Electromagnetic Coupling Reduction Techniques

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By

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FOREWORD

This report was prepared by The University of Michigan, Ann Arbor, Michigan, under the direction of Professor Ralph E. Hiatt and Professor John A. M. Lyon and on Air Force Contract AF 33(615)-3371 under Task No. 435709 of Project 4357 (U) "Electromagnetic Coupling Reduction Techniques". The work was administered under the direction of the Air Force Avionics Laboratory, Electronic Warfare Division, Research and Technology Division, Wright-Patterson Air Force Base Ohio. The Task Engineer was Mr. Olin E. Horton, the Project Engineer Mr. Herbert Bartman.

This report covers the period 15 August through 15 November 1966.

ABSTRACT

During this report period, a number of experimental studies were made in either the X-band or the S-band of frequencies. The favorable results reported here showing various amounts of decoupling due to a number of techniques can be interpreted as applying to any designated frequency band. The chosen frequencies were selected entirely for convenience.

The effectiveness of corrugations surrounding a rectangular slot antenna as a means of decoupling was determined. The decoupling between two slot antennas due to surrounding absorber was also determined. A few experiments confirmed the variation of coupling or decoupling associated with the spacing of antennas when the distances of separation correspond to far field situations. Decoupling was attained for an X-band installation of rectangular slot antennas through the use of a simple additional channel over the ground plane from one antenna to another. More extended studies on RF bridge links are included in this report. Appreciable amounts of decoupling have been obtained with properly arranged parasitic elements. Near field decoupling studies have been made on an experimental basis at S-band using Archimedean spiral antennas.

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I

INTRODUCTION

Continued studies have been made of the decoupling between two rectangular slots utilizing corrugations surrounding either one or both such antennas. For E-plane coupling it has been found that corrugations around one such antenna will reduce the coupling by 10 db over a 30 percent bandwidth. For H-plane coupling, the reduction is 12 db for corrugations around one slot antenna; this reduction holds for the entire X-band.

The study of decoupling of two antennas through the use of absorbing material around one or both antennas has also been continued. Although the resulting decoupling achieved is only moderate, the greatest objection to this method is that much energy has been absorbed and thereby the effectiveness of each antenna is reduced through a reduction of the useful gain.

As a further check on the effect of decoupling associated with the spacing of antennas experimental measurements were made on two E-sectoral horns for various spacings. Over a wide range of frequencies the decoupling achieved corresponded to the known theoretical 6 db per octave for E-plane coupling and 12 db per octave for H-plane coupling.

A simple means of directing energy useful for destructive interference was utilized in providing an auxiliary path channel for the flow of energy just over the ground plane. This method is certainly closely related to the RF bridge links discussed in greater detail in the report. It has been shown experimentally that these surface channels for passing energy can be adjusted to provide a decoupling of 12 db over a 20 percent bandwidth.

Additional studies were made using parasitic elements, one parasitic being placed on each side of a slot antenna. Measurements of decoupling from such a slot used as a transmitter to another plain slot used as receiver showed that 7 db decoupling could be obtained over a 20 percent bandwidth.

Rather detailed studies have been made in the further developments of RF bridge links as a means of supplying destructive interference on a broadband basis. These studies have necessitated proper choice of microwave elements so that critical components can meet the broadband requirement. It is now believed that the refined bridge is one capable of offering decoupling compensation over a wide range of frequencies, perhaps even the entire X-band. Actual decoupling measurements with the improved bridge have not yet been made.

II

EXPERIMENTAL STUDIES

2.1 Decoupling Two Antennas by Means of Corrugations

The technique of creating a capacitive surface impedance by means of corrugations of appropriate depth was further pursued. In the area of the ground plane in the immediate vicinity of a slot fed by a waveguide a number of corrugations were formed as circumferential trenches (Fig. 2-1). All trenches were of the same depth (1 cm). The depth was chosen so that the corrugations would offer a capacitive surface impedance for frequencies in the middle of X-band (Lyon et al, 1966). Since the wavelength in the corrugations varies according to radius, this structure offers some inherent broadbanding.

The coupling between a slot surrounded by these corrugations and a plain slot was measured and compared to that of two plain slots at the same distance. For these measurements a swept frequency method was utilized. Two different orientations were considered; that where the E-planes of the slots are aligned (E-plane coupling) and that where the H-planes are aligned (H-plane coupling). It was found that the maximum E-plane coupling over a 30 percent bandwidth was reduced by 10 db (Fig. 2-2). The effect of the corrugations on the H-plane coupling is somewhat more pronounced producing an increase in isolation of approximately 12 db across the entire X-band as shown in Fig. 2-3. The many peaks and troughs appearing in the curves of Fig. 2-3 were found to be due to scattering from the anechoic chamber interfering with the low level of coupled signal.

It should be noted that if both antennas were similarly surrounded by corrugations twice as much decoupling would be obtained. For example, the maximum H-plane coupling would be -78 db (at 8 GHz) tapering off to -89 db at 12 GHz.

An important aspect of the decoupling problem is how the applied technique affects the radiation patterns of the antenna. The circumferential corrugations

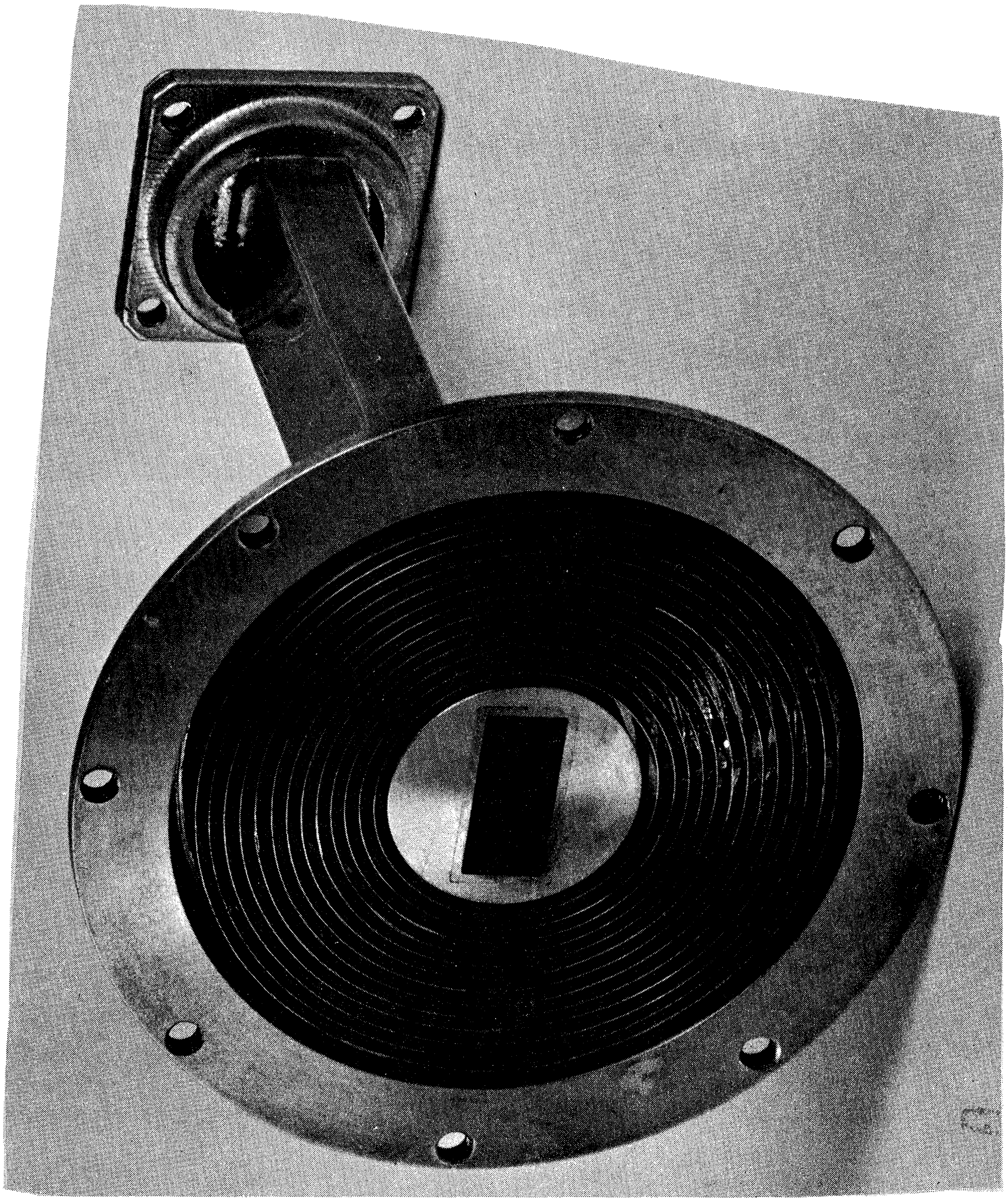


FIG. 2-1: SLOT ANTENNA WITH CORRUGATIONS

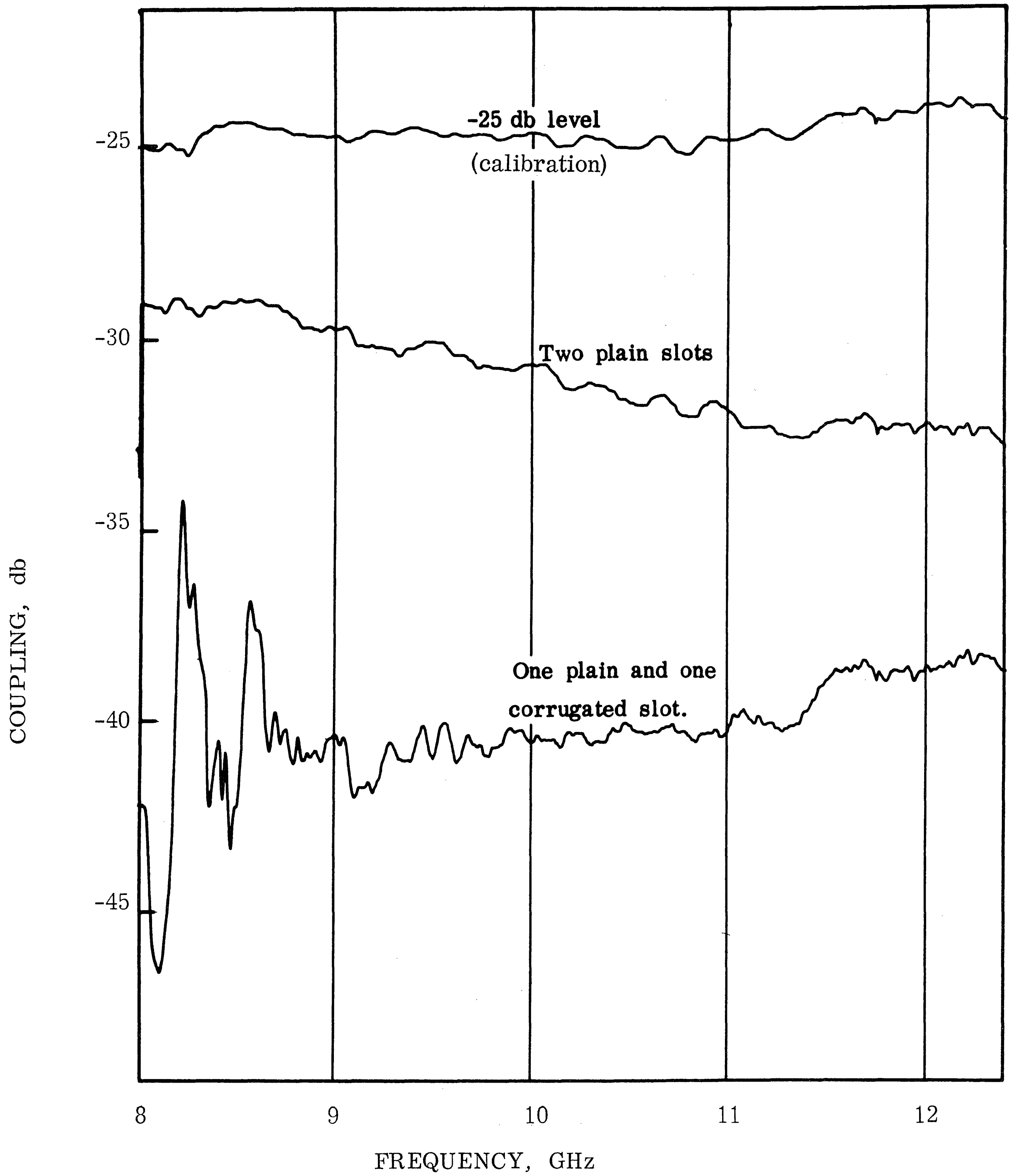


FIG. 2-2: E-PLANE COUPLING VS FREQUENCY FOR TWO SLOTS SPACED 11.43 CM.

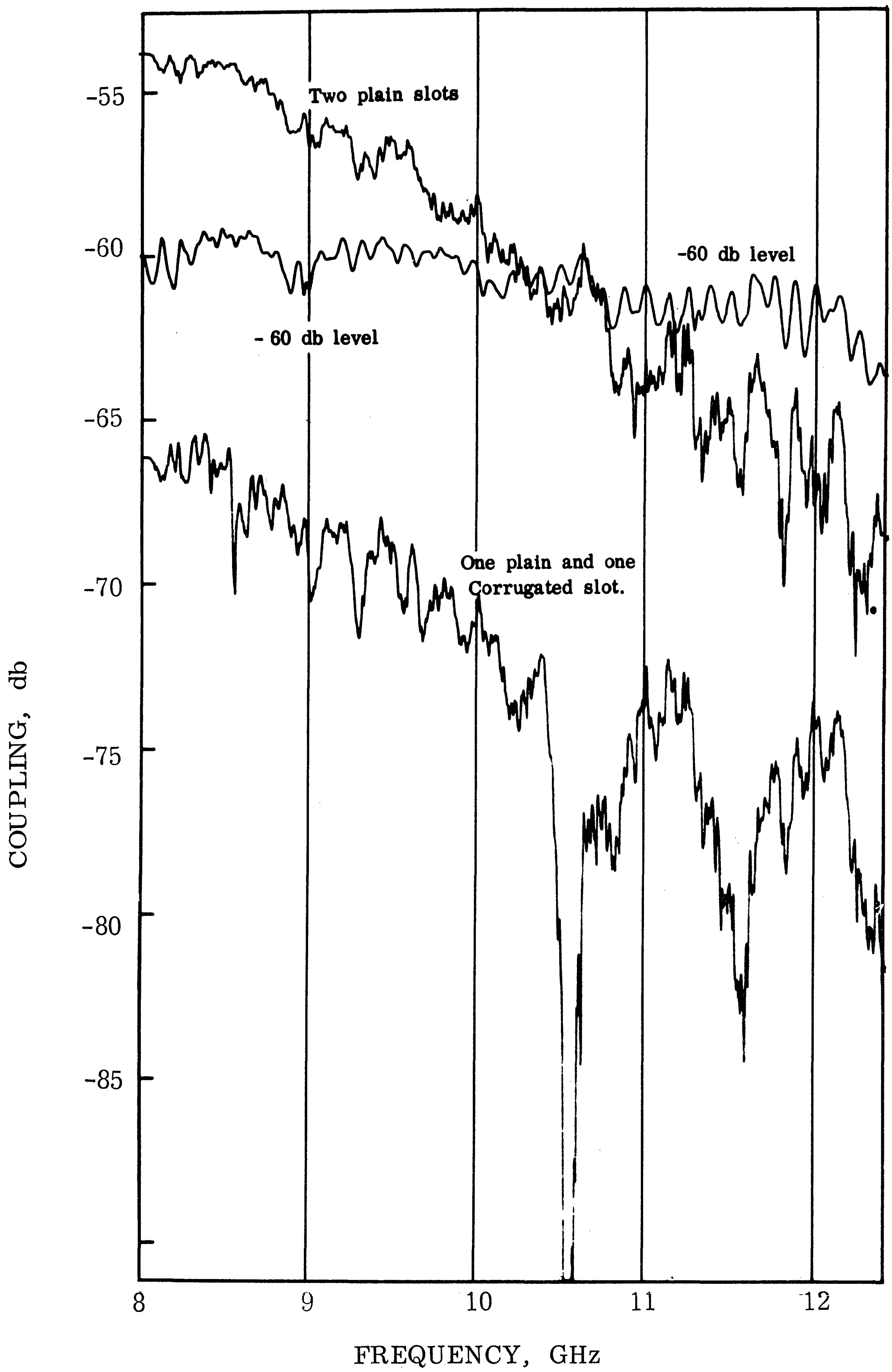


FIG. 2-3: H-PLANE COUPLING VS FREQUENCY FOR TWO SLOTS SPACED 11.43 CM.

have a pronounced effect on the E-plane radiation pattern, increasing the amount of radiated power in the broadside direction and decreasing it along the ground plane. (Fig. 2-4). Thus the maximum gain of the slot with corrugations is always higher than that of a plain slot over the entire X-band (Fig. 2-5).

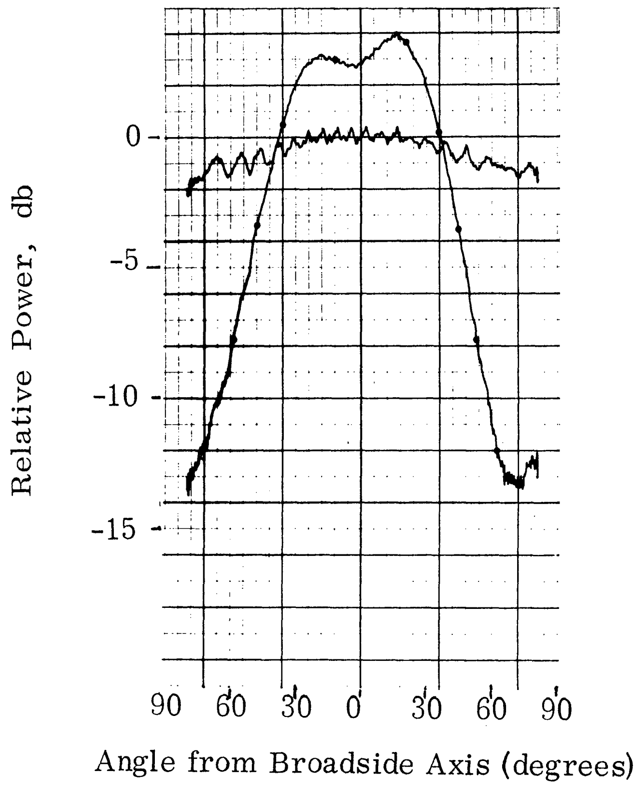
2.2 Decoupling of Two Antennas by Means of Absorbing Materials

The high isolation modification described in Quarterly Report No. 3 (7692-3-Q, p. 6) under this contract, was used with a different absorbing material, Emerson and Cuming's Eccosorb-CR for which the manufacturer specifies an average value of attenuation of 34 db/cm at 10 GHz. The decoupling obtained in the E-plane was of the same order of magnitude with that obtained previously by using Eccosorb MF-124 material; in the H-plane the Eccosorb-CR type material turned out to be less effective by as much as 3 db.

In another series of experiments a cavity of circular cross-section was filled with absorbing material (Eccosorb MF-124) except for a rectangular opening the size of an X-band waveguide. (See Fig. 2-6.) Two different cases were considered: a) The waveguide extends all the way to the surface, being flush with the ground plane. b) The waveguide stops at the cavity bottom being flush with it.

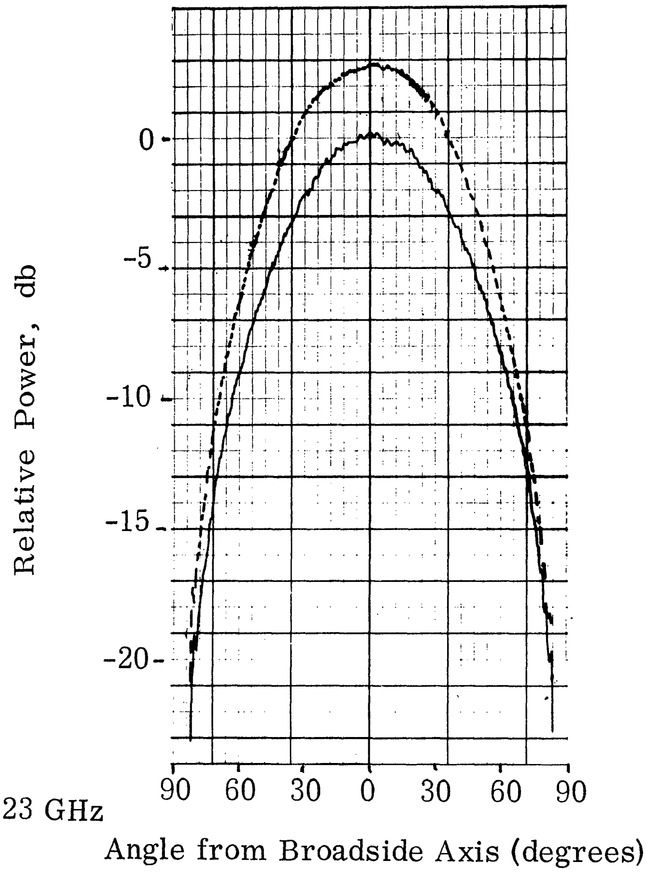
In case (a), with one slot only of a transmitter-receiver system being modified, a decoupling of 3.5 db was observed in the E-plane across the X-band. However, this results in a loss of maximum gain for the modified slot varying from 0.5 to 1.5 db depending upon the frequency. In case (b) a decoupling of 11 db across the X-band was measured, again with one slot only being modified (E-plane). The loss in maximum gain though was also significant varying from 8 db to 4 db.

The above information leads to the conclusion that absorbing materials alone

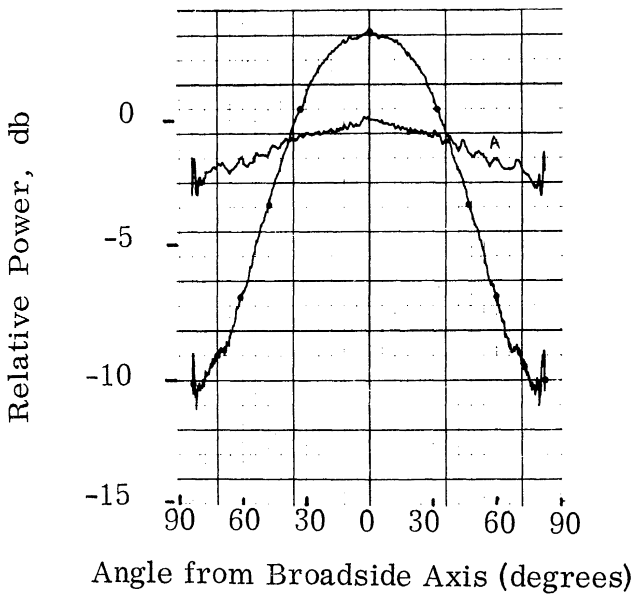


(a) E-PLANE

8.23 GHz

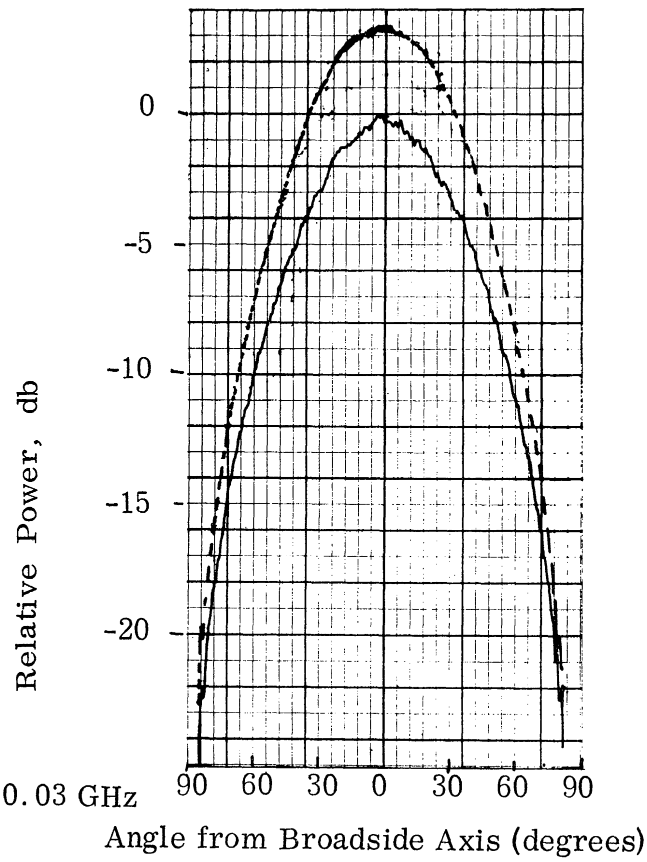


(b) H-PLANE



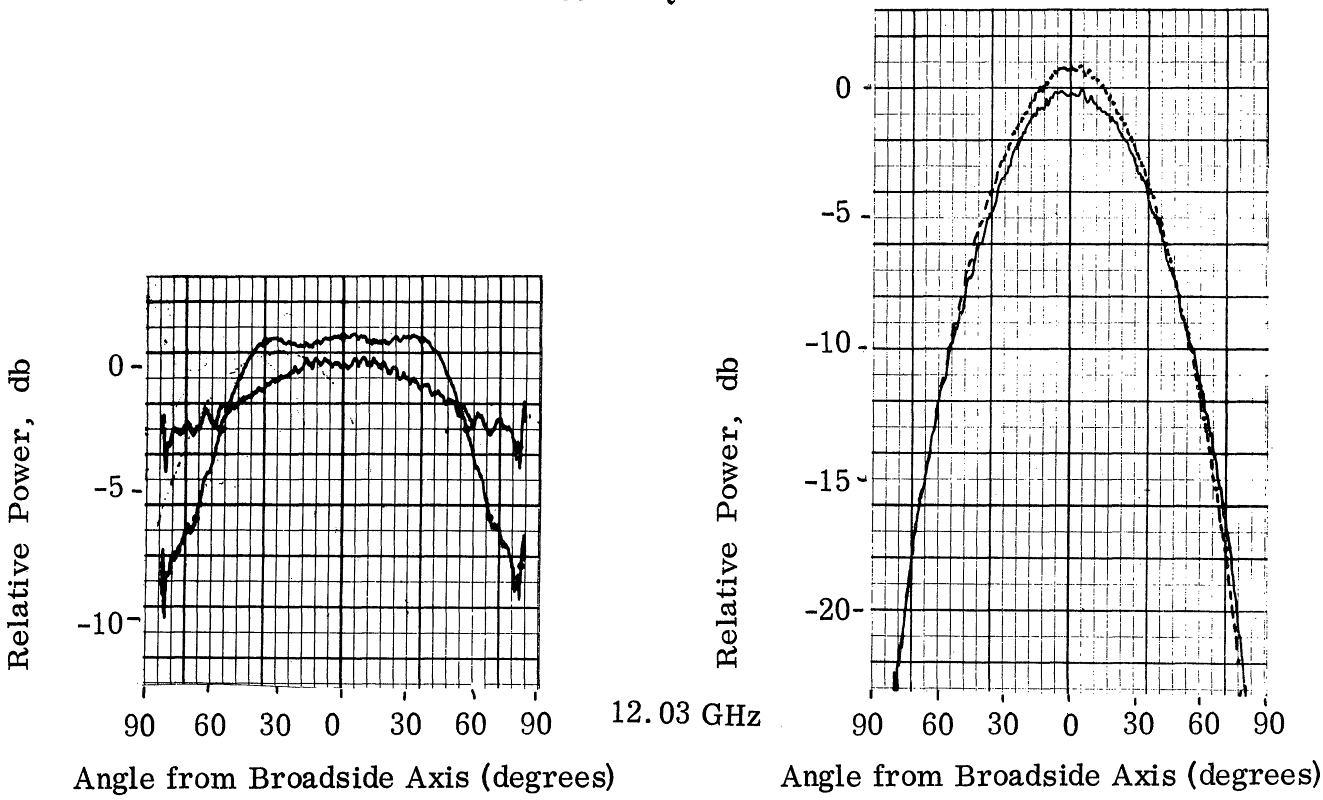
(c) E-PLANE

10.03 GHz



(d) H-PLANE

FIG. 2-4: E- AND H-PLANE RADIATION PATTERNS. (——) PLAIN SLOT; (—●—) OR (- - -) SLOT WITH CORRUGATIONS.



(e) E-PLANE (f) H-PLANE

FIG. 2-4: CONTINUED.

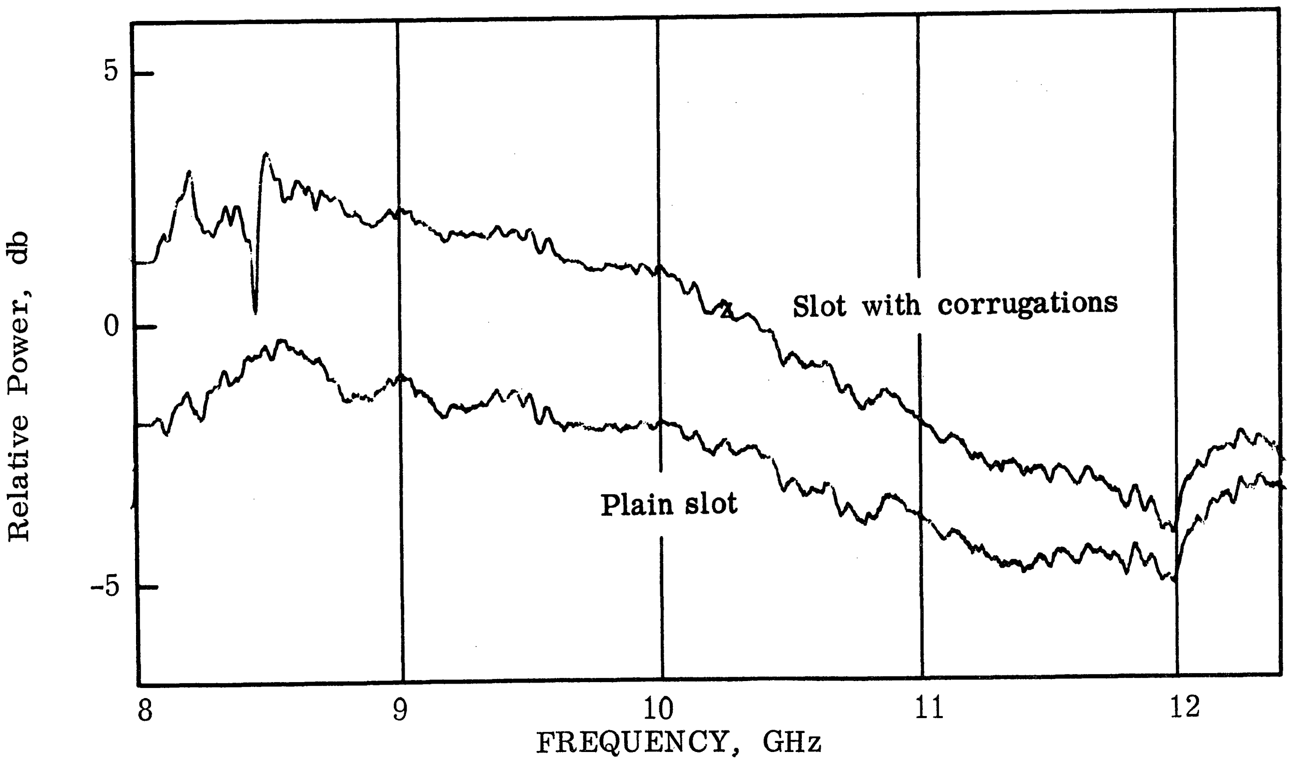


FIG. 2-5: MAXIMUM GAIN VS. FREQUENCY.

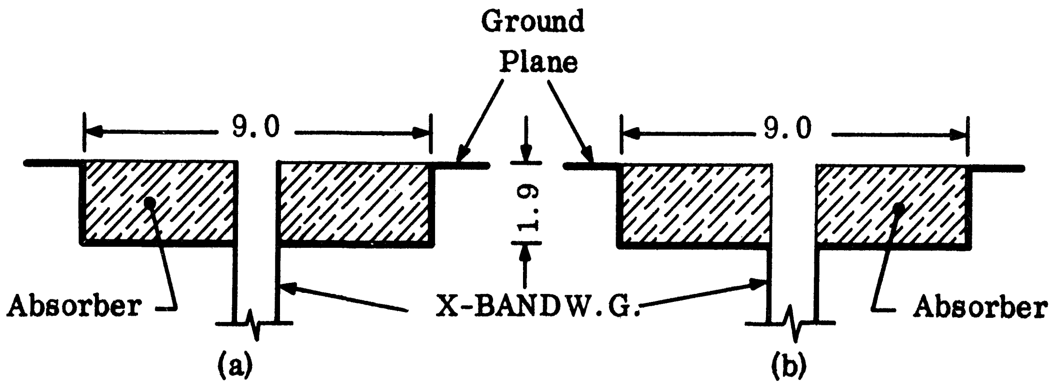


FIG. 2-6: GEOMETRY OF SLOT AND CAVITY (DIMENSIONS IN CM).

used flush on a ground plane do not offer an acceptable means to achieve decoupling.

2.3 Effect of Antenna Spacing on Coupling

Increased spacing, when possible, is a simple and effective means for obtaining increased isolation. Swept frequency measurements shown in Figs. 2-7 and 2-8 for the two E-sectoral horns, demonstrate this fact. The spacings used are in the ratio 1:2:4 and thus successively increase by an octave of distance. In the far field the corresponding couplings are 6 db apart for E-plane coupling and 12 db apart for H-plane. The noise-like irreqularities appearing at the coupling levels of -65 db and below are due to interference with anechoic chamber reflections.

2.4 Decoupling Two Antennas by Phase Cancellation

The technique of phase cancellation can be applied in a number of ways, one of which is the RF bridge discussed in Section 2.7 of this report. An alternate approach has been tried by creating a channel on the ground plane

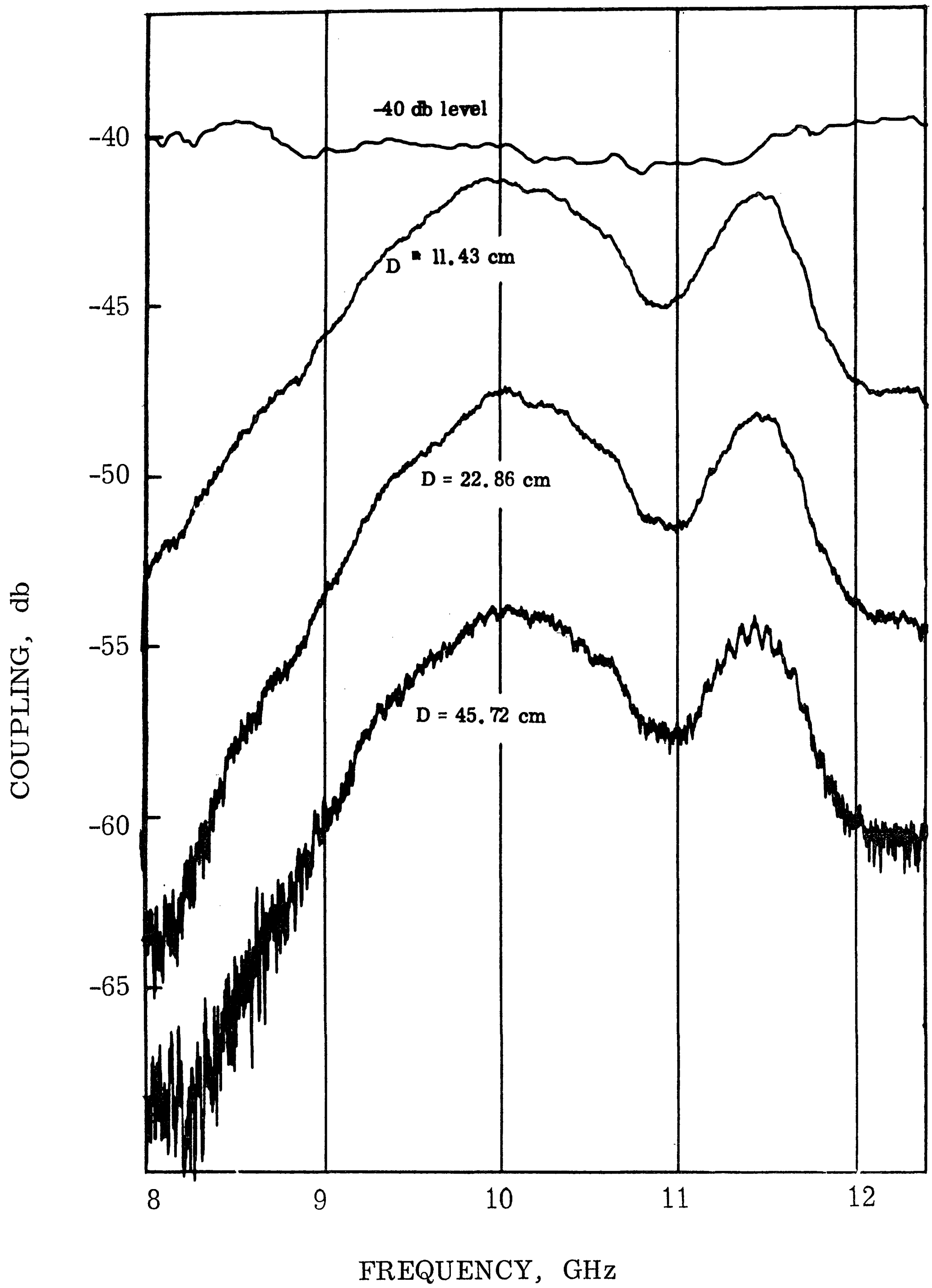


FIG. 2-7: E-PLANE COUPLING VS FREQUENCY FOR TWO E-SECTORAL HORNS (FLARE ANGLE 20°).

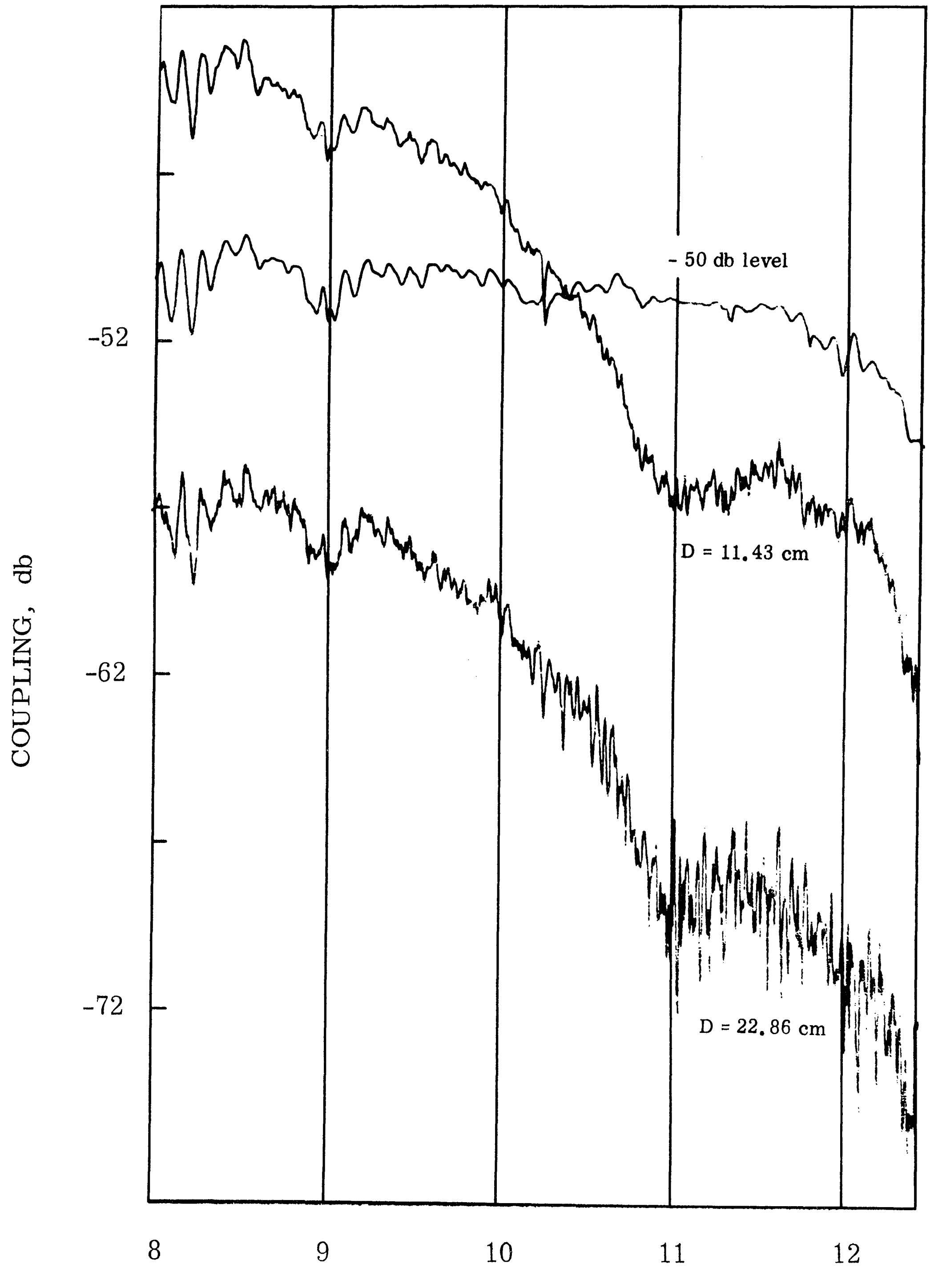


FIG. 2-8: H-PLANE COUPLING VS FREQUENCY FOR TWO E-SECTORAL HORNS (FLARE ANGLE 20°).

between the transmitting and receiving antennas which would direct, to the receiver, an amount of power approximately equal to the coupled power but of different phase. A small strip cut from B. F. Goodrich type RF-X resonant absorber, backed by aluminum foil (the combination corresponds to a quarter-wavelength wave trap in transverse thickness) was used to create this link. In the initial experiments the strip was placed flat on the ground plane. By changing the width and length of the strip as well as its position on the ground plane, it was possible to control the amount of power carried over to the receiver. It was found that a pair of strips placed as shown in Fig. 2-9 gave the best results to date. One of the typical patterns obtained is shown in Fig. 2-10. This is for E-plane coupling of the X-band slots. For this case a decoupling of 12 db over a 20 percent bandwidth is shown.

2.5 Use of Parasitic Elements

Two parasitic slots backed by a cavity were used symmetrically on both sides of a transmitting slot (in the E-plane). A center-to-center spacing of 1.5 cm between the transmitting slot and either of the parasitics and a cavity depth of 1.4 cm which corresponds to 0.35 λg at the center frequency of 10 GHz were found to produce the maximum decoupling. The decoupling obtained in this way was 7 db over a 20 percent bandwidth and 6 db over a 30 percent bandwidth.

The addition of two small reflectors parallel to the ground plane and at 0.4 cm above it increased the decoupling by another 2 to 3 db. In general, the action of the parasitics is similar to that of the corrugations and so far the use of multiple corrugations has produced better results.

2.6 Near Field Coupling Between Two S-Band Spirals.

Coupling data between two circular spirals and also between two square spirals have been taken at various frequencies. The following two cases were studied; a) The two square spirals have the same sense of rotation, b) The

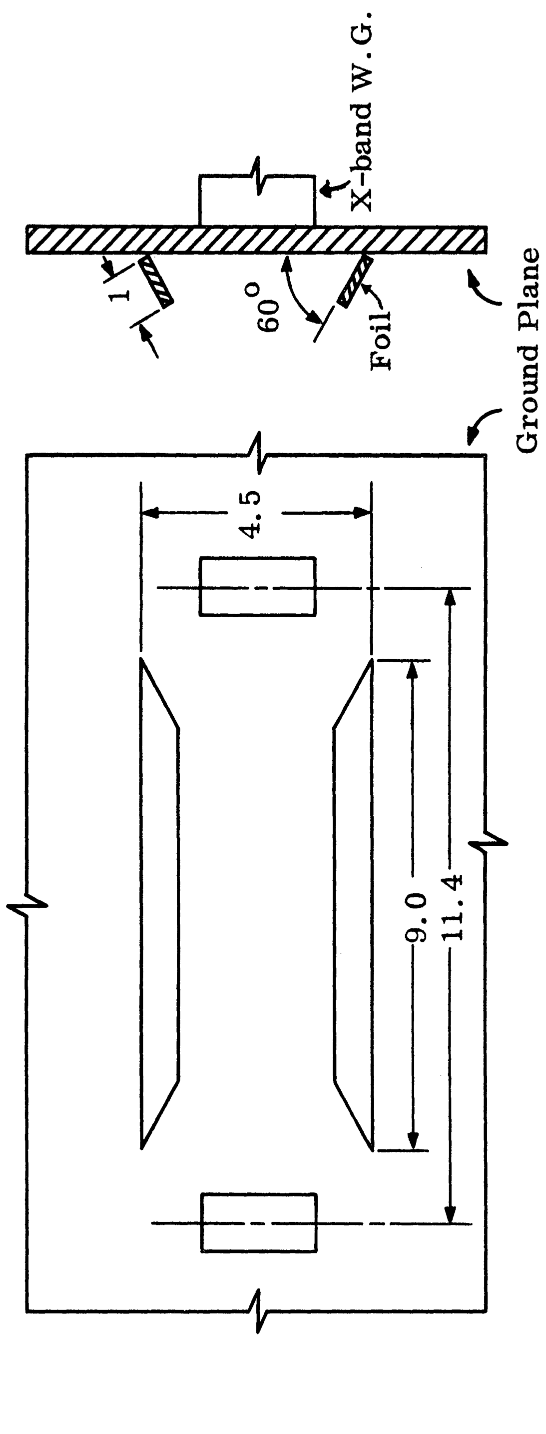


FIG. 2-9: GEOMETRY FOR PHASE CANCELLATION:
(DIMENSIONS IN CM).

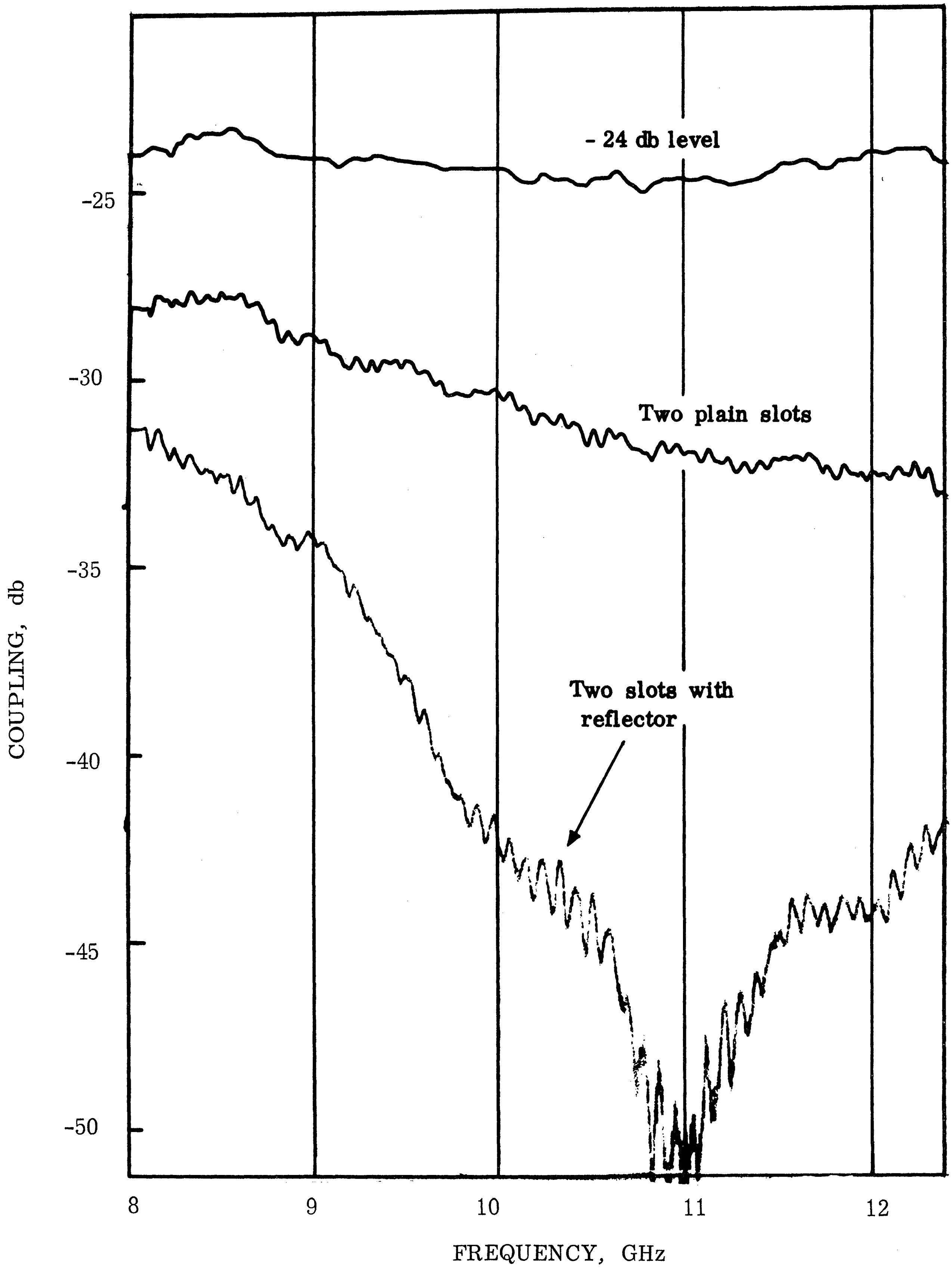


FIG. 2-10: E-PLANE COUPLING VS FREQUENCY FOR TWO SLOTS SPACED 11.43 CM.

two square spirals have different sense of rotation. In both cases the distance between the spirals was small. The experimental results on two square spirals spaced 11.43 cm (center-to-center) at frequencies 2.2 GHz, 3.0 GHz and 3.8 GHz did not show any marked difference in the two cases. However, other experiments using cylindrical helix antennas indicate some difference in the two cases when the spacing between them is small. It is thought that in the spiral experiments the separations between antennas were not close enough and the frequencies were not low enough to yield any observable differences. A modification of the ground plane that will allow the spirals to be placed at a closer spacing for further investigation is in progress.

Figures 2-11 and 2-12 show the near field coupling between two circular spirals vs orientation at different frequencies and separations. Figures 2-13 and 2-14 show the near field coupling of square spirals of both the same and opposite sense of rotation at a center-to-center separation of 11.48 cm.

2.7 Decoupling of Two Antennas by Means of an RF Bridge

As stated in Quarterly Report No. 3 (7692-3-Q) under this contract, the RF bridge produced an isolation of 15 db between two slot antennas over a bandwidth of 1.5 GHz in X-band. Our objective was to increase both the bandwidth and the amount of decoupling produced.

An experiment was performed which implied that the bandwidth and decoupling limitations of the RF bridge were caused mainly by the bridge components. The slot antennas were removed from the coupled path and replaced with waveguide; the cancellation obtained was no better than the decoupling before. Thus, it was decided to work on a so-called Cancellation bridge, which does not actually decouple two antennas; instead, this Cancellation bridge cancels two RF signals. An RF bridge used to decouple two antennas cannot work

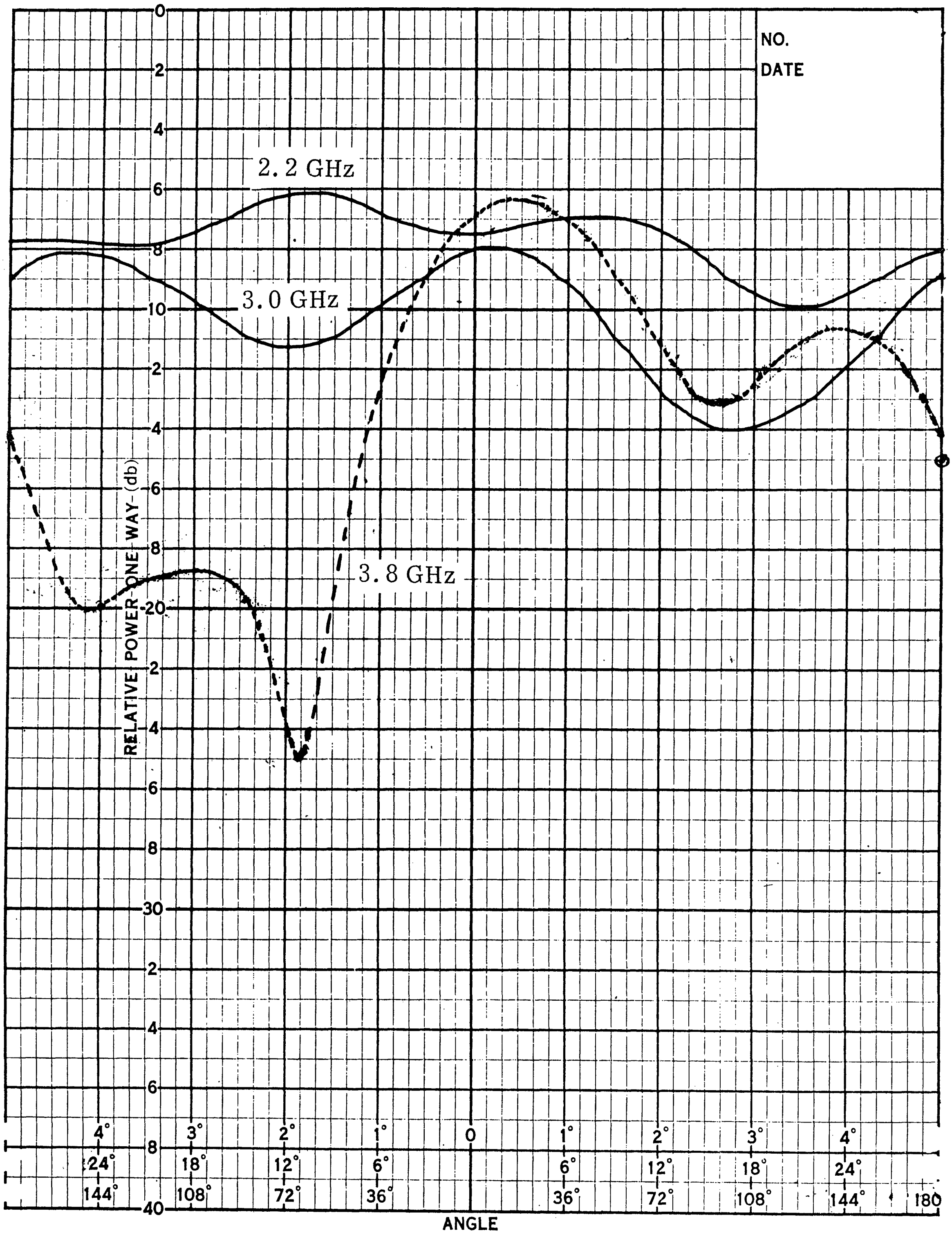


FIG. 2-11: COUPLING VS RECEIVER ORIENTATION (-180° TO 180°) FOR TWO CIRCULAR SPIRALS SPACED 11.43 CM. SAME SENSE OF ROTATION. ZERO REFERENCE IS -25 db FROM DIRECT COUPLING.

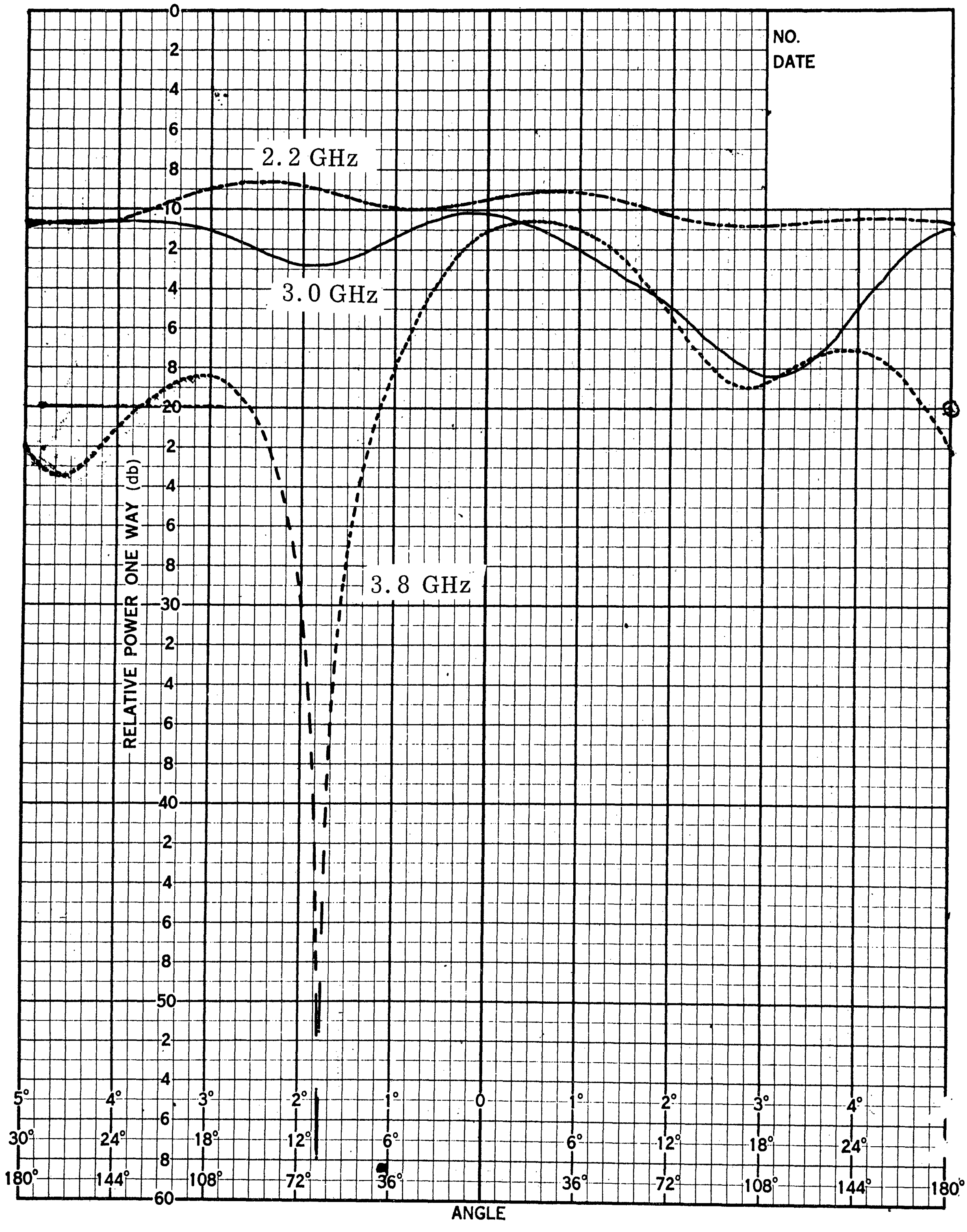


FIG. 2-12: COUPLING VS RECEIVER ORIENTATION (-180° TO 180°) FOR TWO CIRCULAR SPIRALS SPACED 22.86 CM WITH THE SAME SENSE OF ROTATION. ZERO REFERENCE IS -30 db FROM DIRECT COUPLING.

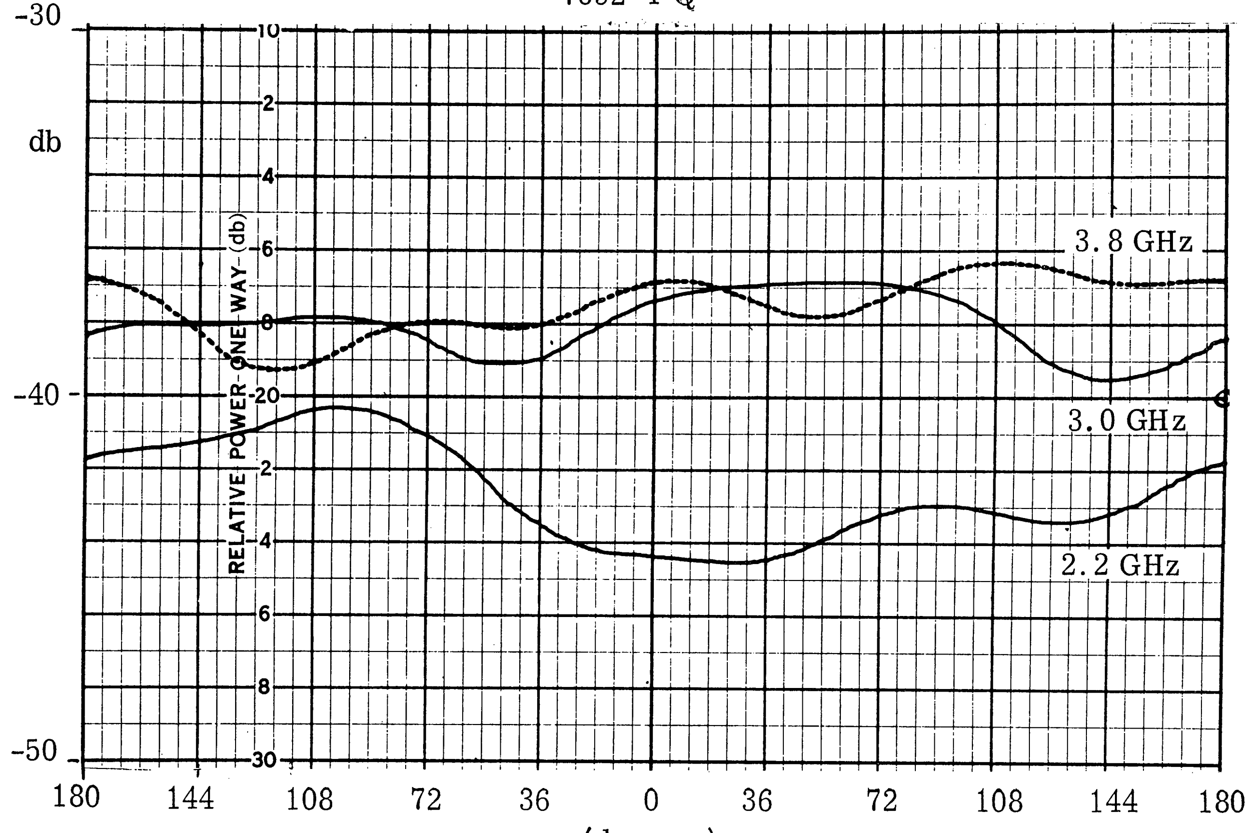


FIG. 2-13: SAME SENSE OF ROTATION

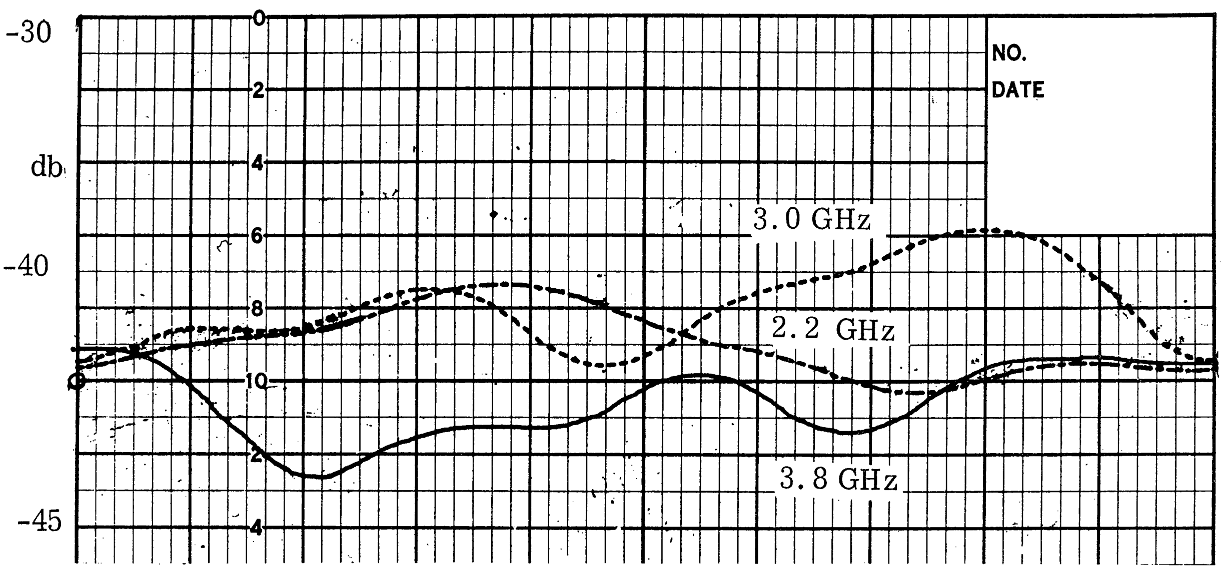


FIG. 2-14: OPPOSITE SENSE OF ROTATION

FIG. 2-13 AND 2-14: COUPLING VS RECEIVER ORIENTATION FOR TWO SQUARE SPIRALS SPACED 11.43 CM.

any better than its associated Cancellation bridge.

The circuit of an X-band Cancellation bridge is shown in Fig. 2-15. Power is generated by the X-band sweeper and is divided into two parts by the magic tee. It flows along the two paths shown and is added up in the "majestic" tee. The "majestic" tee produces 180^{o} phase shift, so the output from the "majestic" tee is the difference of the two signals.

The signal cancellation obtained by this RF Cancellation bridge is shown in Fig. 2-16. The upper curve is the detector power with one arm connected while the other arm is disconnected and terminated with a matched load. The cancellation is approximately 20 db over the entire X-band. This result is far superior to earlier work.

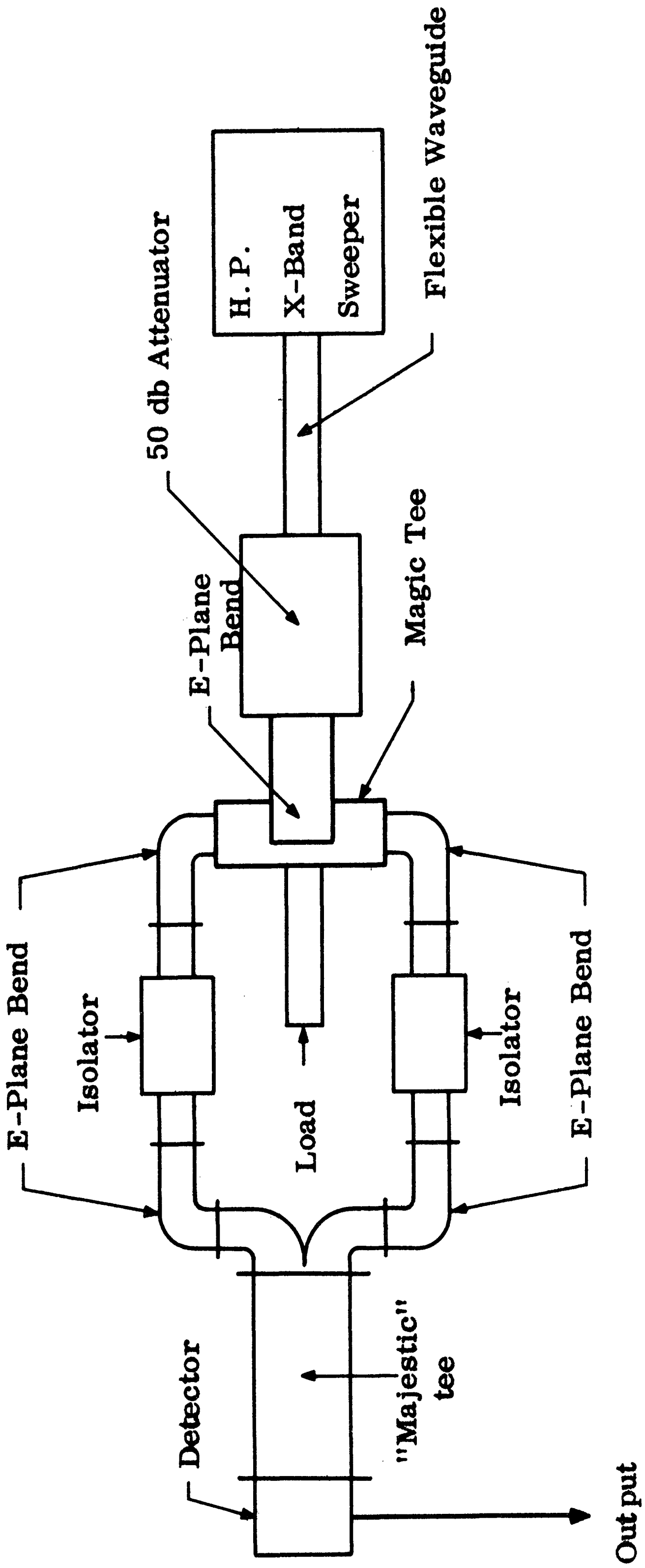


FIG. 2-15: X-BAND CANCELLATION BRIDGE

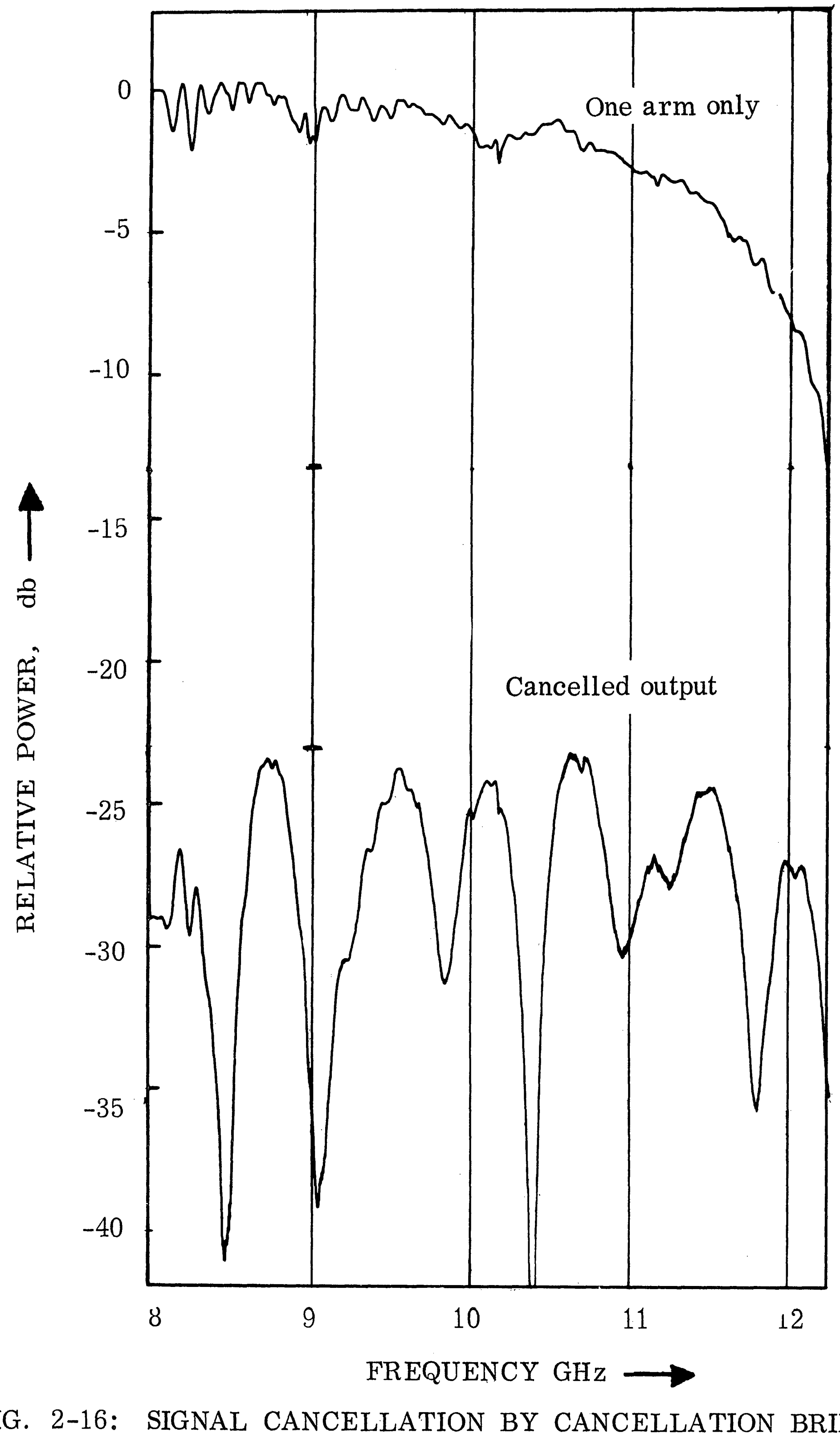


FIG. 2-16: SIGNAL CANCELLATION BY CANCELLATION BRIDGE

III

CONCLUSIONS

Favorable results have been shown for decoupling on a broadband basis. These results are especially significant since they have been derived for two systems designed to operate at the same frequency band.

The two most promising decoupling methods have been corrugations surrounding an antenna and an auxiliary RF bridge link. If corrugations are applied to both transmitting and receiving antennas 25 db increased isolation may be obtained. The RF bridge link would provide another 25 db of isolation. Improvements in each of these methods are contemplated. However the possible 50 db of isolation obtainable by combining the two methods may be highly significant in ameliorating a potential interference situation.

Besides the need for improvements in the two methods cited, other methods should be explored. Some installations may require different solutions because of space or operating limitation.

IV

FUTURE EFFORT

One of the methods which must be extended in order to achieve broadbanded decoupling is that utilizing corrugations surrounding a rectangular slot. For this purpose it appears that in the immediate future the corrugations will be stepped in depth. It is also possible that various depths of filling material, which may be of a lossy nature, may be tried. The present corrugations may be partially filled with a metal such as "Woods metal".

Further work is contemplated in repositioning auxiliary path channels from just over the ground plane to just under the ground plane. Embedding these links will still allow a very simple construction corresponding to what might be tolerated on an aerospace vehicle. It is possible that absorbing and dielectric materials of various types will be used in such a submerged construction. Also, very simple attenuation and phase controls may be built into such channels.

In the study of near field decoupling of Archimedean spirals attention will be given to the effects of the presence of standing waves on spirals. These standing waves are undesirable and occur because of departures from optimum design which is aimed at a pure traveling wave. Experimental procedures will involve the use of various terminations on such spiral antennas. Dependence of the decoupling upon the direction of winding on the spiral will be studied further.

The refined X-band Cancellation bridge described in this report will next be used to decouple two rectangular slot antennas. The coupling path from one slot antenna to another will be one of the bridge paths. The compensating path in the bridge will be one whose frequency dispersion is chosen so as to match the path having the two antennas. This network may contain a mixture of waveguide and co-axial line to simulate the slot antennas and the air coupling path between them. The compensating bridge path must provide the appropriate attenuation and phase to achieve decoupling.

ACKNOWLEDGMENT

Mr. D. R. Brundage of the University of Michigan Institute of Science and Technology, obtained most of the experimental data in this report.

REFERENCES

Lyon, J. A. M., et al (August 1966), "Electromagnetic Coupling Reduction Techniques-Third Quarterly Report," The University of Michigan Radiation Laboratory Report 7692-3-Q, AD 801476. UNCLASSIFIED

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13. ABSTRACT

During this report period, a number of experimental studies were made in either the X-band or the S-band of frequencies. The favorable results reported here showing various amounts of decoupling due to a number of techniques can be interpreted as applying to any designated frequency band. The chosen frequencies were selected entirely for convenience.

The effectiveness of corrugations surrounding a rectangular slot antenna as a means of decoupling was determined. The decoupling between two slot antennas due to surrounding absorber was also determined. A few experiments confirmed the variation of coupling or decoupling associated with the spacing of antennas when the distances of separation correspond to far field situations. Decoupling was attained for an X-band installation of rectangular slot antennas through the use of a simple additional channel over the ground plane from one antenna to another. More extended studies on RF bridge links are included in this report. Appreciable amounts of decoupling have been obtained with properly arranged parasitic elements. Near field decoupling studies have been made on an experimental basis at S-band using Archimedean spiral antennas.

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