CHARACTERISTIC-MODE ANALYSIS OF SYMMETRIC AND ASYMMETRIC LOG-PERIODIC DIPOLE ANTENNAS

Martin Hilbert and Keith G. Balmain
Department of Electrical Engineering
University of Toronto
Toronto, Canada M5S 1A4

Log-periodic dipole antennas that are not perfectly symmetric are known to exhibit strong side radiation and front lobe gain reduction in narrow frequency bands (1). As this is clearly a resonance phenomenon the method of characteristic modes was deemed an appropriate tool for analysis.

The method of characteristic modes provides a set of basis functions which may be summed to give the total current on a structure for a given excitation. The basis functions, or characteristic modes, J_n, are found by using a moment method program to obtain a mutual impedance matrix, $Z = R + jX$, and then solving

$$XJ_n = \lambda_n RJ_n \ .$$

The total current on the antenna is then given by

$$J_t = \sum_n \frac{V_n^i}{1+j\lambda_n} \frac{J_n}{J_n^T RJ_n} ,$$

where V_n^i is the modal excitation coefficient, which, for the case of an antenna being used as a radiator, is given by the product of the applied voltage and the mode current at the position of the voltage source (2).

The moment method program selected is due to Richmond (3) and uses Galerkin's method and piecewise sinusoids. The program was modified (4) to eliminate the "computer generated asymmetry" reported by Vainberg and Balmain (5), which was traced to the neglect of point charge terms in the monopole-to-monopole impedance calculations. Those point charge terms were added which were sufficient to restore symmetry and the new program was thoroughly tested on simple structures. The generalized eigenvalue problem was solved using an IMSL package (6).

The antenna under study was a standard 9 element log-periodic dipole array with $\tau=0.89$, $\sigma=0.15$, feeder $Z_0=135\Omega$, wire radius = 1 mm and wire conductivity = 10 MS/m. The design frequency range was 600 to 850 MHz. Two versions of Richmond's program, the original and the version incorporating the modifications, and three different segmentation schemes produced characteristic modes that were nearly identical. Furthermore there was excellent agreement between results calculated using characteristic mode theory and using matrix inversion.

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The characteristic modes were numbered according to the absolute value of λ_n from smallest to largest. In most cases only the first 10 of the full 110 were closely analyzed as they contribute most of the total current. On a perfectly symmetric structure it was found that there are two types of modes, namely resonant asymmetric modes and radiating symmetric modes [Figs.1 & 2]. Among the radiating modes the two dominant ones supply 70% or more of the total power. The resonant modes are of two types. One has a maximum of current on the feeder between the dipoles carrying the highest currents; the other, a minimum of current in the same region. The eigenvalue of the latter mode is always positive and steady with frequency. The eigenvalue of the other mode changes from negative to positive just below resonance. Two such resonance frequencies exist in the design range, 667 MHz and 779 MHz. The resonant and radiating modes occupy the same elements on the antenna, thus complicating the suppression of the resonant modes.

At 810 MHz an increase in back lobe gain accompanied by a decrease in front lobe gain was encountered. One characteristic mode showed a half-wave resonant current distribution between the feeder termination and the element closest to a half-wavelength, as described by Bantin and Balmain (7).

Distortion of the antenna, by extension of the monopole denoted by a dot in Fig.1, by 12.4% and 5%, produced little effect at the first resonant frequency, 667 MHz, as the monopole carried little current at that frequency. Around the 779 MHz resonance the effect is dramatic. The longer extension changes the resonant frequency to 760 MHz; the shorter, to 771 MHz. The actual resonance currents are not restricted to one cell as originally postulated (1). The characteristic modes for the distorted structure show that the resonant modal current distributions are little changed by the alterations while the radiating modal current distributions are altered almost beyond recognition.

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(2) R.F. Harrington and J.R. Mautz, "Theory and Computation of Characteristic Modes for Conducting Bodies," Sci. Report No. 9, Contract No.F19628-68-C-0180, AFCRL-70-0657, December 1970.
(3) J.H. Richmond, "Computer Program for Thin Wire Structures in a Homogeneous Conducting Medium," NASA Contractor Report CR-2399, June 1974.
(4) M.A. Tilston, personal communication.
(5) M. Vainberg and K.G. Balmain, "On Prediction of the Asymmetry Resonance Phenomenon of Log-Periodic Dipole Antennas," Can. Elec. Eng. Journal, vol.6, No.3, 1981.
(6) Routine EIGZF, IMSL, 6th Floor, NBC Building, 7500 Bellaire Boulevard, Houston, Texas 77036-5085.
(7) C.C. Bantin and K.G. Balmain, "Study of Compressed Log-Periodic Antennas," IEEE Trans. Antennas Propagat., vol. AP-18, pp.195-203, Mar. 1970.

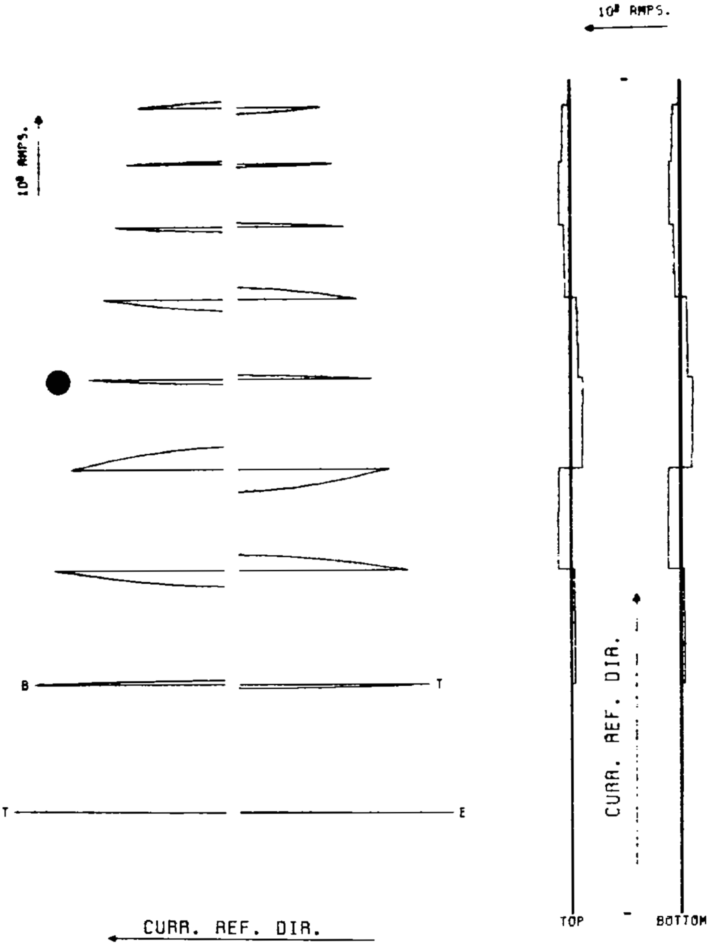

Fig.1. Dominant resonant asymmetric mode. Current amplitude is such that $J^TRJ = 1$. On a symmetric antenna this mode is not excited as there is zero current at the feed point. Dot denotes monopole extended in subsequent calculations.

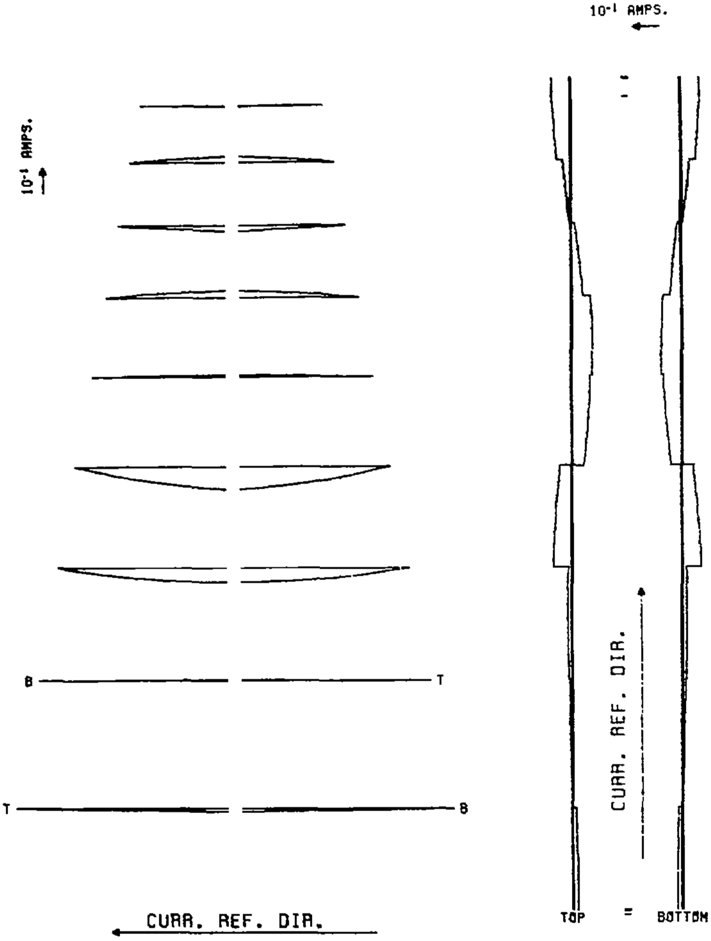

Fig.2. Dominant radiating symmetric mode