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EFFECT OF A DIELECTRIC SUPPORT ON THE BANDWIDTH OF A HELICAL BEAM ANTENNA

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ABSTRACT

In many applications employing a helical antenna it becomes necessary for reasons of mechanical rigidity to mount the helix conductor on the ground plane by means of one or more dielectric supports. Measurements have been carried out to determine the effect of a dielectric core and sleeve on the electrical performance of a helical antenna. For materials having moderate dielectric constants (around 2.5), it is found that the useful bandwidth of the antenna remains unaltered, but the lower cutoff frequency is reduced by about 12 percent.

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EFFECT OF A DIELECTRIC SUPPORT ON THE BANDWIDTH OF A HELICAL BEAM ANTENNA

- J.Y. Wong and R.S. Thomas* -

INTRODUCTION

In many applications employing a helical antenna it becomes necessary for reasons of mechanical rigidity to mount the helix conductor on the ground plane by means of one or more dielectric supports. If the supporting material possesses a dielectric constant very much different from unity, the presence of the dielectric can alter the phase velocity of the current along the helix conductor. One direct result of this effect is a change in the radiation pattern of the antenna, and hence a change in the bandwidth of the antenna. This effect may often be ignored at VHF and UHF frequencies where the size of the dielectric support is relatively small compared with the wavelength. However, at the higher frequencies, the effect of the dielectric can be quite significant and must be taken into account in the overall design of the antenna.

Some experimental results on the effect of encapsulating a helical antenna in a foamed dielectric material have been reported by Jones [1]. Hame [2] has also conducted limited measurements of a helical antenna enclosed in a dielectric. A theoretical analysis of the effect of a dielectric support on the phase constant of a helix has been carried out by Kiryushin [3]. He derived the dispersion equation of a helix enclosed by a dielectric cylinder of finite thickness, using the approximate theory of the tape. Although his analysis and calculations were concerned primarily with a traveling-wave-tube application, the analysis is sufficiently general to include the helical beam antenna case.

In this report, results of measurements are given for the radiation pattern, axial ratio, and voltage standing-wave ratio of a dielectric-supported helical antenna. Two configurations of the dielectric are investigated; namely, a solid core and a sleeve. The measurements were carried out at a center frequency of about 5000 mc/s. It will be shown that the dielectric support has a significant effect on all three above-mentioned properties of the helix.

ANTENNA MEASUREMENTS

The basic antenna used for the measurements consisted of a 6-turn 14-degree helix. The antenna was mounted on a 9-inch-diameter ground plane. Measurements of the radiation pattern, axial ratio, and voltage standing-wave ratio were first carried out on the basic antenna in order to establish a criterion of performance for comparison with subsequent measurements on the dielectric-supported helix. Two configurations of dielectric were investigated: solid core

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* Summer student, 1959

and sleeve. For the core, two different materials were used: polystyrene and Pyrex glass, having dielectric constants of about 2.5 and 4.5, respectively. The sleeve material was of Rexolite (dielectric constant approximately 2.5) having the following dimensions: inner diameter 0.875"; outer diameter 1.0". A drawing of the two different antenna configurations is given in Fig. 1, and a photograph of the antenna with a dielectric sleeve is shown in Fig. 2.

RESULTS

All measurements were conducted over a band of frequencies from about 2700 mc/s to 6000 mc/s corresponding to values of C_λ (circumference of helix expressed in wavelengths) from 0.58 to 1.3. Radiation patterns of the basic antenna are shown in Fig. 3, with C_λ as the varying parameter. Patterns for both vertical and horizontal polarizations are plotted on the same figure, and both patterns have been normalized to unity. Figs. 4 and 5 demonstrate the effect of the dielectric core, polystyrene and Pyrex glass, respectively, on the radiation patterns. The results of axial ratio and VSWR measurements on the dielectric-supported helix are illustrated in Figs. 6 and 7, respectively. One significant effect of the dielectric can be derived from these results; namely, that the useful bandwidth of a dielectric-supported helical antenna is shifted to a lower band of frequencies. For the case of polystyrene, this shift is approximately 12 percent. In terms of the current along the helix these results suggest that the introduction of a dielectric core has reduced the phase velocity of the current along the helix conductor — a result not entirely unexpected. In practical terms, this means that for a given size (diameter) helix, a dielectric-supported helix possesses a lower cutoff frequency than that of the basic antenna — an important factor when space is at a premium. The results for a Rexolite sleeve enclosing the helix are given in Figs. 8, 9, and 10. The results are in all respects similar to the case of a polystyrene core.

To summarize, the following table has been prepared. It shows (in each case) the useful bandwidth of the antenna based on the VSWR, axial ratio, and radiation pattern as criteria. The VSWR has been arbitrarily taken as 3:1 and the axial ratio at 2:1. The bandwidth of the polystyrene and Rexolite-supported antennas has been unchanged. For the case of the Pyrex glass core, the useful bandwidth has been reduced from 1.7 to 1.4.

TABLE OF ANTENNA BANDWIDTHS

ANTENNA	BANDWIDTH BASED ON			USEFUL BANDWIDTH
	VSWR	AXIAL RATIO	PATTERN	
BASIC HELIX	0.75* -	0.70 -	0.70 - 1.3	0.75 - 1.3 (1.7)
POLYSTYRENE CORE	0.63 -	0.63 - 1.18	0.60 - 1.08	0.63 - 1.08 (1.7)
GLASS CORE	0.58 - 1.15	0.60 - 1.07	0.56 - 0.86	0.60 - 0.86 (1.4)
REXOLITE SLEEVE	0.63 -	0.62 -	0.60 - 1.08	0.63 - 1.08 (1.7)

* 0.75 MEANS 0.75 C_λ

CONCLUSIONS

In order to corroborate the measurements, calculations of the phase velocity of the current along the helix conductor are being carried out, based on the analysis and formulas given by Kiryushin. The final form of the dispersion equation [4] is rather complex, and the problem is being programmed for an IBM 650 computer. It is hoped to report the results of these calculations in a future paper.

References

1. G.C. Jones, "An experimental design study of some S-and X-band helical aerial systems", Proc. Inst. Elec. Engrs., Paper 217 OR 103B: 764-70, 1956
2. T.G. Hame, "Microwave helical aerials", Electronic Eng., 29: 181-83, 1957
3. V.P. Kiryushin, "The influence of dielectric on the phase constants of the space harmonics of a helix", Radiotekhnika Elektronika, 2, 7: 901-11, 1957
4. V.P. Kiryushin, loc. cit., Eq. (28)

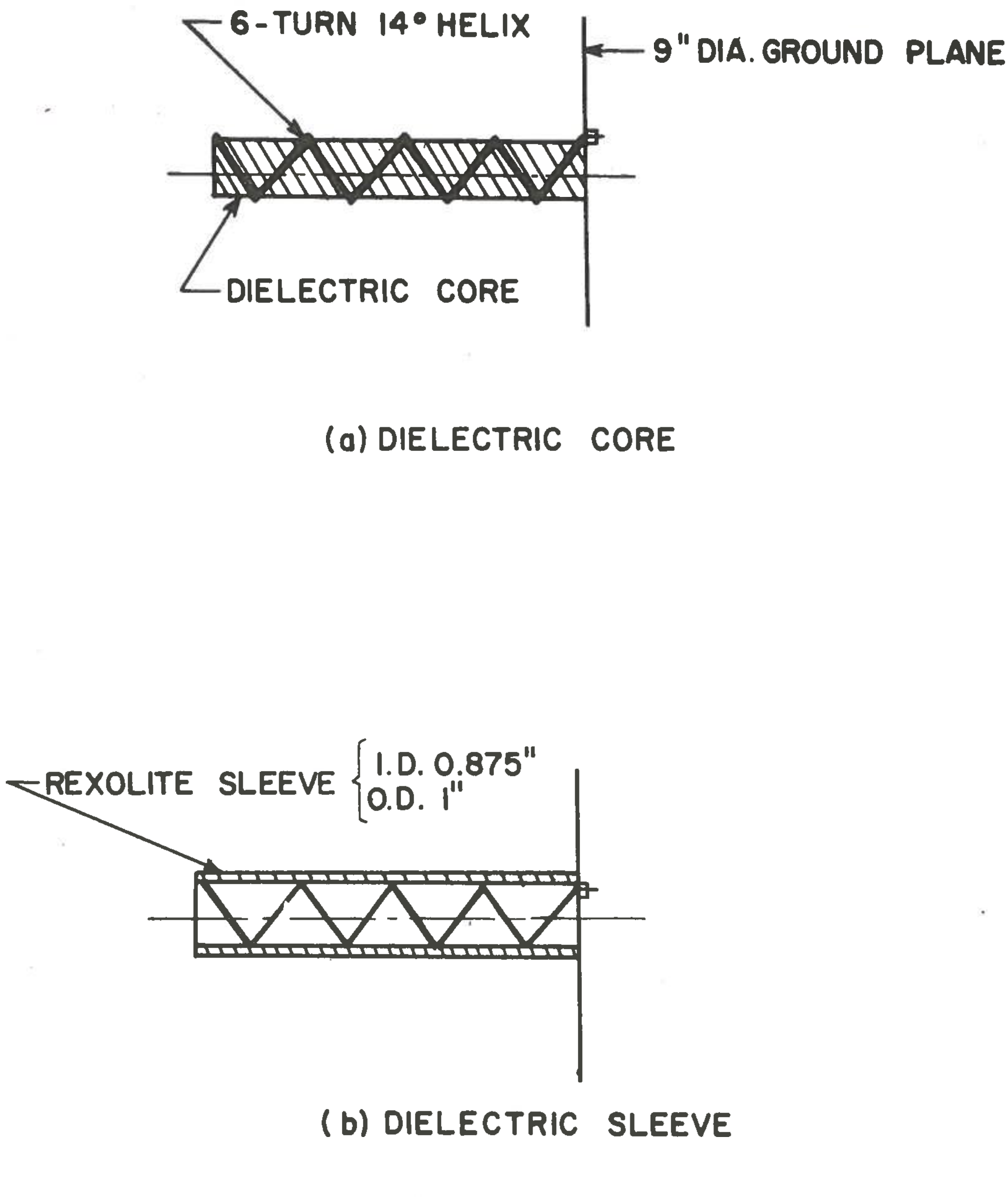

FIG. 1 GEOMETRY OF DIELECTRIC-SUPPORTED HELIX

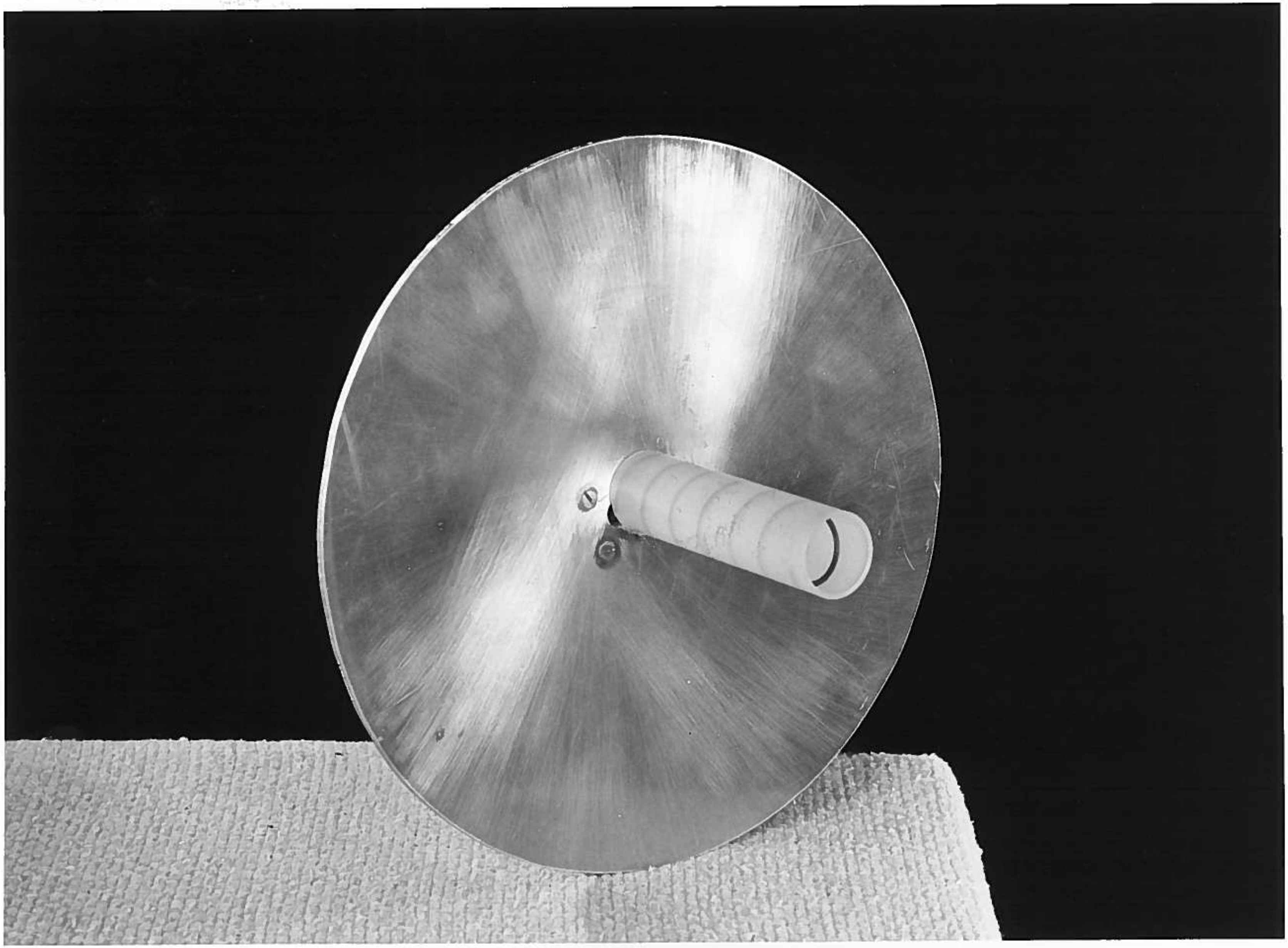

FIG. 2 DIELECTRIC-SLEEVE-SUPPORTED HELIX ANTENNA

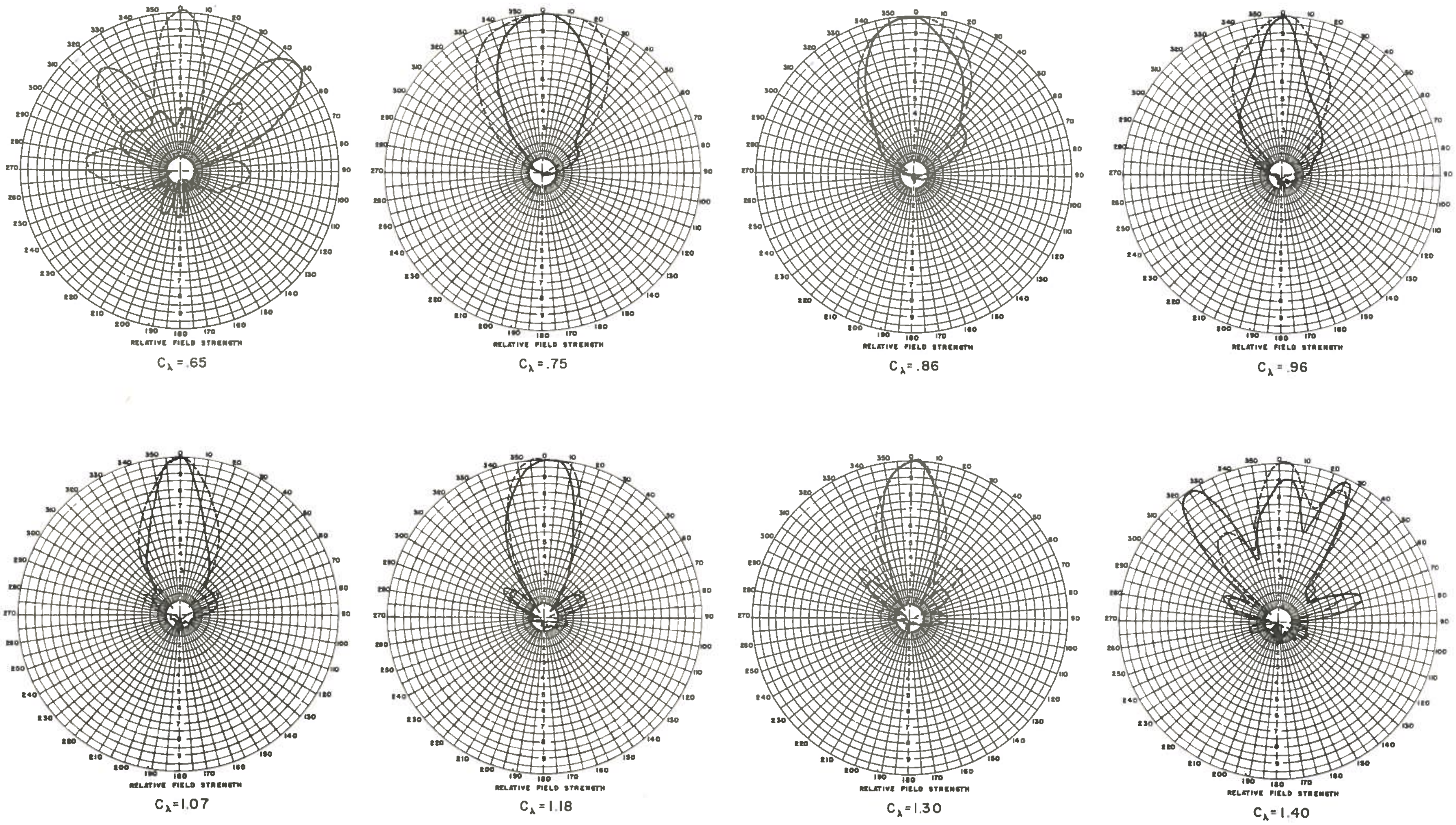

FIG. 3 RADIATION PATTERNS OF BASIC ANTENNA

—— Horizontal Polarization

---- Vertical Polarization

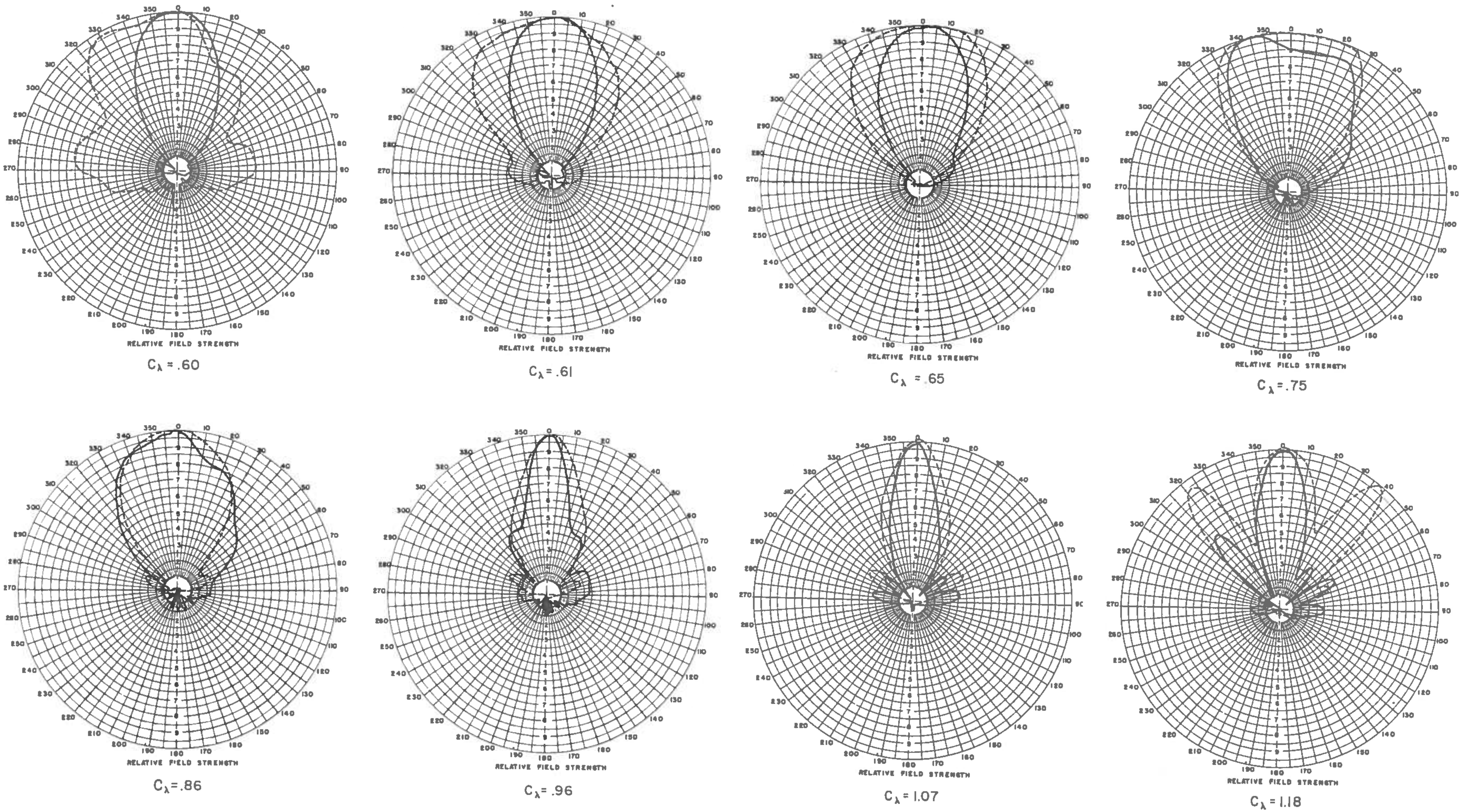

FIG. 4 RADIATION PATTERNS OF HELIX WITH POLYSTYRENE CORE

——— Horizontal Polarization

---- Vertical Polarization

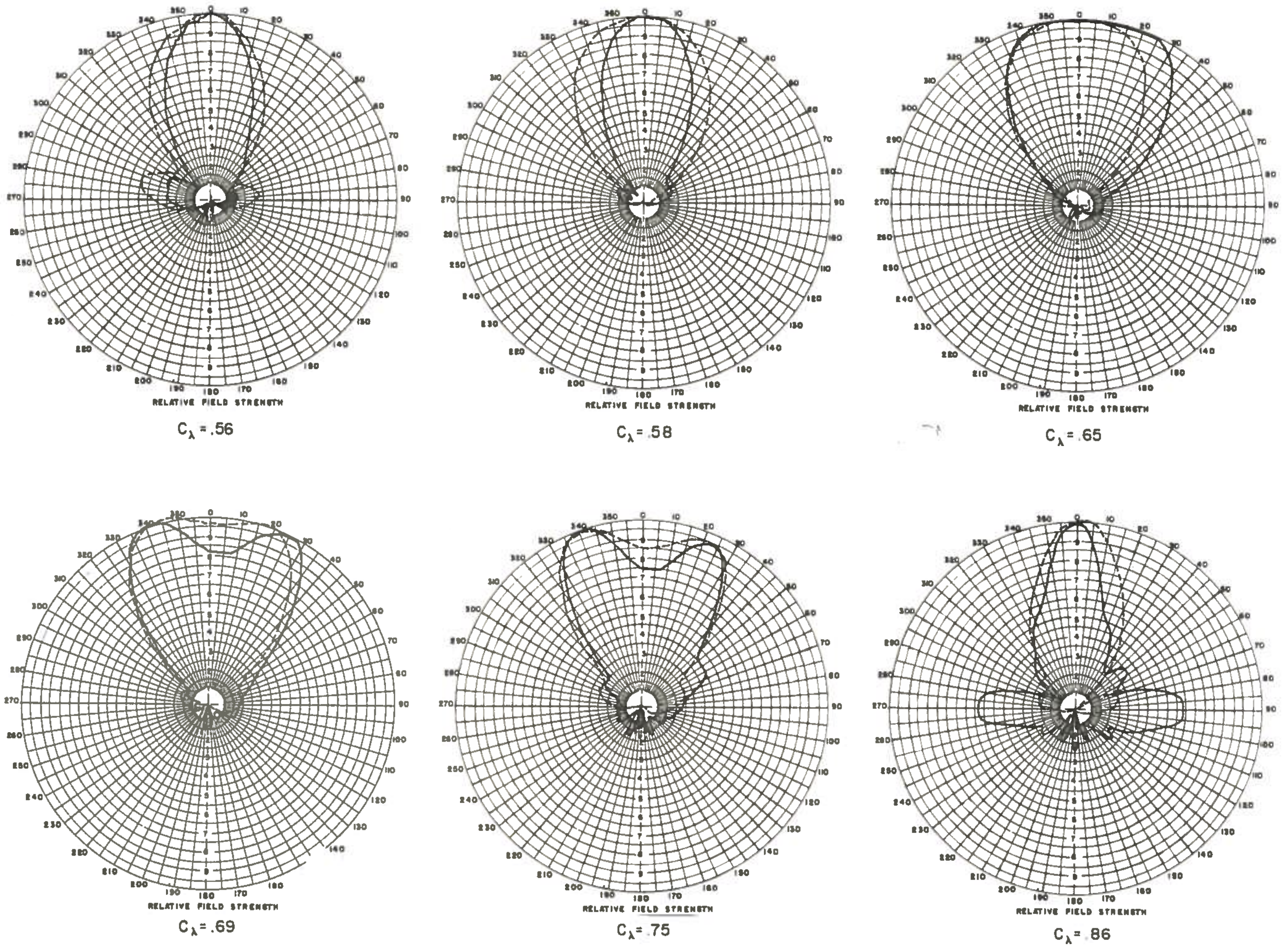

FIG. 5 RADIATION PATTERNS OF HELIX WITH PYREX GLASS CORE

—— Horizontal Polarization

---- Vertical Polarization

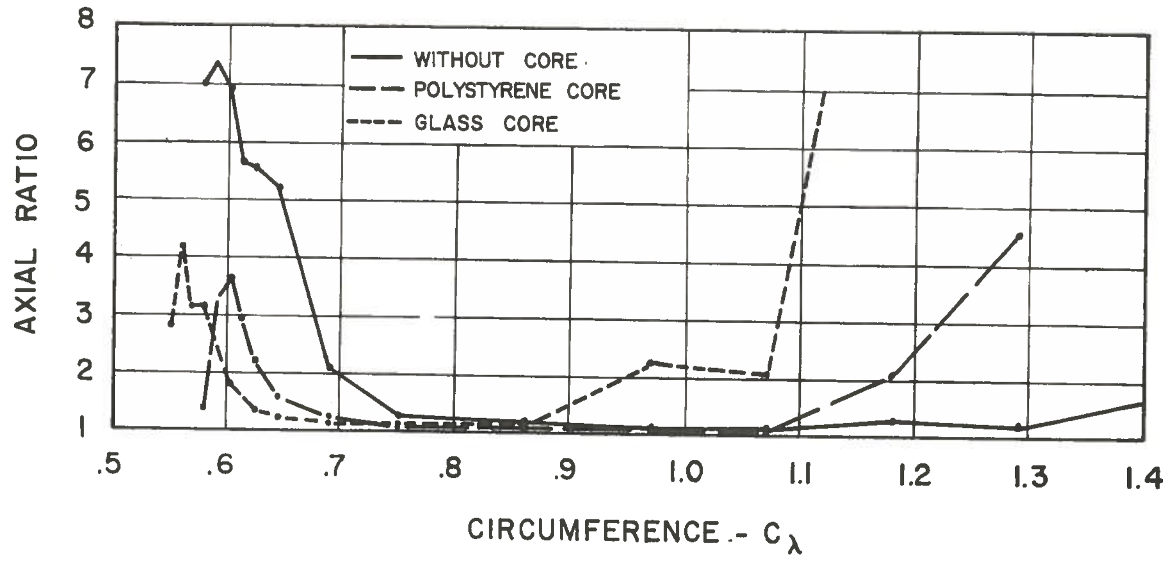

FIG. 6 AXIAL RATIO OF HELIX WITH DIELECTRIC CORE

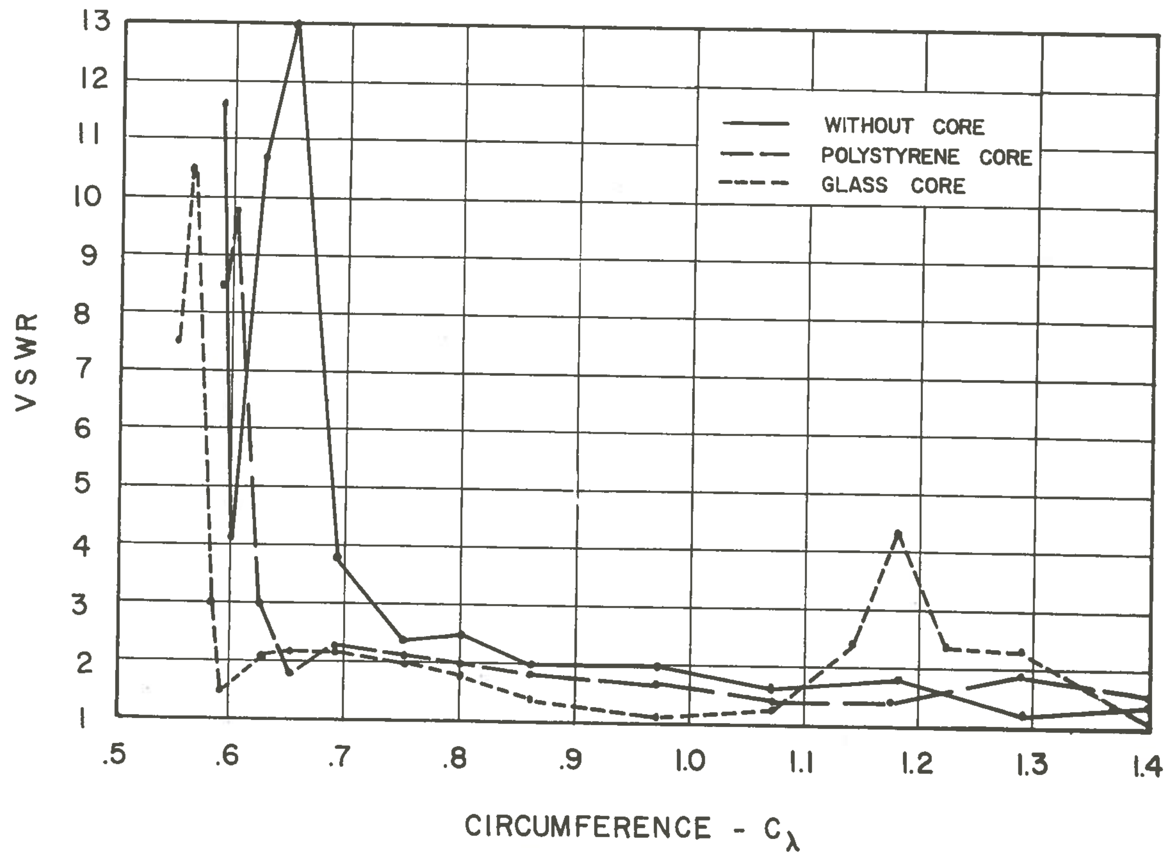

FIG. 7 VSWR OF HELIX WITH DIELECTRIC CORE

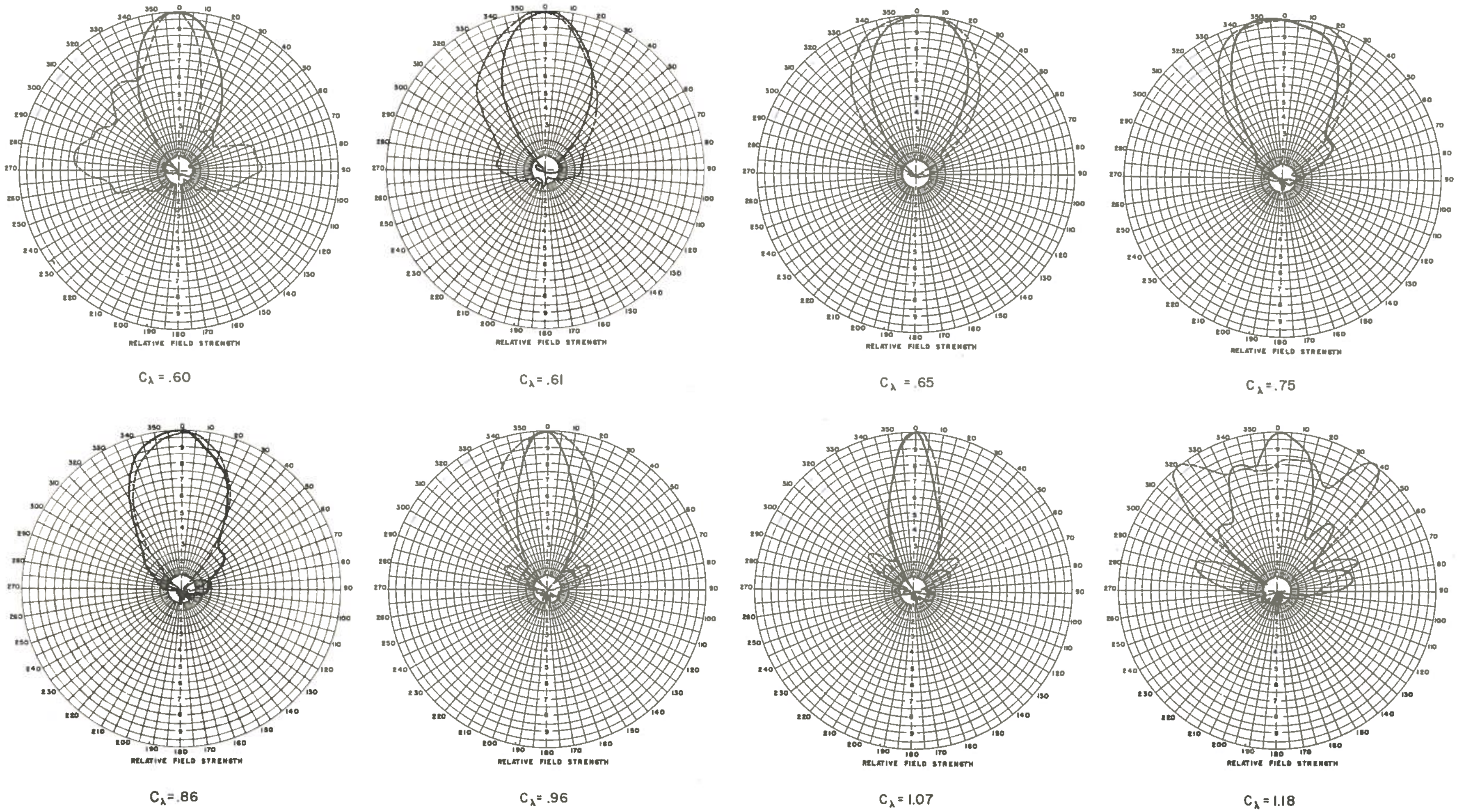

FIG. 8 RADIATION PATTERNS OF HELIX WITH REXOLITE SLEEVE

—— Horizontal Polarization

---- Vertical Polarization

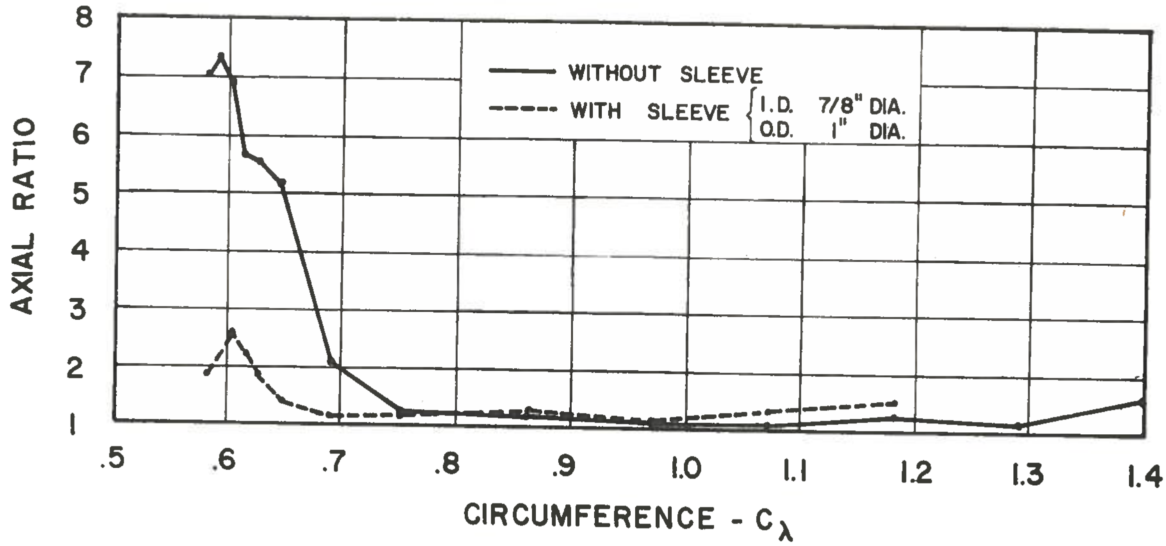

FIG. 9 AXIAL RATIO OF HELIX WITH REXOLITE SLEEVE

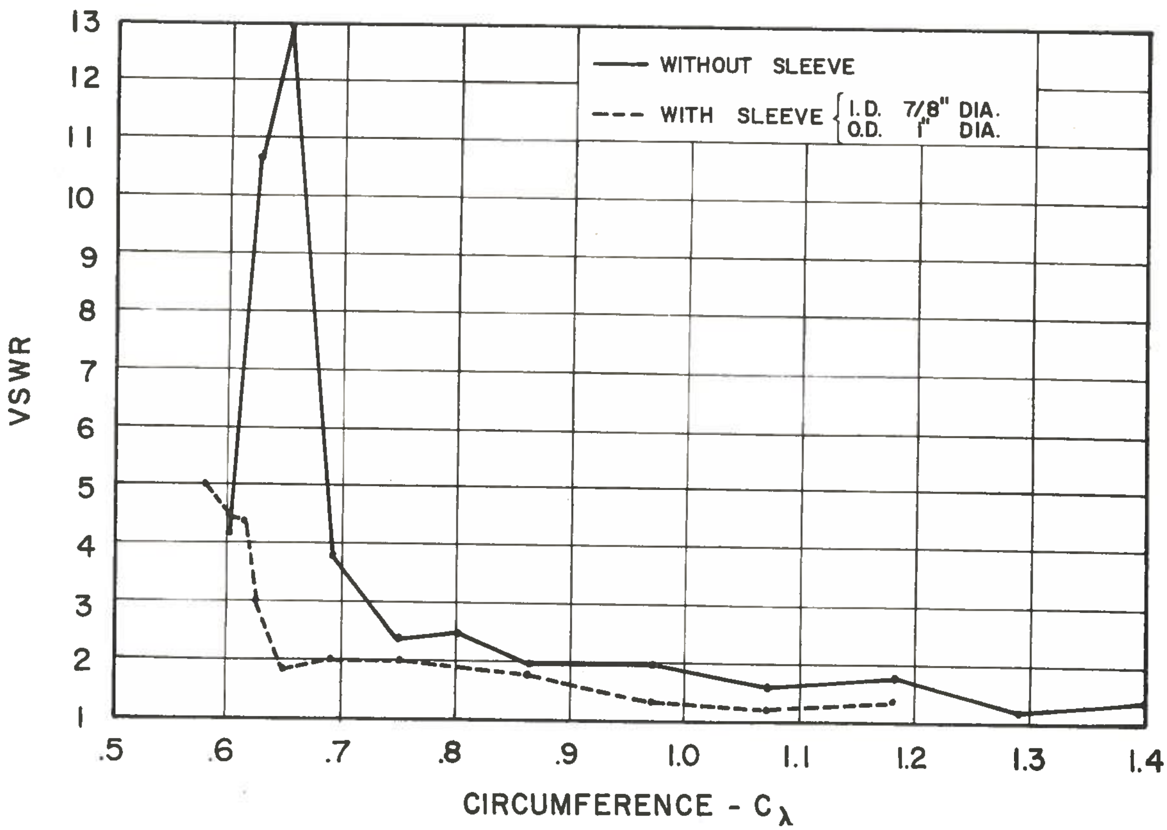

FIG. 10 VSWR OF HELIX WITH REXOLITE SLEEVE