Burnley.

Fig. 11/5.
VHF/FM aerial
(with amplifier kiosk)
specially sited to
avoid interference.

Rank Relays, Ilkley, Yorkshire
RELAY AND COMMUNAL SYSTEMS

Returning to my home town Ilkley in Yorkshire, we find a rather interesting picture. The VHF/FM relay aerial was originally sited on Ilkley Moor along with Bands I and III, but there was interference from a near-by police station (radio variety) operating at about 96 Mc/s. (Holme Moss radiates on 93·7 Mc/s.) The Band II aerial was therefore removed across the valley to a hillside about three miles further away from the transmitter, with better results, thus again showing that location can be more important than mere distance. (Fig. 11/5.)

Moving up now to the UHF regions, the photograph of Fig. 11/6 shows an impressive aerial array by Rediffusion in Southampton, which is 65 miles from London direct. This system provides BBC2 programmes for the Southampton region and a glance at the map in Chapter 6 shows that it is about 30 miles outside the estimated service area of the first UHF transmitter.

Fig. 11/6. Due to the use of the specially designed master receiving aerial photographed here, and Ferranti's new parametric amplifier, Rediffusion subscribers in Southampton can enjoy the BBC2 transmissions from London.
Rate of Development

Table 1 shows the growth of the radio relay industry during its first 21 years in this country.

<table>
<thead>
<tr>
<th>Date</th>
<th>No. of Exchanges</th>
<th>No. of Relay Subscribers</th>
<th>Total Broadcast Receiving Licences</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 1927</td>
<td>10</td>
<td>446</td>
<td></td>
</tr>
<tr>
<td>December 1928</td>
<td>23</td>
<td>2,430</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>34</td>
<td>8,592</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>86</td>
<td>21,677</td>
<td>3,411,164</td>
</tr>
<tr>
<td>..</td>
<td>132</td>
<td>43,889</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>194</td>
<td>82,690</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>265</td>
<td>130,998</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>318</td>
<td>192,707</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>343</td>
<td>233,554</td>
<td>7,402,046</td>
</tr>
<tr>
<td>..</td>
<td>333</td>
<td>250,978</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>331</td>
<td>255,236</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>325</td>
<td>256,294</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>284*</td>
<td>270,596</td>
<td>8,947,570</td>
</tr>
<tr>
<td>..</td>
<td>284*</td>
<td>297,691</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>278*</td>
<td>309,420</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>277*</td>
<td>435,073</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>275*</td>
<td>494,559</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>274*</td>
<td>551,703</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>274*</td>
<td>634,474</td>
<td>9,987,276</td>
</tr>
<tr>
<td>..</td>
<td>283*</td>
<td>714,505</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>297*</td>
<td>793,582</td>
<td></td>
</tr>
<tr>
<td>September 1948</td>
<td>308*</td>
<td>835,407</td>
<td>11,306,808</td>
</tr>
</tbody>
</table>

*Excludes secondary or stand-by stations

It will be seen from this table that the number of relay subscribers in 1930 was less than 1% of the total BBC licence holders. In 1935 and 1939 the proportion was about 3%, but by 1945 it had risen to 7%, in spite of the fact that no new licences to operate relay exchanges were issued during the war. It was, however, easier to buy a new loudspeaker (of sorts) than a complete radio set.

The records also show that up to 1935 there was a rapid expansion in the number of relay companies, but in 1936 the Ullswater Committee recommended that ownership and operation of relay exchanges should be undertaken by the Post Office, and this naturally caused a setback. The Government, however, extended the licences of the companies for a further three years during which period the Post Office conducted experimental work on wire broadcasting.

Early in 1939, the Postmaster-General announced that it had been decided that the licences of relay operators should be extended for an additional ten years. At the same time, the Post Office began to make tests with equipment for operating a carrier wire broadcasting system over the telephone network, and plans for general distribution of radio and television signals by cable were seriously considered.

1 See page 118
RELAY AND COMMUNAL SYSTEMS

The experiments were brought to a full stop by the war; otherwise we might well have had today a nation-wide radio and television service similar to the electricity, telephone and water laid-on amenities, above and below ground.

Post-war Position

After the war, the problems of interference, background noise and fading were tackled by VHF/FM experiments, which were developed in preference to general overhead-cable or land-line distribution.

This was fortunate for the relay companies because it left them free to operate and expand. It was also good for the hi-fi industry, because it eventually gave us FM on Band II with a frequency response about 5 kc/s higher than would have emerged from any other system. The aerial industry also clocked in, as depicted by any village roof-top panorama as seen in this modern age.

Television

The advent of television made a big difference to the relay operator and involved the use of much more complicated equipment.

The rate of growth during the first eight years is shown in Table 2.

**TABLE 2**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Subscribers</td>
<td>326</td>
<td>1,283</td>
<td>2,686</td>
<td>7,737</td>
<td>28,418</td>
<td>53,637</td>
<td>108,019</td>
<td>196,165</td>
</tr>
<tr>
<td>Relay Stations</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>40</td>
<td>59</td>
<td>81</td>
<td>116</td>
<td></td>
</tr>
</tbody>
</table>

The change from sound-only to TV and sound during the last six years is given in Table 3. The totals represent about 7.5% of the number of licence holders in general.

Reference

The B.S.I. definitions are as follows:

**HF Wired broadcast system**

A wired broadcast system distributing television and/or sound programmes on carrier frequencies in the Band 3 to 30 Mc/s, vision reception at the subscriber’s installation being by a line television receiver or by a television receiver designed for use with an aerial employed in conjunction with a signal or receiver adaptor.

*Note 1:* Some HF wired broadcast systems distribute the sound at audio frequencies.

*Note 2:* For sound reception alone, at carrier frequencies, a line sound receiver is used.

**VHF Wired broadcast system**

A wired broadcast system distributing television and/or sound programmes on carrier frequencies in the Band 30 to 300 Mc/s, reception at the subscriber’s installation being by a receiver designed for use with an aerial and suitable for that band.

*N.B.:* In a broadcast relay system the programmes may, or may not, be distributed at the same channel frequencies as the corresponding radio broadcasts.

Under these licence conditions, relay companies have plenty of freedom in methods of operation and many of them offer four sound programmes, including Radio Luxembourg. Most are equipped to give the new 625-line TV programmes as transmissions become available, in addition to the usual 405-line services.

The HF distribution is by multi-pair cable, and VHF is by coaxial. At the end of 1963 about 75% of all relay subscribers were on HF systems.
VHF/FM Sound

The interest taken by relay subscribers in such things as FM and the Third Programme appears to be very small, with the result that most relay companies have to pay more attention to the Light Programme and Luxembourg.

This is not surprising, as we interviewed 85 of our own staff at Wharfedale and only 12 of them used FM receivers or showed any interest in the Third Programme.

Then again, it is the custom today to feed the radio sound on relay into the TV set speaker, and this has to work in a confined space. (Relay companies do, of course, use FM receivers at their main stations.)

But all is not lost, as most relay systems can supply subscribers with a coaxial point with a good VHF/FM signal at say 0.5 mV which can be used with a high-class tuner and amplifier/speaker system. This is useful in districts where Band II reception presents awkward problems.

Even so, I am informed by Rank Relays that the interest in the FM service in Ilkley is negligible, in spite of the special aerial depicted in Fig. 11/5.

It so happens that it is impossible to get a good ITV picture in Ilkley with a roof-top aerial, but BBC1 is not too difficult, and Band II is workable. As the relay aerial system now serves between 50% and 75% of the residents, it follows that ITV is a big attraction.

Relay Equipment

It would be true to say that relay practice today is more popular with radio dealers and set makers in general than it was during the first eight or ten years after the war. The reason is that most relay companies now provide a service to which ordinary TV sets can be connected, thus leaving a free choice to the subscriber and an opening for dealers to do business.

LOUDSPEAKERS

After the war, with sound only, the loudspeaker was rented or supplied by the relay company, tax free. Radio sets were subject to about 50% purchase tax, and set-makers began to complain of unfair competition. The result was that on August 4th 1952, purchase tax was applied to cone-type speakers less than 12" diameter. This, coupled with the introduction of TV relay, put an end to the boom in radio relay, and the demand for separate speakers fell off rapidly.
Although the loudspeaker is at the other end of the chain and often a long way from the aerial, it is hard (for me!) not to mention the following interesting experiment of the 1938 period. As already related, there was a plan to nationalise the relay industry and the town chosen for the first G.P.O. installation was Southampton. One idea was to improve the sound quality by using bigger and better speakers, and the model illustrated in Fig. 11/7 was designed by Messrs. West and McMillan of the Post Office Engineering Department.

This speaker was well ahead of its time and took the bass down at least an octave lower than the normal relay model (but the demand for it commercially was also very much lower!).

**Receivers and Amplifiers**

Bearing in mind that up to seven television and four radio programmes can be handled on a single coaxial cable, and that 9-pair or 12-pair cable may be used for distribution purposes, the receiver/translator units must be quite complicated.

A main station rack made by Belling & Lee Ltd. is illustrated in Fig. 11/8 with brief details of its functions. The working of a translator (Panel 4) has been explained in the previous chapter on transmitters, and it is used here to convert signals to the channels adopted in the relay system. The domestic invertor then re-converts the channel frequencies to suit the receiver, where necessary.
Typical main station Belling-Lee rack. Panels reading from top to bottom, are as follows:

1—A high-quality, proprietary, medium and short wave receiver, with 6 band-spread short wave ranges and choice of band-widths at 5, 7 or 10 Kc/s. The audio output from this is taken to

2—A VHF/FM modulator, the output of which is in Band II, providing a fourth radio programme (originally AM) selectable by the station engineer.

3—A 3-channel preamplifier operating in Bands I, II and III.

4—Crystal controlled channel translator with preamplifier.

5—Band I AGC amplifier.

6—Distributed output stage.

7 and 8—Spare panels, available for UHF translators and AGC units.

9—Stabilised power supply unit.

Fig. 11/9 is a photograph of a BRW station in Dundee, showing the television transmission equipment in the background and five 1 kW Bryan Savage audio amplifiers in the foreground.

Distribution Systems

As already pointed out, the relay broadcasts are at HF or VHF, plus the sound transmissions which may be at audio frequencies.

The VHF systems are mainly coaxial, communal aerial services, but there is today considerable change from coaxial to multi-pair cable in the larger areas.

This cuts down the number of line amplifiers and AGC (automatic gain control) units required to maintain a satisfactory signal level, say a minimum of 500 microvolts (¼ mV) on each vision carrier and 250 microvolts (¼ mV) on FM, with maxima of 1 mV and ½ mV respectively.

Reference

Fig. 11/9. TV and radio relay station operated by British Relay Ltd., Dundee. The five main amplifiers are used to transmit four radio programmes on 100 volt lines.

Coaxial Cable

All TV and FM users must be familiar with the appearance of coaxial cable, which is normally made up of four elements as per diagram in Fig. 11/10.

Fig. 11/10.

Typical coaxial cable.
A—Polythene sheath;
B—Copper screen;
C—Polythene insulation;
D—Copper wire.

Firms like B.I.C.C. offer many varieties, with different impedance, attenuation and power-rating characteristics. The inner conductor may be 7 or 14 strand, or solid wire from .022" to .188" diameter.

For improved screening, Pirelli can now supply a longitudinal solid copper sheath, and B.I.C.C. have available a longitudinal lapped solid corrugated copper sheath.
RELAY AND COMMUNAL SYSTEMS

The main virtue of the coaxial is that a complete radio and television spectrum can be passed through a single cable and sorted out at the receiving end.

Signals in Bands IV and V can be added to existing coaxial relay systems without difficulty, but they must first be translated to an unused channel in the VHF bands, as the UHF characteristics result in very heavy attenuation.

For a full explanation of the working of coaxial systems, the book by Gordon J. King\(^4\), is strongly recommended.

**Multi-pair Cable**

We have seen that many programmes can be transmitted by a single coaxial cable, provided different frequency channels are used.

With multi-pairs the position is reversed in that the same frequency can be used for different programmes, using separate pairs of wire, but AF signals can be added to the same pair if required.

For instance, the system used by British Relay is described by their chief engineer Mr. K. A. Russell as follows:

Television signals are transmitted at a carrier frequency of approximately 3.75 M/cs positive amplitude modulated and the corresponding television sound signals are transmitted at a carrier frequency of approximately 2.1 M/cs, again amplitude modulated. This applies to both 405 and 625 line transmissions. Channel selection is carried out by means of a switch selecting the appropriate pair of wires carrying the receiver programme.

Radio signals transmitted at audio frequency may be received either directly into loudspeakers or via a small audio frequency amplifier, installed in the control box in the subscriber's home.

The frequency range covered by our television networks is from d.c. to about 20 M/cs so far as the actual cables and matching units are concerned. Currently, the equipment associated with these networks occupies the bands up to 10 M/cs in order to provide an adequate band-width for 625 line television signals. No FM signals as such are transmitted but the radio programmes are often originated by means of FM receivers driving audio power amplifiers. The sound associated with BBC2 is, of course, also derived from the broadcast FM carrier where this programme does not originate by direct cable link from the BBC distribution network.

\(\text{K.A.R.}\)

**Reference**

\(^4\)—"Communal Aerials and Coaxial Relay Practice". Book by Gordon J. King. 72 pages, 8/6d. Published 1962 in Brixham, S. Devon.
RELAY AND COMMUNAL SYSTEMS

I am quoting Mr. Russell here because working at 3·75 Mc/s is a bit above my head. (My limit is now 13 kc/s.)

In Fig. 11/11 is illustrated a sample of nine-pair balanced twin cable as now used by Ranks and other relay companies, in preparation for possible future VHF and UHF developments.

![Diagram of multi-pair cable]

For planning even further ahead, 12-pair cable is now available!

COAX. V. MULTI-PAIR

It was stated earlier that there is a move in large areas from coaxial to multi-pair cable. I therefore asked Mr. R. J. Milwidsky (who is vetting this chapter) to give us an outline of the position, and here it is:

It is correct to say that we are going over to balanced multi-pair cable in preference to coaxial systems.

It has been our experience that problems of local transmitter channel allocations, and adjacent channel selectivity, make it difficult to provide six programmes over a coaxial cable.

The multi-pair network uses approximately one-tenth of the number of repeater amplifiers, does not pose the same cross-view problems, requires less maintenance, provides audio programmes which do not need an expensive VHF receiver and also makes it possible for the public, if they so choose, to buy a dual standard terminal unit at 30% lower than the price for a dual standard off-air television receiver. Alternatively, any standard off-air television set can be adapted to the network.

HF multi-pair systems can be used with particular advantage for Hotel and Hospital installations. The saving on the terminal receivers is considerable and there is also the fact that remote control is an integral feature.

R.J.M.
RELAY AND COMMUNAL SYSTEMS

In the Home

To the average reader, the installation required at home will be of more interest than the actual relay equipment.

If the system is purely an aerial relay service, all you have is a coaxial socket, with a splitter for VHF/FM if required.

With a complete multi-channel relay service, there will be a wall-mounted inverter for changing the relay channels to suit the ordinary TV set, or else a programme selector switch for the special wired-television receivers. In Fig. 11/12 we show outside and inside views of a Rediffusion six-channel, mains operated, inverter, and similar views of their nine-channel programme switch in the next illustration.

Fig. 11/12.
Inverter with programme switch and volume control. Allows a subscriber with an ordinary aerial television set of any manufacture to receive television and sound programmes from the wired network.

Fig. 11/13.
Selector switch. Provides a subscriber with the easiest possible means of selecting programmes. Up to six of the nine positions can be used for television programmes while the remaining three are usually a selection of sound radio programmes.

COMMUNAL SYSTEMS

One dictionary definition of communal is “for the community” so the word could be used to describe any relay system. Nevertheless, for our purpose the “Communal” heading is used in relation to television and radio services for blocks of flats, hotel rooms and small housing estates, where separate aerials could be inconvenient and would result in mutual interference if too close together.
A common aerial is installed in the best position, with line amplifiers and coaxial cable for distribution to the various users. Many dealers and most relay companies undertake this type of installation and arrange for regular service work.

A typical network, with immediate change-over facilities to a standby amplifier system—or vice versa—is described in the book by Gordon J. King and is illustrated in Fig. 11/14. The method is based on the “star network” and is planned with both main amplifiers in circuit signalwise.

Changeover is accomplished by switching off the power to a faulty amplifier and switching on the other one.

The distribution cables are of course coaxial, and the signals are dealt with by a splitter at the receiver end. Amplifier gain is adjusted to counter-balance the higher cable loss at the higher channel frequencies.

Signals in Bands IV and V could be added to this type of coaxial system with suitable aerial and an additional amplifier, but it would be necessary to feed the line through a translator and work at an unused channel in the VHF band, to avoid the very heavy attenuation at UHF.

The receiver would be arranged so that pre-selected UHF channels switch from 405 to 625 lines. A number of makers are now releasing sets with such characteristics for use on coaxial relay systems.

* * * *

In concluding this chapter I should like to thank the technicians, relay operators and manufacturers who have generously supplied up-to-date information, and particularly Mr. R. J. Milwidsky, Director of Engineering, Rank Relays, who has kindly vetted the entire chapter.
ACTIVITIES ABROAD

It is usually interesting to learn something about activities in other countries in a hobby or enterprise to which we are attached, either as amateurs or professionals.

We therefore drew up Radio and Television Questionnaires and sent them to a few of our agents abroad; the replies form the basis of this chapter.

In a country like the U.S.A., where all the radio and television activities are run commercially, it is not easy to find group answers. However, our old friend Norman Crowhurst, and his friend Chester Rackey of N.B.C. were able to help us with useful information, for which we express our thanks.

An interesting point about directional effects came up in the report from our friends in Australia. This is a country of large area/population ratio. All TV stations, whether Government or Commercial, serving one area, are either co-sited or closely grouped. For city viewers, who are usually concerned only with their own district stations, this allows the use of one wideband aerial system with fixed orientation; but country viewers who may wish to receive signals from different areas must use a high gain aerial system with rotator, or separately directed aerial systems.

Having picked that up from Australia, we will now give details of the Radio Questionnaire, and then rotate it to receive replies from the various countries. The same plan will then be followed for TV.

RADIO QUESTIONNAIRE

Q. 1. Please state approximate number of Transmitters now in use in different wave bands, and whether AM or FM.
Q. 2. How many give Multiplex Stereo and is it very popular?
Q. 3. Do you have relay services in poor reception areas?
Q. 4. Are coaxial/communal services general for blocks of flats, etc.?
Q. 5. Are indoor aerials adequate in many districts?
Q. 6. Is radio coming back into favour as against TV?
Radio

REPLIES FROM AMERICA

Q. 1. Transmitters.
Medium Waves (535–1605 Kc/s). About 3,900 transmitters, all AM.
Short Waves.—We do not have the figures.
Band II (88–108 Mc/s). About 1,150 transmitters, all FM.
No radio broadcast services are authorized in the other frequency bands included in this question.

Q. 2. Stereo.
About 256 FM stations are equipped to broadcast stereophonic programs.
FM stereo is not developing in a spectacular manner but is becoming increasingly popular.

There are no services of this type made available to the public, as consumers.

Q. 4. Coaxial or communal systems.
Motels, hotels and apartment buildings will make some such service available within their own confines. Then, of course, we have Musak and similar services, some of which use Multiplex FM to transmit the program to subscribers.

Q. 5. Indoor aerials.
Many in use.

Q. 6. Radio v. TV.
During television's dramatic growth years during the 1950's there were serious doubts in some segments of the industry that radio would survive. The industry, however, recognizing its formidable competition, adopted new programming formats which have enabled radio to emerge from its economic difficulties and develop steadily during the past decade. Part of this improvement has been due to the increasing popularity and use of portable transistor sets. While radio is not expected to seriously challenge TV's popularity the industry is here to stay and a modest rate of growth may well be anticipated.

Radio

AUSTRALIA

Q. 1. Transmitters.
Medium Waves 65 Government All AM.
" 110 Commercial 
Short Waves 17 Government 
(Nine of these are Internal and eight External Services.)
VHF and UHF, nil.
ACTIVITIES ABROAD

Q. 2. Stereo.
There is no multiplex stereo service. For the past two or three years, there has been a weekly, half to one hour stereo session broadcast in each of the State capital cities over the two Government transmitters there. This service has been very popular, despite the fact that listeners must provide themselves with two radio receivers, often quite dissimilar in characteristics.

None.

Q. 4. Coaxial or communal systems.
Except for the very largest blocks of flats, built in steel-framed type of construction, communal aerial systems are not provided for radio use. In most cases, of course, the field strength available from the MF stations is high, and sufficient to override all but the most severe local electrical noise.

Q. 5. Indoor aerials.
Indoor, or inbuilt (ferrite) aerials are generally adequate for most city and town locations. In country districts some distance from the transmitters, outdoor aerials are necessary for good reception. During the Summer period in certain areas of the country, severe electrical storms are frequently experienced, and then it is often impossible to receive a usable signal, even from a powerful local station only a few miles away.

Q. 6. Radio v. TV.
There has been a very greatly increased interest in radio over the past two or three years. It is probably due to both an increasing use of portable radio receivers and also to a more rational approach to TV viewing.

Radio
SOUTH AFRICA

Q. 1. Transmitters.
Medium Waves 36  AM
Short Waves 11  AM
VHF Band II 83  FM
Future plans are for 423 Band II FM transmitters to be working by the end of 1967.

Q. 2. Stereo.
Nil.

We have only one rediffusion area and no more will be allowed. In fact, if the one can be eliminated it will be.
National services are relayed throughout the country by land-line and thence by AM or FM transmissions regionally.
Q. 4. Coaxial or communal systems.
A few flats provide communal aerials but they are very much the exception.

Q. 5. Indoor aerials.
On FM in regions where no multipath exists, they are adequate. In any troublesome FM area, directional antennae are always required.
Most AM listeners use indoor aerials but this does not make them adequate. They are nearly always inadequate.

Q. 6. Radio v. TV.
No comparisons, as we do not have TV. When the FM grid coverage scheme of the whole country is complete, we will be free to start on TV, and the service will be 625 lines. So FM has held TV at bay; not the other way round.

Radio
Switzerland

Q. 1. Transmitters.
Medium Waves 7 AM
Short Waves 1 AM
VHF, Band II 36 FM

Q. 2. Stereo.
The studios are just going to be equipped for stereo, but the question of when to start is delayed until the system is definitely chosen.

Q. 3. Relay Services
See next answer.

Q. 4. Coaxial or communal systems.
Switzerland has a very efficient high-frequency service over the complete telephone system, with six stations. Three are used for the main Swiss programmes, and one each for French, German and Austrian programmes. The audio frequency range covered is 80 to 12,000 c/s with very little line distortion.

Q. 5. Indoor aerials.
These are in general use, but for hi-fi reception a roof antenna gives better results.

Q. 6. Radio v. TV.
In our country there is a clear distinction between TV and anti-TV people. There is no doubt that with better FM tone quality and better programs, people (intellectual people) are going back to radio.
ACTIVITIES ABROAD

There we have a sort of radio pattern as developed in four countries. It is interesting to note that there is no TV as yet in South Africa, and that Switzerland is furnished with a good radio relay service through the telephone network—once seriously considered by our own G.P.O. engineers.

Taking a glimpse at one or two other countries, we note the following:

CANADA. Well covered by Government and Commercial stations operating on medium and short waves, AM, and VHF (108 Mc/s), FM, with about 40 transmitters giving multiplex stereo, which is very popular.

Radio is coming back into favour as against TV.

JAPAN has 113 National and 47 Commercial transmitters on medium waves/AM, and 10 National and 1 Commercial on VHF/FM, Band II. Stereo is only in the experimental broadcasting stage. TV is reported to be much more popular than radio.

NEW ZEALAND. 42 medium wave and two short wave transmitters. No VHF/FM service and therefore no multiplex stereo.

Some relay stations operate in poor reception areas and radio is not so popular as TV.

* * * *

Well, so much for radio. We will now take a look at the television picture.

TV QUESTIONNAIRE

Q. 1. Please state approximate number of transmitters, and lines used.
Q. 2. How many give colour TV and is it very popular?
Q. 3. Are TV relay services in use?
Q. 4. Are coaxial/communal services general for blocks of flats, etc.?
Q. 5. Are indoor aerials adequate in many districts?

Television

REPLIES FROM AMERICA

Q. 1. Transmitters.

All transmitters are 525 lines; none 405 or 625.

Low VHF (54–72 Mc/s and 76–88 Mc/s) Approx. 225*
High VHF (174–216 Mc/s) Approx. 315*
UHF (470–890 Mc/s) Approx. 120

(*Assumes that the total number of VHF operating stations, approximately 540, is equally divided among the 12 VHF channels.) In addition there are about 1,400 low-powered transmitters operating as translators, but we have no breakdown into frequency bands.)
Q. 2. Colour TV.

About 420 TV stations can rebroadcast network color programs. Color TV is becoming increasingly popular. The estimated 1.5 million color sets in use at the beginning of 1964 are expected to increase by the anticipated sales of approximately 1.0 million more sets during 1964. On NBC-TV nearly half the total network programming hours are in color. Audiences are larger to color programs than to those in black and white. Additionally, there is the greater advertising effectiveness of commercials in color compared with those in monochrome.

Q. 3. Relay services.

There are two types: one is cable, which uses an antenna in a good spot and boosts the power and feeds it, sometimes for miles (we have one that runs about five miles, from the top of a nearby mountain), to as many consumers who will pay to be connected. The other is a "translator" service, which picks up the TV channels at a similar antenna and then, instead of using a cable, uses VHF channels to beam it to the general area to be served.


There is some use in apartments, hotels and remote places.

Q. 5. Indoor aerials.

Adequate in some areas where the signal intensity is high, as in most of our larger cities.

Television

Australia

Q. 1. Transmitters.

<table>
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<td>8 Government; 2 Commercial</td>
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<td>VHF Band III</td>
<td>1 Government; 22 Commercial</td>
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<tr>
<td>UHF Bands IV and V</td>
<td>Nil.</td>
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These were operating at June 1964. In the next twelve months there will be a further fifteen Government and eleven Commercial stations opening. In 1965/1966, there will be a similar increase, and the present indications point to a number of low-power satellite transmitters being installed before long, as gap-fillers.

Q. 2. Colour TV.

As yet, there is no consideration of any colour service—all resources are being directed to the expansion of the present service to cover the maximum practicable area.


None. All TV reception is "off-air".


In large blocks of flats erected over the last three or four years, it has been a growing practice to wire all flats for TV using a system
ACTIVITIES ABROAD

of aerial sharing (up to about eight or ten flats), or with aerial distribution amplifiers in larger blocks.

Q. 5. Indoor Aerials.

In most city and suburban areas, indoor aerials mounted on the receiver (rabbit ears or similar type) do not provide good reception due to ghosting. Simple directive aerials mounted under the roof (attic) suffice in most cases. In country areas, a good outdoor aerial of the high gain type, and mounted on a tower, is usually necessary, because of the much lower field strengths available.

Television
SWITZERLAND

Q. 1. Transmitters.

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<td>VHF Band II</td>
<td>Nil</td>
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<td>VHF Band III</td>
<td>28</td>
</tr>
<tr>
<td>UHF Bands IV and V</td>
<td>Nil</td>
</tr>
</tbody>
</table>

In some areas of Switzerland, the French (819 lines) TV is receivable; in other parts the Austrian, German and Italian services are picked up.

Q. 2. Colour TV.

None.


Fairly common, especially in mountainous districts.


Most blocks of flats have collective aerials with coaxial distribution. (Also very popular in Germany.)

Q. 5. Indoor aerials.

These are used but result mostly in inferior quality.

* * * *

The replies from other countries were of a routine nature, but the following points are worth mentioning:

CANADA. Channels 2 to 12 in the VHF bands are used, 525 lines, with 71 C.B.C. transmitters and 134 commercially owned.

There is no colour TV service, but many areas can receive from the U.S.A. Two Canadian firms are now building colour receivers and have sold about 10,000 sets so far. It is thus hoped to force the Government's hands in the direction of colour.

Relay and coaxial services are in general use.

JAPAN. The service here is 525 lines, with 37 National and 48 Commercial transmitters in Band II. Coaxial/communal TV services are in general use. Some colour TV transmissions have been in operation for about two years.
General Comments
We will conclude this section by a few notes on the main differences between U.K. and overseas systems.

CHANNELS USED
The division of the Bands into I, II, III, IV and V is exclusively European. Elsewhere, there are two Bands only; VHF and UHF.

In the U.S., channel I is not used. When the channels were allocated, the U.S. industry had the foresight to use their channel I as a standard i.f. channel for receivers, thus ensuring an interference-free intermediate frequency.

POLARISATION
Vertical polarisation is not used in the U.S., and is very rare outside the U.K. Hence the horizontal aerial arrays normally seen during trips abroad.

ROTATING AERIALS
Where a multiplicity of programmes exists in one city such as New York or Los Angeles, the authorities endeavour to site the transmitting aerials on one location (such as the Empire State Building). Where this cannot be done, it often leads to the use of rotatable receiving aerial systems, electrically-driven by remote control from the receiver position. These aerial systems are very popular in the U.S., particularly in the middle-west, where the basic directivity of the aerial system is essential to avoid interference; but it is necessary to point the aerial at the station it is intended to receive. A similar situation exists in Australia, as mentioned at the beginning of this chapter.

FLAT TWIN CABLE
Outside the U.K. feeder cable for VHF has been standardised as balanced ribbon type or flat twin, as illustrated in Fig. 12/1. This has an impedance of 240 $\Omega$ (Germany) or 300 $\Omega$ (U.S.A.).

For UHF, coaxial cable is coming into general use. Ribbon cable is very difficult to install because, unlike coaxial cable, it is not self-screening and must not be run close to metal objects such as gutters or drain-pipes. It has to be held clear of metal objects all the way to the receiver, and this has given rise to a very good business in stand-off cable insulators and accessories.
ACTIVITIES ABROAD

LINE STANDARDS

The chequered history of television standards leaves us now as far from a universal standard as ever. The World's first television system went into operation in 1936 using 405 lines, 25 pictures/sec. The Americans, faced with adopting their standards at a later date, considered that 405 lines did not give good enough definition, so they adopted 441 lines. They had second thoughts on this after about a year and changed their standard to the present 525 lines.

Meanwhile the French, who had also adopted 405 lines, decided that another standard with better definition was required. They considered that, to obtain a really worth-while improvement over 405 lines, it was necessary to double the line structure, so they set up another standard—819 lines. (This gives a picture of superb quality.)

After the War, an international body (the CCIR*) decided that a World standard would be a good idea and, with every country now requiring television introduced a CCIR standard of 625 lines. The French 405 transmitter was (conveniently?) destroyed by fire and not replaced, but we still find four basic standards in use: 405, 525, 625 and 819.

The 819 standard does not look like being used outside France and Belgium because it is extravagant of band-width, and 405 will eventually disappear from the U.K., leaving two World standards. 525 is too widespread to be changed; it is used in all the Americas and Japan. 625 is being adopted over the rest of the World but, unfortunately, as variants on the basic CCIR standard. There are even five variations in use in Europe for UHF. (The variations are concerned with whether the modulation is positive or negative, whether the sound is AM or FM, and some other differences.)

COLOUR STANDARDS

Three contenders existed for adoption as European standards: (1) NTSC†, the standard adopted by the U.S.A. about ten years ago; (2) the SECAM system, developed by French, English and German engineers; (3) the PAL system, a German modification of SECAM.

The EBU‡ has deferred a decision until next year. Meanwhile another candidate has appeared known as ART (a variant on PAL), together with a suggested modification of NTSC. Thus does confusion become worse confounded.

* CCIR = Comité Consultatif International des Radiocommunications, Palais Wilson, Geneva, Switzerland.
† NTSC = National Television Systems Committee (U.S.A.).
‡ EBU = European Broadcasting Union. (Also known as U.E.R., Union Européenne de Radio-diffusion.)
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