THE RIGHT ANTENNA FOR THE JOB

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Choosing the right class of antenna for use on an HF link is very important if the best link performance is to be obtained. the communications engineer is faced with a baffling choice of antenna types. How do they differ in performance? Are they just gimmicks? What is the essential difference between a transmitting and receiving antenna, and how can these differences most effectively be exploited? these are among the questions which will be examined in this article.

The communications engineer strives to design a complete system to provide the required communications facility at minimum cost; choice of the right antenna is important if this objective is to be met. A wide range of antenna types has been developed over the last 60 years or so, and to choose effectively the communications engineer needs to understand not only the basic parameters of antenna performance, but the different ways in which this information will be presented to him by various manufacturers. The most important parameters which he/she will always need to establish are as follows:

For a transmuting antenna

Azimuth radiation pattern
Direction of azimuth maximum
Elevation radiation pattern
Elevation angle of fire
Net power gain
Maximum permitted input power
Input impedance and VSWR
Polarisation

For a receiving antenna

Azimuth radiation pattern
Direction of azimuth maximum
Elevation radiation pattern
Optimum angle of arrival
Directivity
Output impedance and VSWR
Polarisation

Vital statistics

These notes are not intended as definitions, but as comments which may be helpful when examining antenna catalogues in the light of a real requirement.

The *radiation patterns* of an antenna indicate the power (or field strength) radiated in any direction relative to that in the direction of maximum radiation. Take care, as both relative power and relative field diagrams are in use and often no clear statement is made as to which is presented.

Of course the actual radiation pattern of any antenna is really a three-dimensional function. For the sake of simplicity, only cuts through this solid in the horizontal (azimuth) and vertical (elevation) plane are usually presented. These planes are referred to as the principal planes. For one important class of antennas, those for use on short range paths via the ionosphere this practice is—for good reason—not observed (see box).

The radiation pattern in the elevation plane is strongly influenced by the presence of the ground beneath the antenna, as the radiated signal is the sum of the signal radiated directly from the antenna and that re-reflected by the ground. The relative phase of these components changes with antenna height above ground, electrical characteristics of the ground, and polarisation. Manufacturers' data generally refer to 'average ground', usually taken to have a conductivity of 10 mS/m and a relative permittivity of 10. These figures are reasonably typical of land where grass or agricultural crops are growing. Data quoted for ‘ideal ground' should be viewed with more reservation because of course there is no such ground, except perhaps sea water, and an earth mat of copper wires will be required to obtain an approximation to the published performance.

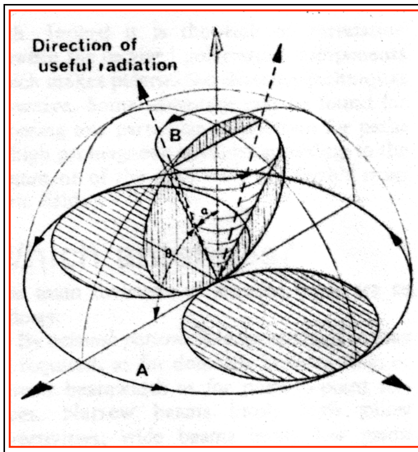
A further characteristic of radiation pattern performance often quoted is the beamwidth —properly the half power beamwidth. This is the angle between the points on either side of the direction of maximum radiation at which the intensity of power radiated has fallen to half the maximum (-3dB). Again care is necessary as in some cases half this angle is quoted. Sometimes, ±n° is stated, removing any ambiguity, but unfortunately this is not always done.

Reciprocity. According to the principle of reciprocity the parameters described above are identical for any antenna when used for either transmitting or receiving. This is true despite the fact that an HF circuit as a whole is often non-reciprocal.

Power Gain. This indicates how much the signal radiated in the direction of maximum radiation is increased if the antenna referred to is substituted for some standard reference antenna fed with the same input power. Here again there are possibilities for confusion. The reference antenna may be either a half-wave dipole or an isotropic radiator, a hypothetical device radiating energy uniformly in all directions in 3-dimensional space. As the power gain of an isolated half-wave dipole is 2.2dB relative to an isotropic radiator, it is obviously important to know which reference is used and this should always be stated in published data. Reference to an isotropic radiator is often indicated by indicating gain as n ***dBi***. Quoted gains generally allow for the enhancement of signal provided by ground reflection, but again the assumed ground conditions are often omitted.

For certain antennas a quarter wave rnonopole over ideal earth makes a more suitable reference, but in such cases this is stated. This reference is convenient for circuits where propagation is by ground waves, as curves relating field strength and distance against distance are readily available (Ref. 1). Observe that in circuit calculations it is the *net power gain* which is significant, that is the quoted gain less allowances for antenna losses—often quoted as efficiency, (ratio of total power radiated to total power input). For some classes of antenna efficiency is compromised in the interests of obtaining a wide impedance bandwidth. Losses due to mismatch must also be deducted to find net antenna gain.

With the increasing use of active antennas for reception it is becoming important to appreciate the difference in function of a transmitting and a receiving antenna in the HF band. (Some older antennas such as the Beverage also exploited the difference.)



Antennas for short ionospheric paths

When considering the behaviour of an antenna operating over a short path and consequently required to direct energy at high angles of elevation, we can see from the figure that the conventional principal-plane radiation pattern is misleading. The normal 'azimuth radiation pattern' would indicate the variation of field strength as we traverse path A, a circle in the horizontal plane. A more useful set of data is obtained by traversing path B which joins all points with constant elevation angle and lie equidistant from the antenna. Clearly the radiation pattern so defined is always circular when θ = 90' as this is a trivial case, and the familiar azimuth pattern will be obtained for θ = 0°. Patterns for a variety of elevation angles from 50° upwards are commonly published. It will be noted that the sense of polarisation of the radiated field changes with bearing. This effect is ignored, but explains why the polarisation direction for antennas for such operation is usually not quoted; it is meaningless.

A transmitting antenna is required to lay down the maximum possible field strength at some defined remote point: to do this the antenna must have the maximum net gain in the appropriate direction. A receiving antenna is required to abstract some wanted signal from an environment filled with other signals and noise from a variety of sources. This task does not require gain: it requires directivity. Directivity describes the sensitivity of the antenna in the preferred direction of reception to the mean sensitivity of the antenna to signals from all directions. As an isotropic antenna is equally sensitive in all directions it will have a directivity of 1 (0dB). Thus if noise is taken to arrive equally from all directions the substitution of an antenna of directivity DdB for an isotropic receiving antenna will improve the received signal/noise ratio by DdB. Directivity is determined by integration of the three-dimensional radiation pattern of an antenna. Notice that in HF work the net gain of a receiving antenna, unless allowed to fall to an exceptionally low level, does not determine the received signal/noise ratio; the system is external noise limited.

In some situations the assumption of isotropic noise distribution is too approximate and separate calculations must be made.

Maximum input power will generally be determined by the onset of one of three effects.

1. Dielectric losses causing overheating of insulators.
2. Ohmic losses causing overheating of conductors carrying large currents.
3. Corona discharge from insulators, element tips and other parts.

As some of these effects are current-determined and others are voltage-determined the ratio of power ratings quoted for different classes of emission may seem at first to be illogical and will vary for different antennas. Take particular care if transmitters operating at different frequencies are to be parallel operated into one antenna, when very high peak voltages may be produced.

Input impedance. As the transmission line feeding an antenna must have the same characteristic impedance as the antenna input impedance it is often the economics and practicalities of transmission line design which determine suitable antenna input impedances. A wide range of efficient broadband transformers is available allowing changes in impedance level and from balanced to unbalanced line systems.

Input VSWR. The maximum permissible input VSWR for a transmitting antenna is generally determined by:

1. The economic need to minimise the size of the transmission line required, especially when large diameter semiflexible coaxial cable is used. The power rating of a cable reduces approximately as 1/□ where □ is the VSWR.

2. The ability of the transmitter output circuits to match a non-optimal impedance.

In practice, condition 1 often dominates. Naturally, wide-band antennas provide most problems in respect of VSWR, as when required a narrow band system may always be matched on site with little difficulty.

HF receiving antennas seldom require a closely specified VSWR.

Polarisation. This parameter describes the direction of the electric field vector of a propagating electromagnetic wave. When referring to a directional antenna it generally describes the polarisation radiated or received in the direction of the radiation pattern maximum. Often signals of other polarisations are radiated in other directions.

Fig. 1 shows the direction of the polarisation vector for what are generally termed horizontal and vertical polarisation, for signals arriving from high angles of elevation.

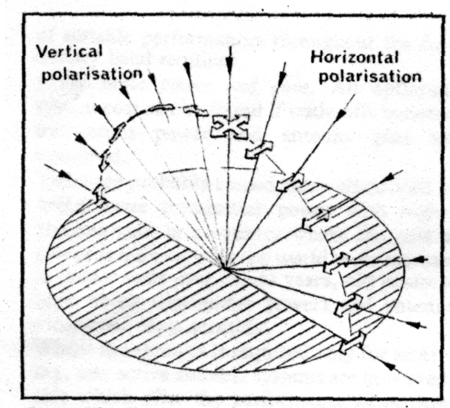


Fig. 1 The direction of the polarisation vector for signals arriving from high angles of elevation.

Polarisation discrimination of an antenna defines the relative sensitivity of the antenna to horizontally and vertically polarised signals, but off-axis the definition is not standardised and when important should be very carefully specified. Circular polarisation is not often used in HF systems except in certain short range antennas where the property of radiating a symmetrical beam directly upwards is required of an antenna.

The polarisation chosen for HF systems is often determined indirectly. Very low take off angles can be obtained from horizontal polarised antennas mounted high above ground.

Vertical polarisation is required if ground wave propagation is to be used, and at sites on highly conductive ground it can provide low angle beams from antennas mounted close to the ground.

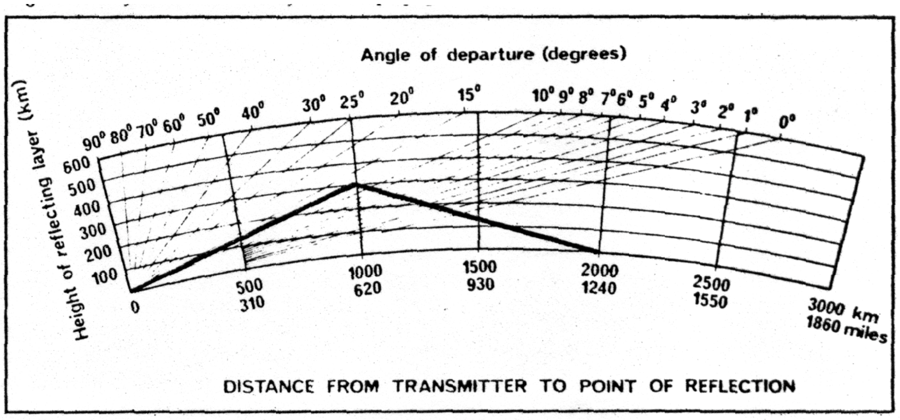
It is generally agreed that owing to the mechanism of ionospheric reflection it is not necessary to employ antennas of the same polarisation at each end of an ionospheric path Indeed it is the lack of correlation between the received polarisation components which makes polarisation diversity techniques attractive. Some advantage may be found for choosing one particular polarisation for paths in high geomagnetic latitudes according to the alignment of the path with the earth's local magnetic field.

Which antennas?

The main divisions of antenna types are as follows:

1. *By azimuth pattern.* A large beamwidth may be required, as for domestic broadcasting, or narrow beamwidth as for point-to-point services. Narrow beams imply high gains and directivities; wide beams imply low gains and directivities.

2. *By elevation pattern.* Analysis of the path(s) to be served will indicate the take-off angles and angles of arrival to be expected. Sophisticated computer methods now exist to aid this work (Ref. 2). A simple geometrical approach is often useful in cases where the mode of propagation and the effective height of the reflecting layers can be assumed. Fig. 2 is an example of a chart for this purpose—the horizontal and vertical scales are related so that propagation paths may be drawn as straight lines with mirror-type reflection occurring at the layer height shown.



To use the chart:

a. Decide on the minimum number of hops which will be required for the path (maximum hop length 4000km). Divide the hop length by 2 to give the distance to the point of reflection.

b. Choose an appropriate layer height. Refer to any standard propagation text if in doubt.

c. Read off the vertical angle from the scale.

d. If the vertical angle is below 4°, repeat using an additional hop. Choose an antenna with a wide enough beamwidth to allow for expected variations with season and sunspot activity. Again beamwidths and gains are related.

3. *By bandwidth.* Analysis of the path will indicate suitable frequencies to use under varying conditions. Assuming suitable allocations are available, make sure that the transmitters, receivers and antennas are all capable of suitable performances throughout the frequency band required.

4. *By input power and gain.* An optimum system cost can be found if trade-offs between transmitter power and antenna gain are examined.

There are probably considerable attractions in using lower transmitter power with higher antenna gain in a country where the cost of power is high—with the world wide increase in power costs over recent years, old assumptions about transmitter powers and antenna gains need close scrutiny.

Where the antenna is required only for receiving, new active antenna systems are now available which offer the performance of conventional receiving antennas but provide flexibility of performance and savings in installed cost. The intermodulation performance of these antennas is now fully compatible with that of modern receivers.

5. *By requirement for land area and labour.* Antennas vary very widely in this demand for land area and in the labour required to erect them. This implies different antennas may be chosen for a site in a highly industrialised country where land is expensive and labour rates high, and a developing country where land is more freely available and labour rates lower.

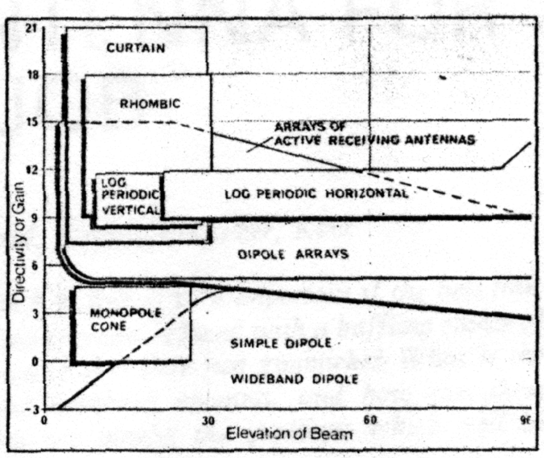


Fig. 3 The range of gains and elevations which can be obtained from a variety of commonly used antennas.

Of the criteria set out above, some of the most important choices which will affect the type of antenna to be chosen and not just its detailed design, are gain and radiation pattern. Fig. 3 indicates the range of gains and elevation angles of fire which can be obtained from a variety of commonly used antennas. The performance of a particular antenna depends on the choice of parameters such as height above ground, number and disposition of elements. Thus the area on the diagram which is accessible with a flexible system such as an array of active loop receiving antennas is much larger than that for a more restrictive design such as a rhombic.

Conclusion

The choice of an antenna is an integral part of the design of an HF communications system. Antenna parameters must be chosen with both technical performance and long term system costs in mind. This article has indicated the parameters which determine the choice of an antenna. Having determined the parameters the system design engineer can then turn to manufacturers' data and find out which antenna type will be suitable for the application, or may see that he/she is specifying performance beyond that usually obtainable, in which case the system design must be modified.

References

1. Ground wave propagation curves for frequencies between 10kHz and 10MHz. CCIR Rec. 368-2 (XIIIth Plenary Assembly Geneva 1974 Volume V B).

2. CCIR interim method for establishing sky-wave field strength and transmission loss at frequencies between the approximate limits of 2 and 30MHz. CCIR report 252-2. (Published separately.)

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