

**Compact Range Improvements
in Performance at 30 GHz**

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**Scientific
Atlanta**
Instrumentation

COMPACT RANGE IMPROVEMENTS AND
PERFORMANCE AT 30 GHz
ILLUSTRATIONS AND EXHIBITS

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Introduction: During the past two years the compact range has emerged from the research laboratory into the field for use by the engineer in antenna and radar cross section measurements. During the development of the compact range, experience has been gained in how to handle many of the problems identified in the early work. This paper describes successful results in the areas of improvement of surface accuracy and the design of the reflector edges; also reported are antenna measurements made at 30 GHz using the compact range.

Background: The compact range operation can be most easily understood as a means of illuminating an antenna under test with a planar wavefront; it replaces the conventional far field illuminator as a source of radiation. The character of the field in the test zone of the range is assessed by probing the field with an antenna moved across the aperture of the test volume. Optimal amplitude and phase data are shown for such a test in Figure 1; the test frequency used was 10 GHz. An ideal range would have constant amplitude and phase; the variations shown in these traces correspond to an amplitude taper of 0.4 dB over 4 ft and a phase variation of ± 0.5 electrical degrees.

Edge Diffraction: One source of stray radiation in the test zone of the range is diffracted energy from the edges of the reflector. Experimentation during the development of the product revealed that a serrated edge design can be very helpful in reducing edge diffraction. Figure 2 shows data comparing traces made with two different types of edge configuration: The trace with the periodic modulation was made with the left side of the reflector terminated as a vertical straight line by covering the side serrations with absorber panels; the smoother trace shows a horizontal plot made with the serrations unmasked. The operation of the serrated edges can be understood using simple heuristic ideas from the geometrical theory of diffraction.

Surface Accuracy: Much of the technical progress in the past two years in the manufacture of compact range reflectors is represented by the excellent surface tolerance now achievable. The influence of the surface accuracy is apparent in Figures 3 and 4 which illustrate the correlation between mechanical surface smoothness and ripple-free vertical amplitude field probe traces.

30 GHz Performance: One of the authors (FGW) has carried out a program of evaluation of the compact range technique for use at Ka-Band. Two of the pattern comparisons from this evaluation are shown in Figures 5, 6, and 7, to indicate the performance observed. Figure 5 shows a set of patterns on an 18 inch parabolic dish at different longitudinal positions in the test zone. Figures 6 and 7 show a comparison between a pattern taken on the compact range and a pattern taken on a 1900 ft outdoor range at a frequency of 30 GHz. The discrepancies which occur between the indoor and outdoor patterns have an equivalent stray signal better than -35 dB. These tests indicate that in many applications useful antenna measurements can be made under conditions where the field probe data are less than ideal.

Conclusion: Results derived over the past two years show that the compact range appears promising for antenna and radar cross section measurements at frequencies above 18 GHz.

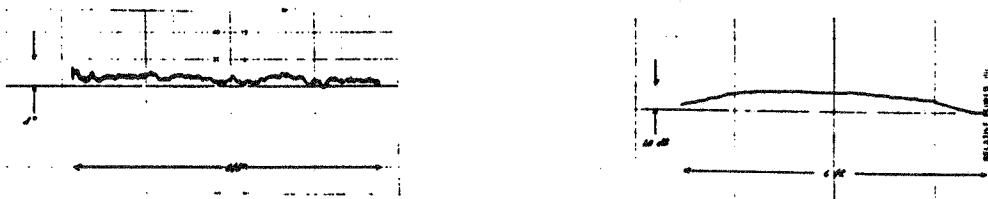


Fig. 1. Data at 10 GHz showing the phase and amplitude variation in the signal received by a standard gain horn as it is moved horizontally across the test zone. The total phase variation is ± 0.5 degrees and the amplitude taper is 0.4 dB for 4 feet.



Fig 2. A comparison of data at 10 GHz showing the effect on the horizontal amplitude traces created by masking the left serrated edge with a line of absorber panels. The probe antenna used was a 30° beamwidth diagonal horn. The length of travel is 6.5 ft.

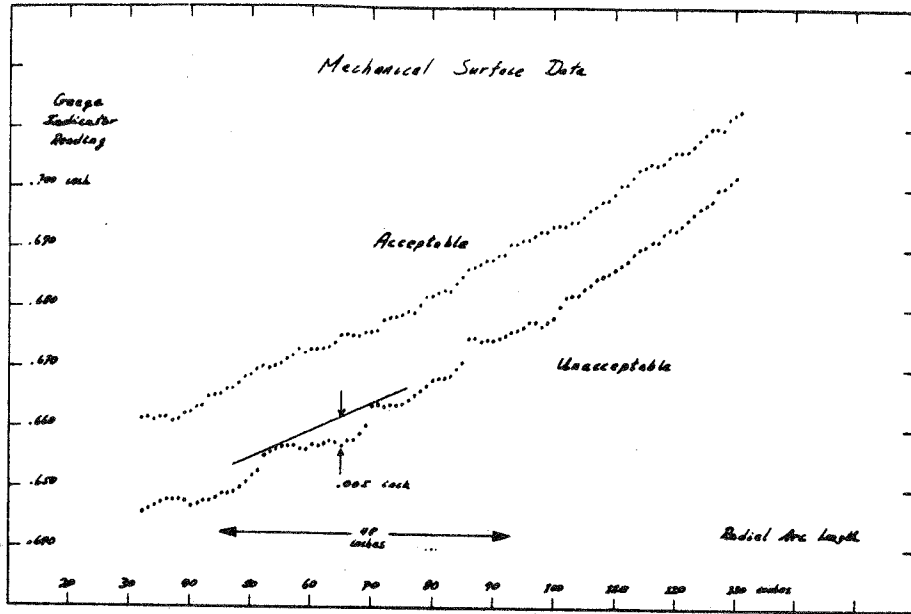


Fig 3. Graphs of mechanical data for two different reflector surfaces. The surface characterized by the upper curve gave measured field probe data judged acceptable by the product standard. The graphs are the dial indicator readings from a three point surface gauge plotted versus radial arc length.

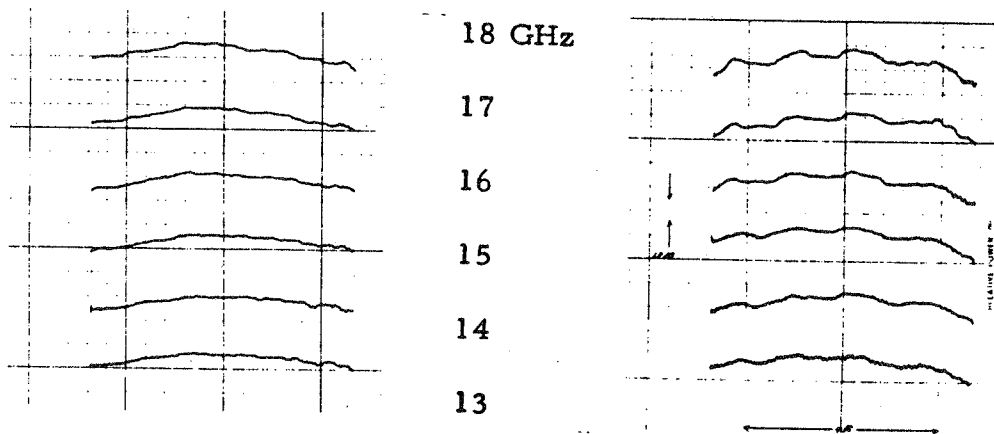


Fig 4. Families of vertical field probe data for the two surfaces characterized mechanically in Fig 3. The data shown on the left is for the acceptable surface; it was taken during field installation. The probe is a Ku-band standard gain horn. The travel is 5.4 ft.

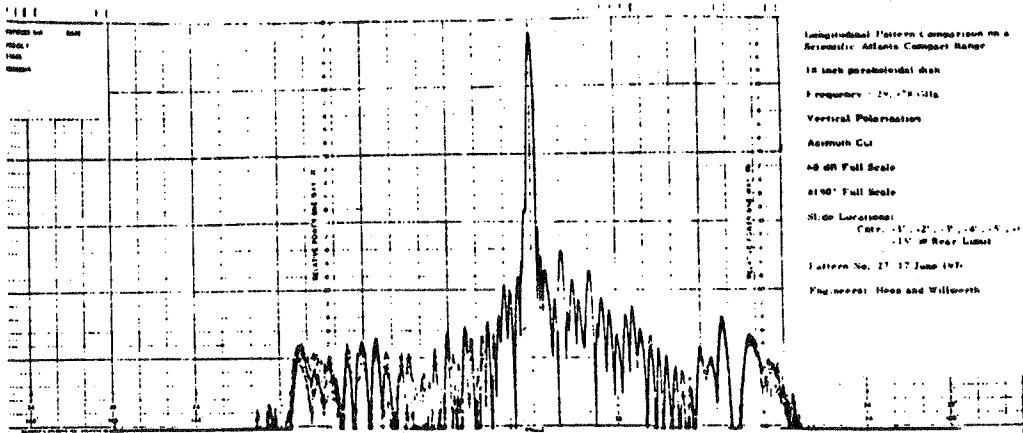


Fig. 5. A longitudinal pattern comparison made with an 18 inch diameter parabolic reflector at 30 GHz on the compact range.

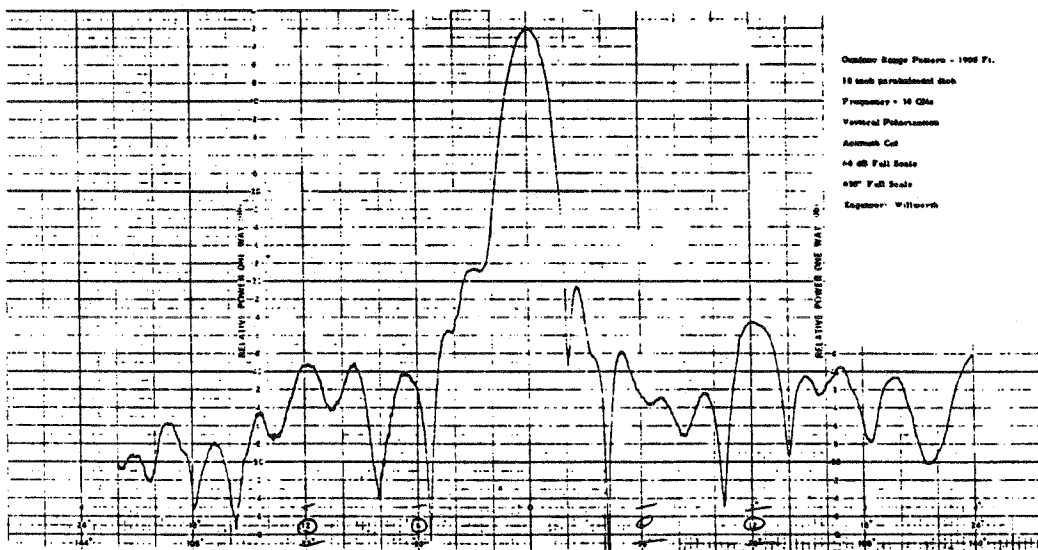


Fig. 6. Outdoor pattern at 30 GHz for the 18 inch reflector.

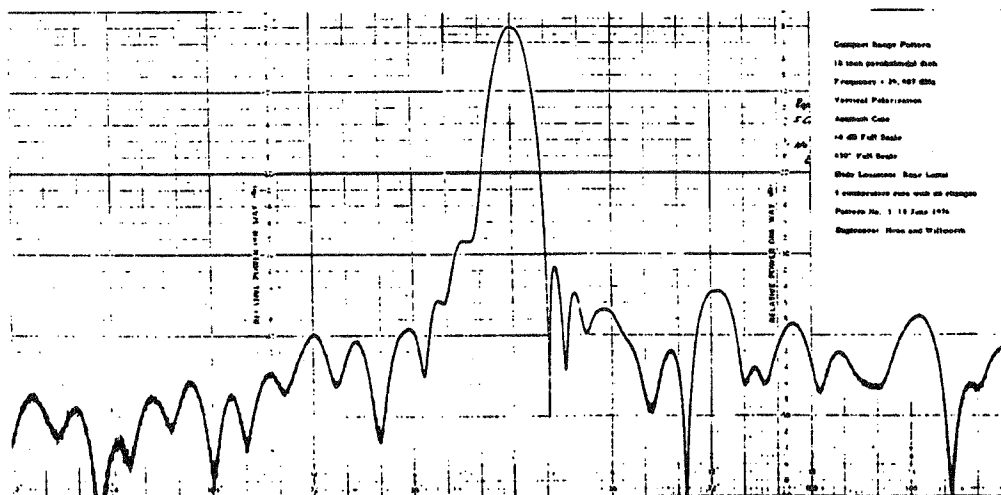


Fig. 7. Compact range pattern at 30 GHz for the 18 inch reflector.

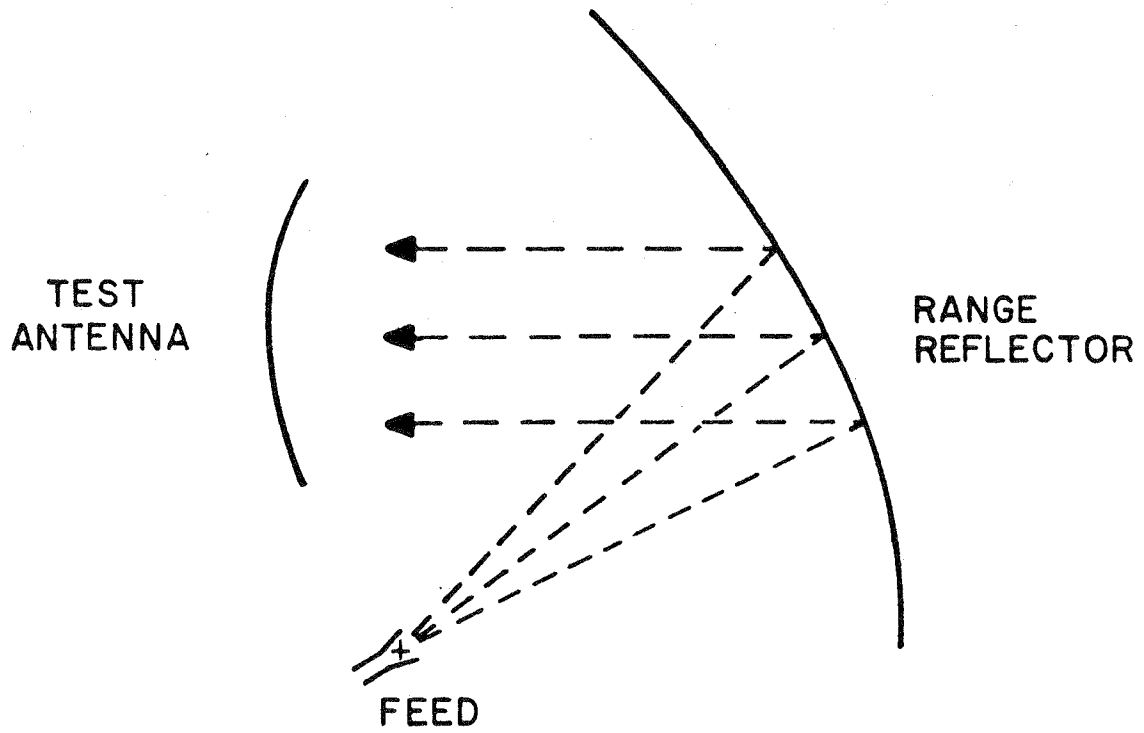
SLIDE PRESENTATION

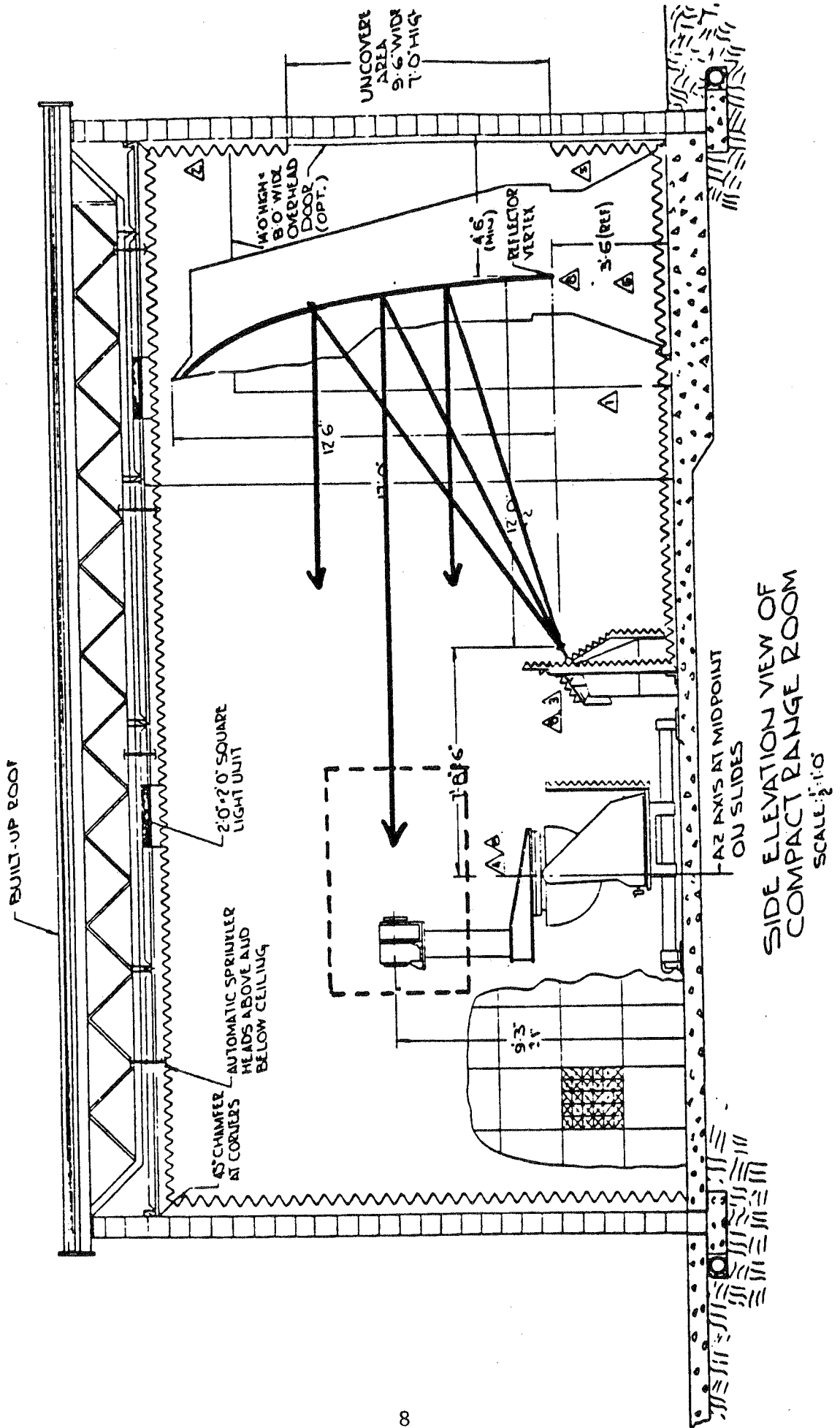
THE COMPACT RANGE

The operation of a compact range can be most easily understood as a means of illuminating an antenna under test with a planar wavefront; it replaces the conventional far field illuminator as a source of radiation. The planar wavefront of the compact range is created by a paraboloidal reflector which collimates the spherical phase fronts radiated by a small feed horn. The reflected wave from the paraboloidal surface consists of planar phase fronts which impinge on the antenna under test.

In a manner identical to operation of an outdoor range, the antenna under test may be rotated on a positioner to change its orientation with respect to the planar wave. Plotting the amplitude response of the antenna as a function of the orientation angle, one may produce the radiation pattern of the antenna. Since the feed and reflector of the compact range are situated in the near field of the antenna under test, use of the compact range is properly classified as a near field technique.

COMPACT RANGE SCHEMATIC DIAGRAM



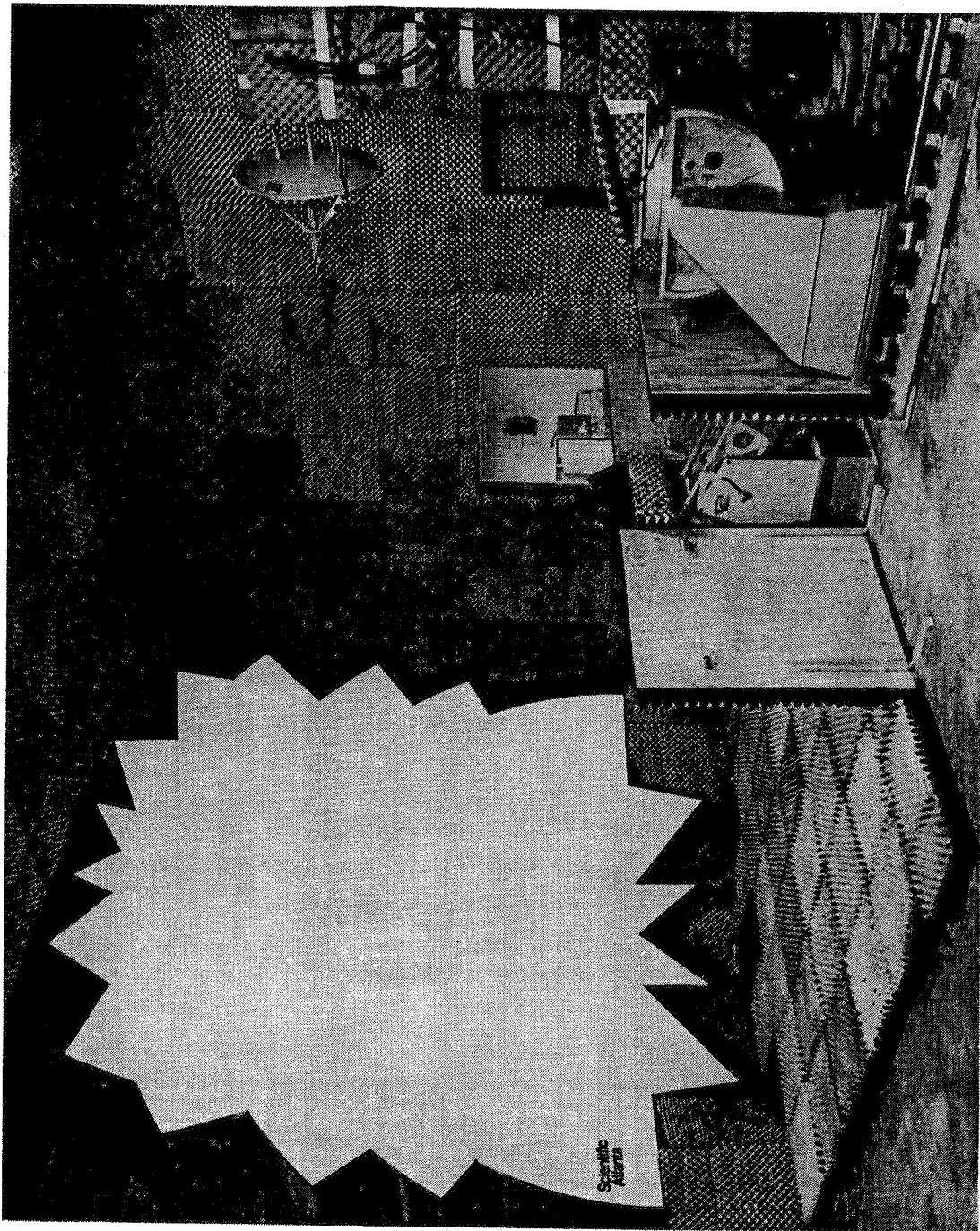


A PRACTICAL DEVICE

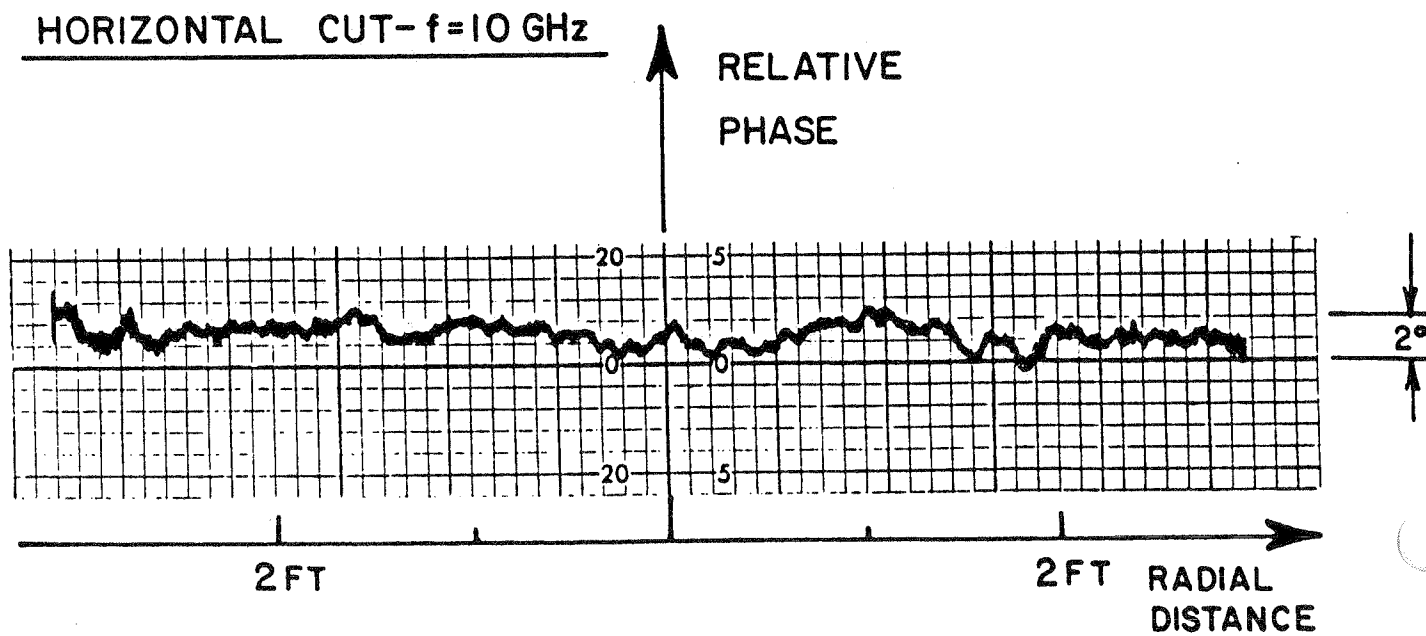
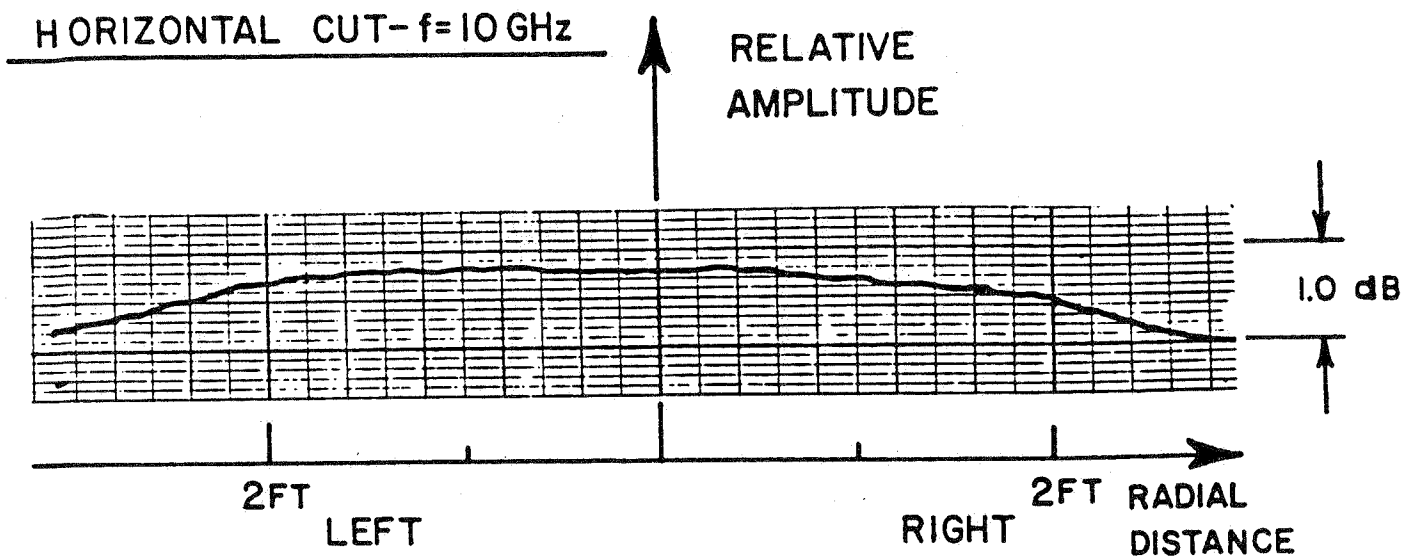
During the past ten years the compact range has emerged from the research laboratory into the field as a useful tool for antenna testing. A commercial version based on an offset paraboloidal design is now available. In some situations a compact range can replace an outdoor range up to 200 meters long. Compact ranges are simple to use; they may be operated with conventional analog equipment and they permit the pattern of an antenna to be measured directly. Compact ranges provide the important advantage of permitting pattern measurements on directive antennas to be made indoors.

The compact range product that is manufactured for sale by Scientific-Atlanta is shown in the accompanying figures. It consists of three basic items - the feed subassembly, the reflector subassembly and the test positioner subassembly. These are installed in a room that is lined with microwave absorber to reduce the effects of unwanted reflection signals which disturb the measurements. The minimum dimensions of the room are 17 feet high by 20 feet wide by 36 feet long.





AMPLITUDE AND PHASE PROBE DATA COMPACT RANGE FIELD



ELECTROMAGNETIC FIELD MEASUREMENTS

The illuminating field of the compact range is measured by use of a phase/amplitude field probe; the data is taken by recording the phase and amplitude of the received signal from a standard gain horn as it is translated across the test zone.

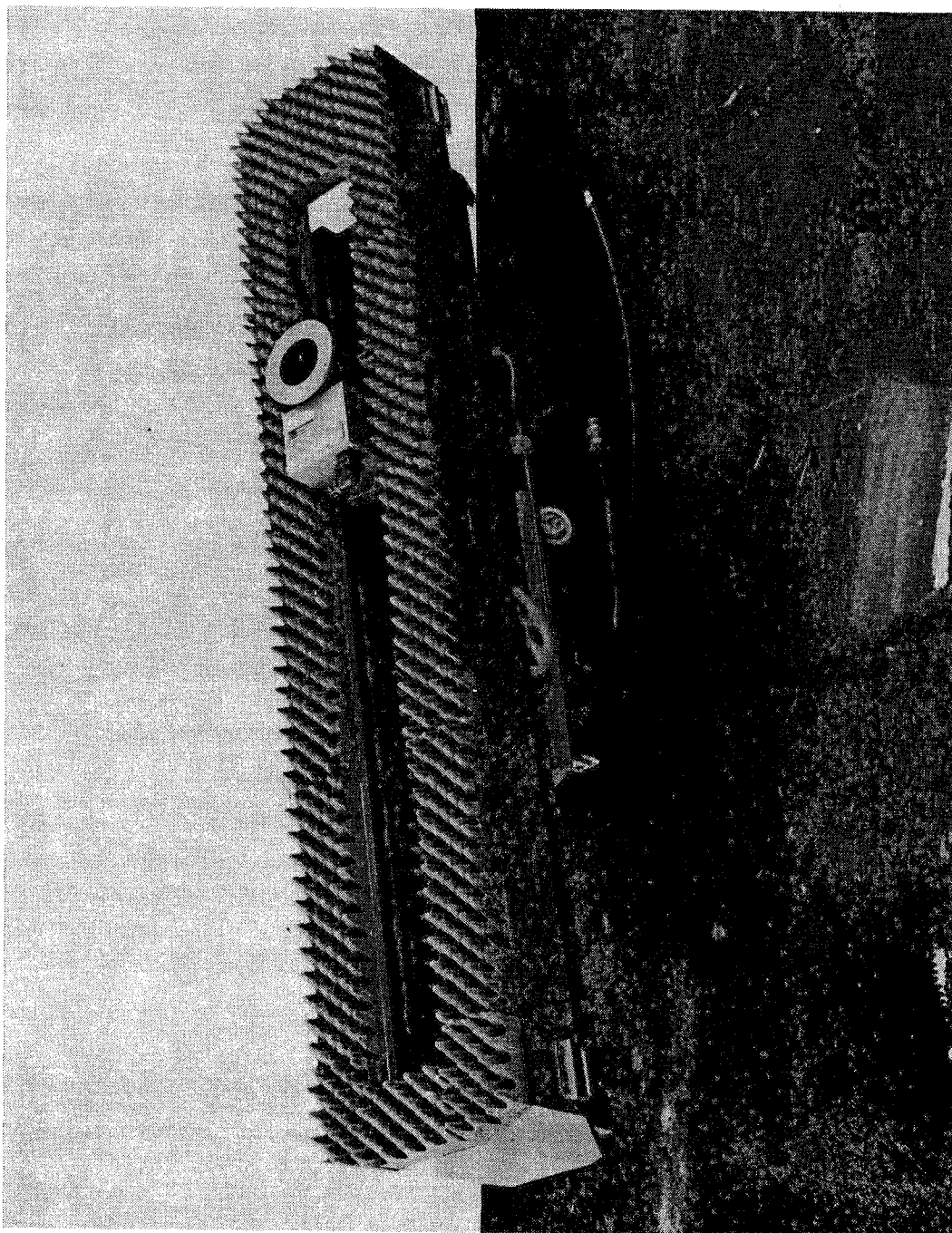
For a four-foot diameter test zone, the amplitude taper is specified to be less than 0.5 dB and the total phase variation is specified to be less than 10 degrees.

The phase variation of the field is a difficult quantity to measure; the variations in the recorded data are due as much to the non-linearity of the carriage travel as to the curvature of the phase front of the field. Using a very accurate field probe, a phase variation of ± 1 degree at X-band has been shown to be achievable.

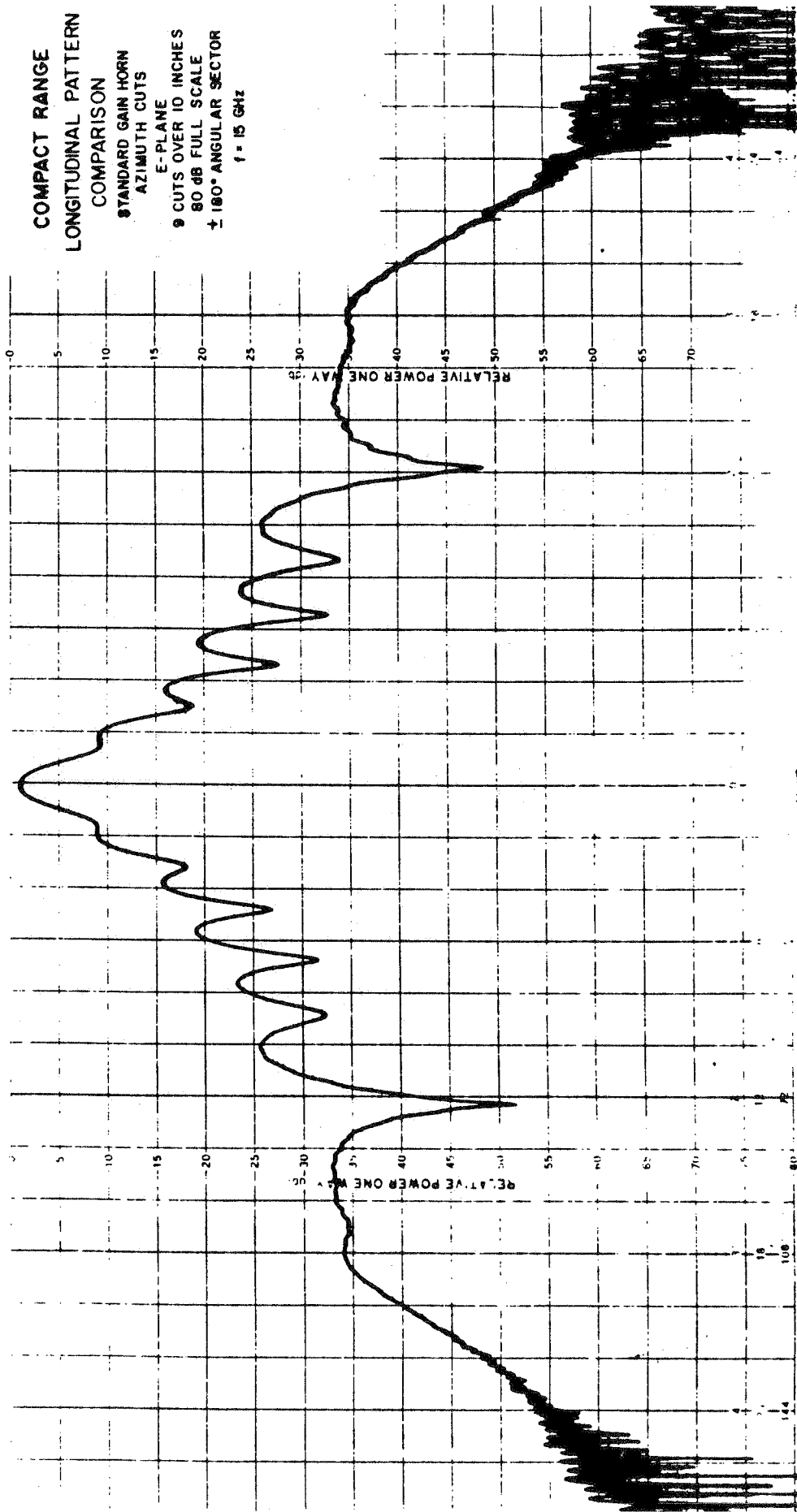
It is interesting to note that the phase variation of an island compact range is 0 degrees; whereas for a $2D^2/X$ outdoor range it is $22\frac{1}{2}$ degrees.

PHASE/AMPLITUDE FIELD PROBE

This special phase/amplitude field probe is used for alignment and verification of performance of the Compact Range. It has a mechanical linearity of $\pm.001$ inch. The unit is covered with absorber to eliminate stray reflections.



COMPACT RANGE
 LONGITUDINAL PATTERN
 COMPARISON
 STANDARD GAIN HORN
 AZIMUTH CUTS
 E-PLANE
 9 CUTS OVER 10 INCHES
 80 dB FULL SCALE
 ± 180° ANGULAR SECTOR
 f = 15 GHz



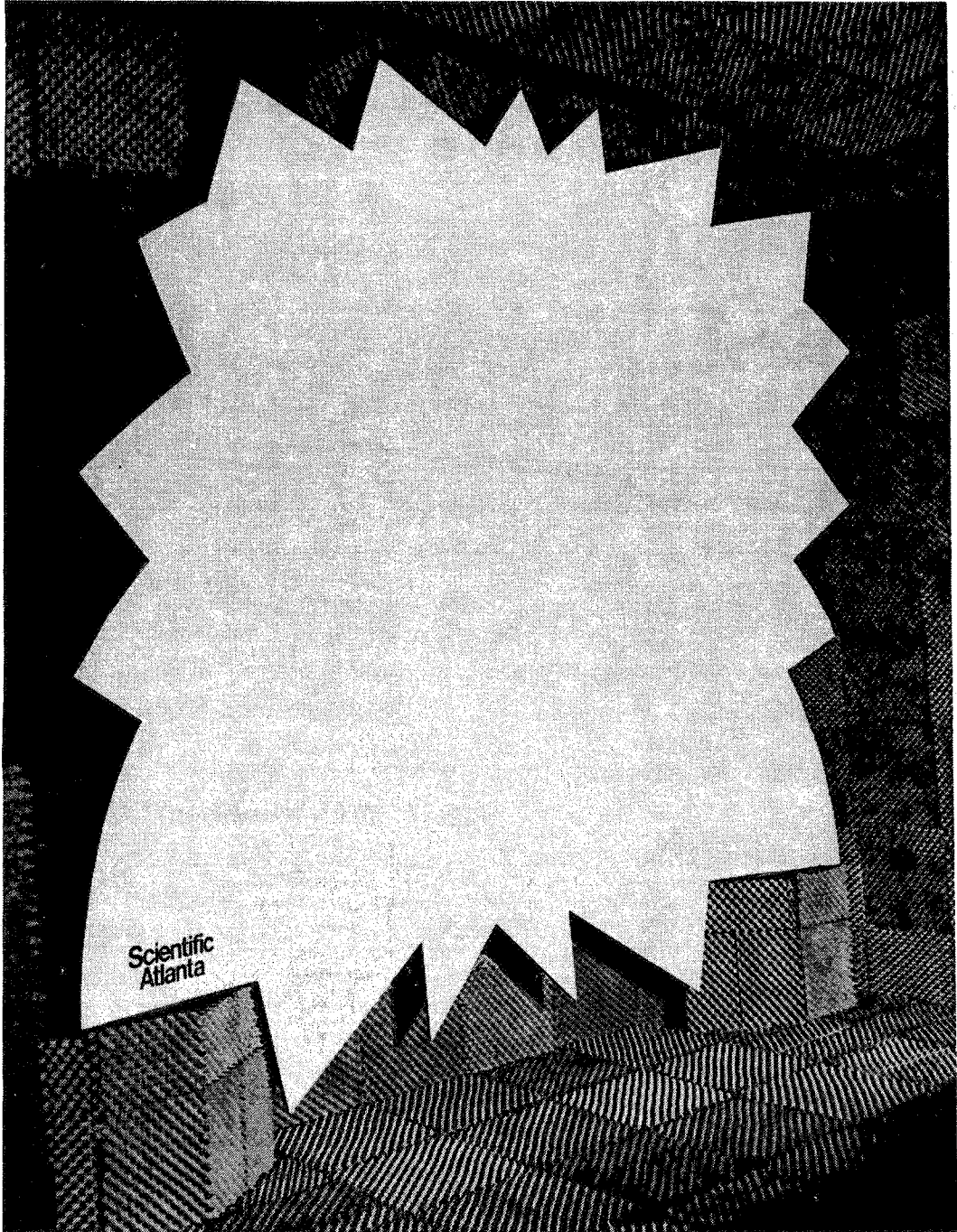
STRAY SIGNAL ASSESSMENT BY LONGITUDINAL PATTERN COMPARISON

The effect of stray signals on the patterns that are taken on the Compact Range can be assessed by use of the slide mechanism underneath the test positioner. By taking a set of patterns at successive longitudinal points along the axis of the range, one can see the changes in the patterns caused by changes in the relative phase between the direct and extraneous signals. The amount of amplitude variation - i.e., the width of the envelope of the overlaid patterns - places bounds on the pattern errors that are due to extraneous signals.

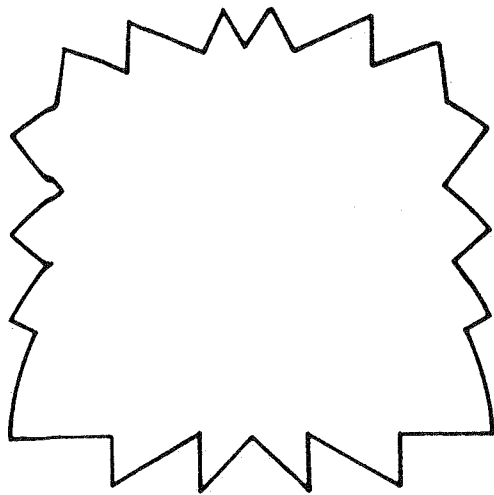
For example, consider the null at an angle of $+18^{\circ}$ in the standard gain horn pattern shown. The 1 dB peak-to-peak variation at a level between -16 and -17 dB corresponds to a stray signal level of -41 dB. Similar tests for directive antennas show stray signal levels typically below -60 dB.

THE EDGE CONFIGURATION

Diffraction from the edges of a reflector can cause a significant degradation in the purity of the plane wave field. In order to handle this problem, the edges of the reflector have been serrated to reduce the classical straight-edge diffraction effect.

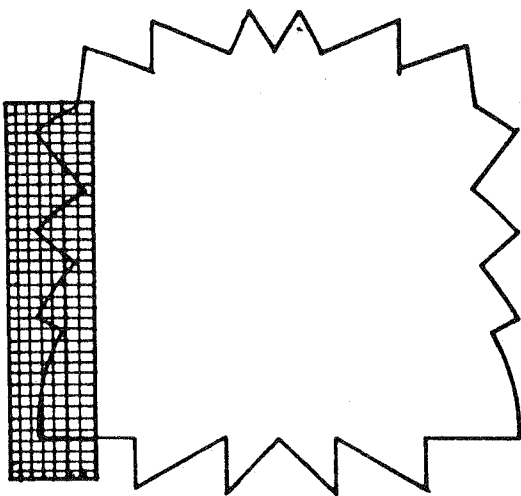
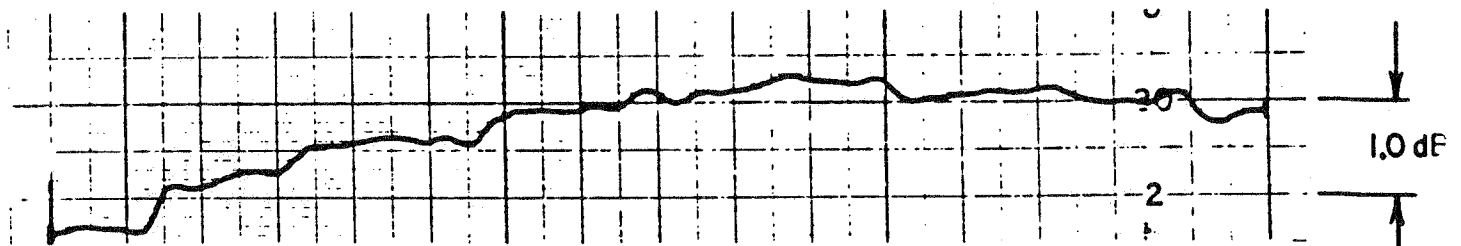


DIFFRACTION FROM SIDE STRAIGHT EDGE

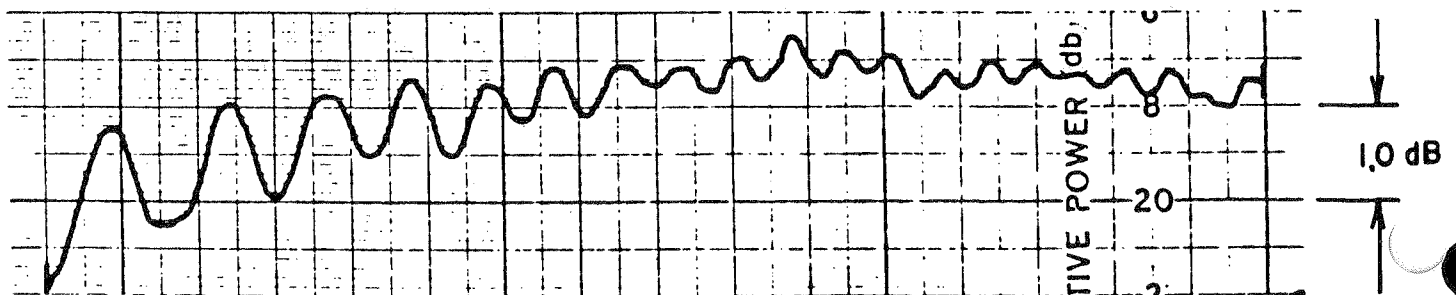


HORIZONTAL AMPLITUDE CUT
WITH SERRATED EDGES

$f = 10 \text{ GHz}$



HORIZONTAL AMPLITUDE CUT
WITH A MASK OF ABSORBER
OVER LEFT HAND SERRATED EDGE

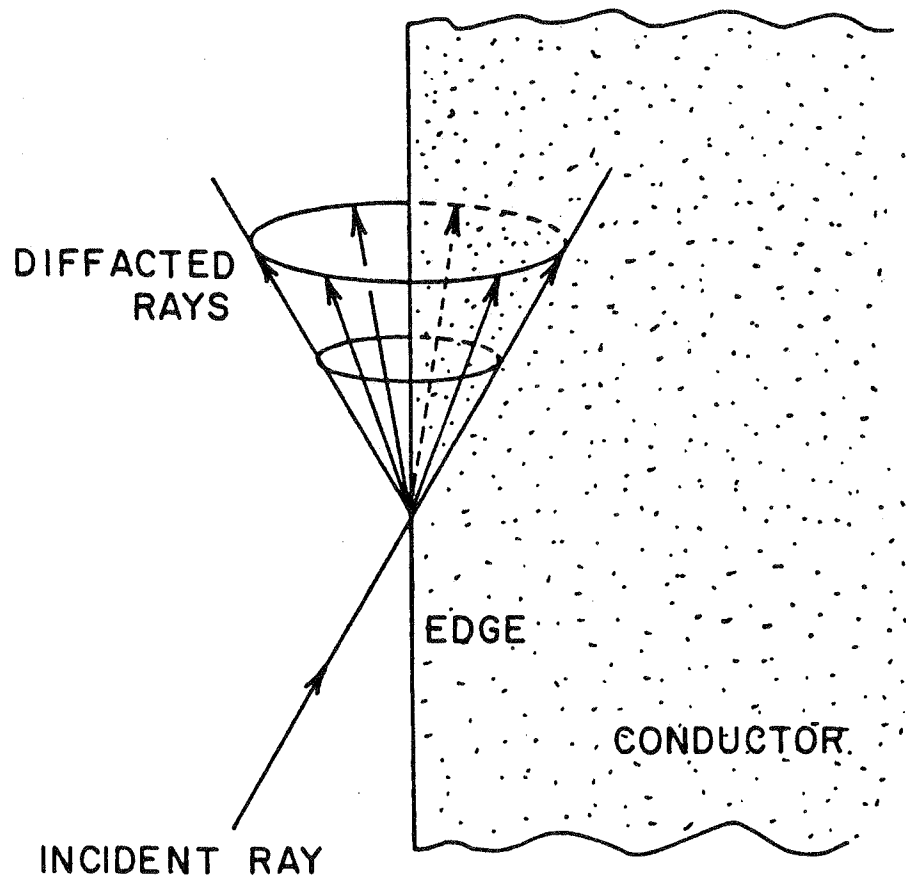


TEST OF THE SERRATED EDGE

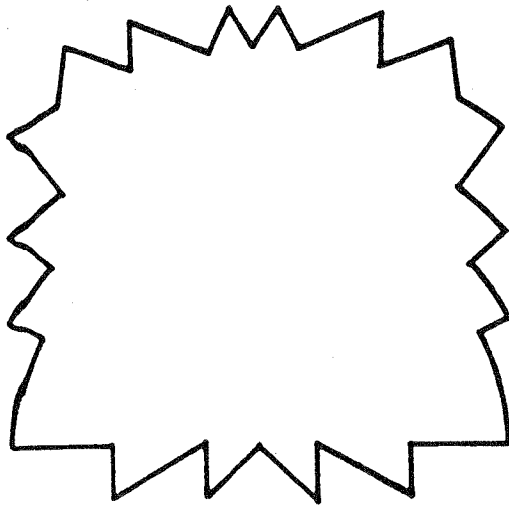
To show that the serrated edges do indeed reduce the diffracted energy in the test zone, one can compare the field probe data for a straight edge and a serrated edge. The straight edge is created by masking the serrations with panels of microwave absorber. The ripples in the field probe data show dramatic enhancement for the straight edge case.



CONE OF DIFFRACTED RAYS FROM THE EDGE OF A CONDUCTOR

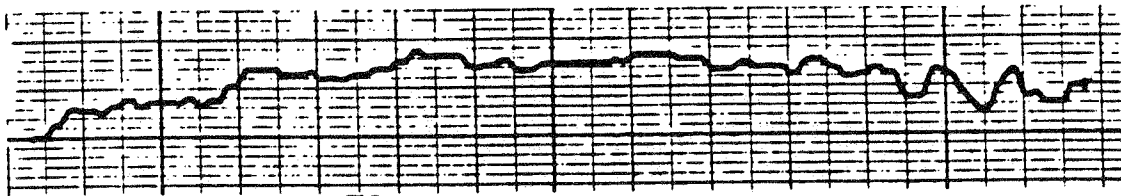


DIFFRACTION FROM LOWER STRAIGHT EDGE



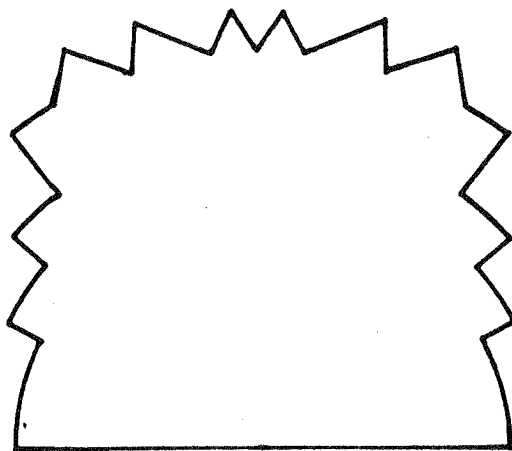
VERTICAL AMPLITUDE CUT
WITH SERRATED EDGES

$f = 12.4 \text{ GHz}$

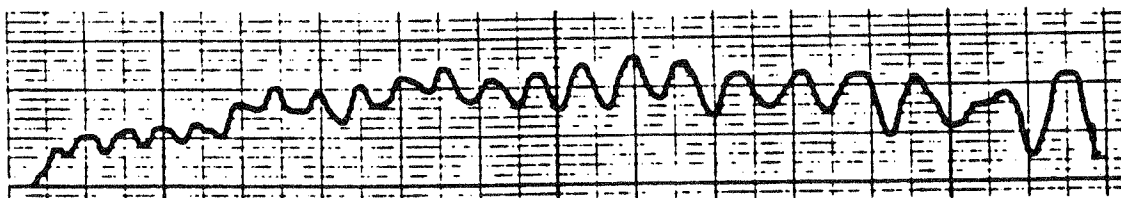


TOP

BOTTOM



VERTICAL AMPLITUDE CUTS
WITH LOWER SERRATION
PANELS REMOVED



TOP

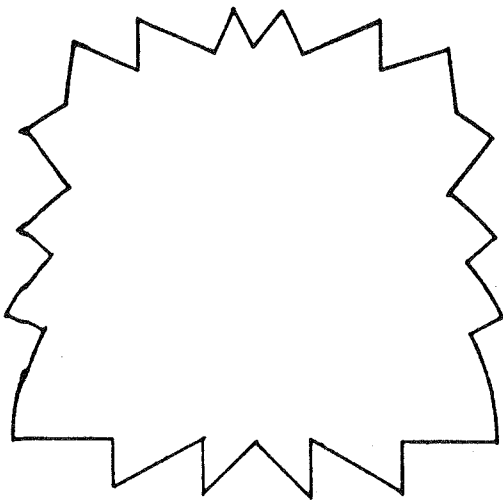
BOTTOM

TEST OF SERRATION PANELS

The top and bottom edges of the Compact Range reflector are removable for the purpose of permitting the unit to be transported. This feature permits a test to be made of the edge configuration. By comparing the vertical field probe data before and after the lower and upper edges are removed, one can see how effective the edges are in reducing the diffracted energy level in the test zone.

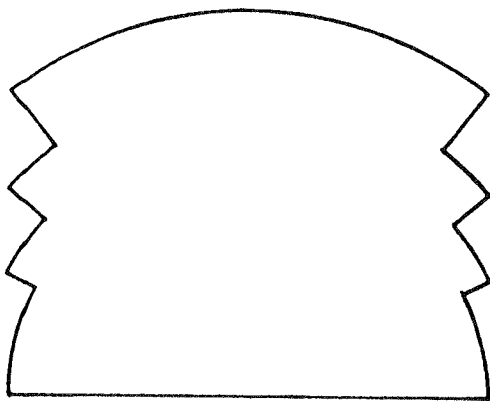
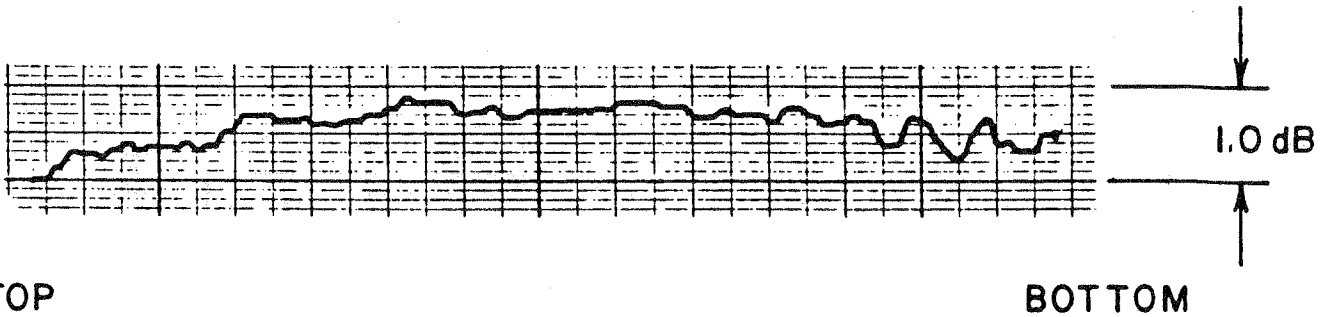


DIFFRACTION FROM UPPER CURVED EDGE AND LOWER STRAIGHT EDGE

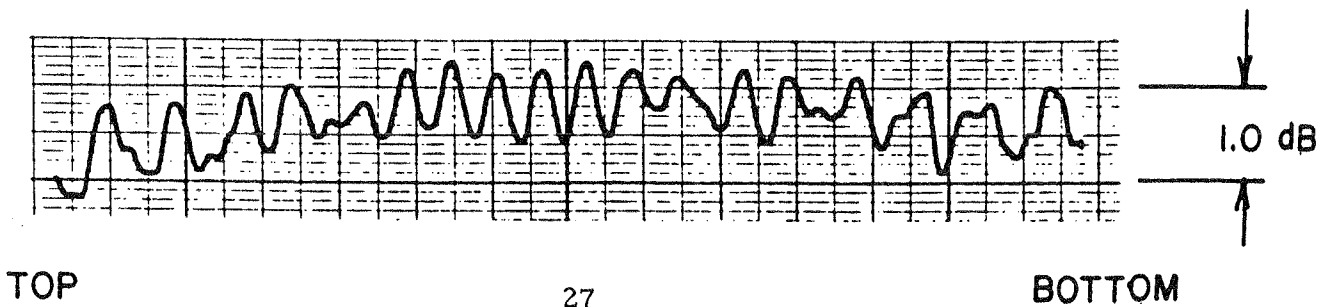


VERTICAL AMPLITUDE CUT
WITH SERRATED EDGES

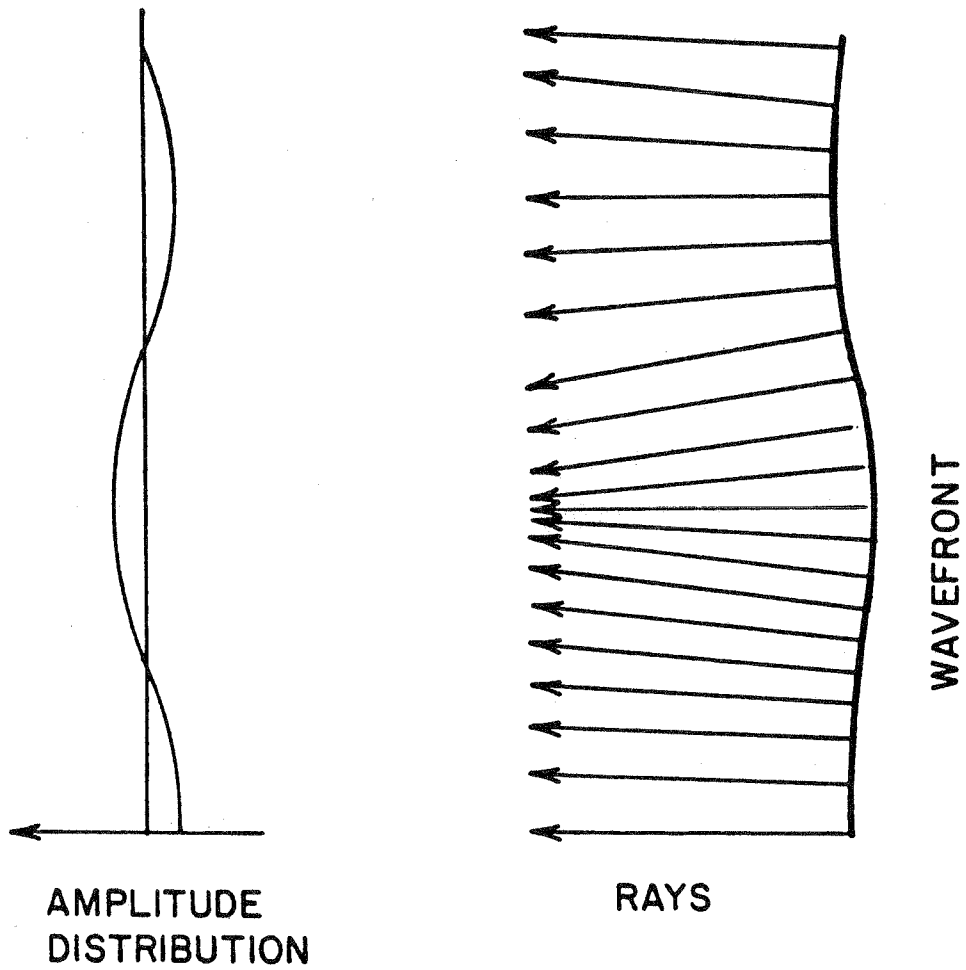
$f = 12 \text{ GHz}$



VERTICAL AMPLITUDE CUTS
WITH UPPER AND LOWER
SERRATION PANELS REMOVED



AMPLITUDE DISTRIBUTION FROM NON PLANAR WAVEFRONT



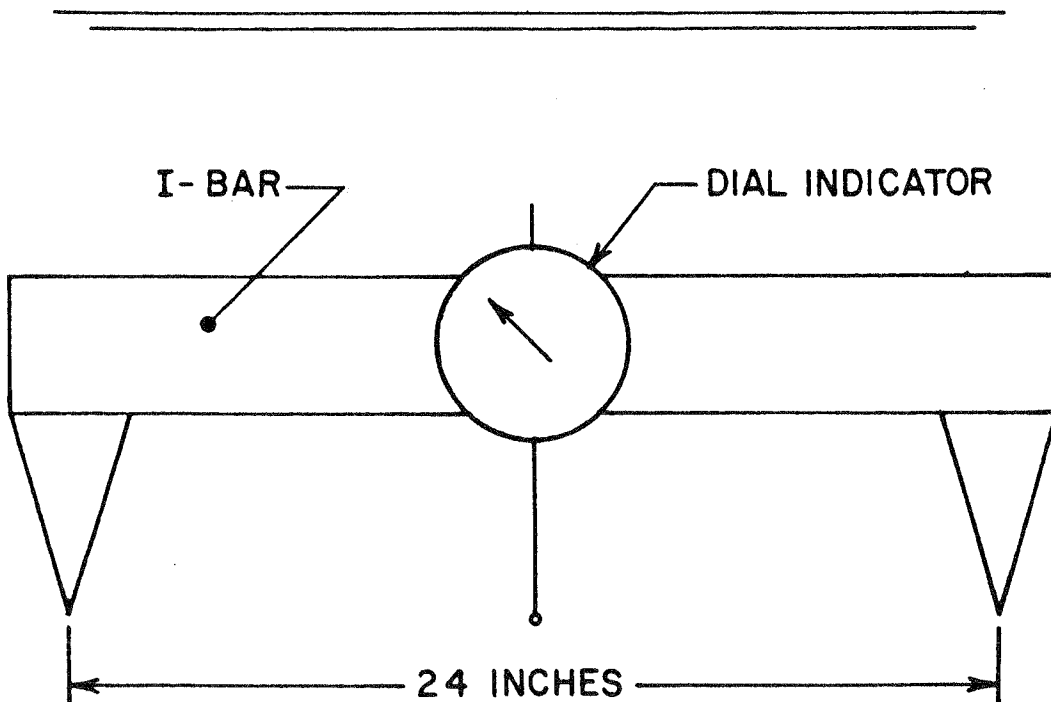
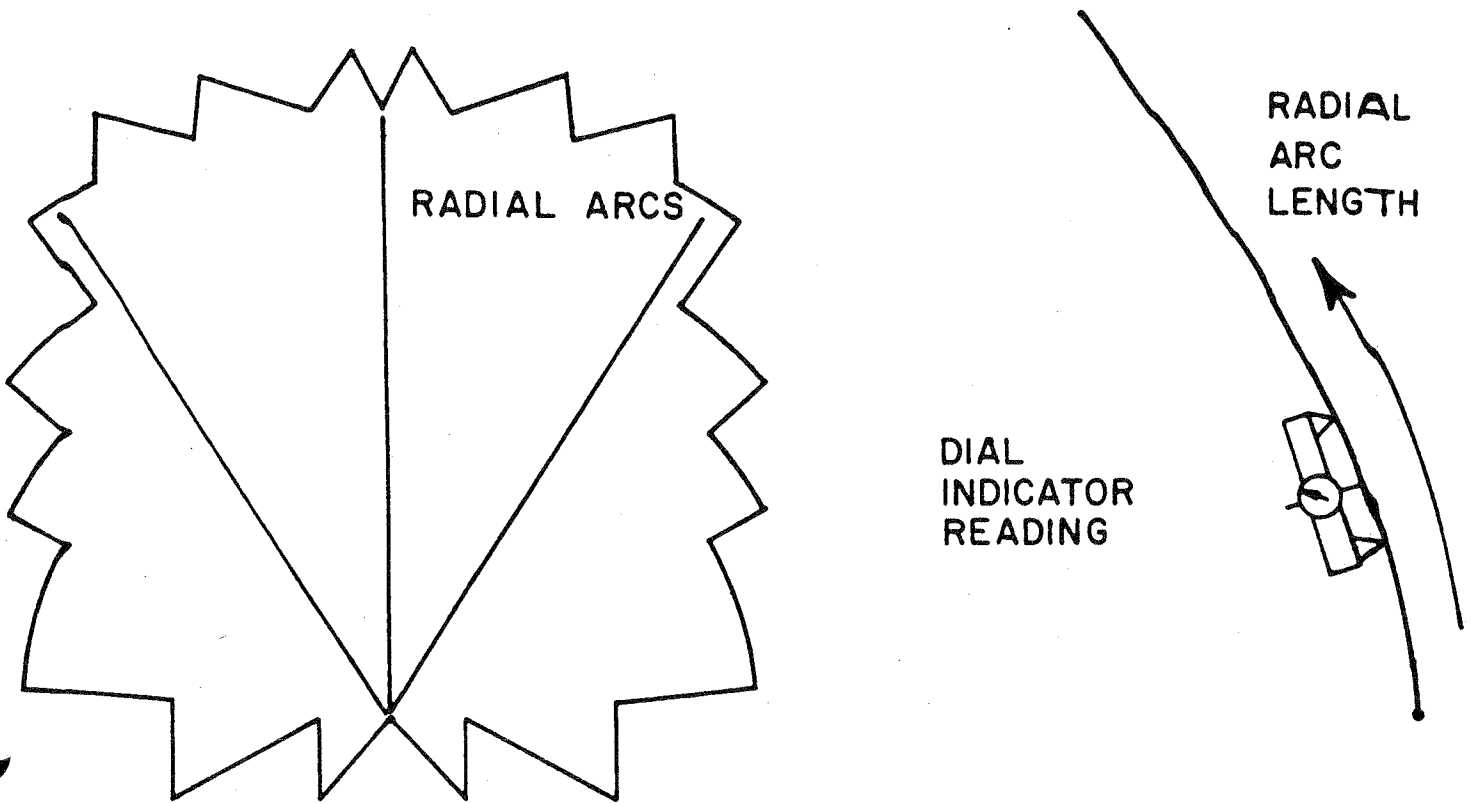
THE CRAZY-HOUSE MIRROR EFFECT AND SURFACE ACCURACY

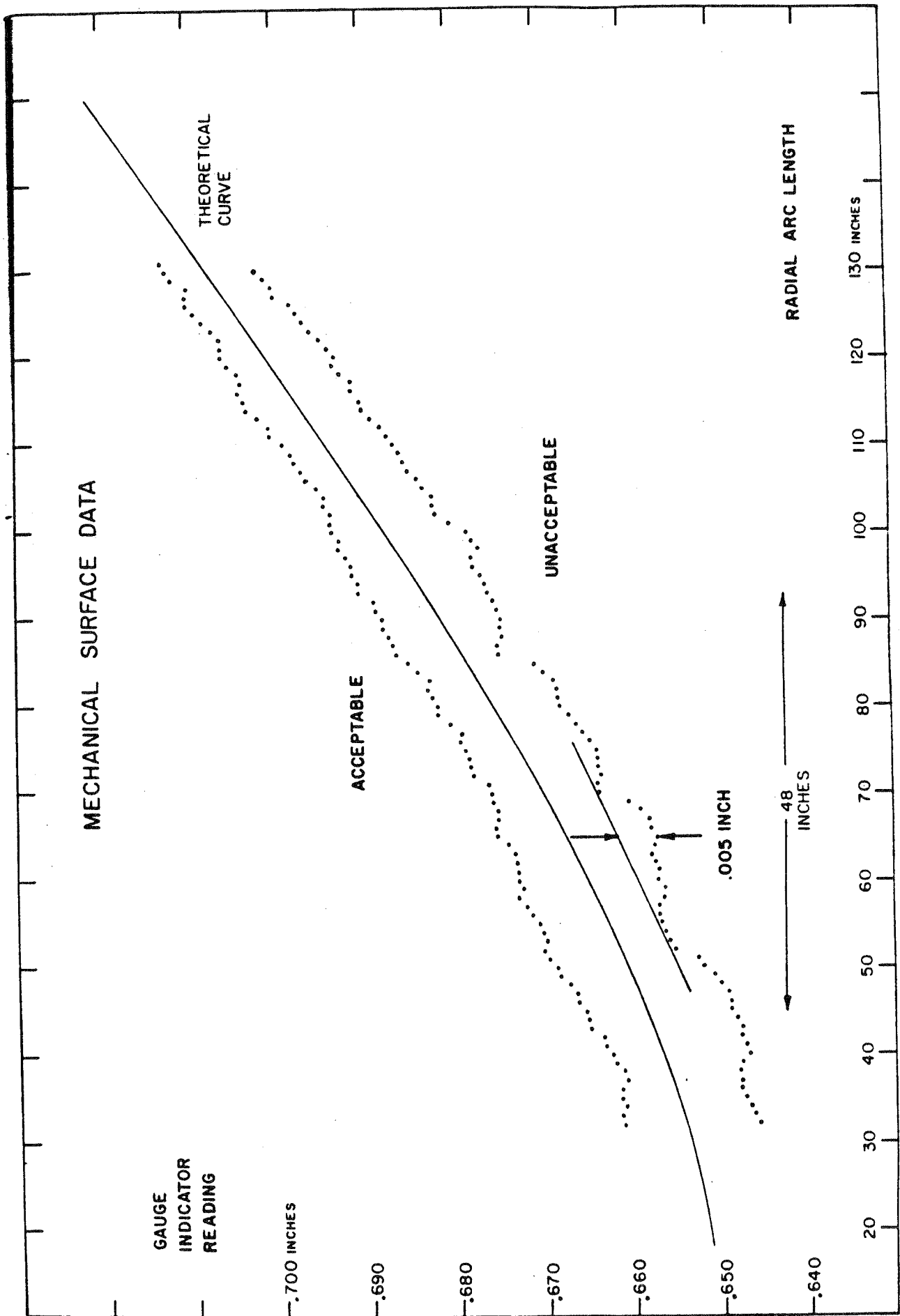
In order to produce a very smoothly varying amplitude in the test zone of the Compact Range one must have a very accurate reflector surface. Imperfections in the surface cause corresponding imperfections in the planarity of the phase front of the reflected wave. These phase deviations cause the reflected energy to be concentrated or dispersed according to the description of raz-optus, and result in amplitude variation of the propagated field.

MEASUREMENT OF REFLECTOR SURFACE

A gauge which measures the curvature of a surface is used to assess the local smoothness of the reflector. It is translated along the surface on radial arcs and the dial indicator readings are recorded. The readings can be plotted versus radial arc length and compared against an ideal curve. The deviations give a measure of the smoothness of the reflector surface.

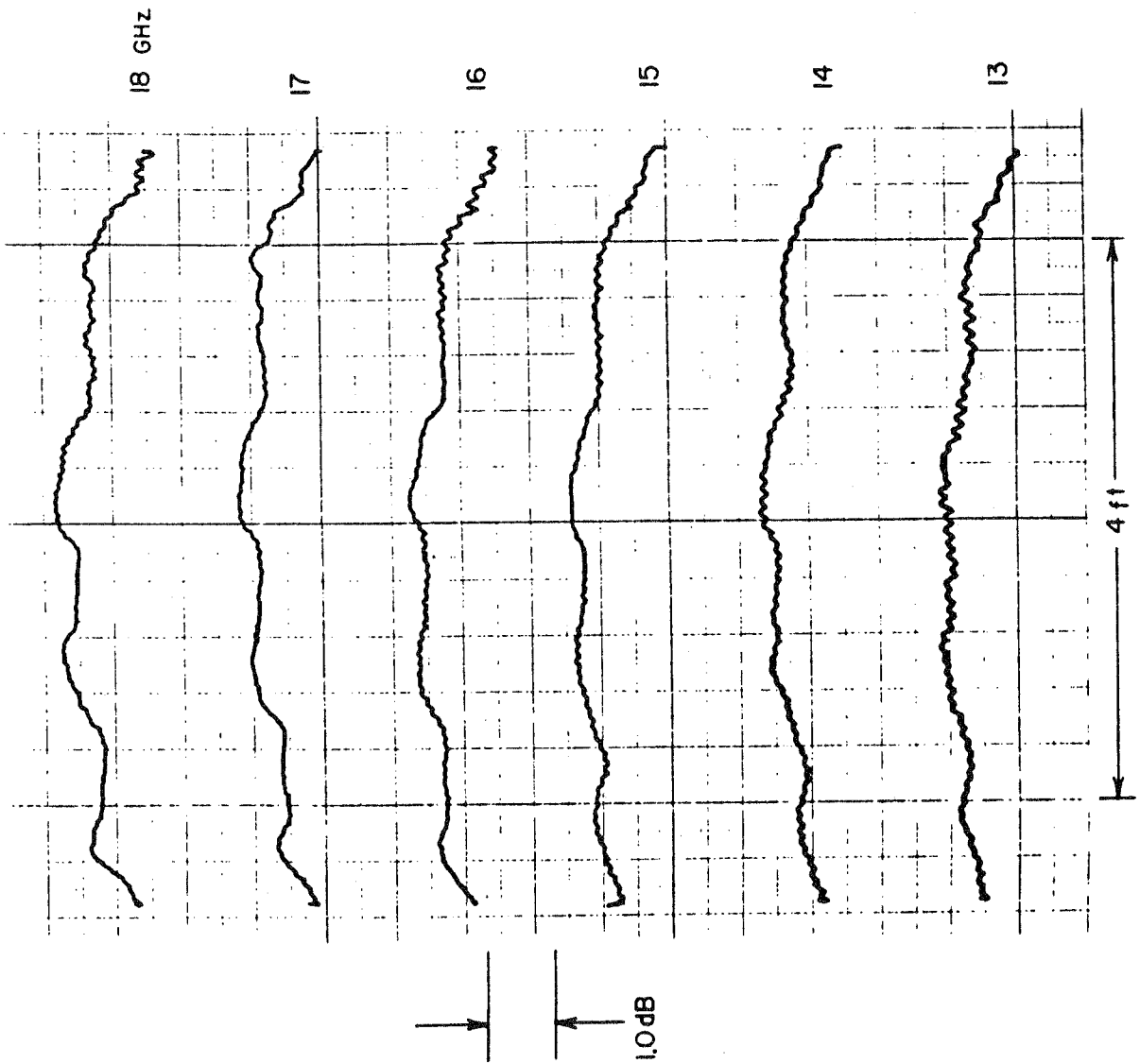
METHOD OF SURFACE MEASUREMENT





COMPACT RANGE
VERTICAL AMPLITUDE CUTS

FOR UNACCEPTABLE
SURFACE SMOOTHNESS

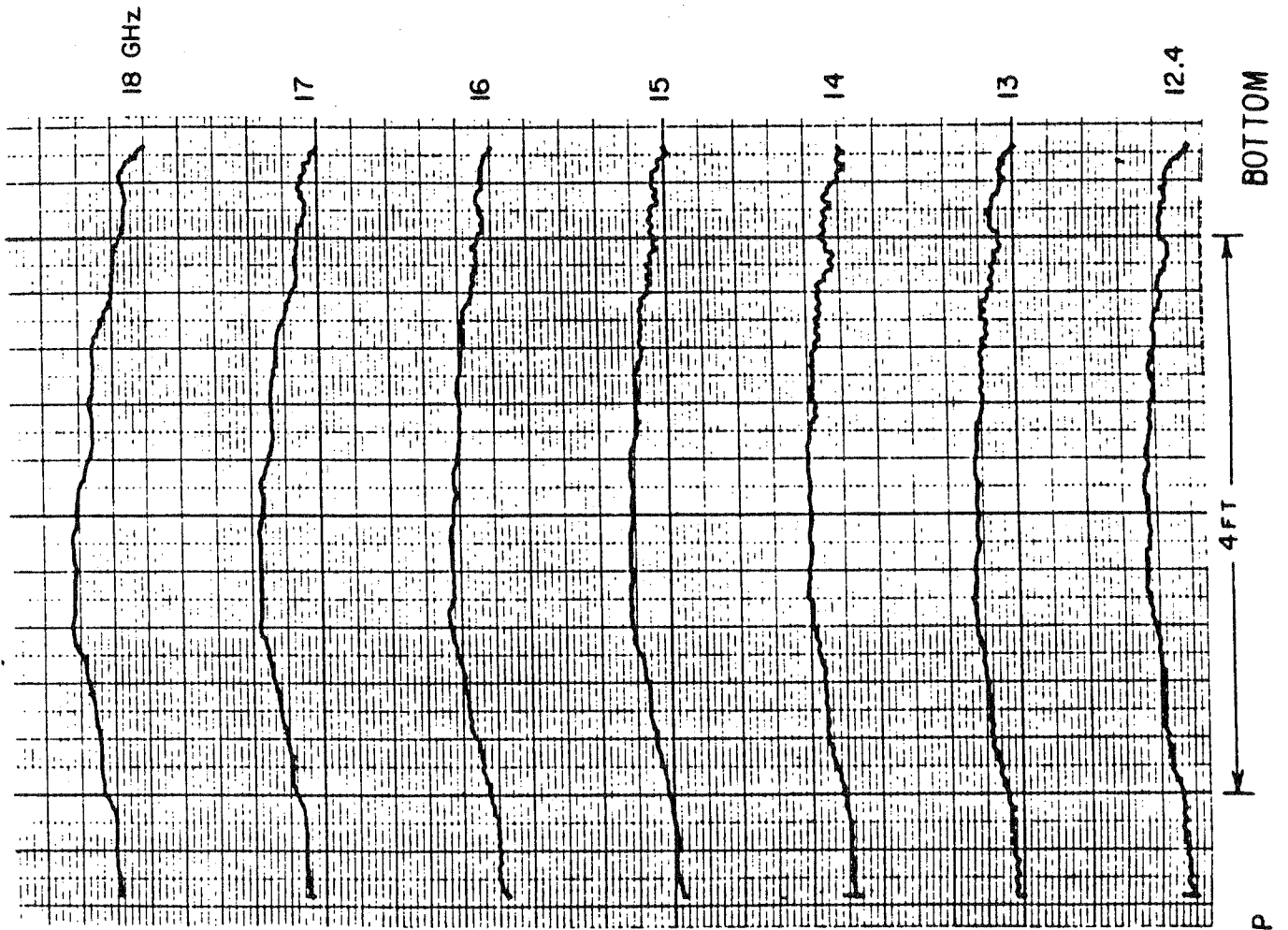


BOTTOM

TOP

COMPACT RANGE
VERTICAL AMPLITUDE CUTS

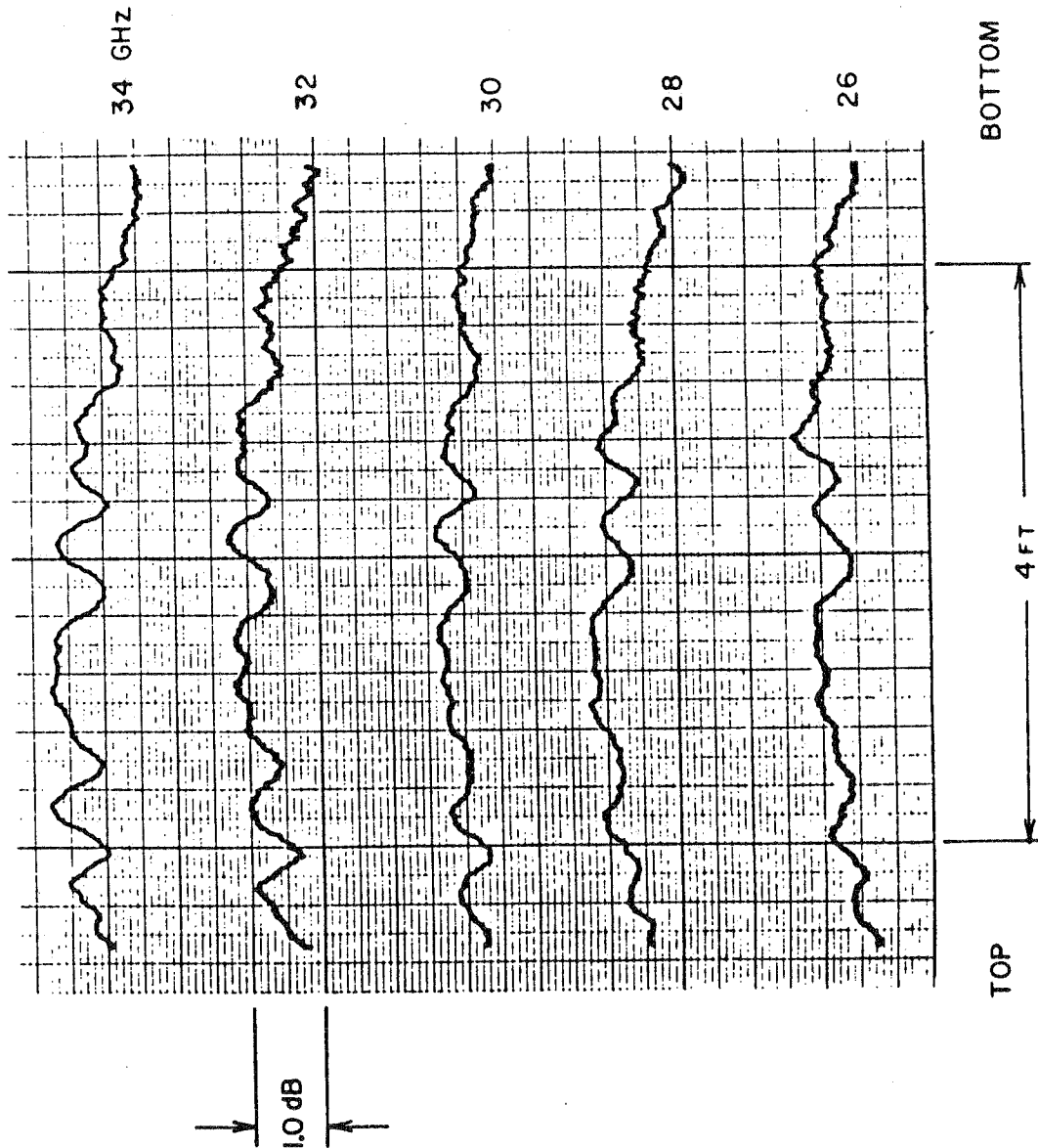
FOR ACCEPTABLE
SURFACE SMOOTHNESS



FIELD PROBE DATA AT 30 GHz

Exploratory measurements have been made on a Compact Range at 30 GHz. The field probe data indicate the limitations imposed by the surface accuracy. The data shows a typical peak-to-peak ripple of approximately 0.7 dB and indicate a stray signal level weaker than -25 dB.

COMPACT RANGE
VERTICAL AMPLITUDE CUTS



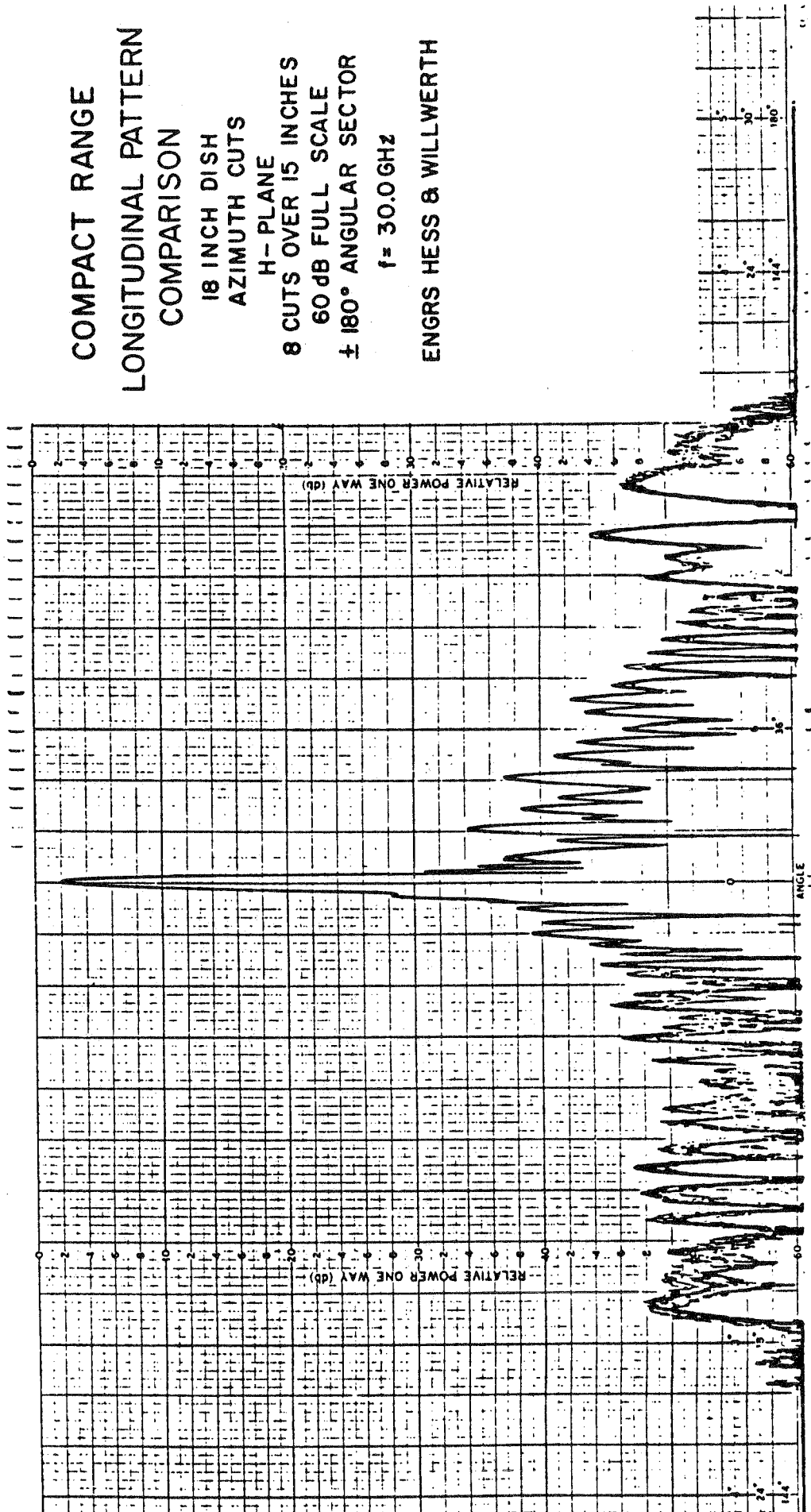
COMPACT RANGE
LONGITUDINAL PATTERN
COMPARISON

18 INCH DISH
AZIMUTH CUTS

H-PLANE
8 CUTS OVER 15 INCHES
60 dB FULL SCALE
± 180° ANGULAR SECTOR

f = 30.0 GHz

ENGRS HESS & WILLWERTH



LONGITUDINAL PATTERN COMPARISON AT 30 GHz

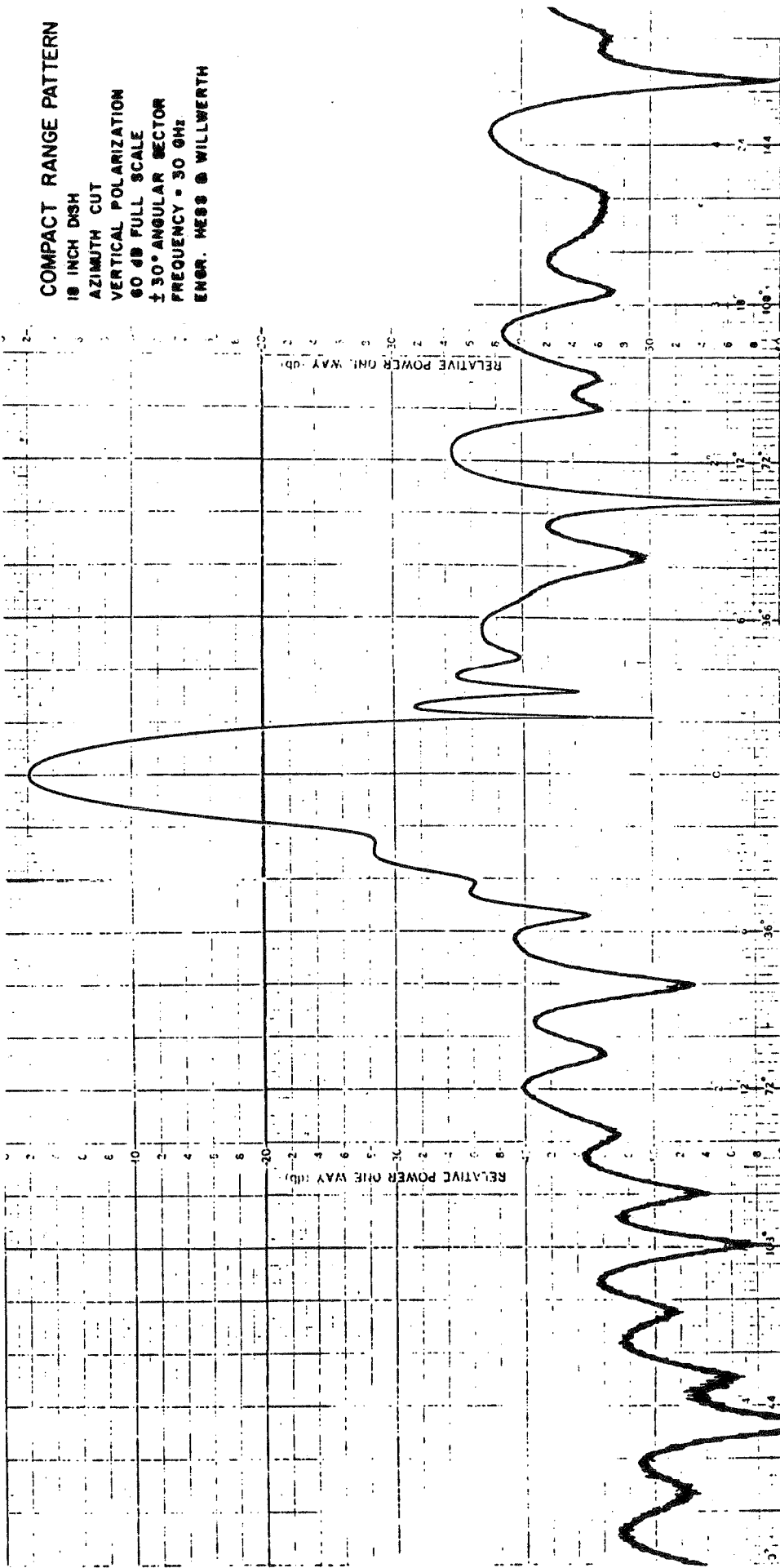
An overlay of successive patterns made at points along the slide travel reveals the strength of extraneous signals. The width of the envelope for an 18 inch dish shows the stray signals to be weaker than -50 dB.

COMPACT RANGE VERSUS OUTDOOR RANGE COMPARISON

A straightforward comparison between patterns taken on a compact range and on an outdoor range shows good agreement. The most significant discrepancy occurs at an angle of $+4^{\circ}$ and corresponds to an equivalent stray signal weaker than -32 dB. Tests of the outdoor range revealed stray signals on the order of -34 dB. Since there were no special precautions taken to insure stable frequency control or identical coordinate geometry, the results can be considered very favorable.

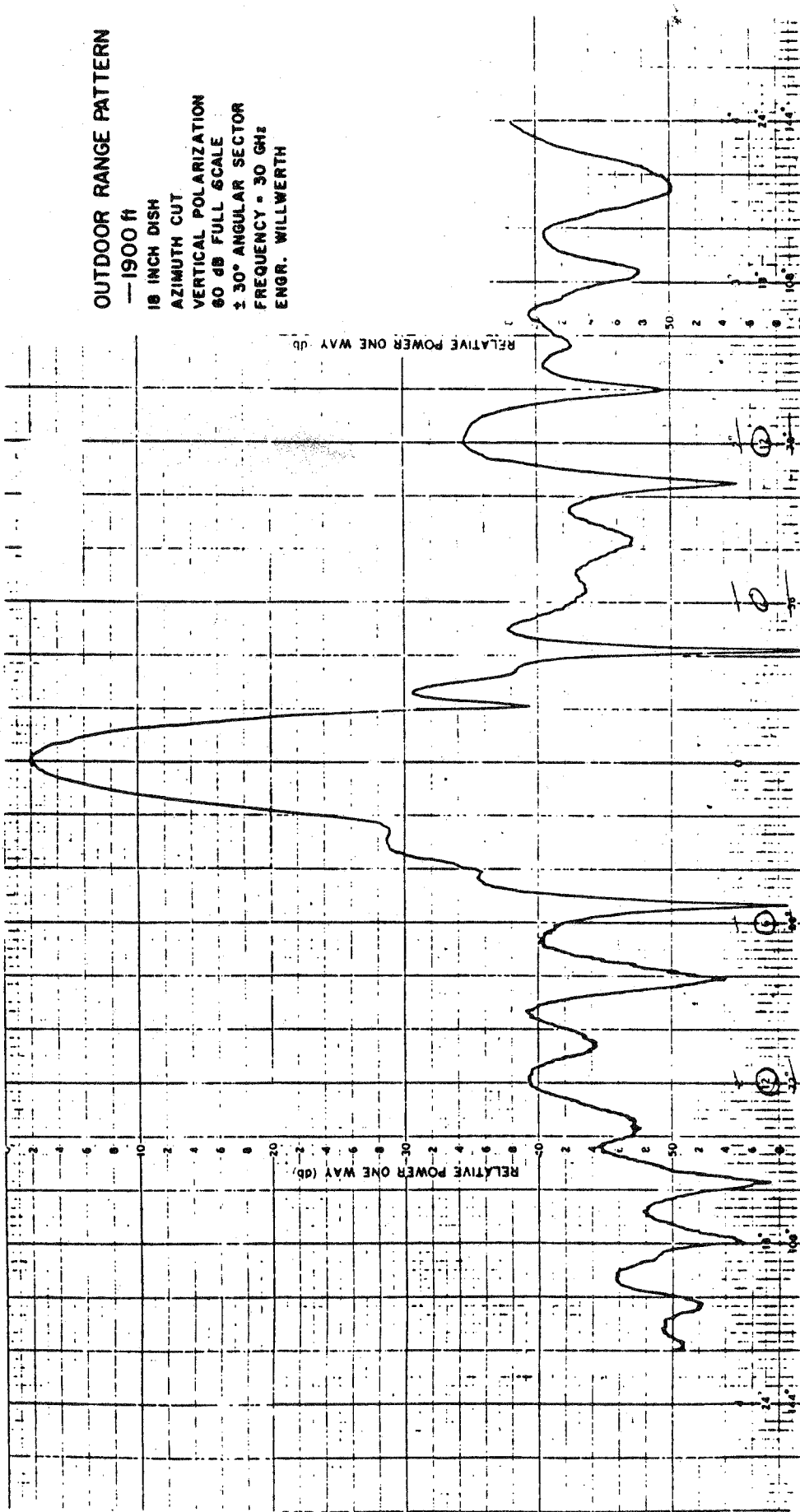
COMPACT RANGE PATTERN

18 INCH DSH
AZIMUTH CUT
VERTICAL POLARIZATION
60 dB FULL SCALE
± 30° ANGULAR SECTOR
FREQUENCY = 30 GHz
ENGR. HESS & WILLWERTH



OUTDOOR RANGE PATTERN

-1900 ft
18 INCH DISH
AZIMUTH CUT
VERTICAL POLARIZATION
60 DB FULL SCALE
± 30° ANGULAR SECTOR
FREQUENCY = 30 GHz
ENGR. WILLWERTH



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