Antenna Lab – Report#3

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Report #1

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Summary: Antenna Ranges

Introduction and Definition

We discussed about the transmitting and receiving side of communication systems in the previous lectures. This lecture is about the media. The third main component in such systems. A Proper media should have **low effect** on antenna's properties and also the **measurements** in such a media would be **directly affected** by **design considerations** of the antenna (in space and frequency domain)

Its also important to note that, radiation properties affect the antenna much more than circuit properties of the components of it.

Far-field Zone:

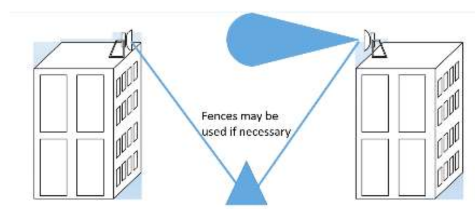
Far field zone is an area where the received wavefronts are approximately uniform wave planes (22.5 degrees deviation across the antenna aperture is accepted; equivalently any distance larger than $R \geq \frac{2D^2}{\lambda}$).We usually approximate far field and don't go that far to actually achieve it completely.

There are 2 Different Antenna Range Types: 1. Free Space Ranges 2. Reflection Ranges

Antenna parameters can be measured in free space where surrounding have a very low impact on measurements. Or as it's done practically, they can be measured in reflective areas where the reflections that we try to avoid can be used constructively to actually form uniform waves as well (compact chambers)

There are mainly 4 type of reflection ranges: **1. Elevated, 2. Slant, 3. Compact, 4. Anechoic chambers**

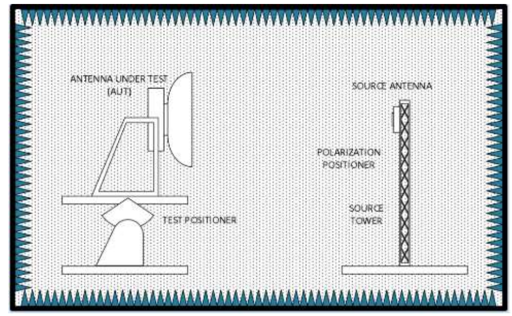
Elevated Ranges: this type of reflection range is based on putting both the source antenna and the AUT in a specific height (above buildings, on mountain peaks, towers, etc.) to avoid the surrounding effects. They are usually used when we chambers are not big enough or the antenna aperture isn't small enough to yield a far-field area within the chamber. This is done by some techniques as follows:



1. **Adequate Directivity** (If the antenna isn't directive enough the pattern can easily be distorted by reflections from objects)
2. **Direct line of sight:** Source antenna and AUT, should be in the direct line of sight of each other to receive maximum radiation power
3. **Avoiding Redirection (Reflection) & Absorption:** obstacles in the path should have least interaction. Usually **Fencing** is used to avoid reflection from surroundings.
4. **Special signal processing techniques:** ex: modulation tagging
5. **Minimizing Interference**
6. **Using short pulses**

Anechoic Chambers: a chamber is a room that's isolated to interfering waves coming from outside and also completely covered with absorbers, in order to avoid reflection. Absorbers are mainly composed of foam and also a layer of carbon. The quality of an absorber is inversely proportional to the reflection coefficient for a broad range in both frequency and power.

A 3-D radiation patter is deployed by means of combining multiple 2-D radiation patterns measured within the far field zone of a chamber. Each 2-D pattern is also measured by setting sets θ, φ angles with a certain accuracy. This angle setting is done by a positioner that's attached to the AUT. The following figure shows the components used in a chamber.

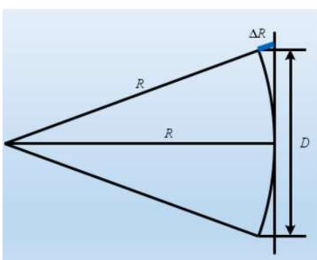


Quiet (Far field) Zone is an area where the received wavefront is approximately a uniform plane wave. This approximation is allowed to have $22.5°$ phase deviation error.

Criteria for Antenna Range

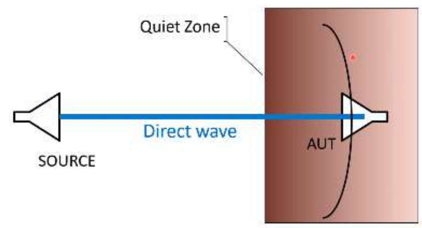
Mutual Coupling: AUT and source antennas experience coupling when they are close to one another. As a result, iterative reactive power exchange will affect measurement results. To avoid coupling results, AUT should approximately be 10λ far from the source antenna.

Amplitude and Phase difference in received wavefront: the less the amplitude and phase difference in the received wavefront, the better planewave is reached, thus more accurate results are obtained. This phase can be calculated via the following formula:

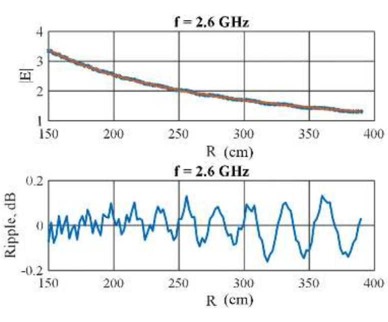


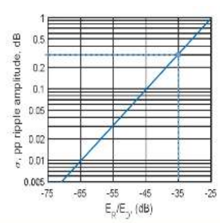
$$\Delta R = \sqrt{R^2 + \left(\frac{D}{2}\right)^2} - R = \frac{\lambda}{16} \Rightarrow R = \frac{2D^2}{\lambda}$$

$$\Delta\varphi = k\Delta R = \frac{\pi}{8} = 22.5°$$

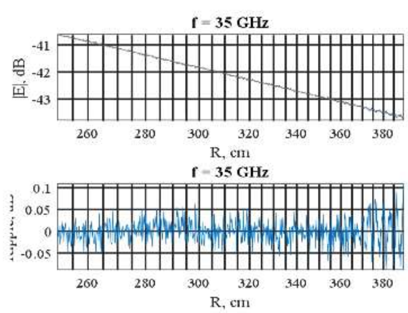


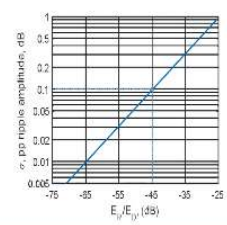
Spatial Variations caused by reflections from non-ideal absorbers: Because of issues such as air-conditioning, we can't cover the whole chamber with absorbers. Moreover, absorbers don't perform completely ideal. Therefore, we observe a ripple on the main measured signal. The distortion caused by the ripple increases with frequency due to the higher reflective potential of material in shorter wave lengths.





$\sigma = 0.3 \text{ dB} \Rightarrow \frac{E_R}{E_D} = -35 \text{ dB}$



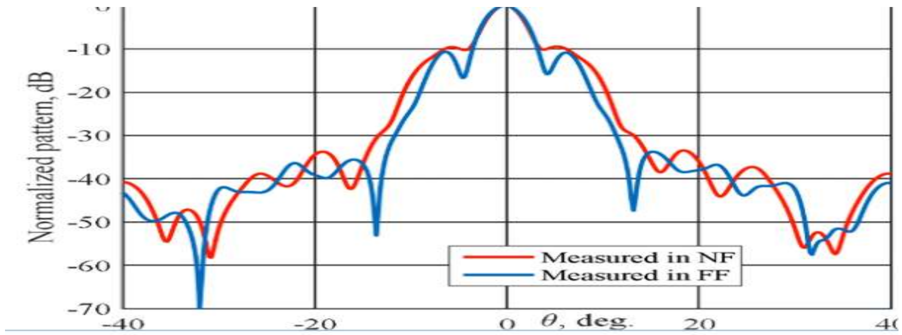


$\sigma = 0.1 \text{ dB} \Rightarrow \frac{E_R}{E_D} = -45 \text{ dB}$

Interference of other devices: They usually make chambers in a way to be as isolated as possible to interference, and this may be considered in this operation frequency

Compact Range Chambers: We use this kind of chamber when the ordinary chamber isn’t capable of making the uniform plane wave within itself, thus we need to use reflections in a constructive way to make this uniform wave ourself.

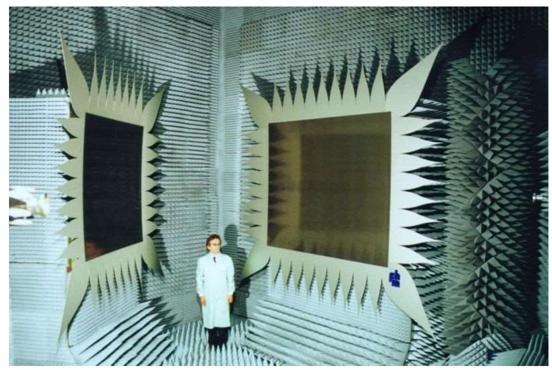
Radiation patterns measured by compact range chambers usually have some filling errors on the side lobes that can be improved via different techniques.



Far-field measurements can also be obtained by applying special transformations on near filed data, plane wave, cylindrical and spherical measurements are integrated, and taken into the frequency domain via Fourier transform to do so.

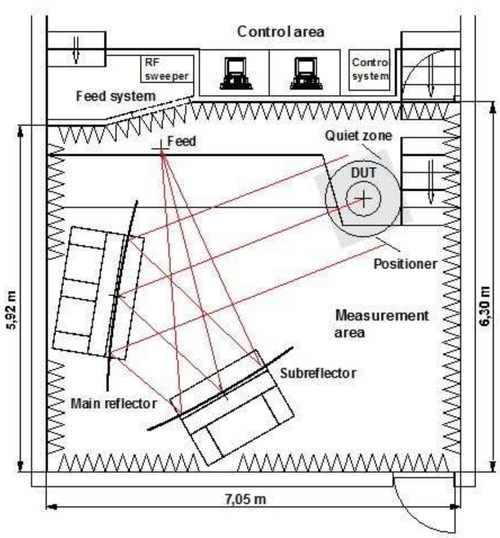
Bonus: Compact Ranges

Compact ranges were a ground breaking invention, that solved many problems measuring radiation patterns, especially for wide aperture antennas such as satellites. The wider an aperture is, the further the far-field region is placed from it. Thus, testing large antennas demands vey big chambers that are impractical deviate from ideal conditions. R. Johnson came up with a solution in 1960's. The main idea was using reflectors in a constructive way to make uniform flat wavefronts. Munich University currently hosts the world's biggest chamber, the CCR (Compensated Compact test Range) that's shown in the figure below.



The CCR is designed based on a double reflection to make an artificial far field zone in a small area around the antenna under test. The reflectors are places in an optimized geometry in order to focus a uniform plane wave on the focal point where the test antenna is placed.

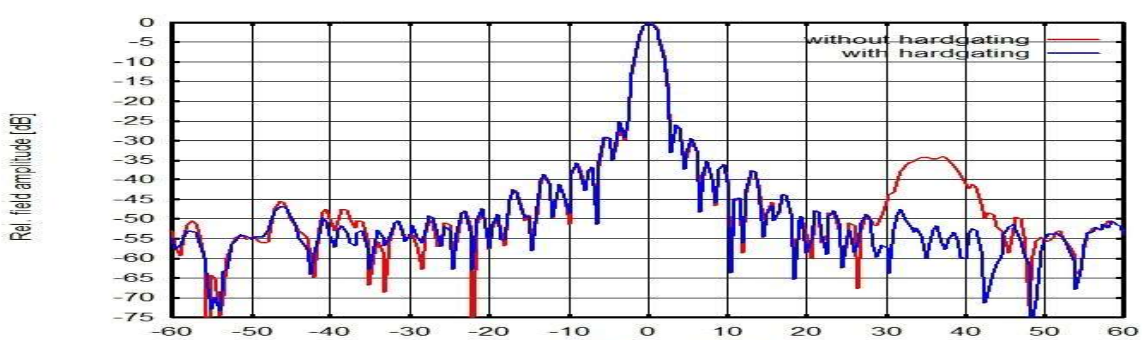
A very accurate plane wave is created using this technique, such that the phase deviation is decreased to only 5 degrees from 23.5 degrees. And this is truly outstanding!



A schematic of the CCR is displayed in this figure. The CCR is also capable of making the wavefronts amplitude deviation decrease to around 0.5dB. CCR uses a six-axis computer to narrow down positioning angles with only 0.01 degrees error.

Size of compact chamber is related to the AUT aperture and also the lowest operational frequency to consider issues for reflecting long wavelengths.

CCR also uses techniques to improve distortion and mistaken fillings in the radiation pattern. One of the techniques used is called hard-gating, that focuses on correcting diffraction errors caused by reflector edges. We can see that performance is highly improved by applying this technique.

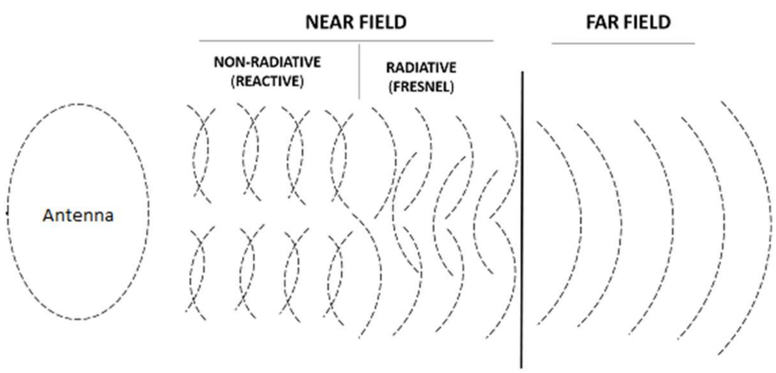


Bonus: Far-field Approximation

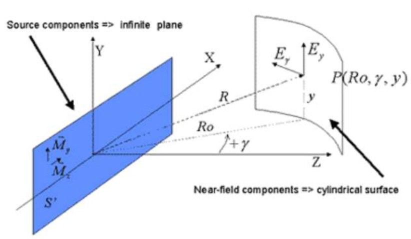
When we can't reach a far-field zone or construct one by ourself, one solution is to use near field measurements in plane, cylindrical and spherical planes and combine the results beside applying Fourier Transform on them to approximate a far-field measurement. There are also interpolation techniques used as an alternative or complementary.

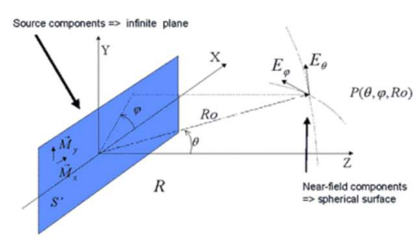
But speaking of near to far field transformations, many papers have been published. Some papers have used array factors to model this transformation. But the common point among all of them is that the measurement is done via a radiating probe.

Array factor methods have the point of only being dependent to the probe's position. Here is a figure showing near and far field wavefront shapes



This figure shows the Near-fields being calculated in cartesian and cylindrical coordinate systems around the source antenna. Applying transformations are found to be a lot easier on cartesian systems.





Also, there's a picture from one of the papers working on array factor method showing how the probe acts as a source antenna. Probe Compensation has also a huge impact on the accuracy of results and lobe detection

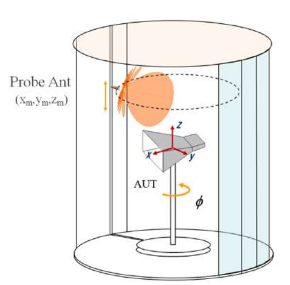


Figure 2. Cylindrical scanning system of near-field measurement