ANTENNA PATTERN COMPARISON BETWEEN AN OUTDOOR CYLINDRICAL NEAR-FIELD TEST FACILITY AND AN INDOOR SPHERICAL NEAR-FIELD ANTENNA TEST FACILITY

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ABSTRACT

A new spherical near-field probe positioning device has been designed and constructed consisting of a large 5.0 meter fixed arc. This arc has been installed in a near-field test facility located at Alenia Marconi Systems on the Isle of Wight, UK. As part of the near-field qualification, testing was performed on a ground based radar antenna. The resultant patterns were compared against measurements collected on the same antenna on a large outdoor cylindrical near-field test facility also located on the Isle of Wight [1]. These measurements included multiple frequency measurements and multiple pattern comparisons.

This paper summarizes the results obtained as part of the measurement program and includes discussions on the error budgets for the two ranges along with a discussion on the mutual error budget between the two ranges.

Keywords: Spherical Near-Field, Cylindrical Near-Field, Pattern Comparison

1.0 INTRODUCTION

A new spherical near-field (SNF) test facility has been built at the Alenia-Marconi System (AMS) Facility on the Isle of Wight, UK. As part of the delivery of the system a measurement study was performed to determine the accuracy of the new facility relative to AMS's outdoor cylindrical near-field (CNF) test facility.

The study was conducted by collecting and processing data collected on a ground-based radar reflector antenna (herein referred to as the reference antenna) both on the outdoor CNF range and on the indoor SNF antenna test range. The measurements consisted of near-field pattern data collected over multiple frequencies, two polarizations and at two radial probe locations on both facilities.

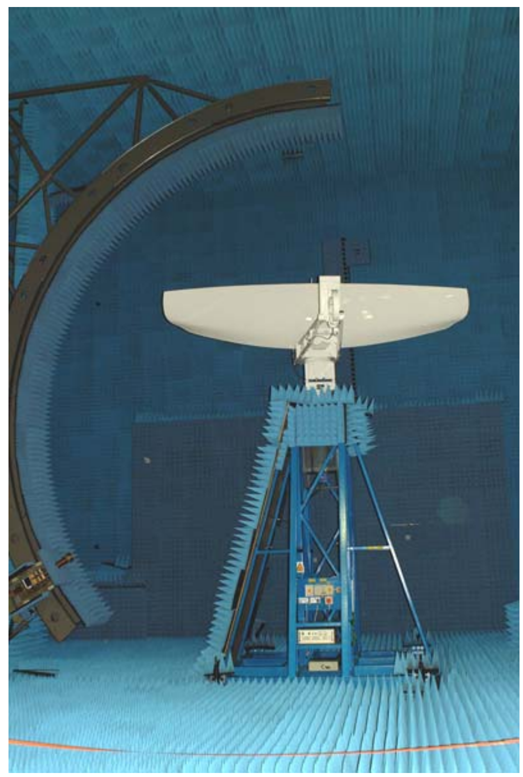

Figure 1 Photo of Arch, AUT and Mounting Structure

2.0 CNF SYSTEM OVERVIEW

The cylindrical near-field test facility was originally installed and qualified in 1994. The details of this facility were reported in Microwave Journal [1], and are only summarized here. The CNF facility consists of a 36 meter probe positioning tower and an azimuth axis for mounting and rotating the antenna. The RF instrumentation consisted of a log-periodic dipole array probe, remote mixers, Scientific-Atlanta Model 1795 microwave receiver and signal source. The positioning system consists of an azimuth rotator and a probe positioning stage using a laser interferometer to measure probe position as the probe travels up the 32 meter of travel.

The original design of this system was carefully reviewed to minimize reflection from surrounding trees, building and other interference sources. The CNF facility was designed to have the sidelobe accuracy over the frequency band of this study shown in Table 1.

Table 1: CNF Predicted Sidelobe Performance [1]

Sidelobe Level (dB)	Sidelobe Error (dB)	Equivalent Error Signal Level (dB)
-30	+/- 0.75 dB	-51
-40	+/- 1.5 dB	-55
-50	+/- 2.5 dB	-61

3.0 SNF MEASUREMENT SYSTEM OVERVIEW

The new facility was provided to AMS by MI Technologies. The spherical near-field test facility consists of a 11m wide x 13m high x 16m long chamber, an arch probe positioner, an MI-4190 series position controller, a dual polarized probe assembly, and an MI-1797 microwave receiver. Additional components provided by AMS for testing of the reference antenna were an antenna positioner and controller, a signal source and a computer for converting synchro feedback into binary controlled decimal (BCD) format.

The position control system consists of an MI-4190 Series Position Controller for positioning the probe along the arch and an AMS built position controller and rotator for rotating the antenna at a constant velocity of 4 RPM. Position feedback for the arch is provided via a linear encoder mounted along the arch. The synchro position data feedback from the phi-axis was converted to BCD format for use by the control system for position monitoring and triggering of the RF subsystem.

MI Technologies' MI-3000 Data Acquisition and Analysis Workstation was used to acquire and process the data. After the data was collected, the MI-3046 Spherical Near-Field Software was used to transform the data from the near-field to the far-field. The MI-3046 SNF software uses the industry standard TICRA SNIFTD software at its core.

4.0 ARCH POSITIONING SYSTEM

A key feature of this new facility is the spherical near-field arch used to position the probe. Spherical near-field testing of electrically large antennas requires highly accurate positioning systems. An approach developed at MI Technologies is to utilize a large cantilevered arc to move a probe positioner along the theta axis of the spherical near-field coordinate system while a rotary positioner and stands move the antenna about the phi axis of the system. Several of these large radius arcs systems have been developed for telematic antenna testing, radar antenna and ground based communication systems test. Figure 1 shows a photo of the arch in the SNF facility and Figure 2 shows a CAD model of the arch and probe.

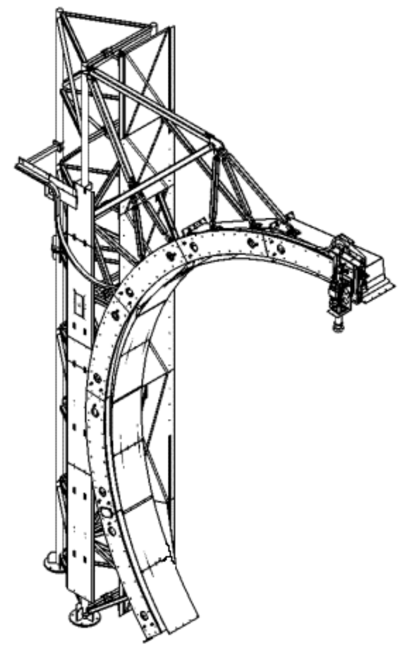

Figure 2 CAD model of the Arch and Probe

The design of any large near-field measurement system must control electrical and mechanical errors that affect the measurement. Provisions for controlling the system cables, RF accuracy, and the probe positioning errors have been made in the design of this large arch.

This arch has a radius of 5.0 meters and a travel range of 130 degrees. The arch was installed and aligned using a tracking laser interferometer and techniques similar to those previously reported [3]. Following alignment, the arch achieved the position accuracies shown in Table 2.

Table 2: Probe Positioning Accuracy

Probe Path Radius	+/- 0.33 mm (.013 in) 0.11 mm RMS (.004 in)
Angular Accuracy (Theta Accuracy)	+0.0058 / -0.0025 deg 0.0019 deg RMS
Phi Accuracy as a Function of Theta	+/- 0.0087 deg 0.0034 deg RMS

5.0 SNF SYSTEM ACCURACY

The new SNF test facility was designed and constructed to meet the antenna measurement accuracy shown in the error analysis summary in Table 4. The system accuracies shown in this table were determined based upon the method reported by Hess [4] in 2002. An equivalent stray signal level of -55.44 dB is shown for a sidelobe level of -26.8 dB. Based on this analysis an equivalent stray signal of -55 dB is used in this study for comparison with measurements made on the CNF facility.

6.0 ANTENNA UNDER TEST DESCRIPTION

The reference antenna consisted of an offset fed parabola designed for use in a radar system, and an integral rotator. A photo of the AUT is shown in Figure 1. The antenna had capability of both vertical and horizontal polarization. The antenna radiates a fan beam with a narrow azimuth beamwidth of approximately 1.5 degrees and a wider elevation beamwidth of approximately 9 degrees. The antenna was tested at three frequencies, 2.7, 3.0 and 3.25 GHz and two polarizations, although space limitations allow only data at 3.0 GHz to be reported in this article.

7.0 METHOD OF COMPARISON

Both the Cylindrical Near-Field facility and the Spherical Near-Field Facility were placed into service with an expectation of exceptional performance. The challenge with any range comparison study utilizing data taken only on two ranges is answering the question, “Which range is correct?” In order to answer the question, we first establish an intra-range baseline.

The method of comparison between the two ranges was to examine the difference between the patterns through the peak of the beam and determine an equivalent extraneous error signal level. This assumes all possible error signals at a single angle are combined into a single error vector which accounts for the difference between the two patterns. Given this assumption the comparison is made by the following equation:

$$20\log\frac{E_S}{E_{Pk}} = 20\log\frac{E_2}{E_{Pk}} + 20\log\left[\frac{1-10^{-\Delta/20}}{2}\right]$$

E_s = equivalent extraneous error signal level

E_2 = the stronger of the two sidelobe levels

Δ = Peak-to-Peak discrepancy ($E_2 - E_1$)

To compare data obtained on a range against data from a different range, an acceptable criterion must be determined. The criterion settled upon with which to compare the equivalent extraneous error signal levels is based upon the combined specifications of the two ranges. Each range is assumed to have equivalent error signals which at some points in the pattern combine out of phase to contribute the maximum possible error. The levels shown in Table 3 were chosen as the acceptable pattern differences between the two ranges.

Table 3:
Expected Error Signal Between Ranges

Sidelobe Level (dB)	CNF Equivalent Error Signal Level (dB)	SNF Equivalent Error Signal Level (dB)	Expected Equivalent Error Signal Level (dB)
-30	-51	-55	-47
-40	-55	-55	-49
-50	-61	-55	-51

8.0 COMPARISONS

Prior to beginning data collection, a number of data acquisitions were performed to test the measurement repeatability and to look for extraneous signals. Based upon the results, additional absorber was placed upon the top and front face of the phi-axis tower. The dynamic range of the system was checked with the antenna present and determined to be approximately 70 dB for a single measurement sample. Leakage levels within the system were checked and determined to be insignificant.

On both ranges, data was collected at two different radial locations of the probe to determine the repeatability of the measurement and to look for interaction between the probe and the AUT. Figure 3 shows sidelobe detail for two azimuth pattern cuts from data collected on the SNF system. The two pattern cuts are from near-field data collected at two probe distances 30 mm apart (0.3 wavelengths). Very little difference is seen in these two patterns. This data shows excellent repeatability of the system between the different locations of the probe. Figure 4(a) shows a histogram of the equivalent extraneous signal level between the two patterns. The histogram shows that 98.95% of the pattern has a equivalent stray signal of below –65 dB. The results support the predicted –55 dB equivalent stray signal level in the SNF facility.

The results of a similar comparison made using the outdoor CNF facility is shown in Figure 4(b). The histogram for the outdoor facility performance shows that 98.2% of the pattern has a stray signal below -55 dB. This data is consistent with the design specification of this measurement facility as listed in Table 1. In comparison to the SNF facility, the CNF facility shows that only 66.2% of the pattern has a stray signal below -65 dB.

Figure 5 shows a comparison made between the SNF and CNF test ranges. These plots show reasonable agreement between the two ranges. Figure 6 shows a histogram of the equivalent stray signal level between the two ranges. The data shows that 96.7% of the pattern has a stray signal level of -45 dB. This data is consistent with the expected levels shown in Table 3.

An elevation pattern overlay is shown in Figure 7. The CNF facility is limited to a scan angle of -15 degrees to +60 degrees for this AUT test due to truncation of the near-field scan surface.

9.0 REFERENCES

[1] Steiner, Fritzel and McCormick, "A High Precision Outdoor Cylindrical Near-Field Test Facility," Microwave Journal, January 1994 pp 128-135.

[2] Hansen, J.E., *Spherical Near-Field Antenna Measurements*. Peter Peregrinus Ltd., 1988.

[3] Fordham, J., Proctor, J., Kremer, D., "Precision Positioner Alignment Techniques for Spherical Near Field Antenna Measurements Using Laser Alignment Tools," 22nd Meeting and Symposium Proceedings of Antenna Measurement Techniques Association (AMTA-00), Philadelphia, PA, pp 317-320.

[4] Hess, Doren W., "An Expanded Approach to Spherical Near-Field Uncertainty Analysis," Antenna Measurement Techniques Association 24th Annual Meeting & Symposium (AMTA-02), Cleveland, OH, pp 495-500.

Table 4 : SNF Facility Error Budget [2],[4]

	Directivity	Main Beam Cross-Polar Level	Beam Width	First Null Position	First Side Lobe Level
	dBi	dB	Degrees	Degrees	dB
Reference Far-Field Values	38.40	-1000.00	2.25	2.95	-26.80
	Change in dB	Increased to (dB)	Change in Degrees	Change in Degrees	Change in dB
Mechanical Inaccuracies	0.06	-48.97	0.01	0.0128	0.18
Receiver Inaccuracies	0.02	-67.89	0.01	0.0010	0.16
Errors Associated with Probe Correction	0.058	-53.495	0.000	0.0050	0.11
Truncation	-0.020	-1000.000	0.020	0.0000	0.14
Extraneous Signals	0.005	-75.000	0.000	0.0000	0.12
Root Sum Squares	0.09	-47.61	0.03	0.014	0.32
(Equivalent Stray Signal/dB)					-55.44

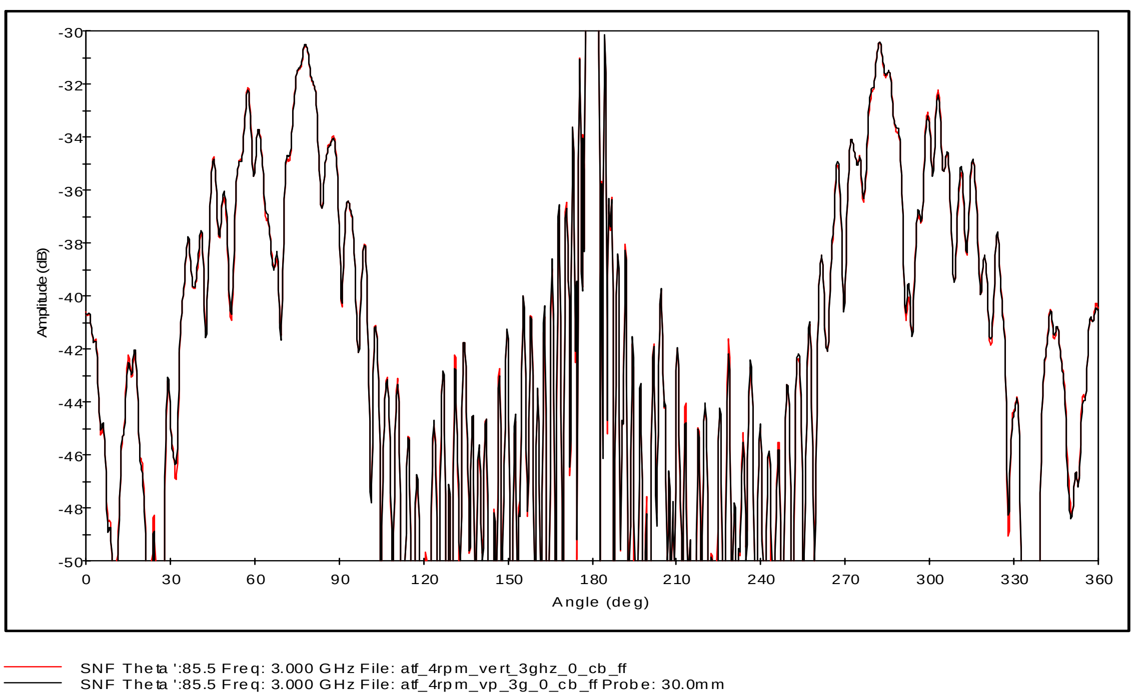

Figure 3: SNF Repeatability after 30 mm Probe Movement. Two Azimuth Pattern Overlays showing sidelobe structure detail. Note the top 30 dB of the pattern is not shown.

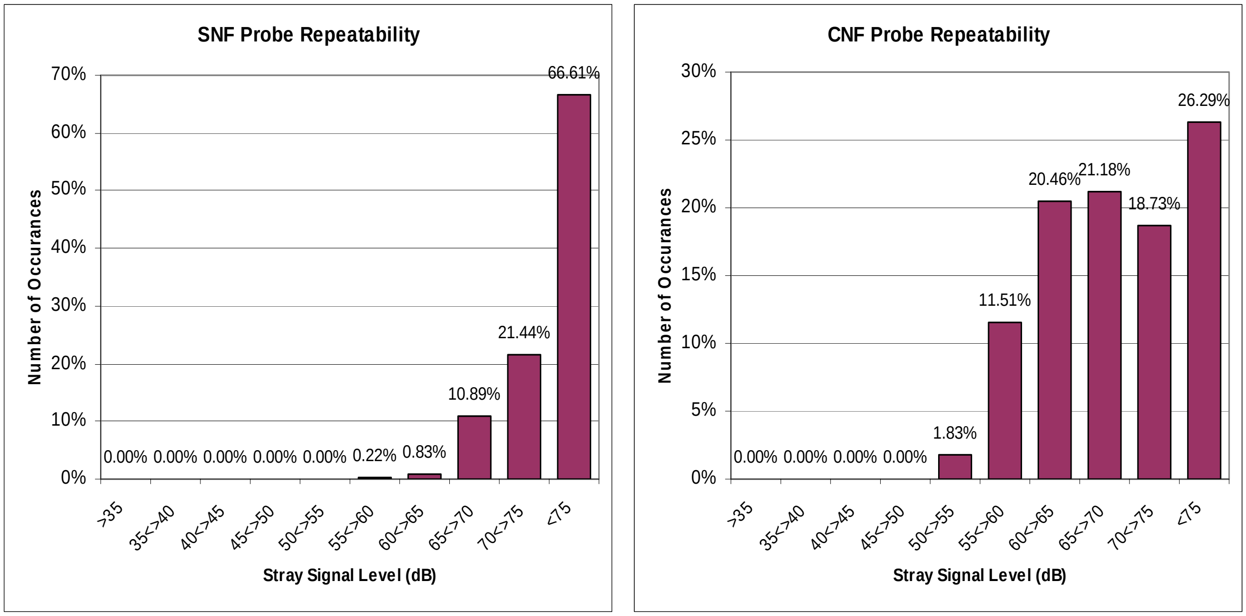

Figure 4: (a) SNF and (b) CNF Probe Repeatability. Histogram of the Equivalent Extraneous stray signals between two NF measurements with the probe moved 30mm between scans. Figure 4(a) corresponds to the patterns shown in Figure 3. The sample size for both figures was 1800 data points equally spaced from 0 to 360 degrees.

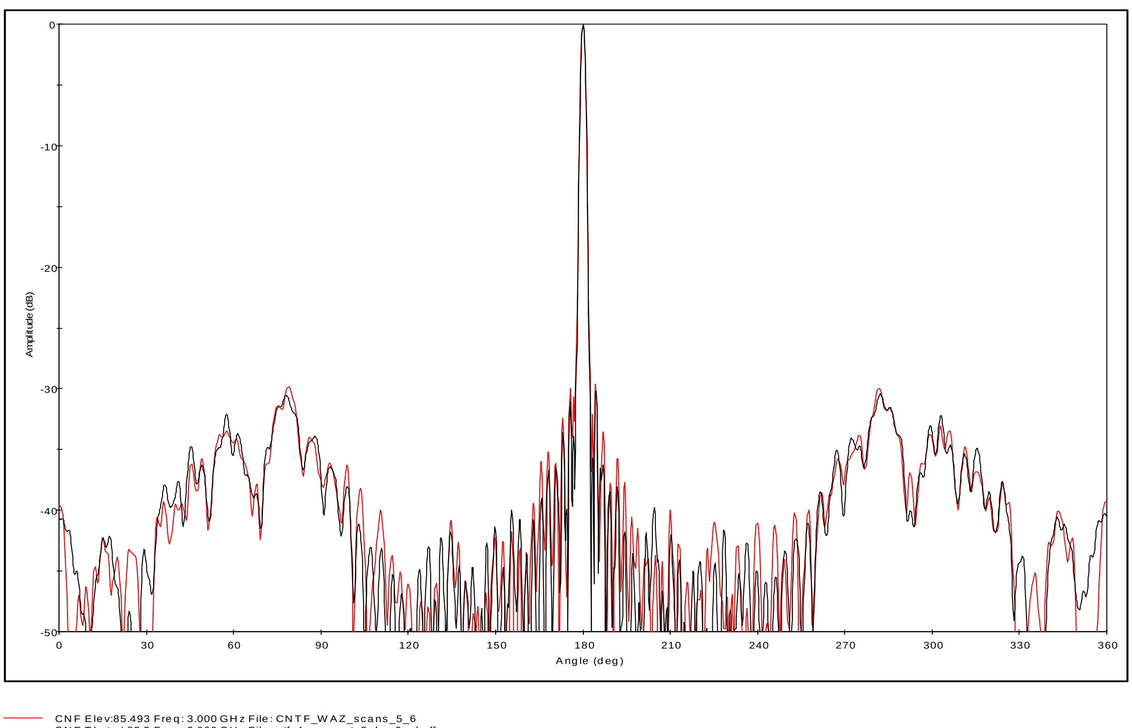

Figure 5: CNF vs. SNF Azimuth Pattern Comparison

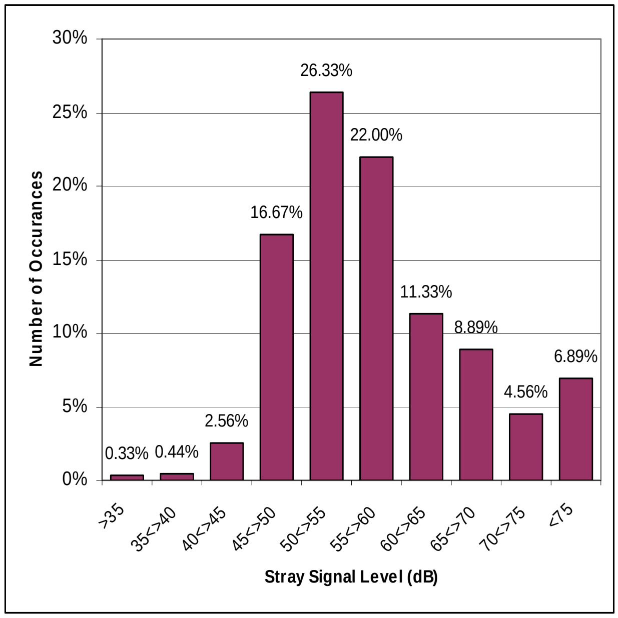

Figure 6: CNF vs. SNF Equivalent Stray Signal Histogram. This corresponds with the patterns shown in Figure 5. The data sample size was 900 data points equally spaced from 0 to 360 degrees.

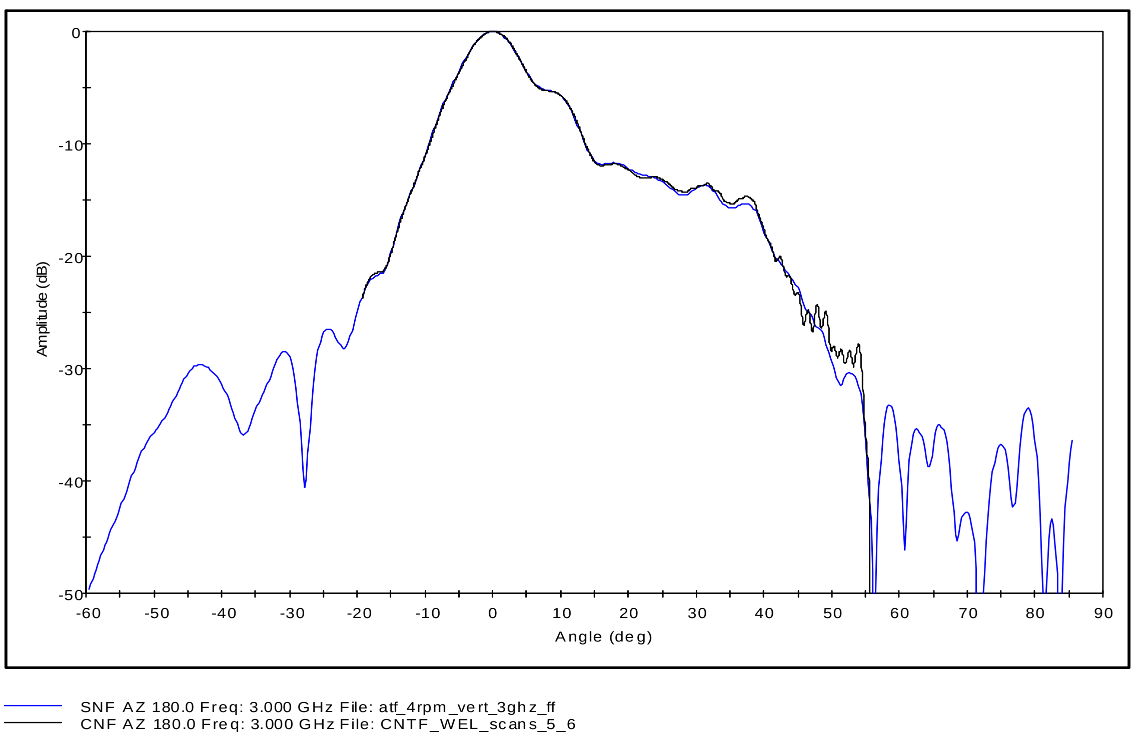

Figure 7: CNF vs. SNF Elevation Pattern Comparison. Patterns normalized to zero degrees elevation. Extent of CNF data based on truncation is from -15 degrees in elevation up to +60 degrees elevation before normalization.