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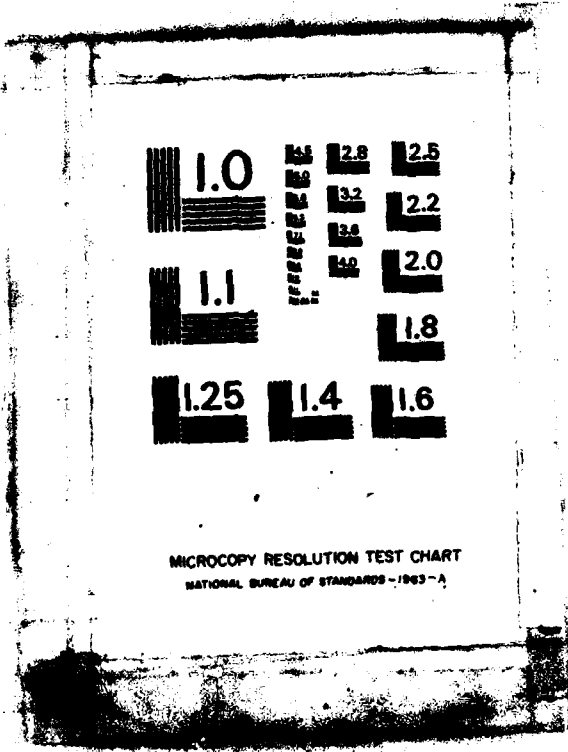
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STUDIES IN FIN-LINE ANTENNA DESIGN FOR
PHASED ARRAY APPLICATIONS

INTERIM TECHNICAL REPORT

E. FARR
K. WEBB
R. MITTRA

NOVEMBER 1983

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20. KEY WORDS (Continue on reverse side if necessary and identify by block number) fin-line; antenna; phased array; millimeter wave; dielectric rod		
21. ABSTRACT (Continue on reverse side if necessary and identify by block number) An experimental study was conducted concerning the development of an endfire fin-line antenna, suitable for phased array applications at 220 GHz. Experimental models of several designs were built and tested at 80 GHz.		

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STUDIES IN FIN-LINE ANTENNA DESIGN FOR PHASED ARRAY APPLICATIONS

by

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Interim Technical Report

November 1983

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INTRODUCTION

There is, at present, a great deal of interest in imaging radar systems to be operated at 220 GHz. We are interested in this frequency because waves in this region penetrate dust and fog better than optical wavelengths, and because systems with such short wavelengths tend to be compact and light-weight. Additionally, at 220 GHz, there is a local minimum in the attenuation constant through air [1]. These characteristics enhance the desirability of this frequency range for imaging radar applications in battlefield situations, where compactness and mobility are of prime concern, and dust and fog may obstruct visibility.

It has been proposed, furthermore, that such an imaging radar system be built primarily from fin-line, a diagram of which appears in Fig. 1. Fin-line components are low loss at high frequencies and are easily built using standard printed circuit techniques [2]. The particular part of the imaging radar system we worked on was the antenna and feed mechanism. Several designs were developed, which were tested at 80 GHz. These designs and antenna patterns are presented in the following sections.

THE FIN-LINE ANTENNA

In order to develop an imaging radar system, a component of primary interest must be the antenna. For this application, we envisage an array of a large number antennas and feed structures arranged in a densely-packed formation. Before studying the array as a whole, we must first study the characteristics of a single antenna element.

Such a fin-line antenna must satisfy several criteria. First, it must have a relatively small cross-sectional area. Next, it must have an overall design that is compatible with a densely-packed configuration. Furthermore,

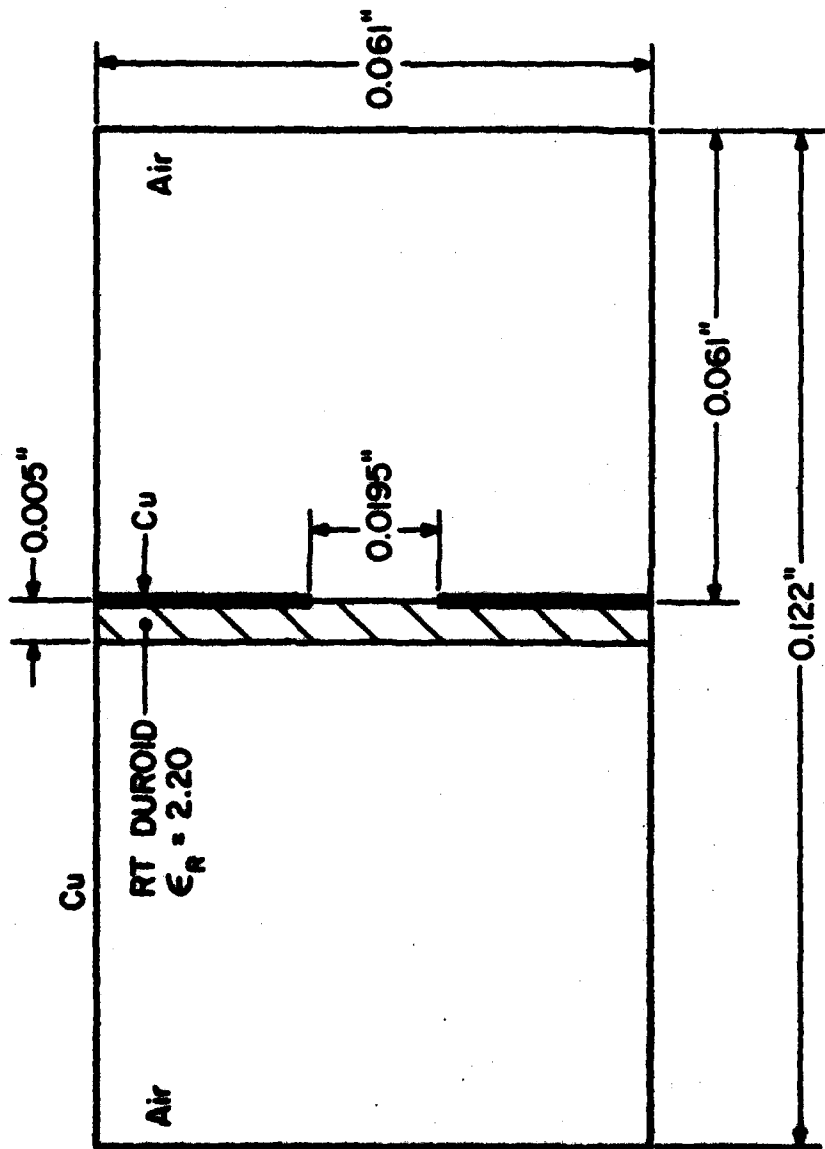


Figure 1. Cross section and dimensions of an E-band fin-line.

this antenna must have a fairly broad beamwidth. Finally, this antenna must be endfire. The latter is perhaps the most difficult criterion to satisfy. It is easy to visualize a broadside fin-line antenna based on a periodic variation in the slot width which operates in a leaky-wave mode. With an endfire antenna, however, no obvious design choice immediately presents itself. Therefore, we have had to try several possibilities.

ANTENNA DESIGN AND EXPERIMENTAL SETUP

We now turn to the design and measurement of the fin-line antennas under study. We tested four designs of endfire fin-line antennas, whose designs are shown in Figs. 2-5. In Fig. 2, an antenna is shown in which the dielectric portion of the fin-line was extended past the end of the metal shield. In Fig. 3, we have a design in which a thicker dielectric rod, made of Rexolite (dielectric constant = 2.53), is protruding from the front end in a similar fashion. Fig. 4 depicts a printed dipole arrangement, while Fig. 5 shows a printed vee dipole. Both dipoles extend beyond the end of the copper shield.

The fin-lines were mounted between two blocks of copper whose inner dimensions were those of standard K-band rectangular waveguide. A diagram of one of these copper blocks is shown in Figure 6. Note that a recess was formed on the right side of the feed in order to allow a standard K-band metal waveguide to couple into the fin-line. The fin-lines were fabricated with standard photolithographic techniques. The substrate was 1/2 oz. copper clad RT/Duroid 5880, made by Rogers Corporation, with a dielectric constant of 2.20 at 10 GHz.

We now turn to the experimental setup used to measure these antennas, a diagram of which is shown in Fig. 7. An 80 GHz oscillator, modulated at

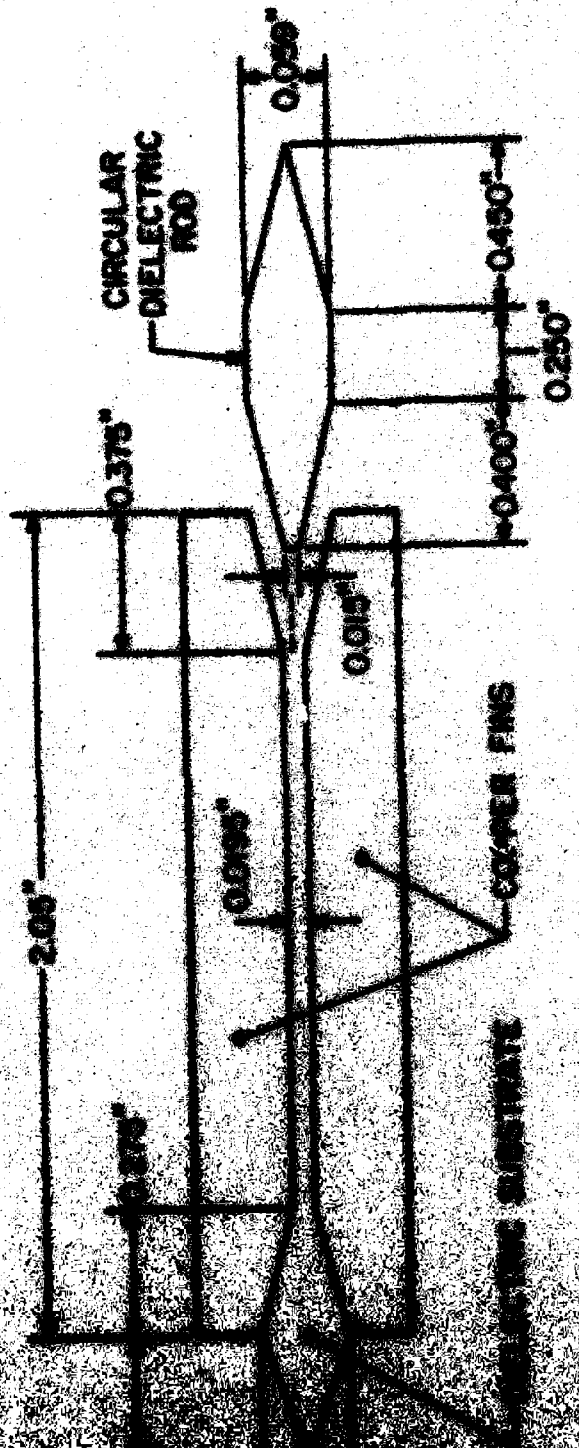


Figure 2. Extended dielectric fin-line antenna.

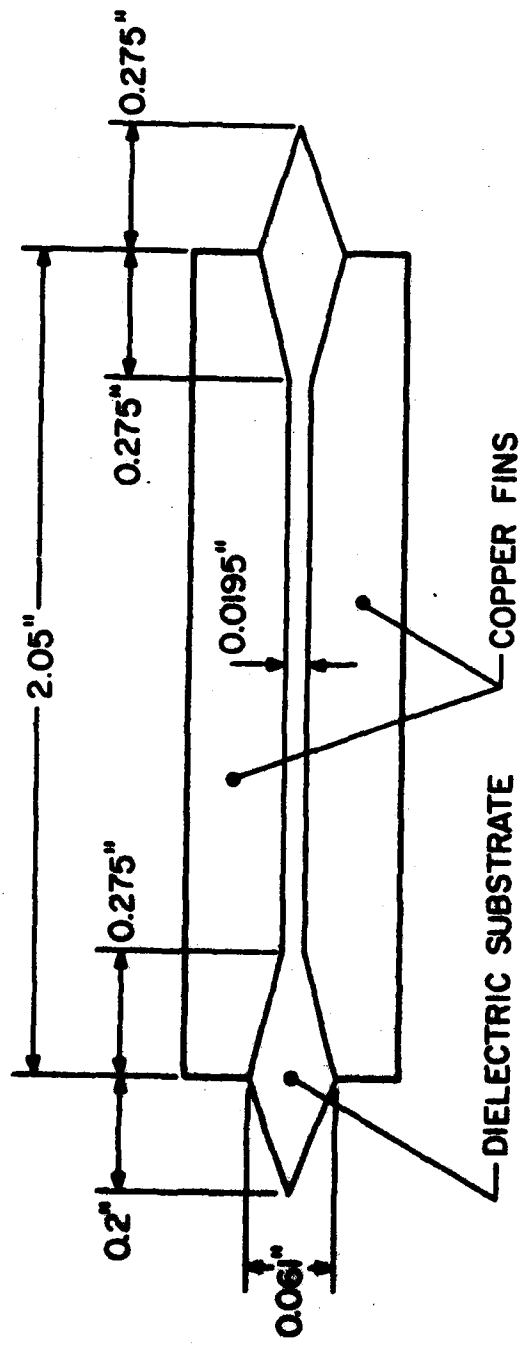


Figure 3. Dielectric rod fin-line antenna.

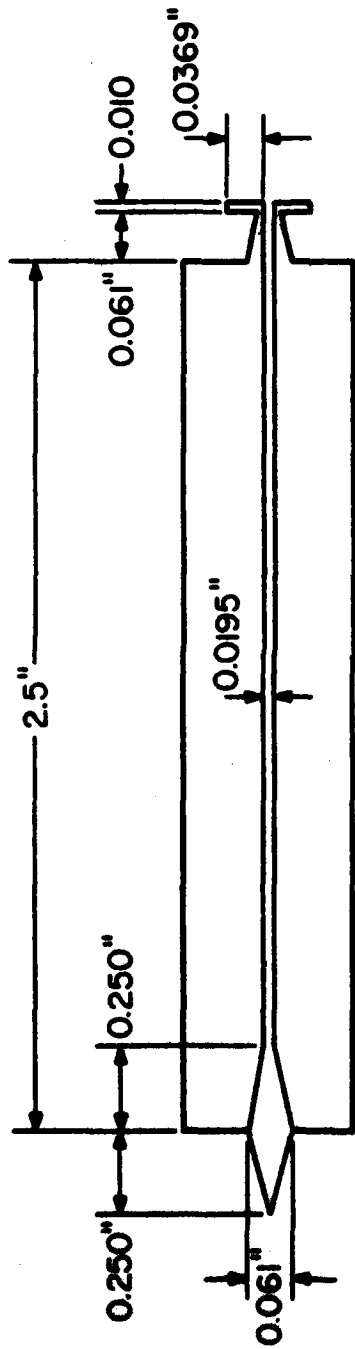


Figure 4. Printed dipole fin-line antenna. The lengths of each half of the dipole are quarter wavelength at 80 GHz. This simulates a half-wave dipole.

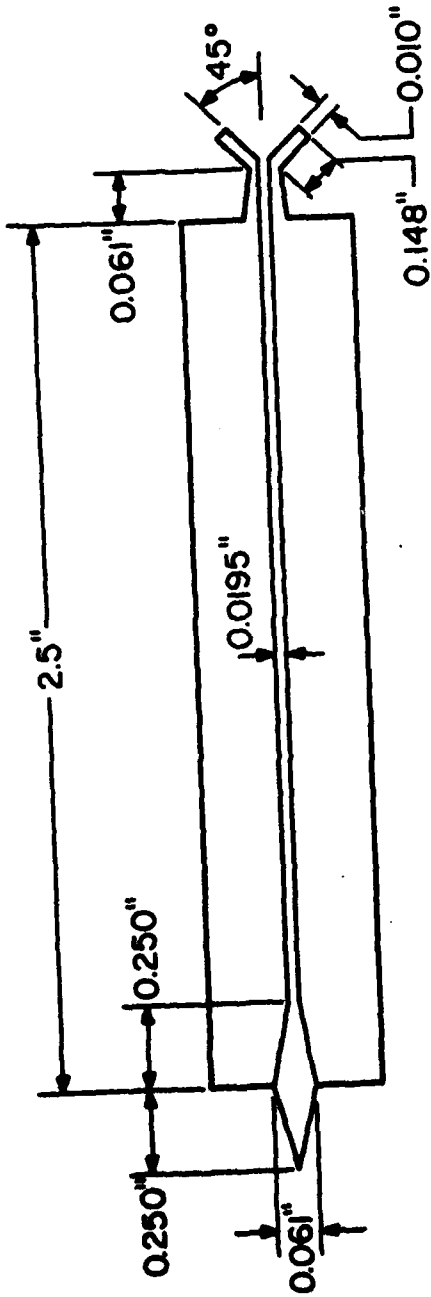


Figure 5. Printed vee dipole fin-line antenna. The length of each vee section is approximately one wavelength at 80 GHz.

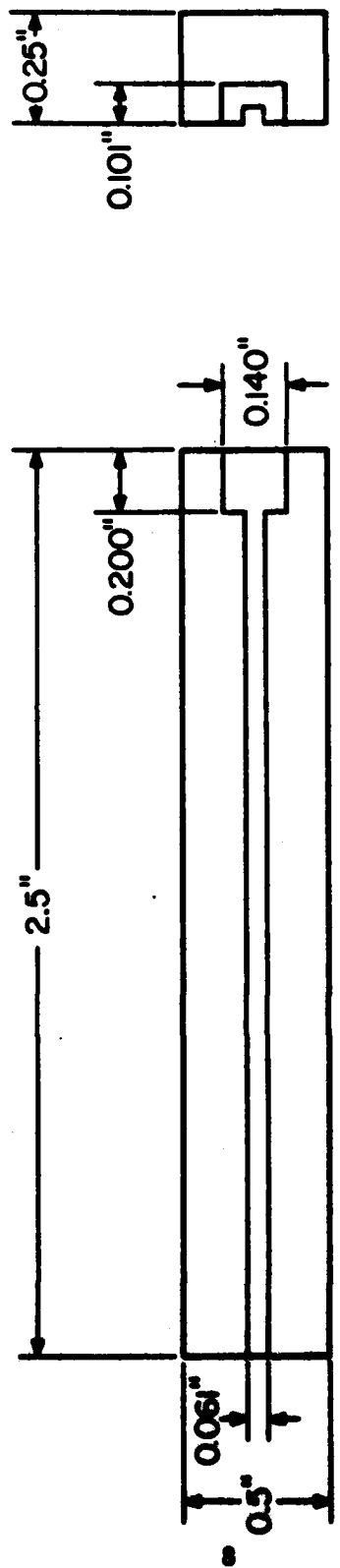


Figure 6. The copper shield for all the fin-line antennas tested.

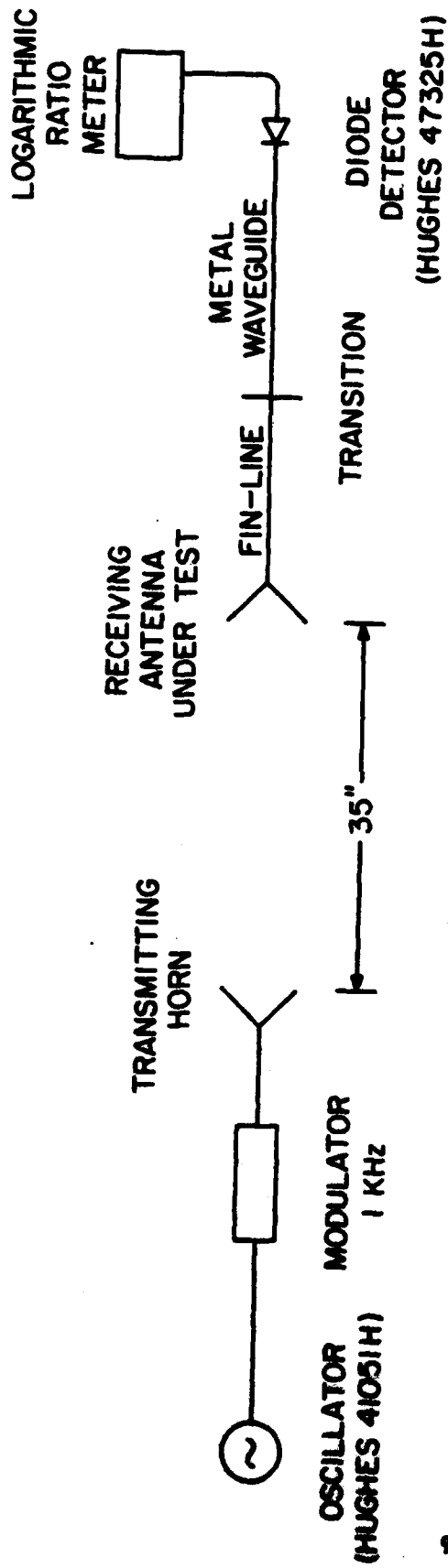


Figure 7. Experimental setup. The antenna under test was mounted on a rotating platform.

1 KHz, generated waves which were transmitted to an antenna under test which was 35" away. The antenna under test was connected via a transition to a standard rectangular metal waveguide which was terminated in a diode detector. The level of the diode detector was measured by a log-ratio meter and recorded on an X-Y plotter as a function of angle.

Now that the antenna designs and experimental apparatus have been discussed, we are ready to look at the results of our tests. These are presented in the next section.

EXPERIMENTAL RESULTS

In order to have some patterns with which to compare our test antenna patterns, we began by plotting the H-plane patterns of a standard gain (24.7 dB) horn and an open-ended waveguide. These plots are shown in Fig. 8.

Next, we plotted H-plane patterns of fin-line antennas for the extended dielectric case (Fig. 2) and the dielectric rod case (Fig. 3). These patterns are shown in Fig. 9. Note that the gain of the dielectric rod configuration (13 dB) is approximately 4 dB higher than that of the open-ended waveguide (9 dB).

Finally, we measured the H-plane pattern for the printed dipole (Fig. 4) and vee dipole (Fig. 5). Neither of these two designs performed satisfactorily.

From these antenna patterns we can draw several conclusions. While neither the dipole nor vee dipole configurations performed satisfactorily, the extended dielectric configuration showed some promise, and the dielectric rod configuration showed a great deal of promise, with a gain of 13 dB and a 3 dB beamwidth of 40 degrees. It is likely that adjustments can be made to this design in order to further improve its performance.

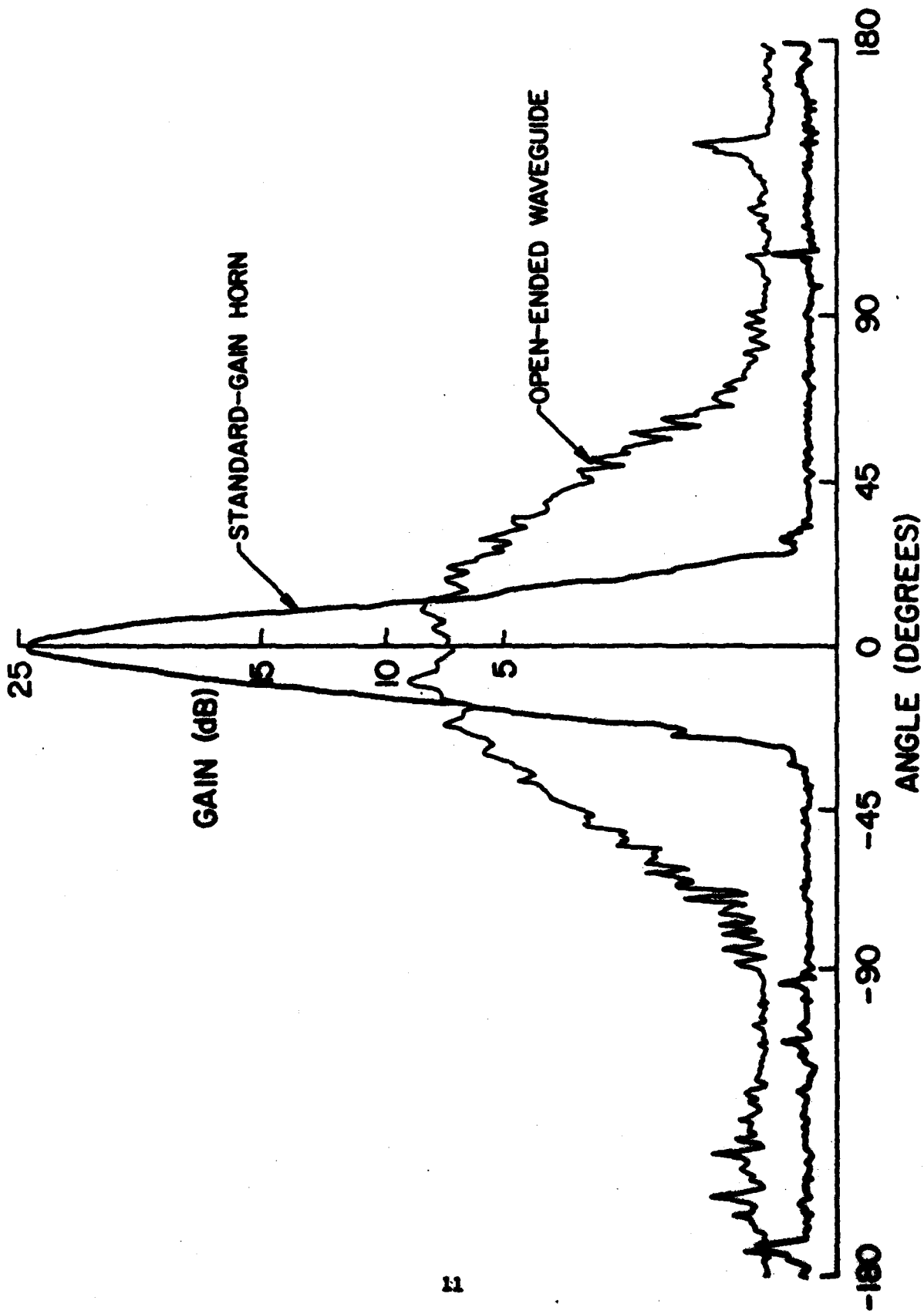


Figure 8. H-plane patterns of standard-gain horn and open-ended waveguide.

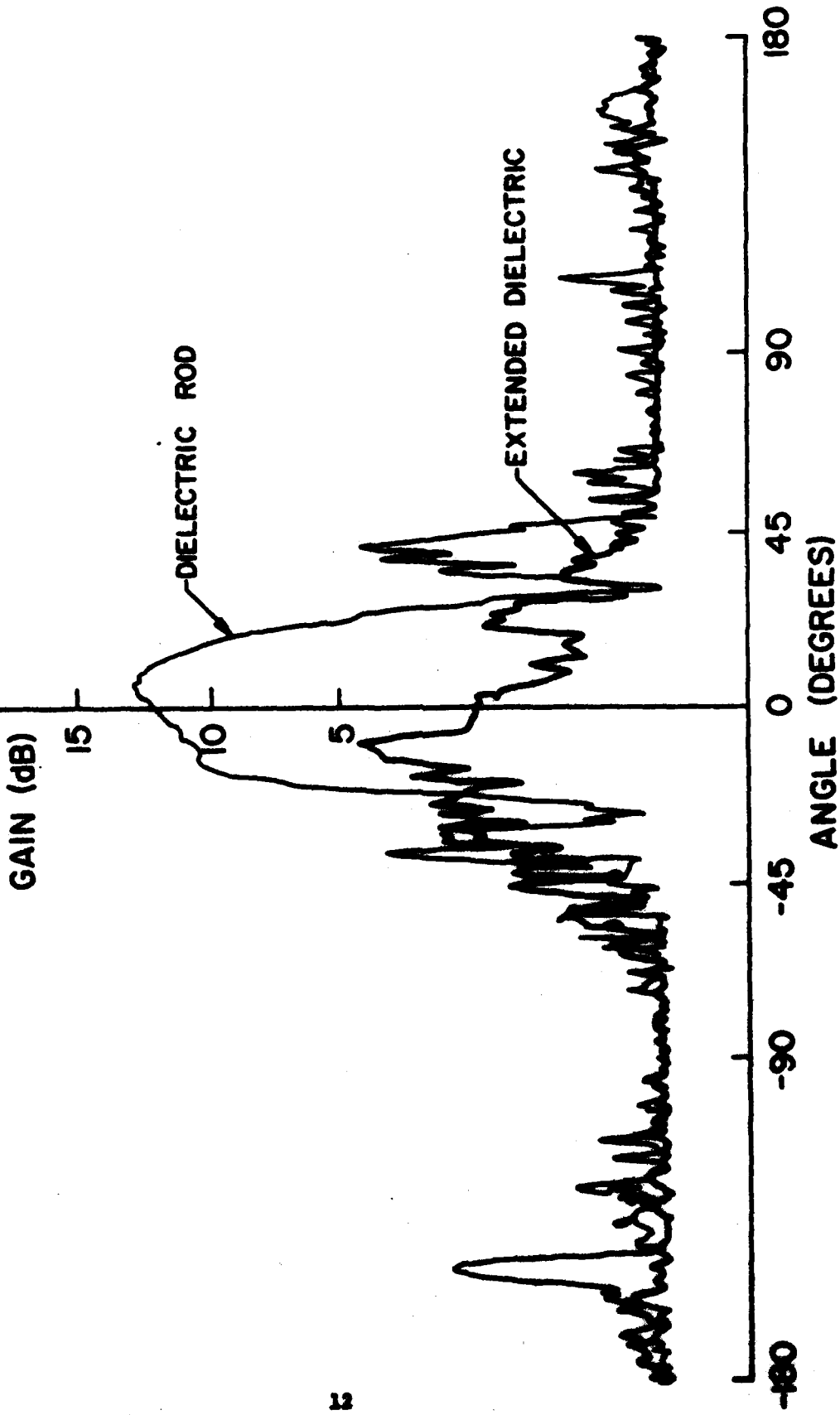


Figure 9. M-plane patterns of fin-line antenna with extended dielectric (see Fig. 4), and dielectric rod (see Fig. 5).

RECOMMENDATIONS FOR FURTHER STUDY

We now present our recommendations for further study of the 220 GHz imaging radar system. We have generated two distinct possibilities for the antenna array, so we will look at each individually.

The first possibility for this antenna is to have a transition from fin-line to metal waveguide, and build an antenna from metal waveguide components. A fin-line to rectangular waveguide transition is easily built, an example of which is shown in Fig. 10. Furthermore, the antenna would consist of either a horn or an open-ended waveguide. The horn would give a higher gain than the open-ended waveguide, but it would also have a larger cross-sectional area, thereby increasing the size of the array. Therefore, one would use only as much flare in the waveguide as was required for sufficient gain.

The second possibility for the fin-line antenna is to use the fin-line directly in a dielectric rod configuration, shown in Figure 3. This configuration produced the best pattern of all the new designs tested. It had a gain of 14 dB and a 3 dB beamwidth of 40 degrees. With further study, it should be possible to improve the antenna pattern by varying the parameters in the design of the antenna.

CONCLUSIONS

An experimental study was performed to determine the feasibility of several fin-line antenna designs for a 220 GHz imaging radar system. Two possible designs emerged from this study. One design involved a transition from fin-line to rectangular waveguide, followed by a horn or open-ended waveguide antenna. The other design involved an endfire fin-line antenna

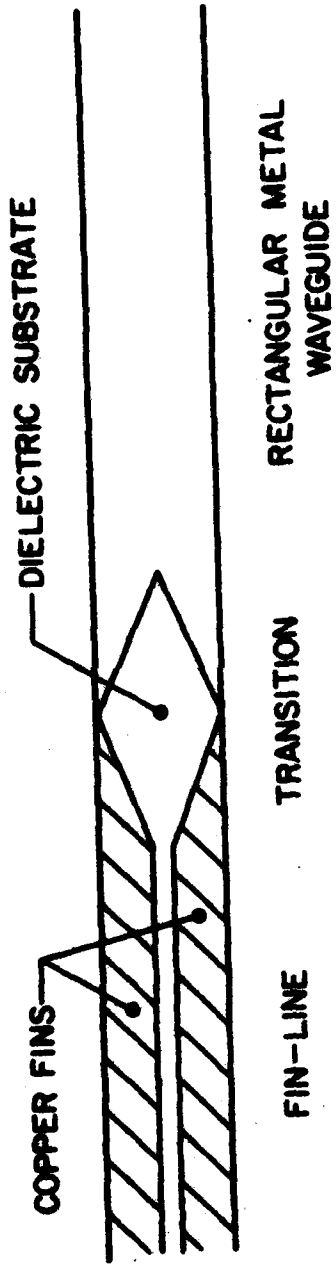


Figure 10. An example of a fin-line to rectangular waveguide transition.

with a dielectric rod protruding from the front end. The initial experimental results are quite promising as this research effort continues.

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