HOW TO CHOOSE AN ANTENNA RANGE CONFIGURATION

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Abstract

Choosing the proper antenna range configuration is important in making accurate measurements and verifying antenna performance. This paper will describe the steps involved so the antenna engineer can select and specify the best antenna range configuration for a given antenna. It will describe the factors involved in choosing between near-field systems versus far-field systems, and the different scan types involved. It will explain the advantages of each type of antenna range and how the choices are affected by such factors as aperture size, frequency range, gain, beamwidth, polarization, field of view, sidelobe levels, and backlobe characterization desires. This paper will help the antenna engineer identify, understand, and evaluate the applicable characteristics and will help him in specifying the proper antenna range for testing the antenna.

Keywords: Antenna Measurements; Far-field; Near-field; Range Configuration.

1.0 Introduction

This paper describes how to specify an antenna range for performing antenna measurement testing. Antennas are becoming increasingly more sophisticated to the meet the needs of more complex technical applications [1]. This precipitates the need for more advanced techniques in testing these antennas to verify the performance. This paper explains the techniques and configurations available, such as outdoor far-field ranges, compact ranges, and near-field ranges. It explores the factors and criteria involved in choosing the best test configuration for a given antenna and application.

2.0 Types of Antenna Ranges

This paper will address the most commonly used antenna ranges, and these fall into two categories: far-field ranges and near-field ranges. Far-field ranges include the traditional outdoor far-field range, the indoor far-field range, and the compact range. Near-field ranges include planar near-field, cylindrical near-field, and spherical near-field configurations.

The far-field region is most typically defined as $2D^2/\lambda$ (D refers to the largest dimension of the antenna under test, or AUT). At this distance, the wave front is nearly of equal phase across the area of measurement. The phase change is less than 1/16 of a wavelength, or 22 degrees. This is shown Figure 1.

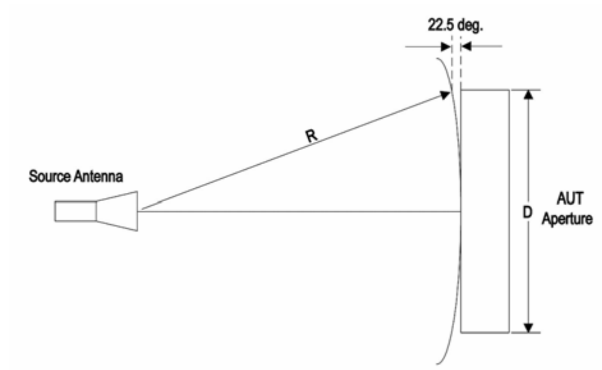

Figure 1 - Far-field Distance Determination

At these distances, the radiated pattern approximates a plane wave and good antenna measurements can be taken. An example of an outdoor far-field range is shown in Figure 2.

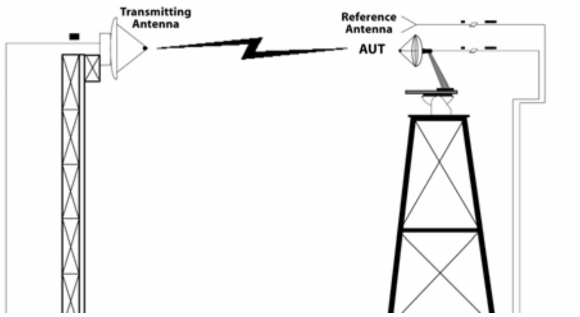

Figure 2 - Outdoor Far-field Range

Far-field Ranges

An outdoor far-field range is used for moderate to long far-field distances. The antennas are usually mounted high to minimize reflections, but other techniques exist, such as ground reflect ranges or slant ranges. Outdoor far-field testing requires suitable real estate and cooperative weather. Also, outdoor ranges presents problems when security or EM shielding is an important.

An indoor far-field range is typically inside an anechoic chamber, like the example shown in Figure 3.

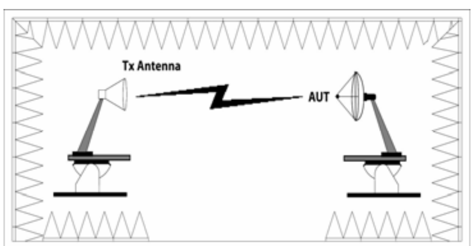

Figure 3 - Indoor Far-field Range

The chamber is used to control reflections. These ranges are good for short far-field distances and provide security measures and protection from environmental elements.

A compact range uses a reflector, or set of reflectors, designed to collimate the radiated pattern and create a plane wave at considerably shorter distances. Figure 4 shows a single reflector compact range.

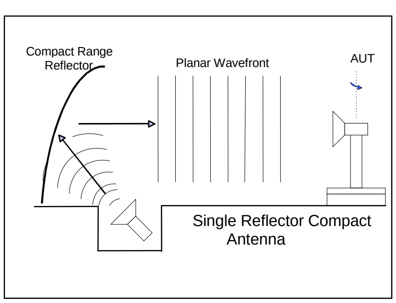

Figure 4- Single Reflector Compact Range

A compact range is typically inside an anechoic chamber, although outdoor compact ranges exist. Indoor, compact ranges provide good protection against weather and are good for providing security measures.

Near-field Ranges

Near-field antenna measurements occur in the radiating near-field region. Figure 5 shows the reactive, or evanescent, energy from a radiating antenna decays very rapidly.

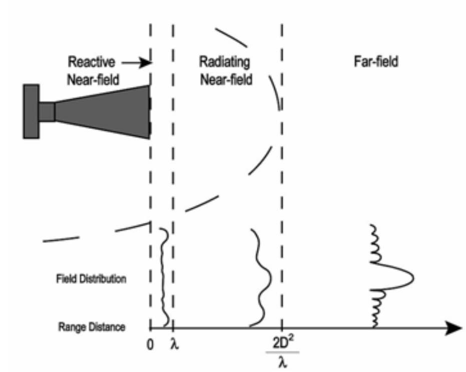

Figure 5 - Fields of a Radiating Antenna

At about one to three wavelengths, this energy has completely dissipated. Beyond this evanescent near-field region is the radiating near-field region. It is in this region that amplitude and phase data is collected for near-field testing at prescribed intervals, usually at $\lambda/2$ spacing.

In a planar near-field range, the energy radiated from the antenna is scanned in one plane (typically, vertically or horizontally). The example shown in Figure 6 is an example of a vertical, planar near-field range. In a planar near-field range the antenna remains stationary. This type of range is good for testing antennas of high directivity.

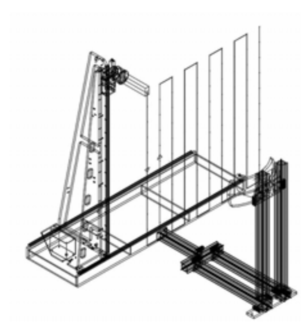

Figure 6 - Planar Near-field Range

A cylindrical near-field configuration is one in which the energy radiated from an antenna is scanned in a cylinder about the antenna. Figure 7 shows a typical cylindrical configuration.

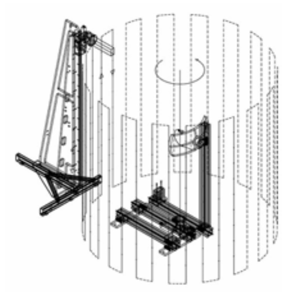

Figure 7 - Cylindrical Near-field Range

In a cylindrical near-field range the AUT is rotated about its axis while the probe scans vertically (typically) to capture a cylindrical grid of samples.

A spherical near-field configuration is one in which the energy radiated from an antenna is scanned in a sphere about the antenna. Figure 6 shows one example of a spherical configuration. In this configuration, the AUT is rotated about two axes, while the probe remains stationary. By rotating the antenna about both axes, the probe can collect a grid of samples in a complete sphere and thus capture nearly all of the energy radiated.

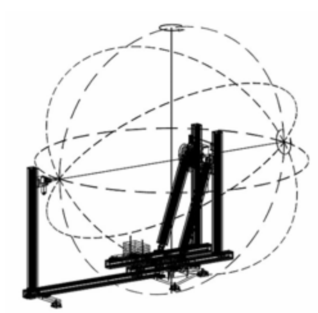

Figure 8 - Spherical Near-field Range

3.0 AUT Characteristics versus Range Choice

The characteristics and application of the AUT are the basic factors that determine which range configuration are best suited for test and measurements of that AUT. One must consider:

- Application
- Far-field Angular Coverage
- Electrical Size
- Directivity
- Frequency
- Environmental and Security Requirements
- Other factors

<u>Application</u>

The application of the antenna test can narrow down the choice of an antenna range between far-field and near-field. If the requirement is to obtain patterns or immediate response at a specific location, then a far-field solution should be considered. If the requirement is to measure the aperture then a near-field solution should be considered. Closed -looped, monopulse tracking, or radar simulation, are examples of applications suited to far-field testing. Phased array element tuning is an example of an application suited to near-field testing.

<u>Far-field Angular Coverage</u>

The far-field angular coverage plays a key role in a range specification. For example, if only principal-plane patterns are required, then a simpler configuration can be used than if inter-cardinal cuts are required. For applications that are suited to near-field solutions, far-field angular coverage desired plays an important role as to which of the three near-field configurations is best. If 75 degrees or less of angular coverage (as measured form the center of the beam peak) is desired, then a planar near-field range is a good choice for high gain antennas. However, trying to capture energy in excess of 75 degrees becomes unmanageable for a planar scanner. Thus, a cylindrical or spherical option needs to be considered for this case.

<u>Electrical Size</u>

Another important factor is the electrical size of the antenna. Consider the $2D^2/\lambda$ far-field definition. As the electrical size of the antenna increases, the distance to get into the far-field region becomes large. This can be a problem for traditional far-field configurations, but is not a problem for near-field ranges.

<u>Directivity</u>

Directivity is the amount of energy in the main beam relative to the amount of energy radiated elsewhere in the pattern. In general, directivity describes the amount of energy radiated forward that can be captured in a relatively small angular space. Figure 9 shows a pattern with high directivity on the left and a pattern with low directivity on the right.

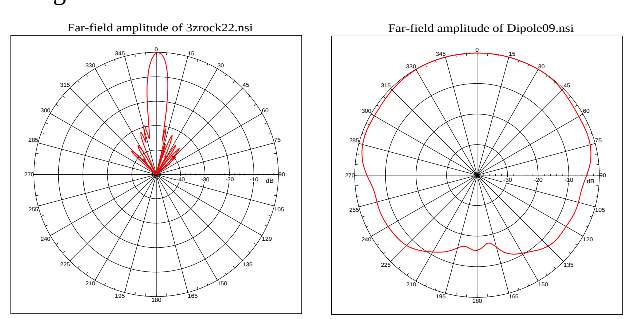

Figure 9 - Patterns of High and Low Directivity

In a near-field configuration, the rule of thumb is: if directivity is greater than 15 dBi, then a planar near-field configuration will be suitable [3]. If directivity is less than 15 dBi, then cylindrical, or spherical configurations are more suitable because one has to scan a greater angular span about the antenna to capture all significant energy.

For example, consider the pattern on the left in Figure 9. A planar scanner can very easily capture the significant amount of energy with a scan of less than ±20 or ±30 degrees beyond the edge of the antenna aperture. Also, sidelobes can easily be characterized with scans out to ±45 or ±60 degrees.

Conversely, the pattern on the right in Figure 9 cannot be adequately characterized with a planar scanner. For that type of radiation pattern, one needs to collect data out to angles well in excess of what is capable with a planar scanner. For this particular pattern one needs to scan a full 360 degrees. A cylindrical scanner is required if the pattern is equivalent to this in only one axis, and narrow in the other axis (a fan beam). A spherical scanner is required if the pattern is equivalent to this in both axes (omni-directional).

In a far-field configuration, directivity is important because it is a good indicator of the far-field distance. Consider that directivity is related to the aperture size of the antenna. Thus, the $2D^2/\lambda$ term will be small for low gain (low directivity) antennas and large for high gain (high directivity) antennas. If $2D^2/\lambda$ is small, and the antenna engineer is interested only in principal plane cuts, then a far-field configuration is the best solution because it offers a simple, inexpensive solution and offers minimal antenna measurement time.

Frequency

Frequency is important in determining chamber sizes and for determining if an outdoor configuration is the best solution. The lower the frequency being tested, the larger the absorber size needed. Further, the percentage of chamber volume used by the absorber becomes greater with lower frequencies. Consider the example shown in Figure 10. (Note, the legend to the right lists absorber sizes in feet.)

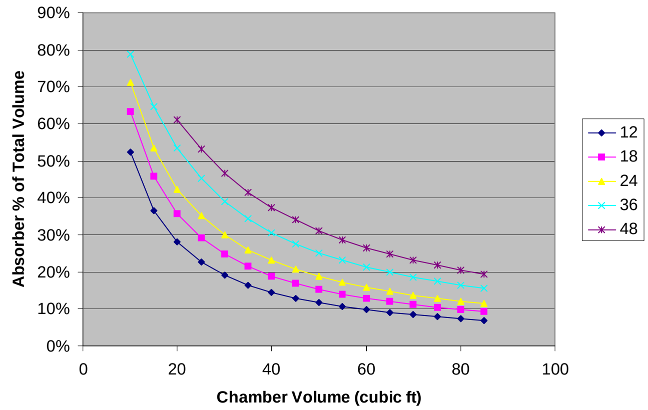

Figure 10 - Chamber Absorber Volume

This figure shows that at lower frequencies (larger absorber), the chamber needs to be larger, even as the far-field becomes shorter, merely to accommodate the absorber size. At lower frequencies, absorber is of greater importance in mitigating reflections, and cannot be disregarded.

Eventually, as frequencies get too low, testing on an outdoor far-field range needs to be considered. This is because lower frequencies present greater challenges in controlling reflections in chambers and because the absorber size required is so large that it becomes unmanageable and extremely expensive. Moreover, the resulting chamber size required to mount the absorber becomes large and costly.

Environmental and Security Requirements

Environmental and security requirements can drive indoor test configurations. Security issues may dictate an indoor facility due to the poor ability to provide physical and electromagnetic security on an outdoor range. Also, an indoor range may be necessary to protect antenna testing from electromagnetic interference or from the elements of the weather. Setting up to perform outdoor testing during a windy, snowy blizzard can make outdoor testing challenging at best.

Other Factors

Other factors, those which affect other components of a range configuration, must be considered in choosing an antenna range. The physical size and weight of the AUT must be considered in analyzing mounting requirements. For example, if the antenna is large and is not stiff enough, then asymmetrical gravitational effects can cause the antenna to warp. This is particularly true of space applications. In these cases one should select a mounting structure that supports the antenna in such a way that its pattern does not change while it is being tested. One common method of handling this issue is with a horizontal, planar near-field configuration. This allows the AUT to remain stationary, and is mounted with its axis aligned with gravity. This mitigates gravitational warping and keeps the distortion more symmetrical and predictable.

In addition, the antenna weight and mounting structure will affect the size, torque, bending moment, and loading requirements of the positioners. Larger, heavier antennas require larger positioners with greater load capacities.

Lastly, the desire to measure co- and cross-polarization, multiple ports, and multiple frequencies must also be considered. These necessitate computer controlled, motorized polarization positioners, computer controlled switches, rotary joints, and slip rings.

4.0 Choosing a Range Configuration

Choosing an antenna range involves trade offs. Each type of antenna range has advantages and disadvantages. The decision tree in Figure 11 (at the end of the paper) shows some general rules of thumb for choosing an antenna range. It is important to remember that these are only general guidelines, and certainly not absolutes.

As this decision tree shows, far-field measurements are generally better suited for lower frequencies, simple pattern cuts, and real-time radar applications. Near-field measurements are generally better suited for higher frequencies involving complete pattern and polarization measurements [2].

Once a far-field solution is chosen, one needs to consider real estate versus building requirements. If real estate is abundant, and weather and security permit, then an outdoor range will be chosen. If the far-field distance is short, then an indoor far-field range is a possibility. If the far-field distance is long, yet environmental or security issues require indoor testing, then a compact range (or a near-field configuration) will be the better choice.

If a near-field range is chosen, then a planar configuration will usually be the choice for antennas of high directivity (> 15 dBi) [3]. In these instances, planar configurations provide adequate angular coverage, and are less complex and costly than a cylindrical or spherical configuration. One example of an exception to this is for backlobe measurements. If these are required, then a cylindrical or spherical option needs to be considered.

If the AUT has lower directivity, then a planar system is not adequate to collect all significant energy. Thus, for low directivity, a cylindrical configuration will be the likely choice for a fan beam pattern. A spherical configuration is needed for more omni-directional patterns. A spherical near-field configuration can be used to measure antennas of any type. It is the most pure and complete near-field antenna measurement solution.

Many of the choices shown in the decision tree do not consider cost and complexity. Nonetheless, the figure shows a good set of rules to narrow down the choices and understand what antenna range works best for a given application. Additionally, Table 1 (at the end of the paper) goes into greater detail regarding trade offs of each type of antenna range for testing various characteristics of an antenna.

5.0 Examples

Consider some antennas and how the correct range is chosen for each:

One example is large satellite reflector with very high gain. This type of antenna typically operates at high frequencies and would have an extremely large far-field distance. It is best tested on a planar near-field range. The same holds true for a large phased-array antenna in which one wants to fine tune the elements and use holographic imagery.

A second example is a cell phone antenna on the handset. This type of antenna radiates in an omni-directional pattern (it is low gain) and operates over moderately low frequencies (typically, in the range of 0.8 to 2 GHz). Additionally, the antenna test engineer is usually interested in taking single, principal plane cuts. This type of an antenna may be best suited for an indoor far-field range using a single axis AUT positioner. The far-field distance is typically on the order of 6 cm, thus facility costs would be relatively inexpensive and test time would be very short.

A third example is a GPS automotive antenna tested in its operational configuration on the car. This type of antenna radiates in a hemi-sphere about the upper half of the car. It is a good fit for an outdoor, spherical near-field facility using a heavy-duty rotational positioner to rotate the car 360 degrees.

6.0 Summary

This paper has shown that selecting an antenna range is not trivial. It involves several complex tradeoffs related to antenna characteristics, range size, and range cost. In general, far-field ranges should be considered for low gain antennas. low frequency measurements, and real-time system measurements. Near-field ranges should be considered for high gain antennas, high frequency measurements, and aperture measurements. Since considerable resources may be required to build an antenna range, both the current and future range requirements should be considered in the tradeoff.

This paper explains – at a high level – the factors that must be considered in making a choice for an antenna range. It gives some useful rules of thumb and gives explanations that should help the antenna engineer get started in making a selection.

References

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.[3] Selecting A System. Nearfield Systems Technical web site. http://techsupport.nearfield.com/theTechnicalDesk/SelectingAsystem.htm

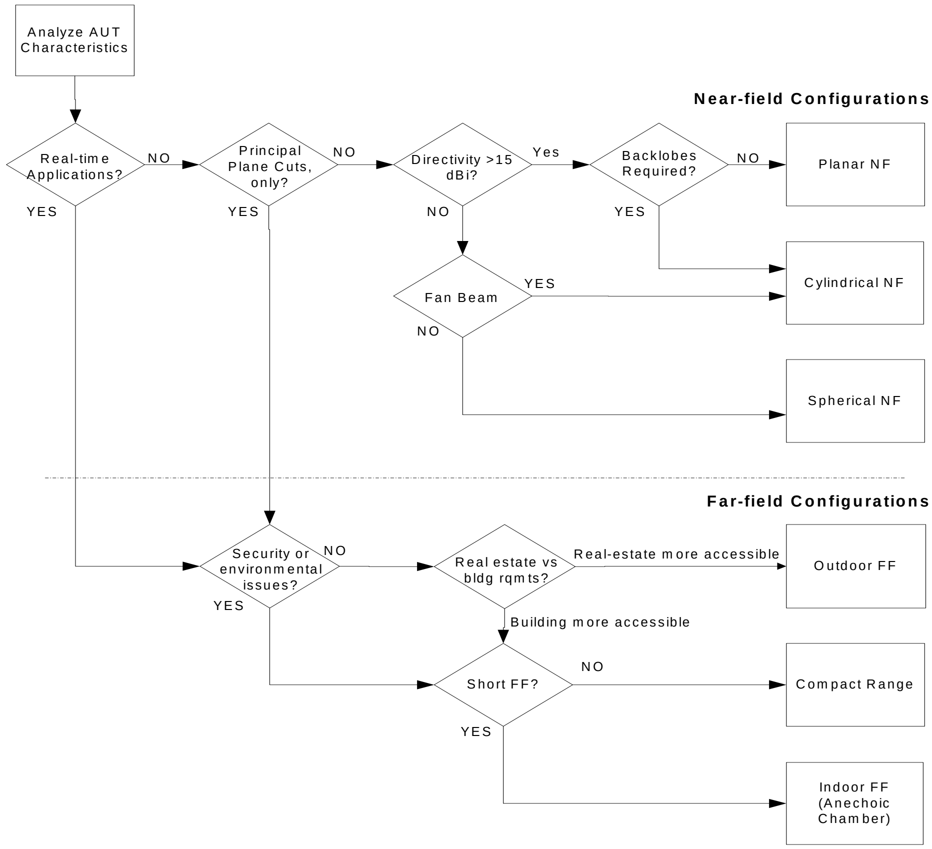

Figure 11 - Antenna Range Decision Tree

Table 1 - Antenna Characteristics versus Antenna Range Selection

	NEAR-FIELD			FAR-FIELD		
	PLANAR	CYLINDRICAL	SPHERICAL	OUTDOOR RANGE	ANECHOIC CHAMBER	COMPACT RANGE
High gain antenna	Excellent	Good	Good	Adequate	Adequate	Excellent
Low gain antenna	Poor	Good	Good	Adequate	Good	Excellent
High frequency	Excellent	Excellent	Excellent	Good	Poor	Excellent
Low frequency	Poor	Poor	Good	Good	Fair	Poor
Gain measurement	Excellent	Good	Good	Excellent	Good	Excellent
Close sidelobes	Excellent	Excellent	Excellent	Good	Poor	Excellent
Far sidelobes	Adequate	Excellent	Excellent	Good	Poor	Good
Low sidelobes	Excellent	Excellent	Excellent	Variable	Poor	Good
Axial ratio	Excellent	Excellent	Excellent	Good	Poor	Good
Zero G effects	Excellent (horizontal mode)	Poor	Good (horizontal mode)	Poor	Poor	Poor
Multipath	Good	Good	Good	Adequate	Adequate	Good
Weather	Excellent	Excellent	Excellent	Poor	Excellent	Excellent
Security	Excellent	Excellent	Excellent	Poor	Excellent	Excellent
Facility cost	Low	Moderate	Moderate	High (land value)	Moderate	Very high
Operating cost	Moderate	Moderate	Moderate	High (remote)	Moderate	Moderate
Speed (complete measurements)	Excellent	Good	Fair	Fair	Fair	Fair
Speed (simple cuts)	Good	Fair	Fair	Excellent	Excellent	Excellent
Complexity	Moderate	Moderate	High	Moderate	Low	High
Mechanical surface measurements	Excellent	No	No	No	No	No
Antenna access	Excellent	Excellent	Excellent	Good	Good	Fair
Antenna alignment	Easy	Moderate	Difficult	Moderate	Moderate	Difficult