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COMPACT ANTENNA RANGE TECHNIQUES

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Georgia Institute of Technology

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FOREWORD

The research reported herein was performed by the Engineering Experiment Station of the Georgia Institute of Technology under Contract AF 30(602)-3594 with the Rome Air Development Center, Research and Technology Division, Air Force Systems Command, Griffiss Air Force Base, New York. The contract was initiated under Project 4506, Task 450604, and the technical direction at RADC was obtained from Mr. Martin Jaeger (EMATA). Messrs. R.C. Johnson and R.J. Poinsett of the Georgia Tech Engineering Experiment Station prepared the report.

The results of this program were possible because of the combined efforts of many persons at the Georgia Tech Engineering Experiment Station and at the Rome Air Development Center. Special thanks go to Mr. John C. Cerny of Georgia Tech for supervising the mechanical design and construction of the large hoghorn. Special thanks also go to Mr. Martin Jaeger of the Rome Air Development Center for his interest and suggestions.

This report is not releasable to the general public because it contains proprietary information on Compact Antenna Range Techniques.

This technical report has been reviewed and is approved.

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ABSTRACT

Techniques for making pattern and gain measurements on full-sized microwave radar antennas on indoor compact antenna ranges are described. A reflector and special feed system near the test antenna is used to produce incident plane waves, and far-zone results are obtained. Three basic configurations of compact ranges are discussed; they are a point-source range, a line-source range, and a two-dimensional range. Pattern and gain measurements of a 30-inch parabolic test antenna were made on the point-source and line-source ranges, and the results were compared with measurements made on a conventional outdoor range. Special studies of stray radiation were made on the two-dimensional range.

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EVALUATION

1. This program consisted of a theoretical and experimental study of Compact Antenna Range Techniques for testing microwave antennas, using incident plane waves produced by a transmitting source in the near vicinity of the test antenna. These techniques enable indoor simulated far-field antenna measurements without the use of expensive anechoic chambers and are applicable to outdoor antenna measurements, requiring only a small amount of real estate. The range illuminator used is either a point-source or line-source antenna configuration having reflector dimensions approximately three times the size of the test antenna. The length of the test range is approximately the focal length of the range illuminator.
2. The feasibility of the point-source and line-source Compact Antenna Range Techniques was successfully demonstrated with X-band breadboard models. Azimuth plane patterns of a 30 in. test antenna measured on a 700 ft. conventional outdoor range and on an indoor compact range, in a 4 ft. sq. test area, compared well over a dynamic recording range exceeding 40 db. Antenna gain measurements conducted on the conventional range agreed with those made on the point-source compact range within 0.2 db over the frequency range of 8.2 to 12.0 GHz. The same measurements conducted on the line-source compact range provided a 0.5 db to 1.1 db difference in gain values.
3. Although results of the study have been encouraging, additional refinements considered beyond the scope of the present effort are required to enhance the performance capabilities of both Compact Antenna Ranges. This includes the utilization of more accurate range reflectors and improved feed horn designs to minimize the stray or uncollimated radiation incident on the test antenna.

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Section I

INTRODUCTION

The testing of microwave radar antennas usually requires that the antenna under test be illuminated by a uniform plane electromagnetic wave, but the creation of such a wave is a difficult task. Conventional techniques require that a transmitting antenna be located at a sufficient distance from the test antenna such that its spherical wave front closely approximates a uniform plane wave incident upon the test antenna. A convenient rule of thumb for determining the minimum distance is given by

$$R = \frac{2d^2}{\lambda} ,$$

where R is the separation between the transmitting antenna and the test antenna, d is the maximum transverse dimension of the aperture under test, and λ is the operating wavelength. Since ranges of several hundred or several thousand feet often are required, far-zone measurements usually are taken on outdoor installations which are subject to adverse weather conditions and changing range effects. Small antennas may be adequately tested in anechoic chambers, but since large high-gain antennas require long ranges, the cost of a chamber becomes prohibitively high.

A technique, which was previously demonstrated at Georgia Tech¹, enables far-zone results on radar and other microwave antennas to be

obtained from measurements made in the immediate vicinity of the range illuminator. The technique provides a means for making pattern and gain measurements on full-size microwave antennas on an indoor "compact antenna range."

Some investigators have attempted previously to make indoor measurements of antenna radiation patterns by generating incident plane waves through the use of lenses² or a reflector³, but the results were not completely satisfactory.⁴ During recent work at Georgia Tech, good performance of indoor compact antenna ranges was demonstrated.⁵ In these tests, a reflector and special feed system near the test antenna were used to produce incident plane waves, and far-zone results were obtained.

A properly focused parabolic reflector will collimate the rays and thus produce a plane wave in its aperture. This wave is not uniform because of the amplitude taper of the feed horn; however, a properly selected feed horn will generate a wave which is approximately uniform over an acceptable area. It is this area of an approximately uniform plane wave that is used to illuminate the antenna under test.

In addition to the collimated energy, there is "stray" radiation which adds both in and out of phase with the collimated energy and hence perturbs the desired plane wave. There are many sources of stray radiation in the aperture of most parabolic antennas; among these are reflection and diffraction from the feed and its supports, back

radiation from the feed, edge effects of the reflector, and phasing effects due to the contour errors of the reflector. The presence of these sources of stray radiation requires that considerable care be taken when designing a compact range to insure that stray radiation is reduced to a very low level.

The present work is concerned with three range configurations. The first is a point-source range consisting of a large parabolic reflector illuminated by an appropriate point-source feed. The second is a line-source range consisting of a parabolic-cylinder reflector illuminated by a line-source feed, and the third is a two-dimensional range in which the large hoghorn, which was used to illuminate the parabolic cylinder of the line-source range, is used by itself to form a compact range which collimates the energy in one plane only. The two-dimensional range can be used for testing antennas whose apertures form a line-source.

Subsequent sections of this report will be devoted to a discussion of each of the three types of ranges.

Section II

STRAY RADIATION MEASUREMENTS

As mentioned in the previous section, the presence of stray radiation in the test region perturbs the plane wave and causes errors in the pattern measurements. This section is devoted to a brief discussion of the effects of stray radiation on pattern measurements and of a technique for estimating stray radiation levels.

Suppose that one wishes to measure the power level of an incident field in the presence of an undesired stray field. Let E_1 and E_2 represent the field strengths of the desired and undesired fields, respectively. When the fields are exactly in phase, the measured power level will be proportional to $(E_1 + E_2)^2$, and when the fields are 180° out of phase, the measured power level will be proportional to $(E_1 - E_2)^2$.

Since one has no control over the relative phase between the two fields, a single measurement may be anywhere between the above values. If one can vary the relative phase, the measured power level will cycle through a peak to peak variation which can be represented in decibels as

$$20 \log \frac{E_1 + E_2}{E_1 - E_2}.$$

For convenience, the peak to peak variation is shown in Figure 1 as a

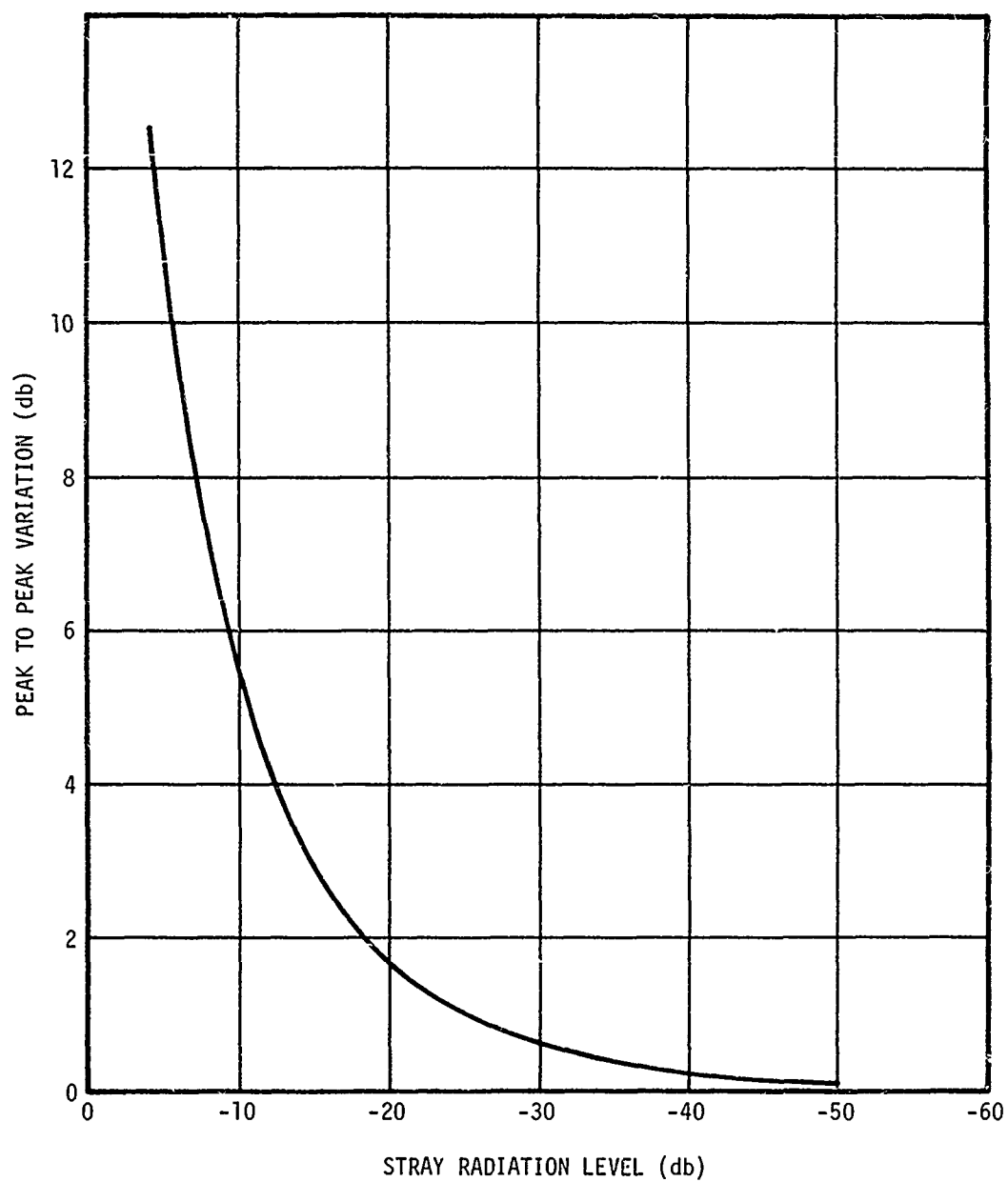


Figure 1. Perturbation of a Field Power Measurement as a Function of the Level of a Stray Field.

function of the stray radiation level; the latter can be expressed in decibels relative to the desired incident field as

$$20 \log \frac{E_2}{E_1} .$$

As applied to antenna measurements, the smaller of the two fields represents stray radiation and the larger represents the collimated or the desired plane wave radiation. An error arises in the measurement of an antenna pattern because the relative phase between the collimated and stray radiation is unknown. Hence, if a source of stray radiation which is 30 db below the collimated radiation is present in the test region, the measured power can fluctuate through a range of 0.6 db as shown in Figure 1.

Use of the curve of Figure 1 presupposes that there is only one source of stray radiation and that the antenna being measured has isotropic radiation characteristics. That is, regardless of the direction from which the stray radiation is entering the test region, the antenna receives it equally as well as the collimated energy. This situation is not experienced in practice since there are, in general, many sources of stray radiation at many different angles and since the antennas of interest often are high gain radar antennas. Consequently, some modification in the use of the curve of Figure 1 is necessary, as illustrated by the following example.

Suppose the actual pattern of the antenna to be tested is that shown in Figure 2. Let $\bar{E}_c$ represent the collimated energy which is incident on the test antenna from the angle indicated, and let $\bar{E}_{sn}$ represent stray radiation fields which are incident on the test region from various angles. When one is attempting to measure a -30 db side lobe while the main lobe is directed toward stray radiation which is -40 db with respect to the collimated energy, the detector is receiving two signals which differ in power by 10 db. Referring to Figure 1, it can be seen that the measured power level can vary over a range of 5.6 db, depending on the relative phase between the two signals. Thus, the measured side lobe level may be anywhere from about -27.2 db to -32.8 db. Note that the additional sources of stray radiation are entering the test antenna on the minor lobes of the radiation pattern. To a first approximation, the level of the signals arriving at the detector from these sources is negligible with respect to that entering on the main lobe.

As another example, suppose that we wish to measure the level of a -30 db side lobe to an accuracy of ± 1 db. From Figure 1, we see that the stray radiation must be detected 18 db below the collimated energy. Hence, the stray radiation must be at a level of 30 db + 18 db = 48 db or more below the collimated energy. For a side lobe accuracy of ± 0.5 db, the stray source must be 30 db + 25 db = 55 db or more below the collimated energy.

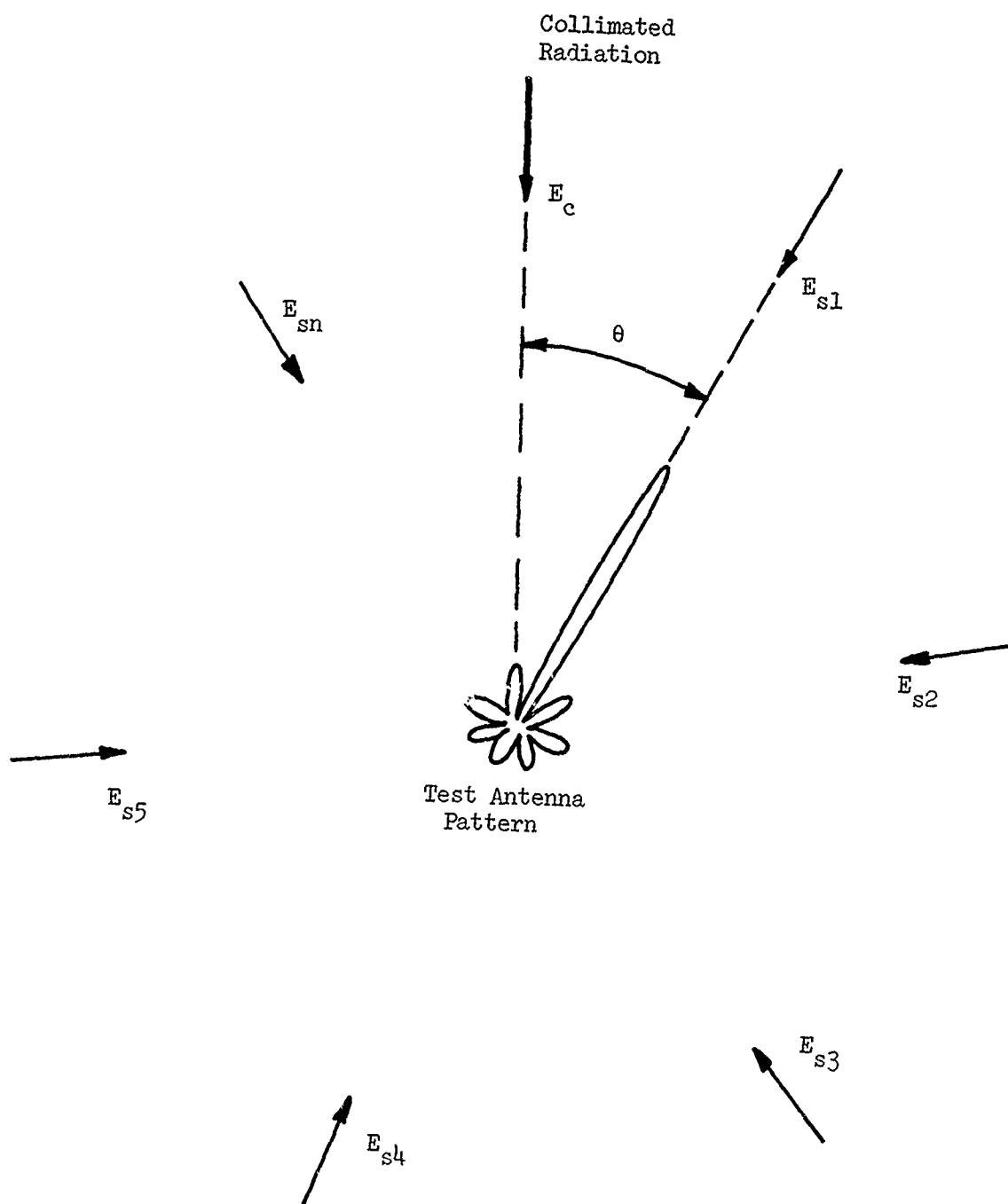


Figure 2. A Sketch Depicting the Situation When Measuring an Antenna Pattern in the Presence of Stray Radiation.

From the above discussion we see that if the level of stray radiation is known, then the accuracy of the pattern measurement can be predicted.

The level of stray radiation can be estimated by providing a means of changing the phasing of the stray radiation while measuring the level of a particular side lobe. This is accomplished by putting the test antenna on a movable table which can travel along the direction of propagation of the collimated energy. Then if the level of a particular side lobe is monitored while the test antenna is moved, the recording device will indicate a fluctuation in received power as the relative phase between the collimated and the stray radiation is changed continuously. Once again, with the aid of Figure 1, the peak to peak magnitude of the fluctuation can be used to determine the relative level of stray radiation. For example, if the peak to peak variation is 3 db, we find that the stray level is -15 db. If the side lobe is -30 db, relative to the main lobe, then the stray radiation is -45 db relative to the collimated radiation.

If the above measurement is repeated for each side lobe of the antenna pattern, the data can be plotted to indicate the stray radiation level as a function of angle θ . The resulting plot is a good indication of the quality of the antenna range.

Section III

THE POINT-SOURCE RANGE

A. Range Description

The point-source compact range at Georgia Tech, which is shown in Figure 3, was modified by using a 120-inch spun parabolic reflector with a contour tolerance of ± 0.060 inch. This reflector was illuminated by a special waveguide feed horn. A 30-inch parabolic dish, mounted on an azimuth-over-elevation positioner, was used as the test antenna, and the positioner was mounted on a movable table which traveled on two sets of orthogonally oriented tracks. This arrangement allowed movement of the test antenna to any position inside a 4-foot by 4-foot square floor area.

The feed horn is essentially an open-ended waveguide surrounded by a pyramidal horn with walls constructed of absorbing material. The open-ended waveguide gives approximately uniform illumination in the upper portion of the reflector, and the absorbing material reduces the back radiation and the illumination at the edges of the reflector.

In order to reduce reflection and diffraction from the feed and its supports, the feed was oriented such that the peak of the feed horn radiation pattern was aimed at the center of the top half of the reflector. Hence, the main beam of the collimated energy came off the reflector above the feed horn, and only the upper portion of the reflector was actually used as shown in Figure 4.

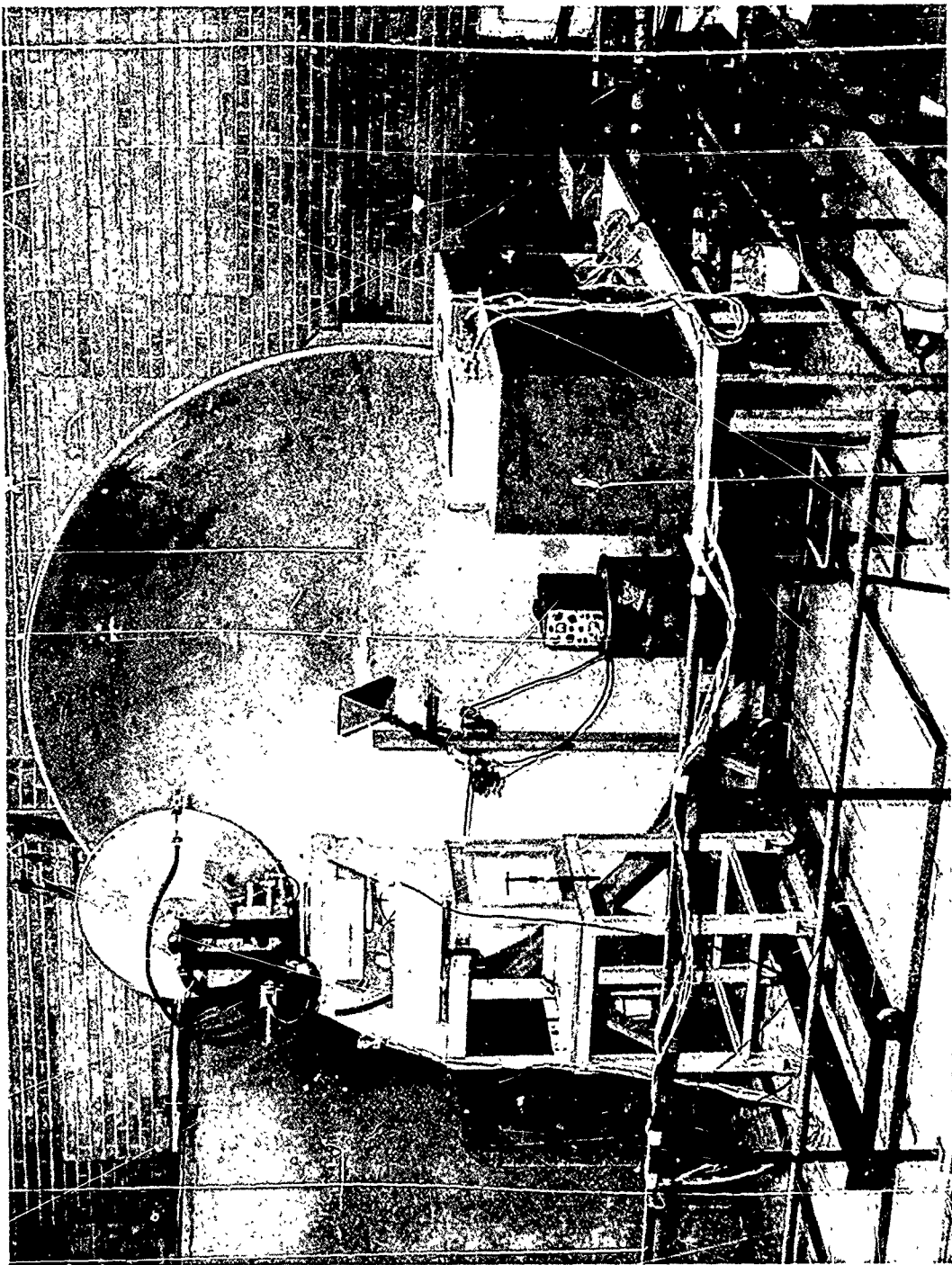


Figure 3. Photograph of the Point-Source Compact Antenna Range.

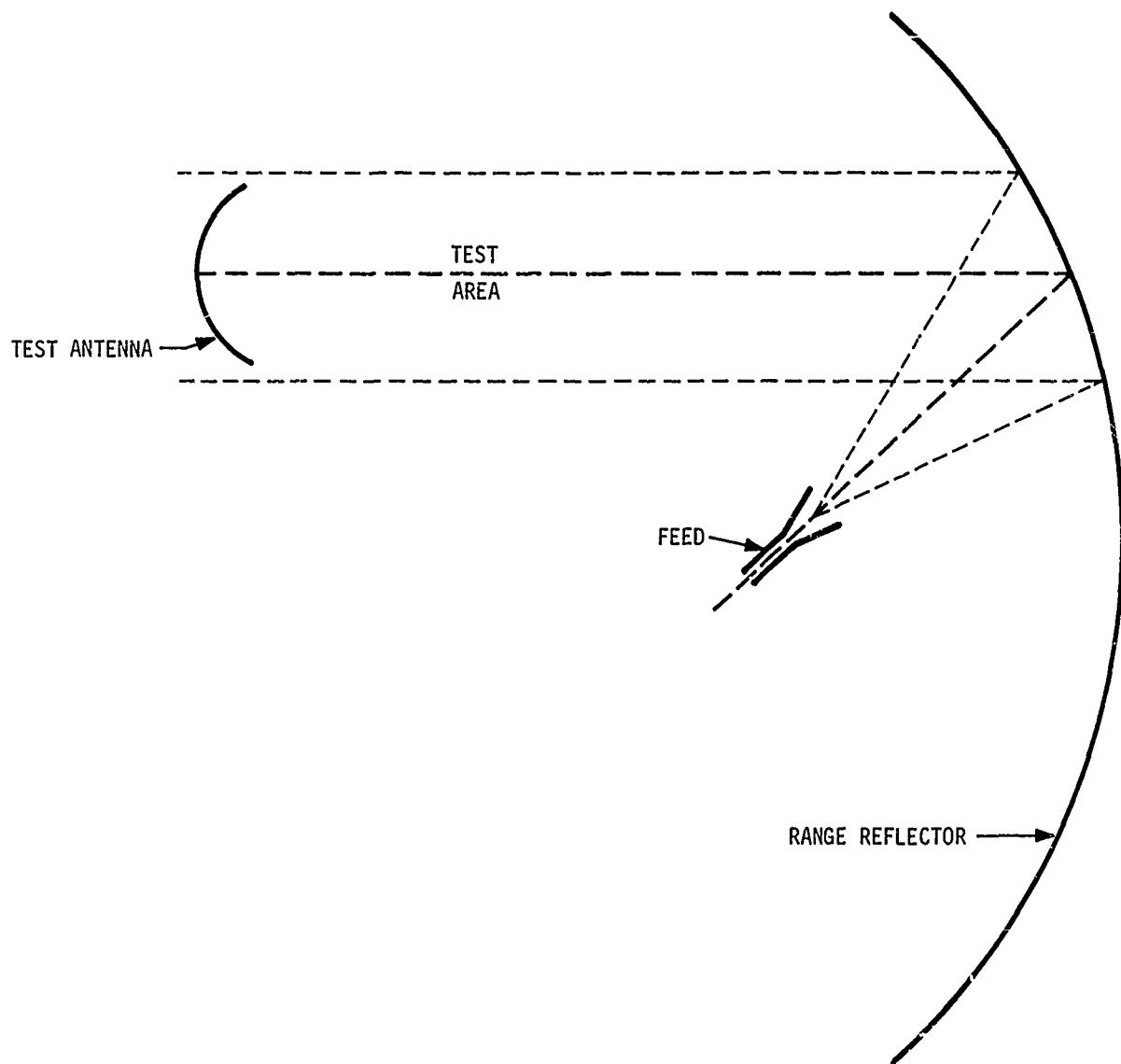


Figure 4. Schematic Drawing of the Point-Source Compact Antenna Range Showing the Available Test Region.

As mentioned above, reflector fabrication errors are a source of stray radiation and must be considered when building a compact range. These tolerances are specified by the manufacturer, and one can expect no better performance from a range than that which is compatible with the purchased reflector. In addition, nearly all large-reflectors are susceptible to appreciable distortions due to gravitational forces, so care must be exercised when mounting the reflector.

Proper range focusing is imperative to successful operation of a point-source range. A simple mechanical alignment of the feed and the reflector is usually not sufficient to insure the necessary collimation of the rays. Consequently, a procedure was developed to focus the range electrically. The procedure is relatively simple and requires a high-gain narrow-beam test antenna. The 30-inch test dish was found to be satisfactory.

A main lobe reference pattern is first recorded with the test antenna located above the axis of the range reflector. Two additional patterns are then superimposed on the reference pattern: one is recorded with the test antenna moved to the right of the center line, and the other is recorded with the test antenna moved an equal distance to the left of the center line. For an improperly focused range, the patterns will be angularly displaced from each other, indicating converging or diverging rays. Considerations of the direction and magnitude of the shift in the pattern will give an indication of which

way to move the feed to attain proper focusing. The procedure then becomes one of trial and error, re-recording the three main lobe patterns each time the feed is moved. When the three patterns coincide, the range is properly focused.

B. Range Evaluation

1. Pattern Comparisons

A set of patterns of the 30-inch test antenna was recorded on the point-source range and was compared with a similar set of patterns previously recorded on the 700-foot outdoor range. The data include 360-degree and 60-degree expanded azimuth plane patterns through the beam maximum and at $\pm 2^\circ$ elevation angle increments up to $\pm 10^\circ$; in addition, a 60-degree expanded elevation pattern through the beam maximum was recorded. All of the above patterns were recorded at frequencies of 8.2, 9.0, 10.0, 11.0, and 12.0 GHz.

The pattern comparisons were very good for azimuth patterns through the beam maximum and for small conical angles above and below the beam maximum. A typical comparison is illustrated in Figure 5. Additional azimuth and elevation comparison patterns are presented in the Appendix.

Some deterioration in comparison occurred for large conical angles, but this is thought to be due primarily to the difficulty of positioning the test antenna at the identical conical angles at which the outdoor

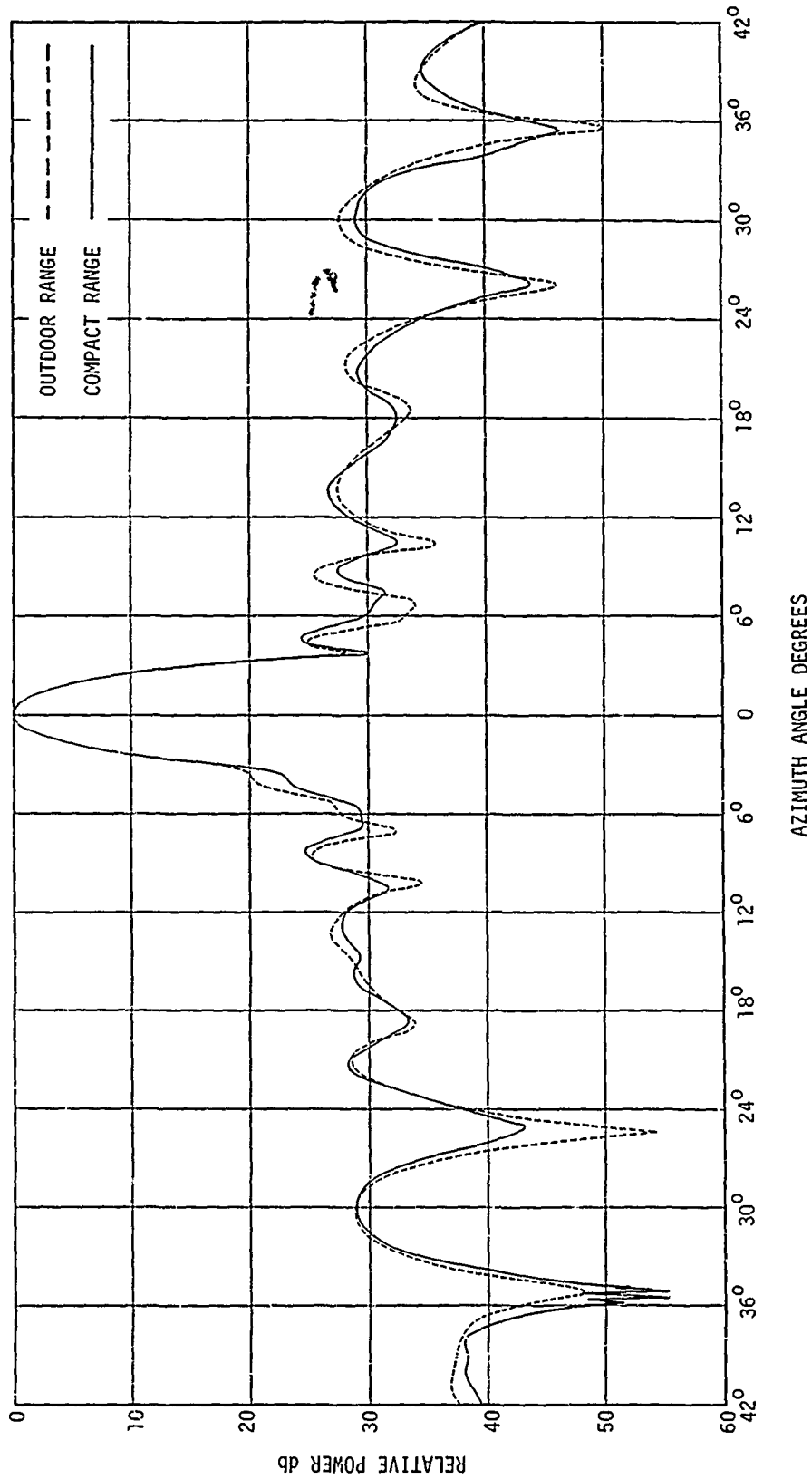


Figure 5. Comparison of the Azimuth Patterns Recorded on the Outdoor Range and on the Point-Source Compact Range at 10 GHz.

reference patterns were recorded. The necessity for accurate angular positioning for conical cuts becomes apparent when one considers that such patterns are usually recorded on the steeply rising or falling sides of the lobe structure, and small variations in angular position create large variations in the field intensity.

As mentioned previously, the antenna positioner is mounted on a movable table; this allows one to record several patterns, each with the test antenna located at a different position within the test region. Figure 6 shows ten such patterns. The patterns are not identical since the relative phase of the stray radiation is different for each pattern; however, note that the patterns compare closely.

2. Stray Radiation

As mentioned earlier, a factor which limits the performance of any antenna range is the interference of stray radiation with the collimated radiation. Major efforts to improve the performance of the compact range are directed, therefore, toward reducing the level of stray radiation. Consequently, it becomes necessary to have a means for obtaining a quantitative evaluation of range performance so that proposed improvements can be evaluated in the light of their effects on the overall performance of the range. Following a procedure similar to one outlined by Buckley⁶ for evaluating anechoic chambers, the stray radiation level of the compact range was measured.

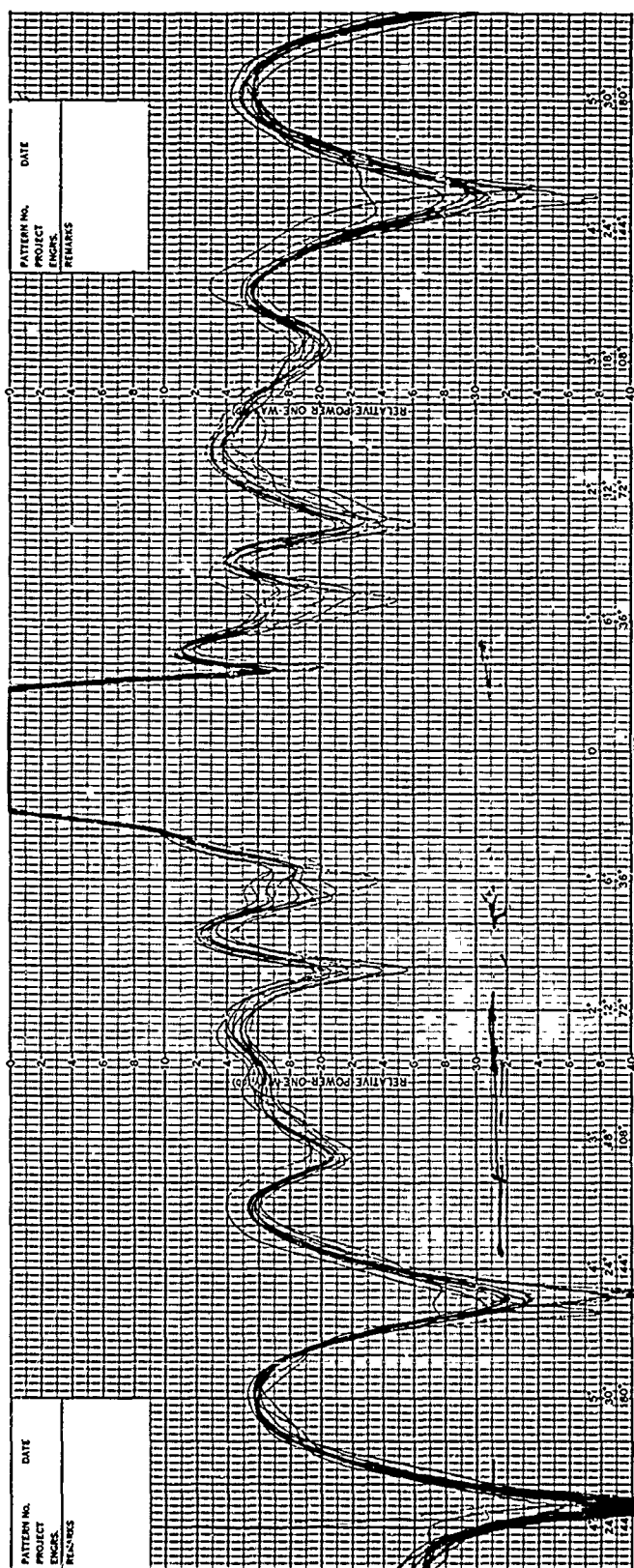


Figure 6. A Group of Azimuth Patterns Recorded on the Point-Source Compact Range at 10 GHz. Each of the ten patterns were recorded with the test antenna located at a different position within the test area. The gain level at the top of the chart is -13 db with respect to the main lobe.

The procedure for measuring the stray radiation level is described in Section II. The test antenna was positioned to receive power on a particular side lobe, and then it was moved along the direction of propagation of the collimated energy. This effectively changed the relative phasing between the collimated radiation and the stray radiation, thus causing variations in the apparent level of a specific side lobe. To a first approximation, the change in the level of a specific side lobe is caused by the stray radiation coming in on the main lobe of the test antenna, hence the stray radiation is measured as a function of the azimuth angle. The peak-to-peak variation of a particular side lobe can be used to calculate the magnitude of stray radiation coming from the direction in which the main lobe is pointing. If the test antenna is moved over large distances compared to a wavelength, the apparent side lobe level will go through many cycles of variation and the peak-to-peak magnitude of the variation for each cycle will not necessarily be the same.

There is a significant difference between the procedure outlined by Buckley and the procedure employed here for evaluating the point-source range. Buckley averages the peak-to-peak side lobe variations and uses this average value to calculate the stray radiation; whereas, the method employed here uses the maximum value of the side lobe variations to calculate the level of stray radiation. Note that the Buckley method estimates the average stray radiation level, whereas the method employed here estimates the maximum stray radiation level.*

*In a later appraisal of the two methods, it was decided that more meaningful range descriptions result from calculating average stray radiation levels rather than maximum levels. Average values were calculated in subsequent range evaluations.

A plot of the estimated maximum value of stray radiation versus azimuth angle for each test frequency is shown in Figure 7. Note that the plot reveals a higher level of stray radiation over the angular region between $\pm \theta_1$. A region of decreasing stray radiation occurs for angles between $\pm \theta_1$ and $\pm \theta_2$, and a region of lower stray radiation occurs for angles greater than $\pm \theta_2$.

The physical significance of angles θ_1 and θ_2 is illustrated in the plan view of the range in Figure 8. It is seen that θ_2 is the azimuth angle to the edge of the reflector when the test antenna is located in the position nearest to the range reflector, and θ_1 is the angle to the edge of the reflector when the test antenna is located at the maximum distance from the range reflector.

In terms of the antenna pattern, if a side lobe which is at an angle less than θ_1 from the main lobe is being measured, then the main lobe is pointed at some portion of the reflector for any position of the test antenna. Similarly, if the side lobe is at an angle greater than θ_2 from the main lobe, then the main lobe never points at the reflector for any position of the test antenna. For side lobes between θ_1 and θ_2 degrees, the main lobe points at the reflector for the close-in positions of the test antenna and misses the reflector for the far-out positions of the antenna. Figure 7 indicates that the stray radiation levels are highest when the main lobe of the

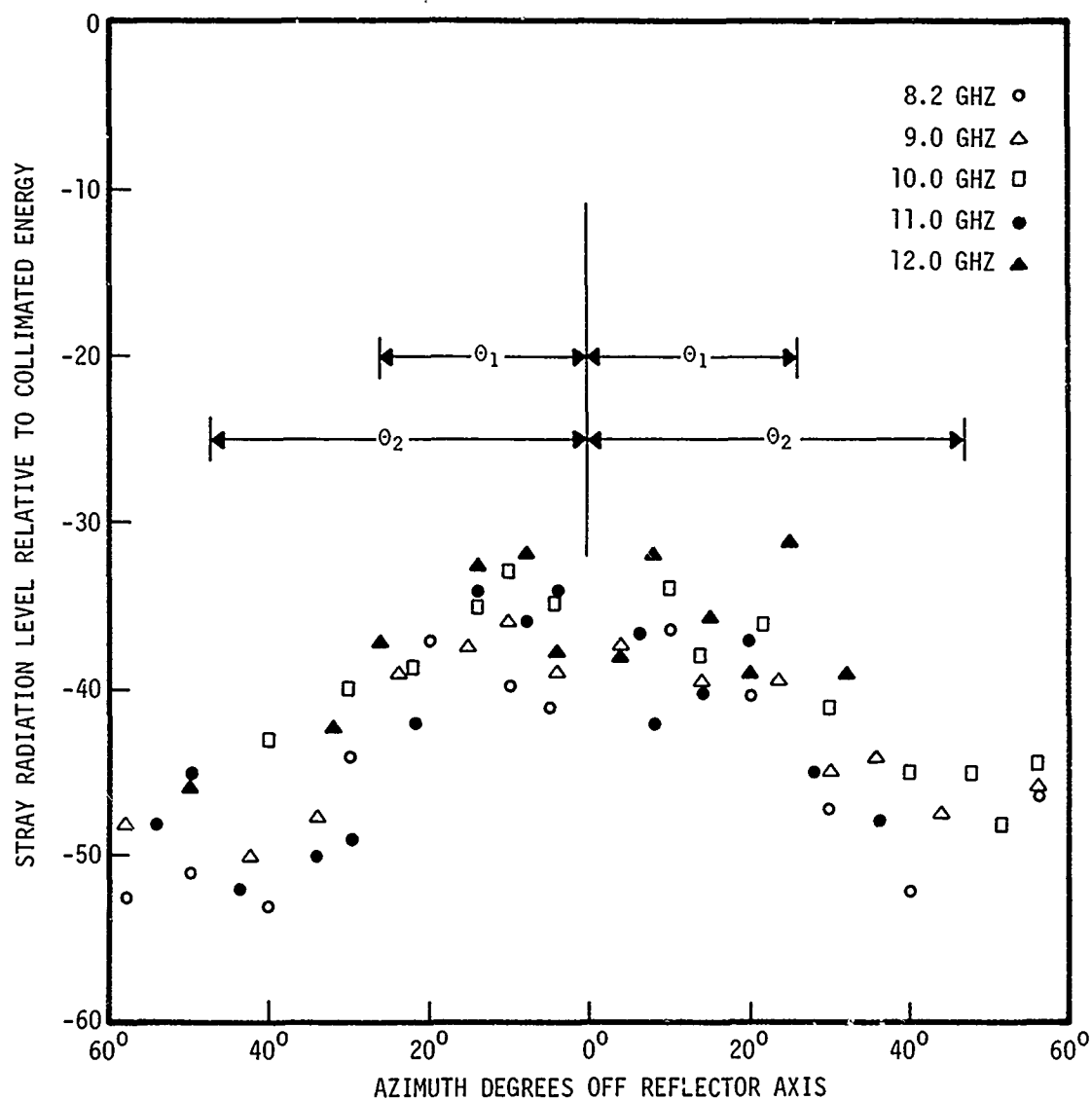


Figure 7. Estimated Maximum Stray Radiation Levels on the Point-Source Range as a Function of the Azimuth Angle.

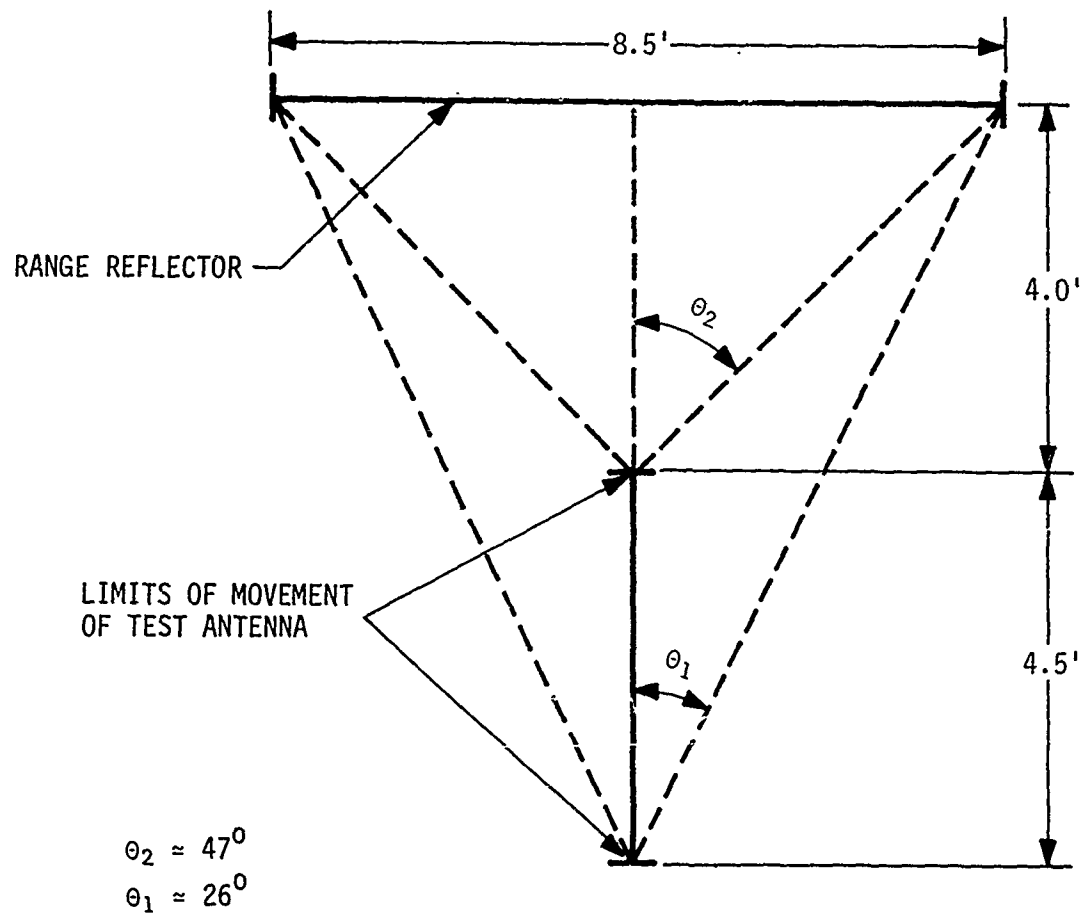


Figure 8. Sketch Showing the Azimuth Angles to the Edges of the Range Reflector for Extreme Positions of the Test Antenna Positioner.

test antenna is pointing at some portion of the reflector. This indicates that fabrication errors in the reflector surface probably are contributing strongly to the stray radiation.

In an effort to further investigate the effects of fabrication errors in the reflector contour, the reflector was intentionally distorted by taping a piece of tinfoil to one portion of the reflector surface. Subsequent measurements showed a considerable increase in stray radiation at the angle for which the main lobe of the test antenna pointed at the distorted portion of the reflector.

3. Coupling Between Range and Test Antenna

A simple test of the amount of coupling between the range and the test antenna is to measure the variation of received power as the distance between the test antenna and the range is varied. For this experiment, a synchro transmitting unit was rigged to track the rail on which the antenna positioner traveled. The synchro provided position data to the pattern recorder, and this allowed the recorder chart to track the position of the test antenna. A plot of received power as a function of distance between the reflector and the test antenna was recorded, and it is shown in Figure 9. This plot demonstrates that the mutual coupling between the compact range and the main lobe of the test antenna was negligible.

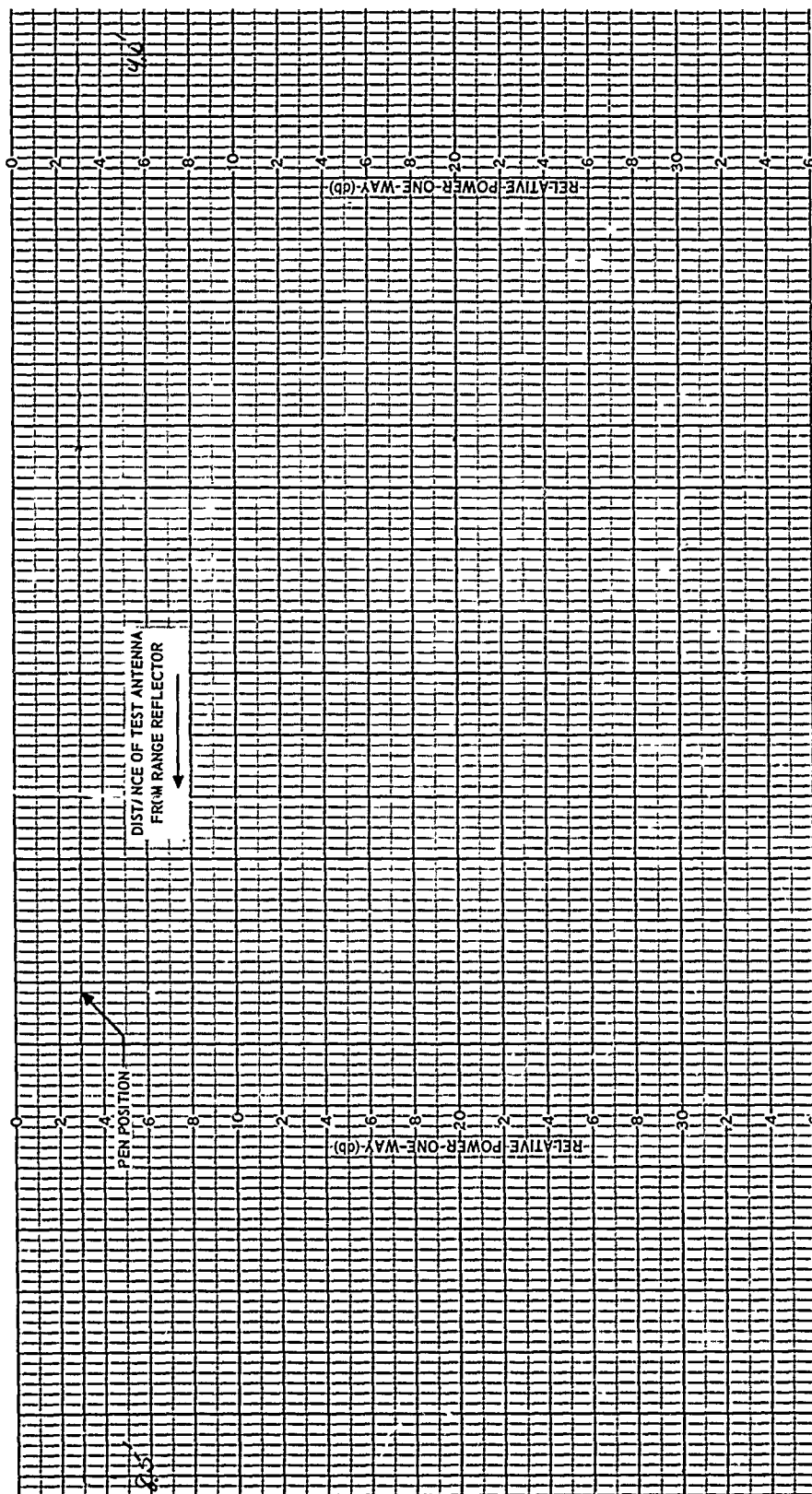


Figure 9. Power Received as a Function of the Separation Between the Test Antenna and the Point-Source Range Reflector.

4. Gain Comparisons

The gains of the 30-inch test antenna which were measured at several frequencies on the outdoor and on the compact antenna ranges are given in Table I. The measurements were made using a standard gain horn as a reference antenna. Note that the gains which were measured on the two ranges agree within 0.2 db; this is considered to be very good.

TABLE I

GAINS OF THE 30-INCH TEST ANTENNA WHICH WERE MEASURED
ON THE OUTDOOR AND ON THE POINT-SOURCE COMPACT ANTENNA RANGE

Frequency	Outdoor Range	Compact Range
8.2 GHz	34.0 db	34.2 db
9.0	34.7	34.8
10.0	35.2	35.2
11.0	35.1	35.0
12.0	35.5	35.3

5. Polarization Measurements

The on-axis cross-polarized component of field was measured by replacing the test antenna with a standard gain horn. After a reference level of the parallel-polarized component was determined, the horn was rotated ninety degrees to determine the relative level

of the cross-polarized component. The cross component was found to be at least 40 db below the parallel component.

C. Results

This brief study of a point-source range demonstrates that far-zone results can be obtained with an indoor compact antenna range. The azimuth patterns, recorded on the outdoor and on the compact range, compare well over a dynamic range exceeding 40 db.

The present performance of the point-source compact range appears to be limited by the surface errors in the range reflector. The maximum stray radiation from the reflector appears to be about 35 to 40 db below the collimated energy; whereas, the maximum stray radiation measured when the main lobe was not directed toward the reflector appears to be more than 45 to 50 db below the collimated energy. It is believed that the stray radiation can be reduced considerably by using a more accurate range reflector and by developing a better range feed horn.

It was demonstrated that the main-lobe coupling between the test antenna and the compact range was negligible; this allows one to make accurate gain measurements. The gain measurements made on the compact range agree with those made on the outdoor range within 0.2 db over the frequency range 8.2 to 12.0 GHz. Polarization measurements indicate that the on-axis cross component was more than 40 db below the parallel component.

Section IV

THE LINE-SOURCE RANGE

A. Range Description

The line-source compact range at Georgia Tech, which is shown in Figure 10, consists of a hoghorn feeding a section of a parabolic cylinder reflector. The specially constructed hoghorn forms a tapered-illumination line source which is approximately eight feet long. The parabolic barrier in the hoghorn is estimated to conform to a true parabolic contour within about ± 0.004 inch. This accuracy is desired to insure that the emerging wave will have a nearly constant phase front. The reflector is a section of a parabolic cylinder approximately seven feet wide by six feet high, and its surface is estimated to conform to that of a true parabolic cylinder within about ± 0.060 inch. This reflector serves to collimate the energy in the elevation plane, producing the desired plane wave in its aperture.

The antenna positioner was mounted on the same track arrangement as was used on the point-source range; this allowed movement of the test antenna to any position inside a 4-foot by 4-foot square floor area.

The same comments regarding mounting the reflector and focusing of the point-source range are applicable to the line-source range.

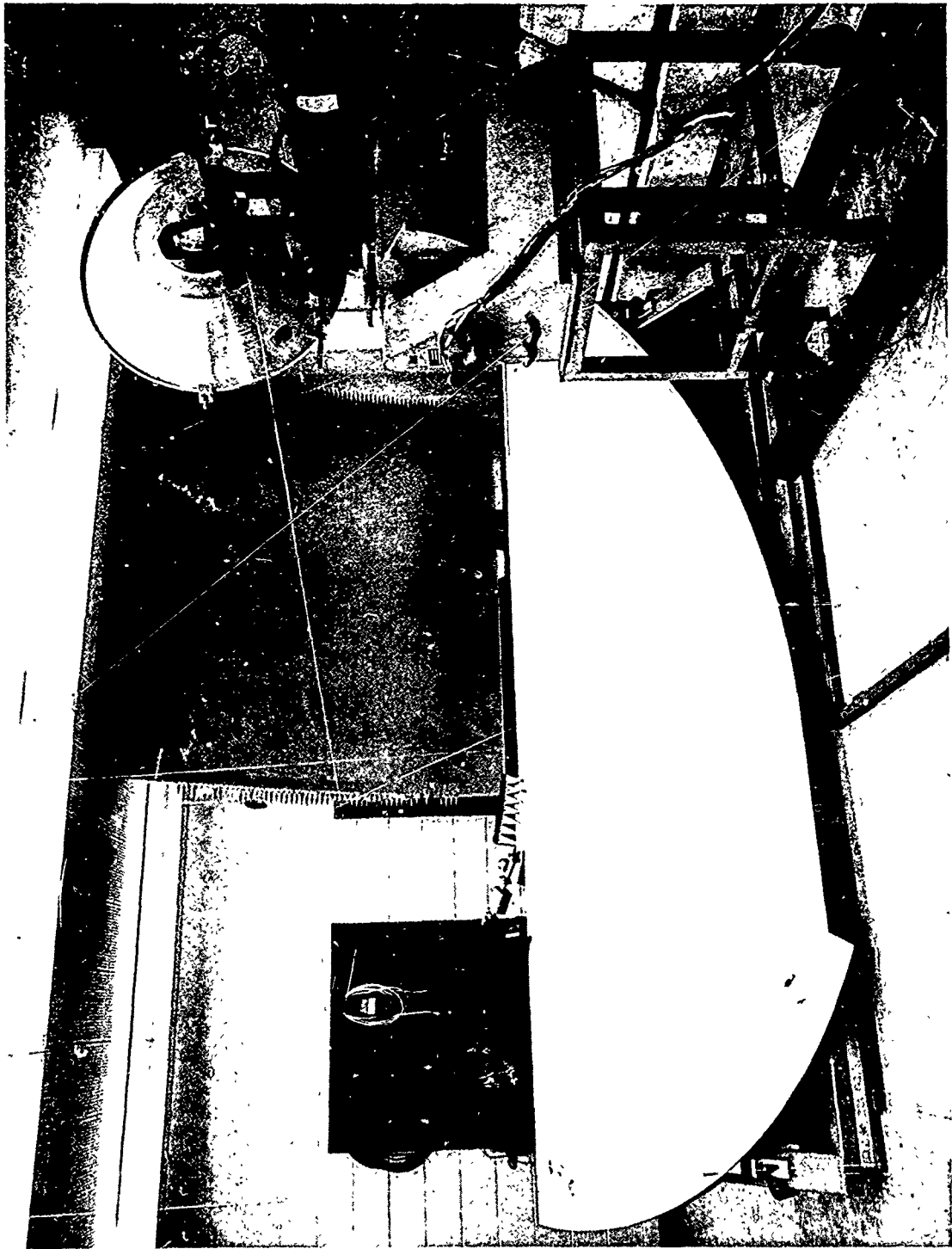


Figure 10. Photograph of the Line-Source Compact Antenna Range.

During the course of recording data on the line-source range, it was observed that the discontinuity at the edge of the parabolic cylinder reflector was contributing appreciably to the level of stray radiation in the test region. The effects of the discontinuity were reduced by terminating the reflector in a toothed edge.

B. Range Evaluation

1. Pattern Comparisons

A set of patterns similar to that recorded on the point-source range was recorded on the line-source range. A comparison of these patterns with those recorded on the outdoor 700-foot range showed them to be in good agreement. A typical comparison is illustrated in Figure 11. Additional azimuth comparison patterns are presented in the Appendix.

2. Stray Radiation

The procedure for measuring stray radiation on the line-source range was similar to that previously used on the point-source range, except that the average value of the side lobe variations was used rather than the maximum value to calculate the stray radiation levels. It was not apparent when the point-source range was being investigated that average stray radiation levels are more meaningful than maximum stray radiation levels to describe antenna ranges. Unfortunately, the data recorded on the point-source range is not in a form which can be used to calculate average levels. Consequently, the estimated stray radiation levels of the point-source and the line-source ranges cannot be compared directly.

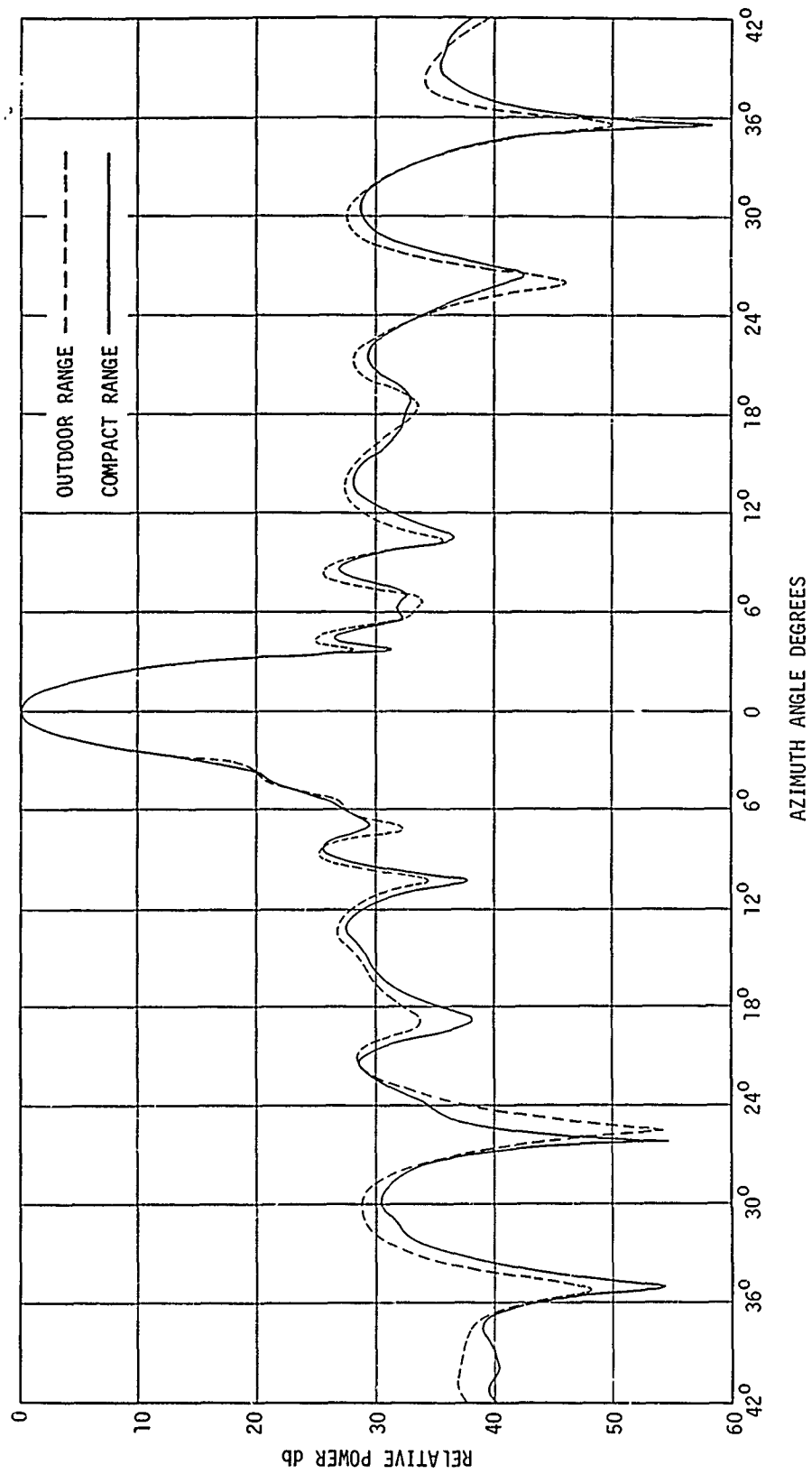


Figure 11. Comparison of the Azimuth Patterns Recorded on the Outdoor Range and on the Line-Source Compact Range at 10 GHz.

A plot of the average stray radiation as a function of azimuth angle on the line-source range is shown in Figure 12. Inspection of this figure indicates that the stray radiation level is highest within the angles subtended by the reflector. These results are consistent with the findings on the point-source range, and they indicate that the reflector surface errors are a primary source of stray radiation.*

3. Coupling Between Range and Test Antenna

The coupling between the main lobe of the test antenna and the line-source range was measured in a manner similar to that used on the point-source range. Once again, virtually no main-lobe coupling was observed.

4. Gain Comparisons

The gain measurements on the line-source range indicated that the gain of the 30-inch test antenna ranged from 0.5 db to 1.1 db below the values measured on both the outdoor range and on the point-source compact range. The gain measurements on the outdoor range and on the point-source range agreed within 0.2 db, as indicated in Table I. The fact that the gain measurements on the line-source range do not agree with the previous measurements is attributed to the amplitude taper in the vertical plane on the line-source range. Whereas the amplitude across the 30-inch test region of the point-source range was less than 1 db, it was found to be approximately 4 db in the vertical plane of the

* Although a direct comparison of Figures 7 and 12 cannot be made, pattern comparisons seem to indicate that the stray radiation levels are about the same on both ranges.

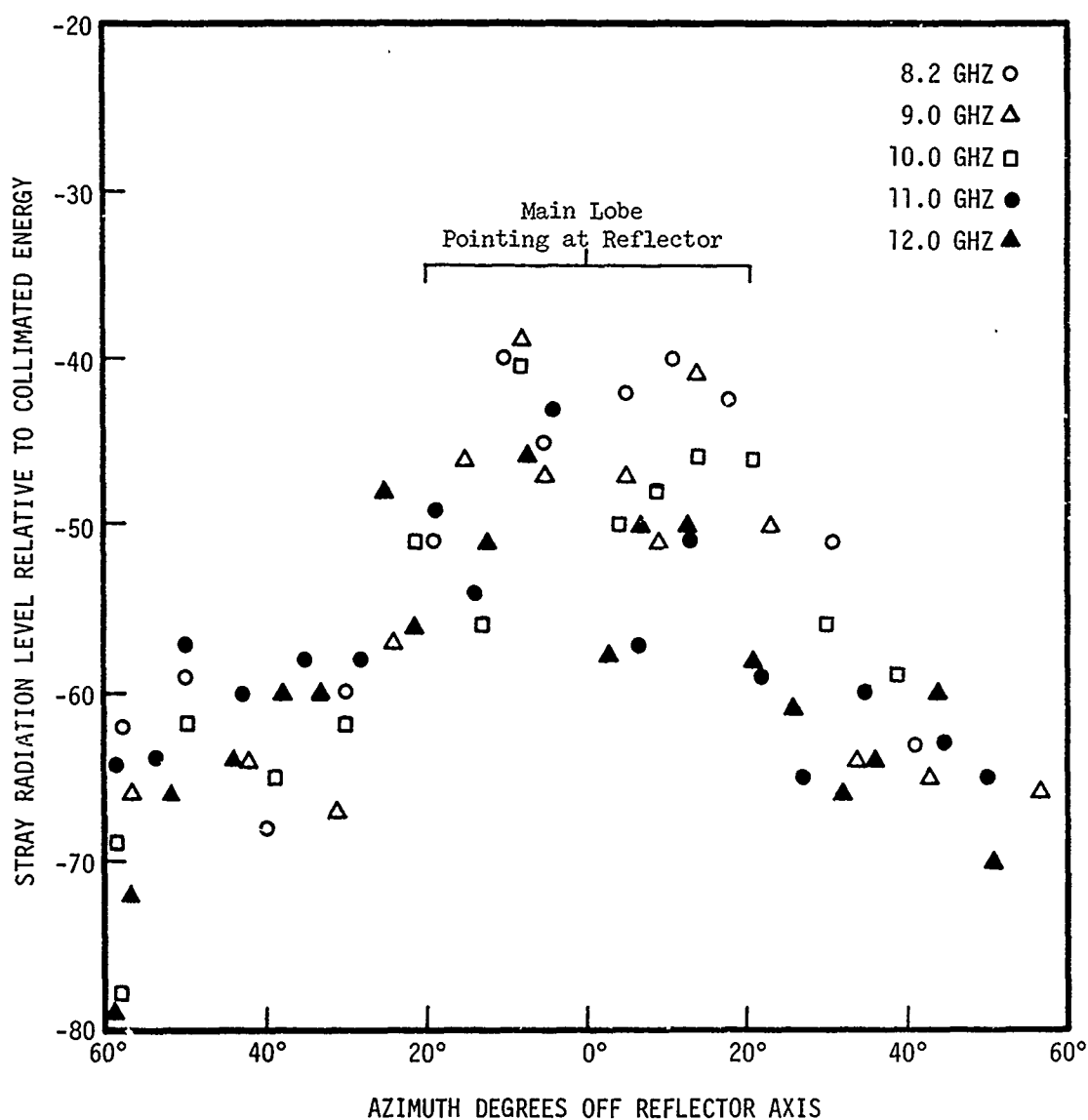


Figure 12. Estimated Average Stray Radiation Level on the Line-Source Range as a Function of the Azimuth Angle.

line-source range. It is felt that this difficulty can be corrected by modifying the feed lips on the hoghorn to produce a broader illumination in the vertical plane.

5. Polarization Measurements

The on-axis cross polarized component of field was measured in the same manner as that used on the point-source range, and it was observed to be at least 40 db below the parallel component.

C. Results

This study of a line-source range demonstrates that a second range configuration is available which can be used to obtain far-zone results on an indoor compact antenna range. The azimuth patterns recorded on the line-source range agree well with those recorded on the outdoor range over a dynamic range exceeding 40 db.

As with the point-source range, the present performance of the line-source range appears to be limited by the surface errors in the range reflector. The average stray radiation from the reflector appears to be approximately 40 db to 55 db below the collimated energy; whereas the average stray radiation measured when the main lobe was not directed toward the reflector appears to be more than 60 db below the collimated energy.

Although the gain measurements made on the line-source range do not agree well with those made on the outdoor range, it is felt that the source of error can be corrected by modifying the amplitude distribution in the elevation plane.

Section V

THE TWO-DIMENSIONAL RANGE

Previous studies with the point-source and line-source compact antenna ranges indicate that fabrication errors in the surface of the range reflector contribute strongly to the levels of stray radiation within the test region. Since stray radiation limits the performance of compact antenna ranges, it was felt necessary to investigate further the effects of reflector surface errors.

As mentioned in the previous section, the line-source range consisted of a large, accurately constructed hoghorn feeding a section of a parabolic cylinder reflector. Considerable care was taken in constructing the hoghorn to insure that a high degree of accuracy was maintained. It is estimated that the parabolic barrier of the hoghorn conforms to a true parabolic contour within a tolerance of ± 0.004 inch.

The availability of this accurately constructed hoghorn offered an opportunity to investigate the effects of reflector surface errors on the levels of stray radiation within the test region of the range. Therefore, a two-dimensional compact antenna range using the large hoghorn as the range illuminator was constructed. A small hoghorn with a 30-inch aperture was used as the test antenna. The two-dimensional range differs from the point-source and line-source ranges

which were previously studied in that the latter collimate the energy in both the azimuth and elevation planes whereas the former collimates the energy only in one plane; the energy in the other plane diverges. Consequently, patterns can be recorded on the two-dimensional range only in the plane of collimation which, in this work, is the azimuth plane.

A. Range Description

A diagram of the two-dimensional compact antenna range is shown in Figure 13. It was anticipated that the broad radiation patterns in the vertical planes of both hoghorns would result in substantial stray radiation reflected from the floor and ceiling of an enclosed area. Consequently, an outdoor site was chosen which would eliminate the effects of a ceiling. The floor was covered with microwave absorber to reduce the effects of this surface. The front side of the antenna positioner also was covered with absorbing material.

As with the point-source range, the test antenna and positioner were mounted on a movable table which traveled on two sets of orthogonally oriented tracks. This arrangement allowed movement of the test antenna to any position inside a 4-foot by 4-foot square floor area.

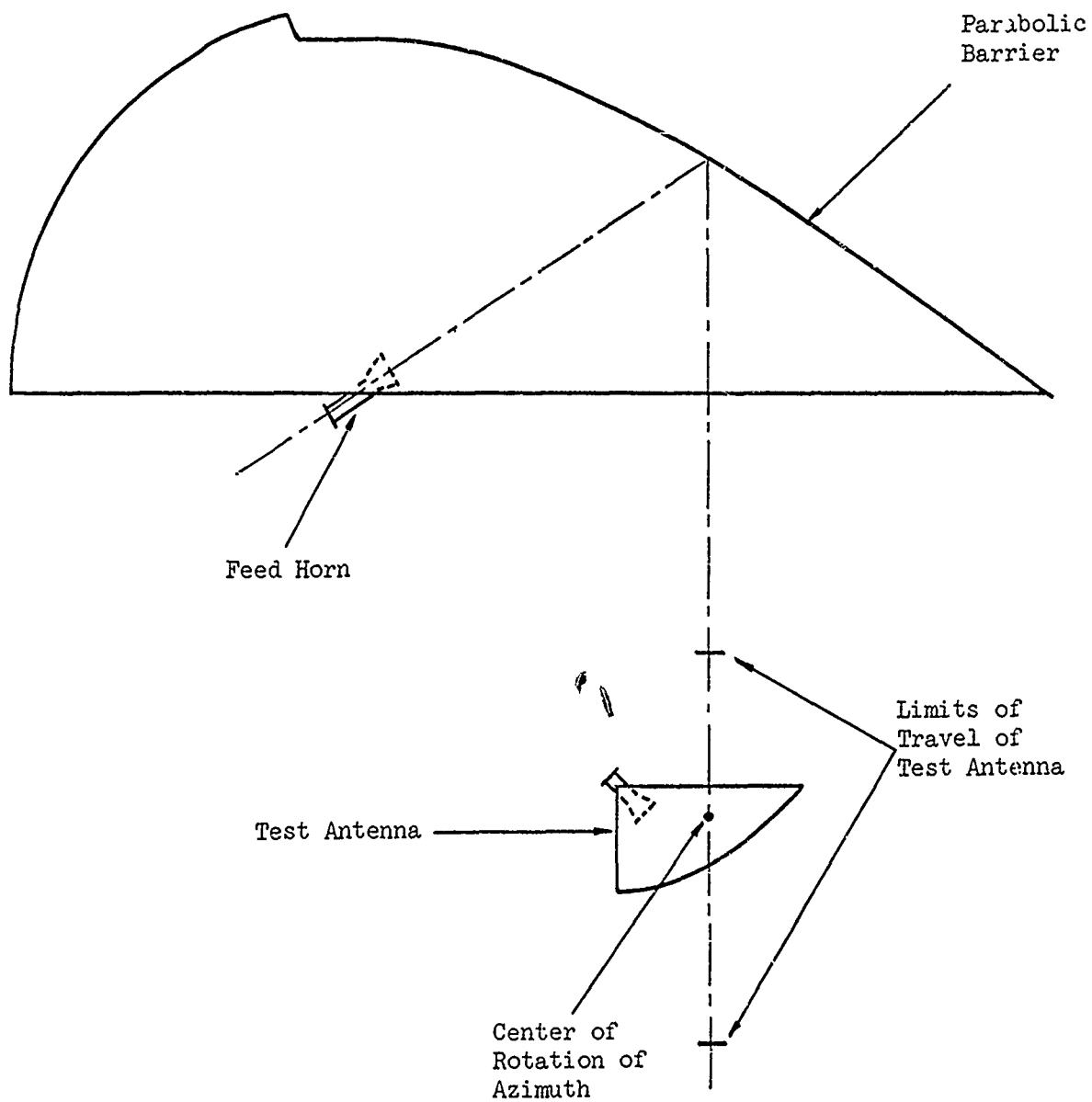


Figure 13. Plan View of the Two-Dimensional Compact Antenna Range.

B. Range Evaluation

The procedure for measuring the stray radiation on the two-dimensional range was similar to that employed on the line-source range. That is, the level of a particular side lobe was measured while moving the antenna positioner along the direction of propagation of the collimated energy. Then, the average variation of the level of the side lobe was used to calculate the magnitude of stray radiation entering the test region from the direction in which the main lobe of the test antenna was pointing. Thus, after repeating the measurement for each side lobe of the antenna pattern, it was possible to locate the major sources of stray radiation.

A plot of the average stray radiation as a function of the azimuth angle is presented in Figure 14. The data indicate that back radiation from the feed horn is the greatest source of stray radiation, and the discontinuity at the end of the parabolic barrier is a second source of considerable strength. The important thing to observe here is the very low level of stray radiation coming from the barrier itself. This is in contradistinction to the results obtained on the point-source and line-source ranges. In those cases, most of the stray radiation appeared to come from the reflectors, both of which were estimated to have contour tolerance of approximately ± 0.060 inch.

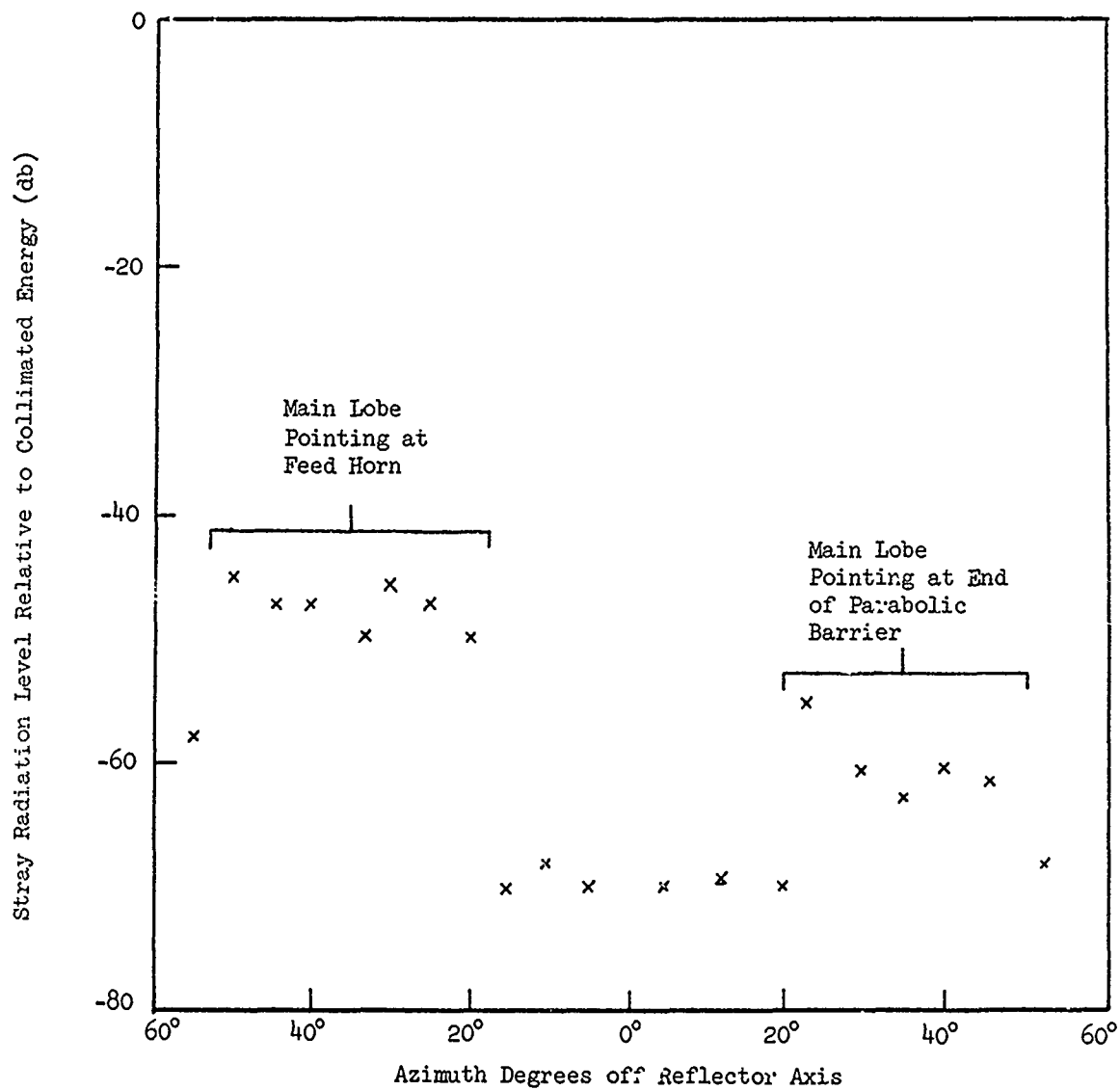


Figure 14. Estimated Average Stray Radiation Level on the Two-Dimensional Range as a Function of the Azimuth Angle.

With the accurate barrier of the new hoghorn, very little stray radiation appears to be coming from the barrier. This result supports the belief that accurate reflecting surfaces improve the operation of high-performance compact antenna ranges.

Section VI

CONCLUSIONS AND RECOMMENDATIONS

The results which have been achieved in the present work are very encouraging. They substantiate the previous work at Georgia Tech, and they further demonstrate that far-zone results can be obtained with an indoor compact antenna range.

The performance of any microwave antenna range is limited by the stray (or uncollimated) radiation which is incident on the test antenna. On outdoor elevated antenna ranges, for example, the predominant stray radiation usually is caused by reflections from the ground or other surrounding objects. In anechoic chambers, reflections from the floor, the ceiling, and the walls are most troublesome. On compact antenna ranges, stray radiation caused by fabrication errors in the range reflector and back radiation from the range feed appear to be most troublesome.

Although good performance has been achieved on both the point-source and the line-source ranges, additional improvements can be made. Work in the future should include the construction of an accurate parabolic-cylinder reflector, which will be compatible with the present hoghorn feed, and techniques for designing improved range feeds should be studied.

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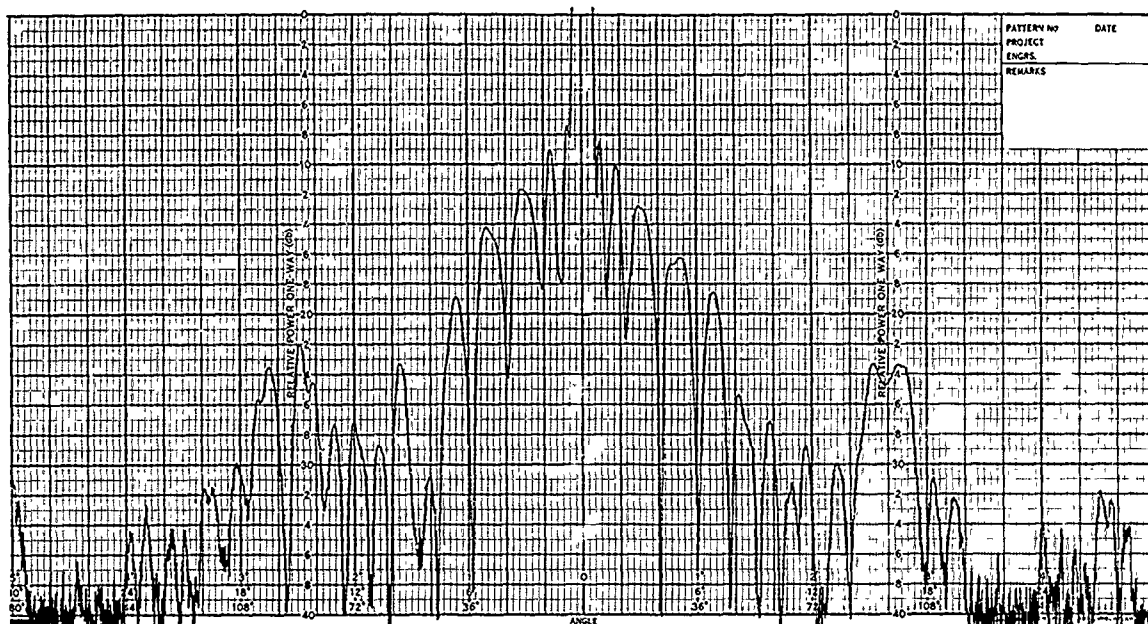
APPENDIX

Some additional patterns are presented here for purposes of comparison. Included are 360° azimuth plane patterns recorded on both the outdoor and the compact ranges. Each figure contains an outdoor reference pattern and the corresponding compact range pattern. Patterns are included for frequencies of 8.2, 9.0, 10.0, 11.0, and 12.0 GHz, and the level of each pattern with respect to the main lobe level is given in the figure titles. Figures 15 through 20 pertain to the point-source range, and Figures 21 through 25 pertain to the line-source range.

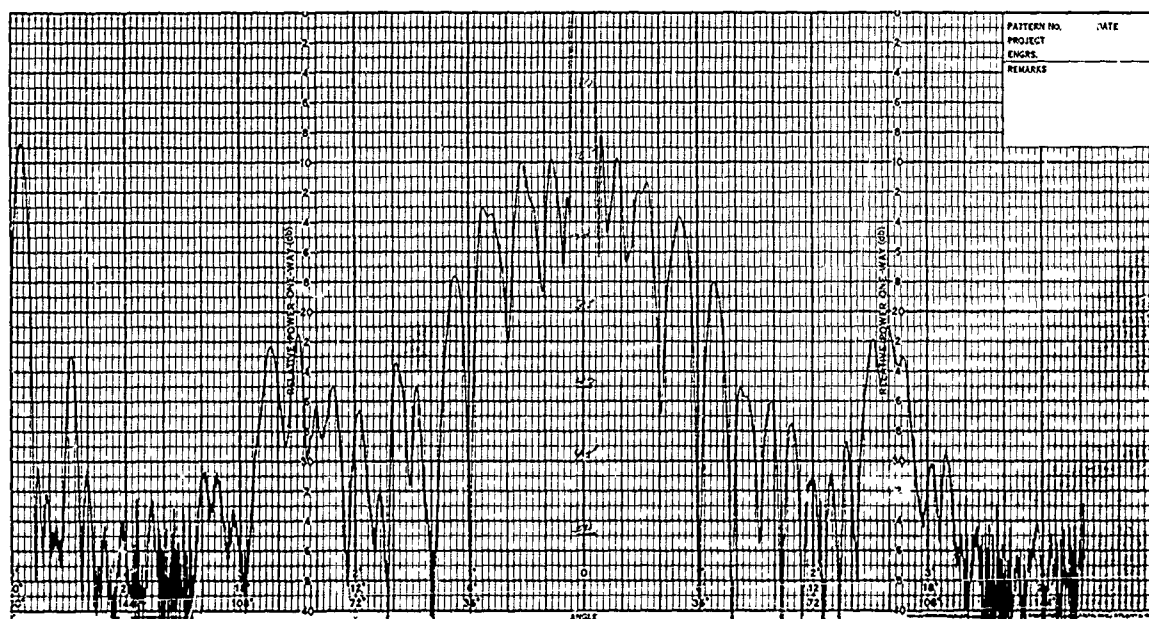
The presence of the relatively large lobe at 180° on the point-source compact range patterns is caused by reflection from the shop wall directly opposite the compact range. This reflection could be eliminated by use of a small absorber wall behind the test antenna, but there was not sufficient room to do this in the present location without extending the balcony.

Figure 20 is a comparison of the elevation patterns which were recorded on the outdoor range and on the point-source range at 10 GHz. These patterns were not expected to compare as favorably as the azimuth patterns because the edge illumination at the top of the range reflector was higher than that at the sides of the reflector and because the main lobe of the test antenna was directed toward the upper edge of the range reflector when measuring the lower side lobes and toward

the range feed when measuring the upper side lobes. In the light of these drawbacks, the comparison is considered to be reasonable. Because of the amplitude taper in the vertical plane of the line-source range, the elevation patterns recorded on the line-source ranges are not considered to be valid; consequently, they are not included.

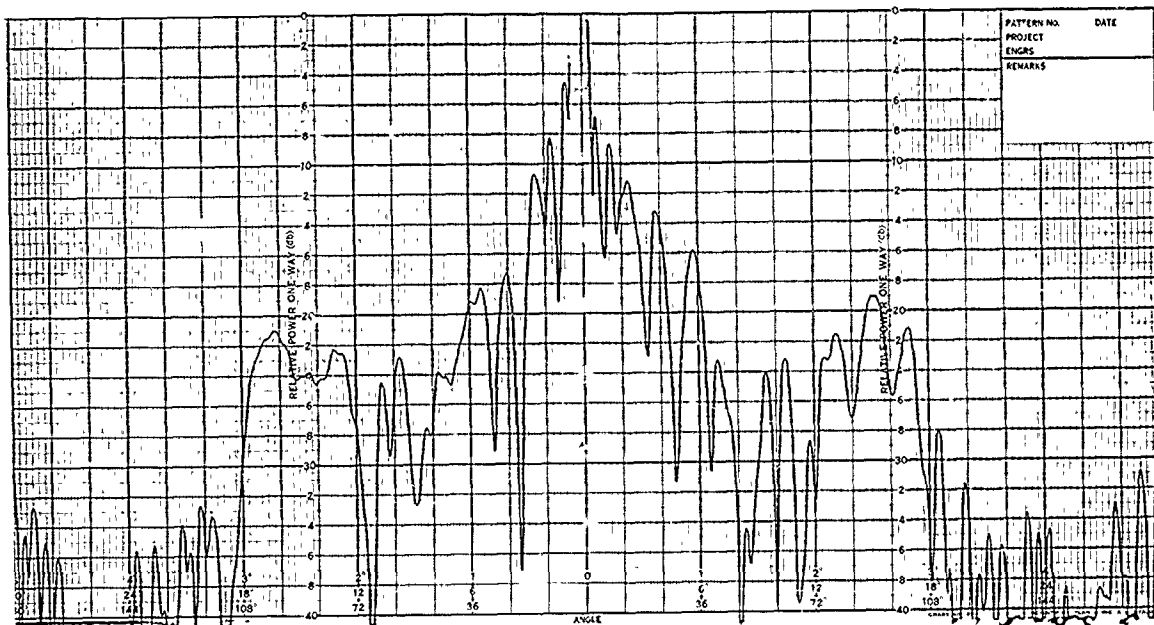


(a) Outdoor range

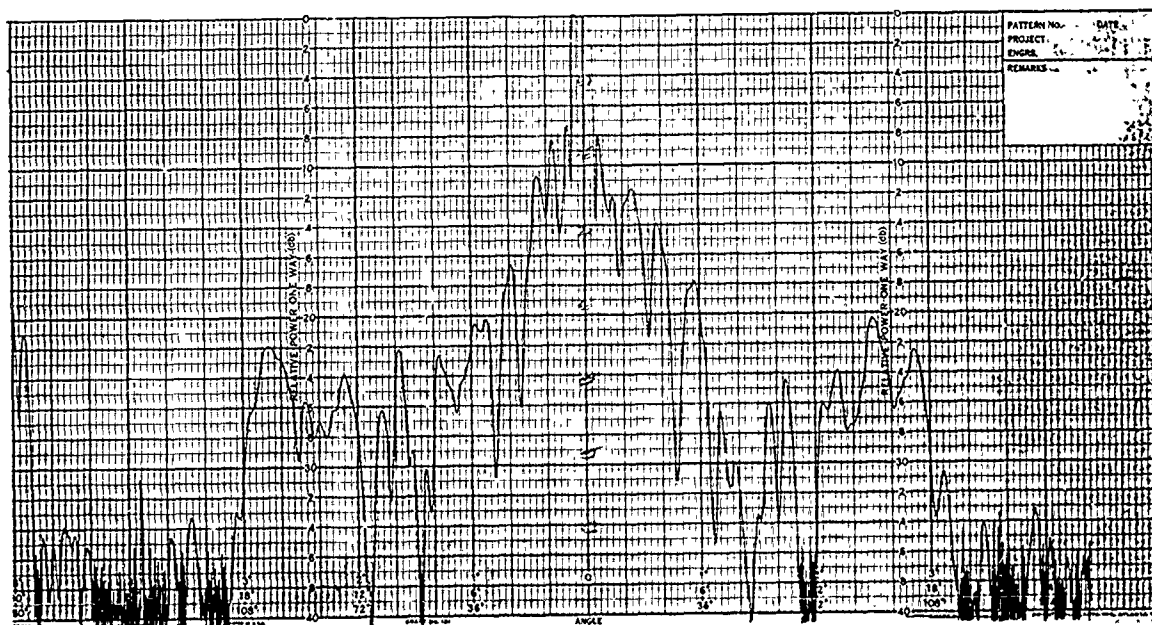


(b) Compact range

Figure 15. Azimuth Patterns Recorded on the Outdoor Range and on the Point-Source Compact Range at 8.2 GHz. The gain level at the top of the chart is -15 db with respect to the main lobe.

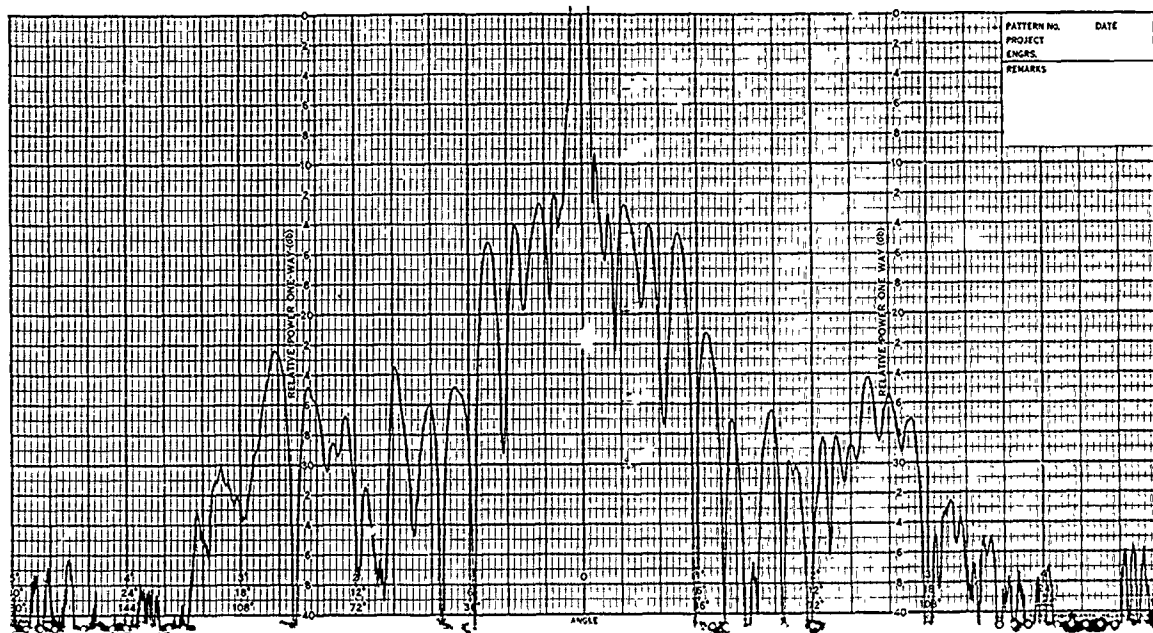


(a) Outdoor range

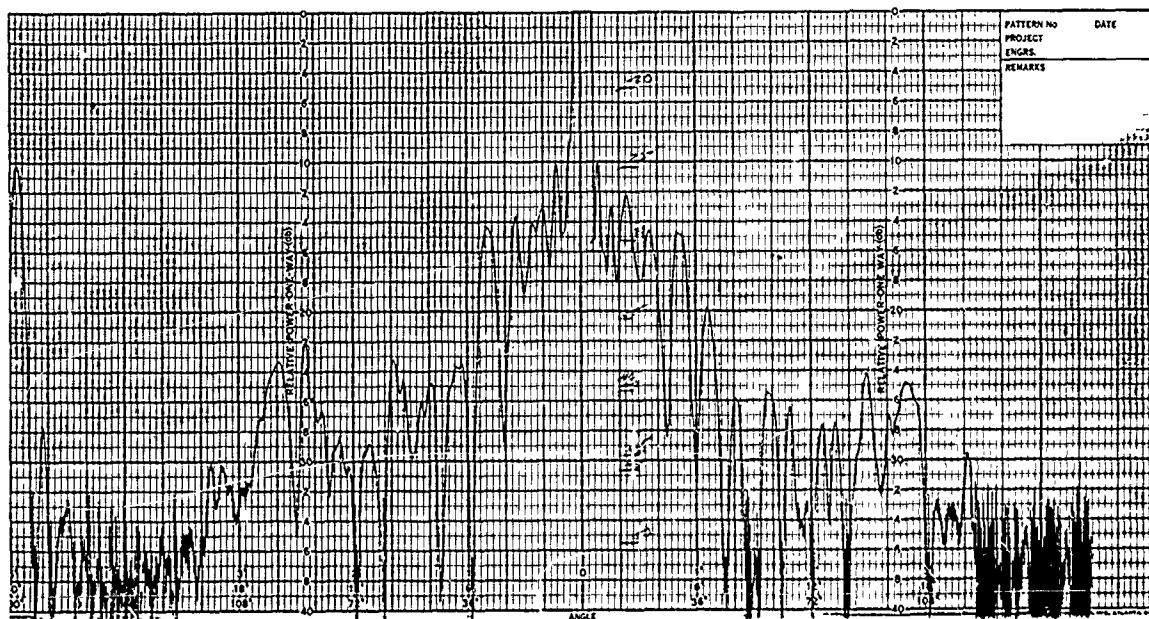


(b) Compact range

Figure 16. Azimuth Patterns Recorded on the Outdoor Range and on the Point-Source Compact Range at 9.0 GHz. The gain level at the top of the chart is -15 db with respect to the main lobe.

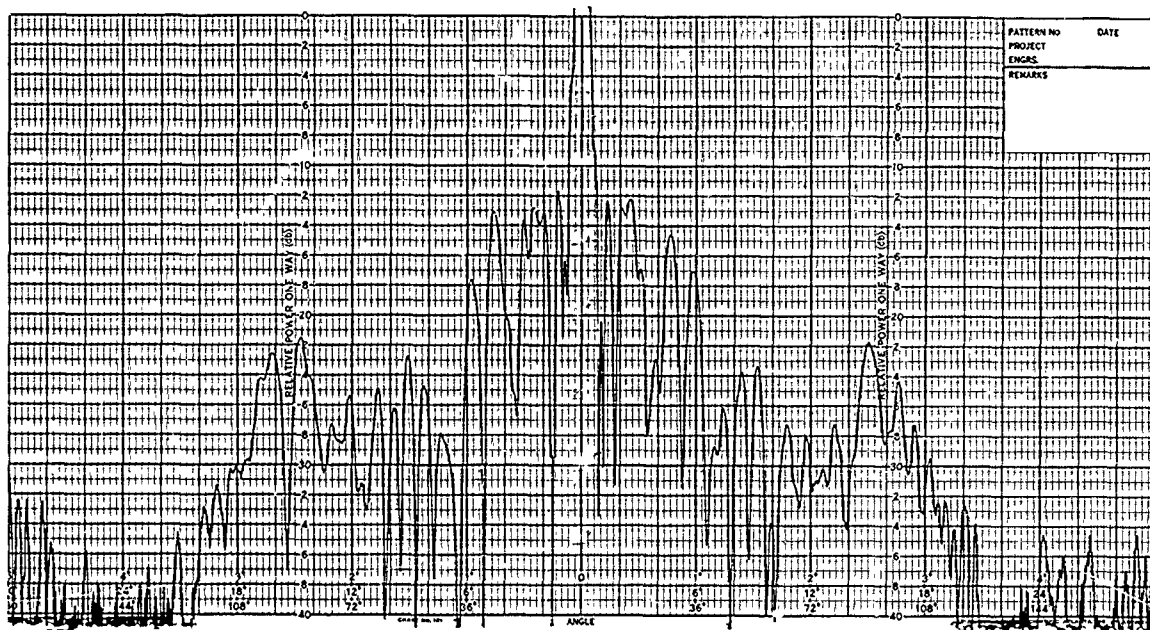


(a) Outdoor range

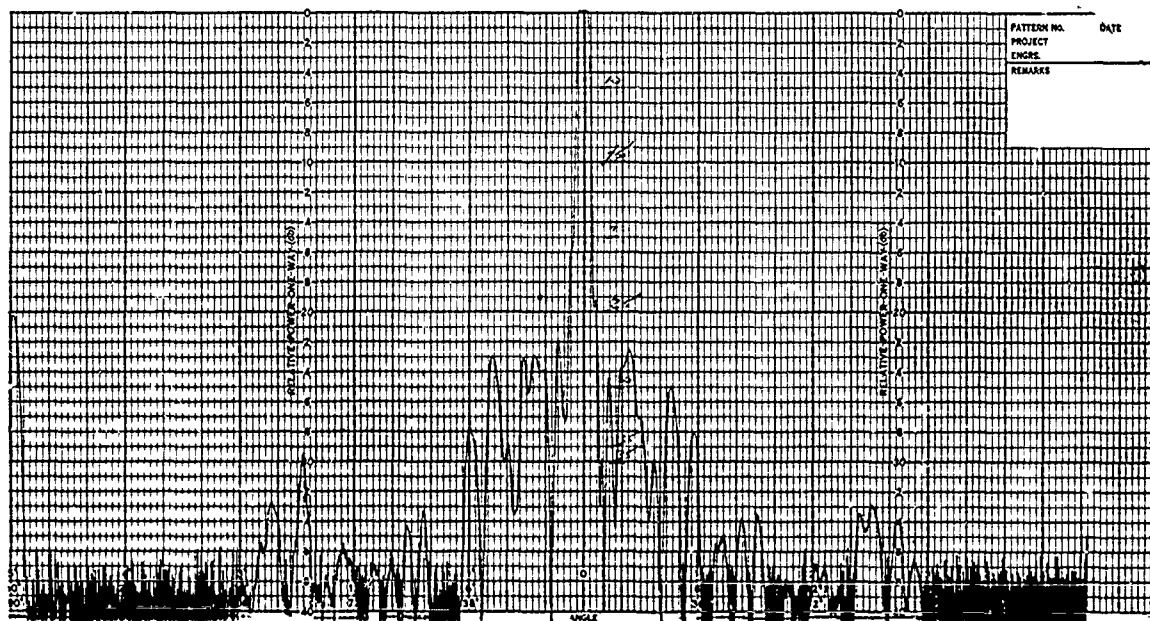


(b) Compact range

Figure 17. Azimuth Patterns Recorded on the Outdoor Range and on the Point-Source Compact Range at 10.0 GHz. The gain level at the top of the chart is -15 db with respect to the main lobe.

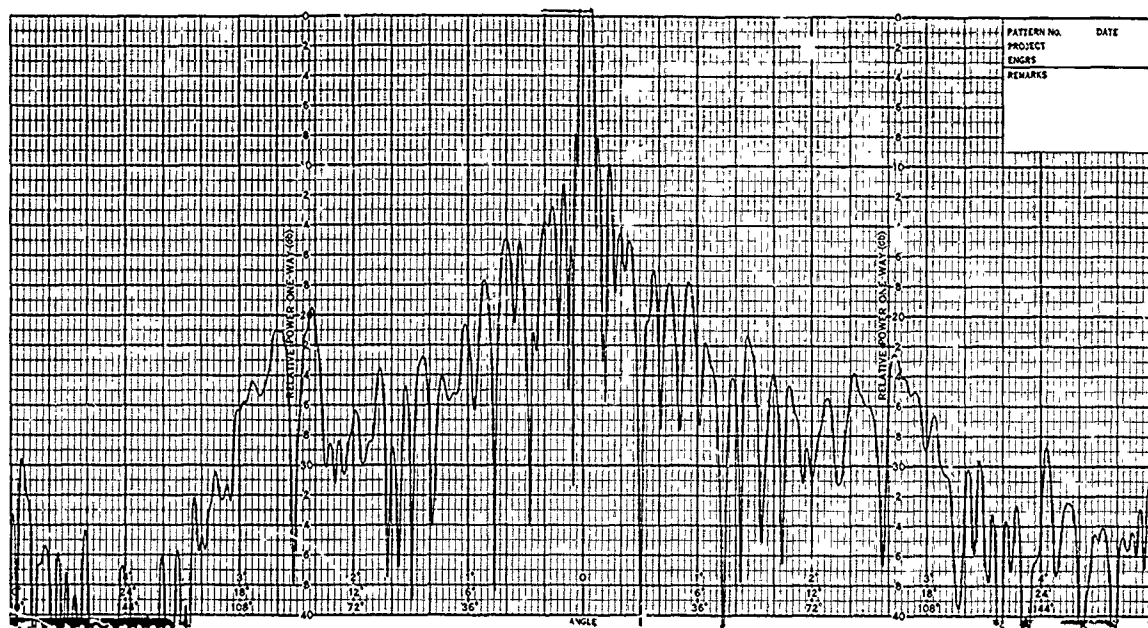


(a) Outdoor range

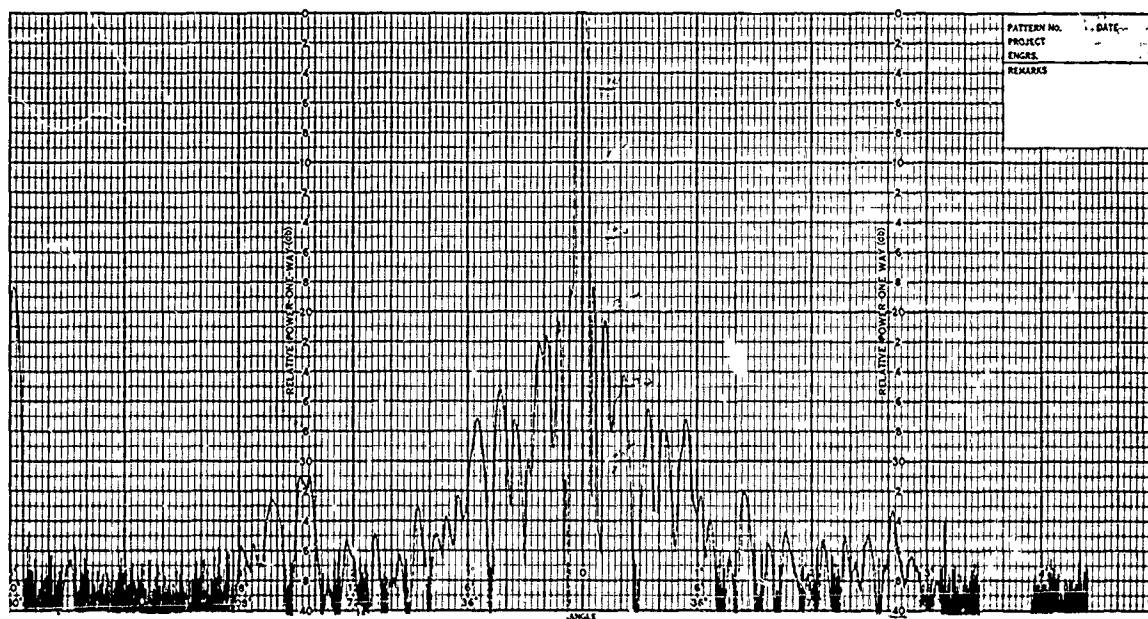


(b) Compact range

Figure 18. Azimuth Patterns Recorded on the Outdoor Range and on the Point-Source Compact Range at 11.0 GHz. The gain levels at the tops of the charts are -15 db in (a) and -5 db in (b) with respect to the main lobe.



(a) Outdoor range



(b) Compact range

Figure 19. Azimuth Patterns Recorded on the Outdoor Range and on the Point-Source Compact Range at 12.0 GHz. The gain levels at the tops of the charts are -15 db in (a) and -5 db in (b) with respect to the main lobe.

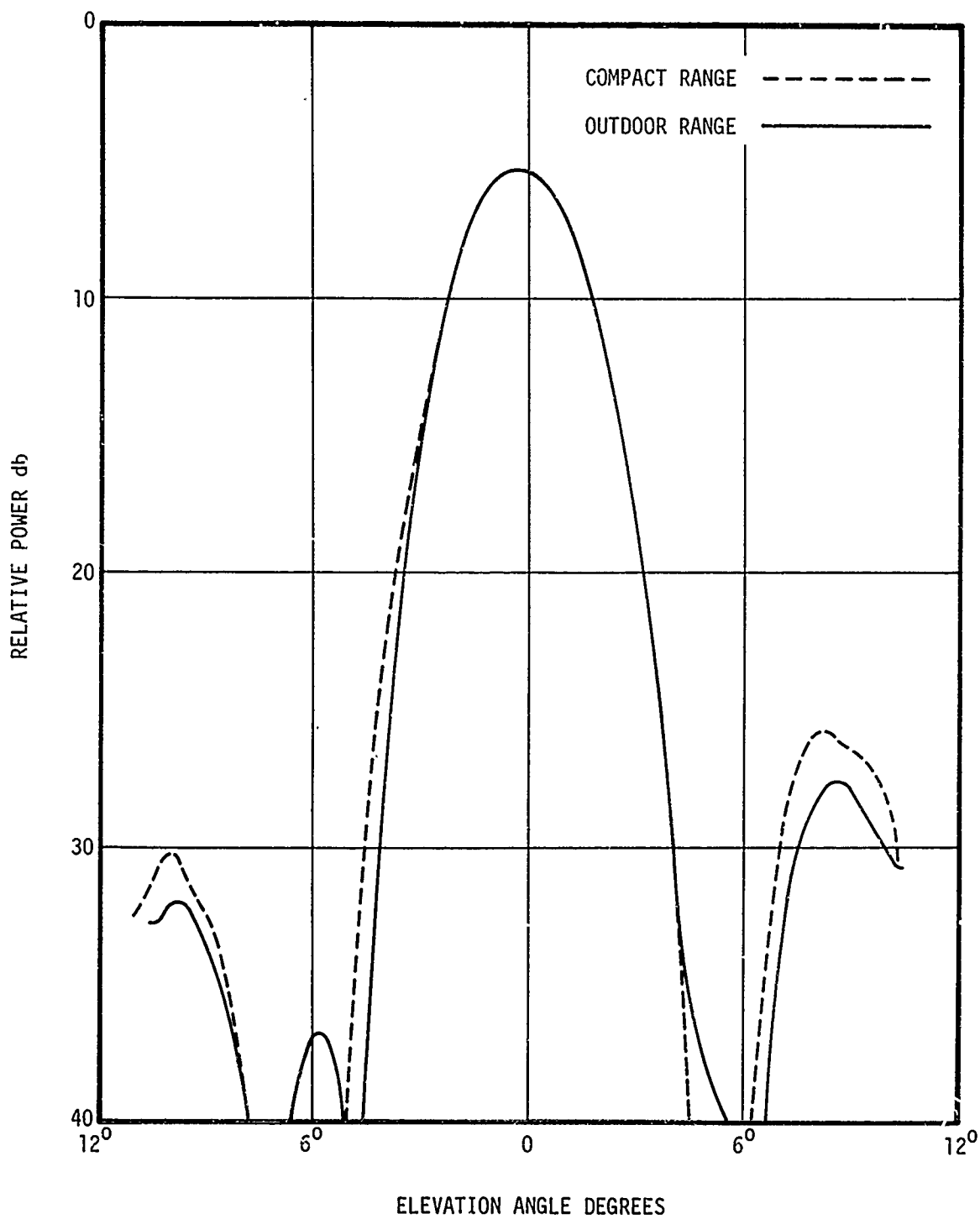
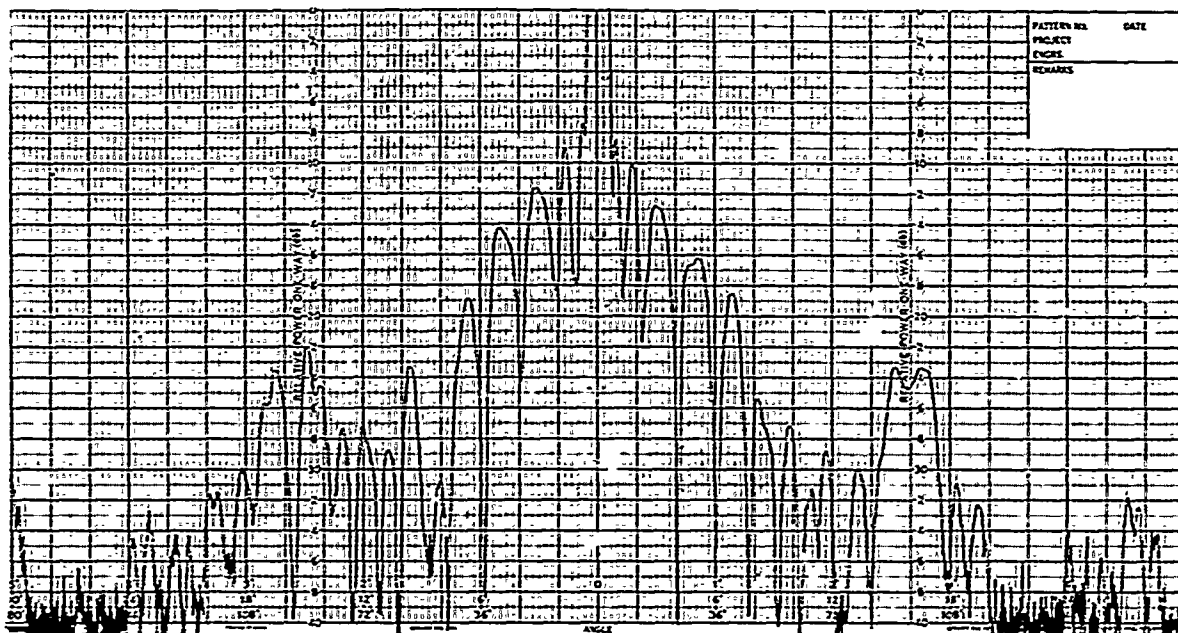
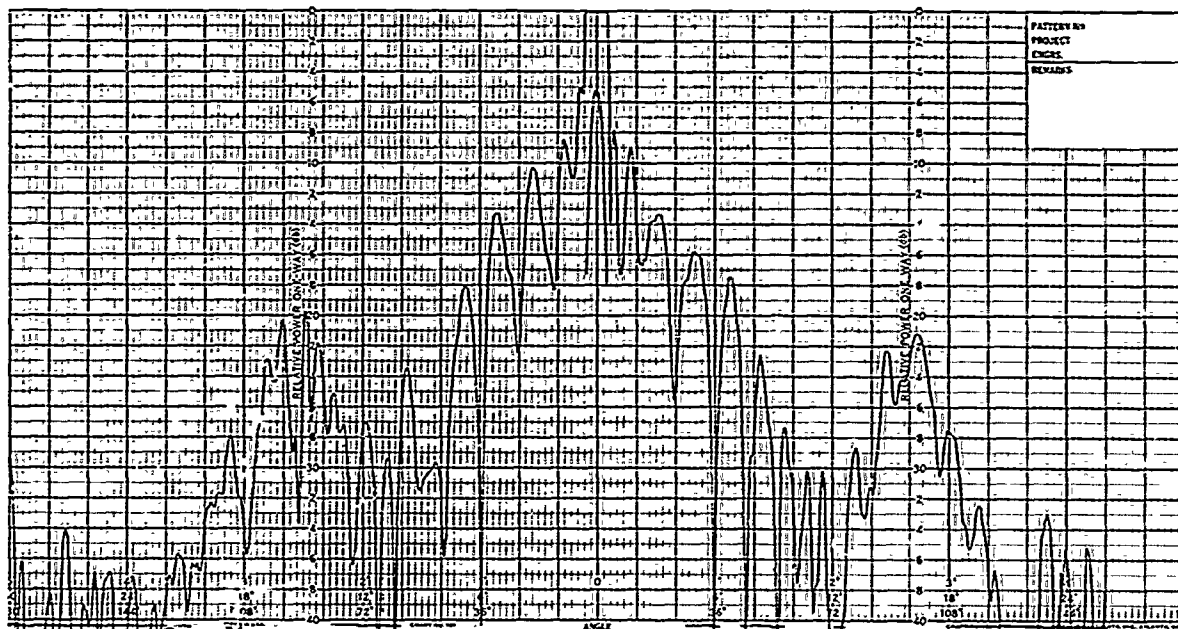


Figure 20. Comparison of the Elevation Patterns Recorded on the Outdoor Range and on the Point-Source Compact Range at 10 GHz.

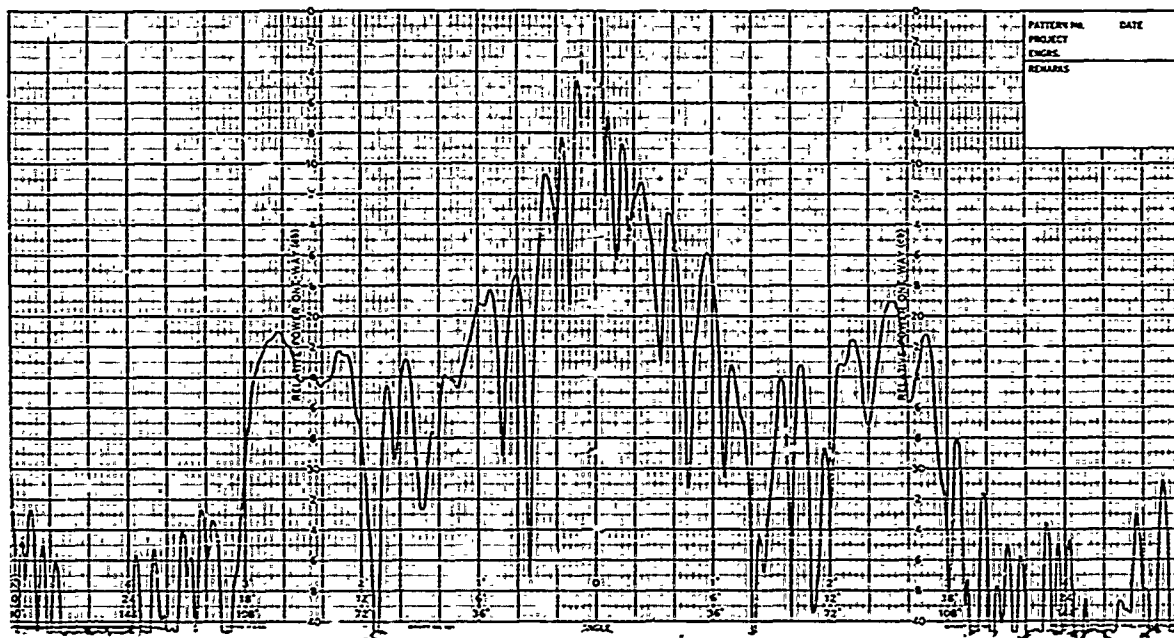


(a) Outdoor range

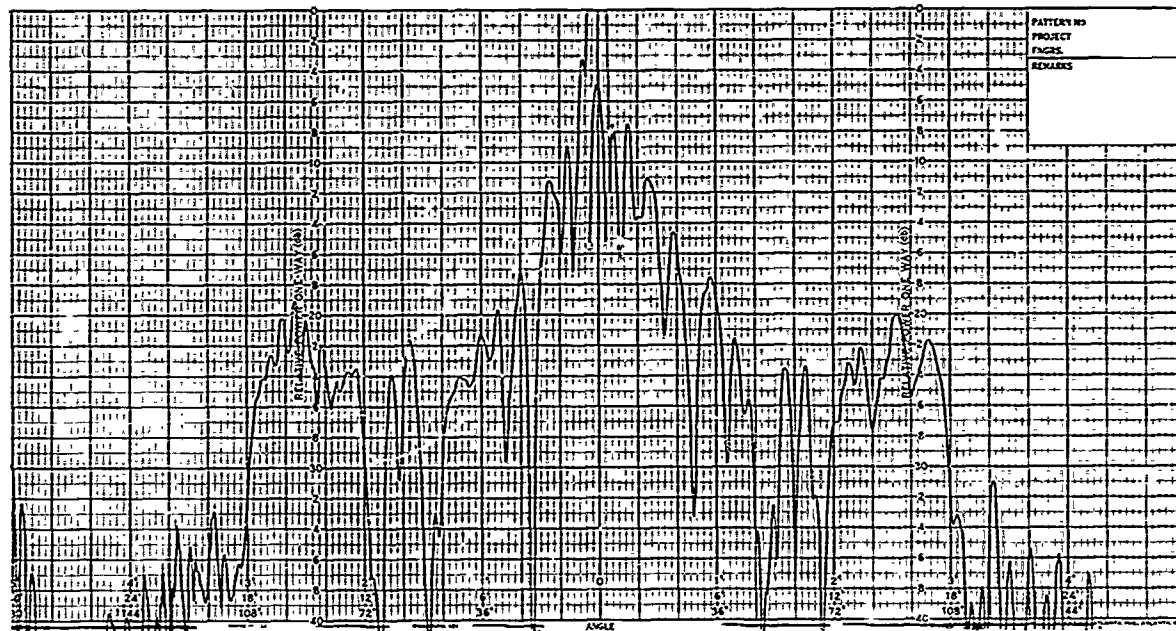


(b) Compact range

Figure 21. Azimuth Patterns Recorded on the Outdoor Range and on the Line-Source Compact Range at 8.2 GHz. The gain level at the top of the chart is -15 db with respect to the main lobe.

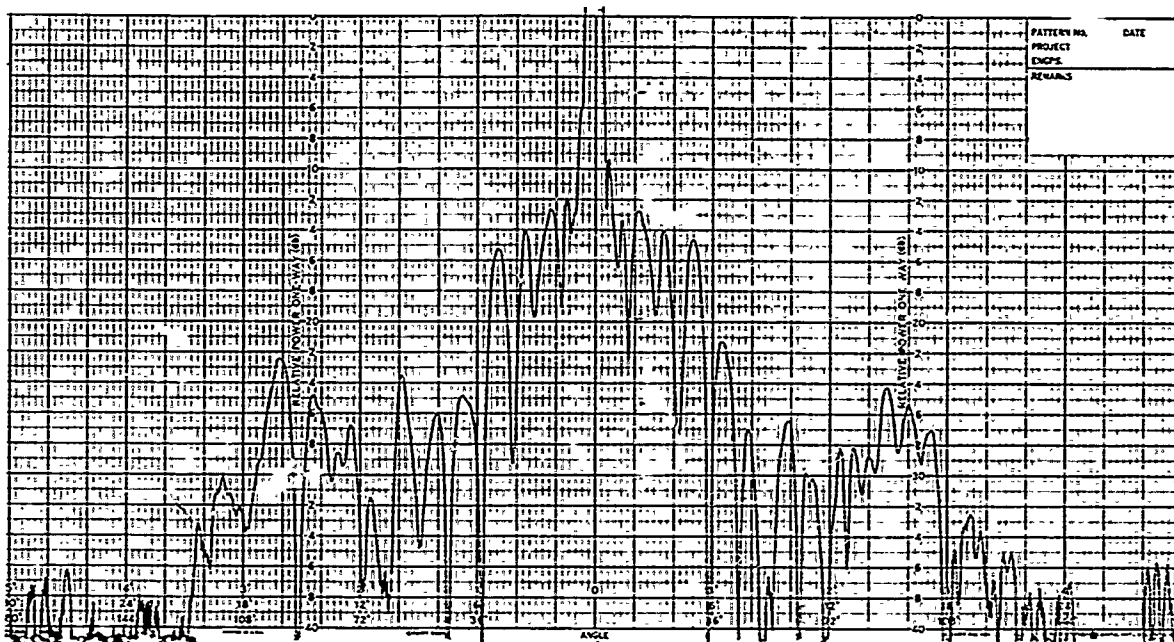


(a) Outdoor range

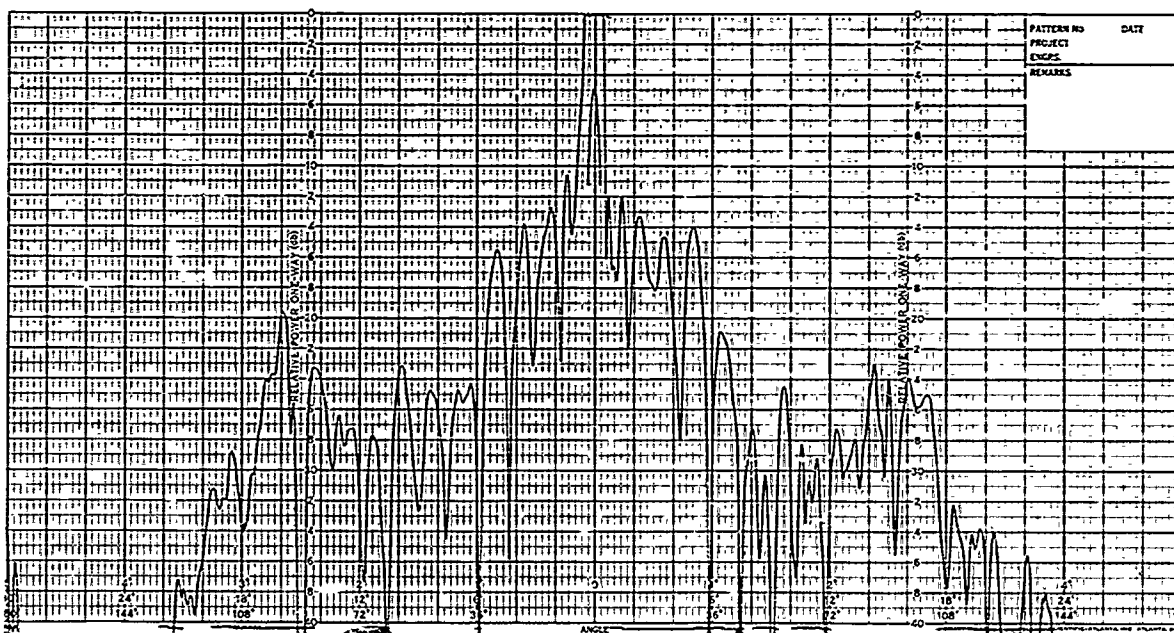


(b) Compact range

Figure 22. Azimuth Patterns Recorded on the Outdoor Range and on the Line-Source Compact Range at 9.0 GHz. The gain level at the top of the chart is -15 db with respect to the main lobe.

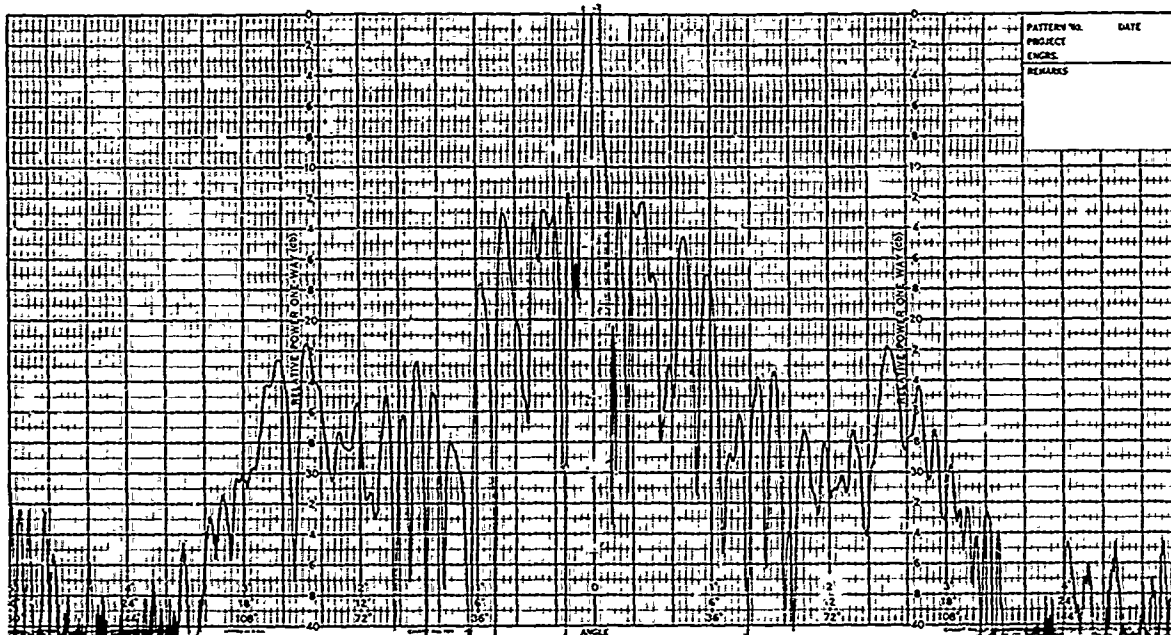


(a) Outdoor range

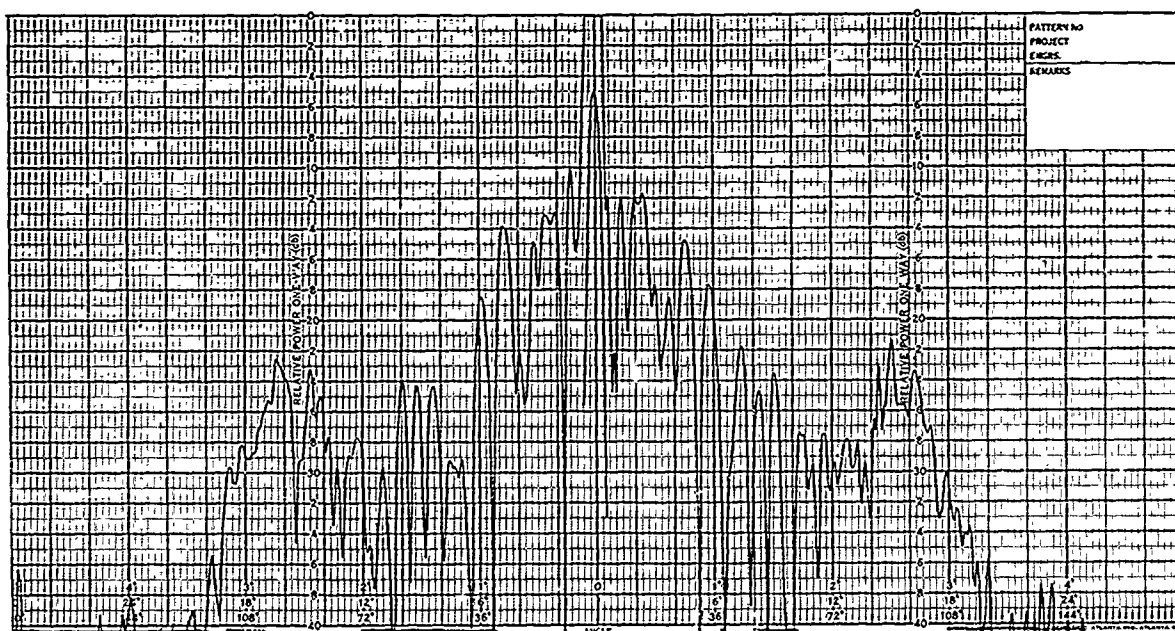


(b) Compact range

Figure 23. Azimuth Patterns Recorded on the Outdoor Range and on the Line-Source Compact Range at 10.0 GHz. The gain level at the top of the chart is -15 db with respect to the main lobe.

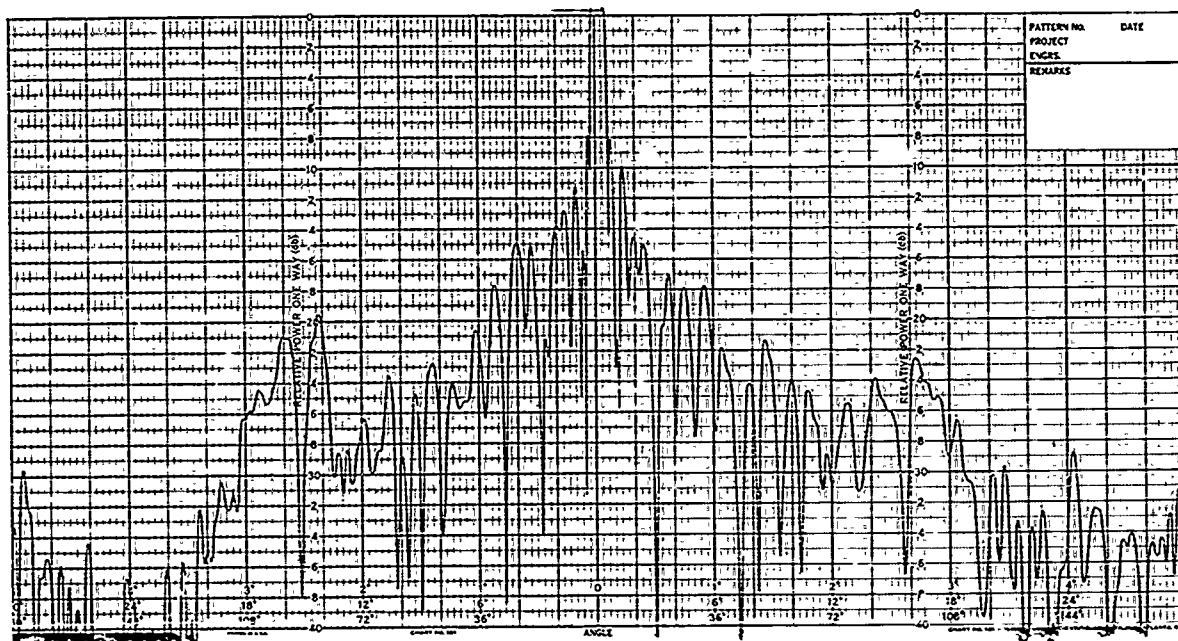


(a) Outdoor range

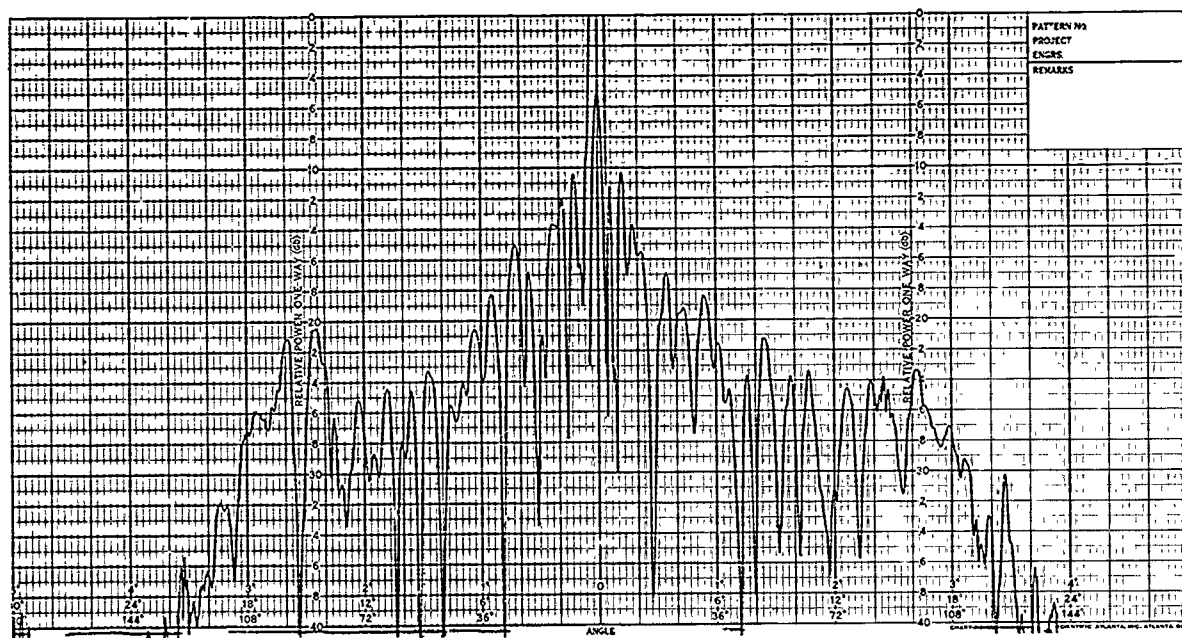


(b) Compact range

Figure 24. Azimuth Patterns Recorded on the Outdoor Range and on the Line-Source Compact Range at 11.0 GHz. The gain level at the top of the chart is -15 db with respect to the main lobe.



(a) Outdoor range



(b) Compact range

Figure 25. Azimuth Patterns Recorded on the Outdoor Range and on the Line-Source Compact Range at 12.0 GHz. The gain level at the top of the chart is -15 db with respect to the main lobe.

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13. ABSTRACT Techniques for making pattern and gain measurements on full-sized microwave radar antennas on indoor compact antenna ranges are described. A reflector and special feed system near the test antenna is used to produce incident plane waves, and far-zone results are obtained. Three basic configurations of compact ranges are discussed; they are a point-source range, a line-source range, and a two-dimensional range. Pattern and gain measurements of a 30-inch parabolic test antenna were made on the point-source and line-source ranges, and the results were compared with measurements made on a conventional outdoor range. Special studies of stray radiation were made on the two-dimensional range.		

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