

When to Perform Antenna Measurements in a Near-Field Range or a Short Tapered Chamber

by Theodore K Anthony

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REPORT DOCUMENTATION PAGE					Form Approved OMB No. 0704-0188		
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.							
1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE			3. DATES COVERED (From - To)		
March 2017		Technical Report			1–31 December 2016		
4. TITLE AND SUB	TITLE				5a. CONTRACT NUMBER		
When to Perfo	rm Antenna Meas	urements in a Near	Field Range or a	a Short			
Tapered Cham	lber				5b. GRANT NUMBER		
					5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Theodore K A	nthony				5d. PROJECT NUMBER		
					5e. TASK NUMBER		
					5f. WORK UNIT NUMBER		
7. PERFORMING C	DRGANIZATION NAMI	E(S) AND ADDRESS(ES)			8. PERFORMING ORGANIZATION REPORT NUMBER		
US Army Rese	earch Laboratory						
ATTN: RDRL	-SER-M				ARL-TR-7963		
2800 Powder N	Mill Road						
			SC/EC)				
3. 3PONSORING/1	NONTOKING AGENC		33(L3)		10. SPONSORY MONITOR'S ACRONINGS		
					11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION	I/AVAILABILITY STATE	MENT			-		
Approved for j	public release; dis	tribution unlimited.					
13. SUPPLEMENT	ARY NOTES						
14. ABSTRACT							
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Research Labo	Research Laboratory's (ARL's) near-field range and tapered anechoic chamber. Our 2 antenna measurement systems obtain						
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test in the mos	t cost-effective ma	anner (man-hours, o	custom mount, et	c.)			
15. SUBJECT TERMS							
electromagnetic, chamber, near-field range, anechoic chamber, antenna measurement							
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON		
					Theodore K Anthony		
a. REPORT	b. ABSTRACT	c. THIS PAGE	TIT	16	19b. TELEPHONE NUMBER (Include area code)		
Unclassified	Unclassified	Unclassified	00	16	301-394-1154		

Standard Form 298 (Rev. 8/98) Prescribed by ANSI Std. Z39.18

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1. Introduction

This study was undertaken to quantify and compare electromagnetic (EM) device (i.e., antenna) measurements using the US Army Research Laboratory's (ARL) near-field range (NFR) and tapered anechoic chamber. Our 2 antenna measurement systems obtain similar results, as reported in a previous ARL technical report, *A Comparison of Antenna Measurements in a Near-Field Range and a Newly Renovated Short Tapered Chamber*,¹ but a decision tree was requested to obtain the results for future antennas under test (AUTs) in the most cost-effective manner (man-hours, custom mounting, etc.). The NFR and tapered anechoic chamber are the basic resources that the antenna team can use to measure and characterize EM fields that are transmitted and/or received by devices (e.g., antennas) to validate simulated performance with measured data. Accordingly, it was imperative that a decision tree mapping out the most cost-effective manner to obtain AUT data be established for either the NFR or tapered anechoic chamber.

The NFR can obtain planar, cylindrical, or spherical near-field measurements of EM fields, while the tapered anechoic chamber can obtain spherical far-field pattern measurements of EM fields. Our NFR has a frequency range of 1.2–50 GHz with maximum internal chamber dimensions of $25 \times 16 \times 10$ ft, while the tapered anechoic chamber has a frequency range of 0.2–50 GHz with chamber dimensions of $20 \times 20 \times 55$ ft.

2. Decision Tree Parameters

Deciding when to use either the NFR or the tapered anechoic chamber, also named the far-field range (FFR), is a complex process. Fortunately, the information needed for this decision can be obtained, but compromises might need to be made for speed, resolution, and setup costs. The most important decision parameters of interest are the customer's output requirements. More decision parameters are the AUT's characteristics such as weight, dimensions, and directivity. These parameters, along with time frame and funding level, determine if there is a need for phi axis AUT custom mounting.

The customer's output requirements can include frequency range and resolution, angular range and resolution, polarization, 3-D and 2-D radiation patterns, and boresight realized gain. The customer's output requirements will navigate most of the route on the decision tree. The AUT's weight, dimensions, and directivity will then narrow the decision tree parameters further, taking you to the final turn. Finally, a decision has to be made if the data collection process needs to be sped up by crafting a phi axis custom mount for the AUT.

3. Decision Tree Questions

This decision tree process is mostly yes/no answers to questions based on the information on hand. The following are a few questions to ask, with the decision and reason in parentheses:

- When must you get this data by? (Helps to set priority level, and sets the bound for the most that could possibly be done.)
- Does the AUT only transmit through its own source? (If yes, the FFR is best suited for this measurement since the NFR would be harder to convert for this type of measurement.)
- Are any of the frequencies of interest below 1.2 GHz? (If yes, only the FFR [0.2–50 GHz] can measure below 1.2 GHz. The NFR measures from 1.2 to 50 GHz.)
- Do you only need boresight realized gain? (If yes, only the FFR can measure just the boresight realized gain. The NFR requires measuring a great portion of the AUT's radiation surface energy [3-D] to calculate the AUT's gain.)
- Is $f_{MAX}[GHz] > 19.685/(D[feet])^2$, where D is the diagonal across the AUT's aperture? (If yes, only the NFR can measure this AUT since this is considered a near-field measurement.)
- Is the AUT's front to back ratio worse than 10 dB? (If yes, only the FFR can measure this AUT since the NFR's back plate will corrupt the data without reflection mitigation.)
- What are the AUT's dimensions and weight? (The FFR is more accommodating than the NFR in that it has more space to maneuver large AUTs and the ability to spin over 5000 N on its turntable.)
- Would the AUT's torque on the phi axis plate be greater than 60 N-m? (If yes, the FFR is best suited for this measurement since the NFR cannot withstand as much torque as the FFR.)
- Do you need 3-D radiation patterns? (If yes, a phi axis custom mount for the AUT needs to be crafted for the NFR, or a Styrofoam cylinder or sphere needs to surround the AUT under test centered along the AUT's phi axis for the FFR.)
- Is there going to be a phi axis custom mounting for the AUT? (If no, the FFR is best suited for this measurement since the NFR cannot cover 330° without a phi axis custom mount.)

• Do you only need 2-D radiation patterns? (If yes, only the FFR can measure just the 2-D radiation patterns. The NFR requires measuring a great portion of the AUT's radiation surface energy [3-D] to calculate the AUT's 2-D radiation patterns.)

4. Antenna Theory

For the purposes of testing in the NFR, the antenna must be situated in the radiating near-field for proper data acquisition. The antenna has a reactive near-field from 0 to λ with a fairly flat field distribution, where objects in this region can possibly cause unwanted coupling to the antenna. As such, near-field systems cannot measure inside this region due to the unknown coupling effects to an AUT. The radiating near-field is from λ to $2D^2/\lambda$ with a fairly smooth field distribution, where D is the largest dimension across the aperture.³ Near-field systems measure inside this region. The far-field region is next, extending beyond $2D^2/\lambda$, where most antenna chamber measurements are done. Figure 1 shows the fields from a radiating antenna.



Fig. 1 Fields from a radiating antenna (image courtesy of Nearfield Systems, Inc.²)

The theory behind near-field measurements was developed at the National Institute of Science and Technology (NIST) in the 1970s by the Technical University of Denmark and NIST. NIST has validated the mathematical calculation of far-field patterns based on amplitude and phase samples in the radiating near-field.

5. Near-Field Range

The near-field planar measurement system is best suited for characterizing highly directive antennas or arrays because less than a hemisphere (spanning $180^{\circ} \times 180^{\circ}$) of energy can be measured with a planar scan. The AUT is positioned 3–5 wavelengths away from the planar scanner, hampering any wideband characterization without relocating the AUT. In addition, the hemisphere transitions to a narrower cone measurement as the test frequency lowers, thereby reducing the angular span of the measurement. The planar NFR uses waveguide probe antennas (7 antennas cover 1.1–18 GHz) with no AUT slide or removable mast and can measure mid- and small-sized AUTs. A single planar scan requires about 1 h of acquisition time for each waveguide probe measurement. No 2-D far-field patterns can be produced until a full planar near-field measurement is completed.

The near-field spherical measurement system can be used for characterizing antennas or arrays and can measure EM fields spanning $330^{\circ} \times 180^{\circ}$ of a sphere on a single setup. For this measurement the AUT should be placed above the azimuth positioner's center of rotation while centered along the phi positioner's center of rotation. The spherical NFR uses waveguide probe antennas (7 antennas cover 1.1–18 GHz) with no AUT slide or removable mast and can measure mid- and small-sized AUTs. A single spherical scan can require 2–72 h depending on wavelength and antenna positioning. Two-dimensional far-field patterns cannot be produced until a full spherical near-field measurement is completed. Therefore, spherical near-field measurements are better than planar for this comparison study with the tapered anechoic chamber.

6. Tapered Anechoic Chamber (Far-Field Range)

ARL's tapered anechoic chamber spherical measurement system can be used for characterizing antennas or arrays and can measure EM fields spanning $360^{\circ} \times 180^{\circ}$ of a sphere. It can measure a single point to determine realized gain, angular sweeps for 2-D pattern cuts, circular polarization, and 3-D patterns. The AUT should be placed above the azimuth positioner's center of rotation while centered along the phi positioner's center of rotation. The chamber uses decade calibration antennas (2 antennas cover 0.2–18 GHz) and has an AUT slide with removable mast, allowing measurement of large and small AUTs. A single 3-D spherical scan will take 3 h for 1–18 GHz, but a 2-D cut plane takes about 5 min. Figure 2, a decision tree, and Fig. 3, a Venn diagram, map out the most cost-effective manner to obtain AUT data from either the NFR or FFR.



- 01. Frequencies of interest below 1.2 GHz
- 02. AUT only transmits (Tx) through its own source
- 03. Only need boresightrealized gain or 2-D patterns
- 04. AUT's front-to-back ratio worse than 10 dB
- 05. AUT too big and/or heavy for NFR
- 06. AUT's torque on the phi axis plate greater than 60 N-m
- 07. Phi axis custom mounting for the AUT
- 08. Need 3-D radiation patterns
- 09. F_{MAX}[GHz] < 19.685/(D[feet])², where D is diagonal across AUT's aperture

Fig. 2 NFR/FFR decision tree



Fig. 3 Venn diagram shows the best antenna range given conditions.

7. Conclusion

This study was initially motivated to further validate our EM device measurements. Then a decision tree, mapping out the most cost-effective manner to obtain AUT data from either the NFR or FFR, was requested. Both systems measure patterns well, but each system has its own unique capabilities. Pattern and gain measurements are done quickest over a wide frequency range in the tapered anechoic chamber. The tapered anechoic chamber can also be used to find an antenna's phase centers. The NFR is best suited to produce far-field patterns from measured near-fields of antenna arrays and finding EM leakage with its NSI software tools. ARL's planar near-field measurement system requires the AUT to have a gain greater than 15 dBi, while a spherical near-field measurement only requires the AUT minimize radiation toward the phi positioner's metal mounting plate.

The initial study proved that the tapered anechoic chamber and NFR do provide comparable results, which further validates our EM device measurements. In addition, the highly detailed antenna range decision tree was successfully developed, clarifying when to use either the NFR or FFR for a given AUT.

8. References

- 1. Anthony TK. A comparison of antenna measurements in a near-field range and a newly renovated short tapered chamber. Adelphi (MD): Army Research Laboratory (US); 2016 Sept. Report No.: ARL-TR-7828.
- 2. Gray D. How to choose an antenna range configuration. Torrance (CA): NSI, Inc.; 2002 [accessed 2016 Sep]. www.nearfield.com.
- 3. Balanis CA. Antenna theory: analysis and design. Hoboken (NJ): Wiley Interscience; 2005. p. 167–170.

List of Symbols, Abbreviations, and Acronyms

2-D	2-dimensional
3-D	3-dimensional
ARL	US Army Research Laboratory
AUT	antenna under test
EM	electromagnetic
FFR	far-field range
NFR	near-field range
NIST	National Institute of Science and Technology

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