RADCOM TECHNICAL FEATURE

The Extended Double Zepp Improved

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THE EXTENDED DOUBLE ZEPP (XDZ) has been a popular amateur antenna since the early days of shortwave radio. It can be used from HF well into the UHF range, where it is especially attractive because shorter wavelength offsets the XDZ's increased physical length. The XDZ provides exceptional gain for a simple antenna, but its impedance properties can create matching problems [1]. This article describes a simple technique for controlling and improving the XDZ's impedance performance.

XDZ geometry is shown in **Fig 1**. The antenna consists of two collinear, end-fed, electrically long radiating elements ('Zepp' elements). The element spacing at the feed is S, the diameter D, and the overall physical antenna length is L. If the length-to-diameter ratio is large (L/D >> 1), the antenna is 'thin'; otherwise it is 'fat'. The electrical length of the original Zepp element is half-wave, but an XDZ element is somewhat longer, approximately 0.64 wave. When the spacing S is small (S/L << 1), the XDZ is essentially a long centre-fed dipole, and its performance is accurately analysed using a dipole model. It is assumed that S/L << 1.

The reason for the XDZ's popularity is apparent from an examination of **Fig 2**, which plots the directivity of a free-space centre-fed dipole vs end-to-end electrical length.

The widely used thin λ/2 provides 2.15 dBi gain (dB relative to an isotropic radiator) with a well-behaved input impedance of approximately 77+j44Ω. But longer dipoles provide much better performance. As the length increases, the directivity also increases, reaching a maximum of nearly 5.2dBi at a length of 1.27 waves. this electrical length is optimum for the XDZ. More than 3dB gain over a λ/2 dipole is obtained by simply making the antenna longer.

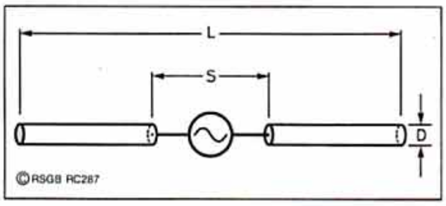

Fig 1: Extended double zepp geometry.

The pattern factor (normalised radiation pattern) for the 1.27-wave XDZ is shown in **Fig 3**. Three lobes appear because the antenna is electrically long. the main lobe, with a maximum gain of 5.2dBi, is oriented broadside to the antenna axis. Its –3dB beamwidth is 31.5°. The XDZ's two sidelobes are almost 10dB down, and, for practical purposes, can be ignored.

Note that Figs 2 and 3 are based on an ideal thin radiator (infinite L/D ratio) having a sinusoidal current distribution. This approximation provides accurate directive gain and the general pattern shape even for 'fat' radiators (small values of L/D). The major pattern effect for a fat element is that the nulls begin to 'wash out'. The sinusoidal current approximation, however, is not accurate for impedance calculations, especially for fat elements.

Considering only the data provided in Figs 2 and 3, the XDZ might seem to be the ideal antenna, one that provides excellent gain in a very simple, easy-to-build structure. Unfortunately however, the XDZ has a serious drawback. Because it is a full-wave antenna, its input impedance is high, possibly thousands of ohms, which can create matching problems.

For this reason an XDZ with a more moderate input impedance would be a better antenna. Fortunately, there is a simple solution to this problem, and it lies in choosing the optimum XDZ L/D ratio.

Figs 4 and **5** plot dipole input resistance and reactance vs electrical length. At its full-wave resonance (X = 0), a thin dipole (L/D = 5000) has a very high resistance (approximately 1,800Ω). In contrast, 'fatter' elements (smaller L/D ratios) exhibit more moderate impedance levels. By properly choosing L/D, the XDZ input impedance can be controlled while still achieving maximum directivity from its increased electrical length. The data in Figs 4 and 5 are based on a non-sinusoidal current distribution for improved accuracy at small L/D values.

The optimum L/D ratio for a 50Ω feed is 30.5, since this value results in a driving point impedance of 50-j123Ω for a 1.27 wave XDZ. These theoretical values provide a starting point for an improved XDZ design. The only matching required is an inductor to tune out the 123Ω capacitive reactance. At most frequencies, the matching inductance is small. At frequencies in the high VHF-UHF ranges, the feed system may well contain enough stray inductance to virtually eliminate the need for adding any.

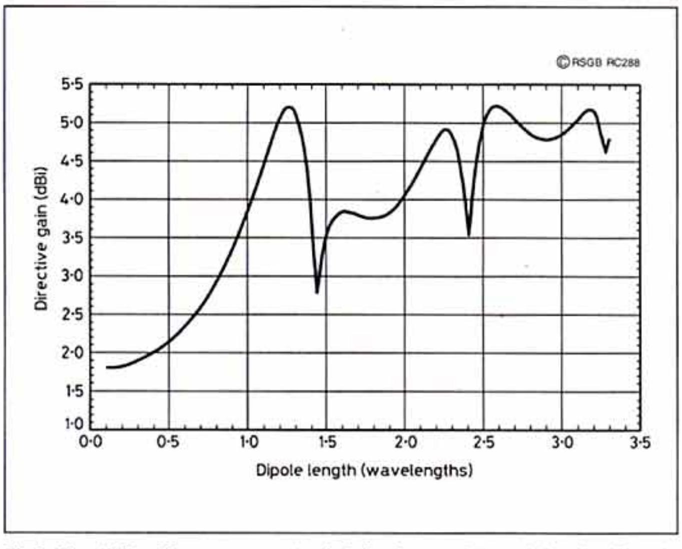

Fig 2: Directivity of free-space centre-fed dipole vs end-to-end electrical length.

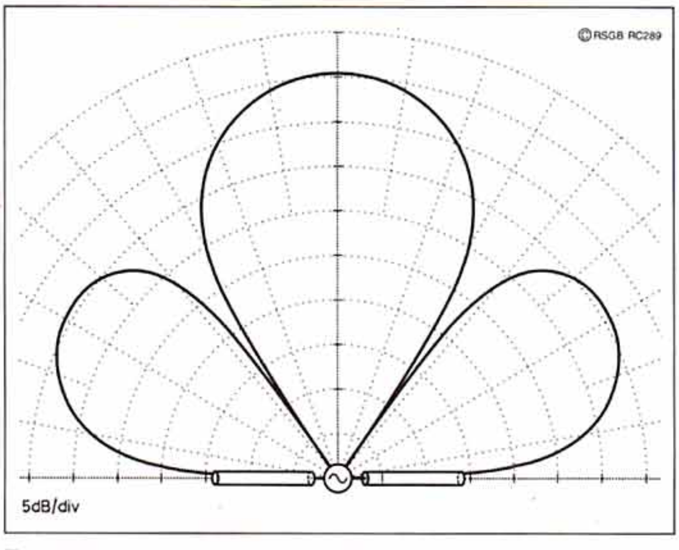

Fig 3: Pattern factor for a 1.27 wavelength double extended zepp.

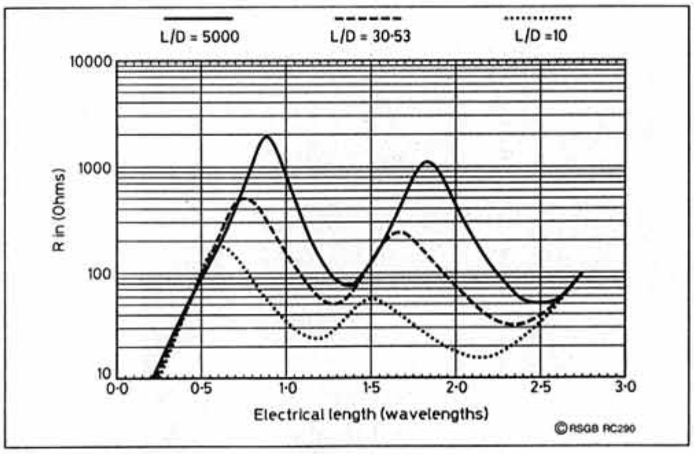

Fig 4: Double extended zepp; resistance vs electrical length.

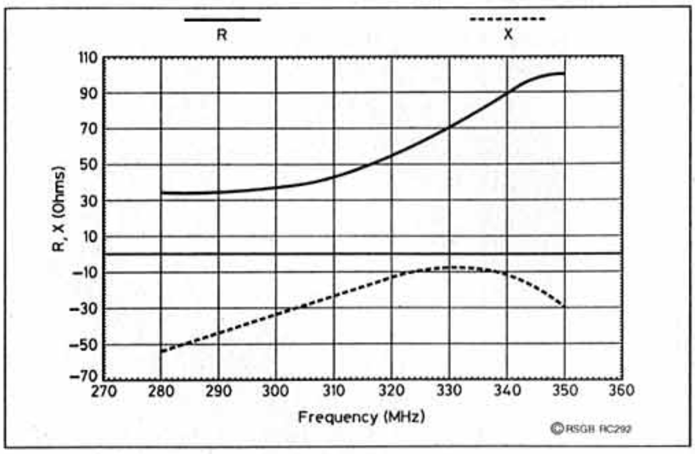

Fig 5: Double extended zepp; reactance vs electrical length.

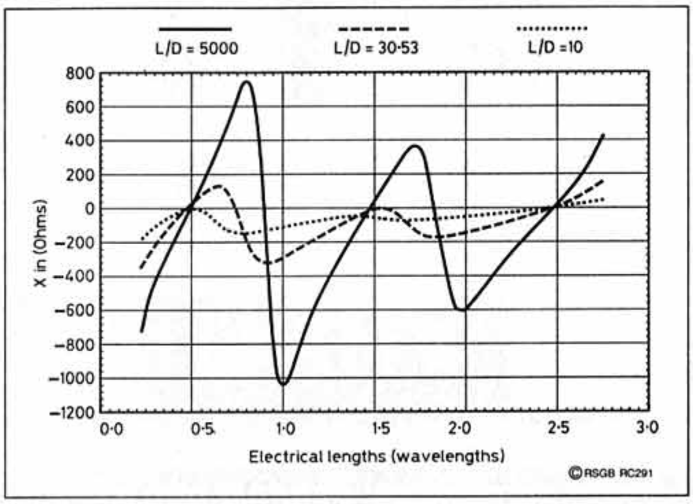

Fig 6: Measured values of Rad X of an XDZ antenna between 280 and 350MHz.

TEST ANTENNA

A SIMPLE 'PLUMBER'S delight' dipole was built and measured as a crude validation of this technique. Even though no effort was made to perform a controlled experiment, the data clearly illustrates the viability of this approach.

The test antenna consisted of two $24^{3}/_{4}$in. x $1^{5}/_{8}$in. OD copper tubes separated 1in. at the feed point. These radiating elements were strapped to a 12in. x 1in. x$^{3}/_{8}$in. plexiglass support using four nylon cable ties on each element. A female type N chassis connector was soldered to the elements using straight 14 SWG solid copper wire pigtails (no balun was used, although normally one would be).

The antenna was mounted vertically in a 10in diameter pine tree about 16in from the trunk. The feed point was approximately 8ft above the ground. The RG-8 coax feed cable was tied horizontally along a branch for a distance of about 4ft from the antenna feed, then dropped to the ground.

Measured values of R and X appear in **Fig 6**. The test XDZ was approximately 1.27 waves long at 300MHz, where the input impedance was 36.7-j35Ω. Without matching, the corresponding VSWR is 2.34:1 (0.76dB mismatch loss). By adding inductance to tune out the −35Ω reactance, the VSWR could be reduced to 1.36:1 (0.1dB loss). Without matching, the minimum measured VSWR was 1.3:1 (0.07dB loss) at 322MHz (input impedance 56.3-j12.4Ω). These moderate values of R and X show how effective L/D can be in controlling XDZ input impedance.

The bandwidth of a 'fat' XDZ is also surprisingly good because the input impedance varies gradually with frequency. VSWRs of less than 2.5:1 are achievable over more than 10% of the design frequency, which is enough bandwidth to cover most amateur bands using one antenna without matching. The XDZ's directivity, however, falls off quickly on either side of the frequency at which the antenna is 1.27 waves long. Nevertheless the gain is still better than that of a λ/2 dipole.

DESIGN APPROACH

DESIGNING AN OPTIMUM XDZ thus consists of three steps:

(1) Choosing the electrical length to provide the desired gain.

(2) Choosing L/D ratio to achieve the desired input antenna resistance.

(3) Adding components at the feed to tune out any reactance at the design frequency, [see Note].

The graphs shown will provide a starting point for these design steps, but design details will vary depending on the specific antenna. For example, resistance and reactance introduced at the feed point will modify the XDZ input impedance. Such effects are difficult, if not impossible, to predict in advance because they depend on exactly how the feed is built. As with any antenna design, some 'tuning' will be necessary after the basic system is fabricated.

XDZ implementations using solid copper or aluminium tubing are feasible at VHF/UHF. But at HF the element diameter needed to obtain the desired L/D ratio is too large for tubing. The 'cage' structures described in [1], Chapter 9, can be used instead of a large diameter conductor. As a general rule, the radiating element should consist of at least eight wires parallel to the element axis to adequately simulate a continuous conducting surface.

The technique of varying L/D to control antenna input impedance and impedance bandwidth is not restricted to the XDZ. Similar considerations apply to monopoles on ground planes, active and parasitic arrays of Zepp elements, and, in fact, any wire antenna structure. Input impedance and impedance bandwidth can be considerably modified by changing L/D. Of course, the optimum L/D ratio depends on the specific antenna geometry and the design objective; there is no universally 'best' value.

All this illustrates how useful the L/D ratio can be in designing wire antennas. It is hoped that this information will encourage experimentation with easily constructed antennas, in particular dipoles and monopoles. Simply changing the element diameter often produces a much better antenna!

NOTE

INDUCTANCE OR CAPACITANCE should be added symmetrically to the radiating elements. for example, if a total of 1μH is required, then 0.5μH should be added in series with each radiating element to maintain the XDZ's electrical balance as a symmetrical radiating system.

REFERENCE

[1] *The ARRL Antenna Book*. Available from RSGB sales.