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LOG-PERIODIC FOLDED MONOPOLE ARRAY

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Fred Ore

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RADIOLOCATION RESEARCH LABORATORY
DEPARTMENT OF ELECTRICAL ENGINEERING
ENGINEERING EXPERIMENT STATION
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

E. C. Hayden

P. E. Mayes

1. Introduction

This technical note describes and gives the results of a limited investigation of a type of unidirectional, vertically polarized, log-periodic antenna referred to as a log-periodic folded monopole array. This structure was conceived in July 1962 and was briefly described in Interim Engineering Report No. 6 of contract NOBSR 85243[1].

It was decided to conduct a limited study of this new structure when it was observed that it possessed the general characteristics which were required of a basic element of the wide aperture radio location antenna (WARLA) being studied under contract NOBSR 85243. The objective of the study was to learn enough about the new structure so that a comparison of its performance could be made with the other possible array elements, namely the Zigzag and Coaxial Fed Monopole Array[3] antennas.

2. Description of Uniformly Periodic Structures

Shortly after the basic idea for this type structure was conceived, a uniformly periodic model was constructed so that the radiation properties of the structure could be studied as a function of several possible feed schemes. This technique of analyzing the performance of a uniformly periodic structure in order to gain some insight as to the performance of its log-periodic counterpart has been used successfully and reported on by several other investigators[1,4,5].

Figure 1 shows a sketch of the most promising of the uniformly periodic structures tested. In particular the feed scheme as shown in this figure gave the best results as far as radiation performance was concerned.

The coaxial feeder line is run parallel to and a small distance, d, above the ground system the full length of the structure. The outer conductor of this coaxial feeder line is broken in uniform lengths corresponding to the spacing between the individual folded monopoles. The front of each of these sections of outer conductor is tied electrically to the ground system. Also, the two sides of the loop making up each of the folded monopoles are connected to either side of each of the gaps in the outer conductor of the coaxial feeder line. In effect, this arrangement places each section of outer conductor in series with its respective folded monopole. The sections of

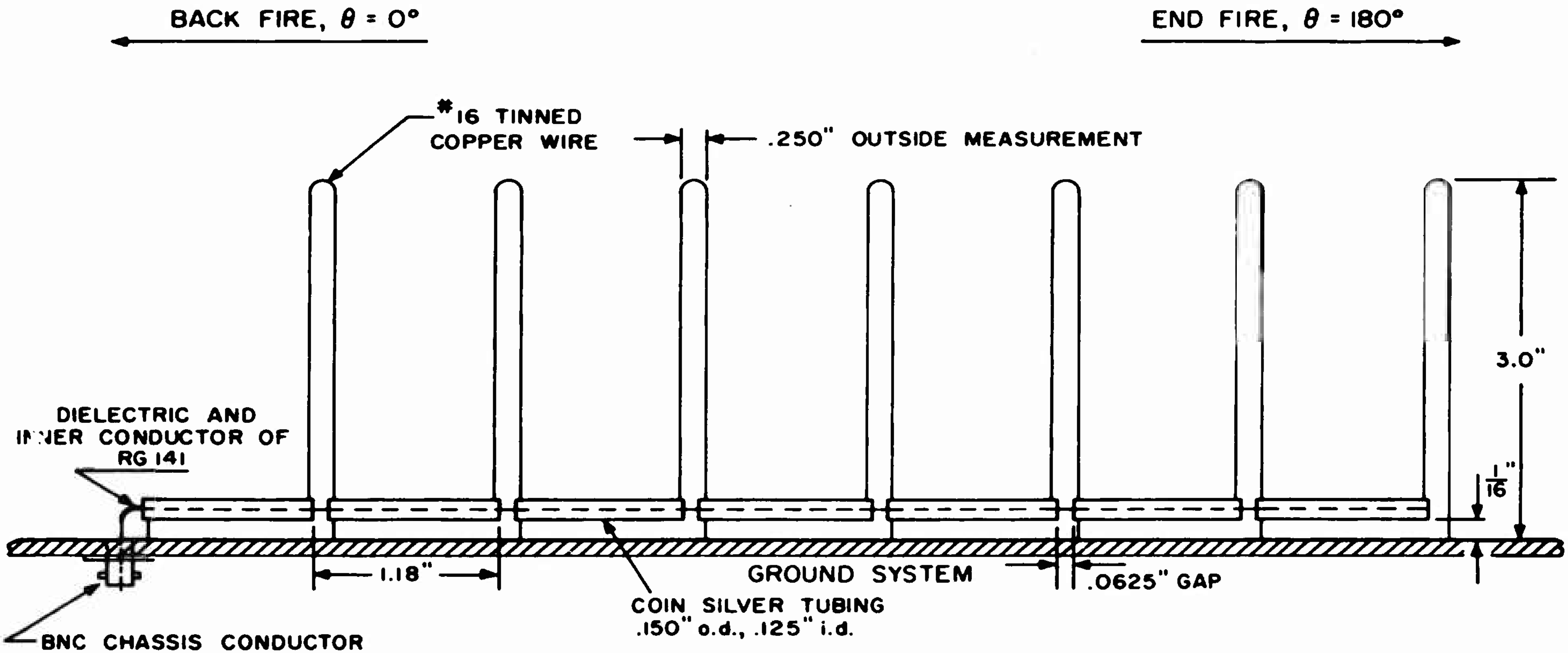

Figure 1. Model of uniformly periodic folded monopole array.

outer conductor are in turn proximity coupled to the center conductor of the coaxial feeder line. Thus, energy is coupled from the center conductor to the outer conductor sections which in turn excite their respective monopoles.

2.1 Radiation Performance of the Uniformly Periodic Structure

Figure 2 shows the radiation patterns of the model of Figure 1 for the frequency range of 1400 Mc to 2000 Mc. At 1400 Mc, the greater part of the radiation occurs in the endfire direction ($\theta = 180^{\circ}$). From 1450 to 1950 Mc the radiation is in the backfire direction ($\theta = 0^{\circ}$). Again at 2000 Mc the radiation is predominantly in the endfire direction. The fact that this uniformly periodic structure produced backfire radiation over a relatively wide band (1450 to 1950 Mc) is a good indication that a similar log-periodic structure would give essentially frequency-independent operation over a wide band. This indeed was found to be the case as will be shown in the next sections.

Since the folded monopoles of this model are approximately 3 inches in length $\left(\frac{\lambda}{4}\text{ at 1000 Mc}\right)$, the good backfire radiation occurred at frequencies where the monopoles were $\frac{3\lambda}{8}$ to $\frac{\lambda}{2}$ in length. In the case of the similar log-periodic structure, the radiation patterns started displaying a good front-to-back ratio where the longest monopoles were between $\frac{3\lambda}{8}$ and $\frac{\lambda}{2}$ in length.

3. Description of the Log-Periodic Structure

A sketch of the log-periodic folded monopole array is shown in Figure 3. This structure has the usual log-periodic structure design parameters α and τ. The α angle, as shown in the sketch, defines the length of the teeth. The τ ratio is the distance from the virtual apex of the structure to the $n - 1$ folded monopole divided by the distance to the nth folded monopole or $\tau = \frac{R_{n-1}}{R_n}$.

The technique used to feed this log-periodic structure is essentially the same as that used in the uniformly periodic case discussed above, the only difference being that the outer conductor of the coaxial feeder line is broken in log-periodic steps instead of uniform steps.

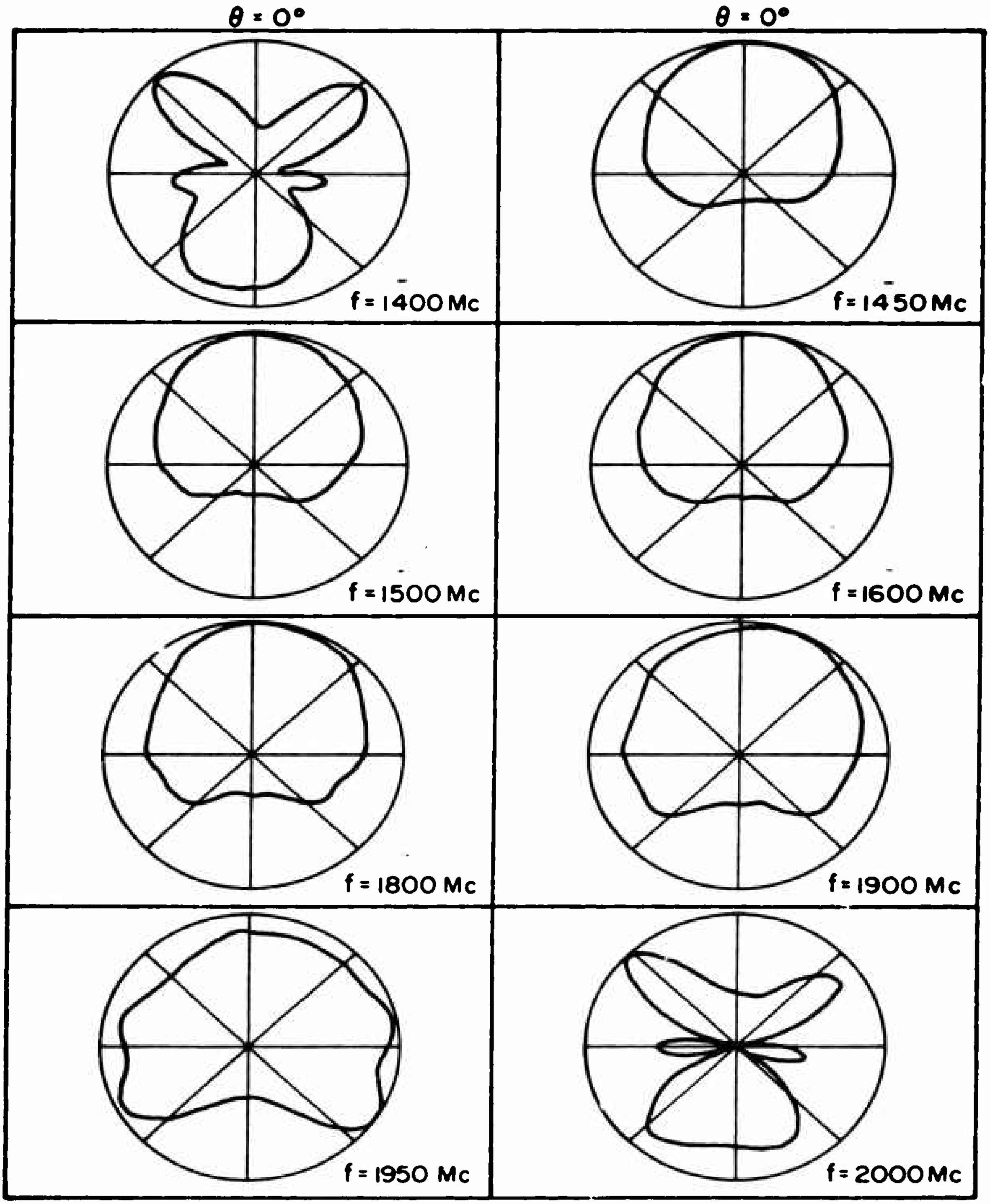

Figure 2. Radiation patterns of a uniformly periodic folded monopole array

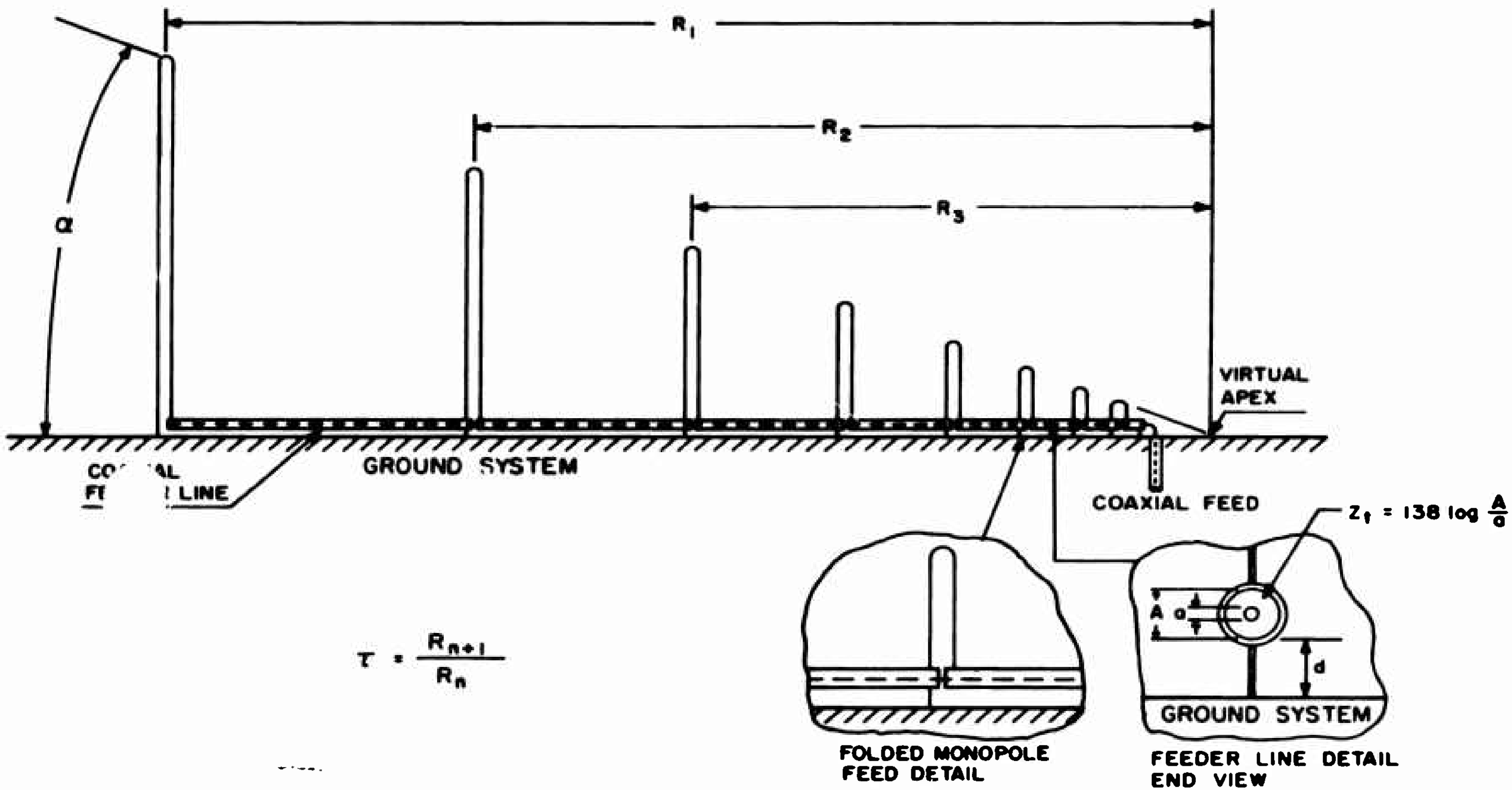

Figure 3. Log Periodic, Folded Monopole Array.

3.1 Experimental Performance Investigation of Log Periodic Structure

Radiation and impedance characteristics were determined by constructing and testing scale model structures. In the case of radiation performance, the models were designed for approximately the 500 to 4000 Mc frequency range. The impedance models were designed for approximately the 140 to 800 Mc frequency range.

3.1.1. Radiation Performance of Log Periodic Structure

Enough pattern models were constructed and tested so that limited curves of average half-power, H-plane beamwidths as a function of α for τ of .84 and .707 could be plotted. Figure 4 shows these two curves. Only these parameters were investigated because it is felt that only structures falling within this general range of parameters would be suitable as an element of the WARLA array. For example, it is felt that an element of the WARLA array should have an H-plane beamwidth of approximately 130°. The structure with an α of 30° and a τ of .84 meets this requirement almost exactly.

The average half-power E-plane beamwidth of this structure is approximately 35°. Representative E and H-plane patterns of this type of antenna are shown in Figure 5. As with other structures of this general type, the front-to-back ratio near the low frequency limit is in the order of 10 db, but becomes much better for the higher frequencies.

Thus, from the results of the limited pattern investigation, it appears as though this type of structure was reasonably well behaved. However, the impedance investigation gave some interesting, but not encouraging, results.

3.1.2. Impedance Investigation

The impedance model was designed to cover approximately the 140 to 800 Mc frequency range. Since the structure having the conventional design parameters τ = .84 and α = 30° had approximately the ideal radiation characteristics, these were the parameters chosen for the first model. The design parameters which are unique to this particular structure are

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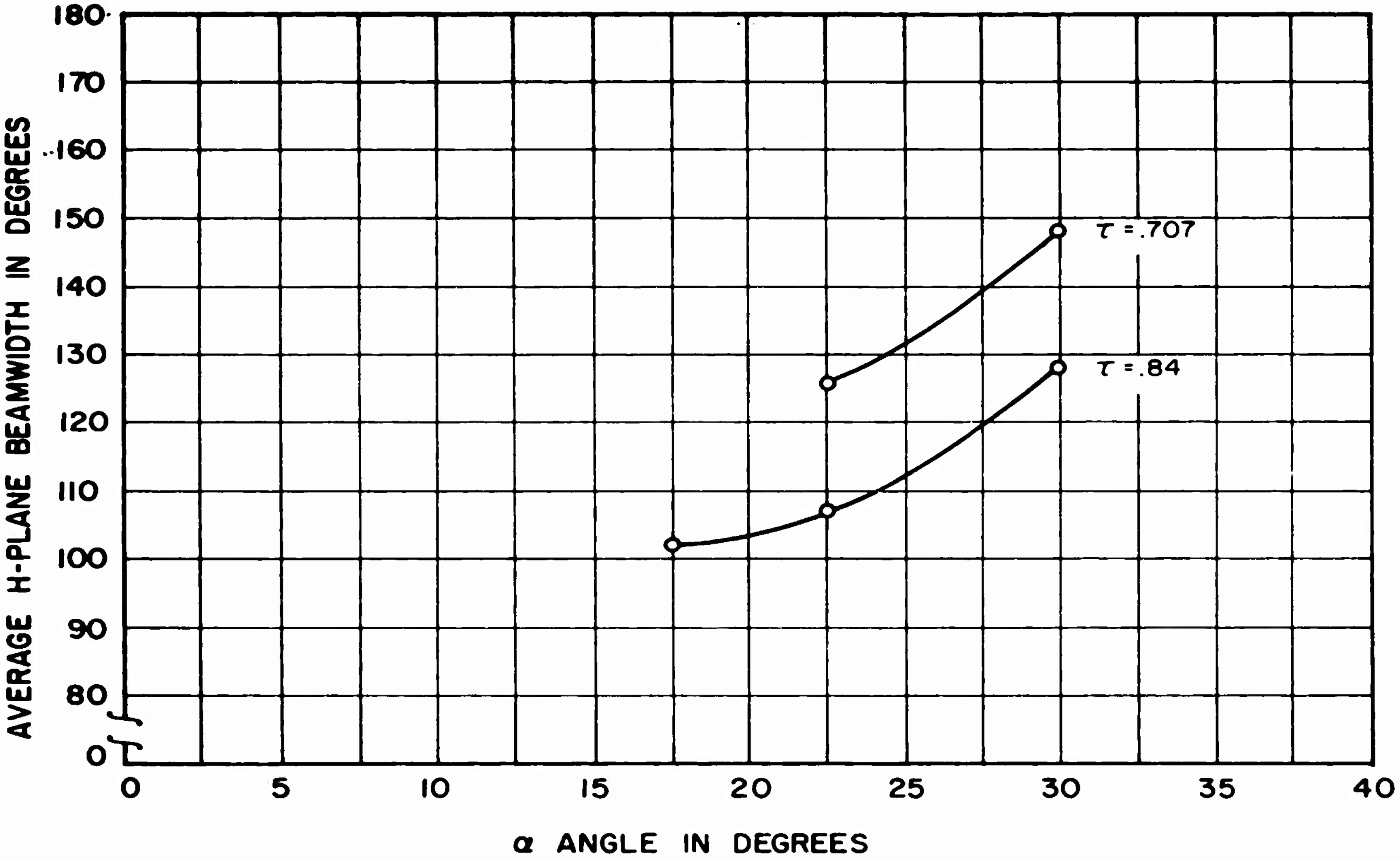

Figure 4. Average H-Plane Beamwidth as a Function of α Angle.

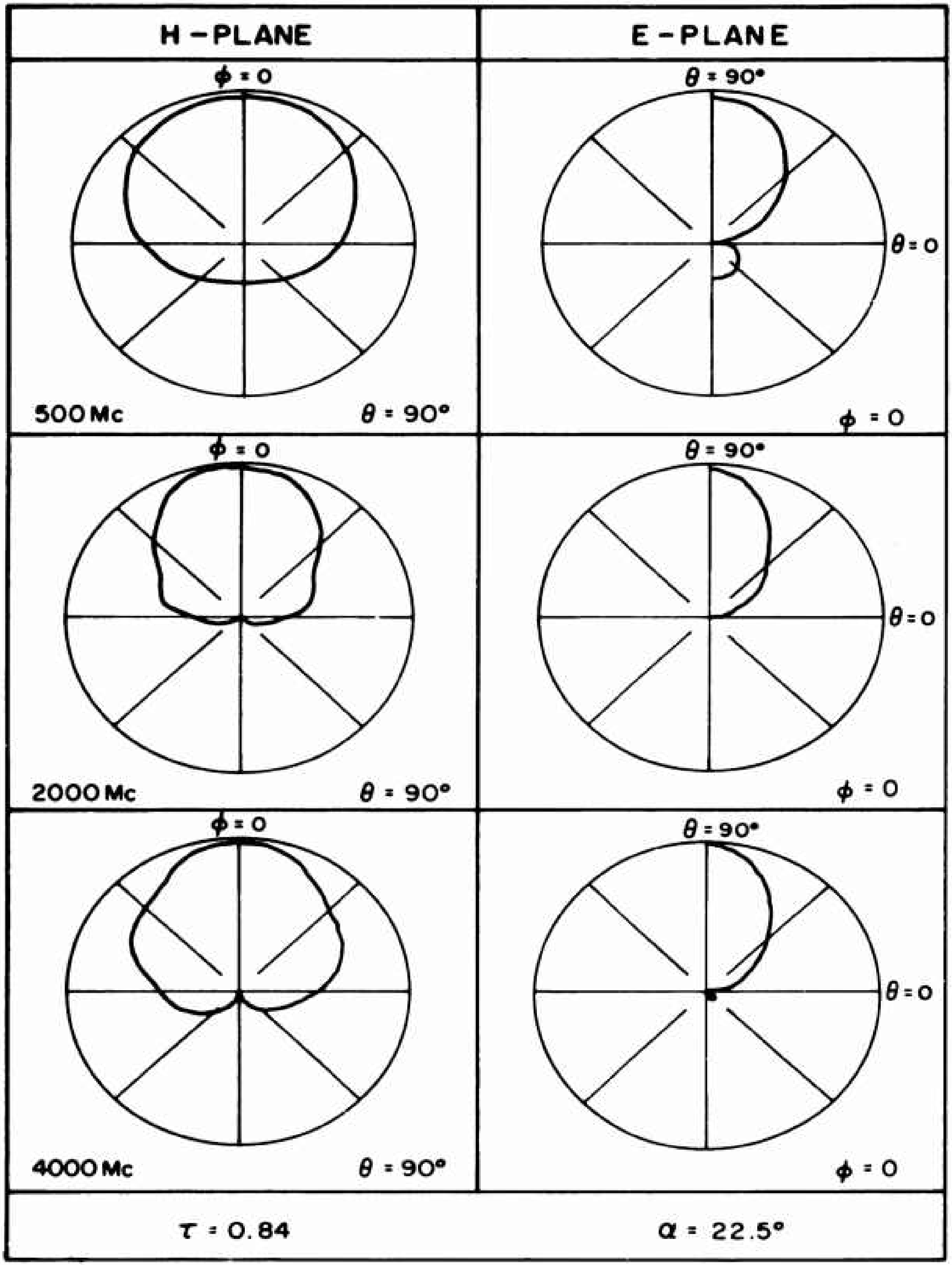

Figure 5. Representative patterns of a vertically polarized log-periodic folded monopole array.

(1) the impedance of the coaxial feeder line, Z_t, which controls the amount of coupling between the center conductor and monopoles and

(2) the height of the coaxial feeder line above the ground system, d. (See Figure 3.)

In the design of the models, the parameters α and τ were fixed for each model while the parameters Z_t and d could be varied with little effort. The impedance of the coaxial feeder line, Z_t, was easily varied by changing the diameter of the center conductor. Since no prior knowledge was in existence of the impedance characteristics of this type structure, Z_t and d were arbitrarily chosen respectively as 40 ohms and $\frac{1}{8}$ inch. The measured impedance of this structure had an extremely high VSWR. The Smith Chart plot of several periods of frequencies indicated that the impedance was log-periodic, that is, the impedance repeated periodically with the logarithm of frequency.

The VSWR of this structure was so high it was decided to reduce the ratio to .707. In effect, this removed every other monopole from the original model. The VSWR of this structure still wasn't acceptable but was within reason. In an effort to determine to what extent the impedance performance could be improved by changing the parameters Z_t and d, data were recorded so that limited curves could be plotted of input impedance and VSWR as a function of feeder height and feeder impedance. Figure 6 shows these curves. Also included on the graph is the curve for $\alpha = 22.5^{\circ}$, $\tau = .707$, and $d = \frac{1}{8}$ inch structure as a function of Z_t.

It is clear that none of the parameters tried are acceptable. The best of the combinations is Z_t 52.5, $d = \frac{1}{4}$ in., $\tau =$ 707 and $\alpha = 30^{\circ}$. For this case the VSWR is still prohibitively high at approximately 3.5 to 1.

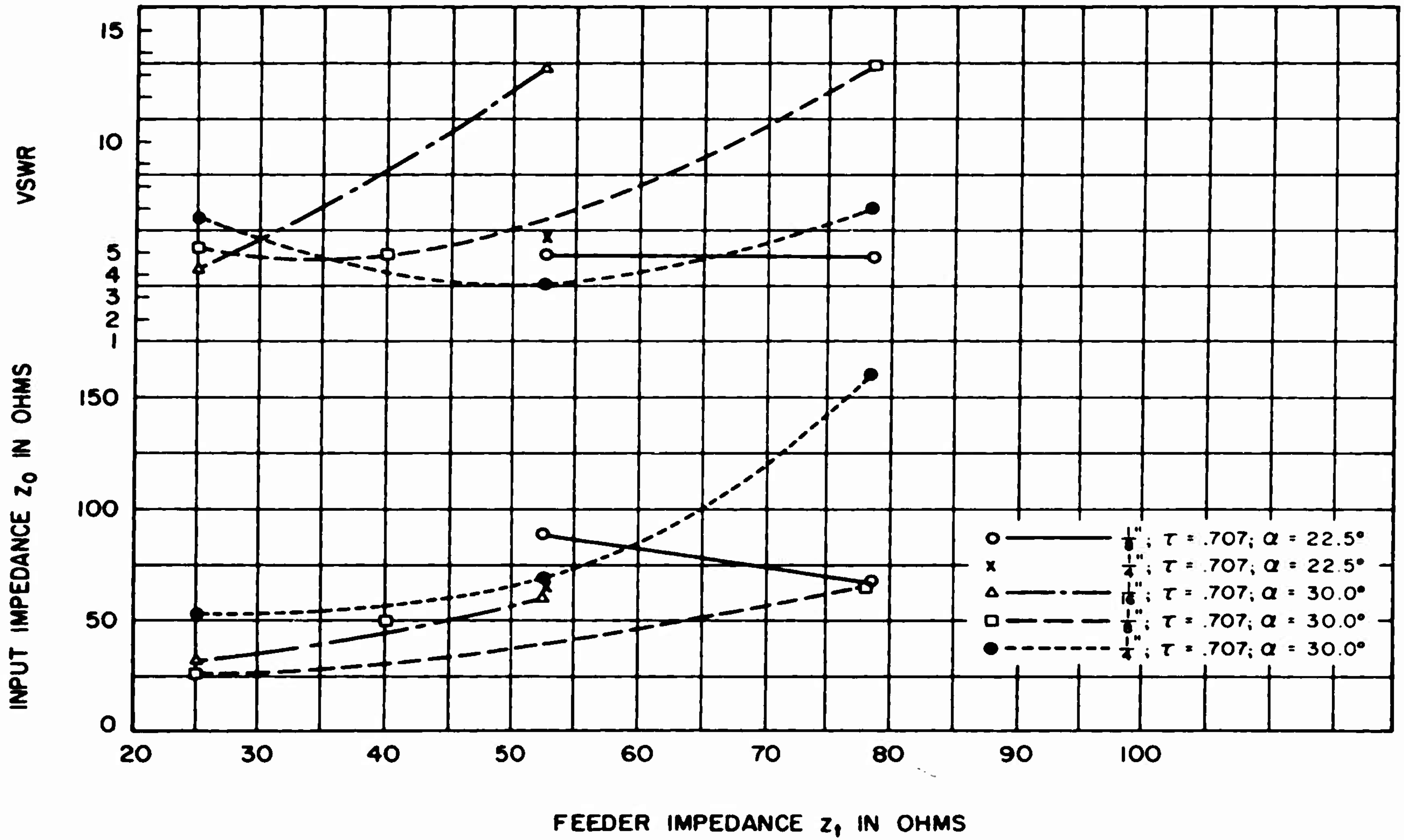

Figure 6. Input impedance and VSWR as a function of feeder impedance for various τ and α.

Conclusion

From [redacted] impedance data, it appears that the impedance characteristics of this type structure are not naturally good, and that a more careful investigation would have to be conducted to determine if there were any modifications which would improve its performance. It was decided that since this type structure offered no great advantage over the zigzag or coaxial fed monopole array it would not be worthwhile going into an investigation in an attempt to improve its impedance performance at this time.

It is interesting to note that this structure represents the first time, to the author's knowledge, that a folded monopole has been incorporated in the design of a log-periodic structure. Since this structure was conceived several other investigators have had varying degrees of success using folded monopoles or dipoles in the design of log-periodic structures.

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