# A NEW GENERATION OF LIGHTWEIGHT TRANSPORTABLE ANTENNAS

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## SUMMARY

The resurgence of HF radio for tactical applications requires the development of new antennas which are light, small and quickly erected; their electrical characteristics must be optimized for the link or net in which they are to be used.

This paper examines the electrical parameters which are necessary to support HF communications at various distances, the choices and trade-offs which can be made to obtain the most useful performance from the minimum equipment, and indicates areas in which important advantages can be gained by the use of modern materials and ingenious design.

## 1. INTRODUCTION

During the last few years there has been a resurgence of interest in the use of HF radio, particularly for tactical communications and the design of antennas for this application has become increasingly specialized. A successful antenna requires a practical compromise between a number of often conflicting requirements in both electrical and mechanical design. The ideal antenna has zero weight, short erection time and high gain : it does not exist. For each application the designer must find the right mix of characteristics.

## 2. THE CONSTRAINTS OF THE PROPAGATION MEDIUM

HF propagation takes place by two different mechanisms which must be understood if successful communication is to be obtained.

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At short ranges propagation is by 'Ground Wave', a term used rather loosely at HF to include both the direct free-space wave - often diffracted or reflected by terrain obstacles - and a surface-coupled wave which will only exist for vertically polarized waves, and whose attenuation increases at higher frequencies and over poorly-conducting ground. These mechanisms typically provide a useful signal to a radius of 15-50km, the signal path being close to a direct line joining the transmitter and receiver.

At longer ranges propagation is by ionospheric reflection. The ionosphere may be envisaged as a series of concentric curved reflecting mirrors at heights of around 120km (E layer), 220km (F1) and 300km (F2). These layers have electron densities which change with solar activity and solar zenith angle in a manner which is generally predictable in the long term, but which shows large short-term variations from the predicted norm. The geometry of the mechanism requires paths with high elevation angles for short ranges and paths with small elevation angles for long ranges. (Figure 1).

It may be seen that there is a sharp change in the elevation angle required as the range of communication increases past the range possible with ground wave. This is inconvenient in some circumstances, but it allows the communications engineer to choose the medium which he intends to use; propagation by two modes simultaneously leads to the reception of two signals with a large relative delay time, causing fading and distortion.

In brief, low angle vertically polarized radiation provides groundwave and long-range skywave communications (0-50km and 750km plus). Near-vertical incidence skywave (NVIS) serves ranges out to 1000km.

Antennas must be designed to suit both the radiation angle of the path which is to be worked, and the range of frequencies at which propagation will be supported. Directional or omnidirectional antennas may be required, depending on whether the application is for a link or a net.

## 3. ANTENNA SIZE

For all practical antennas the relationship between gain and physical dimensions is fixed. High gain antennas must intercept the RF energy flowing through a readily calculated area which is normal to the direction of propagation; low gain antennas can be modestly reduced in size, but as the dimensions are reduced (relative to the wavelength) the proportion of stored energy rises, producing rising losses and reduced frequency bandwidth. Although the shape of an antenna can be modified, its basic overall dimensions are usually fixed by the frequency of operation and the gain which is required; short whip and small loop antennas provide small size, but at the expense of reduced efficiency and limited bandwidth; this compromise may be necessary when there is no space for larger antennas.

Where wideband operation is necessary, antenna dimensions are usually fixed by the gain which is needed at the lowest operating frequency. The designer can choose whether the whole structure is excited at higher frequencies - producing higher gain - or whether the excitation should deliberately be restricted to preserve a particular gain or beamwidth. Log-periodic structures provide a very poor compromise for transportable antennas, as at any operating frequency a large part of the structure is not contributing to its electrical performance; further, they are often mechanically complex and have only modest side and rear-lobe suppression.

## 4. CONFIGURATION

In a crisis, antennas are often deployed by non-specialist personnel, who have little time to erect and re-stow the antennas, and who need to remain as inconspicuous as possible. To meet this requirement, the antenna designer must choose a design which is the simplest possible which will provide the needed gain and bandwidths the result will be an antenna which is light to carry, simple to erect, and which is easy to understand. Any proposal to increase weight and complexity must be examined with suspicion.

When erected in field conditions an antenna will often be distorted by sloping ground, imprecise vertical of masts, mis-tensioning, or even makeshift repairs. It is important for the designer to recognize these constraints, which may impair not only gain and VSWR, but also features such as sidelobe levels, and isolation between adjacent antennas, as well as the mechanical stability of the antenna.

These considerations must be understood by the designer at the outset; if at all possible the performance of the antenna must degrade gracefully.

The electrical design of the antenna must be chosen with the whole operating specification in mind - environment, stowed size, setup and stowing times, maintainability and the rest. The main factors driving antenna design are the need for larger operating bandwidths to accommodate frequency hopping and real-time channel evaluation techniques in the HF band, and the search for smaller structures with acceptable performance trade-offs in the HF and lower VHF bands.

## 5. SIMPLE ANTENNA DESIGNS

The familiar wind-up dipole is still very useful for HF NVIS use; it can be broadbanded by loading (with much reduced efficiency), or by modification to a simple fan with elements of unequal lengths. When efficient broad-band operation is needed, a resistively-loaded fan provides good efficiency if the dimensions are well optimised; careful attention to design minimises the problems produced by greater complexity. Low angle omnidirectional radiation can be obtained from a simple vertical element, fan or cone, and directional radiation from a simple sloping or inverted Vee.

HF skywave propagation between two points is usually possible within a frequency band of up to about two octaves, defined at any instant by the Lowest Useable Frequency (LUF) and the Maximum Useable Frequency (MUF) for the path. There is little practical necessity for an antenna to cover the whole HF band instantaneously, except for use in the groundwave mode. A more common requirement is for antennas which will cover a band of one or two octaves and which can easily be reconfigured to cover different sectors of the HF band; such antennas can be made using the simple designs mentioned above.

For groundwave operation, a low radiated power, often a few tens of Watts, is needed, and antennas commonly take the form of short whips with fast-tuning automatic Antenna Tuning Units (ATUs). Whips are not suitable for short skywave links, as they radiate very little energy upwards and cannot handle the larger powers which are often needed. There is clearly scope for combining fast-tuning ATUs with fixed length dipoles, but the use of these antennas is limited both by the weight and complexity of high power self-tuning ATUS, and the limitation of antenna bandwidth produced by falling efficiency (at lower frequencies) and pattern breakup (at higher frequencies).

The use of active elements for HF reception is now well established, and a wide variety of types is available to meet different operational requirements on NVIS or longer paths. A well-designed array is capable of out-performing a log-periodic or rhombic; it requires no masts and can easily be erected by one man in as little as 10 minutes. These antennas have a very low effective height and can be sited surprisingly close to transmitting antennas before interaction limits their performance; the usual limitation is the level of wideband noise radiated by the transmitter. They are inconspicuous and can be set up without difficulty on rough ground or in wooded terrain.

Small loops are used as transmitting antennas, but they have severely limited gain (especially at the low frequency end of the band) which can probably only be justified when NVIS operation is needed from a very restricted site, or when a vehicle is actually on the move.

Antennas whose elements are close to the surface of the ground are attractive for some applications, providing a different combination of electrical parameters and deployment scenarios.

## 6. MECHANICAL DESIGN

During the past two decades the size and weight of communications equipment has decreased; the antenna now accounts for a larger proportion of the total system. The erection of the antenna often requires the largest investment of time and manpower in getting the system operational. The message is again the need for simplicity and lightness.

### 6.1 Weight Reduction

The key to reducing the weight of an antenna system lies not only in such obvious matters as the use of strong, light materials in structurally efficient designs, but also in designing components which perform several different functions. This approach also reduces the total count of components, reducing deployment time, simplifying logistic support and increasing reliability.

### 6.2 Reliability

Corrosion control methods are well known; all designs should observe simple precautions such as selecting materials and finishes to reduce the electrolytic contact potentials between dissimilar metals. Much greater reliability is obtained when this practice is followed even for components which are nominally sealed from the environment, as accidental damage to sealing will not then lead to inevitable failure.

The achievement of reliability of deployable antennas is a subject which has received insufficient study. Operational failure is seldom caused by the classical problems of electronic equipment and can usually be traced to:

a. Loss of components - perhaps after packing up quickly in darkness, or after dismantling the antenna on scrub-covered ground;

b. Breakage of components after assembly or stowage - this is frequently because personnel using the equipment do not understand how it operates.

c. Ingress of water into assemblies which are supposed to be properly sealed - this is then followed by electrical failure by tracking or carbonisation, or by corrosion. Once failure is detected it is usually final and cannot be reversed by drying out the affected components or assemblies;

d. Accidental damage - dropping, driving over the antenna.........

## 7. MATERIALS

The metals used for rapidly deployed antennas have shown little improvement over the past couple of decades; much more progress has been made in the replacement of metals by plastics or composites which offer better mechanical performance with the added bonus of reduced weight, reduced corrosion and lower maintenance costs. A wide range of new materials is now available to the antenna designer; high strength polymers such as Kevlar, PES and PEEK have application both as bulk materials, as fibres for reinforcement, and as fibres for ropes. Glass/carbon composites (CFRP) provide much higher strength/weight ratios than the older composites which used glass alone.

Man-portable equipment can benefit from the use of high-strength composites for structural supports, antenna booms, whips and other rigid members. The application of CFRP to the design of telescopic masts is now greatly increasing the capabilities of equipment which can be used and deployed single-handed; its greatest benefit in this application is very high resistance to crippling, which results from its combination of high stiffness and large tensile strength. The large cost of the materials is offset by the reduced manpower needed for deployment and the increased speed and effectiveness of communications provided to small units. A typical composite mast 12m high weighs only 8kg and supports an 8kg antenna; this mast is erected single handed - even in a 30km/h wind - in less than 10 minutes.

## CONCLUSION

The availability of new materials has greatly increased the capabilities of lightweight antennas for field deployment with limited manpower. Advances have been made in materials for masts, ropes and antenna conductors. These advances make possible the design of a complete man-portable HF radio station which is capable of providing a wide variety of radiation characteristics, suitable for many roles.

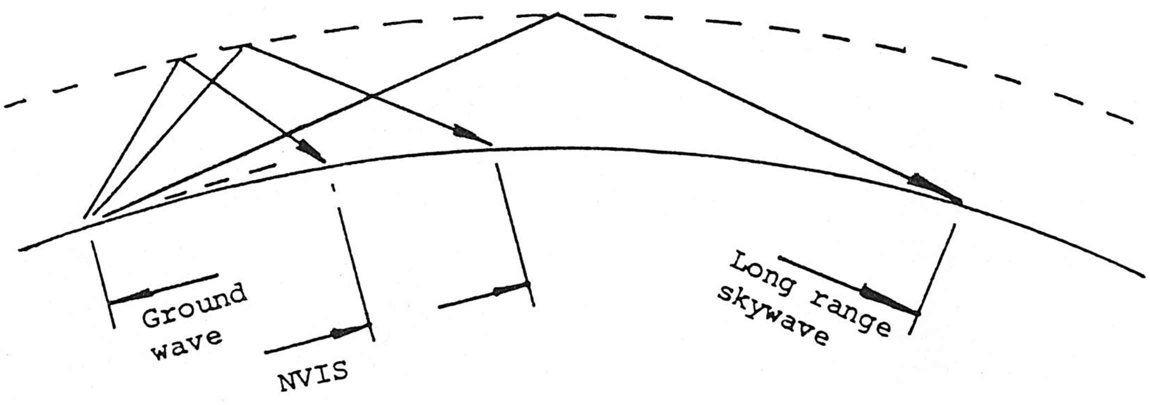


Figure 1 HF link ranges showing associated take-off angles

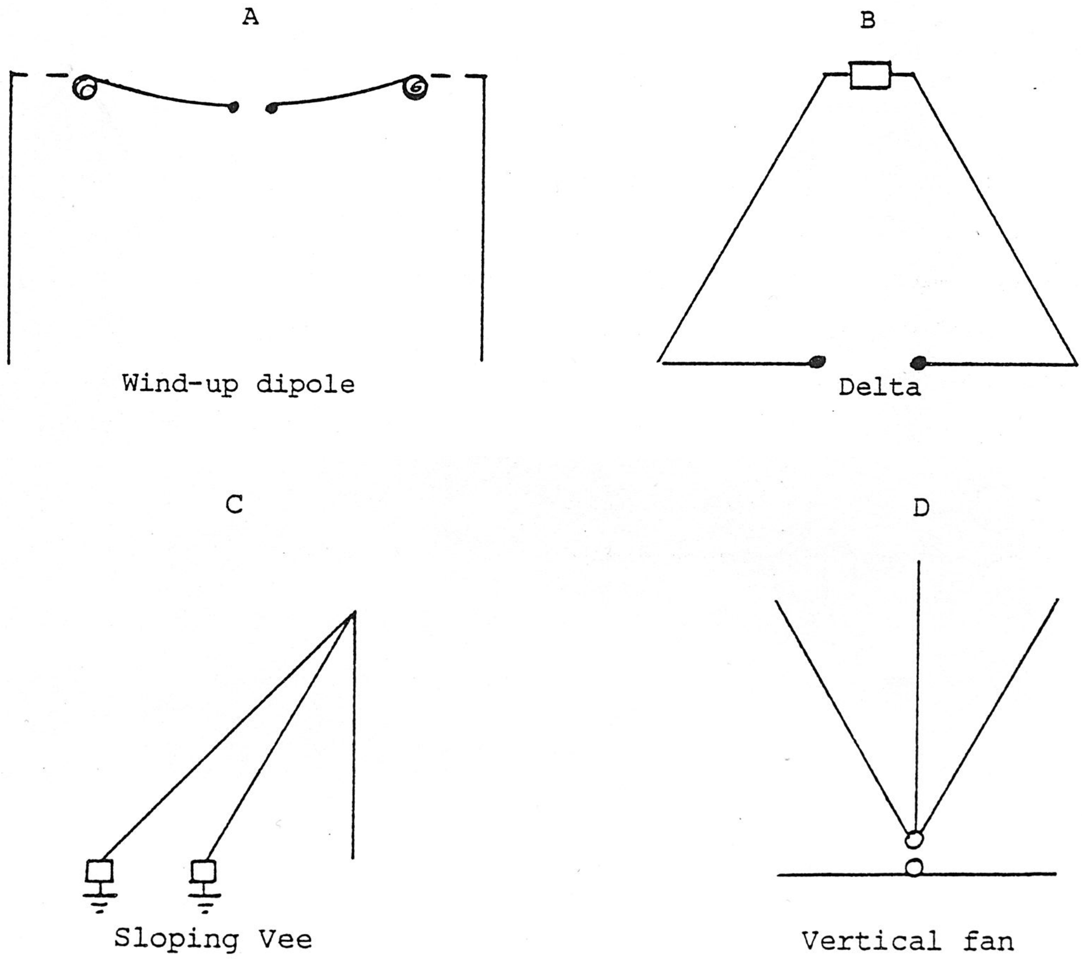


Figure 2 Typical Antenna Configurations