PROBE-CORRECTION COEFFICIENTS DERIVED FROM NEAR-FIELD MEASUREMENTS

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ABSTRACT

Probe correction is necessary in near-field measurements to compensate for non-ideal probes. Probe compensation requires that the probe's far-field pattern be known. In many cases direct far-field measurements are undesirable, either because they require dismantling the probe from the near-field range set-up or because a far-field range is not available. This paper presents a unique method of deriving probe-correction coefficients by measuring a probe on a near-field range with an "identical" probe and taking the square root of the transformed far-field. This technique, known as the "Probe-square-root" method can be thought of as self-compensation. Far-field compensations are given to show that this technique is accurate.

PLANAR PROBE COMPENSATION

In near-field measurements the true far-field pattern of an antenna under test (AUT) is distorted by the interaction of the near-field phase fronts between the AUT and probe antennas. In planar near-field measurements this distortion can be removed by measuring the AUT's near-field with two othogonally polarized probes, transforming to the far-field and then adjusting each far-field value by the probe's directivity at that angle (see Figure 1).

This method works because the uncompensated far-field pattern, as measured by the near-field range, is the product of the probe and AUT's true far-field patterns. The AUT's true far-field pattern can be determined by dividing the uncompensated far-field pattern by the probe's far-field pattern.

Since the probe's cross-pol component is sometimes significant, it must be taken into account. The uncompensated far-field equation are thus a function of both the probe's principle and cross-pol components.

The uncompensated far-field is:

$$Epu = [Ep*Epp1 + Ec*Ecp1]$$
$$Ecu = [Ep*Ecp2 + Ec*Epp2]$$

where:

Ep = True principle AUT response
EC = True cross-pol AUT response
EPU =Uncompensated principle AUT response
ECU =Uncompensated cross-pol AUT response
Epp1,2 = Probe-1,2 principle response
Ecp1,2 = Probe-1,2 cross-pol response

Note that single probe oriented in two different polarization can be used instead of two probes. When the probe is linearly polarized Epp2(ϕ) = Epp1(ϕ+90) and Ecp2(ϕ+90).

Solving for the true AUT far-field (Ep,Ec) gives:

Ep = [Epp2*Epu - Ecp1*Ecu]/d
EC = [-Ecp2*Epu + Epp1*Ecu]/d

with d **= Epp1*Epp2 - Ecp1*Ecp2**

In many cases the probe's cross-pol effect is negligible and can be ignored. This is true of an open-ended waveguide near broadside and along the principle cuts. Ignoring probe cross-pol effects simplifies the probe compensation equations:

Ep = Epu/Epp1
Ec = Ecu/Epp2

It should be noted that the AUT and near-field probe coordinate systems are slightly different as shown in Figure 2. This means that the +el side of the AUT pattern must be corrected by the -el side of the near-field probe pattern and the +az side by the +az side. This fact places a restriction of principle-cut patten symmetry on the Probe-square-root technique.

PROBE SQUARE ROOT METHOD AND THEORY

From planar probe-compensation theory we know that the AUT's uncompensated far-field pattern is the product of the AUT and probe far-field patterns. This implies that if the AUT is 1.) identical to the probe, 2.) symmetrical along the principle cuts and, 3.) has neglible cross-pol then the square root of the uncompensated principle-pol pattern is the probe's true far-field pattern. The following example shown in Figure 3 will explain this idea.

At θO (broadside) the receiver signal is maximum between the probes. At θ1 there is a loss of 10 dB (5 dB from each pattern). When the far-field probe pattern is derived from near-field measurements the pattern at any angle, other than on-axis, will have received twice the signal loss that it should have. Taking the square root of the pattern level (dividing the dB levels by two) will compensate correctly. Taking the square root of the probe pattern can be thought of as self-compensation.

The phase is treated in a similar way by dividing the phase angles by two. It should be noted however, that if the far-field pattern goes through a null, due to a sidelobe, the phase change through the null must be taken into account. In low directivity probe patterns such as open-ended waveguides (OEWG), there are usually no side lobes within the near-field scan limits and so the phase is easier to calculate.

RESULTS

The Probe-square-root method has been used extensively by Nearfield Systems Inc. to characterize open-ended waveguide probes. The reason for this is simple, an abundance of highly accurate, automated near-field scanners and a lack of far-field ranges. Customers of our near-field antenna measurement systems have been interested in this method and have helped verify it on their far-field ranges.

Figures 4A and 4B show the near-field range set-up for the Probe-square-root test. Figures 5 and 6 show the comparison between near-field and far-field-measured probe patterns of a wr-137 C-Band OEWG. Their agreement is excellent along the principle cuts out to 75 degrees. Figures 7, 8 and 9 are near-field and far-field comparisons of a WR-90 X-Band OEWG on a different set of ranges. Even though the far-field range reflections were much higher this time, the agreement is still excellent in both the principle and slant-45 degree cuts.

As an additional comparison, Figure 10 is a contour plot from an OEWG model based on NBS equations (Yaghjian - 1983). Neglecting small ripples it agrees well with Figure 11 which is a contour generated with the Probe-square-root technique from the same measurements as Figure 5 and 6. The agreement is good out to 50 degrees at which point our implementation of the OEWG model departs from theory.

ADVANTAGES AND LIMITATIONS

Probe-coefficient measurements made on near-field ranges have several advantages. Some of these advantages are:

1.) Reduced far-field range dependence. This frees the far-field range for other uses.

2.) Rapid measurement of the probe pattern at new frequencies or quick revalidation without dismantling the probe set-up. With a second probe beside the AUT, dismantling the AUT setup is not even necessary.

3.) Exact near-field configuration and conditions are preserved

4.) Reduced handling of calibrated equipment.

LIMITATIONS

The limitations of this method have not been fully investigated but some restrictions have been noted.

1.) The probe patterns must by symmetrical along the principle-plane cuts.
2.) There is an alignment restriction which requires the probes' pattern boresight to be coincident otherwise the compensation will not be symmetrical. A coincident mechanical boresight alignment spec. of three degrees seems to be adequate for a broad-beamed OEWG.

To date, only principle-pol comparisons have been made and these show excellent agreement with principle-plane as well as off-axis cuts. The cross-pol patterns have not yet been checked. To extract them from the near-field measurements requires additional steps and assumptions in the probe-square-root method. These will be treated in a future paper on this subject.

REFERENCES

1. Yaghjian, A. D. "Approximate Formulas for the Far Field and Gain Open-Ended Rectangular Waveguide". NBSIR 83-1689 National Bureau of Standards, Boulder, CO. 80303

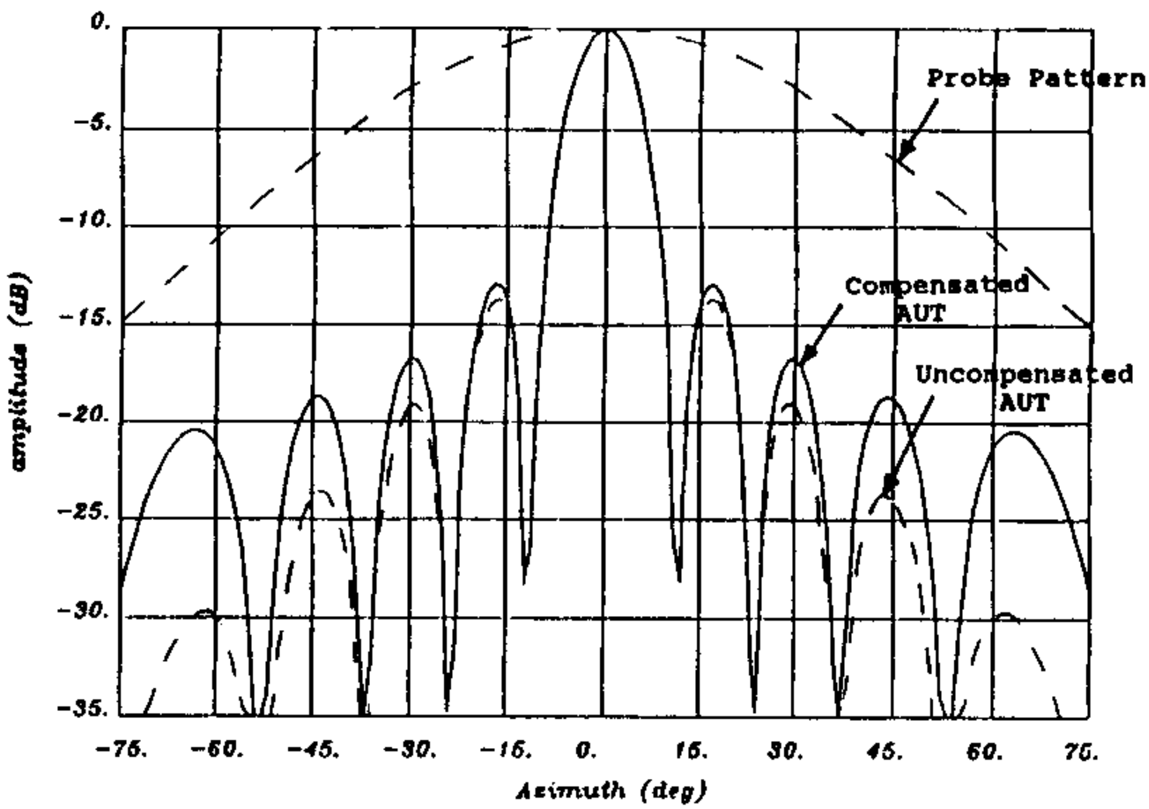
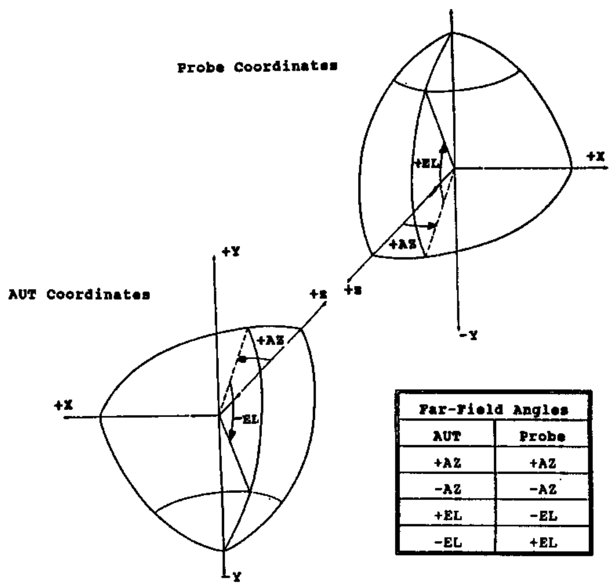


Figure 1 – Adjustment Of Uncompensated Aut Pattern By Probe Pattern



Far-Field Angles	
AUT	Probe
+AZ	+AZ
-AZ	-AZ
+EL	-EL
-EL	+EL

Figure 2 – Comparison Of Aut And Probe Coordinates

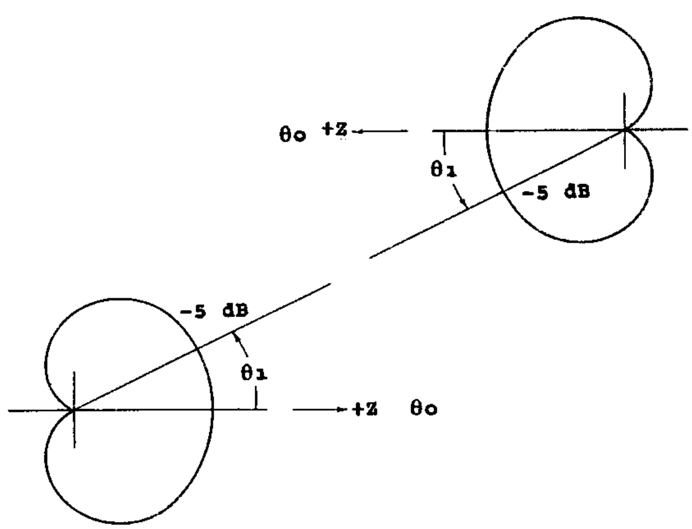


Figure** 3 – **Signal Loss Due To Probe Pattern Directivity

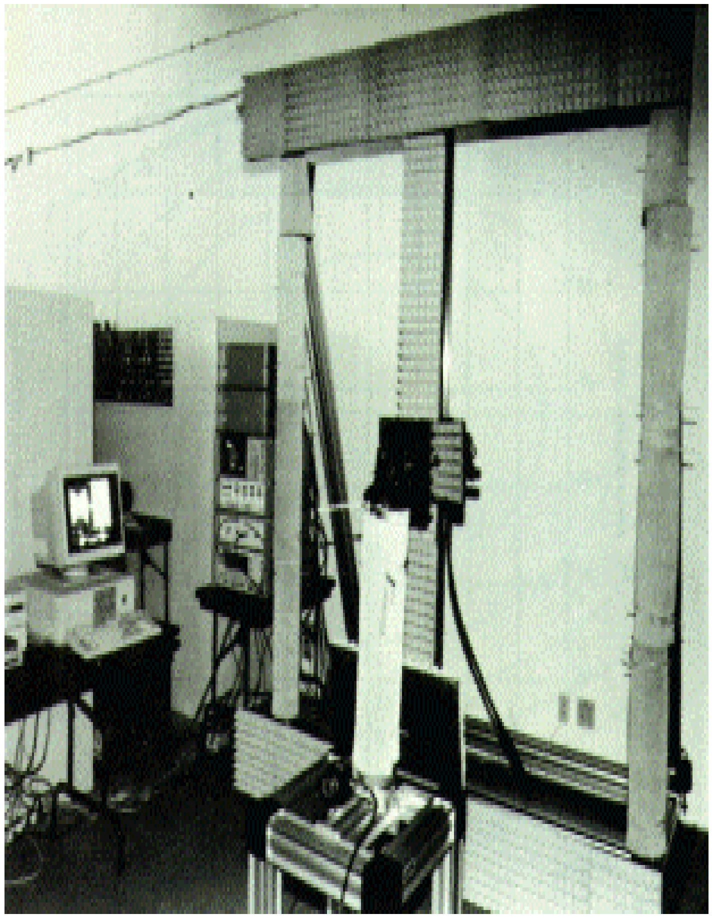


Figure 4a – Near-Field Test Range

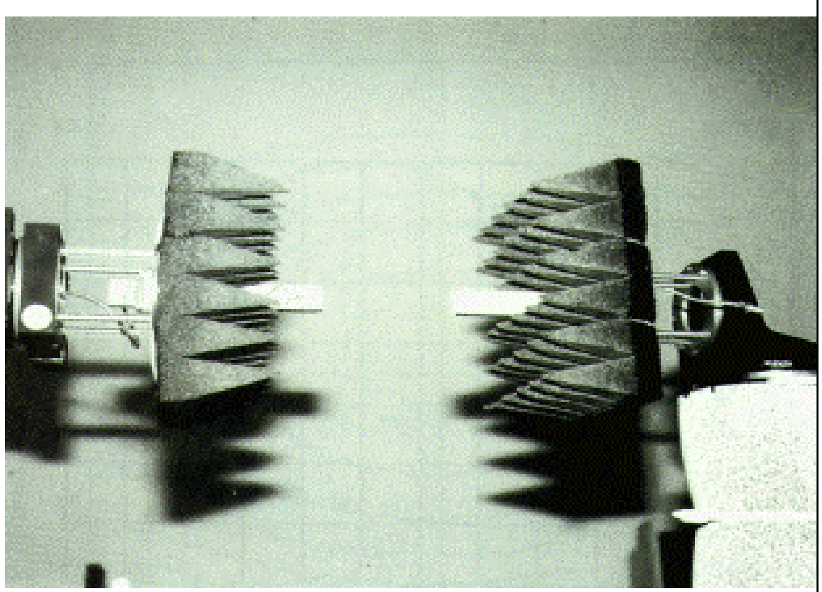


Figure 4b – Probe-Probe Configuration

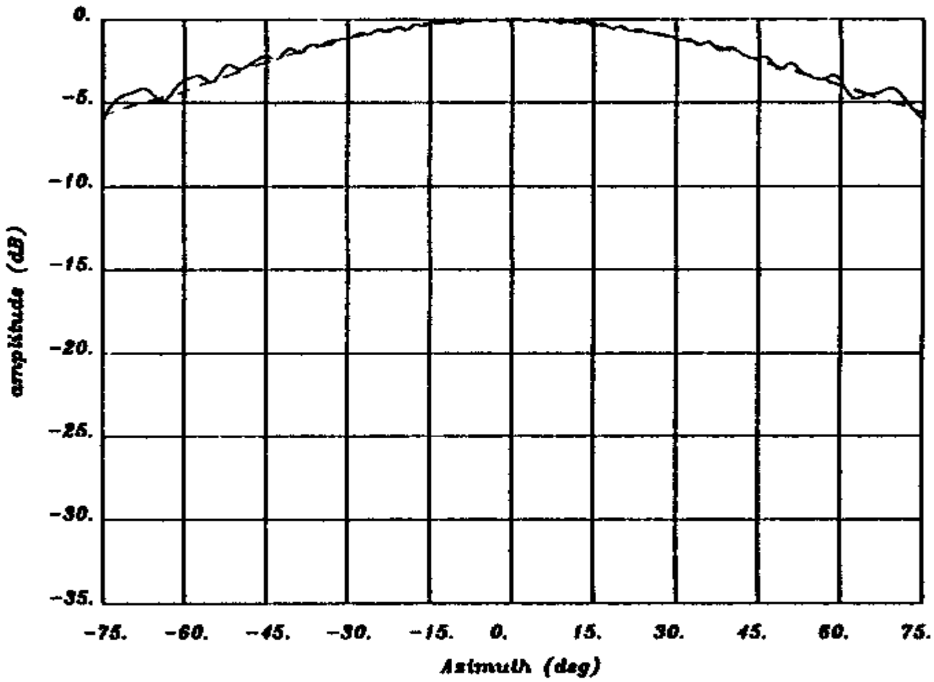


Figure 5 – Wr-137 Oewg, 8 Ghz E-Plane Pattern: Near/Far-Field Comparison

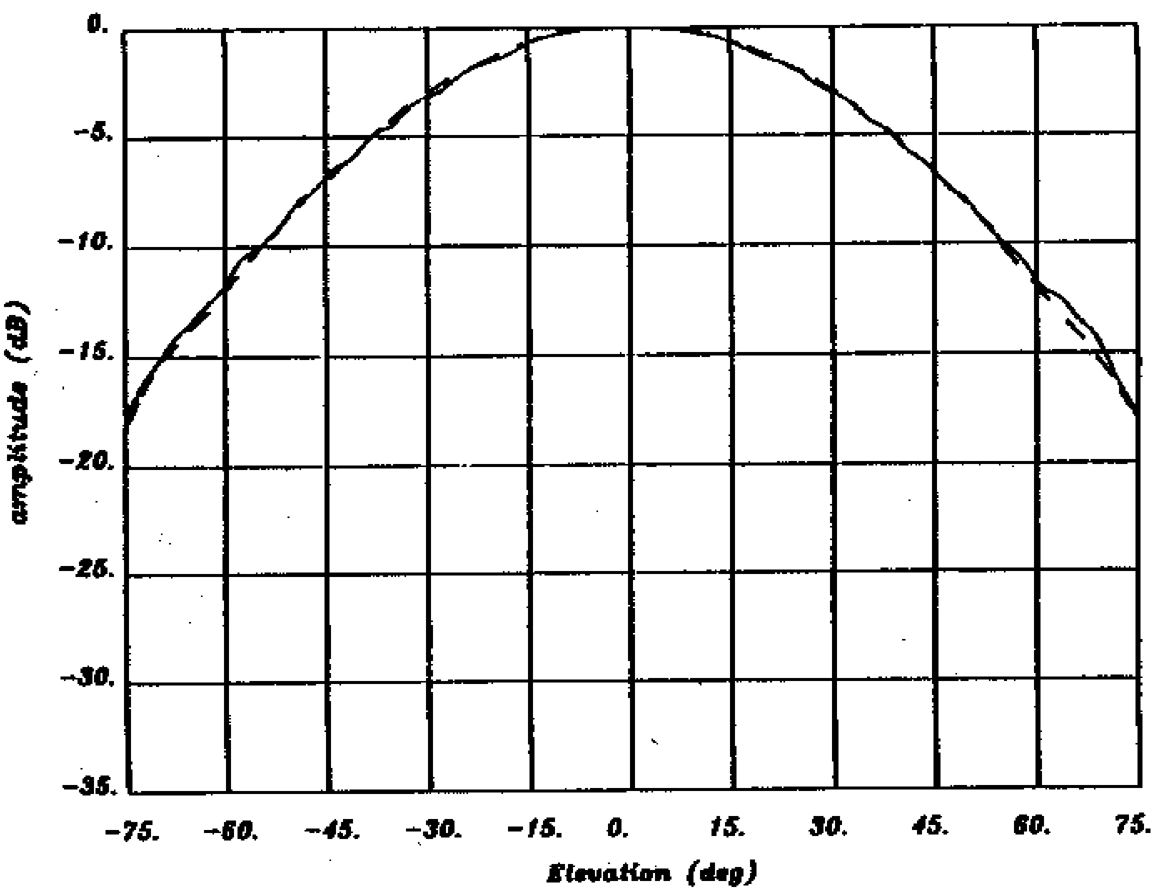


Figure 6 – Wr-137 Oewg, 8 Ghz H-Plane Pattern: Near/Far-Field Comparison

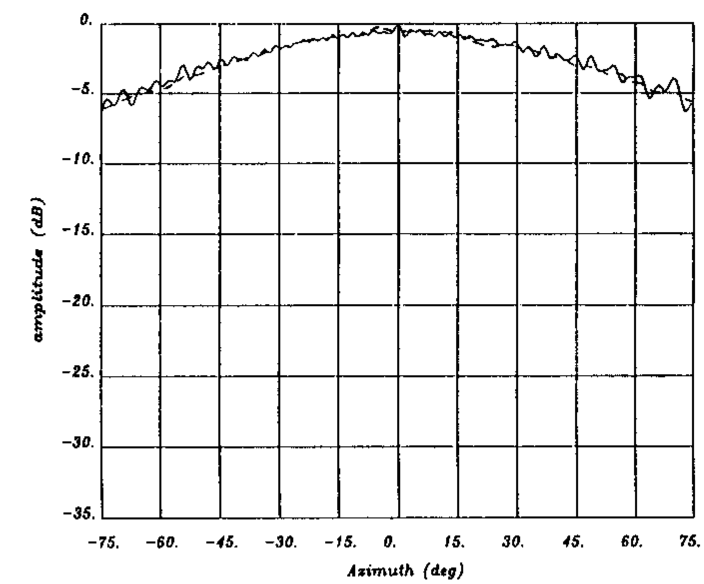


Figure 7 – Wr-90 Oewg, 12 Ghz E-Plane Pattern: Near/Far-Field Comparison

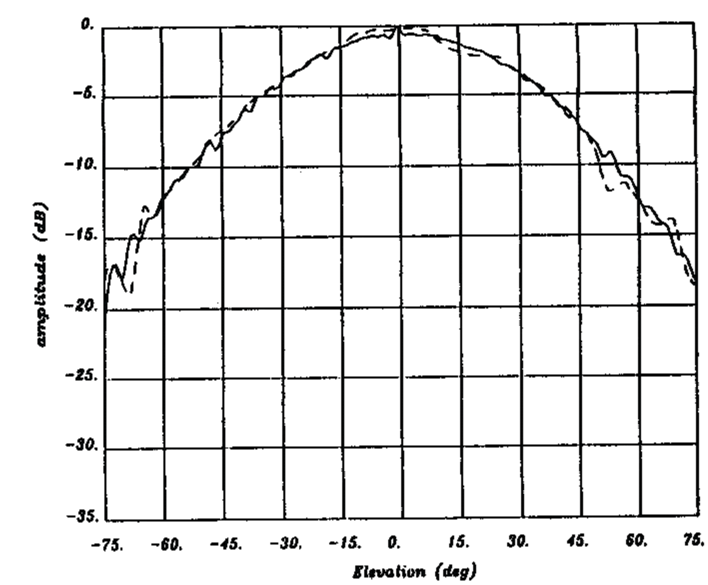


Figure 8 – Wr-90 Owge, 12 Ghz H-Plane Pattern: Near/Far-Field Comparison

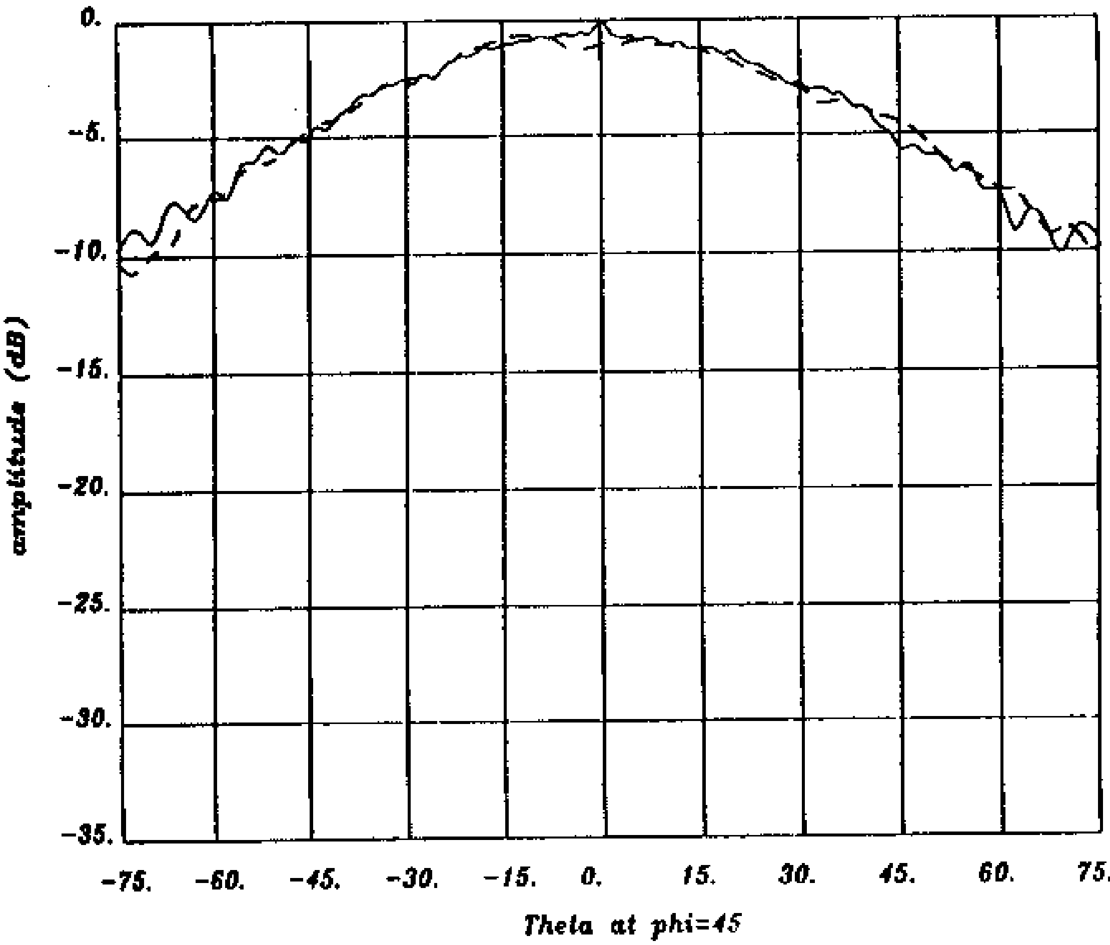


Figure 9 – Wr-90 Oewg, 12 Ghz Slant-45 Pattern: Near/Far-Field Comparison

___________ Near-Field, ------- Far-Field

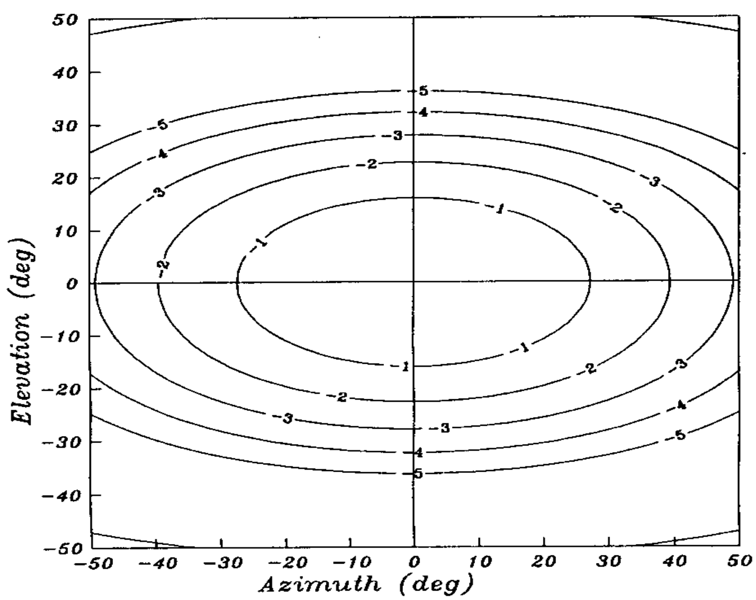


Figure 10 – Wr-137 Oewg, 8 Ghz Far-Field Pattern Contour Derived By Oewg Model

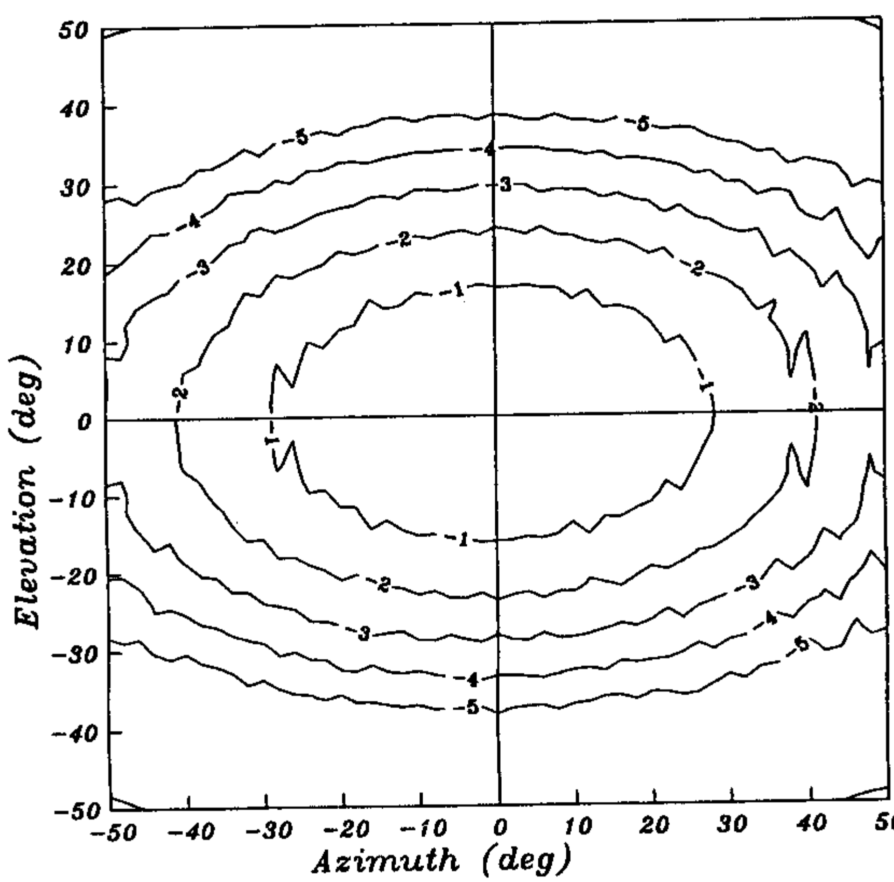


Figure 11 – Wr137 Oewg, 8 Ghz Far-Field Pattern Contour Derived by Probe-Square-Root Method