ERROR SUPPRESSION TECHNIQUES FOR NEAR-FIELD ANTENNA MEASUREMENTS

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ABSTRACT

This paper describes techniques for coherently suppressing multipath and other error sources in planar near-field measurements. Of special interest is a simple, yet effective technique for suppressing axial multipath and mutual coupling between the near-field probe and an antenna. This is of particular value in the testing of low sidelobe antennas. Traditionally, self comparison tests with different separations between the probe and the antenna under test are used to identify the magnitude of multipath errors. What is not generally realized is that these tests can be used to produce a coherent estimate of the induced error, which can often be suppressed. A series of tests was performed with a small X-band phased array antenna, resulting in a reduction of the sidelobe noise background from a 25dB level to better than 50dB.

Keywords: Near-Field, multipath, error suppression, low sidelobe antennas

1. INTRODUCTION

Uncertainty estimates for measured antenna parameters should be an integral part of an antenna measurement plan. Near-field measurements can offer significant advantages over other methods by simplifying the detection and control of error sources. A thorough discussion of near-field range qualification methodology has been written by Joy[(1)].
measurement phase of a project can aid in estimating and minimizing effects of many significant error sources. This paper extends these concepts by developing the idea of coherently suppressing known error sources, given a knowledge of their characteristics. The result is an improved ability to correctly measure the performance of low sidelobe antennas and a minimization of anechoic chamber requirements.

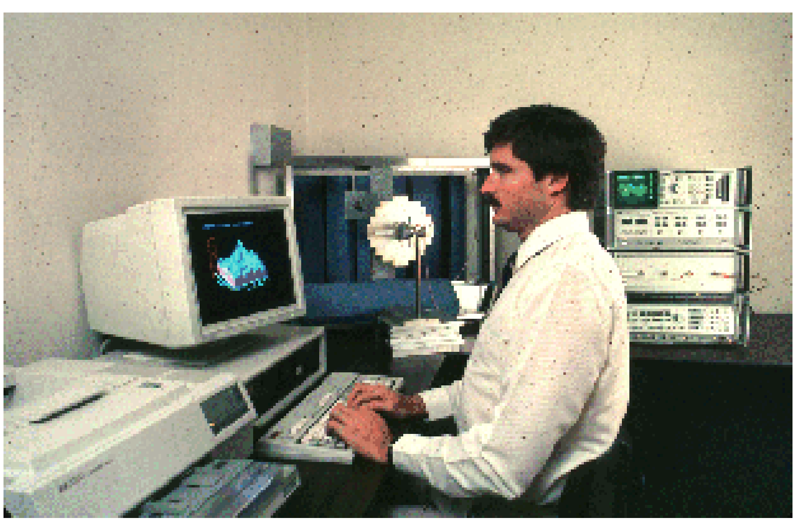


Figure 1 Near-field Measurement System

2. TEST DESCRIPTION

The tests described in this paper were conducted with a small Nearfield Systems Inc. antenna measurement system as shown in Figure 1. This system consists of an XY scanner, HP8510B network analyzer and miscellaneous RF components, all under the control of a COMPAQ 386/20 IBM compatible computer system. This system is further described in another paper(2).

3. LEAKAGE EFFECTS

Microwave leakage within a near-field measurement system distorts the calculated antenna patterns. The leakage sources act as emitters, forming spurious antenna elements. Leakage tests are used to measure any RF energy which is leaking into or out of the microwave interferometer.

Microwave leakage is measured by terminating either the transmitter or the receiver into a load and performing a near-field measurement scan. The leakage is most easily evaluated by first transforming the leakage signal into the far-field equivalent. The equivalent far-field leakage is then compared with the levels obtained in the normal test configuration. Figure 2 shows the derived far-field leakage effect on the E-plane cut with the source cable to the antenna under test (AUT) loaded. A similar test would be performed to assess the leakage with the receiver cable at the probe loaded.

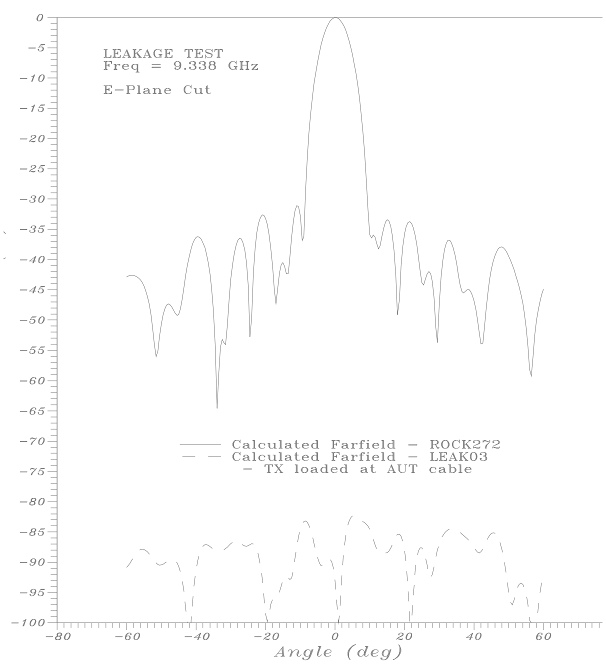


Figure 2 E-Plane Cut / Leakage (AUT Loaded)

The leakage signal is seen to be below 80dB down from the main beam peak, and at least 40dB down from the sidelobe peaks. The resulting effect on gain uncertainty can be readily computed from the vector contributions of the desired signal versus the leakage signal. The contributions to uncertainties in sidelobes at 40dB down are less than $\pm$0.1dB. If 50 or 60dB sidelobes were of interest, the leakage signal, being only 20 to 30dB down, would affect sidelobe measurement uncertainties by up to $\pm$1.0dB.

Loose connectors, bad coax cables, and components with poor isolation can all result in excessive leakage. Wrapping coax connections with copper tape and cable or component substitution are typical approaches used to control leakage sources.

Alternately, if the residual leakage signal from a scan with the AUT input terminated into a load is repeatable, the leakage can be coherently subtracted, resulting in a significant reduction in its effect on sidelobe measurement accuracy.

4. MULTIPATH TESTS

The errors induced by multipath and mutual coupling between the AUT and probe antenna can be estimated by performing a series of self-comparison tests. Repeated near-field measurements on an antenna while varying parameters which should not affect the results form the basis of this technique. As an example, the far-field pattern, gain, AR, etc. should be invariant to AUT/probe separation, AUT/probe rotation relative to the facility, time of day, power into the test antenna, range absorber configuration and other similar parameters. Far-field pattern or gain changes resulting from variation of these parameters are indications of error sources which are directly coupled to those parameters.

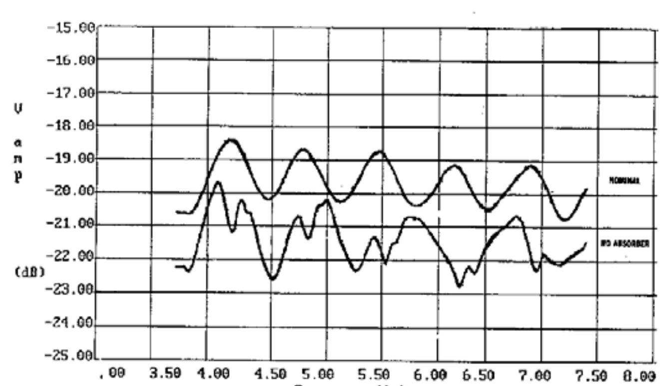


Figure 3 AUT/Probe Separation Test

As seen in Figure 1, a minimal amount of absorber was used as we were interested in eliminating the need for an anechoic chamber. Emerson and Cuming AN-74 flat absorber was placed on the back wall, on the face of the Y axis carriage, and on the probe fixture. In addition, a small piece of AN-72 was wrapped around the probe. The back wall absorber had a slight effect on the results, while the Y-axis carriage and probe absorber is most important. Figure 3 shows a comparison of the amplitude variation with the baseline absorber configuration versus one with all absorber removed (vert. offset 1 dB for clarity).

The absorber is seen to reduce the peak-to-peak signal variation as well as lead to a fairly smooth sinusoidal response. The peak-to-peak amplitude variation of about 1.4dB corresponds to a signal to reflection level of about 22dB. This is consistent with the specified AN-74 return loss of 24.5dB at the test frequency of 9.338 GHz. The period of the sinusoidal response corresponds to 1/2 wavelength at the test frequency.

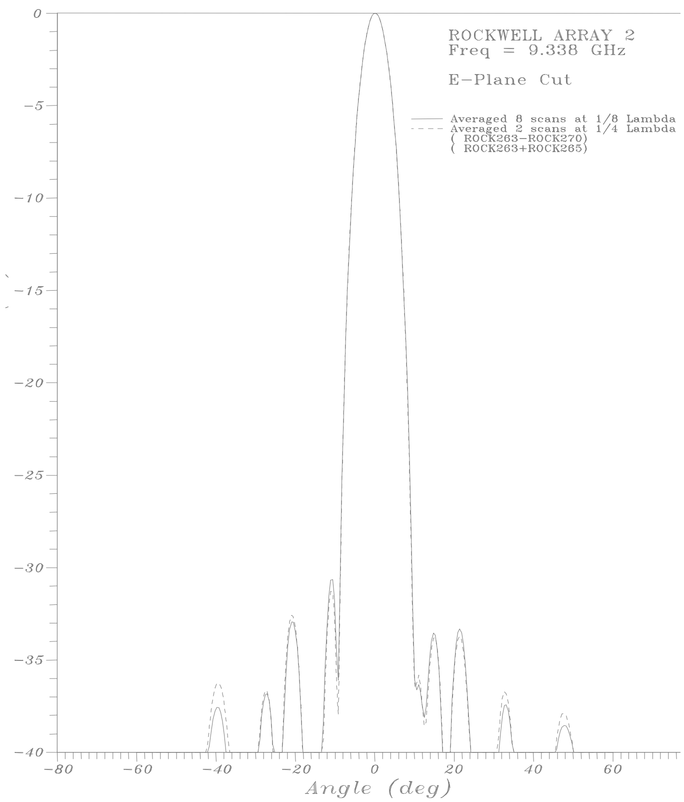


Figure 4 E-Plane Cut Averaged Results

Because of the multipath environment, a self- comparison test with varying AUT/probe distances produced large sidelobe changes. Figure 4 shows the variation in far-field E-plane cuts with the AUT distance varied from 4 lambda to 4-1/2 lambda in 1/8 lambda intervals. Changes on the order of 5-10 dB are noted in sidelobes at the -30dB level. Similar variations were observed in the H-plane sidelobes. A close inspection shows that the two patterns at 4 lambda and 4-1/2 lambda are essentially identical. This suggests the interfering signal goes through one full cycle when the direct signal is only changed 1/2 cycle, thus a round trip reflected signal is evident. With the AUT being a flat waveguide phased array, its face acts as a flat aluminum plate reflecting the scattered energy from the probe and Y-axis absorber directly back to the probe to interfere with the direct signal. A similar analogy exists for parabolic antennas when the multipath path length remains constant during a scan.

Similar large sidelobe differences were noted with self-comparisons done with the AUT and probe rotated together to 90 degrees, and then to 180 degrees. Clearly the test configuration would not support reasonable sidelobe accuracies without further improvements in the absorber or suppression of the multipath effect.

5. CONVENTIONAL APPROACH

One approach used to suppress multipath is to acquire a series of near-field data sets at a number of different AUT/probe separation distances and coherently averaging the results in the far-field domain. As an example, 8 near-field scans separated by 1/8 wavelength between 4 and 5 wavelengths were acquired. These scans were transformed and coherently averaged in the far-field. Figure 5 shows the coherently averaged E-plane cut and the result attained by coherently averaging two data sets spaced precisely 1/4 lambda apart. Averaging two scans yields essentially the same results as averaging the 8 scans leading to the conclusion that the multipath signal is being effectively cancelled with only two scans. The result is a 25dB suppression of axial multipath and mutual coupling, allowing a -50dB sidelobe noise floor in an office environment. The undesired multipath signal undergoes an additional 180 degree phase shift during the second scan because of the round trip bounce with a 1/4 lambda (90 degree) separation.

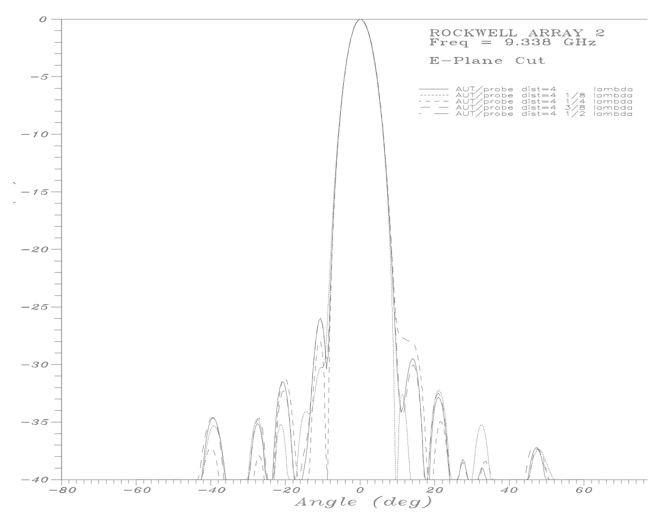
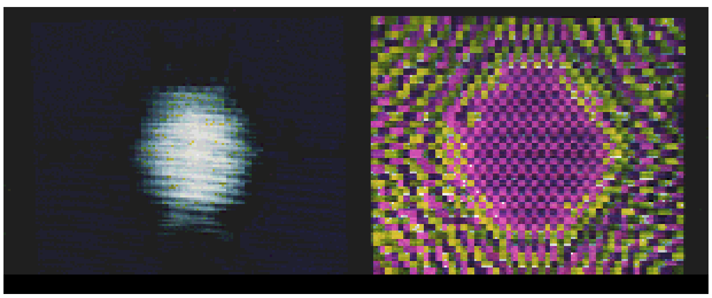


Figure 5 E-Plane Cut vs.AUT/Probe Distance

6. ERROR SUPPRESSION TECHNIQUE

The success of coherently averaging two scans led to an attempt to reduce the testing required to achieve satisfactory results. A single near-field scan was acquired, with every alternate sample point in the raster scan being taken with the AUT in one of two positions - either at 4 lambda, or 4-1/4 lambda from the probe. A computer driven Z translation stage supporting the AUT made this possible. The amplitude, phase, and X,Y and Z positions thus recorded made up a non-planar scan we will term a 'volumetric' or 'staggered Z' scan. The NSI developed far-field transformation software developed has the ability to handle arbitrary XYZ positions on a measurement surface, thus no manipulation was required to process the volumetric scan data.

Figure 6 shows a grey scale representation of the measured near-field amplitude and phase. The checkerboard characteristic of the phase plot is caused by the 90 degree



Amplitude *Phase*

Figure 6 Nearfield Amplitude / Phase

difference in measured phase at alternate near-field X,Y points.

Figure 7 shows the results of the first volumetric scan compared to the averaged result of the 8 scans. The close correlation is self evident.

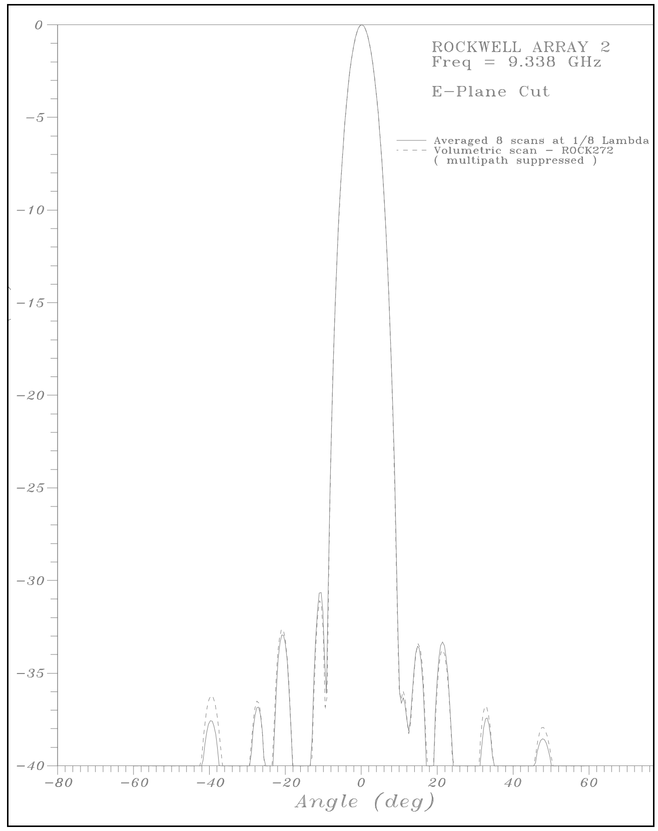


Figure 7 Averaged Result vs. Volumetric Scan

7. SELF-COMPARISON TESTS

Additional volumetric scans were repeated to confirm that the coherent cancellation technique indeed eliminated the multipath problem. Figure 8 shows the correlation between two volumetric scans with starting measurement planes 1/4 lambda apart (one alternated the AUT/probe distance from 4 lambda to 4-1/4 lambda and the other alternated between 4-1/4 lambda and 4-1/2 lambda). Figure 9 shows the good agreement attained in measuring sidelobes with the AUT/probe PHI orientations at 0, 90 and 180 degrees.

The sidelobe differences of the self-comparison tests performed above allow an estimation of the sidelobe uncertainty contribution due to the residual multipath errors not completely cancelled with the volumetric scanning technique. A sidelobe change of 1dB at the -25dB level corresponds to an error signal approximately 25dB down from the sidelobe peak, or about 50dB down from the main beam peak. The volumetric scan is seen to reduce the multipath contribution by on the order of 25dB. In addition, the phase data can be reversed in the coherent addition so that the multipath result is enhanced and the antenna pattern is suppressed. This provides a way of directly observing the multipath (Figure 10).

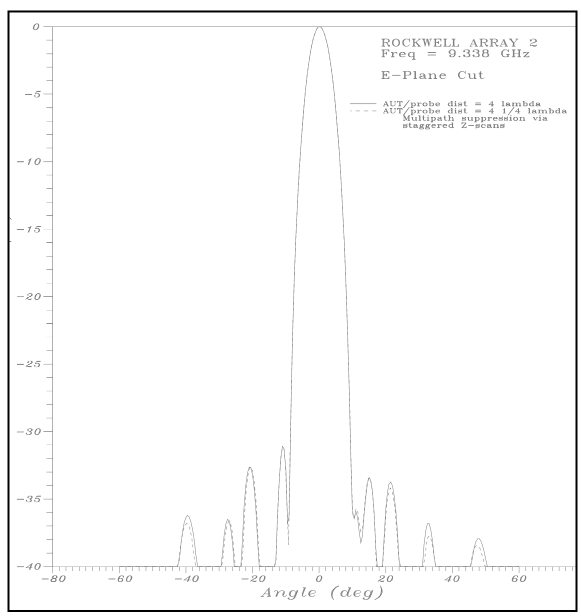


Figure 8 Self Comparison Test
2 Scans @ 1/4 Lambda
(Multipath Suppressed)

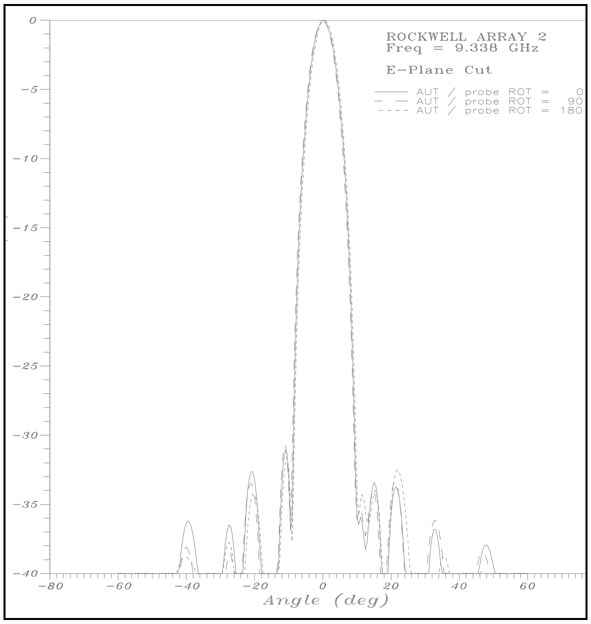


Figure 9 Self Comparison Test 3 Scans @ 0,90,180 Degrees (Multipath Suppressed)

Advantages of the volumetric scanning technique (over simply taking two scans spaced 1/4 lambda apart and averaging them) include reduced acquisition time and reduced data storage and manipulation requirements. Additional work is being performed by NSI to study alternate scanning techniques vs. hardware configurations to optimize the effectiveness of the technique. The general applicability to other types of antennas is also being studied.

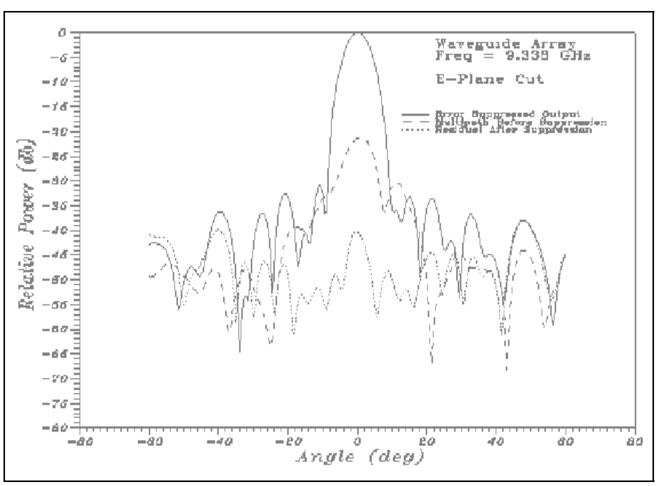


Figure 10 - Multipath vs. Desired Signal

8. FAR-FIELD/NEAR-FIELD COMPARISON

Figures 11 and 12 show the excellent correlation between the customer measured far-field data and the NSI calculated far-field from near-field measurements taken in 1988. The near-field data was taken using the multipath suppression technique described earlier in an office environment with minimal absorber. Sidelobes are generally within 1 to 2.5dB between the two techniques at levels down 30 to 35dB from the main beam peak.

The residual sidelobe uncertainty estimate for the near-field measurements is about +1.5dB at the 30dB level. No far-field uncertainty estimates were available for the far-field test data, however, typical uncertainties for a good far-field range would be around +2dB, and clearly the differences in the sidelobes measured with the two techniques falls within the bounds of the combined uncertainties.

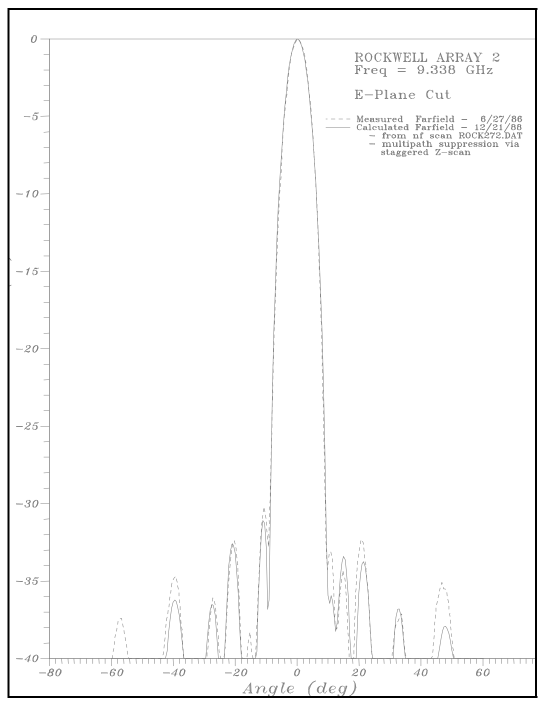


Figure 11 E-plane Cut Near-field vs. Far-field

9. CONCLUSION

This paper has described several methods for substantially enhancing measurement accuracies through error suppression. A novel technique for significantly improving sidelobe measurement performance by multipath cancellation has been demonstrated.

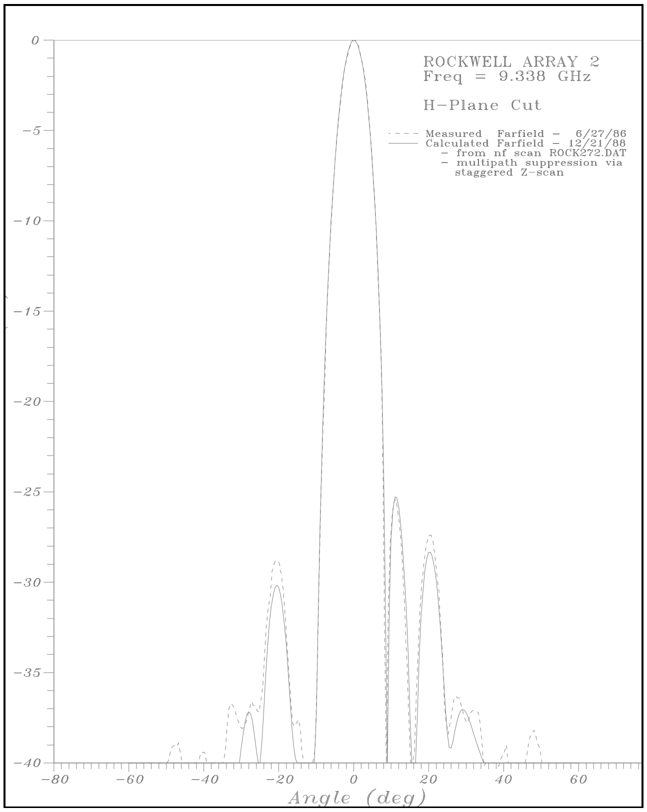


Figure 12 H-plane Cut
Nearfield vs. Farfield

10. REFERENCES

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2. D. Slater and G. Hindman, "A Low Cost Near-Field Antenna Measurement System", 1989 Antenna Measurement Techniques Association Symposium, Monterey, CA Oct 9-13, 1989.