Optimization of Log-Periodic Dipole Antennas

Abstract—It is shown that a log-periodic dipole antenna can be optimized by varying the feed-line characteristic impedance while carrying out swept-frequency far-field measurements. The minimization of narrow-band anomalies in the measured quantities results in a well-defined optimum characteristic impedance.

Bentin and Balmain [1] have discussed reflection anomalies in log-periodic dipole antennas and the elimination of these anomalies by choosing a sufficiently high scale factor $r$ or by attaching a terminating resistance to the large end of the array. They did not consider the effects of varying the characteristic impedance $Z_0$ of the feed line, effects which turn out to be quite significant as shown hereafter. The experimental and theoretical details and the bibliography are the same as in [1].

Swept-frequency far-field measurements are easy to perform and very helpful in optimizing broad-band antennas. Such measurements were carried out on an antenna with a scale factor $r = 0.90$ and a spacing factor $\sigma = 0.10$. The structure bandwidth was 6:1 with the longest element a half-wavelength at 500 MHz and the shortest element a half-wavelength at 3000 MHz. Fig. 1(a) contains an excellent example of a reflection anomaly; the performance of the antenna is generally good except around 740 MHz where the back-lobe rises to within about 3 dB of the front lobe. There is a second anomaly around 920 MHz which deserves comment; they are essentially the variations between

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References

Fig. 2. Theoretical and experimental backlobe levels (relative to front lobe) in vicinity of an anomaly. Note that experimental peaks have all been shifted downward in frequency by 35 MHz for clearer comparison of levels.

Fig. 3. Theoretical input impedance loci for frequencies around an anomaly (same conditions as in Fig. 2).

Fig. 1. Experimental E-plane far-field measurements at various angles with respect to front lobe of radiation pattern, and for three values of feeder characteristic impedance $Z_o$.

same for all orientations and therefore are caused by the range antenna which had an upper frequency limit of about 900 MHz.

Theoretical far-field calculations for the low-frequency anomaly are shown in Fig. 2 for an antenna with $\tau = 0.892$ and $\sigma = 0.101$. As $Z_o$ increases, the relative backlobe level decreases until at approximately $Z_o = 170$ ohms the backlobe at the anomaly has been reduced to an acceptable level for many applications. The experimental values have essentially the same magnitudes as the theoretical values.

Theoretical input impedance calculations are shown in Fig. 3. As $Z_o$ increases, the spread of impedance points decreases in the vicinity of the anomaly, and as would be expected the impedance magnitude increases. In the vicinity of $Z_o = 170$ ohms, any further increase in $Z_o$ tends to make the input impedance appreciably more reactive. Therefore, considering both the impedance and the far field, it appears that the particular antenna under consideration has an optimum feeder $Z_o$ of approximately 170 ohms.

In conclusion, it is clear that the reduction of anomalies by swept-frequency techniques is a very useful way to optimize broadband antennas. Applied to log-periodic dipole antennas, this approach has shown that the feedline characteristic impedance has a marked influence on performance and cannot be varied at the will of the designer in order to set the input impedance to some desirable value. Of course this is true only insofar as the anomalies are undesirable for a particular application; if the anomalies occur at unimportant frequencies, then a considerable variation in $Z_o$ is possible. Furthermore, for $\tau > 0.90$ the anomalous backlobe levels are lower and thus the useful range of $Z_o$ is greater.

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Addendum to “Increased Capacitance for VLF Umbrella Antennas Using Multiple-Wire Rib Construction”

Abstract—A computed value of static capacitance for a 300-ft umbrella antenna with twelve 9-in diameter multiple-wire ribs is presented and compared with measured capacitances of both fractional- and full-scale models of this structure. In addition, the computed values of static capacitance of this umbrella antenna are presented for rib diameters of ½ to 48 in which indicate capacitance increases of approximately 50 percent.

INTRODUCTION

The static capacitance of an umbrella antenna which employs multiple-wire rib construction has recently been reported by Smith and Graf.1 This multiple-wire rib configuration was used to increase the effective rib surface and, thus, to obtain a larger total antenna capacitance with a negligible decrease in antenna effective height. The antenna capacitance of two umbrella antennas, which consist of 300-ft towers (3-ft triangular cross section) top-loaded with 12 ribs 300 ft in length sloping downward at a 45° angle from the vertical, was investigated by these authors through the use of 1) published computer analysis of umbrella antennas [1] and 2) experimental evaluation of fractional- and full-scale models of the structure. However, at that time computed capacitance data for umbrella antennas with the large effective rib diameter of the multiple-wire rib configuration were not available. This rib configuration consists of six ½-in diameter wires equally spaced about a 9-in diameter plastic spacer. The purpose of this communication is to present a computed value of the static capacitance of an idealized model of this umbrella antenna structure for further design considerations.

COMPUTED RESULTS

The static capacitance of an umbrella antenna has been computed using a digital computer program for the solution of the integral equation of the static potential of the antenna configuration for several ratios of rib radius to antenna height \( r_i/H \). This solution technique, which is related to the method of moments as formulated by Harrington [2], is described by Tanner and Andreasen [3], and it is the same approach employed by Gangi et al. [1] for computing the capacitance of similar antennas where \( r_i/H = 5 \times 10^{-5} \) and the ratio of tower radius to antenna height \( r_t/H = 10^{-5} \).

The value of the computed static antenna capacitance of the present investigation for a 9-in rib structure is presented with the tabular data of Smith and Graf as shown in Table I. This computation is based on the representation of each rib as a cylindrical surface where \( r_i/H = 10^{-5} \) according to Gangi et al. [2]. Thus the computed capacitance using this idealized surface should, in general, be larger than the measured full-scale capacitance of the multiple-wire structure due to the reduction in surface area. A comparison of the full-scale measured and calculated capacitance data of Table I for the 9-in diameter ribs indicates excellent agreement between computed and experimental results. In addition, it is significant to note that the 200:1 scale model capacitance measurements and the computed values only differ by approximately ten percent.

The total static capacitance of this antenna structure as a function of rib diameter for two different values of tower radius to height ratio is presented in Fig. 1. These data indicate that quite large increases in static antenna capacitance (50 percent based on an increase from ½- to 48-in diameter cable) can be obtained through the use of the multiple-wire rib configuration. Hence for practical design considerations the total antenna capacitance can be significantly increased through the use of large-diameter ribs consisting of a sufficient number of wires to approximate the idealized cylindrical surface.

### REFERENCES


### TABLE I

<table>
<thead>
<tr>
<th>Rib Type</th>
<th>Round Tower</th>
<th>Triangular Tower</th>
<th>Calculated Capacitance (pF)</th>
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</thead>
<tbody>
<tr>
<td>½-in diameter</td>
<td>4800</td>
<td>4800</td>
<td>4140 [2]</td>
</tr>
<tr>
<td>9-in diameter</td>
<td>5700</td>
<td>5740</td>
<td>5250</td>
</tr>
</tbody>
</table>

*\( r_i/H = 10^{-5} \)

*Computed value of this investigation.*

![Fig. 1. Static capacitance of 300-ft umbrella antenna as a function of rib diameter.](image-url)