MEASUREMENT SENSITIVITY AND ACCURACY VERIFICATION FOR AN ANTENNA MEASUREMENT SYSTEM

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ABSTRACT

An antenna measurement system was developed to complement a new rectangular anechoic chamber (20'L x 10'W x 9'7"H) that has been established at California Polytechnic State University (Cal Poly) through donations and financial support from industry and Cal Poly departments and programs. Software algorithms were written to provide four data acquisition methods: continual sweep and step mode for both single and multiple frequencies. Log magnitude and phase information for an antenna under test is captured over a user-specified angular position range and the antenna's radiation pattern is obtained after post processing. Pattern comparisons against theoretical predictions are performed. Finally an RF link budget is calculated to evaluate the performance of the antenna measurement system.

Keywords: Antenna Measurement System, Link Budget, Continuous Mode, Step Mode, and Repeatability.

1. Introduction

This paper supplements an analysis of measurement tolerances and range accuracy on an antenna measurement system (AMS) built specifically for the Cal Poly State University anechoic chamber. The overall chamber dimensions are 20' x10'x 9.7' designed to provide far field range operability from 2.6-18GHz with phase uniformity across the test aperture. The separation distance between the source and antenna under test (AUT) is 15ft.

The antenna measurement system combines the functions of a Scientific Atlanta single axis positioner, Scientific Atlanta SA4131 positioner controller, and an Agilent 8720B network analyzer to perform radio frequency (RF) testing and pattern measurements. Software algorithms were developed to integrate individual components to function as a system. A block diagram of the antenna measurement system is illustrated in Figure 1 below.

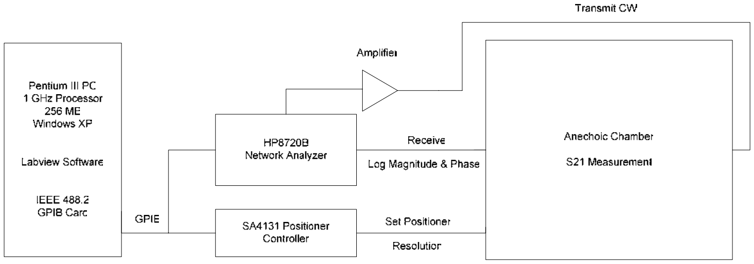

Fig. 1: Antenna Measurement Block Diagram

2. Approach

The objective of the antenna measurement system is to provide a cost effective means of acquiring accurate and repeatable pattern measurements. The development of the system is performed using National Instrument's Labview software, which controls the network analyzer and positioner controller via a general purpose interface bus (GPIB). Software routines were written to provide both continuous and step mode methods of measurement. Measured log magnitude and phase results are captured in ASCII form and tabulated in a spreadsheet.

The interchange between equipment must be coordinated to provide quick accurate amplitude and phase results relative to angular resolution. In the step mode, the interaction between the positioner and network analyzer is synchronized such that the positioner rotates the AUT to an angular position in the azimuth plane, pauses to allow the network analyzer to acquire the appropriate measurement, and then proceeds on to the next angular position. Since the step mode has the ability to sample any number of frequencies at discrete angular positions, the measurement acquisition time is a function of the network analyzer sweep time in addition to averaging, modified bandwidth resolution, or other analyzer settings. Due to the mechanical tolerances of the positioner, the following method has a minimal RMS error of 0.02° from the desired incremental position.

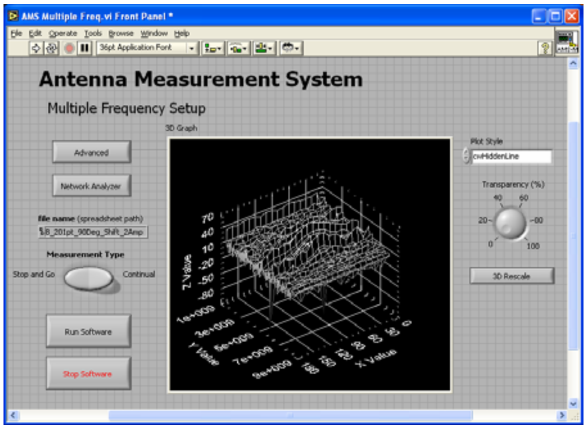

Fig. 2: Antenna Measurement System Software

The continual sweep mode captures data without pausing; as a result this operating mode is quicker and less precise across the test region. To maintain data acquisition at a desired angular resolution, the network analyzer's measurement rate must increase as the rotational velocity increases. As a result, measurements are limited to either CW or a minimal number of frequency points. As data is collected simultaneous to the positioner rotation, angular position accuracy is limited to 0.1° RMS.

Both modes of operation have the capability of specifying angular resolution in addition to the number of frequency points. In general, the total number of samples taken, as a function of angular and frequency increment, is inversely proportional to acquisition speed.

3. Performance Parameters

For accurate and repeatable measurements, acceptable ranges on specific performance parameters are needed to define the antenna measurement system requirements. These parameters include system accuracy, dynamic range, sensitivity, receiver speed, and overall test measurement time [1]. As such, the system performance is limited by a combination of range configurations, source and receive antennas, amplifiers, availability of microwave equipment, RF cables, and connector components. To determine the signal level reaching the network analyzer input, a link budget is calculated over the operating frequency.

As depicted in Figure 1, the RF signal level on the transmitting front end is traced from the network analyzer source to the amplifier and from the cable front end to the source antenna. The receiving end is then traced from the AUT, through the receive cable, and finally back to the receive end of the network analyzer. Transmission line and propagation path losses are calculated and a link budget and expected dynamic range are established.

Path loss as defined in Equation 1 is the attenuation of the RF signal due to spherical spreading. The distance R between the source and AUT is 15ft in the Cal Poly chamber.

$$PL(dB) = 20\log\left(\frac{4\pi R}{\lambda}\right) \qquad (1)$$

Using the performance specification for each component as shown in Table 1, nominal standard gains are used for the link budget calculations. A dipole is used as the AUT to provide the minimum possible gain (2.15dBi) and the standard gain receive horn with an operating frequency matched to that of the dipole is used as the optimal case. Dynamic range is calculated using a specified noise floor of –78dBm for an IF bandwidth of 3 KHz.

To increase measurement sensitivity, the use of averaging and variable IF bandwidth can reduce the effect of noise on the data and increase the sensitivity of the coherent signals at the expense of sweep time. The primary tradeoff is between measurement sensitivity and allowable acquisition time. A reduction in the IF bandwidth from 3 KHz to 100Hz reduces the noise floor by an additional 8dB to -86.5dBm with minimal sweep time increase.

Depending on the sensitivity of the measurements, the optimized link may not be required for measurements at lower frequencies. System losses decrease due to reduced cable and path losses at lower frequencies. Table 2 describes the optimized RF link budget with improved measurement sensitivity.

4. Measured and Theoretical Results

The validity of the results received from the antenna measurement system can be verified if the pattern of the AUT is known. Provided the frequency and the AUT dimensions, in this case a standard gain horn antenna, the expected radiated field amplitude pattern can be computed. For theoretical comparisons to the measured patterns, Personal Computer Aided Antenna Design (PCAAD) software was used to simulate the E and H plane antenna patterns. Measured range patterns of the main beam and the first sidelobe level (SLL) are used for comparison.

As depicted in Figure 3, the measured main beam width and the shape of the antenna pattern align with the theoretical pattern. The main discrepancy as indicated is the amplitude inconsistency in the first sidelobe of the E-plane pattern. Based on theoretical plots as cited by the manufacturer's specifications and calculations performed, the first sidelobes should yield a level of -13dB with respect to the main lobe. The measured pattern yields a SLL of 2dB RMS greater than specification.

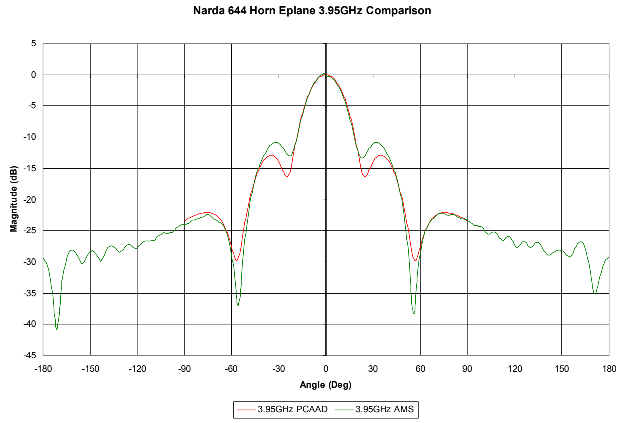

Fig. 3: Theoretical and Measured Pattern Results

Aside from reflections internal to the range, a source of error between the measured and theoretical patterns can be attributed to the illuminating field phase variations incident over the AUT. Phase inaccuracies as determined by the separation distance between the source and AUT results in partial filling of the first null and variations in the sidelobe amplitudes [2].

Since theoretical calculations assume an infinite distance from the antenna, the SLLs are lower relative to the main lobe. Measured error associated in the 2dB RMS SLL deviation corresponds to the minimal allowable separation range approximation of $2D^2/\lambda$. For a closer theoretical approximation, a far field distance of $4D^2/\lambda$ or 18.3ft is required for decreased phase deviations.

5. Repeatability

The object of repeatability is to demonstrate consistent patterns among measurement iterations. Except for positioner errors due to mechanical tolerances, repeatability data indicate that deviations are a result of range reflections arriving at the quiet zone. For the first and second iterations, at frequencies below 7GHz, a 0.5dB RMS variation occurs at the 26dB SLL as shown in Figure 4. For the range 7GHz – 12GHz, a 1dB RMS variation occurs at the 24dB SLL and for 12-18GHz, a 1dB RMS variation occurs at the 18dB SLL. As a result, confidence in chamber measurements depends on deviations of SLL performance relative to theoretical predictions. Reflections contributing to this variation can be quantified by the determining the size and location of the quiet zone region in the chamber. Acceptable deviations are dependent on the desired measurement accuracy.

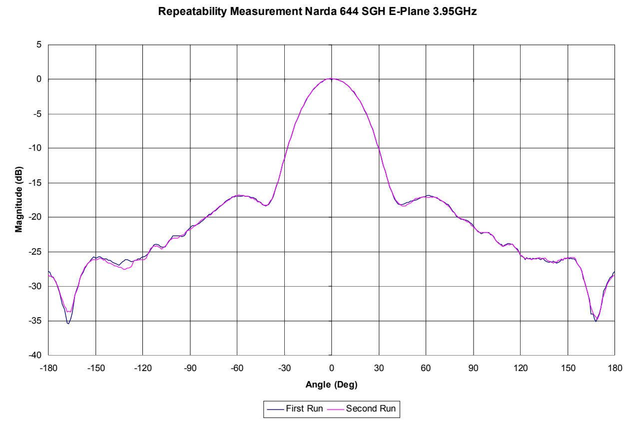

Fig. 4: Repeatability Results

6. Conclusion

An antenna measurement system using two functional modes of data acquisition and pattern measurement: continual sweep and step mode has been described. The modes are designed to provide either rapid data acquisition or a collection of results relative to absolute angular position. In addition to measurement sensitivity and acquisition time tradeoffs, an RF link budget has been established. Pattern measurements also indicate repeatable results as well as responses that compare well to theoretical predictions.

7. References

[1] Fooshe, D.S. and M. Schultz, "How to Specify An RF System for Antenna Measurements." *Antenna Measurement Techniques Association Conference*, 2000.

[2] IEEE Standard Board, *IEEE Standard Test Procedures for Antennas,* NY: 1979.

8. Acknowledgements

The authors would like to thank Deskin Research, Raytheon, and Lockheed Martin for material donations and the employees of Lockheed Martin and JPL for technical support during the construction and testing of the Cal Poly Anechoic Chamber. We would also like to thank Cal Poly's Electrical Engineering Department for financial support of the chamber project through the purchase of absorber foam.

Table 1 AMS RF Link Budget Allocation

AMS RF Link Budget

Frequency GHz	2	4	6	8	10	12	18
Output Power, dBm	-10	-10	-10	-10	-10	-10	-10
Amplifier Gain	22.347	21.886	22.291	27.146	25.957	26.473	26.194
30ft RF cable to Source '62'	-11.104	-11.926	-13.189	-14.566	-16.055	-16.954	-19.453
Antenna Source Gain	16.5	16.5	16.5	16.5	16.5	24.7	24.7
Path Loss	-51.664	-57.685	-61.206	-63.705	-65.643	-67.227	-70.749
Antenna Under Test Gain	2.15	2.15	2.15	2.15	2.15	2.15	2.15
30ft RF cable to NA '63'	-11.299	-12.283	-13.384	-14.789	-16.269	-17.942	-19.434
Power Level Input to NA	-43.07	-51.358	-56.838	-57.264	-63.36	-58.8	-66.592
Specified Noise Floor (3KHz IF BW)	-78	-78	-78	-78	-78	-78	-78
Worse Case Measured Dynamic Range, dB (AUT of 2.15dBi)	34.93	26.642	21.162	20.736	14.64	19.2	11.408
Optimal Case Measured Dynamic Range, dB (SGH)	49.28	40.992	35.512	35.086	28.99	39.15	31.358

Table 2 AMS Optimized RF Link Budget Allocation

Optimized RF Link Budget

Frequency GHz	2	4	6	8	10	12	18
Specified Noise Floor (100Hz IF BW)	-86.50	-86.50	-86.50	-86.50	-86.50	-86.50	-86.50
Worse Case Measured Dynamic Range, dB (AUT of 2.15dBi)	43.43	35.142	29.662	29.236	23.14	27.7	19.908
Optimal Case Measured Dynamic Range, dB (SGH)	57.78	49.492	44.012	43.586	37.49	50.25	42.458