BROADBAND ANTENNAS FOR VHF/UHF RADIO RELAY SYSTEMS

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This paper describes the design, construction and performance of a family of antennas for military point-to-point links. The antennas are currently in service with the British Army as part of Triffid, the radio-relay element of the Ptarmigan communications system and have now been adopted for the US Army.

Introduction

Modern military field communications make use of networks of VHF and UHF links joining switching nodes. The system provides the full facilities of a direct-dial telephone/data network; it has the characteristic that as mobile nodes are added (or removed) from the system, the network reconfigures to optimise the routing of communications traffic. The antennas described in this paper support the principal radio links between the system nodes.

The main design problems were presented by the large operating bandwidths required and the familiar military requirements for light, easily-handled equipment which will survive severe conditions of use. Operating frequency bands are indicated in Table 1 which sets out the most important design objectives.

The antennas are erected on pneumatically-operated telescopic masts mounted on the vehicles which carry the communications equipment. The mechanical design must have low mass and wind loading and must preferably result in minimum bending and twisting moments at the mast head. For camouflage purposes the antennas are often erected through foliage; they must not become entangled or bent. The antennas must not present a conspicuous plane area or outline.

Electrical Design

Band 1   The use of a corner reflector was discounted because of the large size and windloaded area of the reflector, and the difficulty of obtaining stable gain and VSWR over the operating band. The centre of gravity of the assembly cannot easily be kept close to the line of the supporting mast; this results in large bending moments at the mounting point.

A log periodic dipole design was seriously considered, but compact designs have widely different beamwidths in E and H planes.

A plane grid reflector supporting an array of two dipoles was examined. The use of full-wave dipoles with a suitably compensated feed configuration could provide suitable electrical character-isitics, but the projecting dipole ends and complexity of the transmission line feed system were undesirable.

The use of a skeleton slot radiating element supported in front of a plane reflector provided the advantage that only a single feed point is required for the entire structure. The configuration had previously been used for broadband television transmitting antennas and was known to provide significant advantages for military use:

> Stable radiation patterns, gain and input impedance over a wide band;
>
> Almost identical beamwidths in E and H planes; Low side and rear lobes;
>
> Compact mechanical configuration, with no cantilevered members or structural insulators.

The operation of the skeleton slot element may be understood by reference to Figure 1. This illustrates a transition between structures which produce very similar radiation pattern characteristics. The skeleton slot at (d) is the most compact structure and has a typical input impedance of 200 ohms.

A prototype was mocked-up in timber to examine the handling characteristics of the antenna. This led to the adoption of rectangular tube for the screen frame and slot. A split-tube balun provides a 4:1 impedance transformation and is entirely orthodox except for the position adopted for the input connector. This was chosen to avoid damage to the connector if the antenna is dropped on the ground or laid on its back in mud. This decision typifies the way in which designers of military equipment need to identify unconventional modifications which improve the handling characteristics of the product. The reflector was deliberately made exactly the same width as the slot so the antenna would stand stably on the ground.

<u>Bands 2 and 3</u> The first designs assessed for use on these bands were planar dipole and Chiriex-Mésny arrays mounted over mesh reflectors. At Band 3 the antenna has 8 or 16 element feed points and this implied the need for an extensive feed system constructed from coaxial line, stripline or similar fabricated line. Such arrangements were expensive and complex; they contribute substantially to weight and windloading.

The use of a front-fed reflector was examined as a way in which to reduce the complexity of the feed system. It was seen that real economies of weight and stowage space could be achieved if a single reflector could be

Band designation	1	2	3
Frequency band (MHz)	225 - 400	610 - 960	1350 - 1850
Gain (dBi)	>9	13.5 - 16	20 - 21
Sidelobes (rel. main beam)	-16	-9	-9
Front/back ratio (dB)	-14	-20	-20
Polarisation	Linear, horizontal or vertical		
VSWR (Maximum)	2	2	2

Table 1. Electrical design parameters.

used for both bands. A check of the reflector diameter required to produce the required gain at Band 3 (about 1 metre) is only about 2 wavelengths at the lower edge of Band 2 (610MHz). It was unclear whether an adequate feed could be designed to operate properly in such a small reflector; an elaborate feed might produce better reflector illumination at the expense of large blocking loss.

The use of a single log-periodic feed covering both bands was considered; it was discounted because of the comparatively large size of a twin-row LPDA capable of providing suitable illumination, and the compromise introduced by the instability of the position of the phase centre of an LPDA. It was observed that if the f/D ratio of the reflector were chosen suitably and the two bands regarded separately, the specification for the feed units (in terms of relative bandwidth, beamwidth and impedance bandwidth) looked very similar to the performance already achieved from the Band 1 antenna described above. It was already known that the phase centre of such a feed would be very stable (from the use of the skeleton slot/ reflector panel for TV broadcast arrays).

Trials were embarked on, using skeleton slot/reflector feeds fitted to a grid reflector 1050mm in diameter. Although the Band 3 feed was very successful, the input impedance of the Band 2 feed was unstable; it varied very rapidly with frequency and also with the exact position of the feed in the reflector. After experiments it was found that the use of a reflecting plate positioned in front of the reflector vertex could much reduce the impedance variation. The problem was caused by direct reflection of energy from the reflector back to the feed unit. The reflecting plate required is clearly a classical vertex plate in its function, but as it is so close to the feed (in its near field) the usual formulae for its size and position are inadequate and these parameters were determined by experiment.

The vertex plate for the Band 2 feed is attached to the stem of the feed, ensuring that it is removed with the feed and is always correctly located once the feed is fitted. Owing to the manner in which the input impedance of the skeleton slot is modified by the unusual environment in which it operates, an improvement in input VSWR was achieved by replacing the split-tube balun by a transmission line design executed in strip line.

Measured radiation patterns for Band 2 (figure 5) exhibit high first sidelobes, indicating the hole in aperture illumination caused by the central subreflector.

The design of the reflector was heavily influenced by the physical conditions in which the antenna was to be used. The use of an open mesh or grid reflector is an obvious way of reducing windloaded area. Examination of most perforated or expanded meshes show that only a very small reduction of true wind loaded area is achieved - small holes do not have much effect in this respect, and fail completely under icing conditions. An open grid was chosen, the rod spacing being sufficient to limit rearward leakage at 1.85GHz. Welded aluminium construction provides high strength with low weight. A deep reflector was chosen to reduce the mechanical exposure of the feed unit in the event that the antenna is knocked over onto its face. The unorthodox truncated shape was adopted to reduce the stowage space required for the reflector. The feed units are stored separately from the reflector and the chosen unit locked into place before deployment. Feed units are sealed and all internal voids filled with polyurethane foam to control water ingress even if the dealing is breached by physical damage.

All the antennas are required to operate using vertical or horizontal polarisation and locking mechanisms have been fitted to permit rotation of the antennas between positions which are fixed to ensure that the cross-polar discrimination specification is always met.

Testing

The antennas were subjected to severe environmental tests which included vibration, drop and bump tests as well as the more usual climatic and corrosion requirements. Electrical tests were orthodox. The main problem identified in production was the control of the foam injection technique for the Band 3 unit; this has been solved by careful specification of process and method.

Reliability

The prediction of the reliability of an essentially mechanical assembly such as an antenna presents major difficulties. The frequent specification of MIL-HDBK 217D or similar documents is of doubtful relevance, especially as failure is usually related to accidental damage (to transportable equipment) or corrosion. Large numbers of each antenna are in service with the British Army and a very low level of failures is evident, representing an MTBF of at least one million hours.

Conclusion

The design of field equipment must not only provide the electrical performance required by the system designer, but must also have attributes of mechanics, reliability , ease of handling and simple repair. An optimum design requires a careful distinction to be made between the essential and inessential features of traditional designs.

Acknowledgements

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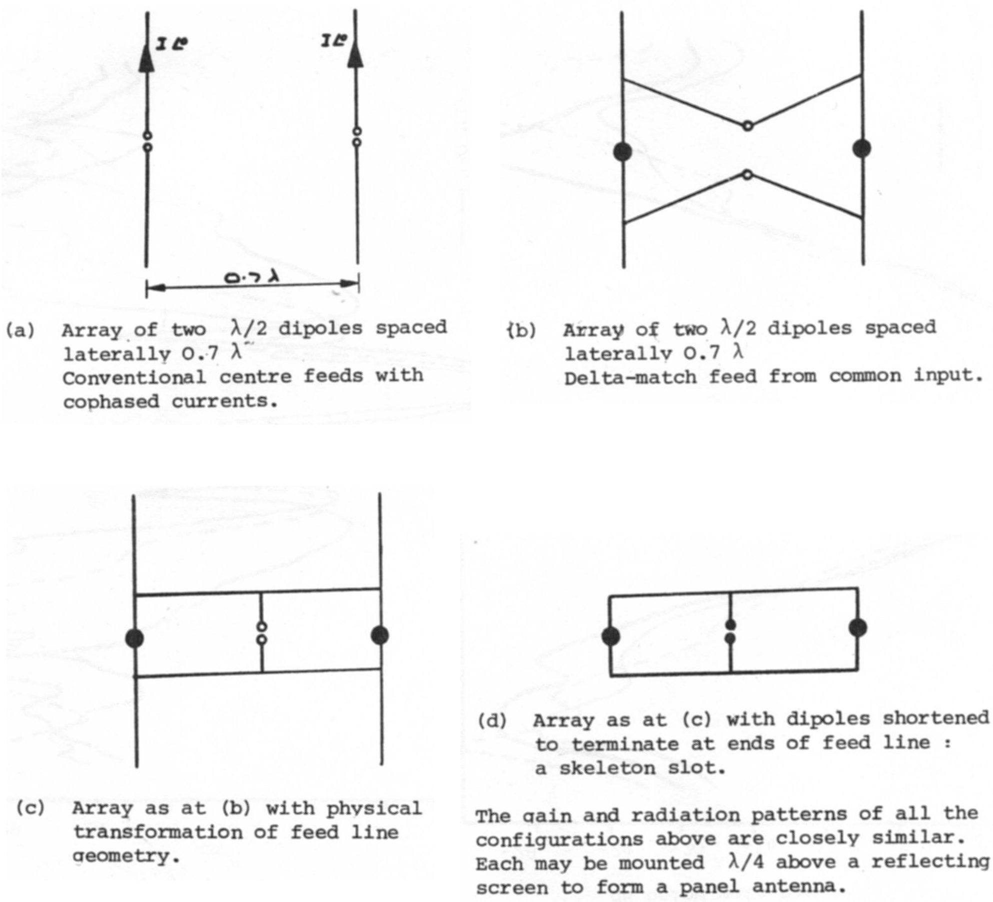

Figure 1: Derivation of Skeleton Slot

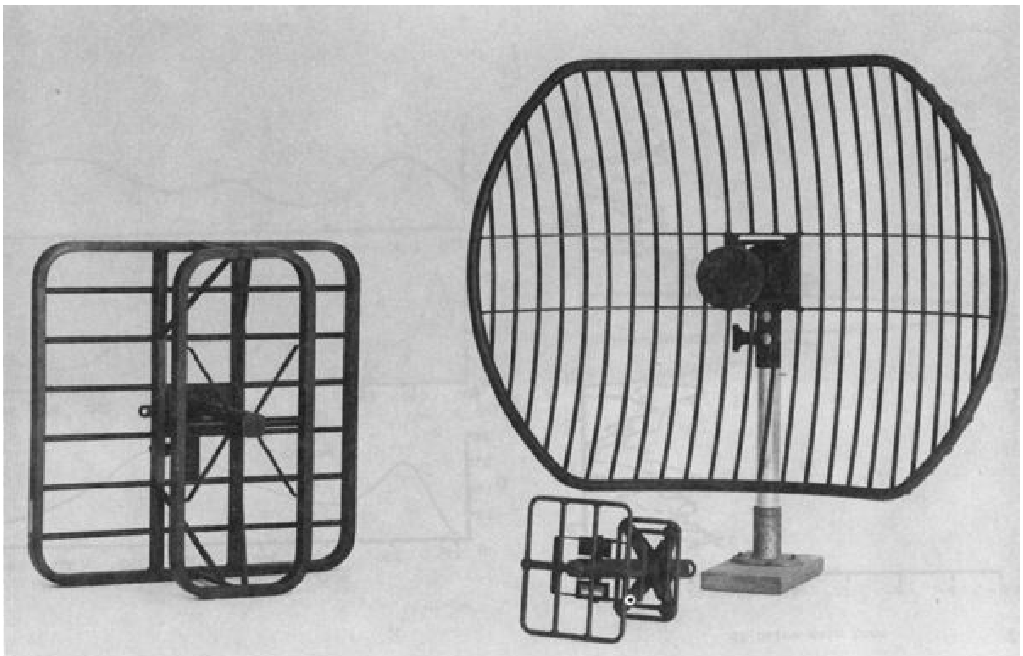

FIG. 2 Band 1 Antenna

FIG. 3 Band 2 and 3 Antennas

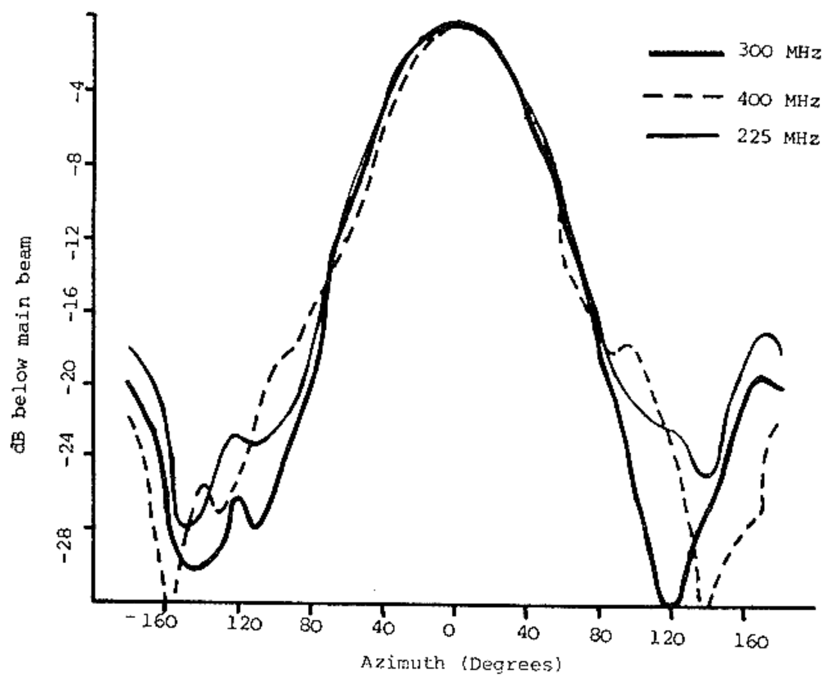

Figure 4: Radiation patterns, Band 1

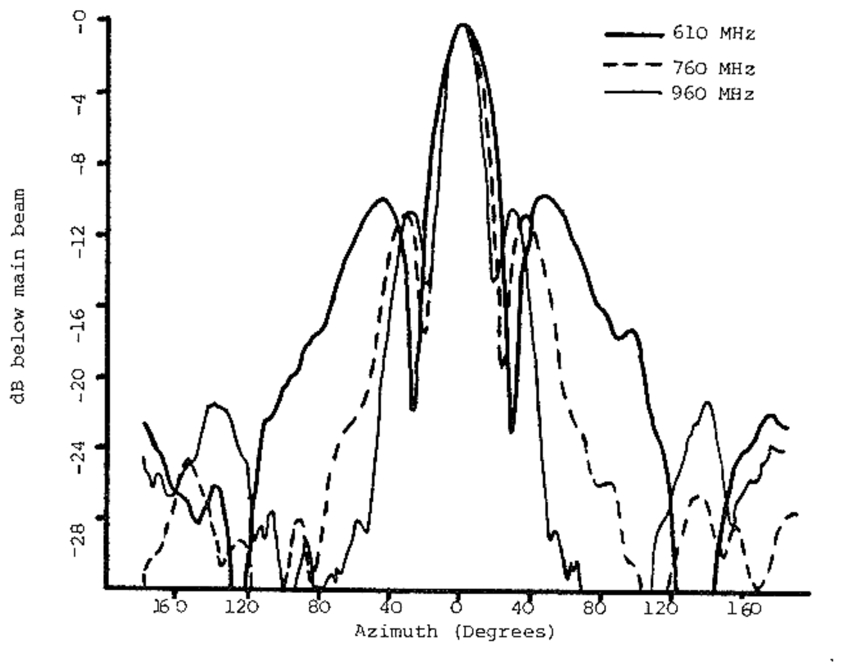

Figure 5: Radiation patterns, Band 2

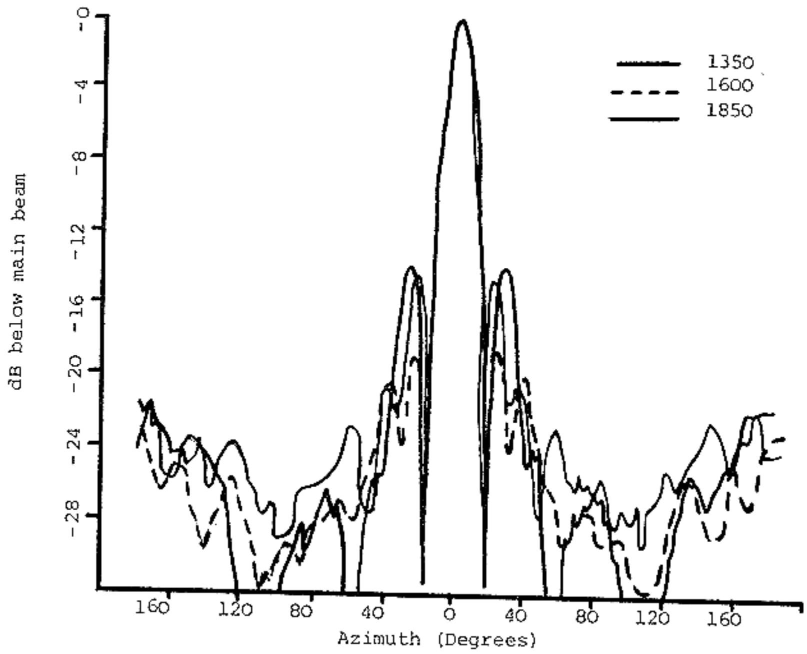

Figure 6: Radiation patterns, Band 3

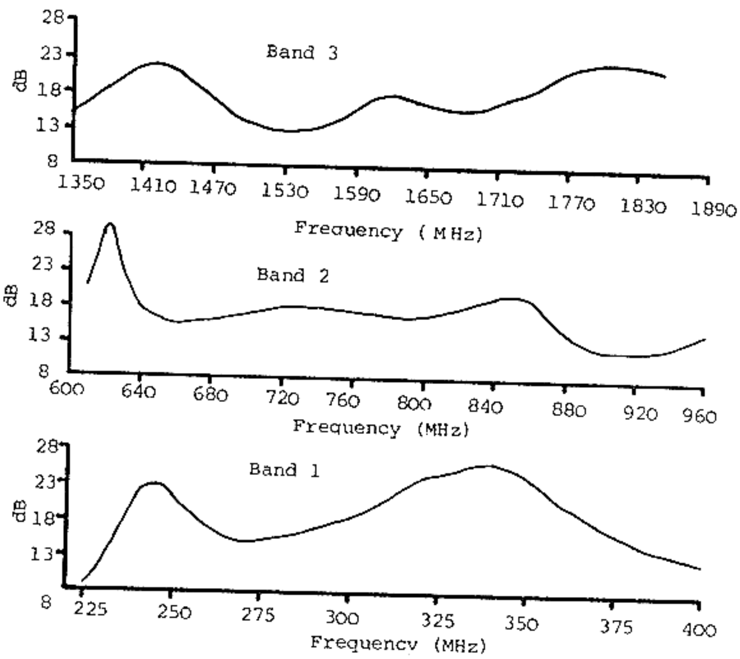

Figure 7: Return loss on each operating frequency band