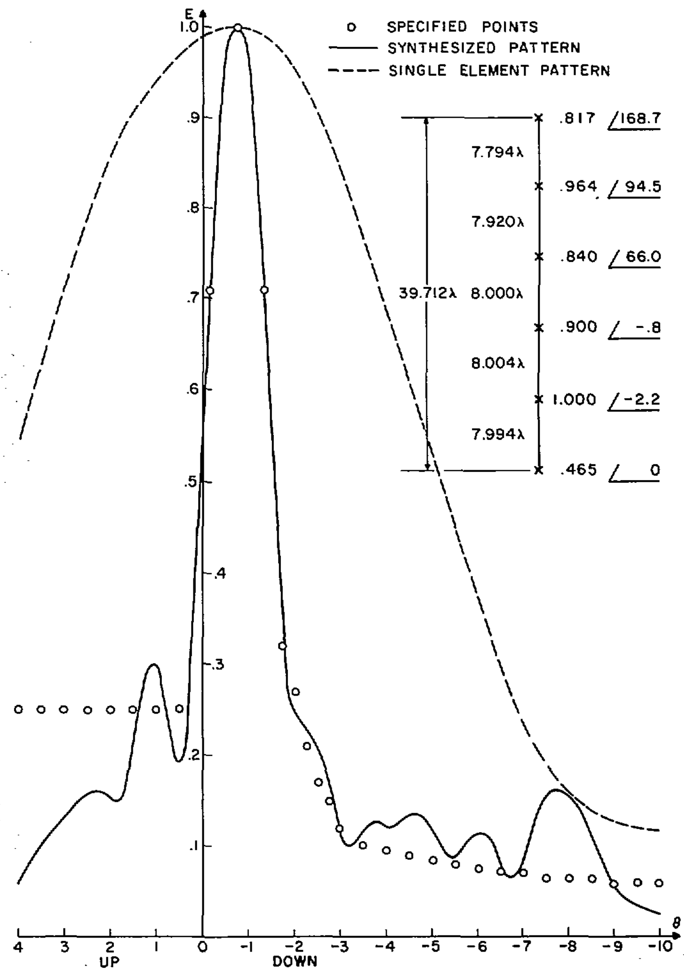

Fig. 3. Synthesis of six-element TV transmitting antenna pattern by unequally spaced array with $d > 7.5\lambda$, current amplitudes are allowed to change, and phases given by physical spacing along feeding line.

180 kW, a smoother fit can be obtained as shown in Fig. 3. In this case the power split between the upper and lower portion of the antenna is 47:53. It should be pointed out that the constraint that the power split be 50:50 in this case could also be very easily implemented.

The computer program used for this calculation was written for a time-sharing system since it readily allows interaction between the designer and the computer. The error, after each iteration or group of iterations, is printed out so that one can observe the progress in each step. The method can be automated for use with batch processing. There are many other numerical methods [4] which can be automated more easily. These methods, however, present some problems for the implementation of the variety of constraints that are desirable in antenna pattern synthesis. Work is progressing in this area and will be reported in the future.

An interesting possibility that this method presents is that of synthesizing a pattern over a certain frequency bandwidth. We have only to modify (1) to read

$$E = \sum_{J=1}^{L} \sum_{i=1}^{N} W(\theta_i)[P_s(\theta_i, f_j) - P_c(\theta_i, f_j)]^2$$

where the f_j, $j = 1,2,\cdots,L$, are L specified frequencies in the bandwidth of interest. This procedure will lead to that set of array parameters which is the least sensitive to frequency in the specified bandwidth.

A question that arises naturally when the steepest descent is used is how do we know that we have reached the bottom of the valley and not a local minima? This question is only relevant if an acceptable solution is not found. If we stop in a relative minima and the solution satisfies all the constraints, then we really do not care if that is not an absolute minima. In any event an investigation can be made to try to determine if we are in a local minima by starting the synthesis from different initial values. If in all cases the syntheses converge to the same solution, then we can be reasonably assured that an absolute minima has been reached.

In closing we would like to point out that no known synthesis method to the knowledge of the authors could have performed the synthesis of Figs. 2 and 3 with all the nonlinear constraints imposed.

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References

[1] V. Eveleigh, *Adaptive Control and Optimization Techniques*. New York: McGraw-Hill, 1967, ch. 5.
[2] R. Fletcher and C. M. Reeves, "Function minimization by conjugate gradients," *Comput. J.*, vol. 7, 1964, p. 149.
[3] J. J. D. Powell, "An efficient method for finding the minimum of a function of several variables without calculating derivatives," *Comput. J.*, vol. 7, 1964, p. 155.
[4] A. Leon, "A comparison among eight known optimizing procedures," in *Recent Advances in Optimization Techniques*, A. Lavi and T. P. Vogl, Eds. New York: Wiley, 1966, p. 23–44.
[5] L. B. Brown and B. A. Scharb, "Tschebyscheff antenna distribution, beamwidth, and gain tables," Clearinghouse for Federal Scientific and Technical Information, U. S. Dep. Commerce, PB 151002, 1958.

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 and impedance measurements. The minimization of narrow-band anomalies in the measured quantities results in a well-defined optimum characteristic impedance.**

Bantin 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 τ 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 $\tau = 0.90$ 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 backlobe rises to within about 3 dB of the front lobe. There is a second anomaly around 920 MHz where the back and front lobes are equal in magnitude. Fig. 1(b) and (c) shows that increasing the characteristic impedance of the feeder removes both anomalies and produces an antenna whose pattern is well-behaved over the entire frequency range of interest. In Fig. 1(c) the variations between 900 and 1000 MHz deserve comment; they are essentially the

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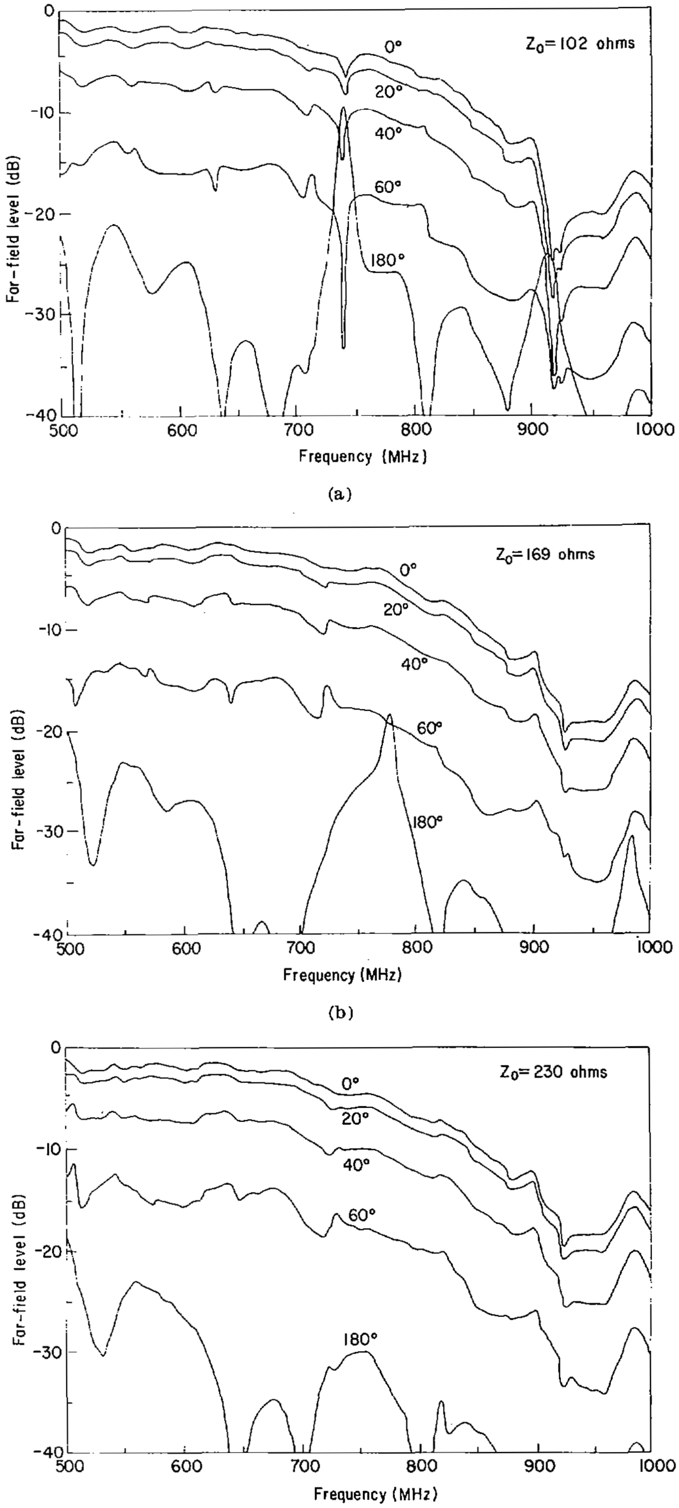

Fig. 1. Experimental E-plane far-field measurements at various angles with respect to front lobe of radiation pattern, and for three values of feeder characteristic impedance Z_0.

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_0 increases, the relative backlobe level decreases until at approximately $Z_0 = 170$ ohms the backlobe at the anomaly has been reduced to an acceptable level for many applications. The experi-

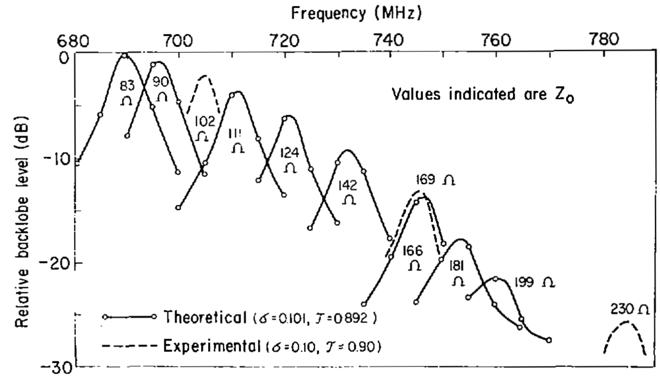

Fig. 2. Theoretical and experimental backlobe levels (relative to front lobe) in vicinity of an anomaly. Note that experimental peaks have all been shifted downward in frequency by 35 MHz for clearer comparison of levels.

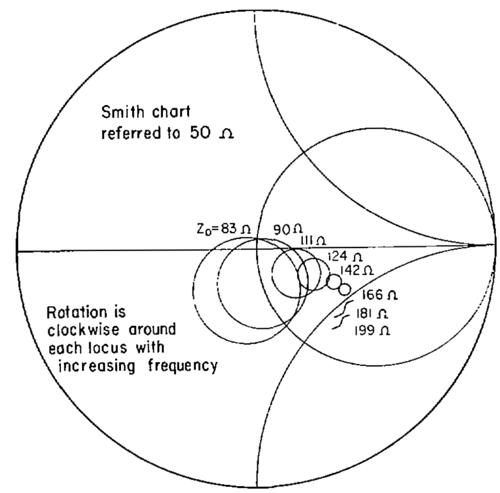

Fig. 3. Theoretical input impedance loci for frequencies around an anomaly (same conditions as in Fig. 2).

mental values have essentially the same magnitudes as the theoretical values.

Theoretical input impedance calculations are shown in Fig. 3. As Z_0 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 $Z_0 = 170$ ohms, any further increase in Z_0 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_0 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_0 is possible. Furthermore, for $\tau > 0.90$ the anomalous backlobe levels are lower and thus the useful range of Z_0 is greater.

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REFERENCES

[1] C. C. Bantin and K. G. Balmain, "Study of compressed log-periodic dipole antennas," *IEEE Trans. Antennas Propagat.*, vol. AP-18, Mar. 1970, pp. 195–203.

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 $\frac{1}{4}$ 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 $\frac{1}{4}$-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_2/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 $r_2/H = 5 \times 10^{-5}$ and the ratio of tower radius to antenna height r_1/H is 10^{-3}.

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[1] as shown in Table I. This computation is based on the representation of each rib as a cylindrical surface where $r_1/H = 10^{-3}$ 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.

TABLE I
STATIC CAPACITANCE FOR TWO 300-FT UMBRELLA ANTENNAS WITH TWO DIFFERENT RIB SIZES[a]

Rib Type	Scale Model Capacitance (pF): Round Tower	Scale Model Capacitance (pF): Triangular Tower	Calculated Capacitance (pF)	Actual Measured Static Capacitance (pF): 1	Actual Measured Static Capacitance (pF): 2
$\frac{1}{2}$-in diameter	4600	4800	4140 [2]	—	—
9-in diameter	5700	5740	5259[b]	5200	5160

[a] $r_1/H = 10^{-3}$.
[b] Computed value of this investigation.

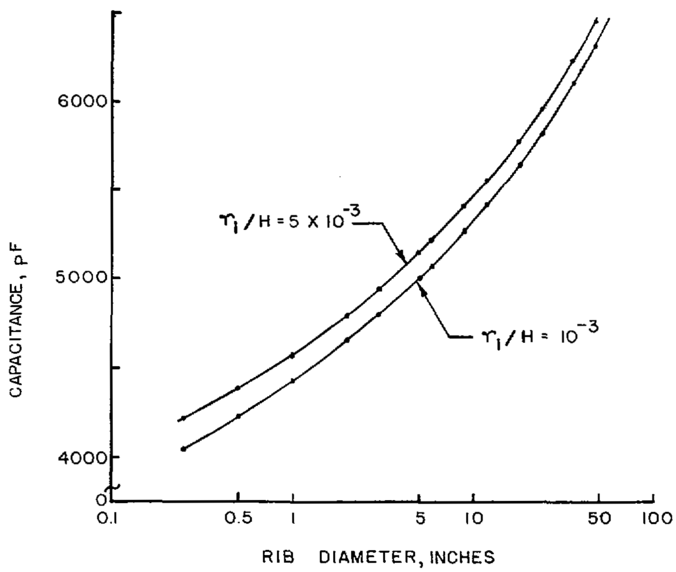

Fig. 1. Static capacitance of 300-ft umbrella antenna as a function of rib diameter.

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 $\frac{1}{4}$- 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.

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REFERENCES

[1] A. F. Gangi, S. Sensiper, and G. R. Dunn, "The characteristics of electrically short umbrella top-loaded antennas," *IEEE Trans. Antennas Propagat.*, vol. AP-13, Nov. 1965, pp. 864–871.
[2] R. F. Harrington, *Field Computation by Moment Methods.* New York: Macmillan, 1968.
[3] R. L. Tanner and M. G. Andreasen, "Numerical solution of electromagnetic problems," *IEEE Spectrum*, vol. 4, Sept. 1967, pp. 53–61.

Manuscript received June 22, 1970.
[1] C. E. Smith and E. R. Graf, *IEEE Trans. Antennas Propagat.* (Commun.), vol. AP-16, Nov. 1968, pp. 766–767.