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Air Force Avionics Laboratory
Research and Technology Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

Study and Investigation of a UHF-VHF Antenna

Eighth Quarterly Report
1 October 1967 through 31 December 1967

J. A. M. LYON, C-C CHEN,
J. C. PARKER and D. L. SMITH

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O. E. Horton, Project Monitor

THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRICAL ENGINEERING
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STUDY AND INVESTIGATION OF A UHF-VHF ANTENNA

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1 October 1967 through 31 December 1967

February 1968

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FOREWORD

This report, 7848-8-Q, was prepared by the University of Michigan, Radiation Laboratory, Department of Electrical Engineering, under the direction of Prof. Ralph E. Hiatt and Prof. John A. M. Lyon, on Air Force Contract AF 33(615)-3609, under Task 627801 of Project 6278, "Study and Investigation of UHF-VHF Antennas (U)". The work was administered under the direction of the Air Force Avionics Laboratory, Wright-Patterson AFB, Ohio. The task engineer was Mr. Olin E. Horton; the project engineer, Mr. E.M. Turner.

This report covers the period 1 October 1967 through 31 December 1967.

ACKNOWLEDGEMENTS

The experimental assistance of Mr. U.E. Gilreath and Mr. J. Brooke Hutt is gratefully acknowledged.

ABSTRACT

This report covers the work in four task areas of the project for a three-month period. All tasks have involved considerable analysis as well as experimental procedures. Machine computation has been used extensively in Task III dealing with ferrite rod antennas. Since the final report on this contract will be prepared very soon, most of the detailed analysis and computer data have been reserved for inclusion in that report. This quarterly report serves primarily to indicate the directions of effort in each of the four task areas. The report also indicates in a somewhat qualitative way the results obtained.

Under Task II, some experimental data have been obtained on slot arrays using ferrite loaded slots. Under Task III, a considerable amount of experimental data have been obtained on ferrite tube antennas. In the other two tasks, one involving ferrite loaded conical spirals and the other low frequency ferrite loaded antennas, the continued progress of the efforts in these areas is reported.

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I

INTRODUCTION

This report describes the activities associated with each of four assigned technical tasks of this project. A separate section describes the effort on each task.

Section II indicates the further development and studies of the log conical spiral antenna. Basic studies on cylindrical helix antennas are covered. These basic studies are useful in assessing the performance of the log conical spiral antenna. A major part of the attention in this report and covering the three-month period has been to study the simultaneous use of a log conical spiral for use as a transmitting and a receiving antenna. Experimental tests to validate the usefulness for simultaneous purposes are described. Such tests were made over a limited selection of frequencies. However, there is evidence to indicate that the results can be extended readily to other frequencies.

Section III describes the use of physically small ferrite loaded slot antennas as elements of an antenna array. The experimental effort described in this report is largely in ascertaining the individual characteristics of the three ferrite loaded slot elements used in the array. This detailed information is necessary in order to properly interpret the array use of the elements. Discrepancies in the array use may, of course, in some cases, be related to the lack of uniformity of the individual elements. Good progress has been reported in this experimental effort.

In Section IV is a description of the use of ferrite tube radiators. The studies under this task have shown that the ferrite loaded tube radiator is a better radiator than the completely filled cylindrical rod radiator. A great dea analysis and experimentation has been accomplished under this task. For purposes of this report, a relatively brief resume has been given in order to show the extent of the accomplishment and the further objectives with respect to such ferrite tube radiators.

In Section V the effort under Task 4 has been described. The work in this area represents a logical continuation of the previously described effort for ferrite loaded antennas usable down to 30 MHz. A systematic approach is emphasized in the selection of various types usable. Currently a detailed analysis of a ferrite loaded radiator is underway. This analysis involves an assumed current distribution together with making appropriate field calculations corresponding to this distribution.

The next report on this project will be the final one for the contract period. In general, the coverage for the various tasks has been restricted to description. Much of the detailed experimental and computer data will be incorporated in the final report. It is also contemplated that the final report will include important analytical effort on each of the tasks.

II

FERRITE LOADED CONICAL SPIRALS

2.1 Introduction

The objective of this task is to develop a ferrite filled conical spiral antenna that will cover the 200 to 600 MHz range and be approximately one-third the size of an unloaded conical spiral antenna. The antenna is to have circular polarization with a broad forward directional main beam. The antenna should also be capable of employing both the transmit and receive modes simultaneously.

Throughout the course of this contract, emphasis has been placed on size reduction of helix antennas instead of conical spiral antennas. The reasons are three: 1) a helix is a special case of a conical spiral antenna that occurs when the cone angle is 0 degrees; 2) helix antennas are much easier to construct and analyze mathematically; 3) the results of cylindrical helices are directly applicable to conical spirals. Therefore more investigations can be made into reduction techniques with the time and money available.

2.2 Transmit-Receive Mode Operation.

To test the usability of a ferrite loaded antenna with both the transmit and receive modes, a bifilar backfire helix antenna with its interior filled with EAF-2 powder was tested. The experimentally determined properties were reported earlier (Rassweiler, 1967). Since the antenna seems to operate most efficiently at 450 MHz, this frequency was chosen as the transmit frequency. The equipment available restricted the reception frequency to 595 MHz. Fig. 2-1 shows the diplexer circuit used to protect the receiver front end from being overloaded by the transmitter.

A 80 mw signal was fed to the antenna and this is approximately the input power to the antenna since the reflected power was negligible. The test was conducted on the 50 ft. North Campus range of the Radiation Laboratory with the

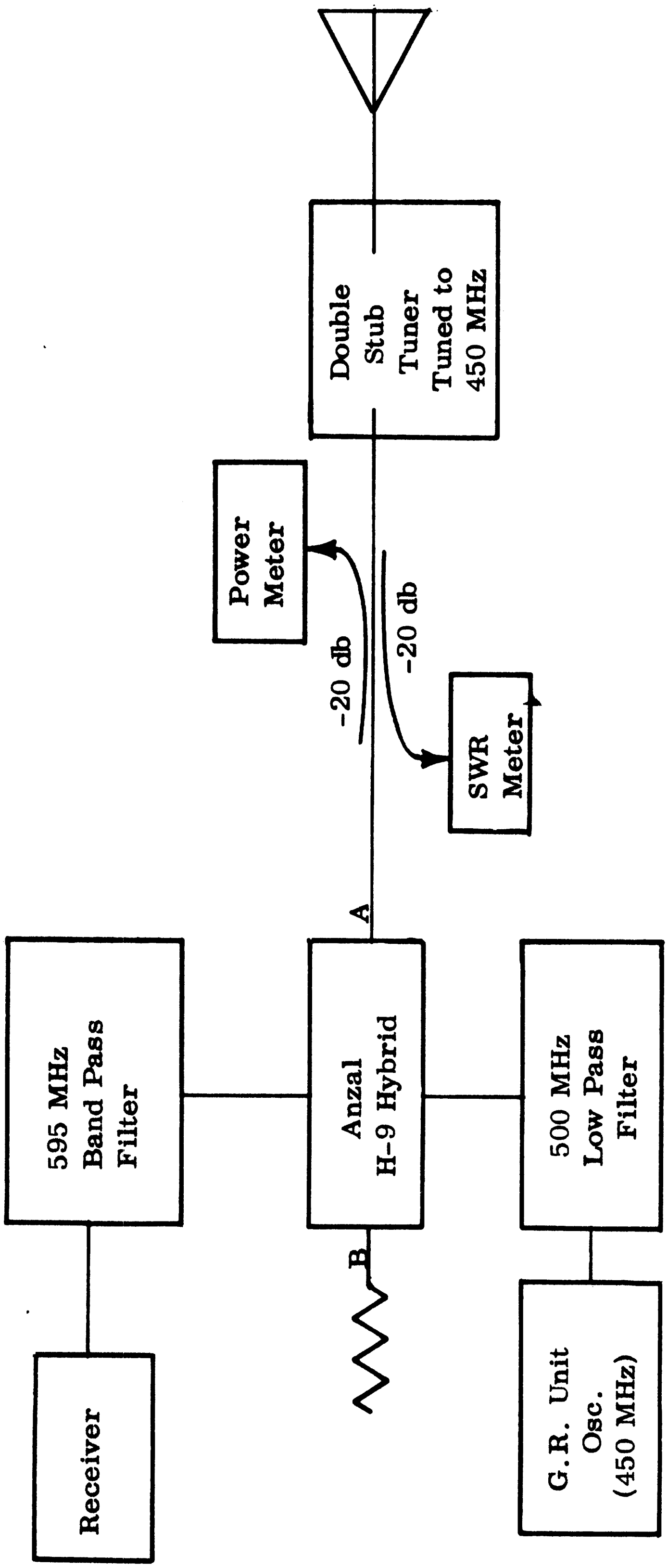


FIG. 2-1: CIRCUIT FOR TESTING SIMULTANEOUS USE OF TRANSMIT AND RECEIVE MODE.

test antenna placed in the field of a 595 MHz signal. Observation of the 595 MHz signal on the receiver was made. The first harmonic addition frequency as a result of possible mixing of the transmitted and received signals (1045 MHz) was not observed. The attenuation of the band pass filter was less than 10 db at this frequency; it is doubtful if this would prevent reception of a 1045 MHz signal if it did exist. Hence, simultaneous transmit and receive mode operation appears to be entirely feasible and harmonic generation should not be a problem for low powers.

III
SLOT ARRAYS

3.1 Introduction.

The purpose of this task is to show the feasibility of a ferrite slot array and to determine if any benefit can result from magnetic tuning. Specifically, beamwidth and gain as a function of frequency, bandwidth as a function of magnetic tuning, and side lobe levels and angles as a function of power distribution are to be studied. The feasibility of using an array of slots within an array is also to be considered.

3.2 Test Array.

Initially, it was felt that a ferrite filled waveguide slot array would best fulfill the requirements of this task. However, due to the unavailability of satisfactory materials at present which are necessary to make such an array feasible, the design was scrapped. Instead, an array of three cavity backed slot antennas has been chosen that operates close to 350 MHz.

One element used was an experimental ferrite filled cavity backed slot antenna originally described by Adams (1964, 1967). Two other ferrite filled cavity backed slot antennas almost identical to it were constructed to permit tests on a three element array. The antennas are shown in Fig. 3-1, and a table summarizing their important properties is presented as Table III-I.

The discrepancy in the appearance between Adams' original slot (107) and the two copies (108, 109) is a result of the placement of the ferrite in the slots. The bars of ferrite (Motorola EAF-2 solid) were placed parallel to the long dimension of the cavity in antennas 108 and 109 since this configuration resulted in the least amount of waste material. The bars were inserted perpendicular to the aperture and cut off flush with the aperture in antenna 107.

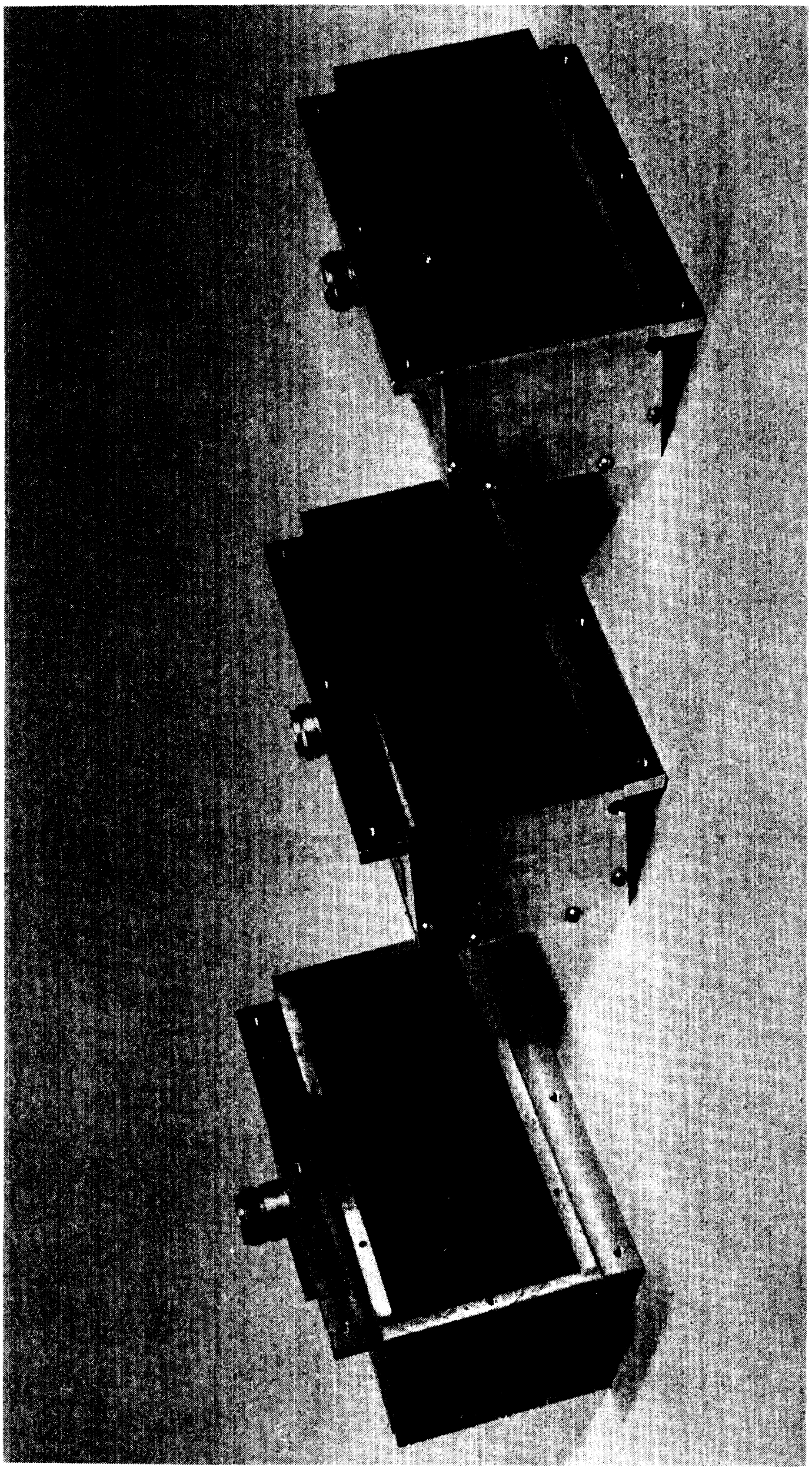


FIG. 3-1: CAVITY BACKED SLOTS 107, 108, and 109

Before constructing an array of the elements, it was felt that each slot should be thoroughly tested to determine how similar they were to each other. Figs. 3-2, 3-3, and 3-4 show the input impedance of slots 107, 108, and 109, with respect to a 50 ohm load, as measured on a 5 ft. square ground plane. The ground plane consisted of brass screening with a 20" by 27" aluminum plate mounted in the center and in which the slots were mounted. To insure electrical continuity, the joint formed by the slot and the ground plane was taped with Scotch brand No. 425 3UAL K3791 Aluminum tape.

The resonant frequencies listed in Table III-I are based on the minimum reflection coefficient observed.

TABLE III-I

PROPERTIES OF CAVITY BACKED SLOTS

Cavity No.	107	108	109
Size of Aperture	2.0" x 5.0"	2.0" x 5.0"	2.0" x 5.0"
Crossection of Cavity	2.0" x 5.0"	2.0" x 5.0"	2.0" x 5.0"
Depth of Cavity	1.5"	1.5"	1.5"
Diameter of Probe	0.25"	0.25"	0.25"
Resonant Frequency (based on Min. reflection)	350 MHz	346 MHz	355 MHz

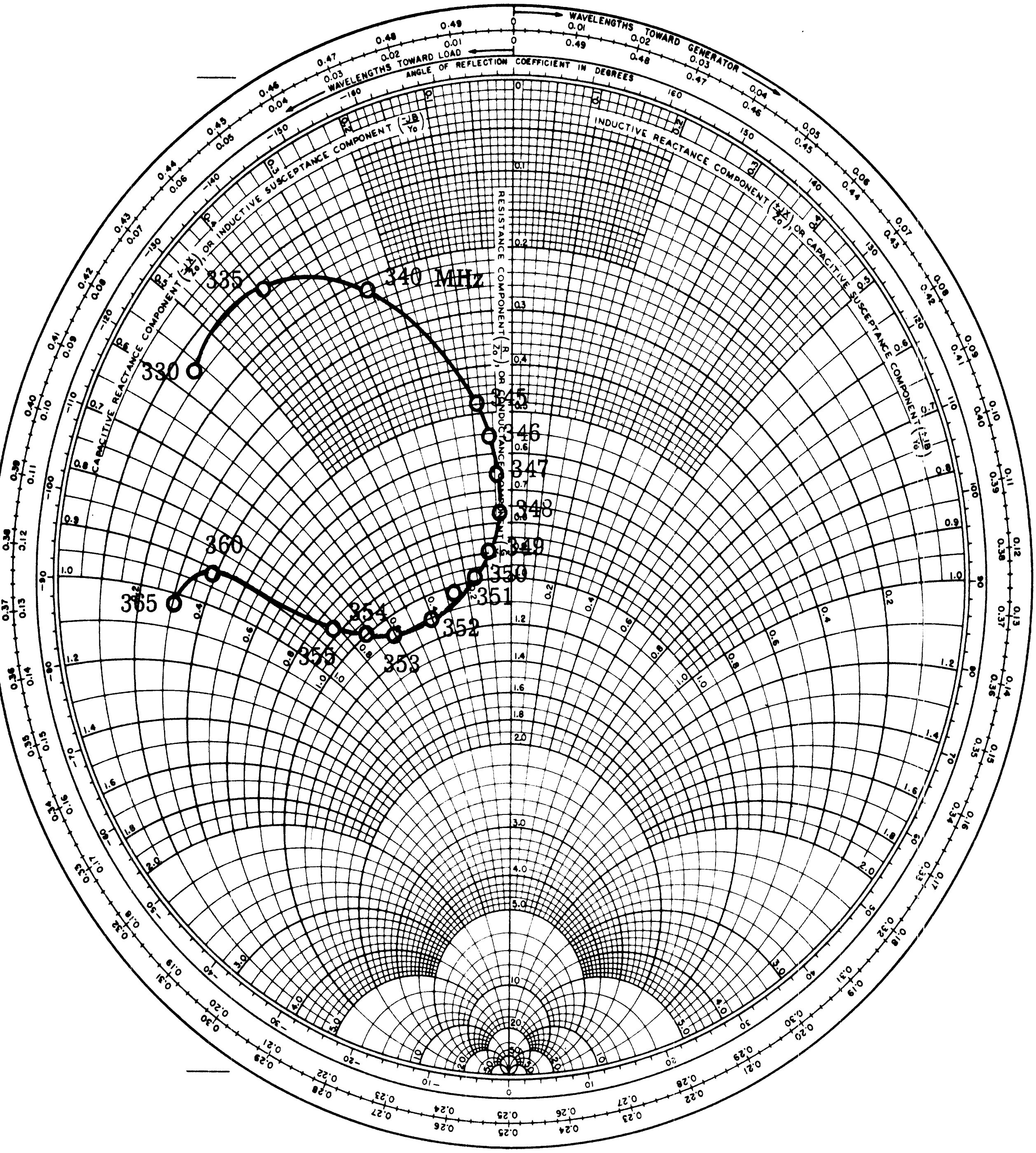


FIG. 3-2: IMPEDANCE OF CAVITY BACKED SLOT 107.

(z_o = 50 ohms)

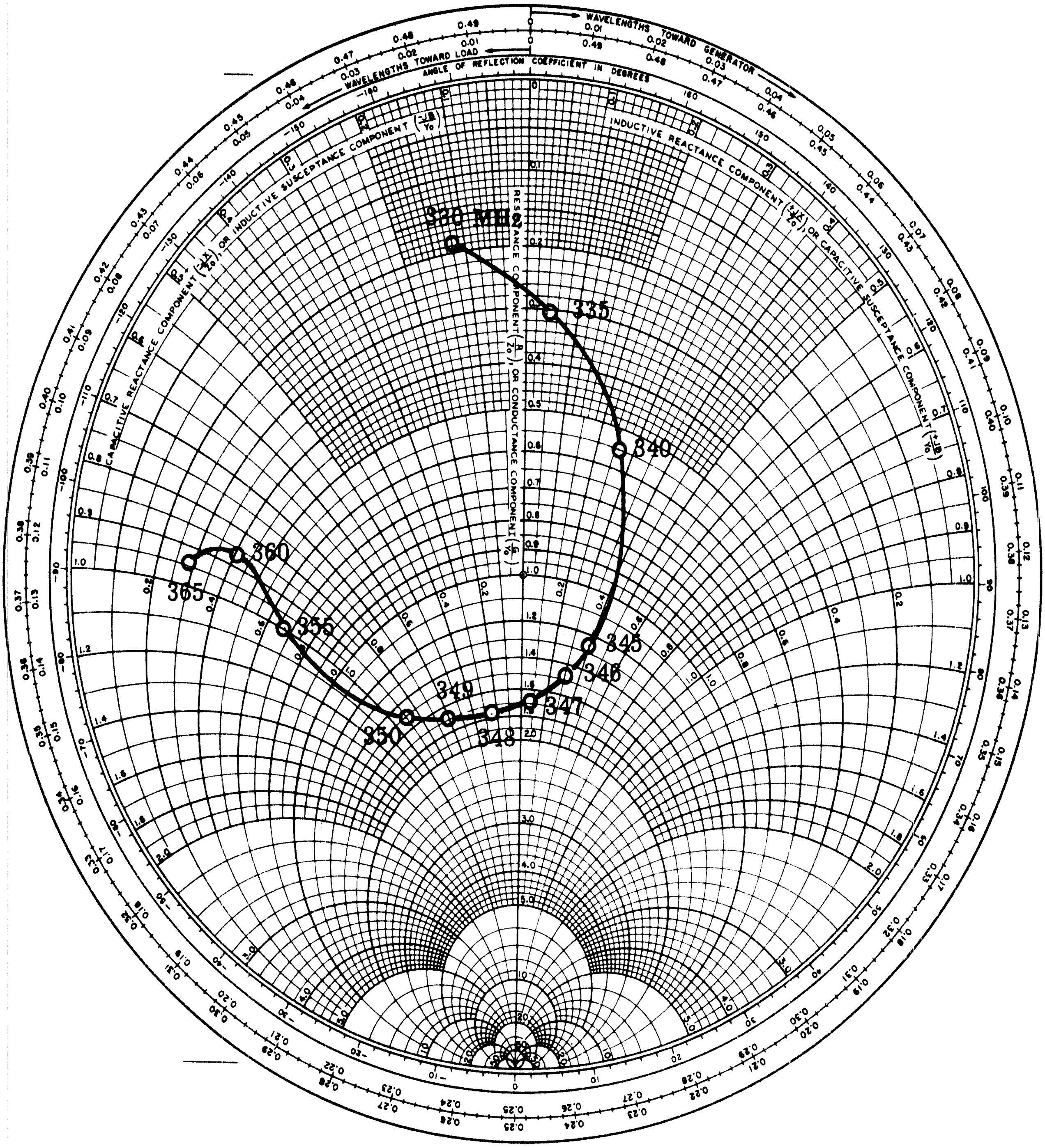


FIG. 3-3: IMPEDANCE OF CAVITY BACKED SLOT 108.

(z_o = 50 ohms)

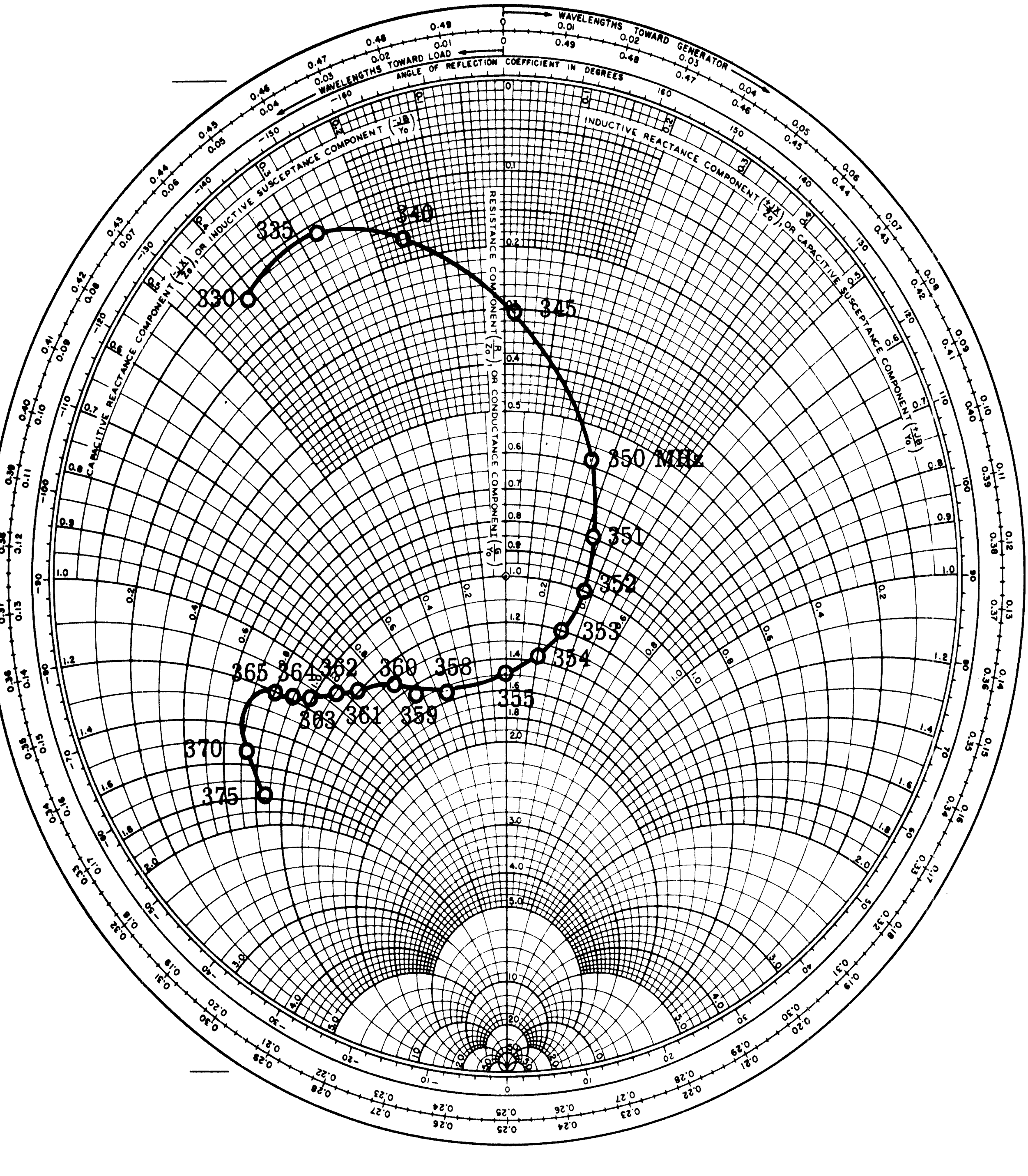


FIG. 3-4: IMPEDANCE OF CAVITY BACKED SLOT 109.

(z_o = 50 ohms)

IV

FERRITE ROD ANTENNAS

4.1 Ferrite Tube Waveguide.

The electromagnetic waves which exist in an infinite ferrite tube can be obtained by solving the Maxwell's equations in a cylindrical coordinate system for the boundaries as shown in Fig. 4-1. In region II, the ferrite material is assumed to have a permeability $\mu = \mu_o \mu_r$ and a permittivity $\epsilon = \epsilon_o \epsilon_r$. Region I and III are free space. The most general type of waves which can exist in a ferrite tube are the hybrid modes which have both axial electric and magnetic components. They may be expressed as:

In region I:

$$\begin{cases} E_{z1} = A_1 I_n (Ws)\, e^{j(wt - \gamma_n z - n\phi)} \\ H_{z1} = B_1 I_n (Ws)\, e^{j(wt - \gamma_n z - n\phi)} \end{cases} \qquad 4.1$$

In region II:

$$\begin{cases} E_{z2} = \left[A_2 J_n (Vs) + A_3 N_n (Vs)\right] e^{j(wt - \gamma_n z - n\phi)} \\ H_{z2} = \left[B_2 J_n (Vs) + B_3 N_n (Vs)\right] e^{j(wt - \gamma_n z - n\phi)} \end{cases} \qquad 4.2$$

In region III:

$$\begin{cases} E_{z3} = A_4 K_n (Ws)\, e^{j(wt - \gamma_n z - n\phi)} \\ H_{z3} = B_4 K_n (Ws)\, e^{j(wt - \gamma_n z - n\phi)} \end{cases} \qquad 4.3$$

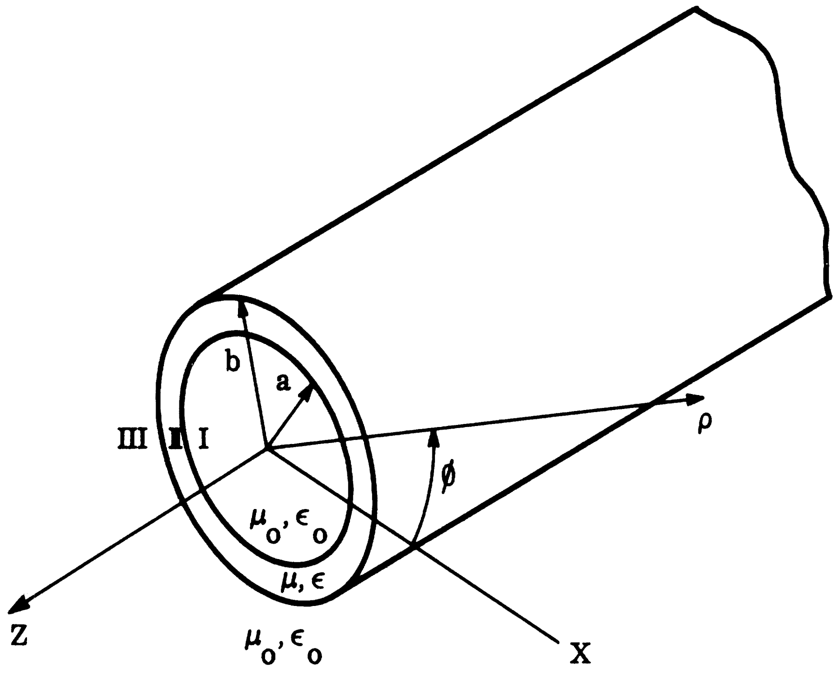


FIG. 4-1: COORDINATE SYSTEM ASSUMED FOR THE FERRITE TUBE WAVEGUIDE.

with

$$s = \frac{\rho}{b} \quad , \quad jW = k_{n1}\, b \;, \quad V = k_{n2} b \qquad 4.4$$

and

$$\begin{cases} k_{n1}^2 = w^2 \mu_o \epsilon_o - \gamma_n^2 \\ k_{n2}^2 = w^2 \mu \epsilon - \gamma_n^2 \end{cases} \qquad 4.5$$

I_n and K_n are modified Bessel functions of the first and second kinds respectively and of order η. The remaining ρ and ϕ field components can be derived from the Maxwell's equations. All the tangential field components on the boundary surfaces at $\rho = a$ and $\rho = b$ must be continuous. In matching these boundary conditions one obtains eight equations for the eight A's and B's which are coefficients. In order to have a non-trivial solution, the determinant of the coefficients of those eight constants must be zero. It results in the following determinantal equation:

$$-n^4 T^4 (\Delta_3 - \Delta_4)^2 - C^4 Q^2 \Big[\Delta_3 (\epsilon_r \Delta_1 - \Delta_8)(\epsilon_r \Delta_7 - \Delta_5)$$

$$- \Delta_4 (\epsilon_r \Delta_6 - \Delta_8)(\epsilon_r \Delta_2 - \Delta_5)\Big] \cdot \Big[\Delta_3 (\mu_r \Delta_1 - \Delta_8)(\mu_r \Delta_7 - \Delta_5)$$

$$- \Delta_4 (\mu_r \Delta_6 - \Delta_8)(\mu_r \Delta_2 - \Delta_5)\Big] - 2n^2 T^2 \mu_r \epsilon_r Q C^2 \Delta_3 \Delta_4 \cdot$$

$$(\Delta_1 - \Delta_6)(\Delta_2 - \Delta_7) + n^2 T^2 Q \Big[\Delta_3^2 (\epsilon_r \Delta_7 - \Delta_5)(\mu_r \Delta_7 - \Delta_5)$$

$$- \Delta_3 \Delta_4 (\epsilon_r \Delta_7 - \Delta_5)(\mu_r \Delta_2 - \Delta_5) - \Delta_3 \Delta_4 (\epsilon_r \Delta_2 - \Delta_5)(\mu_r \Delta_7 - \Delta_5)$$

$$+ \Delta_4^2 (\epsilon_r \Delta_2 - \Delta_5)(\mu_r \Delta_2 - \Delta_5)\Big] + n^2 T^2 Q C^4 \Big[\Delta_3^2 (\epsilon_r \Delta_1 - \Delta_8)(\mu_r \Delta_1 - \Delta_8)$$

$$- \Delta_3\Delta_4(\epsilon_r\Delta_1 - \Delta_8)(\mu_r\Delta_6 - \Delta_8) - \Delta_3\Delta_4(\epsilon_r\Delta_6 - \Delta_8)(\mu_r\Delta_1 - \Delta_8)$$

$$+ \Delta_4^2(\epsilon_r\Delta_6 - \Delta_8)(\mu_r\Delta_6 - \Delta_8)\Big] = 0 \qquad 4.6$$

where $C = a/b$

$$\Delta_1 = \frac{J_n^1(CV)}{CVJ_n(CV)} \qquad \Delta_2 = \frac{J_n^1(V)}{VJ_n(V)}$$

$$\Delta_3 = \frac{J_n(CV)}{N_n(CV)} \qquad \Delta_4 = \frac{J_n(V)}{N_n(V)}$$

$$\Delta_5 = -\frac{K_n^1(W)}{WK_n(W)} \qquad \Delta_6 = \frac{N_n^1(CV)}{CVN_n(CV)}$$

$$\Delta_7 = \frac{N_n^1(V)}{VN_n(V)} \qquad \Delta_8 = -\frac{I_n^1(CW)}{CWI_n(CW)}$$

$$T = \frac{1}{V^2} + \frac{1}{W^2} \qquad Q = \left(\frac{\lambda_g}{\lambda_o}\right)^2 = \frac{V^2 + W^2}{V^2 + \mu_r\epsilon_r W^2} .$$

By eliminating γ_n in equation 4.5 with equation 4.4 gives:

$$\left(\frac{2b}{\lambda_o}\right)^2 = \frac{V^2 + W^2}{\pi^2(\mu_r\epsilon_r - 1)} \qquad 4.7$$

$$\left(\frac{\lambda_g}{\lambda_o}\right)^2 = \frac{V^2 + W^2}{V^2 + \mu_r\epsilon_r W^2} . \qquad 4.8$$

For a wave propagating along the ferrite tube, the parameters W and V must satisfy the determinantal equation 4.6. By substituting the corresponding values of W and V into equations 4.7 and 4.8, the relation between the tube diameter and phase velocity can be obtained. For V >> W, λ_g/λ tends to unity. For W >> V, λ_g/λ tends to $1/\sqrt{\mu_r \epsilon_r}$. Therefore the guide wave length has the range:

$$\frac{\lambda_o}{\sqrt{\mu_r \epsilon_r}} < \lambda_g < \lambda_o \quad . \qquad 4.9$$

The cutoff properties of the waves can be found from equation 4.7 by substituting the values of V when W approaches zero.

$$\left.\frac{2b}{\lambda_o}\right|_{cutoff} = \frac{1}{\pi \sqrt{\mu_r \epsilon_r - 1}} \cdot V \Big|_{W \to 0} \quad . \qquad 4.10$$

The above equation shows that the surface waves cannot propagate along the tube without attenuation in the absence of a material with μ_r and ϵ_r other than unity.

4.2 Experimental Results.

Several ferrite tube antennas excited by a quadrifilar helix, a quadrupole and a dipole have been built and tested during this report period. More than 200 far field patterns were taken for various tube length and thicknesses for the study of the beamwidth, sidelobe level and position. All patterns were taken on an outdoor range with the test antenna rotated through 360 degree and receiving from a linearly polarized zig-zag transmitting antenna operated in the 200 to 1400 MHz frequency range. All ferrite tubes used in this experiment were formed by placing EAF-2 ferrite powder with μ_r = 3.8, ϵ_r = 2.2 between the fiber glass shell and the balsa wood core. The effects of the fiber glass and the balsa wood have been found to be very small. Fig. 4-2 shows the coordinate system assumed and the radiation plane defined for the ferrite tube antenna.

4.2.1 Ferrite Tube Excited by a Quadrifilar Helix.

A uniform ferrite tube with 12.5 cm outside diameter, 10 cm inside diameter and 85 cm in length was fed from one end by a quadrifilar helix with a 10 cm diameter, a 32^o pitch angle and 27 cm in length excited in $0^o - 90^o - 180^o - 270^o$ phase sequence. It was planned to launch a surface wave along the axis of the tube like the HE_{11} mode to radiate in the endfire direction. The radiation patterns are shown in Fig. 4-3 from 750 MHz to 1000 MHz. At 750 MHz it corresponds to having a tube $0.313\lambda_o$ in outside diameter and $2.1\lambda_o$ in length. At 1000 MHz, it corresponds to having $0.42\lambda_o$ in diameter and $2.83\lambda_o$ in length. Below 1000 MHz the antenna is well below the cutoff frequency of the symmetric TM_{0m} or TE_{0m} modes. Above 1000 MHz the sidelobe level increases and the tube antenna tends to radiate in the broadside direction. It may be due to the unwanted symmetric modes becoming more important.

4.2.2 Ferrite Tube Excited by Quadrupole.

The same ferrite tube as described in section 4.2.1 was used in this experiment except the quadrifilar helix was replaced by the 13 cm quadrupole placed parallel to the axis of the tube. Again the quadrupole was excited in a $0^o - 90^o - 180^o - 270^o$ phase sequence. Fig. 4-4(a) shows the radiation patterns of this antenna when the quadrupole was placed at the inside circumference of the tube. The mainlobe of the pattern is very close to that of the quadrifilar helix excited antenna except the sidelobes are slightly lower at high frequency.

When the excitation quadrupole was moved to the outside circumference of the tube, this antenna radiated in the broadside direction as shown in Fig. 4-4 (b). The guiding effect of the ferrite material is very obvious. When it was excited

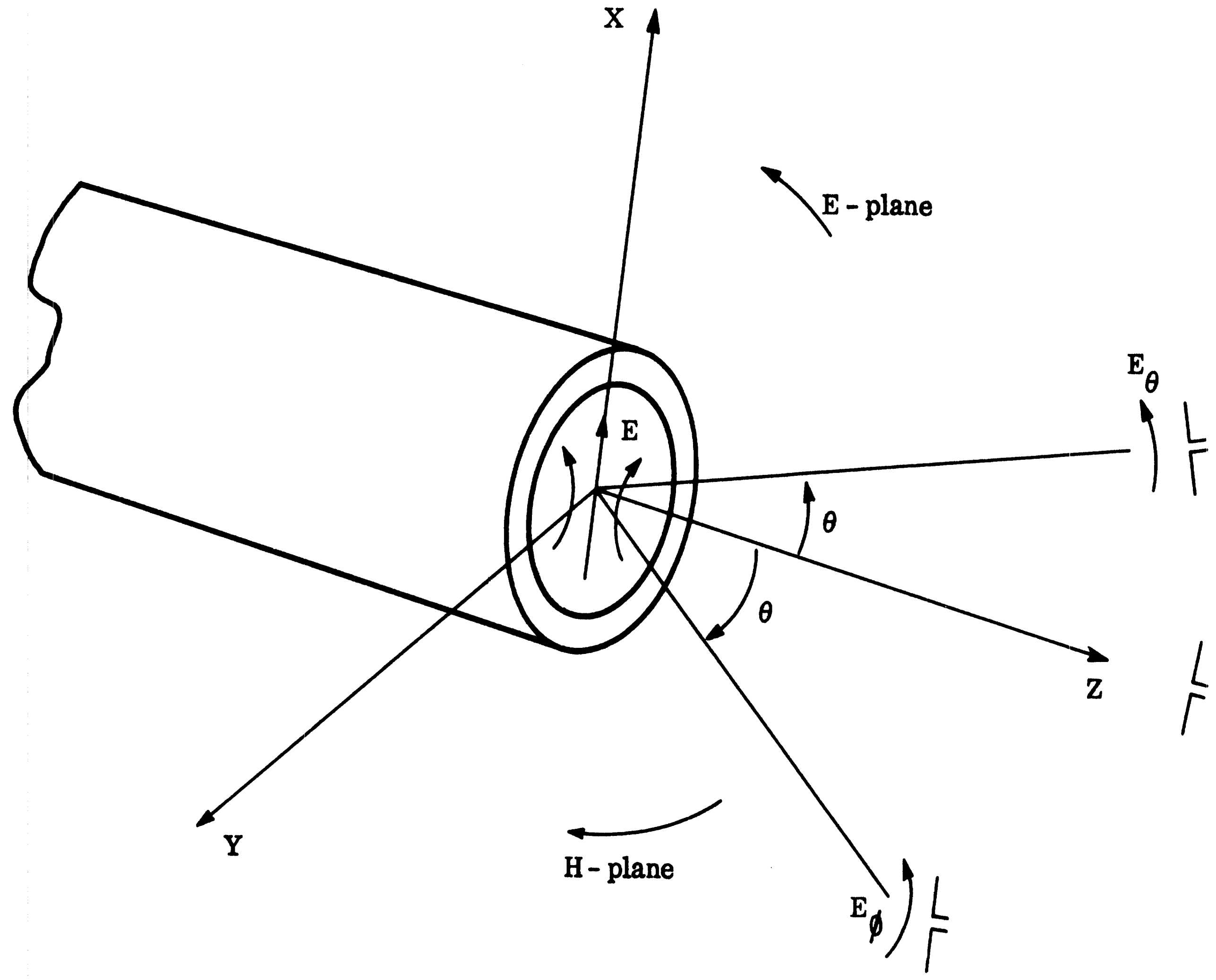


FIG. 4-2: COORDINATE SYSTEM ASSUMED FOR THE FERRITE TUBE ANTENNA AND THE RADIATION PLANE DEFINED.

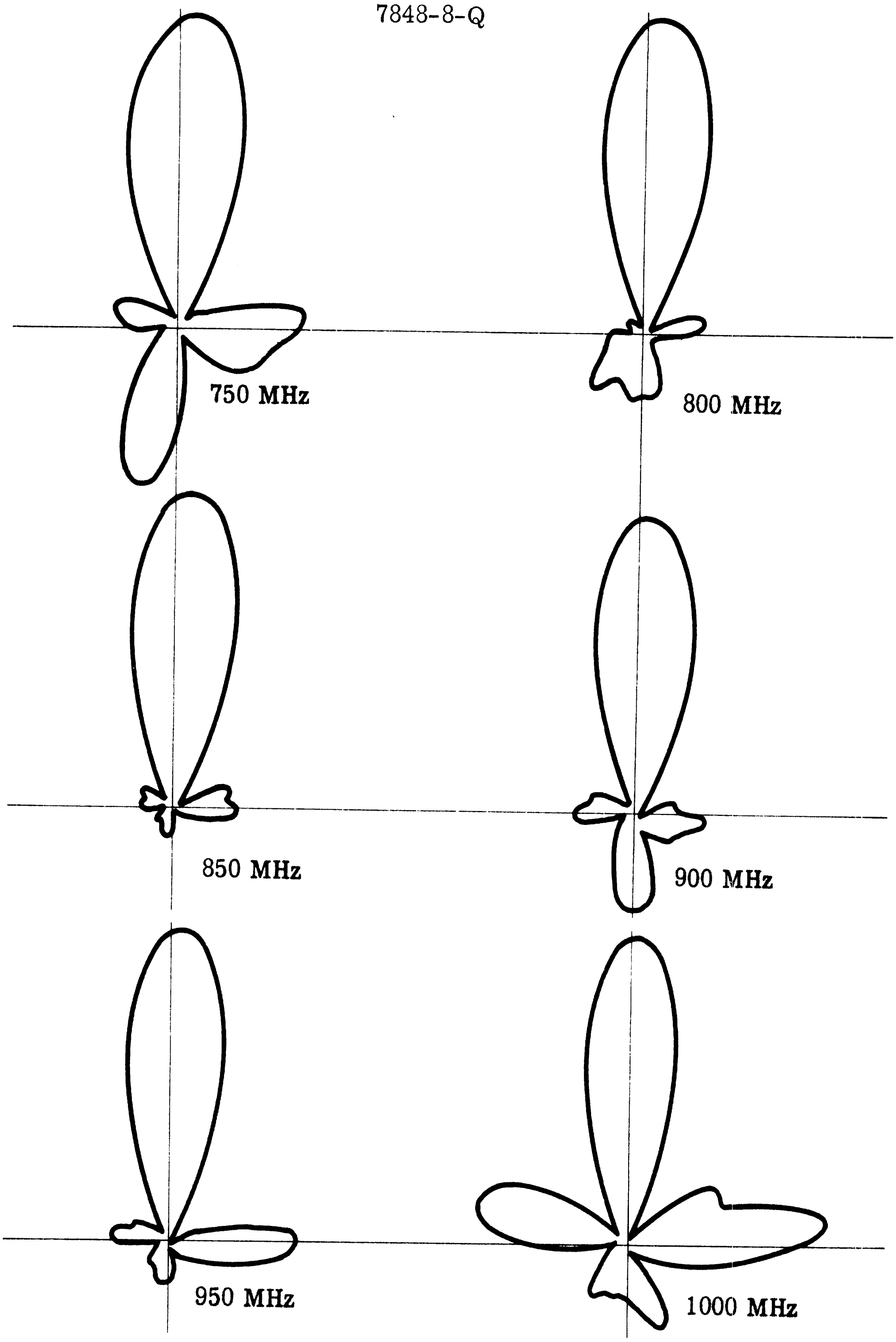


FIG. 4-3: LINEAR POWER PATTERNS FROM A QUADRIFILAR HELIX EXCITED FERRITE TUBE ANTENNA.

Ferrite Tube = { O.D. = 12.5 cm; I.D. = 10 cm; Length = 85 cm }

Feeding Quadrifilar Helix = { Diameter = 10 cm; Pitch Angle = 32°; Length = 27 cm }

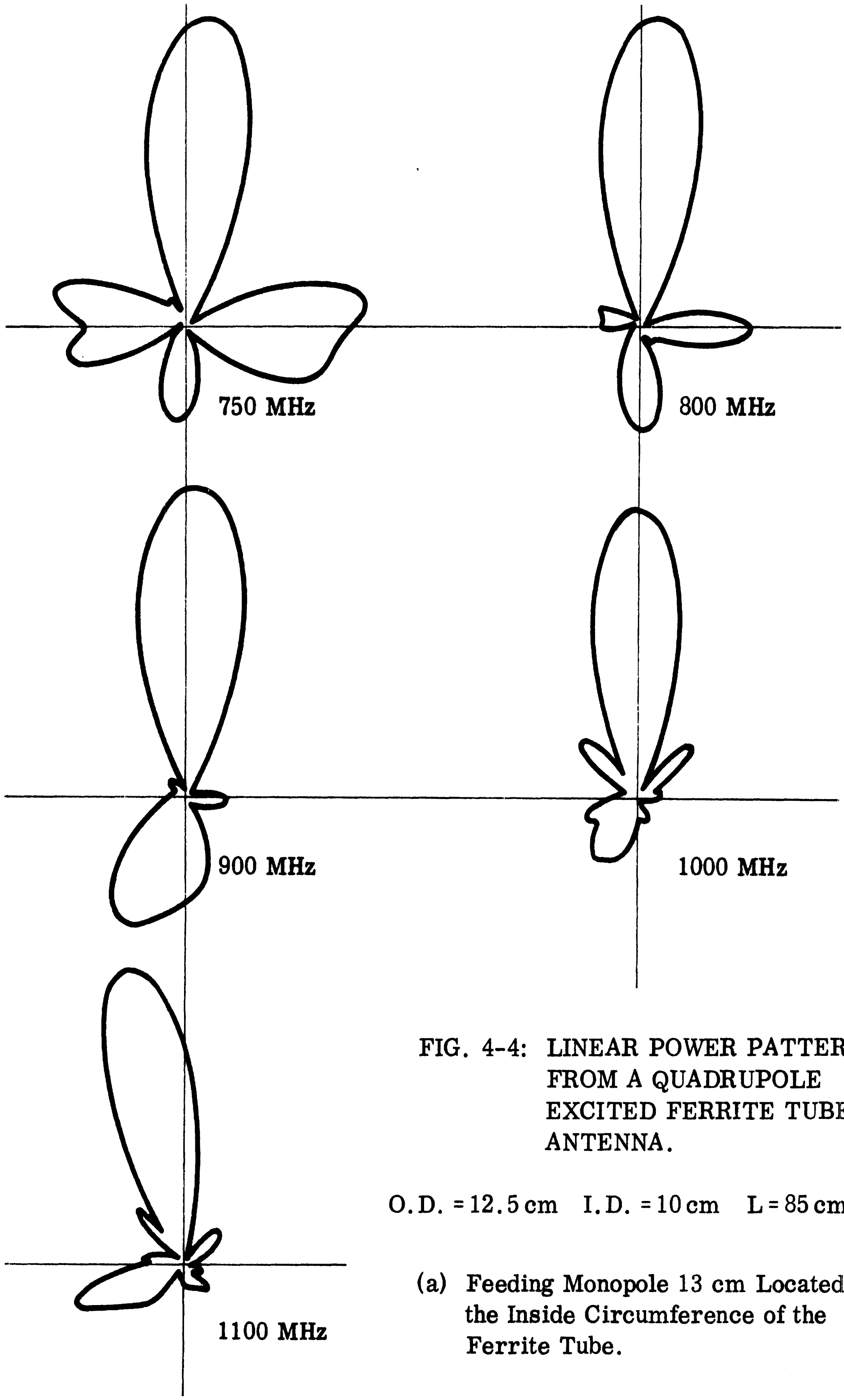


FIG. 4-4: LINEAR POWER PATTERNS FROM A QUADRUPOLE EXCITED FERRITE TUBE ANTENNA.

O.D. = 12.5 cm   I.D. = 10 cm   L = 85 cm

(a) Feeding Monopole 13 cm Located at the Inside Circumference of the Ferrite Tube.

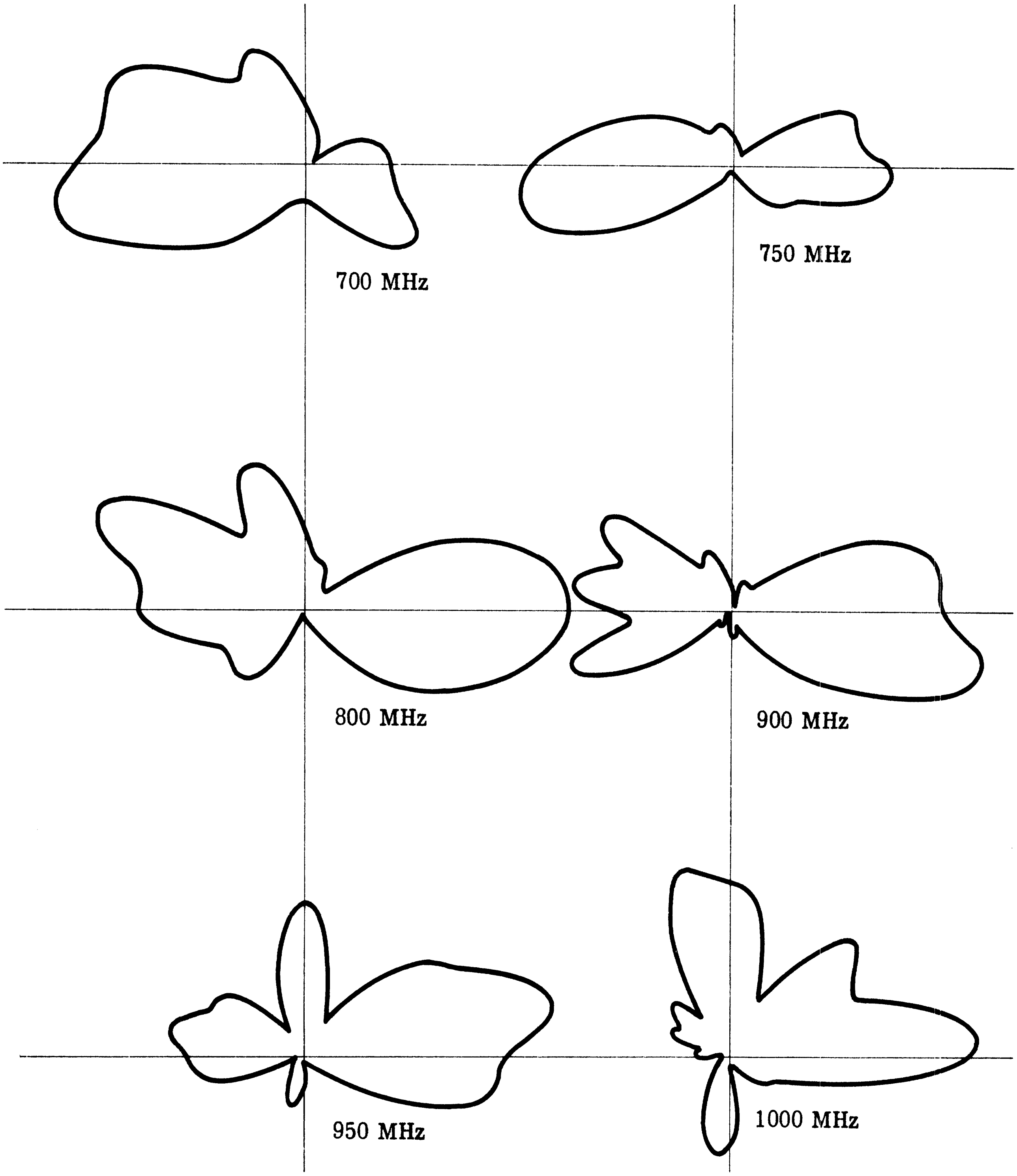


FIG. 4-4: LINEAR POWER PATTERNS FROM A QUADRUPOLE EXCITED FERRITE TUBE ANTENNA.

(b) Feeding Monopole 13 cm Located at the Outside Circumference of the Ferrite Tube.

from the outside instead, most of the energy radiated directly to the surrounding space and little remained in the tube.

4.2.3 Ferrite Tube Excited by a Cylindrical Cavity.

In the last quarterly report 7848-7-Q, results were reported on a dipole mode conical end ferrite tube. The endfire radiation patterns in both E and H-plane were satisfactory except the average VSWR found to be 3.5 was rather high because of the reflection from the conical free end. When the conical free end was removed as shown in Fig. 4-5, the average VSWR is reduced to less than 2 due to the improved matching from the open tube end to free space. Obviously, this also indicates that the open end aperture is the main radiation mechanism of this antenna and the surface wave propagating along the tube axis is bounded. A series of radiation patterns were taken for this kind of antenna with various tube lengths and thicknesses as shown in Table IV-1.

TABLE IV-1

Dimension Antenna No.	O.D. 2b(cm)	I.D. 2a(cm)	Thickness C = a/b	Length ℓ(cm)
1	15	11.2	0.75	38
2	15	12	0.8	41
3	15	12	0.8	51
4	15	12.8	0.85	33
5	15	12.8	0.85	68.5
6	15	13.5	0.9	36
7	15	13.5	0.9	71.5

In order to check the guiding effects of the ferrite material, a 15 cm diameter phenolic shell and a 13.5 cm balsa wood core both 100 cm in length including the feeding cylindrical cavity were tested before the ferrite powder was inserted

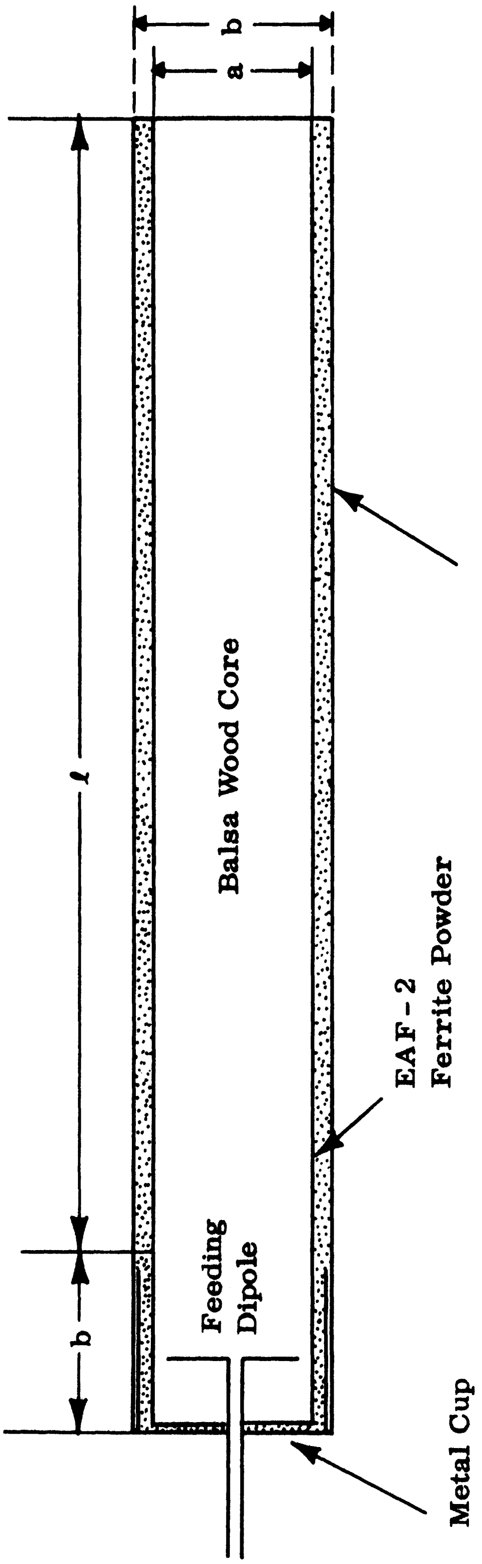


FIG. 4-5: GEOMETRY OF THE FERRITE TUBE ANTENNA.

between the phenolic shell and balsa wood core. Radiation patterns shown in Fig. 4-6 are essentially the TE_{11} mode cavity patterns. Most experiments were done with the outside tube diameter having $2b = 0.3\lambda_o$ to $0.6\lambda_o$ and tube length from $\ell = 0.7\lambda_o$ to $3\lambda_o$. The radiation patterns of a thick short tube antenna indicated as No. 1 in Table IV-1 are presented in Fig. 4-7. At 600 MHz, it corresponds to having a outside diameter $2b = 0.3\lambda_o$ and length $0 = 0.76\lambda_o$. As the tube becomes thinner and longer, both directivity and sidelobe level are slightly improved. This might be due to the better matching at the open end and to the continuous coupling to the free space while the wave propagates along the tube axis towards the open end. Fig. 4-8 presents the radiation patterns of a thin tube indicated as No.7 in Table IV-1. At 1200 MHz, the tube has a diameter $2b = 0.6\lambda_o$ and length $\ell = 2.8\lambda_o$. The measured 3db, 6db and 12db beamwidths varying with frequency for the thin tube antenna No.7 are presented in Fig. 4-9. The positions of the first sidelobe are plotted in Fig. 4-10 and the maximum sidelobe or backlobe level is plotted in Fig. 4-11. These will be checked with theory later in the final report. It is noted that the mainlobe and sidelobe positions in both E and H-plane have no significant difference. The sidelobe levels in E-plane are more prominent which is expected, partly due to the asymmetric field distribution of the HE_{11} mode in the ferrite tube and partly due to the symmetric TM_{01} mode excited at higher frequency which has no contribution to E_ϕ patterns in H-plane. The input impedance of the thin tube antennas Nos. 6 and 7 are shown in Fig. 4-12 and Fig. 4-13. These values were measured with the Hewlett Packard Model 8405A Vector Voltmeter referenced to a 50 Ω line. Since there is good matching from the open end to the free space the average VSWR is less than 2 and the input impedances are almost the same while the tube length is changed. However, when the open end is replaced by a conical closed

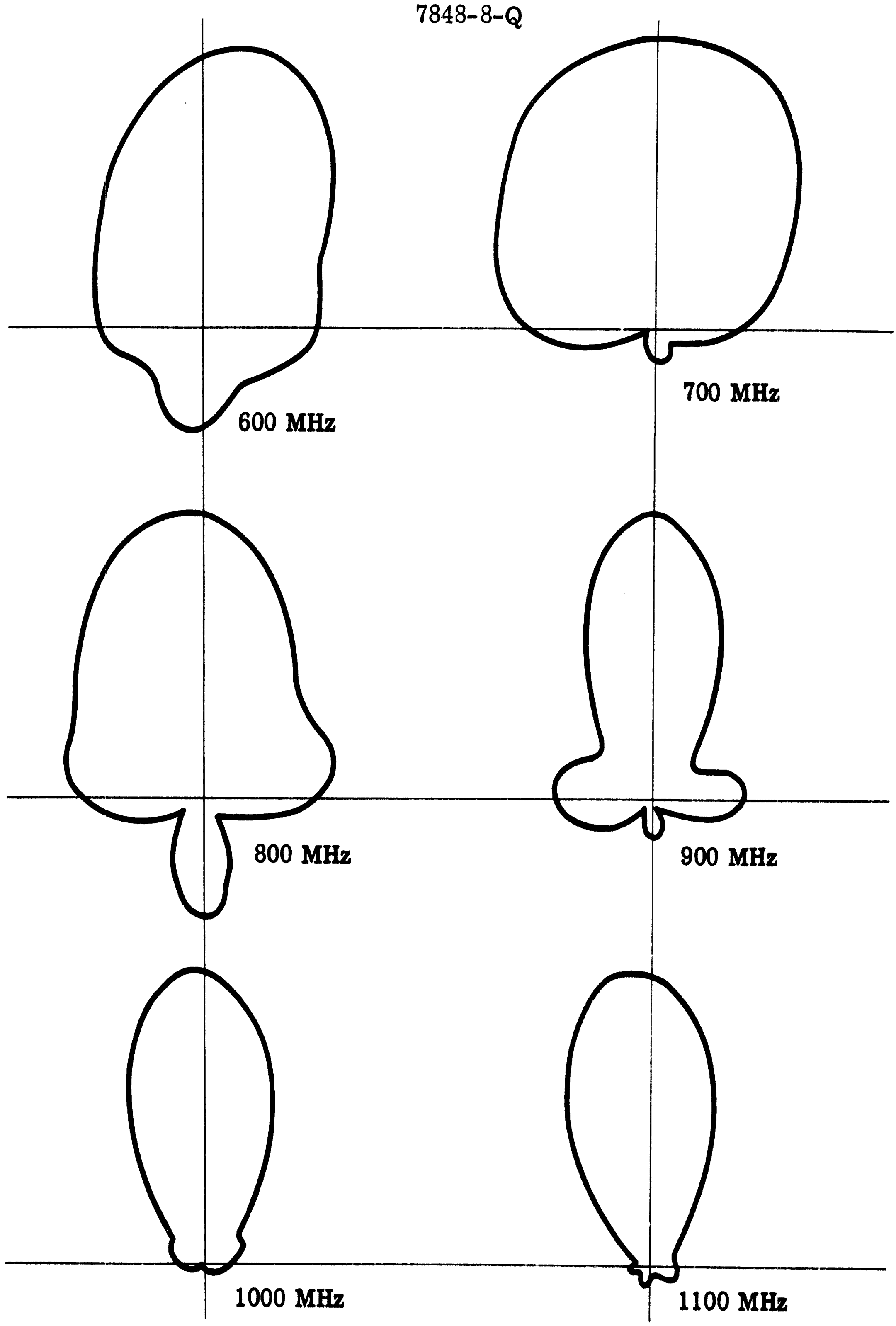


FIG. 4-6: LINEAR POWER PATTERNS FROM THE DIPOLE EXCITED METAL CUP WITH THE BALSA WOOD CORE AND THE PHENOLIC SHELL WITHOUT EAF-2 FERRITE POWDER.

(a) $|E_\theta|^2$ Plot in E - plane.

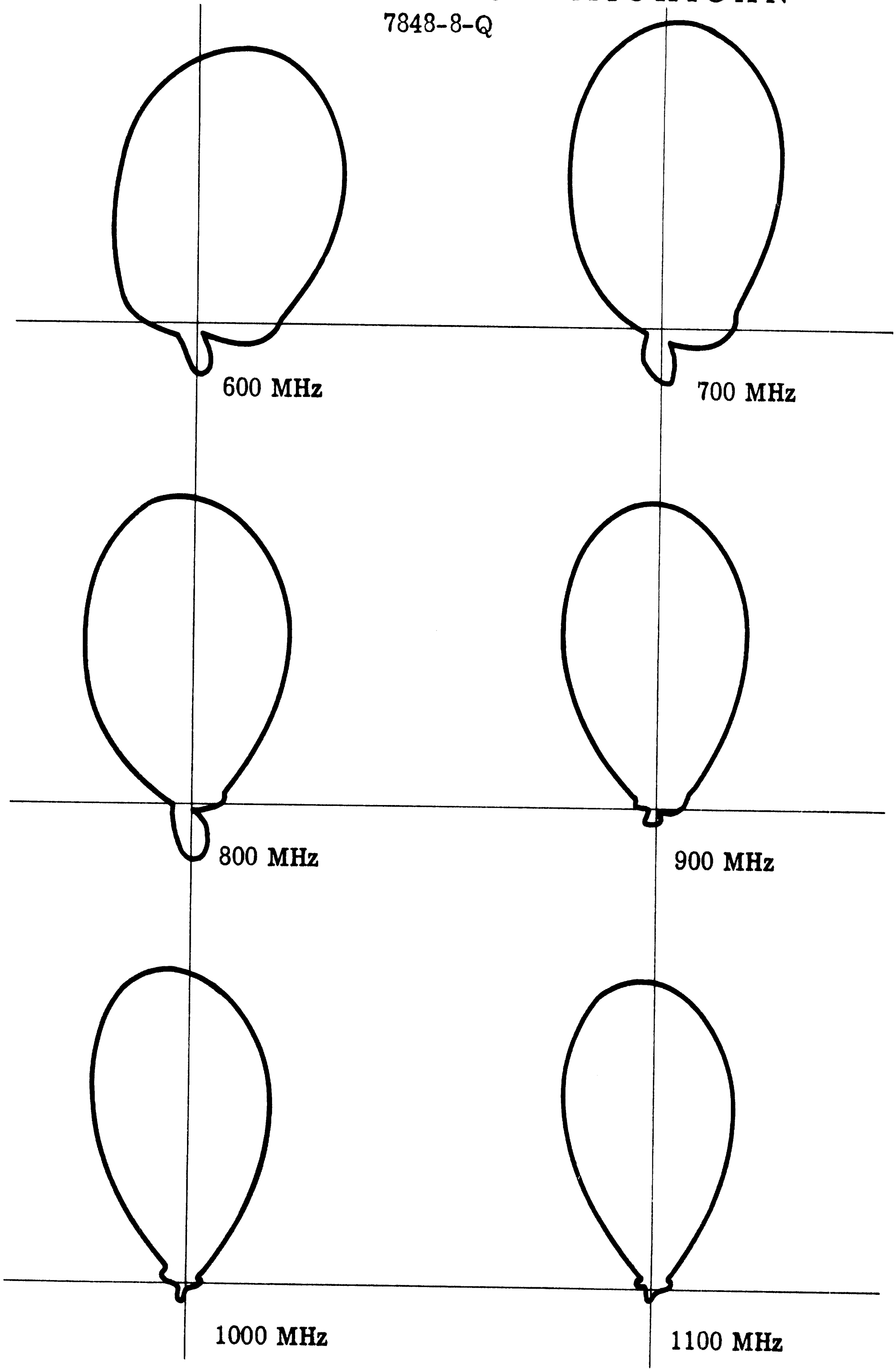


FIG. 4-6: LINEAR POWER PATTERNS FROM THE DIPOLE EXCITED METAL CUP WITH THE BALSA WOOD CORE AND THE PHENOLIC SHELL WITHOUT EAF-2 FERRITE POWDER.

(b) $|E_{\phi}|^2$ Plot in H-plane.

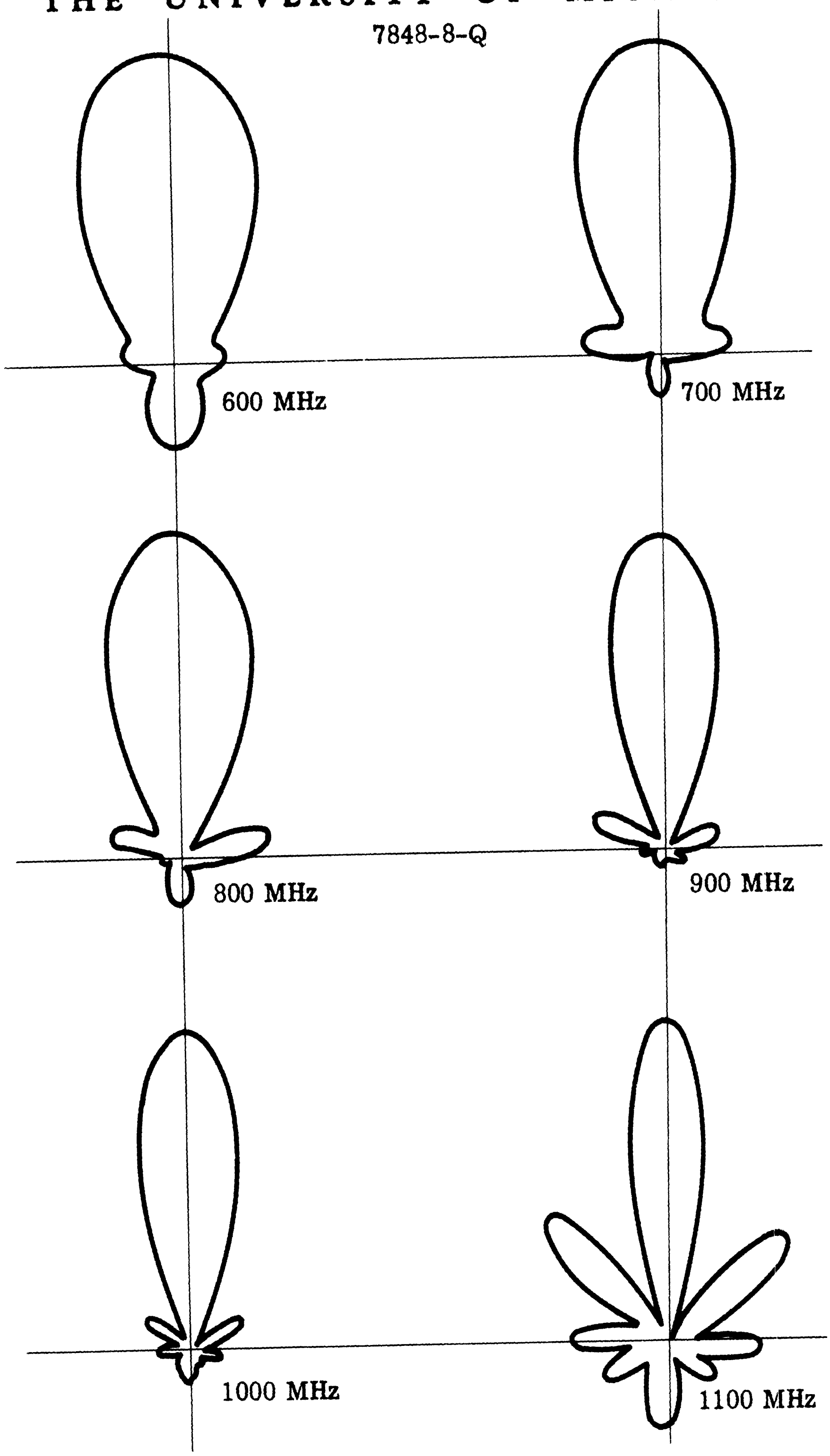


FIG. 4-7: LINEAR POWER PATTERNS FROM A DIPOLE EXCITED FERRITE TUBE.

O.D. = 15 cm I.D. = 11.25 cm Length = 38 cm

(a) $|E_\theta|^2$ Plot in E - plane.

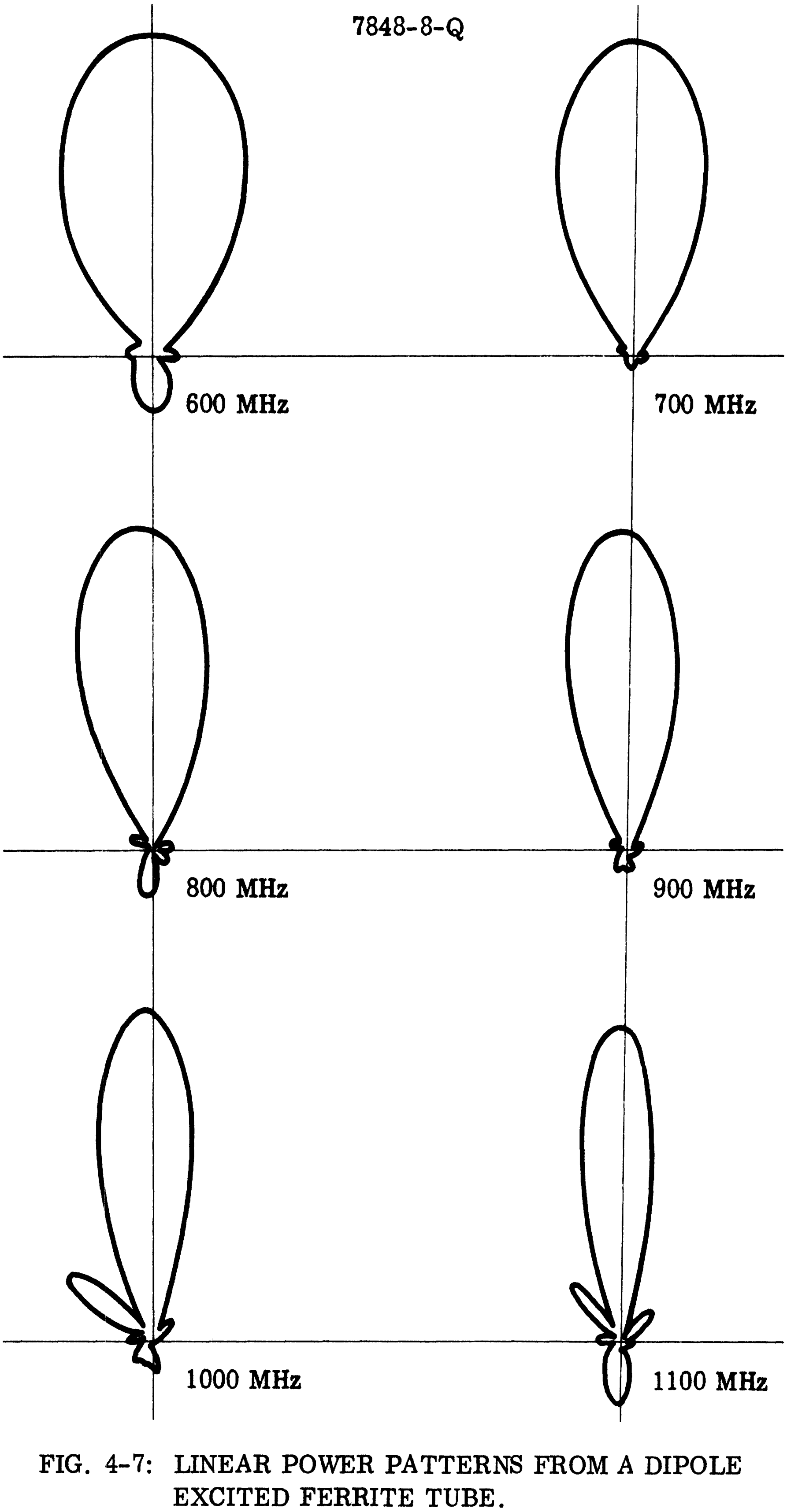


FIG. 4-7: LINEAR POWER PATTERNS FROM A DIPOLE EXCITED FERRITE TUBE.

(b) $|E_{\phi}|^2$ Plot in H-plane.

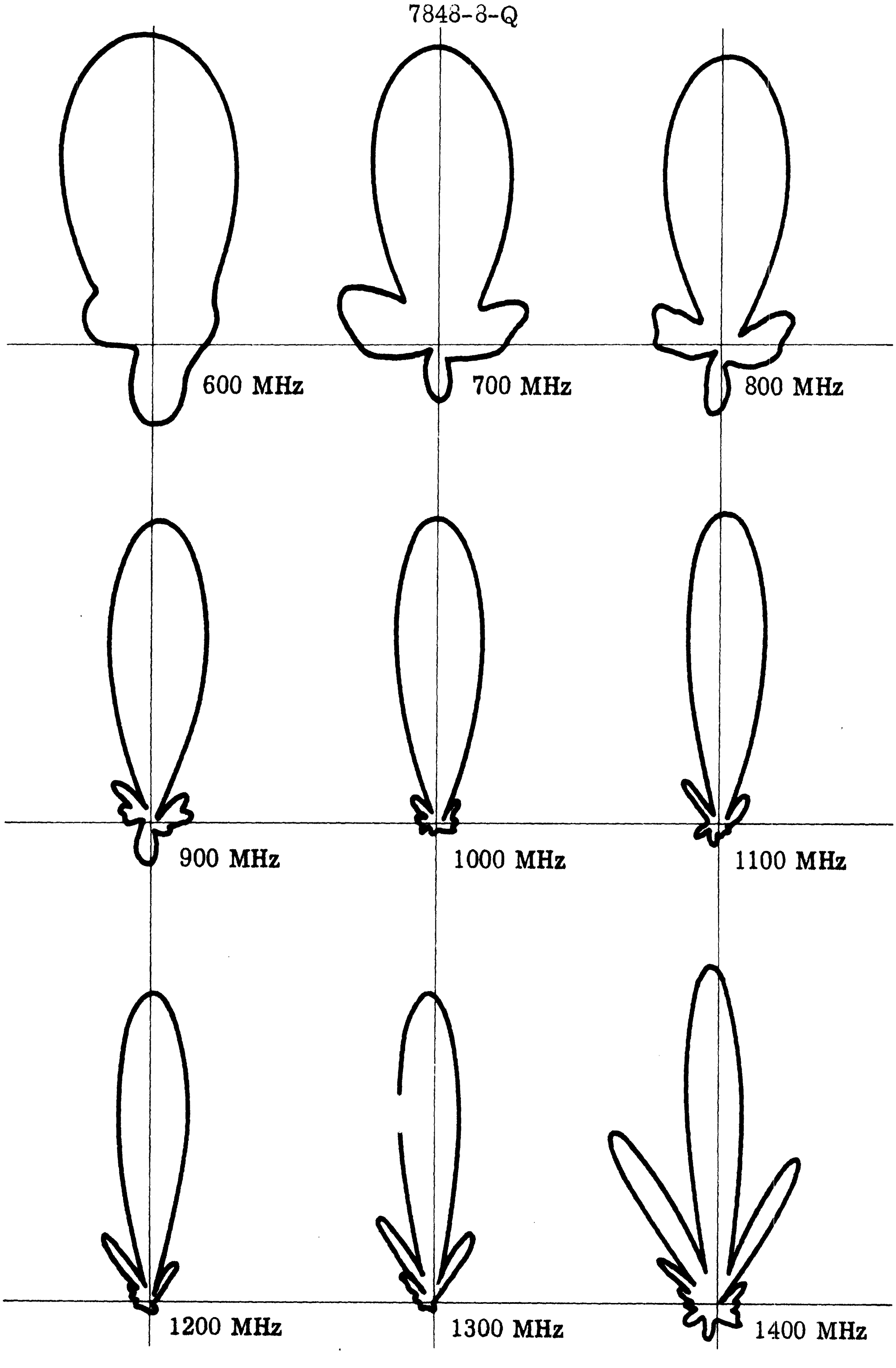


FIG. 4-8: LINEAR POWER PATTERNS FROM A DIPOLE EXCITED FERRITE TUBE.

O.D. = 15 cm I.D. = 13.5 cm Length = 71.5 cm

(a) $|E_\theta|^2$ Plot in E - plane.

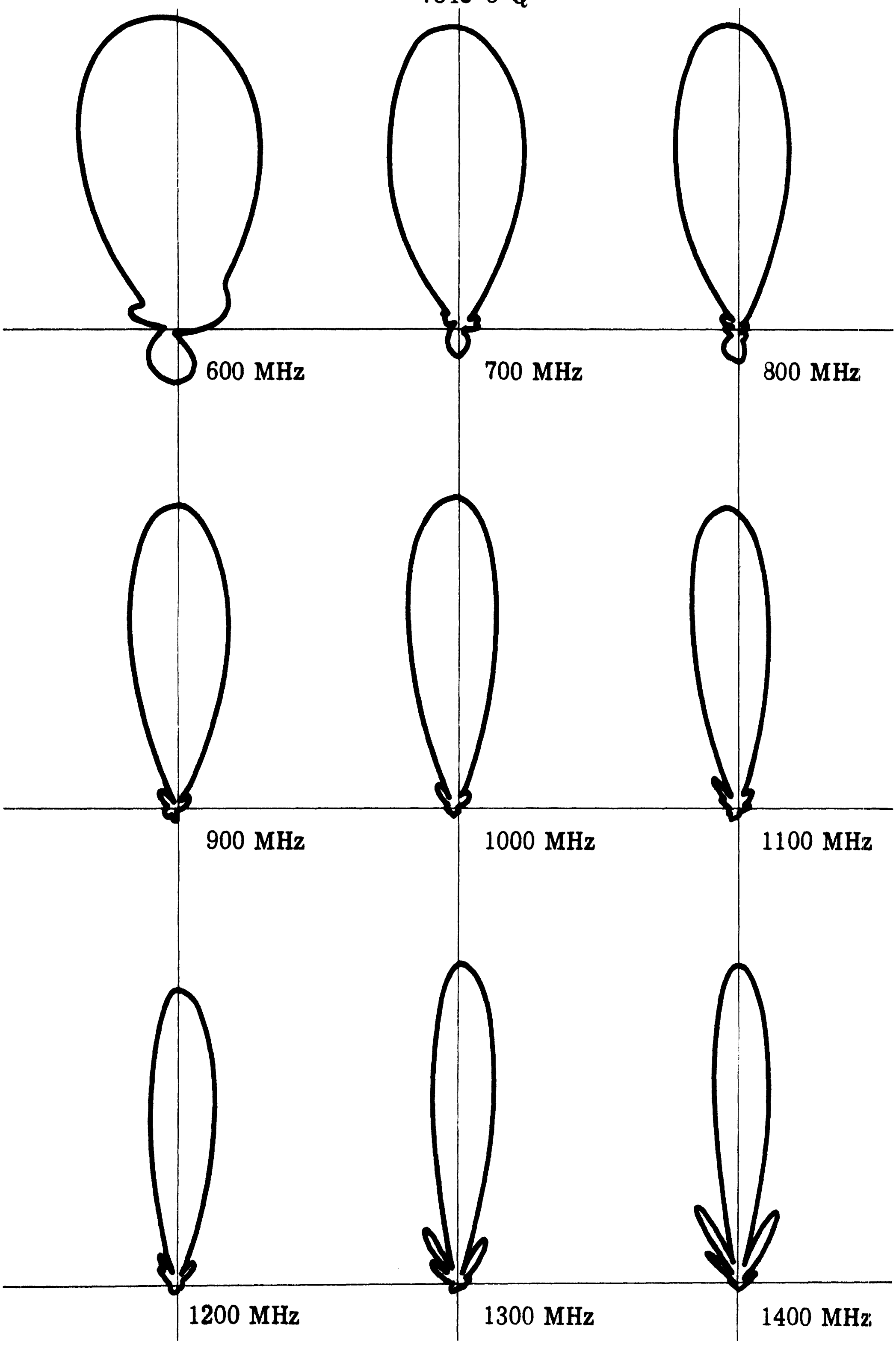
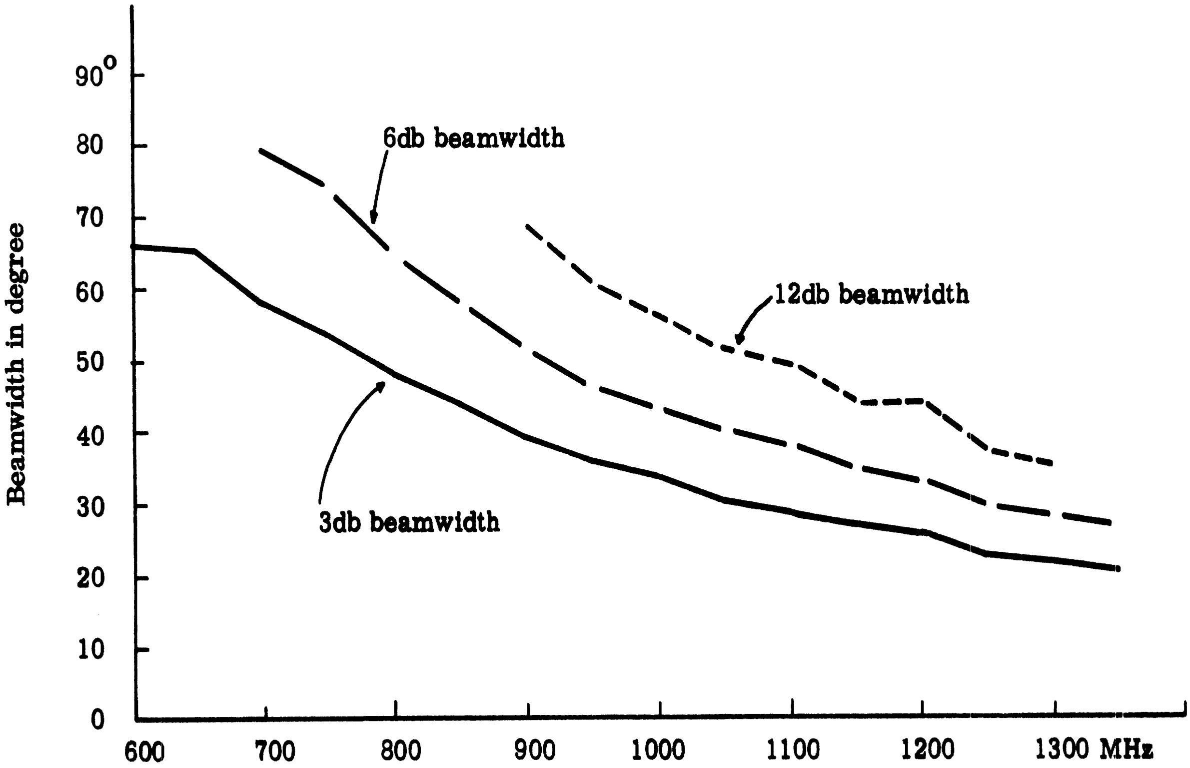


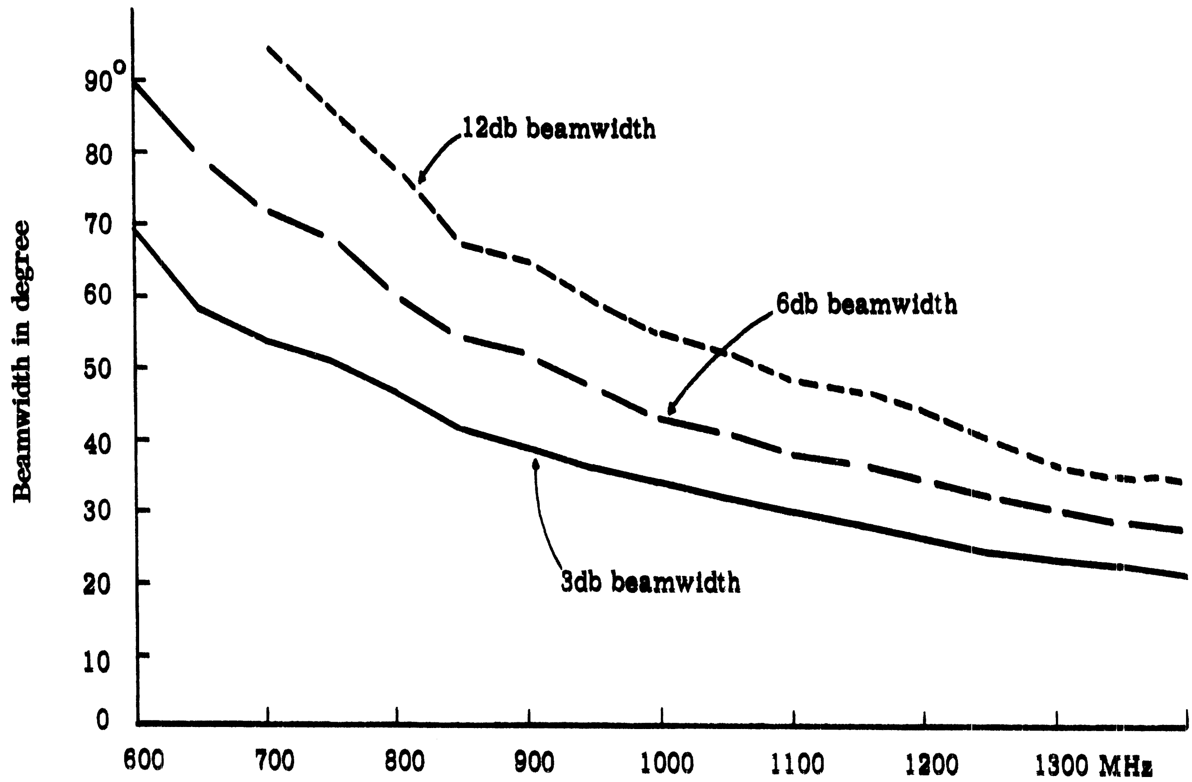
FIG. 4-8: LINEAR POWER PATTERNS FROM A DIPOLE EXCITED FERRITE TUBE.

(b) $|E_\phi|^2$ Plot in H-plane.



(a) E - plane

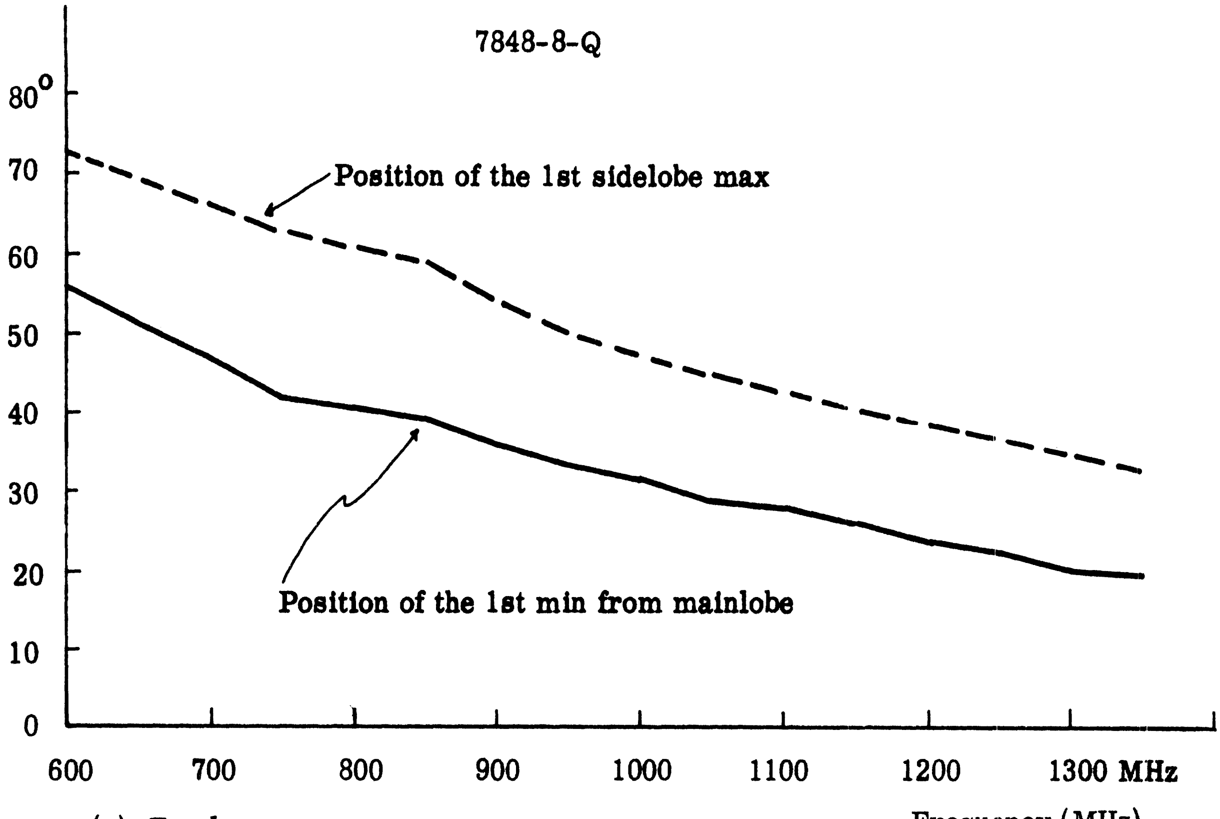
Frequency (MHz)



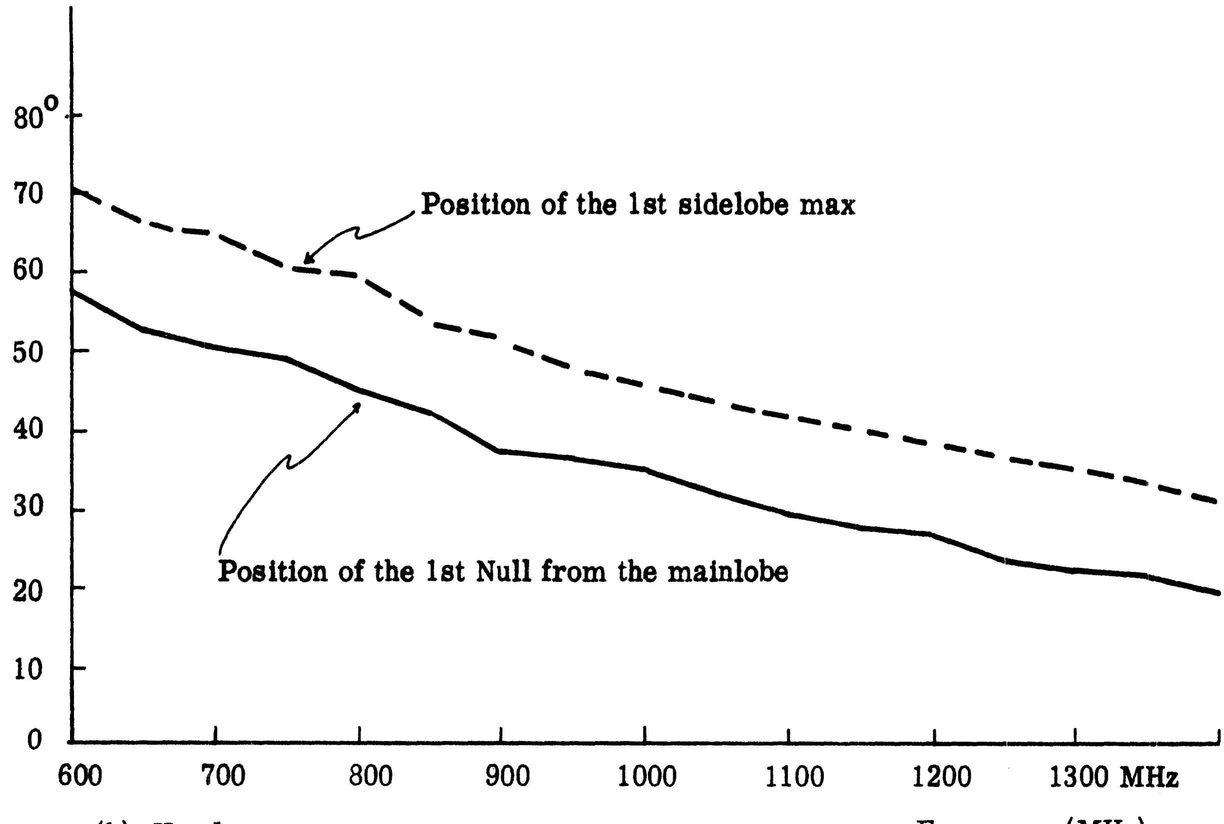
(b) H - plane

Frequency (MHz)

FIG. 4-9: VARIATION OF BEAMWIDTH WITH FREQUENCY.



(a) E - plane



(b) H - plane

FIG. 4-10: POSITION OF FIRST SIDELOBE VARYING WITH FREQUENCY.

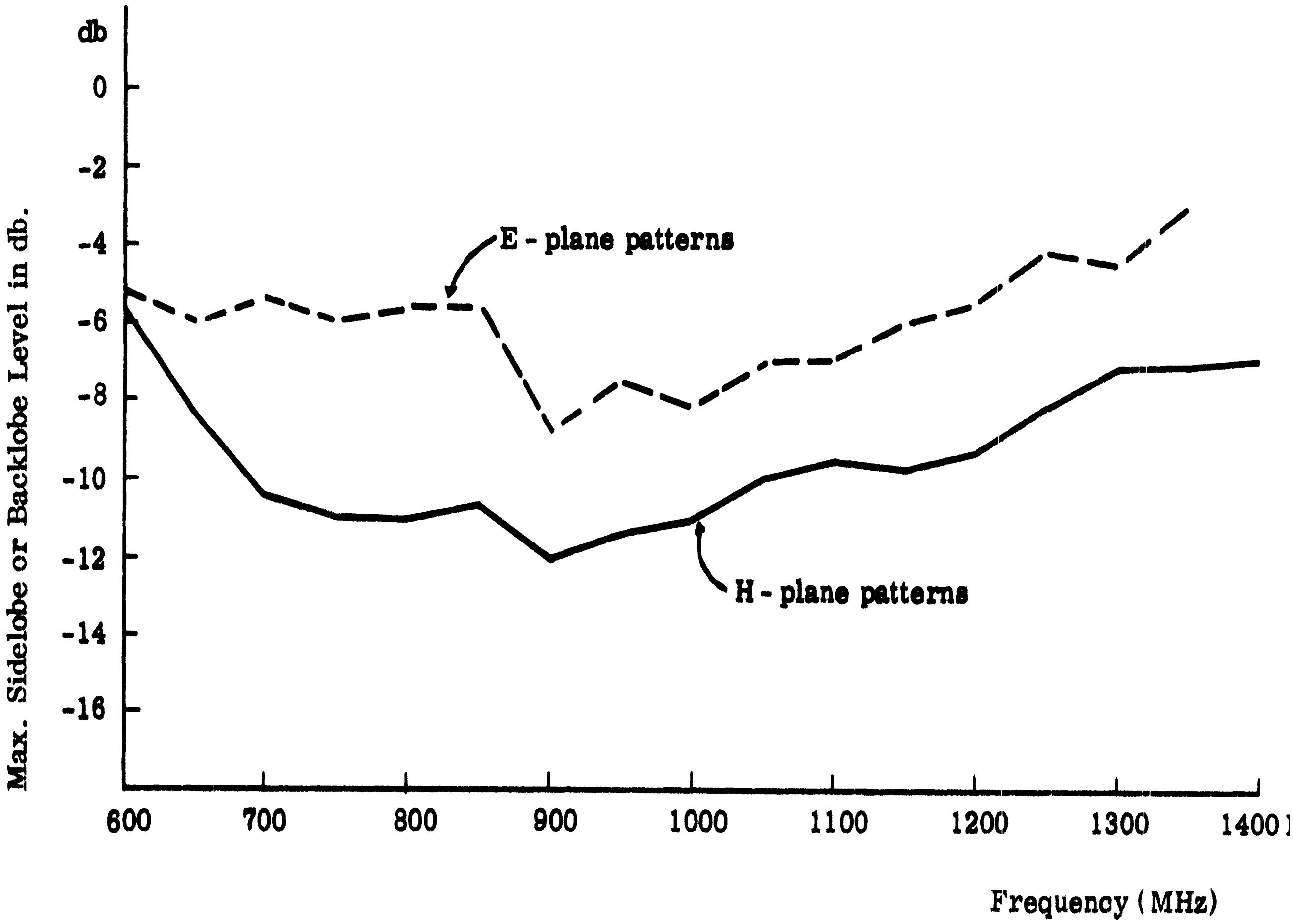


FIG. 4-11: MAXIMUM SIDELOBE OR BACKLOBE LEVEL VS FREQUENCY.

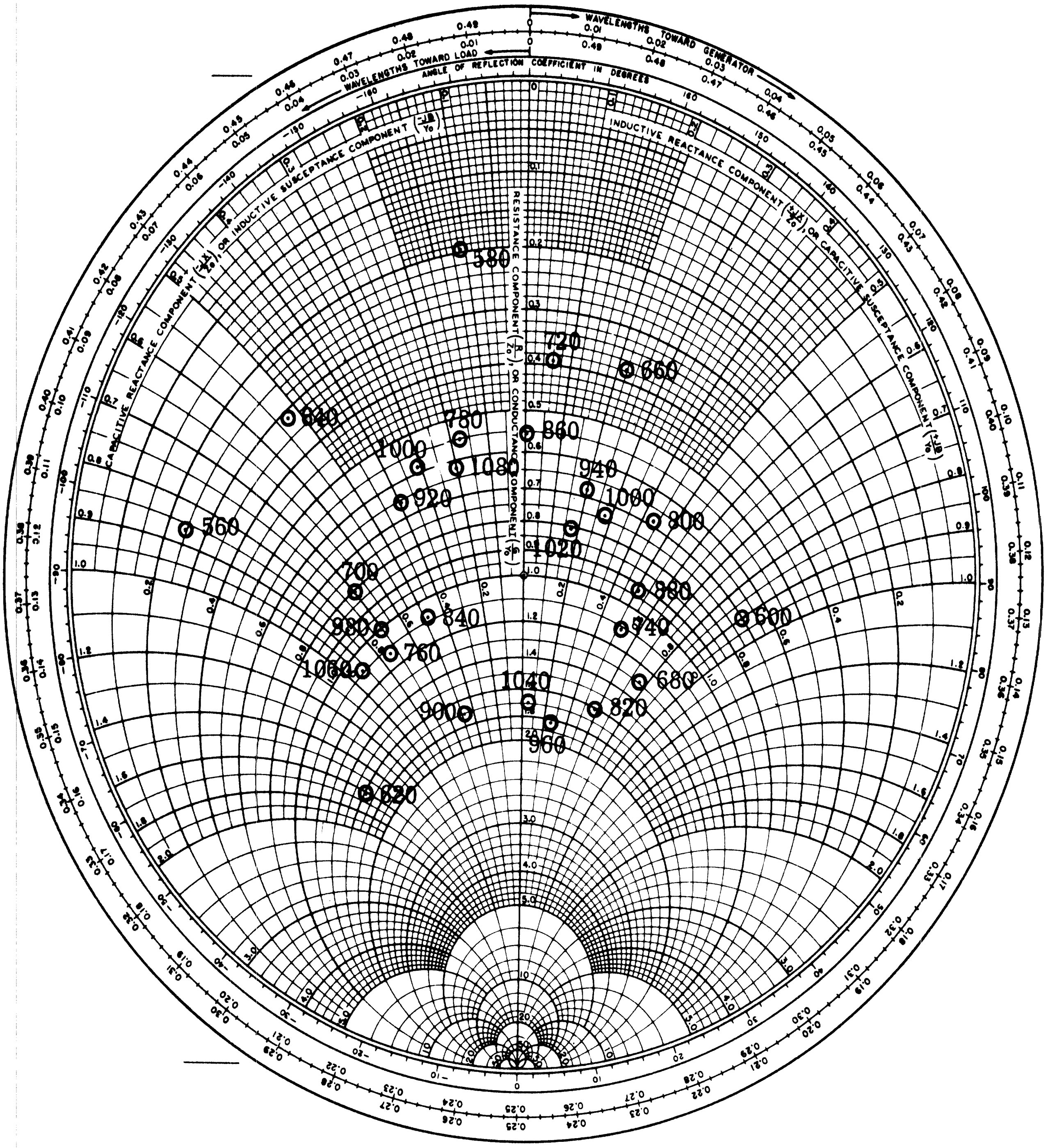


FIG. 4-12: INPUT IMPEDANCE OF THE DIPOLE EXCITED FERRITE TUBE ANTENNA.

O.D. = 15 cm   I.D. = 13.5 cm   Length = 36 cm

(Referenced to 50 ohms)

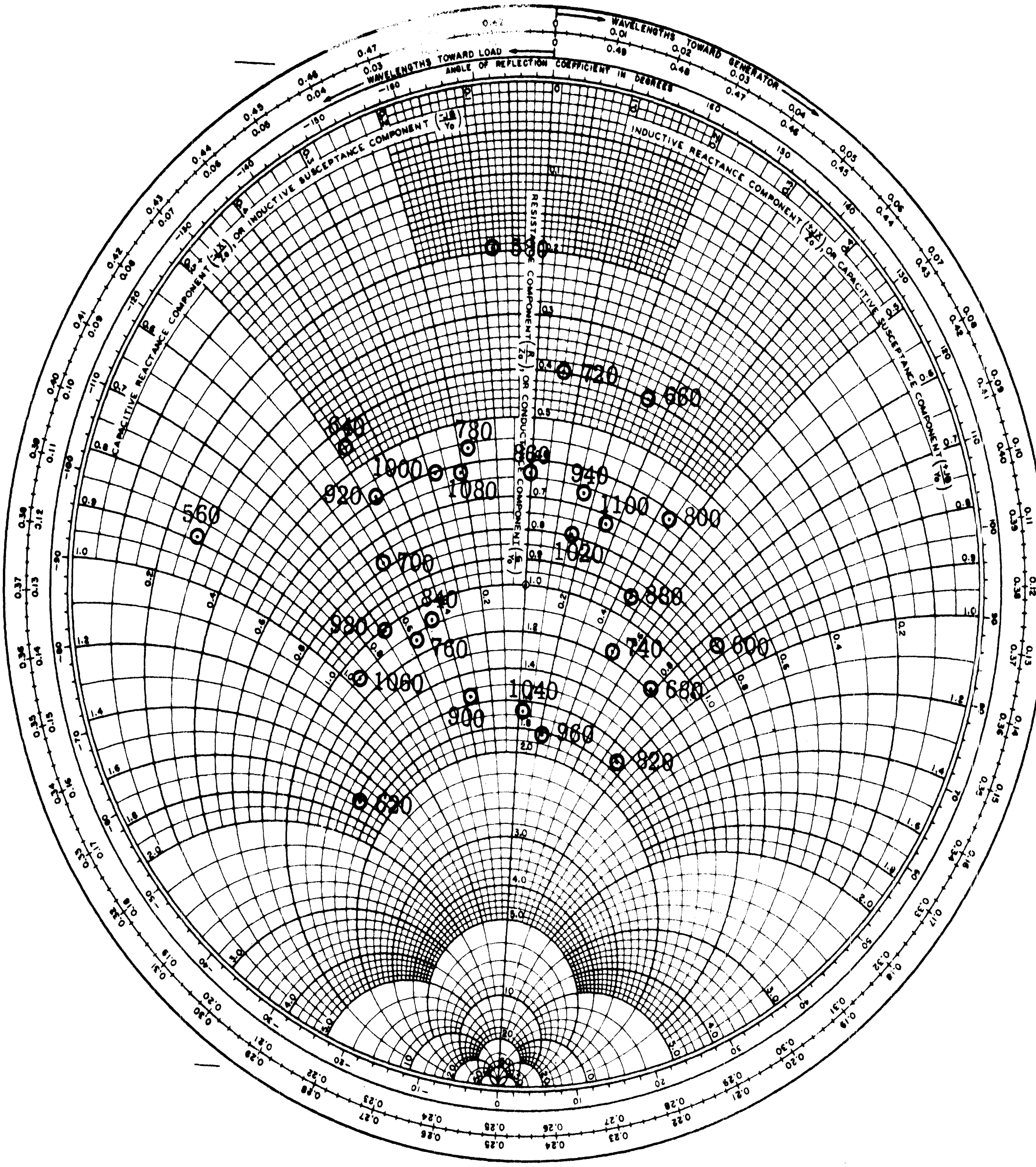


FIG. 4-13: INPUT IMPEDANCE OF THE DIPOLE EXCITED FERRITE TUBE ANTENNA.

O.D. = 15 cm I.D. = 13.5 cm Length = 71.5 cm

(Referenced to 50 ohms)

end the average VSWR will increase to 3.5 and about 30 percent of the incident input power is reflected.

V

LOW FREQUENCY FERRITE ANTENNAS

The objective of this task is to investigate the design feasibility of new types of ferrite antennas that are usable at frequencies as low as 30 MHz. An effort has been made to identify realistic applications of ferrite loading to linear radiating elements. Accordingly, the investigation has focused upon applications which improve the performance of antennas that are relatively small. The range of sizes considered is $0.1\lambda < 2h < 0.5\lambda$, where λ = free space wavelength, and h = element half-length. The low end was chosen so as to avoid severe supergain limitations in element performance, while the high end was considered to be a practical size limit for a loaded 30 MHz element. Moreover, the detailed discussion is limited to center fed (or ground plane imaged) elements which support standing wave current distributions.

Some inherent advantages of applying static biasing fields to various material loaded linear radiating structures have been discussed in previous reports (Lyon et al, 1967a, b). In particular, it has been shown that a small diameter helix may be tuned by applying a magnetic field to its ferrite core. This tuning results from an ability to control the helical structures axial phase velocity. Due to a fundamental limitation on the percentage change in phase velocity, effort has been directed toward obtaining an optimum utilization of this phase velocity control. Accordingly, a more detailed analysis of the multiple resonance behavior of composite slow wave structures (Lyon et al, 1967a) has been undertaken.

The interesting features of a composite slow wave structure are: (a) the ability of the structure to generate multiple resonances, and (b) the sensitivity of the locations of resonance upon the structure's controllable phase velocity. An approximate theoretical model was previously presented which described the dominant reactance behavior for the special case of two dissimilar slow wave structures. An improved formulation based upon the EMF method is presently being developed which describes the input impedance for the general case of an arbitrary number of dissimilar structures. The EMF formulation has two advantages: (1) the reactance variations are described more accurately, thereby allowing a better determination of the resonant frequencies, and (2) the method furnishes information about the input resistance. Having a reliable formulation for the input impedance should allow a precise assessment of the tuning capabilities resulting from continuous phase velocity control.

The status of the EMF formulation is discussed below. Since the derived expressions are more illuminating when compared with prior work, the details will be presented in the final report. The accuracy and usefulness of the EMF method depends heavily upon the extent to which the assumed current distribution is realistic, and also the ease with which the resulting integrals may be evaluated. Following the long established approach used for the familiar linear dipole, the approximate current distribution for the composite slow wave structure is obtained from the solution of an analogous uniform transmission line problem. From the resulting current distribution, the magnetic vector potential is obtained, thereby leading to a determination of the electric field. The electric field expression contains integrals which must in turn be integrated against the assumed current distribution in order to obtain the input impedance. Such an evaluation appears possible for relatively thin structures. The evaluation depends upon forming a rapidly convergent series expansion of the integrand and retaining after integration the leading terms. This method also permits an extension of the single structure result to cover element half lengths greater than $\beta_s h = \pi$, which was a prior restriction.

VI

CONCLUSIONS

Currently, it appears that the log conical spiral antenna design required under Task I can be completed with conformance to the requirements as stated in the contract. The experimental data presented in this report indicates satisfactory performance for the simultaneous operation of this type of antenna both in transmitting and receiving. Information now available indicates that a log conical spiral antenna suitable for operation in the region from 200 - 600 MHz can be achieved with a substantial reduction in size.

The results on Task II described in this report indicate that the ferrite loaded slot elements which have been designed and built are entirely satisfactory for incorporation in an array of three elements. On the basis of this small array, certain deductions can be made upon the advantages of elements of reduced size being incorporated in an array.

The work to date on the ferrite loaded endfire rod antennas as in Task III has indicated that it is appropriate to use ferrite loaded tubes. The tube construction appears to produce better characteristics including better efficiency as a radiator.

Under Task IV, certain selections of types to be studied have been made. In this report a brief description has been given showing the attractiveness of using a composite slow wave structure as a radiating element. In particular, the study has been on a dipole utilizing sections which have different phase velocities. Final conclusions have not been reached since the analysis is still in progress.

VII

FUTURE EFFORT

In the next few weeks it is anticipated that each of the four tasks of this contract will be brought to reasonable conclusions. Some of the natural extensions of the work described in this report will not be covered in this section since such work will be part of a follow-on contract effort.

Under the present contract, the main future effort will be devoted to preparing a complete final report indicating the accomplishment under each area of study. It is believed that Task I will be sufficiently covered in the final report so that the studies in this area can be considered to be complete. It is believed that the objectives of this task will be met fully.

Under Task II, the study of arrays of elements of reduced size, additional experimental work will be undertaken during the remaining part of the contract. It is intended that this experimental work will give information on the advantages of such small elements with respect to mutual coupling and driving point impedance. It is anticipated that additional work in this general technical area will be covered in a follow-on contract to commence in the fiscal year 1969.

Under Task III, it is expected that the boundary value problems dealing with the ferrite filled tube radiator will be substantially complete at the end of the present contract period. However, it is expected that there will be further work on this general type of radiator including a study of the input impedance characteristics of such a radiator.

The study on antenna types at frequencies as low as 30 MHz as under Task IV, has continued to give useful information on appropriate techniques for relatively small antennas in this frequency range. In the next few weeks the information on this subject will be assembled so as to provide ready access. It is expected that there will be a continuation in this general technical area including further work on helically wound, partially ferrite loaded elements.

REFERENCES

Adams, A.T.(1964) "The Rectangular Cavity Slot Antenna with Homogeneous Isotropic Loading," Cooley Electronics Laboratory Technical Report No. 147.

Adams, A.T.(1967) "Flush Mounted Rectangular Cavity Slot Antennas--Theory and Design," Trans. IEEE, AP-15, No.3, 342-351.

Beam, R.E., et al (1950) "Investigations of Multi-mode Propagation in Waveguides and Microwave Optics," Northwestern University Microwave Laboratory Report AD94929.

Duncan, J.W. and R.H. DuHamel (1957) "Launching Efficiency of Wires and Slots for a Dielectric Rod Waveguide," University of Illinois Technical Report No.24.

Lyon, J.A.M., C.C. Chen, E.S. Greene, J.C. Parker and D.L. Smith (1967a) "Study and Investigation of a UHF-VHF Antenna," The University of Michigan Radiation Laboratory Report No. 7848-8-Q, UNCLASSIFIED.

Lyon, J.A.M., C.C. Chen, J.C. Parker and D.L. Smith (1967b) "Study and Investigation of a UHF-VHF Antenna," The University of Michigan Radiation Laboratory Report No. 7848-7-Q, UNCLASSIFIED.

Rassweiler, G.G.(1967) "Helical and Log Conical Helical Antennas Loaded with an Isotropic Material," University of Michigan Radiation Laboratory Report No. 7848-3-Q, UNCLASSIFIED.

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13. ABSTRACT

This report covers the work in four task areas of the project for a three-month period. All tasks have involved considerable analysis as well as experimental procedures. Machine computation has been used extensively in Task 3 dealing with ferrite rod antennas. Since the final report on this contract will be prepared very soon most of the detailed analysis and computer data have been reserved for inclusion in that report. This quarterly report serves primarily to indicate the directions of effort in each of the 4 task areas. The report also indicates in a somewhat qualitative way the results obtained.

Under Task 2, some experimental data have been obtained on slot arrays using ferrite loaded slots. Under Task 3, a considerable amount of experimental data has been obtained on ferrite tube antennas. In the other 2 tasks, one involving ferrite loaded conical spirals and the other low frequency ferrite loaded antennas, the continued progress of the efforts in these areas is reported.