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STUDY AND INVESTIGATION OF UHF-VHF ANTENNAS

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ABSTRACT

This second quarterly report indicates the effort devoted to each of the four assigned tasks of this project. Preliminary design considerations have been undertaken in Task 1 which requires a conical spiral antenna of very much reduced physical size. In order to meet specific performance requirements some time has been devoted to arrangements for experimental facilities. Power sources each with an output over a 100 watts at specified frequencies within the range 200 - 600 MHz have either been made or are in a state of preparation.

Under Task 2, an array consisting of interdigital slots is being adapted for ferrite loading, initial studies have emphasized beam pattern and gain. At this point, further work on magnetic tuning and bandwidth are being started.

Under Task 3, some mathematical studies of endfire ferrite rod antennas suitable for the range 300 - 1000 MHz have been started. The determinantal equation corresponding to the boundary value problem is being subject to computation through the use of a computer.

Under Task 4, a broad view as to approaches for ferrite loaded antennas capable of operating as low as 30 MHz has been taken. The cubical quad antenna has been one selected for fairly intensive detailed studies under loading conditions.

I

INTRODUCTION

During this report period, progress has been made in each of the four tasks areas specified under the contract. Some of this effort has been by way of preliminaries occasioned by the detailed requirements of the contract. For instance it has been necessary to make provisions for power sources in order to adequately test the conical spiral antenna in Task 1. Other work of a general nature included modifications to the pattern range to facilitate the experimental work required under Task 1 on the conical spiral antenna, Task 2 on the ferrite slot array antenna, and Task 4 on the antennas useful at 30 MHz and utilizing ferrite loading. Studies on Task 4 impose a fairly difficult range problem which is being solved through the use of a new ground range station which utilizes the ground reflection and directs a beam up to the rotator on top of the Fluids Building.

A major part of the effort has been put on Task 1 involving the conical spiral antenna. Each design requirement has been examined in terms of the known theory of conical spirals together with the modifications of such theory occasioned by the use of ferrite loading. Detailed studies of impedance measurements on bifilar complementary helical antennas are shown in an accompanying section. Studies on a helical antenna are considered fundamental to an understanding of the operation of conical spiral antennas. A discussion of the major effects of ferrite loading of conical spiral antennas is also given in an accompanying section.

Under Task 2, further analysis has been given to possibilities of using loading on an interdigital array of slots. Also, some effort has been devoted to the obtaining of a more sophisticated method of magnetic tuning on slot arrays. During this report period, some delay has been occasioned on this task due to modifications of the antenna range. For this reason, a separate section is not devoted to Task 2 but only this brief indication of progress is made.

Endfire ferrite rod antennas as described in the requirements for Task 3 are being studied by first utilizing a boundary value solution of the electromagnetic problem and the resulting determinental equation. The equation which has resulted has then been subject to numerical analysis using the 7090 computer. A separate sectio indicates briefly the scope of the mathematical analysis which is not new. However, the numerical methods are being extended to the appropriate range of parameter values. A simple ferrite rod radiator utilizing a cylindrical retaining form to properly confine EAF-2 ferrite powder as a core is being planned. It is anticipated that initial tests will be available at the end of the next report period.

Under Task 4, various types of antennas which are possibly suitable for ferrite loading and which also show promise of use down as low as 30 MHz are being considered. A broad scale approach is advocated. One of the specific antennas used for further study is the familiar cubical quad antenna. As indicated in the literature these antennas have previously been used where the size was reduced through the use of a lumped inductance at appropriate positions. Reference is made to this in the appropriate section. One of the most promising possibilities of the studies of the cubical quad antenna under loading situations as described briefly under Task 4, is that it may offer a possibility of use under Task 1. The only part of the cubical quad which might be pertinent to Task 1, would be the use of a tuned reflector loop at the lowest frequency of a conical spiral. This project has found through its previous experience a need to absorb or redirect energy at the low frequency end of a conical spiral antenna. The use of a single loop which had been tuned to the appropriate frequency and reduced in size with ferrite loading would be useful for application at the low frequency end of the conical spiral. This means, in effect, a single resonantly tuned loop using ferrite loading may be a very important adjunct to the conical spiral antenna described in Task 1.

II

LOADED CONICAL SPIRAL ANTENNA

2.1 Task 1 Requirements

The size requirements for the antenna to be developed are listed in Table II-1. The assumption is made that "length" means the height of the cone and "base diameter" means the diameter of the bottom of the active region. This assumption makes the requirements of the contract consistent.

TABLE II-1

SIZE REQUIREMENTS OF THE ANTENNA

	Lowest Frequency (200 MHz)	Highest Frequency (600 MHz)
Length	0.4λ (60 cm.) max.	1.3λ (65 cm.) max.
Base Diameter	0.14λ (21 cm.) min.	0.3λ (15 cm.) min.

Thus, it is quite obvious that the cone describing the antenna should have a diameter at the base of 21 cm and a height of 60 cm.

2.2 Methods of Loading

From previous project experience with loaded conical helix antennas, the following conclusions can be drawn: 1) Only the diameter can be effectively reduced by ferrite loading, not the length; 2) The wrap angle of the conical helix must be increased with loading. These conclusions apply when the radiation patterns of the loaded and unloaded antennas are to be the same. Condition number one is the more important of the two. Usually, the effect of not increasing the wrap angle is not too great .

Using published design curves (Dyson, 1965, page 37) for the conical log-spiral, and basing the design on the a_{10}^{+} curves, a prediction can be made on what the patterns of this antenna shouldbe, assuming a uniform loading of ferrite throughout the center of the antenna.

The loaded antenna would have radiation patterns equivalent to an unloaded conical helix with a cone angle of 55° and with the same height. This means that the patterns would probably have a half-power beamwidth of about 70° to 90°, (depending on the wrap angle) with a variation of about 40° from this average over the frequency of operation of the antenna. This would give an approximate directivity of 6 or 7 db. Efficiency measurements conducted on helix antennas indicate that the gain of the loaded antenna should be about 3 to 4 db. (Lyon, et. al, 1966). In comparing the diameters of the proposed antenna with that of its unloaded electrical counterpart, the reduction factor is found to be 0.365. This is a worthwhile reduction factor.

There appear to be three possible techniques of using ferrite material to make an antenna of the desired size operate over the frequency range of 200 to 600 MHz: 1) Full or partial loading of the antenna with ferrite material; 2) Surrounding the wire of the winding with a jacket of ferrite having a circular cross-section; 3) Usin ferrite toroids as lumped inductances approximating continuous inductances so that the phase and group velocities are slowed down on the antenna structure.

The first method should work provided that the multiplicative reduction factor $\sqrt{\frac{1 + \frac{1}{\mu_r}}{1 + \epsilon_r}}$ is precise enough for ferrites whose product of μ_r and ϵ_r is greater than 10 (Hong, et al, 1966). If this formula, developed by this project group, is valid, several Emerson and Cuming microwave absorber materials appear to be promising loading materials. Published material for Eccosorb MF-124, 117, 116, 114 indicate they have high enough μ_r and ϵ_r to accomplish the reduction. The MF-124 may be too lossy, but certainly the MF-114 should not be.

The second method, surrounding the wire of the winding with a coating of ferrite, could offer a light-weight way of obtaining a small conical helix. Loading helix antennas with thin layers of ferrite placed inside the windings indicates that even thin layers of ferrite can give a substantial part of the reduction obtained with full core loading. (Lyon, et al, 1966). This indicates that the energy on the antenna structure is very closely bound to the windings until it reaches the active zone. Other experimental evidence points to this same conclusion. Thus, removing the ferrite material from in between the windings, except for that next to the wires themselves, should give essentially the same result as a thin loading. In effect, this would be coating the wire with a ferrite.

The third method is using ferrite toroidal cores with windings to form lumped inductances that are inserted in series with the winding of the antenna. A simplified model of the conical helix antenna is that the antenna consists of a transmission line which radiates at a certain point when successive turns are in phase. Using this model, it follows that if the phase velocity of the transmission line can be slowed down by a certain factor, the linear dimensions of the antenna can be reduced proportionately.

If the equations for an ideal transmission line are solved for the inductance per unit length (L) and capacitance per unit length (C) in terms of the characteristic impedance (Z_o) and the phase velocity (V_p), the following expressions result: $C = (1/Z_o)V_p$ and $L = Z_o/V_p$.

It follows that if the antenna size is to be reduced by a factor R and the capacitance is to remain unchanged, then the inductance per unit length must be changed by L/R^2, where L is the original inductance per unit length. In addition, the characteristic impedance will be increased to Z_o/R. (Note, since R is the ratio of the lineal dimensions of the loaded to the unloaded antenna, R is always less than one.)

2.3 Antenna Impedance

To specify the inductance to be added, the characteristic impedance must be known. There are three ways of determining the characteristic impedance, Z_o: 1) by measuring the input impedance of the antenna, 2) by measuring the output impedance of the antenna, 3) by comparing input impedance versus frequency data. The results given by all three are not consistent, however.

The measured input impedance of a conical helix antenna is generally around 100 to 200 ohms. Usually, this input impedance decreases as the active region moves farther from the tip. This last result, however, seems inconsistent because as the active region moves away from the tip, the spacing between the windings increases, and therefore the characteristic impedance should increase. Indeed, measurements made by the Radiation Laboratory indicate that the latter is the case. The necessary terminating impedance turned out to be about 2000 ohms when measured by attempting to terminate the windings of a conical helix operating below its lower cut-off frequency in the resistance that would give a minimum reflection of energy. Although 2000 ohms is probably an upper bound and 100 ohms a lower bound on the characteristic impedance, the amount of inductance necessary to accomplish the task will have to be determined by trial and error. Due to complexities of the network the terminating impedance does not correspond to the characteristic impedance; also, at the frequencies involved the resistors do not represent pure resistance.

2.4 Antenna Construction

To carry out experiments using methods one and two, two antennas are being built. The frame for each is a frustum of a cone having a diameter at the base of 21 cm. and a diameter at the top of 6 cm. The cone height is 60 cm. and the frustum height is 42.9 cm.

2.5 Task 1 Facilities

This contract requires 100 watts of power in the frequency range of 200 MHz. to 600 MHz. to the conical helix antennas. The maximum power available in this frequency range at this laboratory was 10 to 20 watts from an AIL type 124A Power Oscillator. It would be quite expensive to purchase a 100 watt oscillator to continuously cover this entire frequency band.

It was found to be economical to select three representative frequencies in the 200 MHz to 600 MHz range for tuned power amplifiers to provide 100 watts output. It was decided to use 250 MHz , 400 MHz , and 550 MHz. The 400 MHz and the 550 MHz amplifiers can be driven directly by the AIL power oscillator; the 250 MHz amplifier will need a separate oscillator with a few watts output.

The 400 MHz amplifier has been completed. The circuit design is similar to power amplifiers discussed in The Radio Amateur's V.H.F. Manual, published in 1965 by the Americal Radio Relay League. The amplifier is operated Class C, and needs only a few watts driving power, easily supplied by the AIL oscillator. The plate circuit uses a tuned cavity, and the tube is an inexpensive 7203/4CX250B. This forced-air cooled tube has a plate dissipation rating of 250 watts, which safely exceeds the required 100 watts. The circuit diagram of the 400 MHz amplifier is shown below in Fig. 2-1.

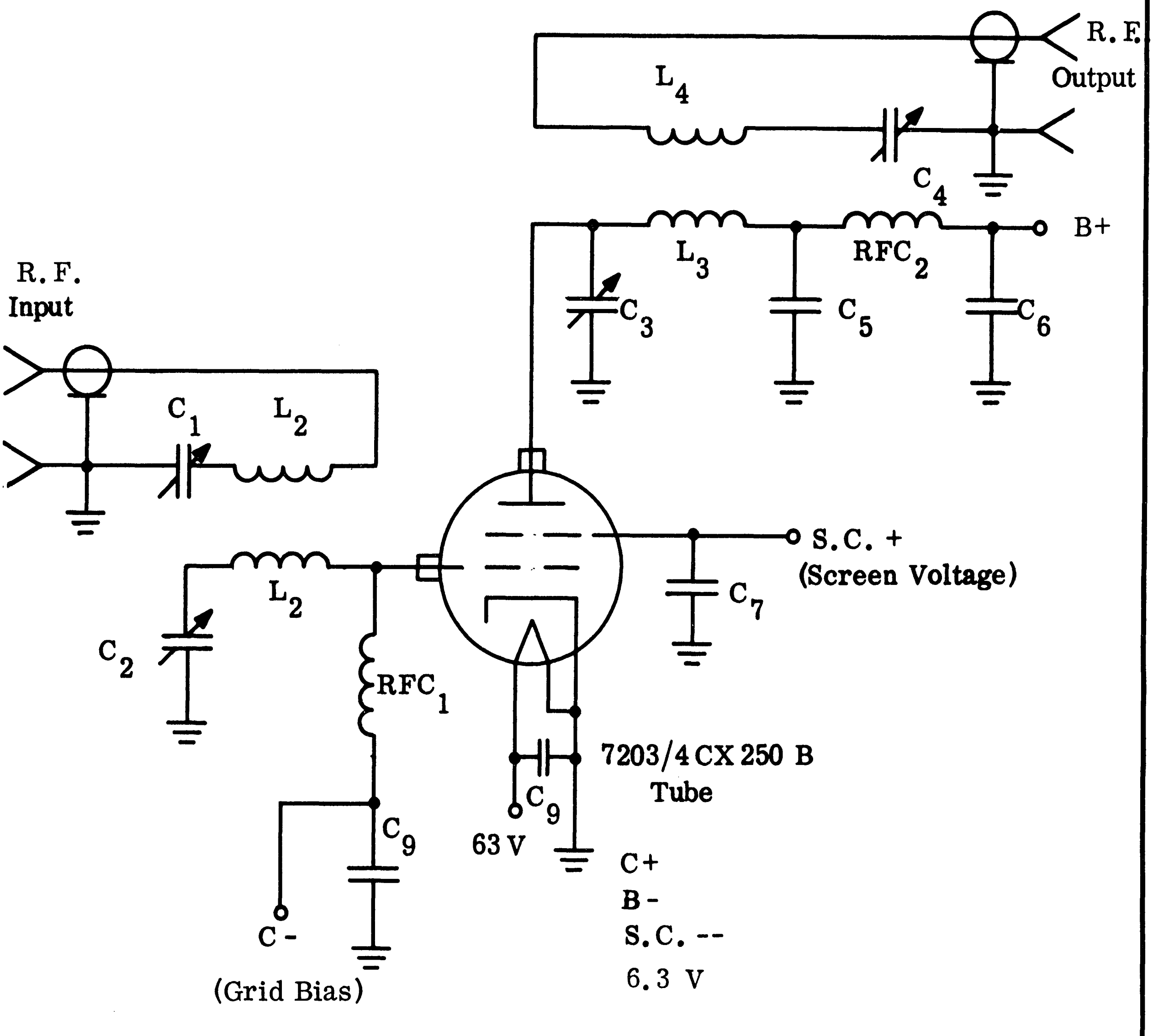


FIG. 2-1: 400 MHz AMPLIFIER

2.6 Backfire Bifilar Loaded Helix Antenna

The backfire bifilar loaded helix antenna has been analyzed to a considerable extent both theoretically and experimentally, although neither investigation can be considered complete. Such study is appropriate to the understanding of the loaded conical spiral antenna.

Both the sheath and tape models have been analyzed theoretically. The sheath model analysis has been reported by (Lyon, et al, (1966). Both full core and an inner shell loading were covered. The sheath mode analysis has some difficulties. Only one mode is considered, the "dominate" mode, in determining far field patterns. Also, only the slow wave zone of the k-β diagram can be calculated, and this must then be extrapolated linearly on the k-β diagram into the radiation zone. The sheath analysis indicates that a reduction factor of $\sqrt{\dfrac{\frac{1}{\mu}+1}{\epsilon+1}}$ can be expected with a full core interior loading in the slow wave zone, and thus presumably also in the fast wave zone.

The tape analysis for a full core loading has been completed, but the numerical results are not yet ready for presentation. However, some theoretical insight is already possible. The dispersion equation can be approximately written as two terms. One term roughly corresponds to the only term of the sheath equation, although some factors appear to be slightly different. The second term expresses the effect of the higher order modes of the helix that are necessary to match the boundary conditions of the tape conductor. The higher order modes appear to contribute the dominating effect on the phase velocity of the wave, as shown by the numerical solution to the dispersion equation. Thus, the solution to the dispersion equation for the sheath helix would appear to be in serious error where it does not correspond to the higher mode solutions. Nevertheless, in the slow wave region, the asymptotic behavior of both terms is that expressed by the reduction factor given above. Moreover, in the fast wave region, the reduction factor still applies because the higher modes behave this way and dominate the determination of the phase velocity. This, then, actually supports the crude sheath helix method of extrapolation from the slow wave region.

The question of effect of layer thickness is, however, made more difficult by the higher mode contributions since each mode will be affected differently by the layer thickness. This problem could be solved numerically with the present theory, but as yet has not been attempted.

Questions on attenuation of current due to radiation may be clarified by the numerical analysis which will be reported soon.

The experiments on loaded helices and conical helices reported in the last report 7140-1-F roughly support the theory as far as the reduction in phase velocity and "resonant diameter", achieved in practice. Nevertheless, the theory is much closer than a prediction based on $\frac{1}{\sqrt{\mu \epsilon}}$ would have been, corresponding to the reduction of a plane wave in an infinite medium. The most accurate check data was from phase velocity measurements. Far field patterns were found to be poor indications of the loading effect because of the broad bandwidth of these antennas. There is another problem with helical antennas. Since they are largely being investigated as periodic counterparts to log-conical helix structures, they must maintain the same modes and current decays as the conical structure to be most useful. Nevertheless, the experiments show that the current decays of the loaded helix structure are essentially the same as the unloaded structure, and provide no indication of the "near field break-up" problem in a loaded log-conical structure, (Lyon et al, (1966). In addition, there are apparently some standing waves near the feed tip of the helix slightly off resonance that cannot be explained by end reflections. These indicate several modes in the feed tip region, possibly a result of the sudden discontinuity there. This problem may be similar to the several modes found (Ingerson, et al, 1966) with periodic dipole arrays, where it is concluded that the far field patterns of periodic dipole arrays resulted mostly from the discontinuity at the feed point, not from a dominant leaky mode. A tapered spiraled feed to the helix will be used to investigate this problem.

In summary, it appears that the experimental work with the log-conical antenna has been more useful than the experiments with a helix in studying loaded log-conical helix behavior. However, theoretical helix calculations have provided valuable insight into the problem.

The input impedance of a bifilar complementary helical antenna was measured for various loading materials. The antenna is shown in Fig. 2-2 and 2-3. The details of the antenna have been described in an unpublished memorandum (Wu, 1966). The experimental set-up for the measurement is shown in Fig. 2-4. The antenna was fed by an unbalanced feed across the gap at the center of the feed point of the antenna. The input impedance for the unloaded antenna is shown in Fig. 2-5 and it is seen that the impedance stays fairly constant over the frequency range. The bandwidth determined from the far field and near field patterns is from 600 up to 900 MHz. The variation of the input impedance in this range is 28 to 47.5Ω for the real part and $j\,15$ to $j\,28\Omega$ for the imaginary part. It is interesting to note that the input reactance is inductive within the frequency range. As will be discussed later, this property has a very interesting result when the antenna is loaded with a dielectric or a ferrite material.

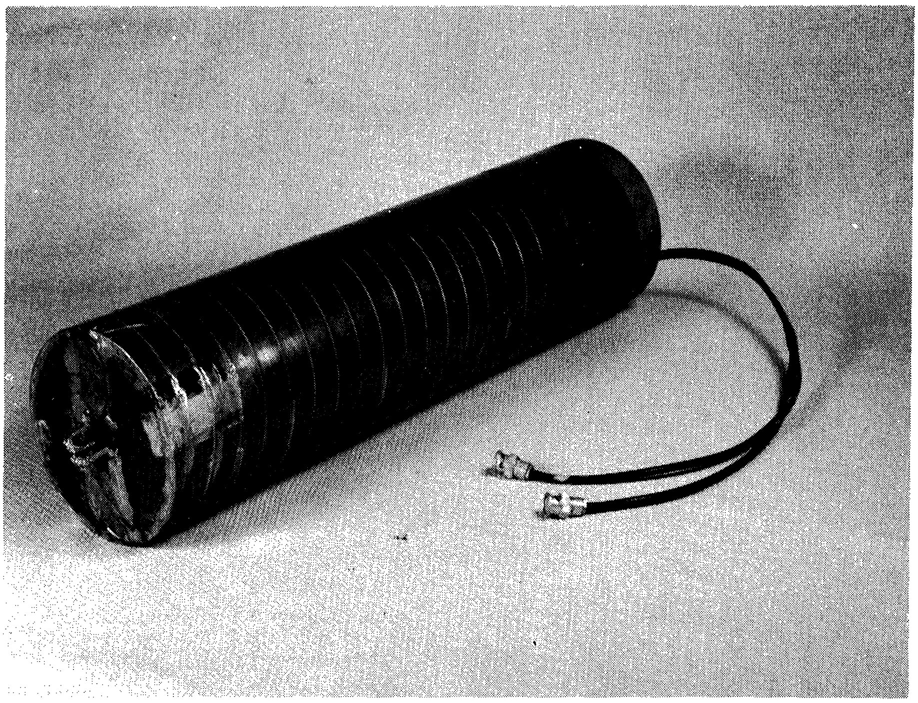


FIG. 2-2: A BIFILAR COMPLEMENTARY HELICAL ANTENNA

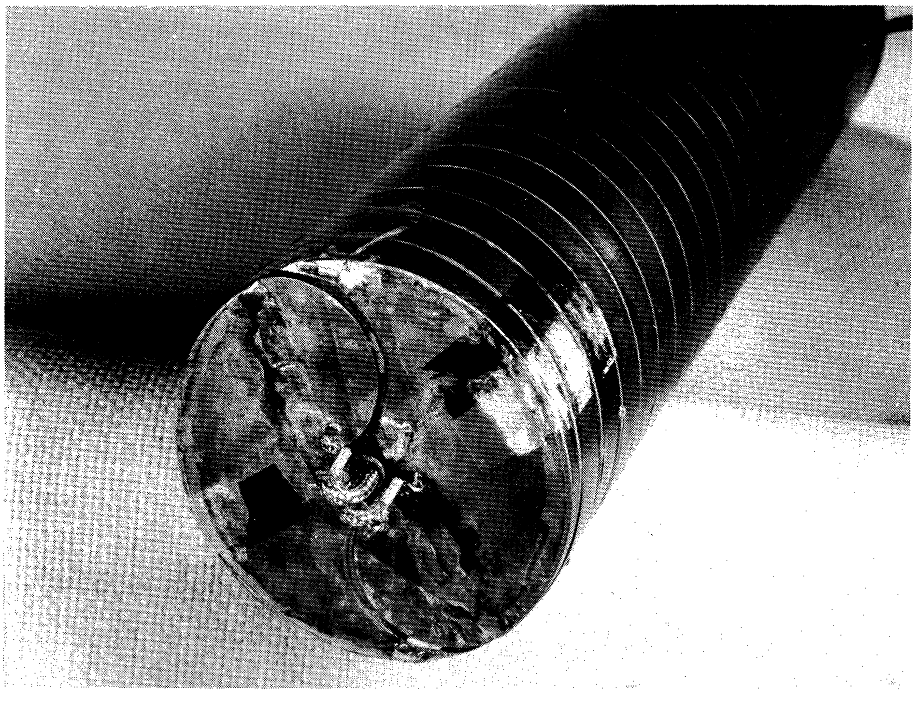


FIG. 2-3: A BALANCED FEED OF THE ANTENNA

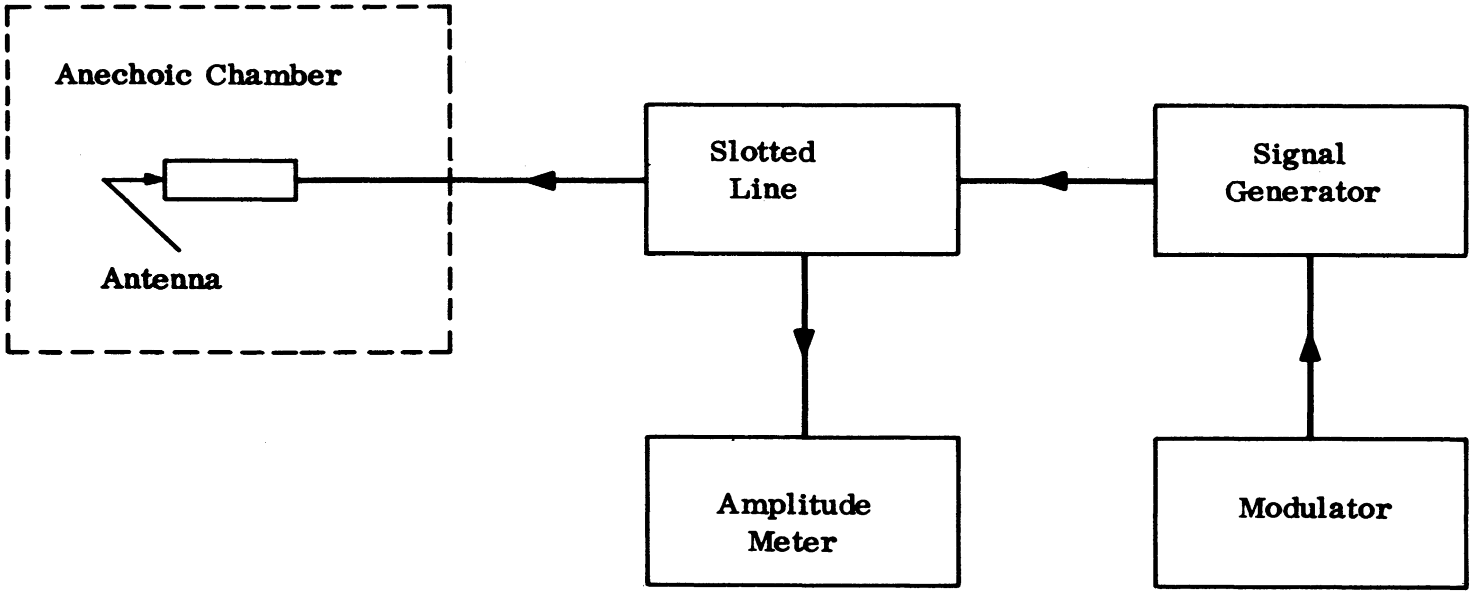


FIG. 2-4: THE EXPERIMENTAL SET-UP FOR THE IMPEDANCE MEASUREMENT

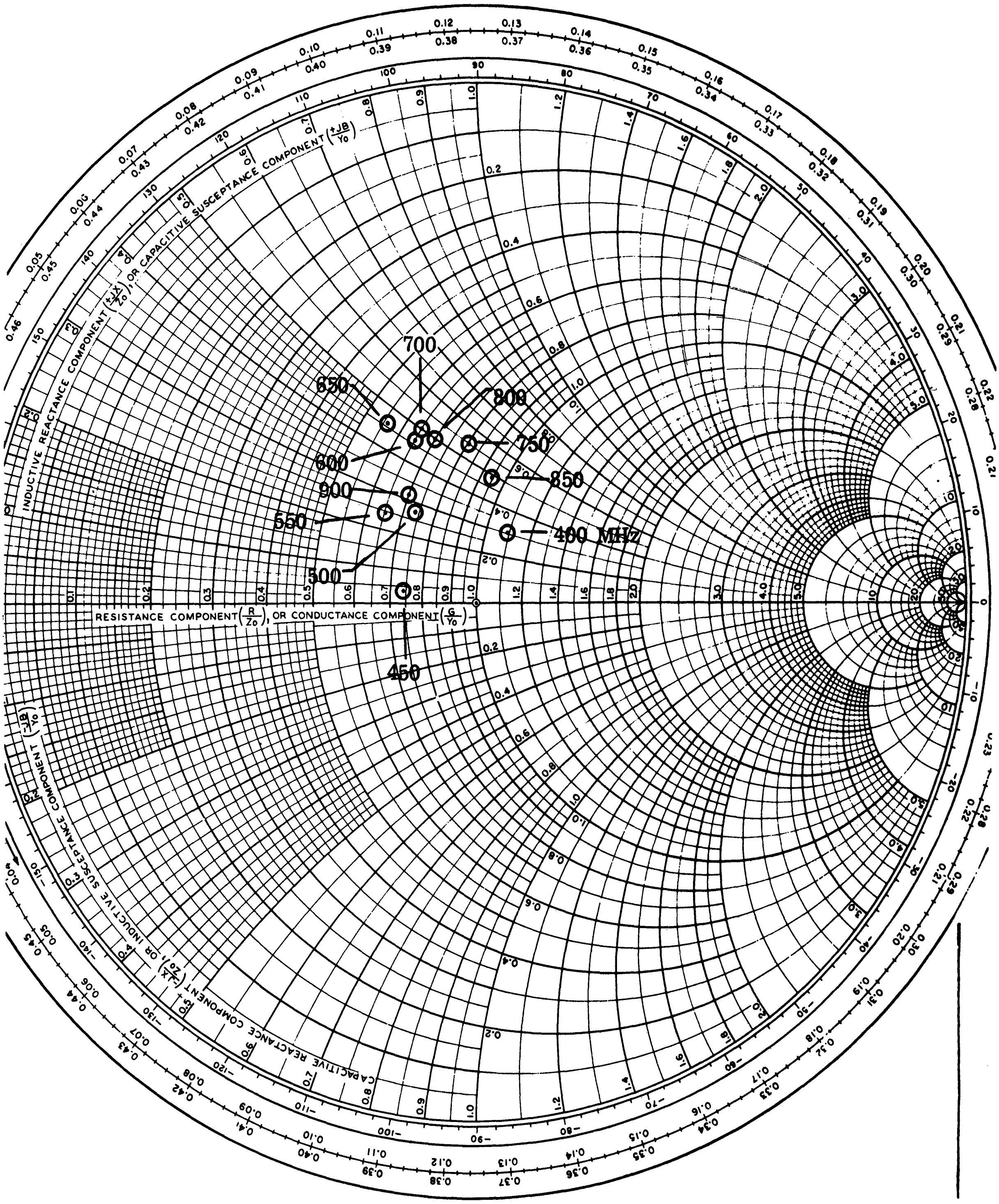


FIG. 2-5: UNLOADED COMPLEMENTARY HELIX ANTENNA

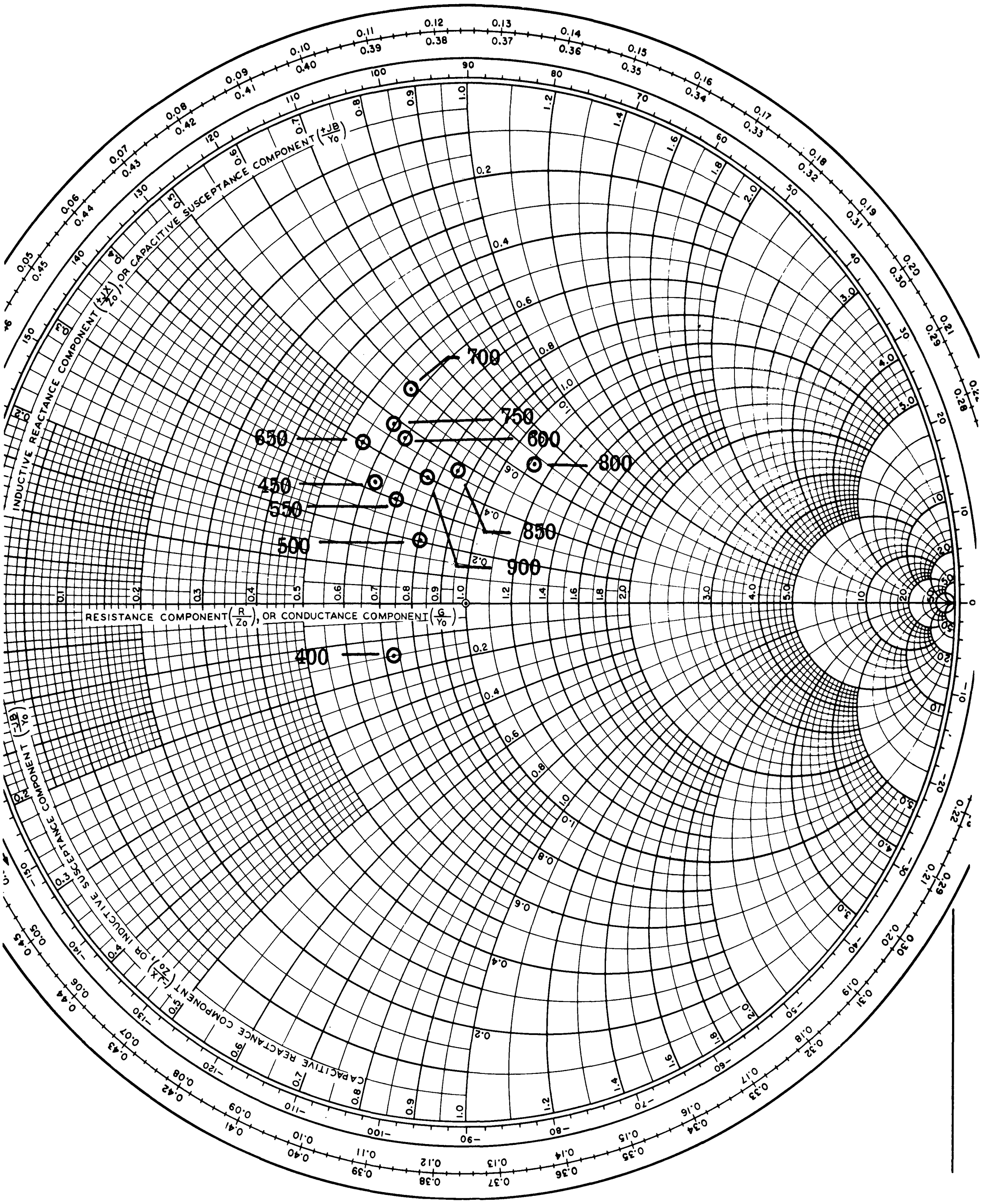
2.7 Impedance Measurements on a Bifilar Complementary Helical Antenna

2.7.2 The Loaded Cases

The input impedance for a K-10 dielectric loaded antenna is shown in Fig. 2-6. The general pattern is not changed significantly, due to the fact that the antenna is inductive within the frequency range. The loading of the dielectric material will move the frequency range (determined by the near and the far field pattern) down but the input impedance does not seem to be affected much except for some marginal frequencies. However, the input impedance of the antenna is affected by a ferrite loading precisely for the same reason; that is, the inductive nature of the antenna is further affected by the ferrite loading. The input impedance seems to cluster and thus becomes less dependent on the frequency. This is shown in Fig. 2-7 where EAF-2 ferrite was placed inside the antenna. The trend of less frequency dependence of the input impedance ude to a ferrite loading is further evidenced by Fig. 2-8 where Q-3 ferrite was used; Q-3 ferrite has much higher relative permeability. The input impedance seems to converge toward 38 + j 15Ω with a small variation as the frequency is changed (31 to 42Ω for the real part and j 10 to j 22Ω for the imaginary part over the frequency range of 400 to 900 MHz). A metal loaded helix was also measured; the effect is not very significant (Fig. 2-9).

2.7.3 Comments

From the above observations it can be said that the input impedance of a bifilar complementary helical antenna is affected by the loading materials in a very interesting way. Since the antenna is inductive over the frequency range, the loading of the dielectric material is not as effective as the ferrite material. It is also noted that the input resistance of the antenna is very low compared to that of the wire helix antenna, as it should be, corresponding to the usual reciprocal relationship of impedances of two complementary antennas. It can be observed


700
750
650
600
800
450
550
850
500
900
400
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE COMPONENT (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE COMPONENT (-jB/Yo)

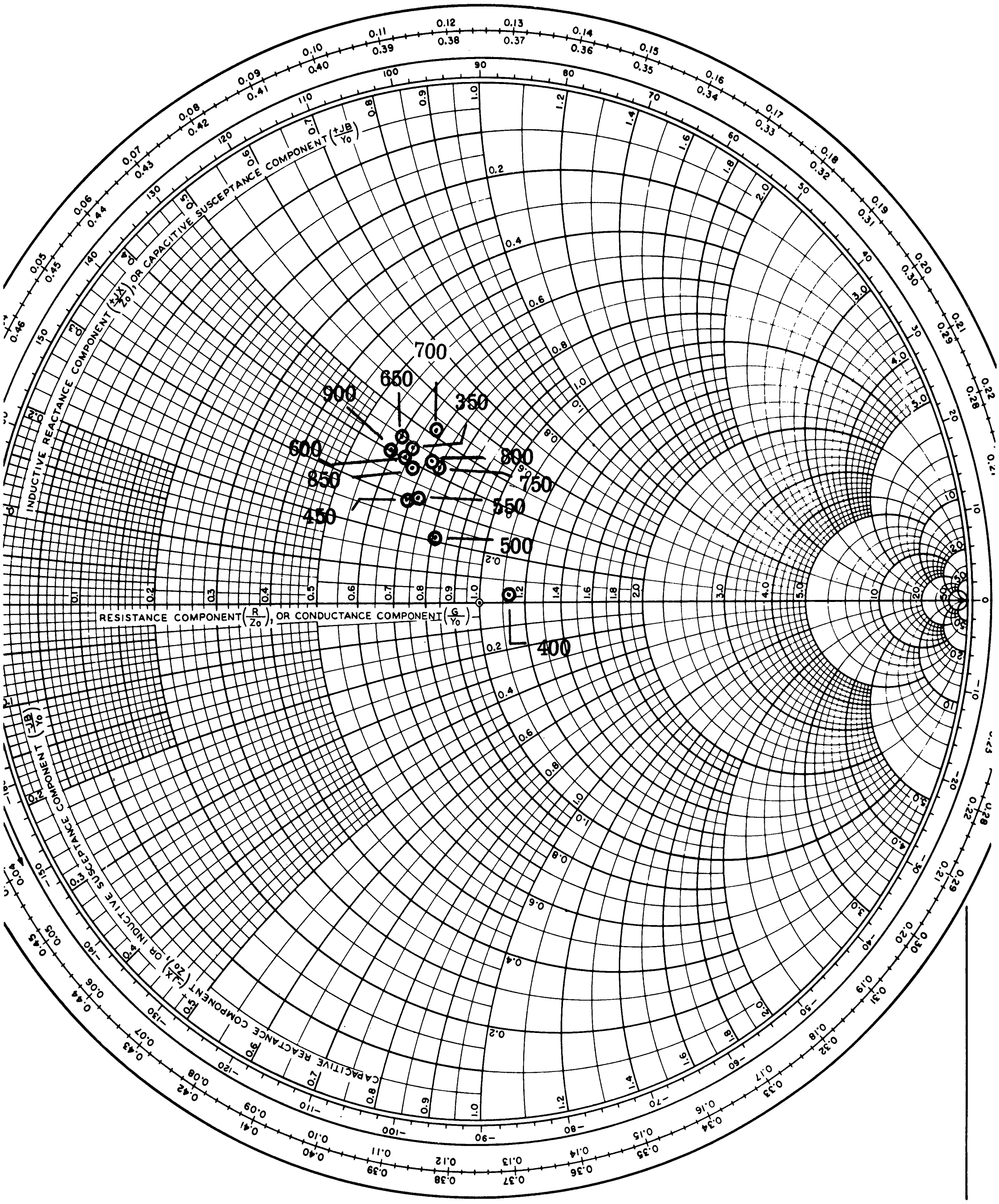


FIG. 2-7: EAF-2 LOADED COMPLEMENTARY HELIX ANTENNA

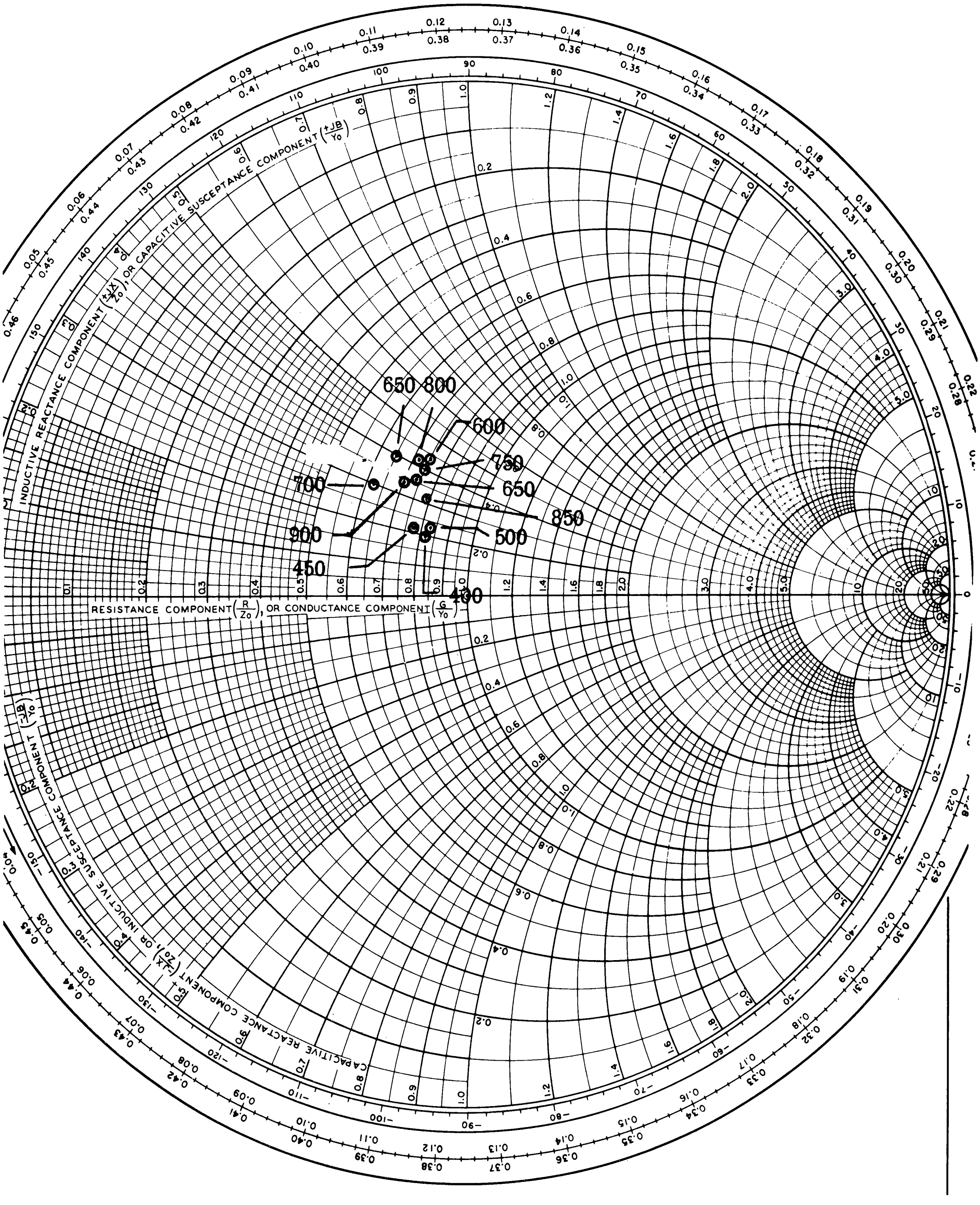


FIG. 2-8: Q-3 LOADED COMPLEMENTARY HELIX ANTENNA

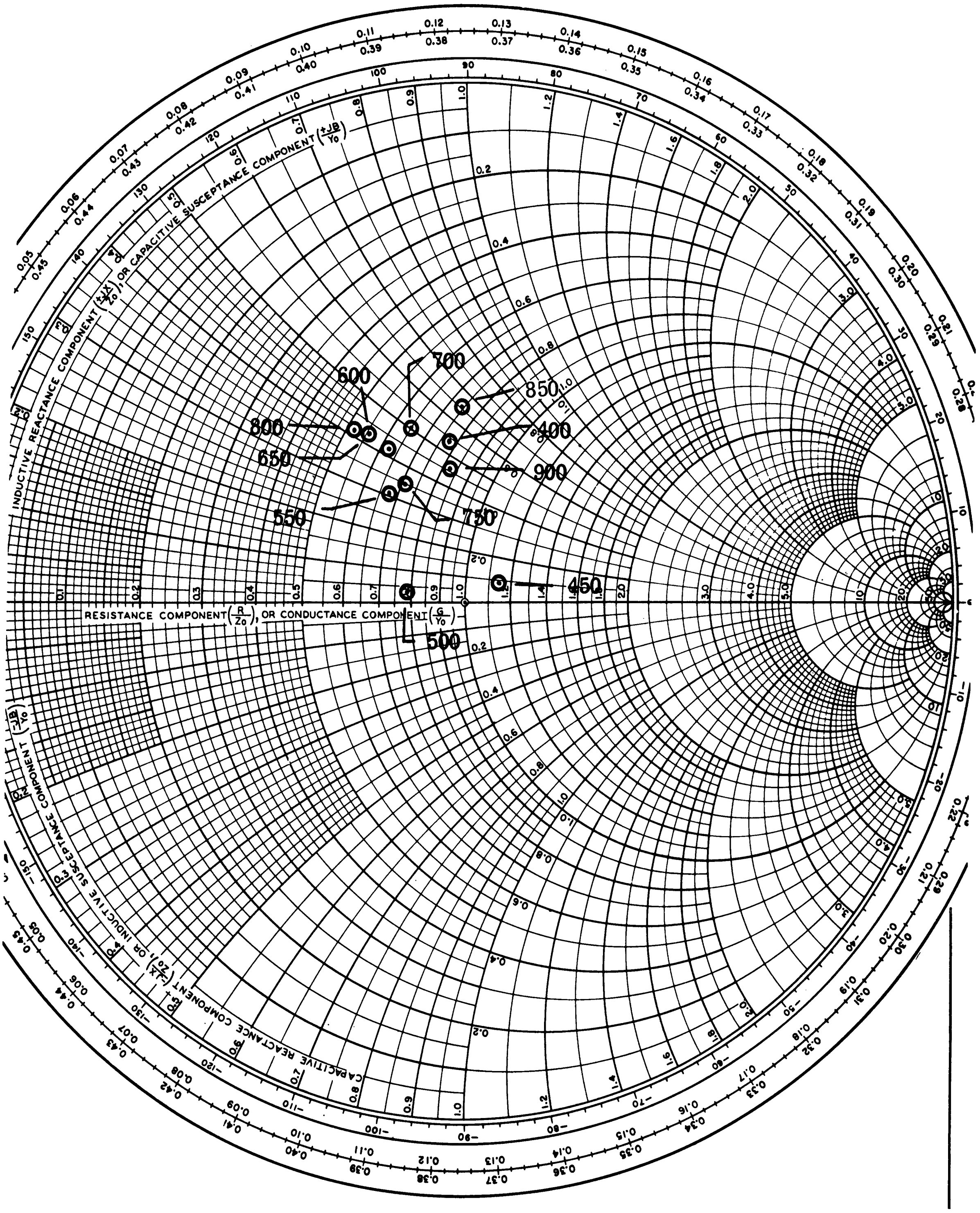


FIG. 2-9: METAL LOADED COMPLEMENTARY HELIX ANTENNA

from Fig. 2-10 that the most efficient radiation takes place around 650 MHz for all cases. This seems to imply that the input resistance of the antenna is not affected by the loading materials quite as much as the resonant frequency except at the marginal frequencies where the effect seems to be a little greater.

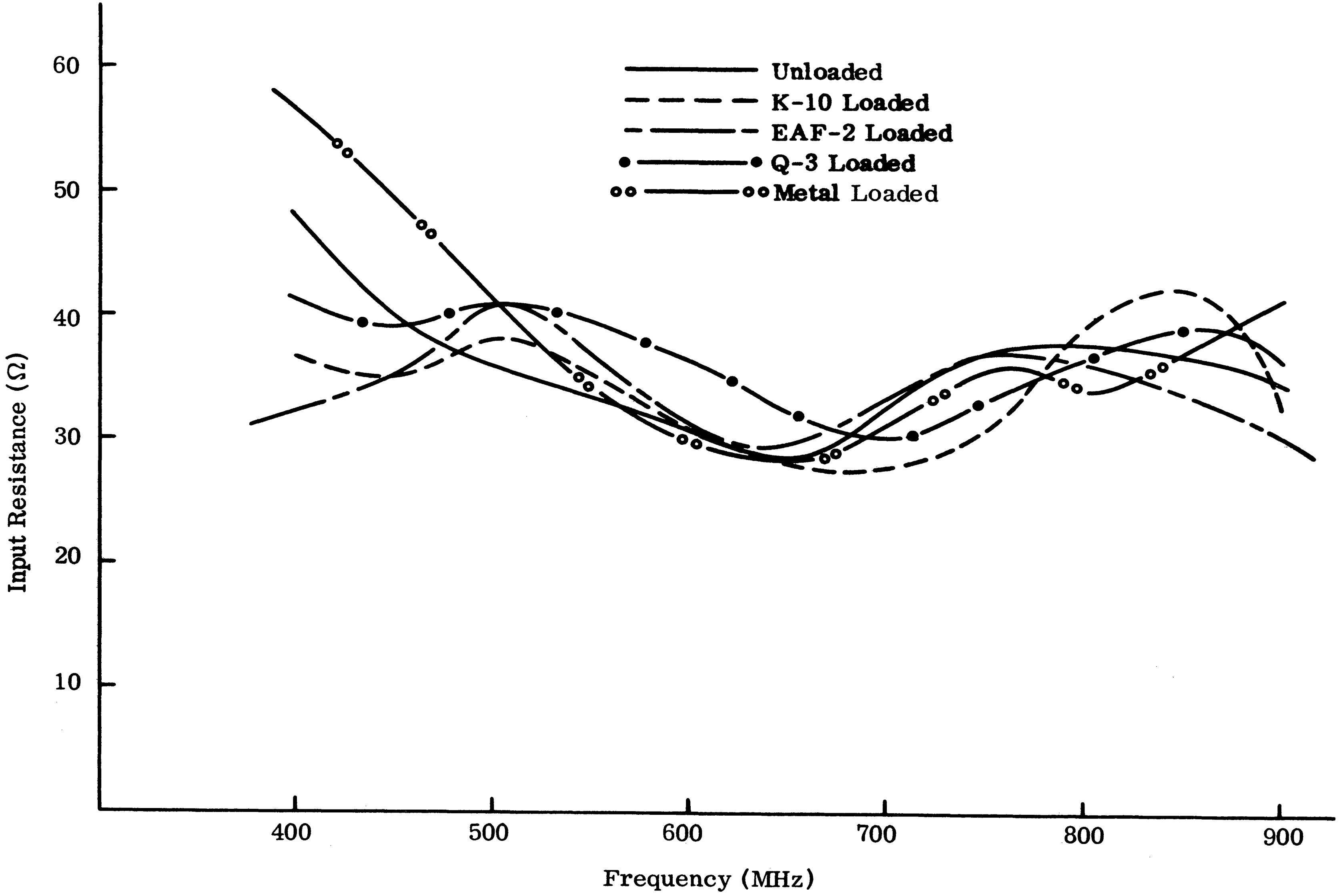


FIG. 2-10: THE INPUT RESISTANCES FOR VARIOUS LOADING MATERIALS

III

THE FERRITE ROD ANTENNA

3.1 General

In general ferrite media are anisotropic. As such, they are characterized by a tensor permeability which under steady magnetization along a certain direction "z", is as follows:

$$\bar{\bar{\mu}} = \begin{bmatrix} \mu & i\mu_\alpha & 0 \\ -i\mu_\alpha & \mu & 0 \\ 0 & 0 & \mu_z \end{bmatrix} \tag{3.1}$$

Assuming the ferrite to be isotropic electrically ($\bar{\bar{\epsilon}} = \epsilon$, a scalar), the analysis of wave propagation phenomena is very complicated due to the nature of (3.1).

In a preliminary investigation, it will be assumed that in the absence of an applied steady magnetic field and of a steady remanent magnetization in the direction of propagation, the permeability can be approximated by an effective scalar. That is, the preliminary analysis will be for a ferrite rod characterized by: $\bar{\bar{\mu}} = \mu_0 \mu_r$, $\bar{\bar{\epsilon}} = \epsilon_0 \epsilon_r$. These are scalar relations. Also, this analysis will assume negligible losses in the medium.

3.2 Analysis

Since primary interest is in the case of end fire radiation, the hybrid modes HE_{nm} will be investigated for the case of an infinitely long rod. Criteria for the design parameters, the radius "a", and finite length will be developed later.

$$\frac{\omega^2\mu_0\epsilon_0}{k_0^2}\left\{\frac{H_n'^{(2)}(k_0a)}{H_n^{(2)}(k_0a)}\right\}^2 + \frac{\omega^2\mu_r\epsilon_r\mu_0\epsilon_0}{k_1^2}\left\{\frac{J_n'(k_1a)}{J_n(k_1a)}\right\}^2 \tag{3.2}$$

$$-\left(\frac{\omega^2\mu_r\epsilon_0\mu_0}{k_0k_1}+\frac{\omega^2\mu_0\epsilon_0\epsilon_r}{k_0k_1}\right)\left\{\frac{J_n'(k_1a)H_n'^{(2)}(k_0a)}{J_n(k_1a)H_n^{(2)}(k_0a)}\right\} = -\gamma^2\eta^2\left[\frac{1}{k_1^2a}-\frac{1}{k_0^2a}\right]^2 \tag{3.2}$$

with

$$\gamma^2 = \frac{k_0^2\mu_0\epsilon_0\mu_r\epsilon_r - k_1^2\mu_0\epsilon_0}{\mu_0\epsilon_0\mu_r\epsilon_r - \mu_0\epsilon_0}$$ the square of the propagation constant

and (3.3)

$$\omega^2 = \frac{k_1^2 - k_0^2}{\mu_0\epsilon_0(\mu_r\epsilon_r - 1)}$$

The analysis for the determination of the propagation constant is that used for dielectric circular rod radiators. The wave equation is solved for the electric and magnetic fields in cylindrical coordinates. The boundary conditions at the interface of the ferrite medium and free space are considered for the determination of the arbitrary constants and the following determinantal equation results.

Substituting relations (3.3) in (3.2) and considering the case for the HE_{11} mode $(n = 1)$ the determinantal equation is modified as

$$\left(\frac{2\pi a}{\lambda}\right)^2 \frac{1}{(k_0 a)^2} \left\{\frac{H_1'^{(2)}(k_0 a)}{H_1^{(2)}(k_0 a)}\right\}^2 + \left(\frac{2\pi a}{\lambda}\right)^2 \frac{2\mu_r\epsilon_r}{(k_1 a)^2} \left\{\frac{J_1'(k_1 a)}{J_1(k_0 a)}\right\}^2 - \left(\frac{2\pi a}{\lambda}\right)^2 \left(\frac{\mu_r+\epsilon_r}{(k_0 a)(k_1 a)}\right)$$

$$\left\{\frac{J_1'(k_1 a)H_1'^{(2)}(k_0 a)}{J_1(k_1 a)H_1^{(2)}(k_0 a)}\right\} = -\left\{\frac{1}{(k_1 a)^2} - \frac{1}{(k_0 a)^2}\right\}^2 \left\{\frac{(k_0 a)^2\mu_r\epsilon_r - (k_1 a)^2}{\mu_r\epsilon_r - 1}\right\} \qquad (3.4)$$

where:

a = radius of the radiator, λ = wavelength in free space. In the above relations the transverse propagation constants in ferrite k_1 and in free space k_0 are related to the axial propagation constant γ as follows;

$$\left.\begin{aligned} \gamma^2 &= \left(\frac{2\pi}{\lambda}\right)^2 - k_0^2 \quad \text{free space} \\ \gamma^2 &= \left(\frac{2\pi}{\lambda}\right)^2 \mu_r\epsilon_r - k_1^2 \quad \text{inside medium} \end{aligned}\right\} \qquad (3.5)$$

Eliminating γ in (3.5)

$$(k_1 a)^2 - (k_0 a)^2 = \left(\frac{2a}{\lambda}\right)^2 \pi^2 \left[\mu_r\epsilon_r - 1\right] \quad \text{results.} \qquad (3.6)$$

To determine the propagation constant Eqs. (3.4) and (3.6) will be solved in the computer by successive approximations for (k_1a) and (k_0a) using several μ_r, ϵ_r and $2a/\lambda$ values. Then a graph of c/v versus $2a/\lambda$ will be plotted which will serve as a guide to design criteria, where

$$c/v = \frac{1}{\left(\frac{2a}{\lambda}\right)\pi} \sqrt{\frac{(k_1a)^2 - \mu_r \epsilon_r (k_0a)^2}{\mu_r \epsilon_r - 1}} \qquad (3.7)$$

Since most of the energy travels in free space when $c/v \approx 1$ this will serve as a design criterion for each particular μ_r, ϵ_r, and frequency.

IV
LOADED ANTENNA TYPES FOR 30 MHz OPERATION

4.1 General

Work on this topic aims at fulfillment of the objectives of Task 4 of the contract.

It is apparent that several antenna types are amenable to ferrite loading techniques in the 30 MHz region. In a few cases one can make an intelligent estimate as to both the types of geometrical configuration and the loading technique that will likely yield a relatively efficient radiating system. However, in pursuing such likely choices too early in a study whose purpose is to determine feasibility, one risks overlooking other less obvious choices which potentially could be more rewarding. Such is especially the case when attempting to extrapolate known loading techniques which are applicable at different frequency regions into an intermediate frequency region. For instance, size reduction techniques for the lower HF region and below have been existent for sometime. These techniques consist typically of lumped loading on various narrow band antenna structures. More recently size reduction techniques have been developed for the upper VHF region and above. By way of contrast, these techniques consist typically of distributed loading on various broad band antenna structures. For the region around 30 MHz, it is not evident a priori which of the above techniques, if either, are appropriate for a given application.

Consider as an example an application in which specified constraints are imposed on a particular geometrical structure. For specified limitations on weight, size, and bandwidth, it could be that the most efficient antenna would result from using a combination of both lumped and distributed loading. One can settle such an uncertainty by exhaustively trying all likely possibilities. However, the knowledge obtained from such an effort is often meager and unsatisfactory; for ones knowledge is limited to a particular antenna having particular constraints. Alternatively, if one had quantitative knowledge of the fundamental relationships connecting radiation efficiency with frequency, bandwidth, size, and weight, for various elementary types of antennas, a sizable portion of the experimentation could be eliminated. Moreover, this fundamental information would be of use in evaluating new antenna designs proposed in the future which are combinations of loaded elementary types.

The early portion of this investigation will consist of a systematic approach to obtain quantitative information for loaded elementary antenna structures on the relationship between radiation efficiency and specified constraints. Various constraints which will be considered are frequency, bandwidth, size reduction, and weight. Care will be taken to correlate results with the appropriate constants which describe the loading technique. This should enable one to better estimate the effect of improved loading materials which may be available in the future. All of the loaded elementary antenna structures tested will not show equal promise of being developed into optimum engineering designs. Systematic exploration of a less promising loaded structure is nevertheless worthwhile to the extent that it lends quantitative insight into the nature of the fundamental trade-offs involved.

Concurrent with the systematic investigation of loading elementary antenna structures, some time will be spent applying the more promising loading techniques to less elementary structures. Emphasis will shift toward this area as the investigation continues.

4.2 Specific Types

Some structures now under consideration are various loop arrangements, such as a multiple frequency cubical quad, and the scimitar, a frequency independent antenna. These structures possess some degree of geometrical compactness even before loading, and are conductive to imaging techniques which enhance the mechanical desirability. It may be that the cubical quad cannot be reduced by continuous ferrite loading while still maintaining a reasonable weight. However, at higher frequencies such as 200 MHz, the lowest frequency specified for Task 1, it is entirely possible that information on loading the cubical quad would be useful. Furthermore, there is available in the literature (Pinner, 1964) some information on size reduction of this type of antenna using lumped inductance loading.

V
CONCLUSIONS

Some progress has been made in each of the four assigned tasks under this project. However, due to the limitation of experimental facilities, Task 2, involving arrays of ferrite slots, has progressed more slowly than expected. The restricting situation has been corrected and substantial effort will now be made on Task 2.

Much of the accomplishment in this report period, has been a better understanding of the radiation of loaded helical and log conical antennas.

The mathematical analysis of the ferrite rod antenna has progressed. Detailed results of a numerical analysis of the ferrite rod radiator are expected from the computing center, momentarily.

A major start has been made upon antennas useful at 30 MHz which utilize ferrite loading material.

VI

FUTURE EFFORT

Under Task 1, the major emphasis in the next report period will be coating the winding of a conical helix antenna with ferrite. This will probably be done by holding a powdered form of the ferrite EAF-2 around the wire with plastic tubing. Also, a start will be made on fabricating lumped inductances using toroidal cores that will be inserted in the winding of a conical helix.

Purchase of additional ferrite materials, which promise to be useful at UHF and VHF, is being made. These materials will be tested for electrical characteristics to confirm the published advertising data.

It is expected that a ferrite rod radiator using a rod formed by a cylindrical container filled with EAF-2 ferrite will be tested shortly. This radiator will be given complete pattern tests.

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13. ABSTRACT

This second quarterly report indicates the effort devoted to each of the four assigned tasks of this project. Preliminary design considerations have been undertaken in Task 1 which requires a conical spiral antenna of very much reduced physical size. In order to meet specific performance requirements some time has been devoted to arrangements for experimental facilities. Power sources each with an output over a 100 watts at specified frequencies within the range 200-600 MHz have either been made or are in a state of preparation.

Under Task 2, an array consisting of interdigital slots is being adapted for ferrite loading, initial studies have emphasized beam pattern and gain. At this point, further work on magnetic tuning and bandwidth are being started.

Under Task 3, some mathematical studies of endfire ferrite rod antennas suitable for the range 300-1000 MHz have been started. The determinantal equation corresponding to the boundary value problem is being subject to computation through the use of a computer.

Under Task 4, a broad view as to approaches for ferrite loaded antennas capable of operating as low as 30 MHz has been taken. The cubical quad antenna has been one selected for fairly intensive detailed studies under loading conditions.

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