Pat Hawker's

Technical Topics

THE FOLDED-TEE ANTENNA

IN *TT*, JULY 1987 and again in August 1991, some details were given of the investigation by Arch Doty, K8CFU, of the advantages of the quarter-wave folded monopole antenna, including the possibility of feeding such antennas directly from 50Ω coaxial cable feeders (or 75Ω cable with different diameter conductors) and the reduction of ground losses brought about by the higher feedpoint impedance. But, as noted then, a 1.8MHz monopole requires a height of some 115ft (35m) - a height not really feasible for the vast majority of amateurs. Even for 3.5MHz a quarter-wave monopole needs a height of some 66ft (20m) or so.

Anthony Preedy, A45ZZ/G3LNP, a professional broadcast-antenna engineer writing from the Sultanate of Oman, has come up with an effective way of reducing the height of folded monopoles with an original design - the 'folded-Tee antenna'. This design was first proposed for use in Saudi Arabia to enable MF transmitters to be tuned rapidly to various frequencies but would seem to offer significant advantages for amateur operation on 1.8MHz and the lower HF bands. Tony Preedy writes:

"DX operation on the lower bands usually calls for a vertical antenna. The height of a self-resonant quarter-wave or half-wave antenna for 1.8MHz is generally beyond the facilities available to most amateurs.

"An 'L' or 'T' configuration is the usual solution to this problem. The 'T' is preferred because, otherwise wasteful high angle (horizontally-polarized) radiation is conserved by cancellation between each half of the horizontal section. But a single wire 'T' for 1.8MHz with a 'reasonable' height of, say, 15m will have a feed resistance of only about 10Ω and requires a matching network if coaxial feeder is to be used. A tuned network will considerably reduce the effective bandwidth of the antenna.

"**Fig 1** shows how a 'folded-Tee' antenna can be derived from the quarter-wave folded monopole as described in the standard handbooks or *TT*, July 1987. This is a special form of 'T' antenna developed for MF broadcasting, and largely retains the significant advantages of the folded monopole which are bandwidth, a static discharge path to earth and a moderate feed resistance.

"With similar diameter conductors, the feed resistance of the folded-Tee is four times that of a simple 'T' and varies as the square of the height as shown in **Fig 2**. A match to 50Ω coaxial feeder requires a height of approximately only one-tenth of a wavelength, although this is dependent to some extent on earth loss resistance. Earth resistance should be minimised for optimum efficiency as with any vertical antenna driven against ground.

"Adjustment is simple and this feature made the antenna attractive for MF broadcasting during the 1991 Middle East conflict. Determine the height which provides 50Ω feed resistance, then trim the top lengths symmetrically at the centre for resonance.

"Dimensions for a 1.85MHz antenna are shown in **Fig 3**. This requires supports a little over 15m high and should cover the whole band with low VSWR without the need for base matching networks. The dimensions can be scaled for other bands with final top lengths trimmed for minimum VSWR".

It is interesting to note that a folded-Tee antenna for 7MHz DX with support heights of one-tenth wavelength would have a height of only about 4 to 4.5m. It should prove effective in any location having reasonable earth conductivity, or alternatively could be used with elevated resonant radials or counterpoises.

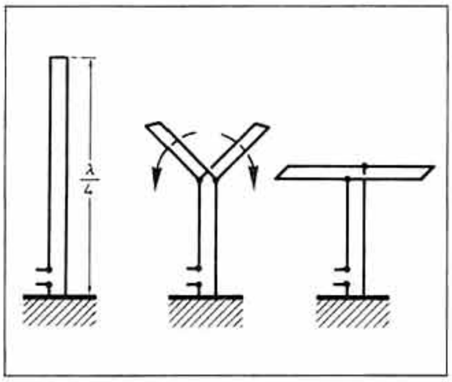

Fig 1: The deriviation of the G3LNP/A45ZZ folded vertical quarter-wave monopole antenna.

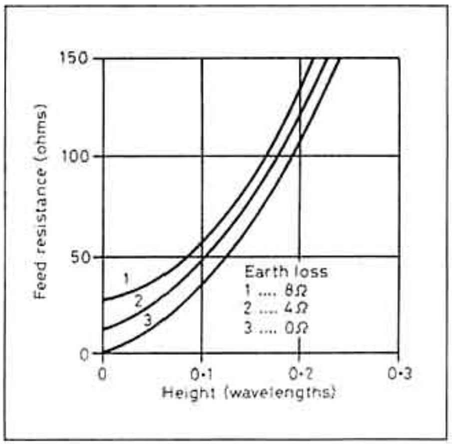

Fig 2: Resonant feed-point resistance versus height for the folded 'T' antenna.

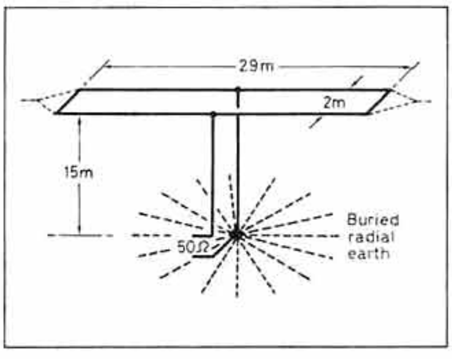

Fig 3: Dimensions for a 1.85MHz folded 'T' antenna. Dimensions can be scaled for higher-frequency bands.

EFFICIENCY OR EFFECTIVENESS?

SEVERAL COMMENTS HAVE been received concerning the criticisms levelled generally by Dr John Belrose, VE2CV, at the looseness of terminology found in amateur-radio publications with particular reference to the comments in *TT* (December 1991) on the G4HOL horizontal loop antenna.

Dr Brian Austin, G0GSF, felt that VE2CV was too severe in his criticisms of *TT* and of G4HOL's comments on the performance of his loop on 3.5MHz but also brings out the important difference between antenna 'efficiency' and antenna 'effectiveness'. He writes:

"G4HOL didn't say in *TT* that his new loop had 9dB more gain than his sloper but simply that it 'was consistently some 9dB better'. That surely is completely fair comment since that is what he observed on the signals and over the period of time concerned. At no stage was gain actually mentioned.

"I certainly agree with VE2CV when he says that there are probably more erroneous statements made and written about antennas than any other aspect of amateur radio but in my experience *TT* has not been guilty of many, if at all.

"One example of loose terminology which I see and hear often involves the concept of efficiency. Frequently one will hear amateurs comparing antennas on the basis of their 'efficiency' when, in fact, they don't mean efficiency at all. If they had said 'effectiveness', I would have been entirely satisfied since effectiveness can be a subjective assessment of an antenna's performance. It is not a characteristic that is defined mathematically, unlike 'efficiency' which is. AJ Henk, G4XVF, in his articles about electrically small loops (*RadCom*, Sept/Oct 1991) made the distinction between efficiency and effectiveness very clearly, but maybe it needs restating in completely general terms lest anyone thinks that only such small antennas can be inefficient.

"Mathematically the gain, G, of an antenna and its directivity, D, are related by the radiation efficiency or just the efficiency, e, thus G = eD. As in all cases where efficiency is involved in engineering we mean the ratio of output power to input power, usually expressed as a percentage. Since the output power from an antenna is a measure of how well it radiates, we would expect the radiation efficiency to involve the radiation resistance R_{rad}, and the overall loss resistance, R_{loss}, of the antenna. Hence:

$$e = R_{rad}/(R_{rad} + R_{loss}) \times 100 \text{ per cent}$$

"For most antennas that amateurs use in a fixed installation, the radiation efficiency will be very close to 100%, in which case gain and directivity can be used interchangeably. However, mobile whips with sizeable loading coils and any other antenna containing significant amounts of lumped loading may well be rather inefficient: the so called Australian Dipole and the T2FD which have become popular again because of their broadband performance by trading efficiency for bandwidth. In both cases their radiation efficiencies, which vary with frequency, are typically less than 50 per cent and considerably less than that at the low end of the HF band".

If I have understood G0GSF correctly (and to save protests from users of Australian dipoles and T2FD antennas which use resistive loading) he is emphasising that antennas which have only low or moderate efficiency can yet prove quite effective in certain applications. For example, the small loop in those situations where an antenna of dimensions comparable to half-wavelength is impracticable; or the Australian dipole where multiband operation matching adjustments are more important than radiating every watt of transmitter output - 50 per cent efficiency, after all, represents a drop of only 3dB, or less than one S-point. After all, it is only the power radiated towards the target area, at the right elevation angle for the propagation conditions at that moment, which governs the signal strength.

ANTENNA MODELLING WITH ELNEC AND MN-PRO

DR BRIAN AUSTIN, G0GSF, as we have noted in *TT* over the years, was one of the early users of computer-modelling of antennas based on the Methods of Moments including pioneering work in validating derivatives of the original Numerical Electromagnetic Code (NEC) software programs.

His studies have recently been expanded to include two MININEC programs that have been written by radio-amateurs - ELNEC written by Roy Lewallen, W7EL, and MN written by Brian Beezley, K6STI. G0GSF writes:

"I've noticed in a number of *TT* items of late that the MININEC-derivative programs, such as ELNEC and MN, are becoming increasingly popular. As you will remember I've long been a user of MININEC from its very first version, which was written for the Apple computer in the early 'eighties, through each development since, including THE MININEC SYSTEM and MININEC from the original developers of the code. Within the past few months I've been able to use both ELNEC and MN-PRO. Without a doubt these two very similar 'amateur' programs, leave the 'professional' codes in the shade as far as 'user-friendliness' is concerned. In fact, once one has experienced the ease with which a virtually unlimited range of wire-type antennas can be analyzed using them, I see no need to go back to the 'professional'; PC-based programs.

"Both benefit enormously from having very useful graphics capabilities 'built-in'. Whereas THE MININEC SYSTEM does too, it is a tedious business to use it and even then the graphics available are somewhat limited. ELNEC and MN-PRO have graphics which form an inherent part of the programs and which are very easy to access by just a couple of keystrokes.

"Anyone who has used the earlier PC Moment Method codes to analyze antennas will no doubt have encountered the problem of inaccuracy when modelling any antenna containing wires which join at an acute angle, such as the inverted vee. It was realized quite some while ago, when many people were 'validating' these codes, that the accuracy could be greatly improved by tapering the segmentation scheme used on the wires, particularly in those regions where the current distribution was known to be critical. For those unfamiliar with what is meant by this it should be realised that the program works by treating a wire as consisting of a number of short elements, called segments, which are joined in series. If the length of these segments is progressively reduced along the wire then the segments are said to have been tapered. This process is quite tedious to do manually but is most necessary if an accurate value is required for the input impedance of an antenna.

"Both ELNEC and MN-PRO contain automatic tapering facilities, selectable by just one or two keystrokes, for performing this task. To show just how effective they are in computing the accurate impedance, see **Fig 4**. This shows the calculated input impedance of a halfwave inverted vee antenna, in free space, for various values of included angle. This theoretical curve is from "Analysis of the symmetric centre-fed V-dipole antenna by J E Jones (*IEEE Trans Antennas & Propagation, AP24*, May 1976, pp316-322).

"Also shown on the graph are the values for input impedance computed by NEC (the large main-frame moment method program) and by MININEC without tapered segments, and then after using the automatic tapering scheme mentioned above. It will be noticed that all the programs compute the resistive component accurately but that the untapered MININEC shows an increasing error in the reactive term as the included angle is decreased. Note that how both NEC and the tapered MININEC schemes produce excellent agreement with Jones' results.

"I've subjected these new codes to a fairly extensive set of my own validation tests and they've been shown to produce very good agreement with results from NEC, experimental data and the antenna 'literature'. Of course, any computer-based analytical technique is just as capable now, as they ever have been, of producing results which are clearly nonsense (ie GIGO - Garbage In = Garbage Out) if the user makes inappropriate or simply incorrect decisions when setting up the model. So, as previous *TT* warnings have made clear, a good understanding and 'physical feel' for how antennas behave is still necessary when using these new antenna codes".

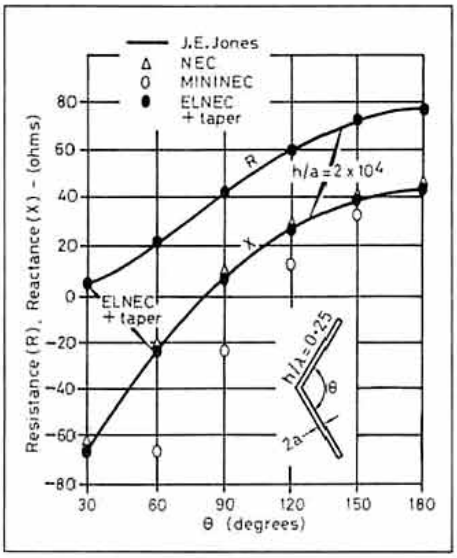

Fig 4: Calculated input impedance of a half-wave inverted-vee antenna showing the extremely close correspondence between the 1976 theoretical curve of J E Jones (*IEEE Trans A&P*) and computer-modelling using NEC and ELNEC + taper whereas the MININEC program shows significant divergence on the reactive component. Note that all three programs agree in the resistive component.

Al Christman, KB8I, is another amateur concerned with engineering education who has underlined the value of computer modelling of antennas using MININEC and ELNEC. In 'Phased Driven Arrays for the Low Bands' (*QST*, May 1992, pp49-52), he shows how arrays of driven monopoles and also inverted-vee arrays offer great promise for directive low-band arrays when the various elements are fed at the correct amplitude and phase. This is an approach long used for directional broadcast MF arrays but in the past usually considered difficult for amateur designers. He presents ELNEC-computed horizontal and vertical radiation patterns over real earth for four-square, three-in-line and cross vertical arrays, and the three-in-line inverted-vee array: **Fig 5**. He provides references to the literature on the design of suitable phasing networks while expressing the hope that some enterprising amateur will manufacture and sell a phasing box making it easier to experiment with multi-element driven arrays.

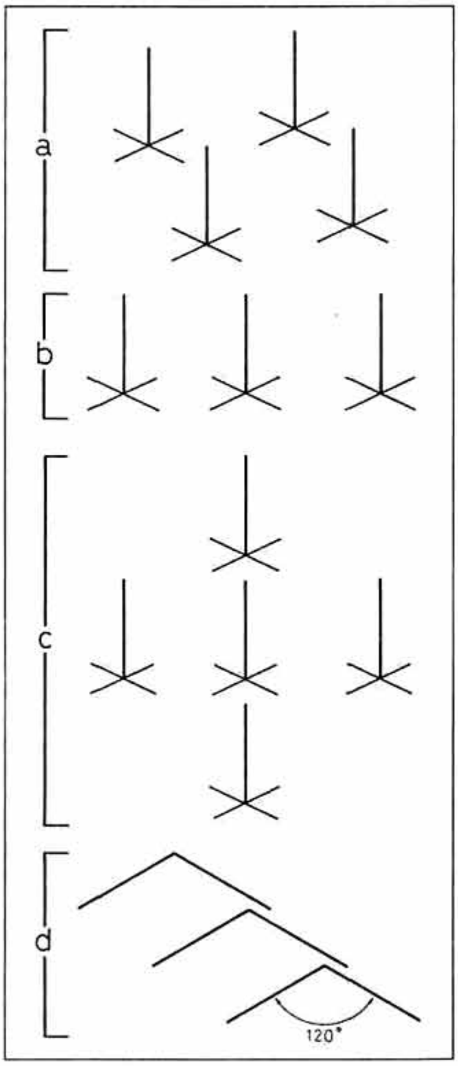

Fig 5: Four types of directive arrays subjected to computer-modelling by KB8I in the May *QST*. (a) Four-square array of monopoles. (b) Three-in-line array. (c) Cross (five-square) array. (d) Three-in-line inverted-V array.