

ANTENNAS FOR TACTICAL RADIO SYSTEMS

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The design of antennas for field use by armed forces is constrained by the needs of transportability, performance and ease of camouflage. New materials, the use of micro-processors and the development of active antennas are some of the designer's tools.

Before discussing antenna performance it is useful to look at some basic concepts of antenna engineering.

Efficiency: In an ideal antenna, all the radio-frequency energy fed into its matched terminals would be radiated in the outgoing radiowave. As the mechanism by which radiation occurs requires currents to flow in the conductors which form the antenna, some of the input power is lost as heat. The efficiency of an antenna is the ratio

$$\frac{\text{total radiated power (in all directions)}}{\text{input power}}$$

Directivity: For point-to-point working it is obviously very desirable that an antenna radiate energy only in the direction of the station to be contacted. This avoids power being wasted in other directions and avoids other stations eavesdropping or fixing the position of the transmitter. The directivity of an antenna is the ratio

$$\frac{\text{power flux in the wanted direction}}{\text{average power flux in all directions}}$$

at any distance from the antenna.

Gain: This is a measure of the difference in the signal level received by an antenna compared with that which would have been received by some standard reference antenna in its place. Suitable reference antennas include a lossless halfwave dipole, a lossless monopole or an isotropic radiator. The latter is an unrealisable idealised antenna that radiates uniformly in all directions and therefore, by the definition above, has a directivity of one or 0dB.

It is useful to notice the relationship:
 $\text{gain (relative to isotropic radiator)} = \text{directivity} \times \text{efficiency}$

In the definition above the antenna is assumed to be receiving a signal, but a similar definition applies to a transmitting antenna. The gain when transmitting or receiving will be identical for any passive antenna. Substantial

gain requires an antenna whose size is, in at least one dimension, a substantial fraction of a wavelength. This represents a very important constraint, especially when working in the h.f. band, where wavelengths are of the order of 10 to 100m.

Propagation in the h.f. band is by groundwave over short distances and by ionospheric reflection over longer distances. Even with fixed, permanent stations practical problems of antenna size restrict the gain obtained. For field use it is clear that at lower frequencies it is unlikely that any significant gain will be obtained, although above about 10MHz some gain is possible. Two very familiar antennas are widely used:

Vertical whip: This is the standard antenna for vehicles and for packsets. A whip radiates in all azimuth directions, but in elevation it radiates best at low angles (Fig. 1). This makes it very useful for short distance ground-wave use, but not very good over short ionospheric paths, which have a high take-off angle (Fig. 2).

The efficiency of a whip is governed by its length as a fraction of the operating wavelength. A quarter-wave whip is very efficient and requires little matching. By contrast, a whip that is only one-fortieth of a wavelength is not efficient. To radiate the input power from a very short wire, high currents must be excited, and these generate losses. The input impedance looks like that of a slightly lossy capacitor, so a matching network must be introduced between the antenna and the feed line; this network introduces further losses. Because of the large reactances present in the circuit the Q-factor is large and the resulting bandwidth is small; the adjustment of the matching network is correspondingly critical. Adjustment of the matching network is often made by hand, perhaps with the aid of calibrated-knob tables of settings for various frequencies, but various automatic systems are possible.

Much effort has been expended over many

years to determine the most efficient way to load a short whip by using inductance and top-capacitance, and various forms are seen in use. However, for general use the plain unloaded whip tuned by a series of inductors at its base remains the most common arrangement.

Horizontal dipole: As long as some form of support is available, say, 5 or 10m above ground, a horizontal dipole can be erected. This radiates most strongly at high angles of elevation and above 45° elevation it can be thought of as being omnidirectional in azimuth. Various wind-up arrangements are available, so that with a simple antenna kit a halfwave dipole can be erected quickly by using lightweight masts, trees or buildings for support. The use of an antenna tuning unit next to the transmitter makes the length of the dipole noncritical, and good results may be obtained with dipole lengths of 0.3λ to 2λ. The efficiency of the antenna is good, but if it is mounted too low an increasing proportion of the radiated power will be lost in the ground around the antenna: losses increase rapidly when the height of the antenna is reduced below about λ/10.

Dipole systems with increased bandwidth can be made by introducing losses that damp out impedance variations. These losses may be in the form of lumped resistors, lossy wires or ground loss; other forms for loading including lumped and distributed reactance loading and a variety of ingenious feeding arrangements are also available. These present various compromises between efficiency, ease of use and complexity.

Merely lengthening a dipole increases its gain only slowly and the direction of maximum radiation changes in an unhelpful manner. The commonest directional transmitting antennas for field use are two derivatives of the familiar rhombic antenna: the sloping Vee and the inverted Vee (Fig. 3). These are simple and effective, but their characteristics depend strongly on dimensions and ground characteristics. However, as they are quick and easy to erect they are often worth trying if a dipole is inadequate. In receiving applications it is directivity rather than gain that determines the received signal/noise ratio. Increasing use is being made of active antennas, which combine quite small elements with low-noise high-linearity preamplifiers. An array of these elements can provide high performance from an inconspicuous, quickly erected array.

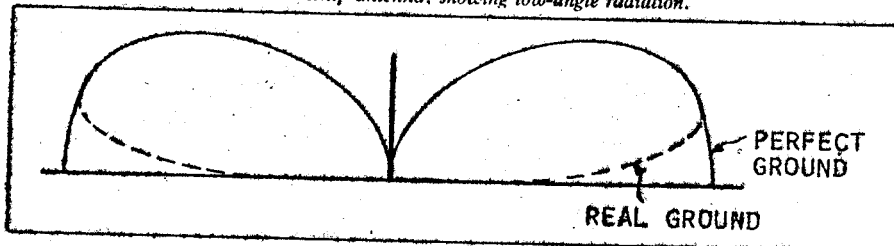
Simplified forms of other standard h.f. directional antennas have been designed for field use, but they are too large, vulnerable and complex for forward positions.

VHF

The v.h.f. band sees a transition from the wire antenna techniques used on the h.f. bands and the neatly engineered arrays of rod elements familiar at u.h.f. A major problem is obtaining adequate bandwidth, especially below 100MHz. Log-periodic arrays for the 30 — 100MHz band are unwieldy, require good

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Fig. 1 Azimuth radiation from a whip antenna, showing low-angle radiation.



FOCUS antennas

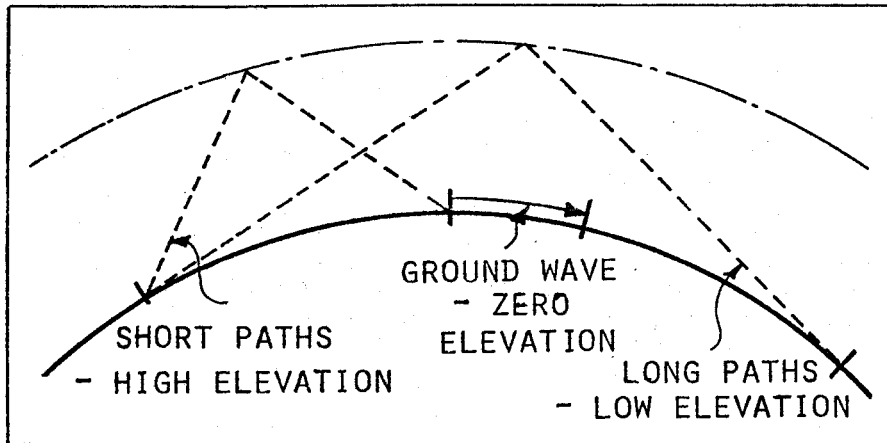


Fig. 2 Different radiowave propagation paths. Whip is unsuitable for high elevations.

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support if they are to survive high winds, and are easily broken while being deployed or restowed. A disccone is an attractive low-gain antenna, but when mounted with its base at ground level the advantage of any height-gain is lost. As at h.f., another solution to the problem of increasing bandwidth is to add loss deliberately to the antenna and suffer the consequent loss of efficiency. Isolators and directional couplers can similarly be made to help a transmitter see an acceptable match even when the antenna itself is very poor.

Vehicle antennas can be very efficient; for example whips $\lambda/4$ or $5\lambda/8$ high. However if efficiency can be traded, much smaller antennas are possible, and any discontinuity in a vehicle's skin can be excited — windows, roof racks and other external fittings are all potential antennas for the expense of a suitable matching network.

Between about 200 and 1000MHz a large variety of Yagi, log-periodic and dipole panel antennas can be designed. Antenna efficiency is not a design problem and the size, strength and weight of antennas are well-adapted to field conditions. As the frequency increases beyond about 750MHz the elements of the antenna become small and fragile. The necessary mechanical tolerances become more stringent, so a mechanically damaged antenna is less likely to work acceptably. Dipole panel antennas require increasing numbers of elements if they are to provide sufficient gain. For these reasons, reflector antennas are used at higher frequencies. Reflectors may take various forms, such as corners, troughs or paraboloids. Corner reflectors have the advantage of folding flat for stowage, but a paraboloid is much more robust. Whenever possible, perforated or mesh reflectors are used to reduce both the weight and windloaded area of the antenna.

Above 1000MHz the directivity of antennas becomes potentially very large. The main beam may have a width of only 20° , so it becomes increasingly important to point the antenna in exactly the right direction and also to hold it on that bearing even in gusty wind. As the antenna must be mounted on a mast, usually telescopic, the weight and, especially,

the wind force acting on the antenna become very important characteristics if the antenna system is to operate correctly. As the frequency rises further, the achievable gain increases and the antenna beamwidth decreases to only a few degrees. This has the desirable effect that communication is restricted to the wanted direction, but it imposes very severe requirements on the accuracy with which the correct pointing direction must be set up and maintained. The practical effect of this is that for mast-mounted antennas there is a practical upper limit to useful gain of about 25dBi. For ground mounted antennas, pointing accuracy and stability are less of a problem, so antennas for tropospheric scatter links and wideband satellite terminal links are commonly ground mounted. For satellite links this is no disadvantage; the antenna can still be mounted among trees as the path to the satellite is generally at a conveniently high angle of elevation.

Environment

As well as the need to strive for the best electrical performance, together with acceptable size, weight and deployment times, the antenna may need to be used in the Arctic, a desert or a tropical rain forest. Connectors and mechanical fittings must work even when covered in mud or filled with sand. The need to erect antennas at night, perhaps when wearing Arctic gloves dictates that all fasteners be simple to operate, fully captive and be robust and unfussy in design.

Equipment must be designed for very rough use, although this requirement must not result in overweight designs. However large and complex the equipment, it must be transported in man-size units, which will usually be stowed in the radio vehicle. The need to camouflage equipment requires assemblies wherever possible to have broken surfaces, non-reflective finishes and colours which merge into the terrain.

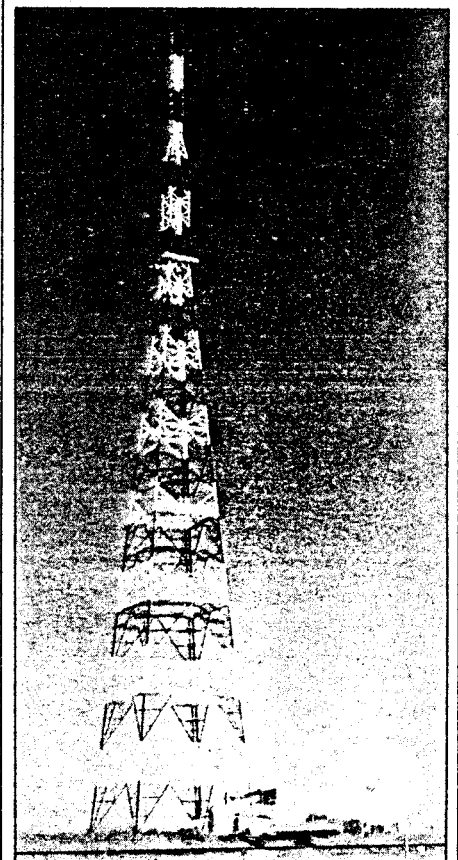
Military equipment often spends many years in use during training and exercises. It must not degrade by the effects of corrosion and wear so that it becomes unreliable just at the stage when lives depend on it. Systems must

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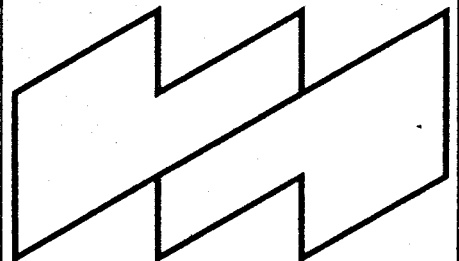
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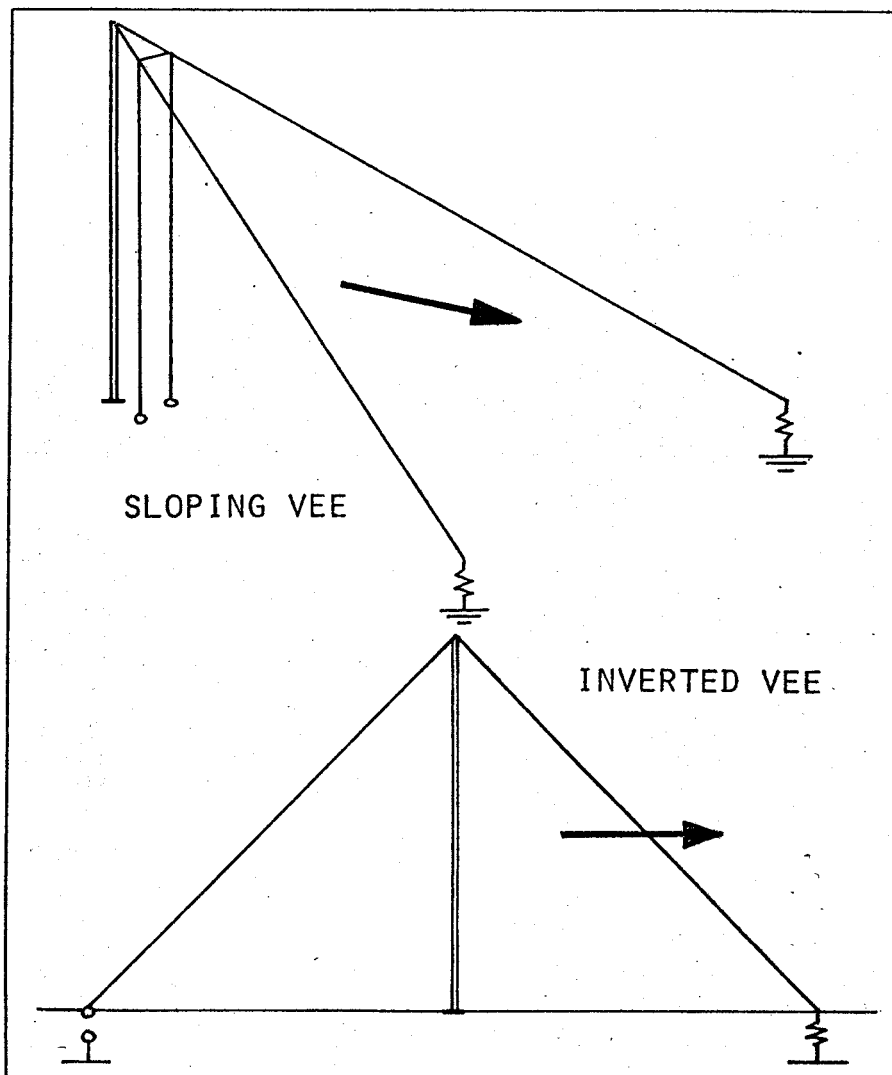


Fig. 3 Sloping Vee and inverted Vee antennas, derived from rhombic antenna.

be designed for a clearly specified lifespan; they must be capable of being inspected and maintained so that the originally specified performance and reliability are always available. The general purpose material for antennas is high-quality aluminium alloy, with copper and stainless steel being used where higher conductivity or greater strength are required. Aluminium is often anodised or chromate converted, and is always painted, to increase corrosion resistance. Copper and stainless steel are often plated to reduce the severity of the electrolytic attack on adjoining aluminium components.

The advent of synthetic ropes has led to a very wide variety of strong, electrically insulating, rot-proof cords and ropes, which are universally used in place of traditional materials. Nylon and Terylene (polyester) cords are commonest for halyards and antenna supports. Glass reinforced plastics (g.r.p.) provide robust insulators suitable for many antenna applications. G.r.p. is lighter and much more resistant to breakage than porcelain or other ceramics, which are not well suited to field use.

Masts, usually made from aluminium alloy, may be of telescopic design operated by hand, wound up by wires or pumped up by compressed air. Alternative designs use simple falling-derrick erection or systems of breech loading. Most masts need some staying, although for small antennas this may be necessary only in high winds. Masts may be designed for ground mounting or may be built into the communications vehicle.

Coaxial cables and connectors are the hazard-prone components of the system, as most cables become degraded by kinking or by having vehicles driven over them. Connectors become worn with repeated use and frequently part company with the end of the cable at inconvenient moments. Cable problems become especially acute at upper u.h.f. and s.h.f. frequencies when, because of increasing cable attenuation, semiflexible cables of large diameters must be used. Reliability will be assured only if good reeling facilities are provided, the men using the equipment are familiar with the problems and the cables and connectors are regularly inspected and maintained.