EVALUATING NEAR-FIELD RANGE MUTI-PATH

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Abstract

Near-field range design includes the placement of RF absorber in the test area. Absorber placement depends highly on the antennas being tested. A common approach is to design an expensive low-reflection chamber around the near-field scanner. The chamber and the additional floor space can sometimes cost more than the near-field scanning system itself. Another approach seeks to identify multi-path reflection to minimize cost by optimally placing absorber to meet specific antenna test requirements. The result is a lower cost range using less floor space. This paper describes a technique of evaluating near-field range multi-path.

Introduction

Near-field measurements are becoming increasingly more popular with the advancement of low cost scanning systems and fast personal computers. Many users find advantages in portable systems because it allows them to bring the antenna range and measurements directly to the:

- Flight-Line
- Engineering Office
- Manufacturing Area.

Near-field range evaluation assigns far-field uncertainties to its calculated far-field patterns. It is important and involved process which can take many weeks. Typically it begins with a pattern error budget table as shown in Table 1. Combined error is an RSS with the errors assumed to be independent and uncorrelated. A -30 dB sidelobe level was chosen because the antenna to be tested has a first sidelobe spec. at -30 dB. The elements of this table are discussed by Newell (1). Some errors in this table are assessed through analytical modeling and others are determines through measurements. In the design phase theses items are typically estimated. In the acceptance phase these items are evaluated.

1.	Probe Relative Pattern	0.20
2.	Probe Polarization Ratio	0.05
3.	Probe Gain	0.00
4.	Probe Alignment	0.00
5.	Normalization Constant	0.00
6.	Impedence Mismatch	0.00
7.	AUT Alignment	0.00
8.	Aliasing Error	0.03
9.	Measurement Area Truncation	0.05
10.	Probe X-Y Position Error	0.10
11.	Probe Z-Position	0.20
12.	Multiple Reflections	0.87*
13.	Receiver AMP Non-Linearity	0.00
14.	System Phase Errors	0.15
15.	Rec. Dynamic Range	0.10
16.	Room Scattering	0.48*
17.	Leakage and Crosstalk	0.07
18.	Random Errors in AMP and Phase	0.22
	Rss Combination (db)	1.03

Table 1 Error Budget for -30 dB Sidelobe Measurement

Multiple Reflections (Item 12) and Room Scattering (Item 16) often account for the greatest contribution to far-field uncertainty. Evaluation and reduction of these sources can result in lower total measurements uncertainties. In the example of Table 1 an allocation of 0.87 dB has been made for multiple reflections and 0.48 dB for room scattering. This results in an overall ±1 dB uncertainty at a -30 dB pattern level. Each item in the budget must also be evaluated but this is beyond the scope of this paper.

Evaluation of the error budget is important in low scattering anechoic chambers as well as portable systems in noisier RF environments. The test case used in this paper is in a manufacturing or office environment.

Near-field Range Multipath Effects

Reflected waves on the antenna range corrupt the antenna-under-test's (AUT) true pattern by adding in and out of phase with it. Antenna radiation reflected by the probe and walls scatters in directions of sidelobes. Scattered energy thus increases or decreases sidelobe amplitude. Scattered energy that is received by the measurement system from fixed objects in the range is defined as room scattering in the error budget, while scattered energy from moving objects is defined as multiple reflections. Both of these are forms of multipath. Sources of multipath on a near-field range include:

- -AUT and Probe
- -AUT and Scanner/Support Structure
- -AUT and Walls (including Floor and Ceiling)

Multipath effects can be identified on a range by observing the far-field effect of changing near-field test parameters which should not affect the AUT's far-field pattern. These are known as "self-comparison" tests. Some of these parameters are:

- -AUT-to-probe separation
- -AUT-to-scanner separation
- -AUT-to-wall separation
- -AUT orientation to phi
- -AUT orientation in Az and El
- -AUT lateral movement

When self-comparison test are used to evaluate range performance for a particular antenna project, the characteristics of the antenna used for evaluation should be very similar to the project antenna. An engineering or breadboard model may serve this purpose well. The AUT used in this paper is a 10 in. diameter waveguide array.

To the extent that the same pattern cut is made through the AUT's pattern, observed pattern changes in the self-comparison tests indicate errors due to multipath. When these variations are larger than that allocated in the budget, additional effort is needed to meet the test requirements.

Two approaches are commonly used to reduce scattering effects. They are:

1.) RF Absorber
2.) Averaging Measurement

Approach 1 places RF absorber in areas suspected to be highly reflective such as positioners, antenna support structure, walls floor and ceilings. Approach 2 averages scans and/or coherently adds the result to suppress the multipath (2). This suppression approach has been shown to yield a 10-20 dB multipath reduction in an office environment with the little absorber required. There are advantages and disadvantages to both approaches (See Table 2).

Approach	Advantages	Disadvantages
RF Absorber	Shorter Test Times	Dirty Envir. More Real Estate Less Portable
Averaging Measurements	Clean Envir. Less Real Estate More Portable	Longer Test Times

Table 2. Using RF Absorber vs. Averaging Scans

In order to determine the approach or combination of approaches requires, near-field range multipath must first be evaluated.

Locating and Evaluating Near-field Range Multipath

Near-Field Error	Near-Field Scan Tests	Reduction Method
RF Leakage		
Cable	Load Cable at Probe	Replace Cable, add Metal Tape
Receiver	Load Rec. Output	Service/Calibrate Rec.
Random Phase and AMP.		
Cable	S11 Moving Cable Test	Reorient Cable
Receiver	S21 Fixed Probe Test	Increase SNR

Table 3 Self-comparison Repeatability Tests

Several techniques have been used to locate and evaluate the far-field effects from scattered energy in the room 2,3. They include: CW SAR Imaging (Quiet-zone imaging) and self-comparison test.

Quiet-zone imaging involves using the near-field range to probe radiated energy and then converting it to an angular spectrum so that high-reflection area in the room can be located. An angular scattering map is created which can be used in conjunction with a device such as a theodolite to locate the source. Upon location various methods can be applied to reduce the levels such as:

- ♦ Adding Absorber
- ♦ Rearranging Scanner System W.R.T. Room
- ♦ Relocating Equipment In The Room

Quiet-zone imaging is an effective method of evaluating absorber reflections in the chamber but is discussed in detail in another paper (3).

Self-comparison tests are done by making two measurements with different test parameters and comparing them. The resulting angular plot indicates the direction and level of the multipath signal.

Prior to performing self-comparison test certain other near-field error parameters must be identified and reduced to insure that the self-comparison test method will give repeatable results. Some of these test are:

- Random error (Cable and receiver
- Leakage (Cable and receiver)

The effects of these error are best identified by noting variations in far-field results rather than near-field quantities. For example, leakage in a receiver is best identified by taking a near-field measurement with one port loaded and transforming to the far-field, then adjusting it relative tot he far-field peak from a normal scan. In a similar way. Cable leakage and phase variations can also be evaluated in the far-field domain.

Each test results in a far-field error level below the main beam peak. To evaluate the sidelobe error effect of a particular contributor, we convert the Pattern-to-error (Signal-to-Noise) ratio to an uncertainty.

For example:

- ♦ -30 dB Sidelobe (Signal)
- ♦ -62 dB Repeatability Error (Noise)
- ♦ 32 dB Pattern-to-Error Ration (SNR)
- ♦ ±0.22 dB Uncertainty due to Repeatability

Once the far-field error due to repeatability between scans is low enough, we are ready to begin the self-comparison tests. The results of the tests are shown in Table 4.

Table 4. Self-Comparison Repeatability Test Error Levels for -30 dB Sidelobe Level

Error Source	FF. Error Level below – 30db Sidelobe
Leakage -Cable -Receiver Total Leakage	 -42db -65db -42db
Random Amp Phase -Cable -Reciever Total Random Error	 -40db -33db -32db
Total Repeatability Error	-32db

Testing

Several tests were performed to identify and isolate the near-field range multipath under the test conditions of Table 5.

Test Parameter	
Antenna	10in. Diam Waveguide Array
Frequency	9.338Ghz
Probe	WR90 Open-Ended Waveguide
Probe Seperation	3 Wavelengths
Scan Size	13x14 in.
Scanner	NSI's 211T Portable XY Scanner

Table 5 Self-comparison Test Configurations

Table 6 shows the three main multipath contributions and how to identify them. It should be noted that movement perpendicular to the scanner will identify multipath near scanner boresight (o° Az, 0° El). For sidelobes near boresight this is very effective.

Multipath Source	Wear-Field Scan Tests	Reduction Method
AUT-Probe	2 Scans with probe Moved λ/4 in Z	Add Probe Absorber Avg. Scans
AUT-Scanner	2 Scans with Scanner moved λ/4 in Z	Add Scanner Absorber
AUT-Wall	2 Scans with AUT moved λ/4 in Z	Add Absorber Avg. Scans

Table 6. Multipath Self-comparison Tests

Three sets of multipath test were made on the range and methods of reduction were apparently applied.

In test #1 two near-field scans were taken with the probe at locations one quarter wavelength (λ/4) apart. The difference between the two far-field patterns is due to the multipath between the AUT and the object moved. A λ/4 separation will insure that the difference between the patterns reveals the peak multipath in the z-directions. This test is done twice, once in the bare configuration (no probe absorber) and the other with 4 in. pyramidal absorber on the probe.

Multipath Source	Before Reduction		After Reduction	
	SNR (db)	Unc (db)	SNR (db)	Unc (db)
AUT-Probe	5	±3.9	20	±0.85
Aut-Scanner	3	±4.6	30	±0.27
Total Multiple Reflections (#12 Table 1)	--	±5.6	--	±
Aut-Wall Room Scattering (#16 Table 1)	13	±2.0	25	±0.48

Table 7 Multipath Effects Before and After Reduction

Figure 1 shows the result of the measurements. The solid line is the antenna pattern with probe absorber, the higher of the dashed lines is the multipath without probe absorber, and the lower dashed line is the reduced multipath after adding absorber to the probe. Note that the multipath error is very angular dependent and therefore will affect the antenna differently in different directions. The high multipath on boresight is clearly due to the larger reflections off the probe mounting plate.

In the first case, the multipath level is only 5 dB down from the first sidelobe, given rise to a 3.9 dB uncertainty. In the second case, the multipath level is 20 dB down, given rise to a 0.85 dB uncertainty (see Table 7).

Test #2 moves the scanning structure to identify its multipath. Two scans are again taken moving the scanner by λ/4 in Z. The probe-AUT-separation is kept constant however, in order to keep the probe coupling constant, the test is repeated twice with and without absorber on the scanner. The -30 dB sidelobe error results are found in Table 7.

In test #3 the AUT is moved λ/4 in Z. The probe-AUT separation is kept constant by moving the probe also. The scanner was not moved however for simplicity, but the multipath effect from the scanner was so low in test #2 that it was ignored. Figure 3 and Table 7 show that the multipath effect from absorber behind the wall accounts for 0.48 dB uncertainty at the -30 dB sidelobe. It should be noted that elimination of the wall absorber would have only increased the overall uncertainty by 0.3 dB to 1.3 dB. This is consistent with many such portable systems.

At this point, it was noted that the first sidelobe test requirement was met and so no further absorber testing was necessary. If greater accuracy was required on sidelobes further form scanner boresight, other things could have been done to reduce the multipath, such as replacing the AN-74 flat absorber with pyramidal and by adding absorber behind the AUT. In addition, increasing the distance between multipath sources will also reduce their effect. This can be done by increasing probe-AUT separation.

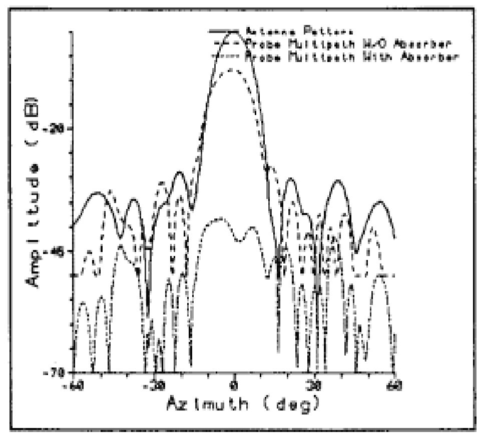

Figure 1 Multipath Effects from Probe Structure

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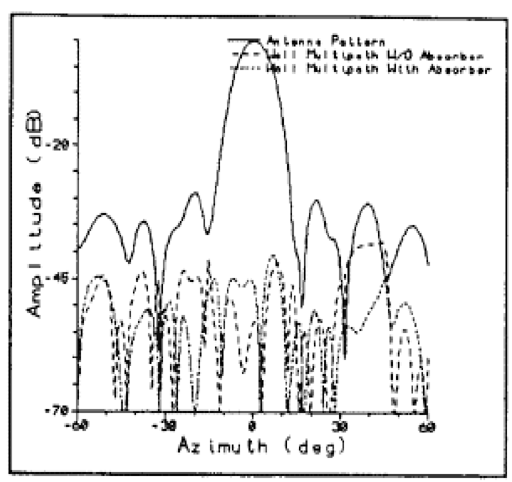

Figure 2 Multipath Effects from Scanner

Results

Multipath suppression in the office environment was achieved to meet the test requirements of ±1.0 dB at the -30 dB sidelobe level with 4 in. pyramidal absorber on the probe and scanner and AN-70 flat absorber on the wall behind the scanner. This is significantly less costly than building an enclosed chamber and keeps the system portable and flexible. A further reduction of approximately 10-20dB can be made in the direction perpendicular to the scanner by coherently adding multiple scans (2). It should be noted that the mu ltipath tests performed for this paper were limited due to time. A more rigorous application of these techniques would include more tests in different configurations and gave more confidence in the uncertainty levels.

The example shown here is typical of the test environments of office and production areas. This technique allows the antenna test group to empirically determine the placement and quality of absorber required through simple one-button automatic tests. As test requirements change (i.e. uncertainty spec., relocation of the range, antenna types.) multipath errors can be reevaluated with ease.

Conclusion

Methods of multipath evaluation and location are essential to determine measurement uncertainties in the near-field range. When the evaluation is made and it is determined that the measurement uncertainties are too high, multiple automated self-comparison measurements will locate multipath reflections sources and aid in reducing their efforts.

This method has a wide application in both minimizing absorber placement in the production and office environment, and in enhancing the low-scattering anechoic chamber.

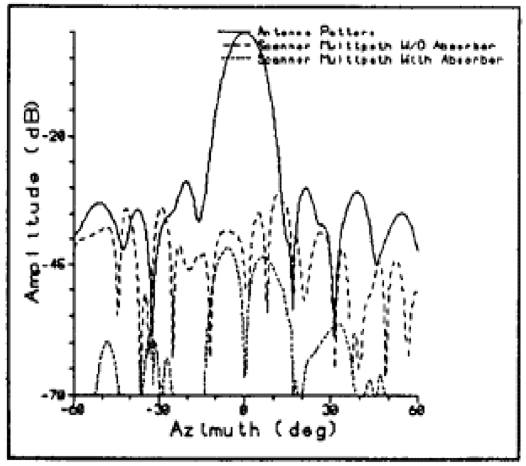

Figure 3 Multipath Effects from Walls

References

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3. Hindman, G. Anechoic Chamber Diagnostic Imaging, 1992 AMTA Symposium