MODERN AERIALS

The transmitting aerial radiates the energy generated in the transmitter. The energy is fed from the transmitter to the aerial by a transmission line and the aerial can be regarded as an impedance matching device to match the impedance of the transmission line to that of free space. Radiation from the aerial takes place by virtue of the expanding magnetic and electric fields which accompany the charges flowing in the aerial. Maximum energy is transferred from the transmitter to the aerial when the aerial input impedance appears as a pure resistance matched to the Transmitter impedance. The aerial input impedance appears as a pure resistance when the aerial is resonant. For a grounded monopole - e.g. a whip or wire aerial with the feed point between ground and the base of the aerial, resonance occurs when the physical length is somewhat less than $\lambda/4$. The input impedance of such an aerial is approximately 35 ohms. When the physical length of the aerial is equivalent to other multiples of $\lambda/4$, the input impedance of the aerial appears as a pure resistance but the value will vary to 600 ohms at $\lambda/2$, 70 ohms at $3\lambda/4$ and 700 ohms at λ. At the lower frequencies of the HF band it becomes impracticable to use an aerial $\lambda/4$ in length. An aerial that is short compared with $\lambda/4$ has a complicated impedance and is not a very efficient radiator. For example, the input impedance at the base of a vertical monopole at height $\lambda/8$ is of the order of 8 ohms resistance and about 500 ohms net capacitive. Normally the capacitive reactance will be tuned out by adding inductance at the base of the aerial and the resistance matched in some way. If the aerial is greater than $\lambda/4$ but less than $\lambda/2$ in length, then the aerial is inductive and the reactance is tuned out by using a capacitance at the base. The standard HF transmitting whip aerial is about 35 feet long and has a maximum efficiency at about 7 Mc/s. At 1.5 Mc/s it is approximately $\lambda/16$ in length and at 30 Mc/s greater than λ. The range of inductance and capacitance to tune the aerial to resonance over such a wide range of equivalent wavelength is considerable. In addition, the input resistance when the aerial is made resonant varies over 1 to 700 ohms and for maximum efficiency this must be matched to the impedance of the transmission line.

The aerial can be matched to either the feeder or to the transmitter. When the aerial is matched to the feeder the matching components are sited at the base of the aerial and the method is known as Base Tuning. Base tuning has the advantage that the feeder is operated with a Voltage Standing Wave Ratio, v.w.s.r., approximately equal to unity
The v.w.s.r. is defined as

$$\frac{Vi - Vr}{Vi + Vr}$$

where Vi is the r.m.s. value of the voltage of the incident wave and Vr is the r.m.s. value of the voltage of the reflected wave produced by the mismatch.

With a v.s.w.r. of unity the losses on the feeder are small. The disadvantage of using Base Tuning is that the tuning must be carried out at a remote position and therefore involves the use of complex control circuits. However, with modern servo systems this method of tuning finds increasing favour and is used in the Comist system.

When matching is carried out at the transmitter, the tuning components are normally contained within the transmitter cabinet. Tuning is carried out manually and no remote control is involved. With this type of tuning, v.s.w.rs. of less than 0.01 may exist on the feeder and considerable losses are present. Also, under these conditions the feeders have to be specially constructed to withstand the high voltages and currents present due to the standing waves developed.

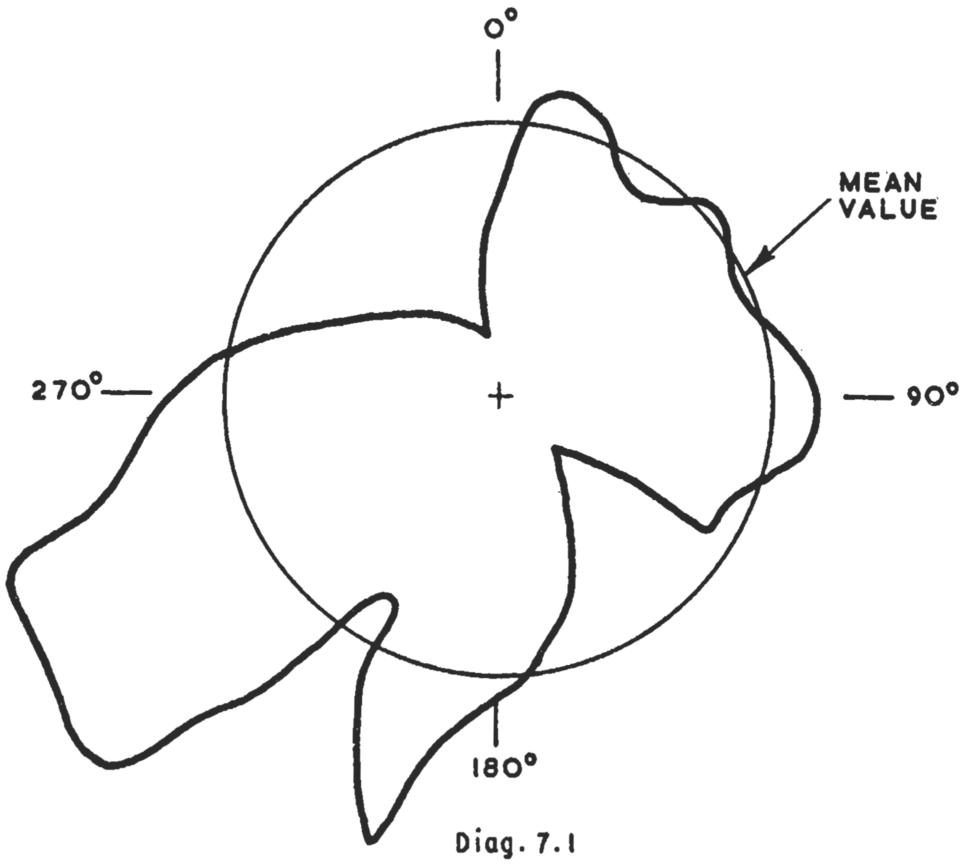
For propagation by surface waves it is essential to use vertically polarised waves because with horizontally polarised waves the electric field is parallel to the surface and is rapidly absorbed, resulting in a very rapid attenuation of the radio waves. For a mobile transmitting station the ideal is for a vertical aerial to be capable of transmitting equally in all horizontal directions. However, even for the simplest aerial that can be installed, the ideal is not attained and more power is radiated in some directions than in others, and the aerial is said to possess directivity.

The increase in radiated power in a certain direction with respect to radiation from some reference aerial is termed the gain of the aerial in the given direction. The reference aerial commonly used is the hypothetical isotropic aerial, which is assumed to radiate equally in all directions. More practically, the reference is the simple half wave dipole, which has a free space directivity gain of 1.64 (2.15 dB) in power, over the isotropic aerial. This means that in the direction of maximum radiation the dipole will produce the same field strength as an isotropic aerial radiating 1.64 times as much power.

A graphical presentation of the directional characteristics of an aerial is termed its radiation pattern or polar diagram, and illustrates the relative magnitude of the radiation intensity as a function of direction.

The two planes of interest are the horizontal at ground level and the vertical.

As already stated the ideal horizontal radiation pattern for a mobile station, is a circle. In a ship the superstructure considerably modifies this pattern as shown in Diagram 7.1.



Diag. 7.1

Typical horizontal plane radiation diagram for a whip aerial at 8 Mc/s. The large minima present may be as much as 30 dB down on the maxima.

The vertical radiation pattern depends upon the height of the aerial above the earth, the length of the aerial, the wavelength and the properties of the intervening ground and the directional properties of the aerial.

For sky wave propagation the requirement for the correct angle of propagation can be critical and difficult to achieve with a whip aerial. For maximum ranges the required angle of maximum radiation is a geometrical problem depending on the height of the ionospheric layer which is being used, and in general the angle required is of the order of 6 to 8 degrees. However, when HF sky wave propagation must be used for shorter ranges the angle of maximum radiation may be much greater.

A normal whip aerial therefore suffers from the following defects

(1) The terminal input impedance varies considerably over the frequency band and the aerial tuning unit to cope with these variations is fairly complicated.

(2) The horizontal radiation pattern has large minima due to the effect of the superstructure.

(3) At some frequencies the vertical radiation pattern is by no means optimum for the purpose required.

Gapless Cover

Up to a few years ago the main Tactical communication link between ships in a task force, was by VHF/UHF. At the present time, with pickets operating out to several hundreds of miles from the main force, the communication problem is rather difficult. If the power is available then low HF or MF may be used, utilising the ground wave. If distance is too great then low HF sky wave propagation must be used using very high angles. There are two main requirements for this low HF link to operate successfully.

Firstly, the operator must have a good deal of information about the local ionospheric conditions and secondly the aerial system must be capable of transmitting the radiation at high angles. As has been shown the standard 35 ft whip aerial is not suitable for this.

Communication over these intermediate distances will always be difficult to achieve due to variations in the ionosphere. Even when signal strength is sufficient, there is a tendency, for the sky wave and ground wave arriving together, to cause serious interference.

Modern Ship Aerials

Broad band aerials

These aerials are in common use in the VHF - UHF band of frequencies and their operation is well known. The pass band of an aerial is a function of its Q value ($Q = \frac{1}{R}\sqrt{\frac{L}{C}}$).

The band pass is therefore proportional to $\frac{L}{C}$.

If the aerial is shortened the inductance L is decreased and if the diameter of the aerial is increased C will increase. Thus Q will be made smaller and the band pass broadened while keeping the resonant frequency the same.

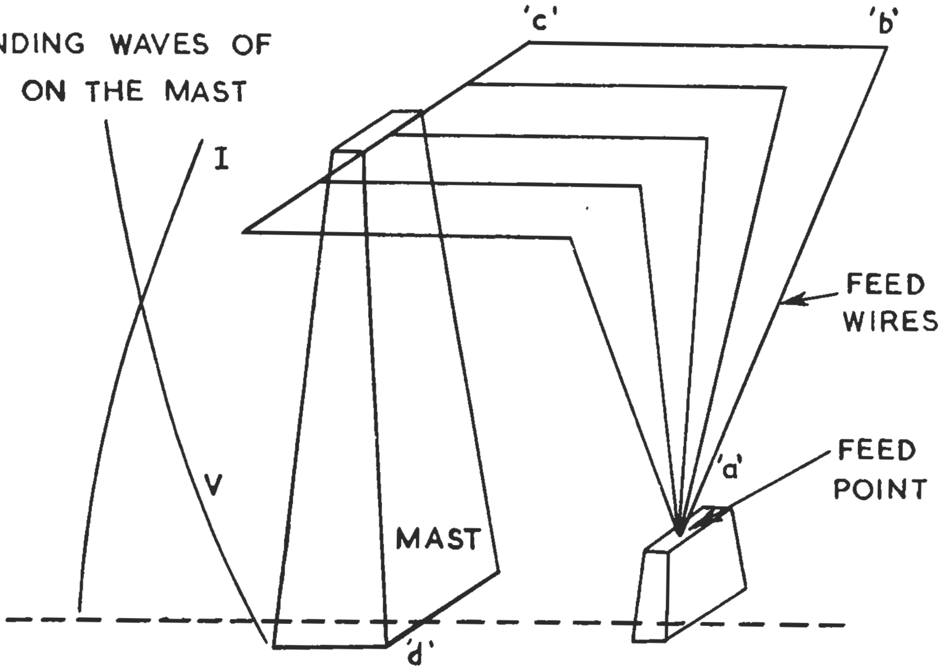
Shipborne HF aerials have now been developed having broad band characteristics. A ship aerial will probably be a vertical aerial fed at the base. If the aerial is made thicker than normal, it shows much less variation in input impedance over the frequency band and the problem of matching and tuning out the reactance are eased.

Following the successful Sheffield experiments in the early 1950s modern I.C.S. fitted ships use parts of the ship's superstructure to form the aerials. Obviously the number of aerials is strictly limited and an efficient common aerial working system is vital.

Three aerials are required to cover the range 2 - 24 Mc/s. The aerials are tailor made for each type of ship, using the superstructure existing.

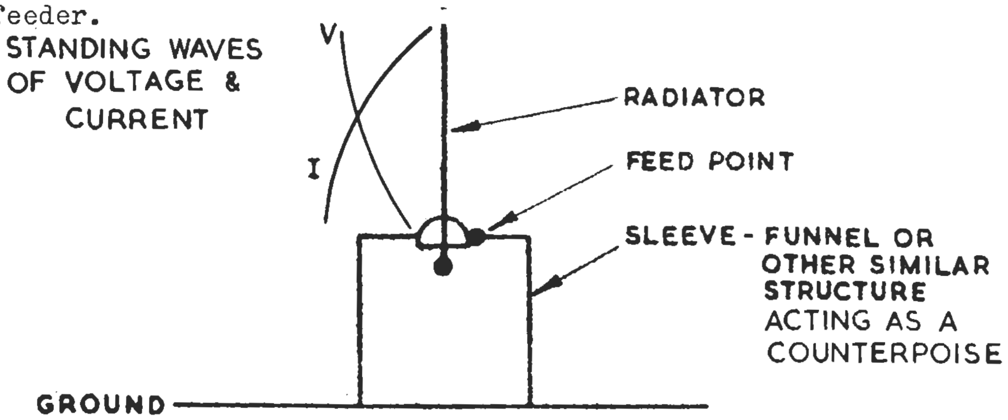
With a reduced frequency range of about 3 : 1 and using fixed base tuning a v.s.w.r. of better than 0.33 can be obtained. This can be improved to as high as 0.85 by the use of Common Aerial Working Filter Units.

Two types of aerial are principally employed, the folded monopole and the sleeve aerial.

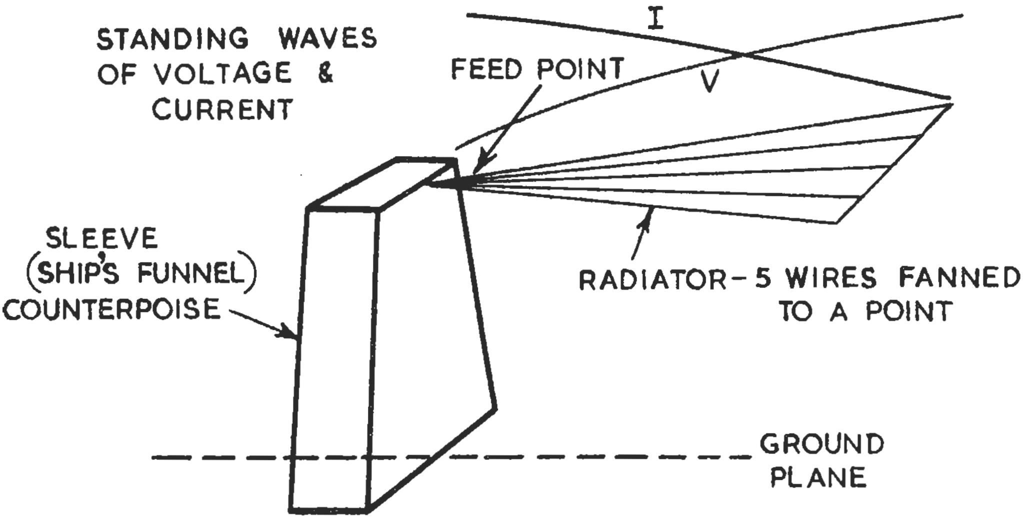


Diag.7.2

By choosing suitable dimensions for the exciter leg ab and the 'top' cb, any given structure cd can be made to work over a specified frequency range. Fixed base tuning has to be used in order to obtain the maximum possible bandwidth and to enable the aerial to work from a 50 ohm feeder.



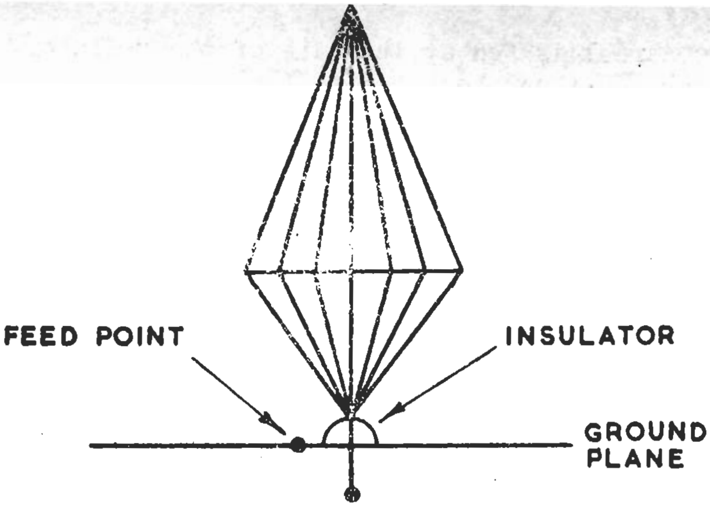
The sleeve aerial is fed at the base of the radiator. The frequency coverage that can be obtained for any overall height is dependent on the ratio of the length of the radiator to the length of the sleeve and upon their respective diameters. The sleeve aerial can be built in many forms with the radiator offset from the centre of the sleeve and inclined at angles from the vertical.



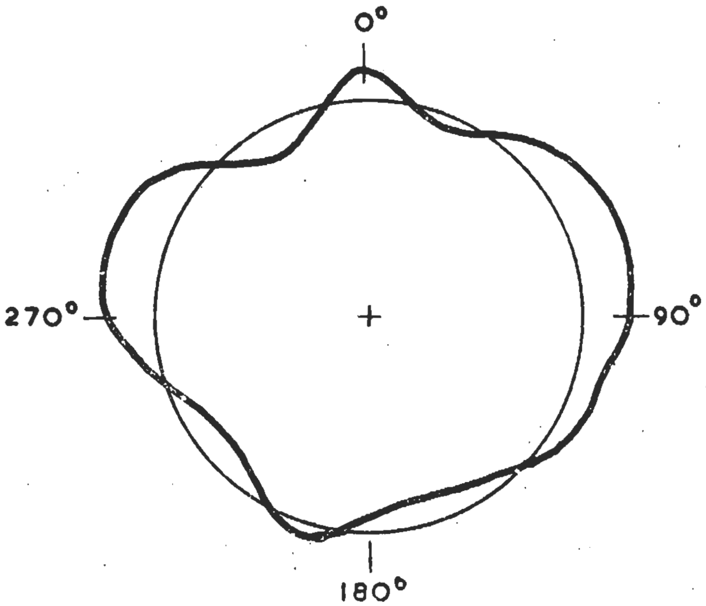
Modified Sleeve Aerial. Diag. 7.4

Another type of broad band aerial is the biconical aerial, so called because it is comprised of two cones. The aerial is essentially a fat monopole and is sometimes used to cover the high frequency part of the band 8 - 24 Mc/s, when suitable ship's structure is not available to construct a folded monopole or sleeve aerial.

The use of parts of the ships superstructure as aerials improves the horizontal radiation pattern over that of a whip aerial. Restricting the frequency band avoids the poor vertical radiation patterns which are obtained when using a whip at the higher frequencies in the band, thus improving the chances of obtaining gapless cover.



BICONICAL AERIAL



TYPICAL HORIZONTAL-PLANE RADIATION DIAGRAM
BROAD BAND AERIAL 8Mc/s

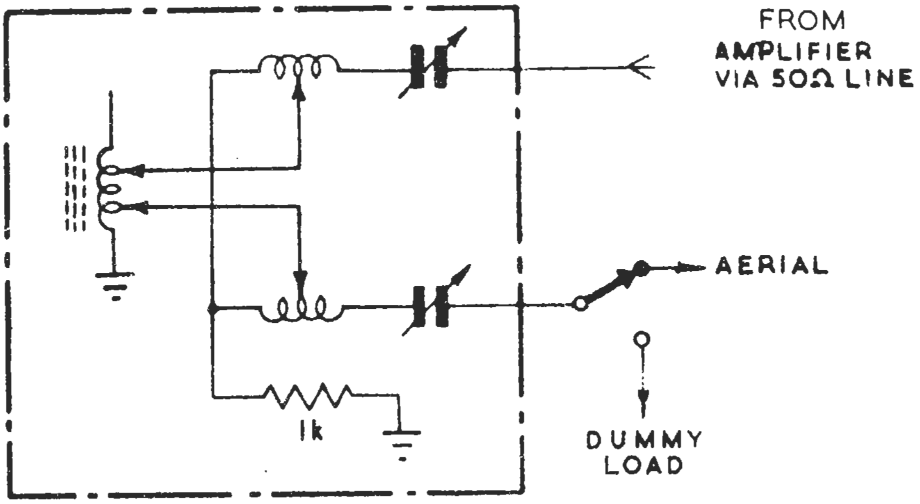
Diag. 7.5

Common Aerial Working Filter

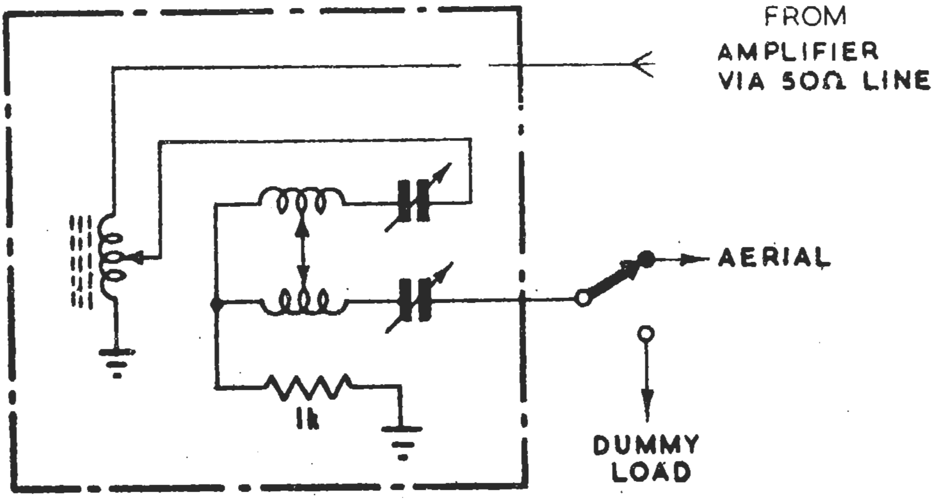
The use of parts of the superstructure for transmitting aerials, inevitably requires the use of a common aerial working system since there are not sufficient aerials available to provide one set to each transmitter. It is normal for the C.A.W. to allow up to 8.1 kW linear amplifiers on any of the three broad band aerials. For this, multi-couplers or filter units are needed to prevent the energy from one transmitter being fed to the other transmitters. The design of such a filter must always be a compromise between selectivity and radiated power loss. A figure of 25% has been arbitarily set as the target for the loss in the worst case. At this level the filters will give a rejection of 20 dBs between two transmitters spaced 10% apart in frequency. Using linear amplifiers this is sufficient to reduce the third order and higher intermodulation products to an acceptable level.

The overall frequency range of 2-24 Mc/s is covered in three bands 2 to 5 Mc/s, 3 to 11.5 Mc/s and 8 to 24 Mc/s.

The filters not only act as frequency selective devices but enable a relatively poor match presented by the aerial to the feeder to be improved to a value acceptable to the amplifiers. The general layout of the component parts and the circuits are illustrated below.



2 to 5 Mc/s Filter. Diag.7.6



Diag.7.7 **High Frequency Filters.** 3 to 11.5 Mc/s, 8 to 24 Mc/s

Each filter consists of two series tuned circuits in which both the capacitive and inductive elements are variable, a resistance matching transformer and an output circuit switch. In the 2 to 5 Mc/s band filters the power is fed from the amplifier feeder through one of the tuned circuits to the resistance matching transformer. From the transformer the power is fed through the second tuned circuit to the output switch and may be dissipated either in a dummy load or fed through the parallel feeder assembly to the aerial feeder.

Filters designed for use on the higher frequencies have their resistance matching transformers connected directly to the amplifier feeders. The alternative arrangement results from impracticability of balancing the two resonant circuits on the higher frequencies at different impedances. Since only one third of the total number of turns on the inductors are utilised at the upper frequencies of each band it is necessary to fit a terminating resistor. The effect is to damp any spurious resonances in the unused turns.

C.A.W. Tuning

(1) The filter is connected to the dummy load.

(2) The resistance matching transformer is connected to the 50 ohm tap.

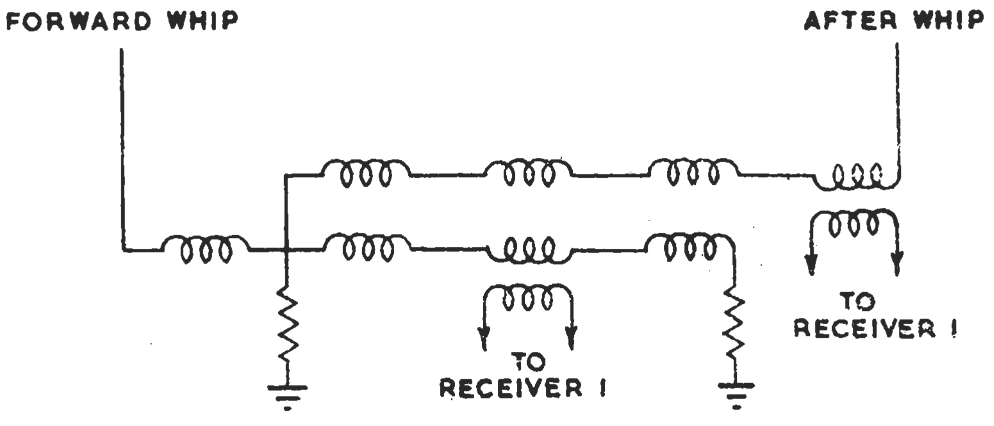
(3) The drive unit is then set to drive the W.B.A. at reduced power on a selected frequency.

With the aid of a metering circuit, the filter tuned circuits are adjusted to give the best position of match. The filter is then switched to the aerial circuit and the transformer and the tuned circuit again adjusted to give the best condition of match. (Matching of the reflected resistance from the aerial is achieved by the transformer and the reflected reactance by the tuned circuits.)

Provided the v.s.w.r. presented to the filter is better than 0.33, the v.s.w.r. presented by the filter to the amplifier will be better than 0.85.

Receiving Aerials

Whip aerials are used for the receiver system. Where possible one aerial is placed as far forward as practical and the other aft. Each receiver can switch into a matched line from either aerial to obtain the optimum signal.



Diag. 7.8

Each receiver can switch to either aerial or can be removed from the line for testing. The line is then matched with a resistor. (See chapter on Receivers).

Fixed Aerial Systems

For many years now rhombic and HAD (Horizontal Array of Dipoles) aerials have carried nearly all the HF communications traffic of the world and Yagi aerials have carried much of the VHF.

Consisting of four straight wires hung in diamond formation between four masts, the rhombic is a cheap and straight forward aerial. It can handle high power and it is useful over a 2:1 frequency range. However, its high sidelobe level is responsible for much spurious radiation when transmitting and gives poor discrimination against interference when receiving.

The vertical curtain of half wave dipoles is an excellent aerial over its limited bandwidth, having a high gain and good power handling capabilities, but in order to provide full coverage of the HF spectrum, several of these expensive arrays are required. Curtains are consequently preferred for point to point circuits with high traffic densities where the higher initial cost is justified.

The HAD consists of one or two endfine arrays of horizontal dipoles fed from a transmission line and hung between four or six masts. It provides a reasonable gain over a 2:1 frequency band, but its impedance match is poor and it is generally used only as a receiving aerial.

As traffic density increases, more and more circuits demand frequency allocations in an already overcrowded spectrum. Interference and noise levels rise and quiet sites become more difficult to find. Existing sites become more crowded with masts whose distribution is often the result of haphazard growth rather than systematic planning. A new approach to aerials system design has become an urgent necessity.

To overcome these problems, an HF aerial of great bandwidth, coupled with good directivity and low sidelobe level is required. These last two criteria give good discrimination against noise and interference on reception, and benefits other users by restricting transmission in unwanted directions.

Excessive directivity can prove an embarrassment unless coupled with some beam scanning system, as it limits the aerial to a very narrow bearing coverage.

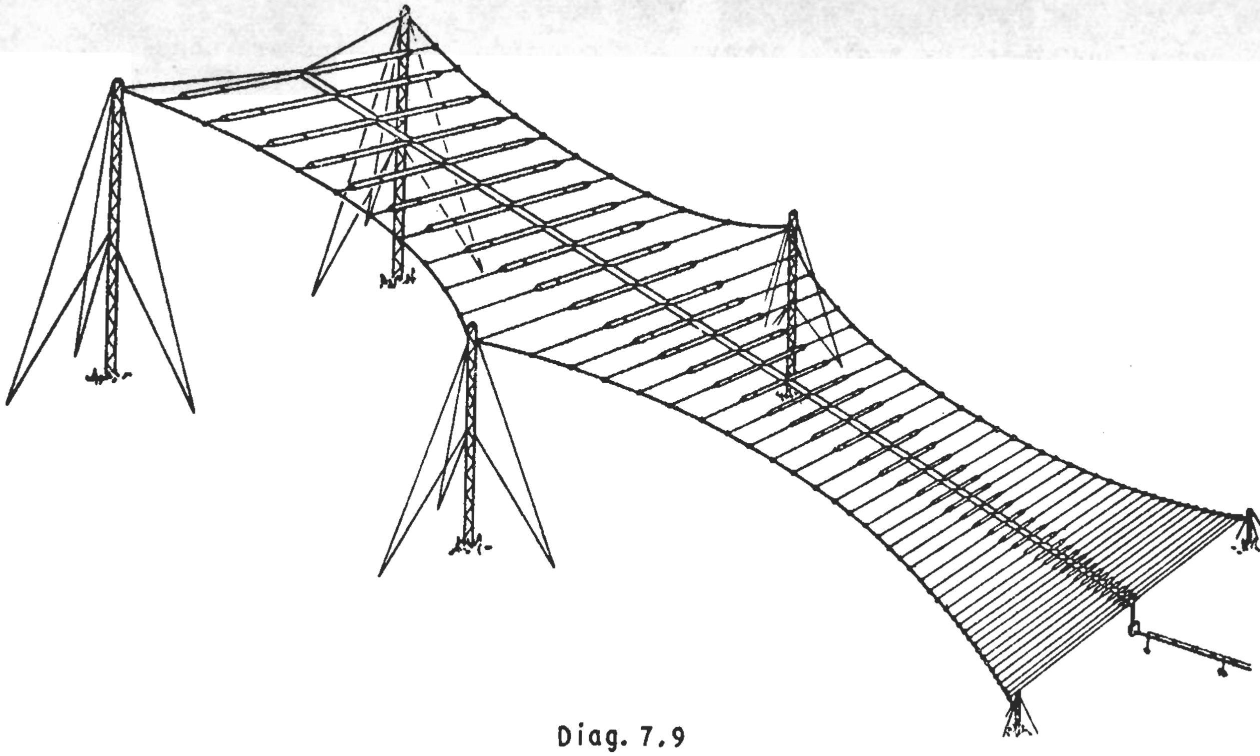
A solution to the bandwidth problem was found with the discovery of logarithmic aerials. These aerials have gains, radiation patterns and input impedances that are largely independent of frequency. Early examples of these aerials usually had low or medium gains and moderate radiation patterns, but recent advances in design techniques have enabled gains to be increased and side lobe levels to be reduced. Logarithmic aerials are now able to provide ample gain and at the same time offer much better protection against interference than conventional aerials. In addition they provide coverage of the whole HF band without switching. It is obviously a great operational advantage to be able to complete a change to a new frequency in the shortest possible time. This can be done by coupling together a wideband transmitter and a wideband aerial. Such a combination has the further advantage of permitting simultaneous multiple frequency operation.

Basic design of logarithmic aerials

There is one fundamental principle underlying the operation of all logarithmic aerials. The aerial itself is some repeated structure, whose dimensions increase in geometrical progression from the feed point. Energy is propagated along the structure until it reaches a part where the dimensions, in terms of wavelength, are such that resonance takes place. Energy is radiated from the resonant part and beyond the resonant part, negligible power is left on the structure. It is thus unimportant how far the structure is continued and end effects need not be taken into consideration.

If the frequency is changed, the resonance shifts to another part of the structure, the geometrical relationship ensuring that the characteristics are substantially unchanged. Bandwidth is limited only by the dimensions of the structure at the large and small ends.

One highly promising design is the logarithmic array of dipoles. Since the two functions of feeding and radiating are separable, much better control over the radiation is possible and high performance designs are readily achieved.



Diag. 7.9

The diagram shows a horizontally polarised, high gain log aerial suitable for the frequency range 4 - 27.5 Mc/s. This is an endfine rather than a broadside array, since it is more compact for the performance required. As construction must be in wire having a high length to diameter ratio, simple dipoles are not very suitable as their Q factors are too high. Folded dipoles are better and are fed from a balanced open line.

Performance of such an aerial is as follows:

Gain over isotropic	15 dB
Polarisation	Horizontal
Frequency Range	4 - 27.5 Mc/s
Beam-width (azimuth)	48° to 3 dB down
Elevation cover	10° to 35° to 3 dB down
Side and backlobes	22 dB down average level over the band

In laying out a site plan, it must be remembered that a wideband aerial necessarily obscures other aerials over its full bandwidth. On the other hand, the low side and back radiation makes it feasible to operate side-by-side arrays with common masts. Side-by-side arrays may be splayed outwards so as to overlap at 3 dB points, 8 being required for 360° coverage, or two or three aerials may be combined in a broadside array to give additional steerable directivity.

VHF and UHF Aerials

A number of new logarithmic aerials are suitable for application to communications in this part of the spectrum. One of the most useful is the low sidelobe array. It has been found possible to obtain sidelobe levels of 30 dB or better by using very gradual tapers on ordinary logarithmic dipole arrays. As the gain of these arrays are high, of the order of 15 to 20 dB above isotropic, they could be used to replace Yagi arrays with a useful improvement in overall system performance, even when the wideband facility is not itself important. In particular, when several aerials are to be grouped together, with low cross talk, the low spurious radiation of the logarithmic array could be a great advantage.