Antenna Lab – Report#5

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Report #1

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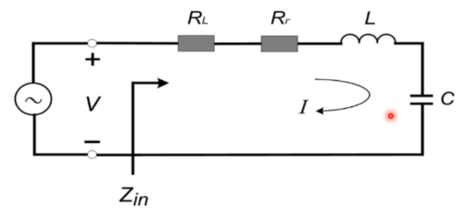
Summary: Antenna Measurements

What to measure?

Parameters measured in antenna labs are mainly in one of the following categories:

1. **Circuit Parameters**

   Impedance, Radiation resistance, Loss



- A complex impedance is seen from the input, including a real part (loss and radiation resistance) and an imaginary part (Inductance and Capacitance). We want a high radiation resistance in ideal conditions for an antenna and low imaginary power (high power factor), also a low loss resistance.

- Antennas show different performances in different frequency ranges. This is due to different input impedances that are directly

- The best radiation performance is when the imaginary part is zero due to resonation of inductance and capacitance, and moreover, the radiation resistance has a sufficient amount to provide our necessities (this implies a high VSWR as well)

2. **Radiation Parameters**

   Beam width, Side lobe level, Gain

How to measure?

Measuring Impedance (actually measuring scattering paramters)

- By feeding an antenna, a known current and voltage, and measuring the reflected current and voltage at the same point, we can obtain AUT's scattering parameters. As we know scattering parameters, impedance and VSWR are closely related to each other.
  So, we can calculate impedance through this measurement process indirectly. This can be done via a Network Analyzer, because it can produce a reference voltage and current and also measure reflected signals at the same time.
  As it was mentioned in the previous report, its important whether our network analyzer has one or multiple ports, if more than 2 ports are used, we can also measure filter responses

- As discussed in the third report, anechoic chambers are used as an ideal environment for antenna measurements, because of their low reflection.

Return Loss Measurement

- $\boldsymbol{S_{11}} = \boldsymbol{-10dB}(VSWR \approx 2)$ is a common threshold for a **sufficiently small return loss**. **Frequency ranges** corresponding to a loss lower than this threshold, can be considered as well-performing frequencies

- We should also use higher **number of points** for cases where wider frequency ranges are under test.

- **Connections** should be as matched as possible. Loose collectors should have the **lowest mismatch factor** as possible, so they can pass as much power we have entered to the antenna circuit, as possible.

- As mentioned before, quality of measurement media/environment plays a main role as well.

Antenna Radiation Pattern:

- An omni directional antenna is an antenna that radiates in a uniform spherical pattern in all directions with the same directivity. The radiation intensity and power of such an antenna can be obtained using the following formulas:

$$P = \frac{W_t}{4\pi R^2} \qquad U = \frac{W_t}{4\pi} = R^2 P$$

- Directivity of an antenna is the ration between the maximum power at certain angle to the average power in all angles:

$$D = \frac{U_m}{U_0} = \frac{\text{Maximum radiation intensity}}{\text{Average radiation intensity}}$$

$$D = \frac{4\pi U_m}{4\pi U_0} = \frac{4\pi U_m}{W_t} = \frac{4\pi(\text{Maximum radiation intensity})}{\text{Total radiated power}}$$

- Gain considers antenna loss as well, therefore is the main parameter we deal with. It can also be calculated using the following relation:

$$G = \frac{4\pi(\text{Maximum radiation intensity})}{\text{Total input power to the antenna}}$$

$$G = \eta D$$

- The previous relations referred to the maximum gain and directivity that indicated the best radiation angle of an antenna. Gain and Directivity can also be defined in a functional manner:

$$D(\theta,\phi) = \frac{4\pi U(\theta,\phi)}{W_t} = \frac{4\pi(\text{radiation intensity in}(\theta,\phi)\text{ direction})}{\text{Total radiated power}}$$

$$G(\theta,\phi) = \frac{4\pi(\text{radiation intensity in}(\theta,\phi)\text{ direction})}{\text{Total input power}}$$

- Applications of omnidirectional antennas: Wireless modems, walkie talkies
- Applications of directional antennas: Radar antennas.
- Creating 3-D radiation patterns are very difficult, we have to use a combination of 2-D patterns seen from different point of views

- There are 2 kinds of patterns based on what is reported as the main radiation parameter:

  - Power pattern (Power is the main radiation parameter)

  - Field strength pattern (E filed strength is the radiation parameter)

- **Other important parameters:**

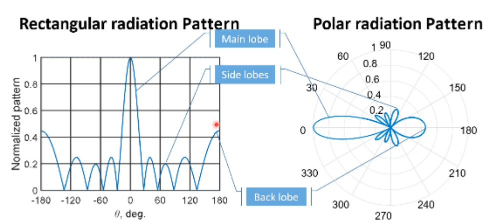
  - **Boresigh**t:
    Direction of maximum directivity

  - **Main Lobe(beam):**
    The lobe corresponding to maximum power (field strength) is the main lobe

  - **Principle plane:**
    The orthogonal plane which contains boresight.

  - **E-plane:**
    The plane containing linearly polarized electric field
  - **H-plane:**
    Perpendicular to E-plane, contains linearly polarized magnetic field.

  - **Horizontal and Vertical Planes:**
    They should be defined if the antenna has a specific position angle relative to ground.



- 2-D patterns can be described in a rectangular or polar pattern:

- Main lobe, side lobe and back lobe levels can be detected using a 2-D pattern.

- Main side lobe is the side lobe beside the main lobe. Side lobe level is the power difference between main lobe and main side lobe power levels

Antenna Radiation Regions:

1. Reactive Near Field Region:

When measurements are done sufficiently close to the antenna reactive portion of antennas power is considerably large to effect measurement. The region around the antenna with this property is called the "Reactive Near Field" region.

Reactive dominance means E and H waves are 90 degrees out of phase relative to each other.

Reactive region is defined mathematically by the following equation:

$$R < 0.62\sqrt{\frac{d^3}{\lambda}}$$

2. Near Field (Fresnel) Region:

Near field region is where the reactive affects are smaller. Measured power has comparable real and imaginary parts. We are close enough to the antenna that we still don't experience uniform plane waves in our receptive field.

Shape of radiation pattern varies over this region.

$$0.62\sqrt{\frac{d^3}{\lambda}} < R < \frac{2d^2}{\lambda}$$

3. Far Field (Fraunhofer) Region:

A region where reactive portion of power is negligible and we mainly receive uniform plane waves in our receptive field (less than 22.5 phase variation according to report#3)

Independence from reactive elements means patterns independence from frequency. We finally can map a pattern describing antennas radiation characteristics regardless of measurement and radiation frequency in this region.

E and H are orthogonal and also in phase. Field strength dependency is limited to spatial angles, taking directivity into account.

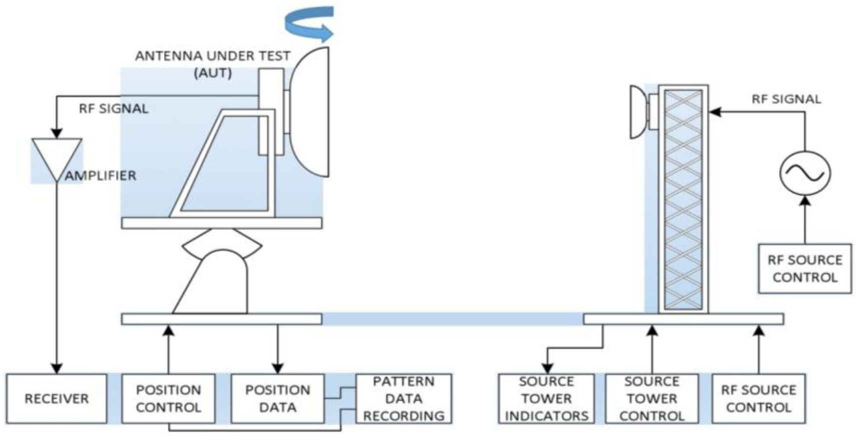
$$E(R,\theta,\phi) = \frac{e^{-jkR}}{R} D(\theta,\phi)$$

$$\left.\begin{matrix} R \gg d \\ R \gg \lambda \end{matrix}\right\} \Rightarrow R > \frac{2d^2}{\lambda}$$

This distance is also called the Rayleigh distance, where d should be the largest dimension along antenna lengths.

Antenna Reciprocity:

Antennas consisting passive elements in their circuit, are identical in transmission and reception modes. Such elements are called reciprocal material. As a result, measurements can be done in either modes.



Reciprocity helps mapping patterns in reception mode for examining <u>radiation</u> characteristics. Positioners also help setting proper angles for power reception of the test signal.