ASYMMETRY ANOMALIES OF LOG-PERIODIC ANTENNAS

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Log-periodic dipole antennas have been in use for almost twenty years, and their basic properties are well known [1]. A few years ago resonant back-lobe anomalies were observed [2,3], and found to be due to resonance in the transmission-line feeder between any reactive large-end termination and the stop-region existing in the vicinity of the half-wave dipole element. This paper is concerned with yet another type of resonant anomaly, one which requires for its existence some kind of structural asymmetry.

Consider first the following postulated form of resonance on a log-periodic dipole antenna. Begin with a simple two-wire transmission line "half-wave" resonator (resonant when slightly shorter than $\lambda/2$). Then twist it in the middle to generate one cell of a log-periodic antenna as shown in Fig. 1.

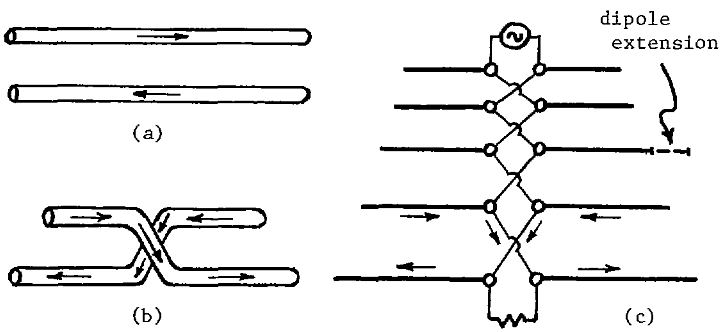

Fig. 1. Evolution of an asymmetric resonance from a simple resonator (a), to a twisted resonator (b), to one cell of a log-periodic antenna (c), with current directions shown by arrows.

If the current distribution remains essentially unchanged throughout this geometric distortion (and it might, in part because the distortion occurs near a voltage minimum), then the resonance could exist in the antenna structure itself. However on an ideal symmetric antenna such a resonance could not be excited by a generator connected at the antenna terminals. With such a generator, the excitation of the resonance would require the existence of asymmetry, provided for example by the dipole extension indicated in Fig. 1(c).

Extended-element asymmetry was studied experimentally using swept-frequency far-field measurement techniques, for which a few results are shown in Fig. 2. These are E-plane far-field magnitude measurements on one "front quadrant" of the radiation pattern (from boresight to 90° off boresight). The top line in each pattern is the boresight or front-lobe measurement, and the lines below are taken in 5° increments off boresight, with the lowest-level measurements giving side radiation at 90° off boresight. Three resonances are apparent, characterized by approximately log-periodic frequency variation, and by maximum radiation to the side of the antenna, as one would expect from the postulated current distributions of Fig. 1. The resonances do not occur above the frequency at which the extended element is about $\lambda/2$ in length.

Similar results were found for asymmetry due to bent elements, due to feed-point asymmetry, or due to random inaccuracy of construction. In fact, because construction inaccuracy and post-construction damage both tend to be asymmetric, both conditions can be diagnosed by measurement of the asymmetric resonances. Furthermore it is clearly possible to establish mechanical construction tolerances by relating them to tolerable limits on resonant side radiation. For the antenna of Fig. 2, element length tolerances of the order of ±1% would be adequate for many purposes.

The asymmetric resonances can be detected for a perfectly symmetric antenna whenever there is an appropriate relationship between the incident and detected fields, as for example when the structure is used not as an antenna but rather as a scatterer. A wave incident from the side of the antenna and polarized parallel to the boom would excite the resonances, which in turn could be detected using any other antenna positioned to pick up re-radiation from the boom. This procedure was used to study the resonant frequencies for both single cells and whole antennas, with the conclusion that the single-cell frequencies were little changed by assembling several cells to form a complete antenna.

Another important example is that of two perfectly symmetric log-periodic antennas connected in phase and arranged to form a common-apex E-plane array. In such an array each individual antenna illuminates the other asymmetrically, generating the very strong anomalies of Fig. 3, at exactly the frequencies of the single-antenna asymmetric resonances. These anomalies appear to be the same as the gain-reduction anomalies observed by Elfving and Miller [4] and described by Kuo [5], for E-plane arrays.

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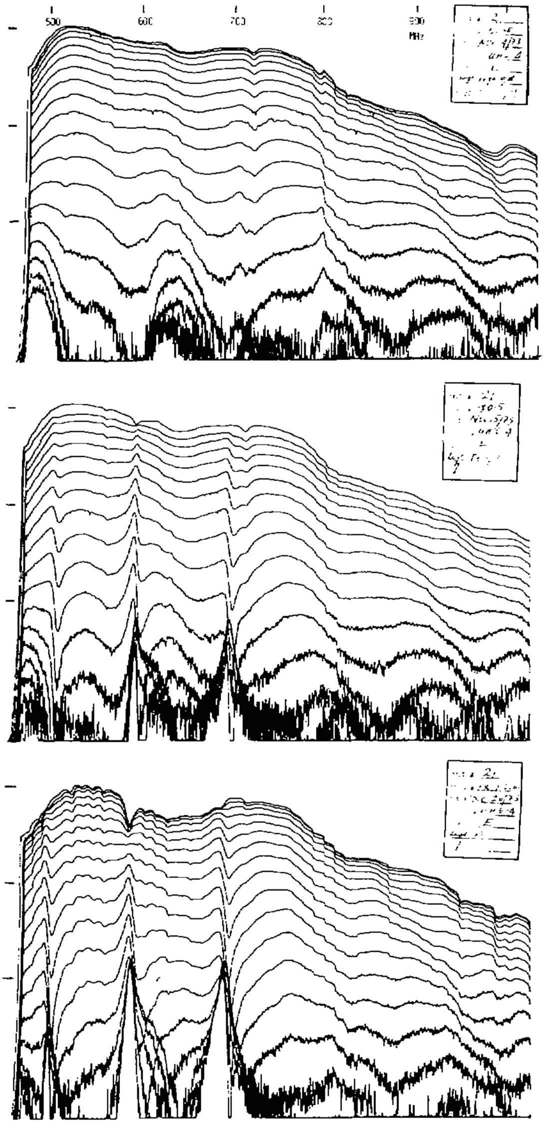
[1] E.C. Jordan, G.A. Deschamps, J.D. Dyson, P.E. Mayes; IEEE Spectrum, April 1964, p.58.

[2] C.C. Bantin, K.G. Balmain; IEEE Trans.A.P., Mar.1970, p.195.

[3] K.G. Balmain, C.C. Bantin, C.R. Oakes, L. David; IEEE Trans. A.P., Mar.1971, p.286.

[4] C. Elfving, S. Miller; Sylvania West Tech. Report ECOM-0503-P005-G815, Nov.1969.

[5] S.C. Kuo; 1970 G-AP Symposium Digest, p.151.



(a) zero extension

(b) 2.4% extension

(c) 4.7% extension

Fig. 2. Excitation of asymmetry anomalies by extension of one end of middle dipole in 7-dipole log-periodic antenna. Extensions are given as percentages of total dipole length. Indicated amplitude intervals are 10 dB. Parameters: τ=0.89, σ=0.15, longest dipole 27.3 cm.

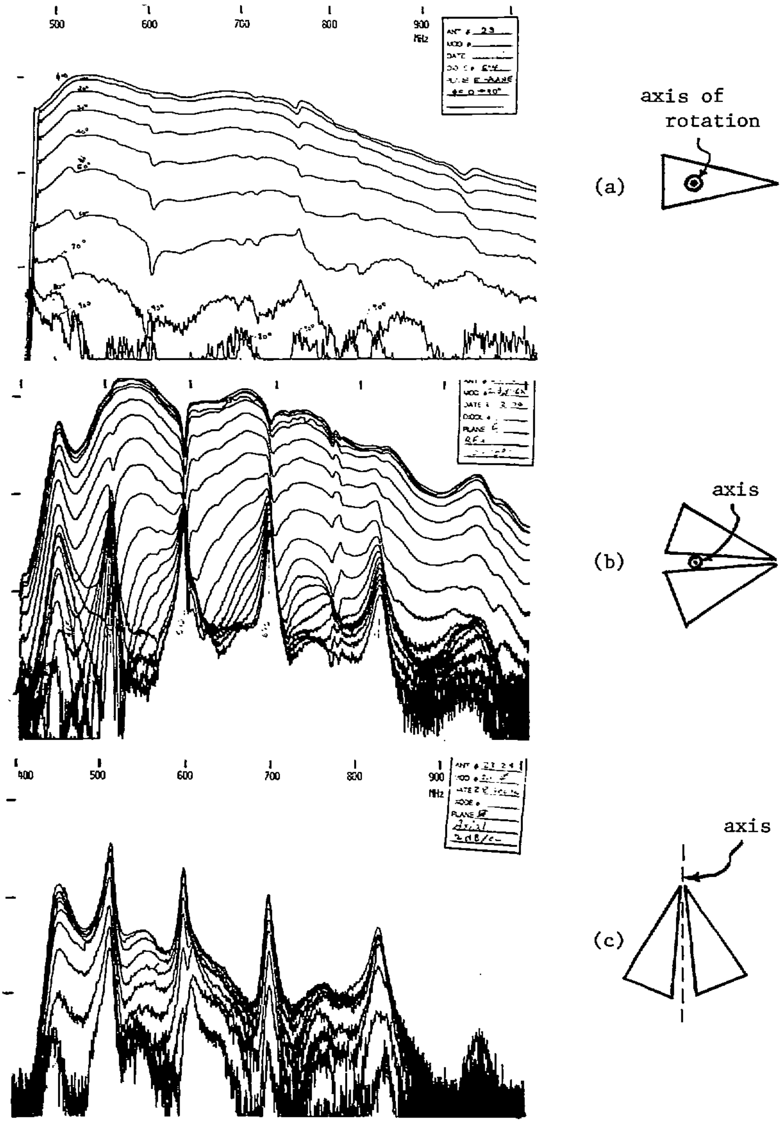


Fig. 3. E-plane array far-field anomalies: (a) single antenna, E-plane radiation showing very slight anomalies; (b) E-plane radiation from array; (c) side radiation from array. Indicated amplitude intervals are 10 dB. Parameters: same as for Fig. 2.