Antennas & Measurement of its parameters

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ABSTRACT

As all of us aware, a communication system comprises Transmitter, Receiver and Channel. Channel is alternately termed as Medium. The basic common element in both transmitter and receiver is an antenna. We all knew that the communication field has taken a great change over the past decade and the antenna became basic electronic component in every communication system we come across today. Hence antenna has become inherently an important component in any type of electronic item today. Knowing about antenna by Electronics Engineers working in communication field is very much essential. The antenna and its parameters are very critical in many communication systems and hence many methods have been evolved in antenna parameter measurements. Antenna parameters include radiation pattern, beam width, gain, polarization, etc., are required to be measured before using them in the intended applications. In light of this, I would like to present the details of antennas consisting of fundamentals and antenna measurements to provide insight of antenna fundamentals.

KEY WORDS: Anechoic chamber, *dBi, dBLi, FBR, CAR, Fire Retardant, Quiet Zone*

I DEFINITION

Antenna is defined in many ways by engineers and one simple definition is given below,

> “*a transducer that couples the energy between transmitter or receiver and free space*”.

Hence the main function of antenna during transmission is to convert the electrical signal to electromagnetic signal and concentrate the radiated energy in to a shaped beam which points to the desired direction in space. On receiver side, the antenna collects the electromagnetic energy around the free space and converts in to electrical signal that is used by receiver.

The most basic antenna is called "a quarter wave vertical" radiator, which a quarter wavelength long antenna and is a vertical radiator. This is the most popular antenna installed on motor vehicles for two way communications. Technically the basic antenna is an "isotropic radiator" and normally called as standard antenna. The isotropic antenna is an imaginary antenna and radiates energy in all directions. Hence the energy radiated from this antenna is similar to a sphere where antenna element is located at the center of the sphere. It is the standard antenna against which we compare the practical antennas.

II ANTENNA TERMINOLOGY

The following paragraphs explain various terms related to antennas.

1 *ISOTROPIC ANTENNNA*

It is an *imaginary antenna* that radiates energy equally in all directions (x, y & z in 3 dimensional co-ordinates) and hence the energy level from the antenna at fixed distance in all directions is same (x, y & z). This antenna is not practically realizable and hence used as reference antenna only.

2 *DIRECTIONAL ANTENNAS*

These are practical antennas and are seen every-where in our day to day life. The energy from the receiver is directed towards the *desired direction* [2] both in azimuth and elevation using these antennas. Hence these antennas provide gain in a particular direction with respect to isotropic antennas as the energy is concentrated in that direction and the following definitions are applicable in case of directional antennas.

2.1 Beam width: It is defined as angular coverage between the 3 – dB points of an antenna beam pattern [2] [4] [6]. Figure 1 shows the beam pattern of a typical antenna. In Figure 1, BWϕ is the azimuth beam width and BWθ is the elevation beam width. *Beam width* is normally measured at the half-power or -3 dB point unless otherwise specified. The unit for beam width is degrees. In some applications, in addition to 3 dB beam width, 6 dB and 10 dB beam width would also be considered.

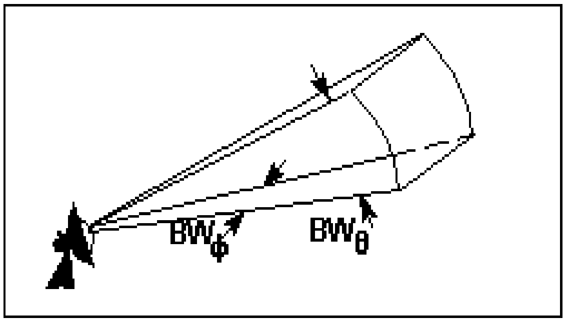

Figure 1. Azimuth and Elevation Beamwidths

2.2 ***Radiation pattern*:** It is defined as graphical representation of field strength at all points which are at equal distance from antenna [2] [4] [6]. This is an important characteristic of an antenna and this pattern is three dimensional. Radiation pattern can be in *rectangular, Polar and 3D formats*.

From the radiation pattern one can analyze the antenna characteristics. Different formats of radiation patterns are given below.

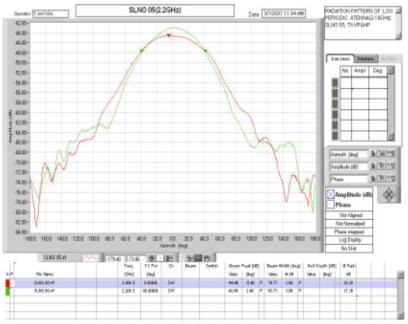

Figure-1(a) – *Rectangular plot*: Azimuthal Radiation pattern of Log Periodic antenna (Directional antenna) at 2.2 GHz frequency (Source: Measurements carried out in an anechoic chamber)

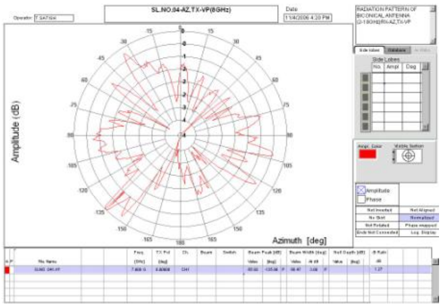

Figure-1(b) – *Polar Plot* - Azimuth Radiation pattern of Biconical antenna (Omni antenna) at 8 GHz frequency (Source: Measurements of antenna at anechoic chamber)

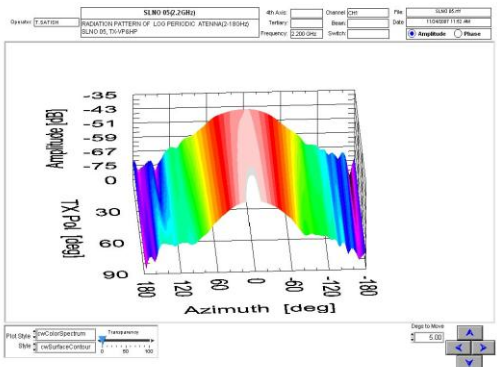

Figure-1(c) – *3D radiation pattern plot*: Azimuth Radiation pattern of Log Periodic antenna (Directional antenna) at 2.2 GHz frequency)

The derived parameter from radiation pattern is *shape factor* of the main beam is defined as the ratio of 10 dB beam width to 3 dB beam width

2.3 Gain: The *gain or directivity* [2] [4] [6] of an antenna is the ratio of the radiation intensity in a given direction to the radiation intensity averaged over all directions. Quite often directivity and gain are used interchangeably. The difference is that directivity neglects antenna losses such as dielectric, resistance, polarization, and VSWR losses. Since these losses in most antennas are usually quite small, the directivity and gain will be approximately equal. The gain of an antenna is normally measured in dBi (i.e., with respect to isotropic antenna) or dBLi (i.e., with respect to linear antenna).

Normalizing a radiation pattern by the integrated total power yields the directivity of the antenna. This concept in shown in equation form by:

$$\textbf{[1]} \quad D(\theta,\phi) = 10\ \mathrm{Log}\left[\frac{4\pi P(\theta,\phi)}{\int\!\!\int P_{in}(\theta,\phi)\ \mathrm{Sin}\ \theta\ d\theta\ d\phi}\right] \quad \begin{array}{l} 0 < \phi \leq 360^\circ \\ 0 < \theta \leq 180^\circ \end{array}$$

Where: $D(\theta,\phi)$ is the directivity in dB
$P(\theta,\phi)$ is the radiation pattern power in a specific direction normalized by the total integrated radiated power

The derivation for the equation can be referred from standard antenna hand book if interested. *Another important concept is that when the angle in which the radiation is constrained is reduced, the directive gain goes up*. For example, as shown in Figure 2 (a) using an isotropic radiating source, the gain would be 0 dB by definition and the power density (P_d) at any given point would be the power in (P_{in}) divided by the surface area of the imaginary sphere at a distance R from the source. If the spatial angle was decreased to one hemisphere (Figure 2(b), the power radiated, P_{in}, would be the same but the area would be half as much, so the gain would double 3 dB. Likewise if the angle is a quarter sphere (Figure 2 (c), the gain would be 6 dB. Figure 2(d) shows a pencil beam. The gain is independent of actual power output and radius (distance) at which measurements are taken.

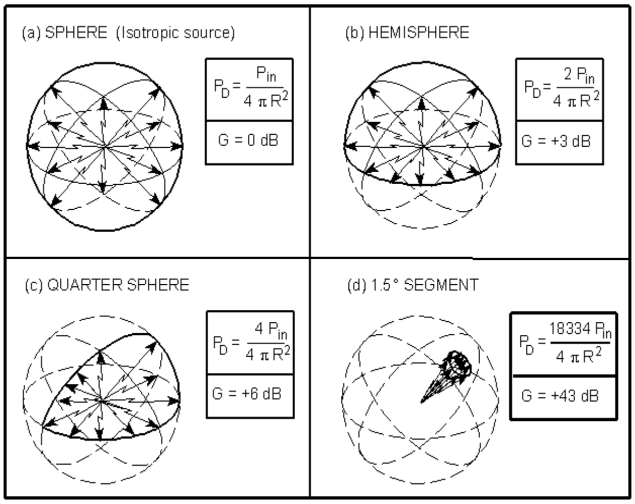

Figure 2. Antenna Gain

Real antennas are different, however, and do not have an ideal radiation distribution. Energy varies with angular displacement and losses occur due to side lobes. It can be noted that as the gain increases for a particular antenna shall decrease the segment width and reduces the beam width of the antenna.

Assuming the antenna pattern is uniform, the gain is equal to the area of the isotropic sphere ($4\pi r^2$) divided by the sector (cross section) area.

$$G = \frac{\text{Area of Sphere}}{\text{Area of Antenna pattern}} \qquad [2]$$

It can be shown that:

$$G \approx \frac{4\pi}{BW_{\phi az} BW_{\theta el}} \quad or \quad \frac{4\pi}{\phi\theta(\text{radians})} \qquad where: \begin{matrix} BW_{\phi az} = \text{Azmith beam widthin radians} \\ BW_{\theta el} = \text{Elevationbeam width in radians} \end{matrix} \qquad [3]$$

2.4 Antenna Polarization: It is defined as orientation of electrical field vector of an EM wave radiated by the antenna. Depending upon how the antenna is orientated physically determines it's polarization for linear type of antennas. An antenna erected vertically is said to be "vertically polarized" while an antenna erected horizontally is said to be "horizontally polarized". Other specialized antennas exist with "Cross polarization", having both vertical and horizontal components and we can have "Circular polarization". Note that when a signal is transmitted at one polarization but received at a different polarization there exist a great many decibels of loss. The following table provides the some of the additional information related to loss due to Transmission and Reception polarizations in more clarity.

Transmitted polarization	**Received polarization**	**Power loss (Ideal) in dB**	**Due to**
Vertical	Vertical	0	Matched polarization
Horizontal	Horizontal	0	Matched polarization
Vertical	Horizontal	Large (Practically more than 30 dB)	Crossed polarization
Horizontal	Vertical	Large (Practically more than 30 dB)	Crossed polarization
Slat 45º	Vertical	3	-
Slat 45º	Horizontal	3	-
Slant 45º	Slant 45º	0	Matched polarization
Slant 45º	Slant -45º	Large (Practically more than 30 dB)	Crossed polarization
Vertical	Slant 45	3	-
Horizontal	Slant 45º	3	-

Figure 3 Level of Signal reception due to polarization

In normal communications, if there is a chance of co-channel interference then it is recommended to use cross polarization. This type of requirement all of us might have noticed for vertical and horizontal TV antennas (well known Yagi - Uda antenna which is slowly going out of usage) in some of our residential areas. *Radars normally do not use circular polarized antennas to avoid phase shift in echo signal and thus affects the detection ranges.* For ESM receivers [3], it is recommended to use Slant +45º or Slant -45º or Circular Polarized antennas (Right hand or Left hand) due to lesser loss for varied transmitted polarizations of radar signals.

2.5 Antenna Impedance: Technically, antenna impedance [4] [6] is the ratio at any given point in the antenna of voltage to current at that point. Depending upon height above ground, the influence of surrounding objects and other factors, quarter wave antenna with a near perfect ground exhibits a nominal input impedance of around 36Ω. A half wave dipole antenna is nominally 75Ω while a half wave folded dipole antenna is nominally 300Ω. Hence it is recommended to use a 75Ω coaxial cable and 300Ω ribbon line for TV antennas. The derived parameter from impedance is Voltage Standing Wave Ratio (VSWR), a familiar word to electrical engineers.

2.6 Reciprocity of antenna: Antenna exhibits same characteristics (radiation pattern, gain, beam width, effective impedance etc.,) either as a transmitting or as a receiving antenna. That means the characteristics of the antenna are same in both transmission and reception mode. The only difference in selection of antenna between transmitter or receiver is the power handling capability. The transmitting antenna should be able to withstand higher power levels and a receiving antenna need not withstand such high power levels.

2.7 Antenna band width: It is defined as the range of frequencies for which the performance of the antenna conforms to a specific standard. This is measured in Hz or KHz or MHz or GHz etc.

2.8 Front to back ratio (FBR): Ratio of power radiated intensity in desired direction to opposite direction and is measured in dB.

***2.9 Frequency independent & dependant antenna*:** Frequency independent antennas are the antennas where an antenna can be physically realized for different frequency ranges, like Cavity Backed Spirals (0.5-2 GHz, 2-8 GHz, 8-18 GHz, 18-26 GHz etc.,) Biconicals (0.5-2 GHz, 2-12 GHz, 12-18 GHz etc.,), Log periodic (very variety of frequency ranges are available), etc.,. Generally the band width of these antennas is high to very high. Frequency dependant antennas are the antennas where an antenna can be physically realized in a particular frequency ranges only like Horns, Dipoles etc. Generally the band width of these antennas is less.

III TYPICAL ANTENNAS

1 The quarter wave vertical antenna

To understand various concepts, let us consider few fundamental antennas. The quarter wave vertical antenna is usually the simplest to construct and erect among all other antennas.

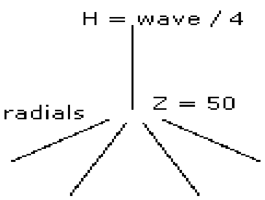

Figure - 4 - a quarter wave vertical antenna with drooping radials

In Figure 4 a quarter wave vertical antenna [4] [5] [6] with drooping radials which would be about 45° from horizontal. These 45° drooping radials simulate an artificial ground and lead to an antenna impedance of about 50Ω. A quarter wave vertical antennas could also be erected directly on the ground and indeed many AM radio transmitting towers accomplish this especially where there is suitable marshy ground is observed for good conductivity. An AM radio transmitting tower of a quarter wave length erected for say 810 KHz in the AM band would have a length of nearly 88 meters (288') in height.

The formula for quarter wave is L = 71.25 meters / freq (MHz) and in feet L = 234 / freq (MHz). Note the variance from the standard wavelength formula of 300 / freq. This is because we allow for "velocity factor" of 5% and wavelength formula becomes 285 / freq. When a quarter wave antennas is erected and "worked" against a good RF ground the earth provides a "mirror" image of the missing half of the desired half wave antenna (Marconi antenna).

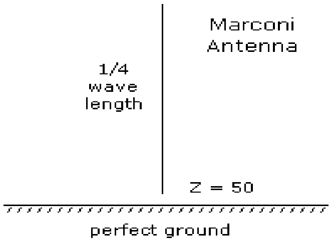

Figure 5 - Marconi antenna

In Figure 5 above, where we have considered the Marconi Antenna, imagine a duplicate of the quarter wave antenna being in existence from the top of the ground and extending down the page. This is the mirror image.

2 Half wave dipole antenna

The half wave dipole antenna becomes quite common where space permits. It can be erected vertically but is more often than not erected horizontally for practical reasons.

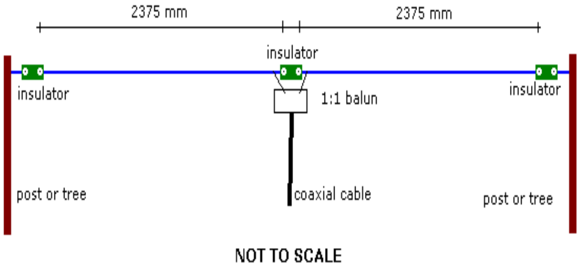

Figure 6 - Half wave dipole antenna

This particular antenna was dimensioned for use at 30 MHz. You will note that the left and right hand halves are merely quarter wave sections. The input impedance is nominally 50Ω. As with all antennas, the height above ground and proximity to other objects such as buildings, trees, guttering etc. play an important part in the performance.

3 *Folded dipole antenna*

The folded dipole antenna[1] [3] is familiar antenna seen as a TV antenna (earlier days). It exhibits an impedance of 300Ω whereas a half wave dipole is 75Ω.

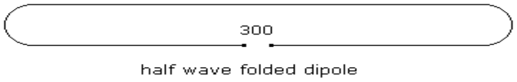

Figure 7 - Half wave folded dipole

One powerful advantage of a folded dipole antenna is that is has a wide bandwidth, in fact a one octave bandwidth. This is the reason it was often used as a TV antenna for multi channel applications. Folded dipole antennas were mainly used in conjunction with Yagi antennas.

4 *Yagi – Uda antenna*

The Yagi - Uda antenna was developed by Japanese scientists in the 1930's [1] [3]. It consists of a half wave dipole, a rear "reflector" and may or may not have one or more forward "directors". These are collectively referred to as the "elements". This particular antenna has been optimized for dual band operation. It is designed to pick up both VHF and UHF transmissions.

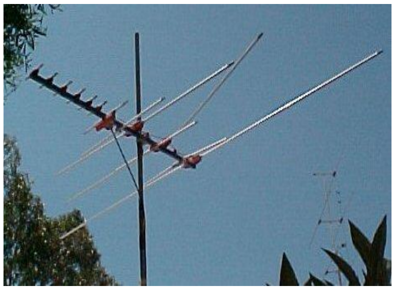

Figure. 8 - A practical Yagi - Uda TV antenna

Looking from left to right on this dual band Yagi - Uda antenna, we have six UHF "director" elements which improve gain and directivity. Next is the UHF half wave dipole which could have easily been a folded dipole but is in fact a plain half wave dipole. The next three much longer elements form a "phased array" for the VHF band. Note that this is a horizontally polarized antenna.

IV ANTENNA PARAMETERS & MEASUREMENTS

The characterization of the antenna include measurement of various parameters that include

- Radiation patterns
- Omni variations
- Gain (Directive gain)
- Axial ratio
- 3-dB and 10-dB Azimuth and Elevation beam widths
- Voltage Standing Wave Ratio (VSWR)
- Impedance
- Polarization
- Main and side lobe levels
- Front to Back ratio (FBR)
- Power Handling capability etc.,

1 *Radiation pattern*

Most of the antenna parameters are derived from the measurement of radiation patterns [5] and these are listed below. Hence measurement of radiation pattern is very important for characterizing the antenna.

- 3-dB and 10 dB beam width (Azimuth and Elevation)
- Gain
- Axial ratio
- Front to Back Ratio (FBR)
- Side lobe level
- Omni deviation/variations

2 *Regions around transmitting antenna*

The radiation field from a transmitting antenna is characterized by the complex Poynting vector $E \times H^*$ [4] [6] in which E is the electric field, and H is the magnetic field. Close to the antenna, at a distance r from the antenna, the Poynting vector is imaginary (reactive) and the fields decay more rapidly than $1/r$, while farther away from the antenna the Poynting vector is real (radiating) and the fields decay as $1/r$. These two types of fields dominate in different regions of the space surrounding the antenna. Based on this characterization of the Poynting vector, we can identify three major regions as below.

2.1 Reactive Region: This region is the space immediately surrounding the antenna. The extent of this region is given approximately as $0 < r < \lambda/2\pi$, [4] [6] where λ is the wavelength. In this region, all three spatial components decay more rapidly than$1/r$.

2.2 Radiating Near-Field: Beyond the reactive region, the radiating fields begin to dominate. The extent of the radiating near-field region is $\lambda/2\pi < r < 2D^2/\lambda$, where D is the largest dimension of the antenna. This region can be divided into two sub-regions. For $\lambda/2\pi < r < D^2/4\lambda$ [4] the fields decay more rapidly than $1/r$ and the radiation pattern (relative angular distribution of the field) is dependent on r. For $D^2/4\lambda < r < 2D^2/4\lambda$ the fields decay as $1/r$, and the radiation pattern is still dependent on r. The radiation pattern is given as the Fourier transform of the aperture distribution (with a phase error in excess of $\lambda/16$). The phase error is dependent on r. This region is often referred to as the Fresnel region.

2.3 Radiating Far-Field: Beyond the radiating Near-Field region, for $r > 2D^2/\lambda$ the Poynting vector is real (only radiating fields are present) and has only two spherical coordinate components. The fields decay as 1/r and the radiation pattern is independent of r. The radiation pattern in this region is approximated by the Fourier transform of the aperture distribution (with a phase error of less than $\lambda/16$). This region is referred to as the Fraunhofer region.

3 Measurement Condition

3.1 As explained above, in the radiating near field zone, the angular distribution of radiated energy is dependant on the distance from the antenna, whereas in the radiating far field region the angular distribution of radiating energy is essentially independent of the distance from the antenna. Thus the electro magnetic signal will be varying in amplitude and phase in near field zone and is relatively varies by small amount in amplitude and phase in far field zone. Since the antenna is normally used in far filed zones, the antenna parameter measurements are generally carried out in far field conditions.

3.2 Second condition for to reducing the influence of ground on antenna measurements suitable height of the transmitting and receiving antennas are to be considered. Typically, an height of 4D to be maintained where D is the maximum dimension of the antennas used in the measurement

3.3 The third condition to be met is the line of sight transmission between transmitting and receiving antennas. According to antenna scientists, the quiet zone region (where AUT is mounted) should meet the following conditions.

- The amplitude variations below 0.2 dB over the angular distribution
- The phase variations are below $\lambda/16$ over the angular distribution

The above requirement can be achieved by separating the two antennas by a minimum of $2D^2/\lambda$. Although this condition is proposed by many antenna engineers, one must remember that this is an arbitrary choice and it may be inadequate in some applications. For example if one must accurately measure the patterns of antennas having high side lobe levels, the distance may be required very much higher than $2D^2/\lambda$. However to meet the measurement accuracies for general applications D^2/λ separation is also sufficient.

4 Antenna test ranges

The antenna test ranges can be of three types near field or far field or Compact test rages. The required volume of an antenna test range may be reduced by making measurements in the Near-Field of the AUT, and then using analytical methods to transform the measured Near-Field data to the Far-Field radiation pattern.

4.1 Near Field test ranges*:* The measured Near-Field data (amplitude and phase) is acquired by using a probe to scan the field over a geometrical surface, which is typically a plane, a cylinder, or a sphere. The measured data is then transformed to the Far-Field pattern using post processing.

4.1.1 Planar: In the planar scanning technique, a probe antenna is moved over a plane situated in front of the AUT. The position of the probe is characterized by coordinates (x, y, z) in the coordinate system of the AUT. During the scanning process z is kept constant, while x and y are varied. The distance z is usually set within the range of 3λ - 10λ to avoid sampling of the reactive energy of the AUT. The dimensions of the Near-Field scanning aperture must be large enough to capture all significant energy from the AUT. The scan dimensions D also have to meet the criterion $D > D+2z \tan \theta$, where D is the largest AUT dimension and θ is the maximum processed radiation pattern angle.

The basic types of scans exist in planar Near-Field measurements: rectangular, plane- polar and bi-polar. In the plane-rectangular scan the data is collected on a rectangular grid and processed by the conventional FFT algorithm. The sampling spacing is usually $\Delta x = \Delta y = \lambda/2$.

In the plane-polar technique, the AUT is rotated about its axis and the probe is attached to a linear positioner placed above the AUT. The combination of the antenna rotation and linear probe motion yields planar Near-Field data collected on concentric rings with data points lying on radial lines. The polar Near-Field data is processed to the far field by a Jacobi-Bessel transform or by interpolation to obtain a rectangular grid for an FFT algorithm.

The bi-polar technique is similar to the plane-polar configuration in the sense that the AUT is rotated, but differs in the probe motion. The probe is rotated about a second axis and describes an arc that passes through the AUT axis. The combination of antenna rotation and probe arm rotation yields planar Near-Field data collected on concentric rings with data points lying on radial arcs. The Near-Field data is interpolated into a plane-rectangular grid. The rectangular data is then processed using the FFT to obtain the radiation pattern.

4.1.2 Cylindrical: In the cylindrical scanning technique, the AUT is rotated around the z axis of a xyz-coordinate system, while the probe is moved along a linear axis parallel to the z axis. The probe is located at a distance a, typically chosen to be the smallest cylinder radius enclosing the AUT. The cylindrical scanning enables obtaining the exact azimuth pattern but only a limited elevation pattern due to the truncation of the scanning aperture in z direction. In accordance with the sampling theory the sampling spacing is given as $\Delta\varphi = \lambda/ 2a$ and $\Delta z = \lambda/2$.

4.1.3 Spherical: In the spherical scanning technique the AUT is rotated around the z axis, and the probe is moved on a circular track in the θ direction. The radius of the rotation is typically chosen as the smallest radius enclosing the AUT. An alternative is to keep the probe stationary and move the AUT in two axes, often chosen as a "roll-over-azimuth" positioner configuration. The advantage of spherical scanning is that it delivers the full extent of the AUT three-dimensional pattern. The sampling spacing is determined by the sampling theory to be $\Delta \varphi = \Delta \theta = \lambda/2a$.

4.2 Far Field test ranges: Far-Field measurements can be performed using either outdoor or indoor ranges. In general, there are two basic types of far-field antenna ranges: ground reflection ranges and free space ranges. In the ground reflection range, a constructive interference between the direct ray from the source antenna and the reflection from the ground is utilized to illuminate the test zone. In the free space ranges, the reflections from the ground are minimized. There are several types of free space ranges, primarily elevated ranges and slant ranges. A related type of range is a free-space class range that utilizes a compact range reflector to achieve a plane wave illumination that is approximated by other far-field measurement ranges.

4.2.1 Ground Reflection Range: In a ground reflection range, the reflection from the ground is used to obtain uniform amplitude and phase distribution over the AUT. This requires a smooth range surface. The range length r is designed to meet the Far- Field criterion. The interaction of the direct radiation from the source and the ground reflection over the test zone produces an interference pattern, with alternating maxima and minima. The heights of the source and AUT are chosen so that the AUT is centered on the first interference lobe. This criterion determines the relation between the source height, ht, and the AUT height, hr, to be $ht \approx \lambda R/4hr$. If the amplitude taper over the AUT is required to be no more than 0.25 dB, the height of the AUT should meet the criterion $hr > 3.3D$.

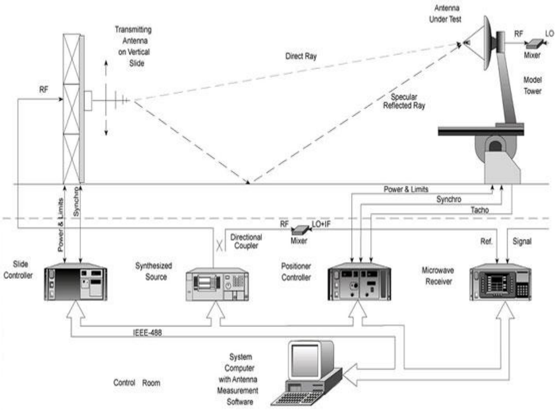

Figure 9: Ground Reflection Range Configuration

4.2.2 Elevated Range: Elevated ranges are usually designed to operate mostly over terrain. The antennas are typically mounted on towers or on roofs of adjacent buildings. The range length r is designed to meet the Far-Field criterion $r > 2D^2/\lambda$, in which D is the largest dimension of the source or AUT. The height of the AUT, h_r, is determined by two criteria related to the source antenna. The source antenna is typically chosen so that the amplitude taper over the AUT is typically no greater than 0.25 dB. In addition, to minimize the range reflections, its first null points toward the base of the test tower. These two criteria determine the height of the AUT to be $h_r > 4D$. Occasionally diffraction fences are required to further suppress ground reflections. In some cases the elevated range is implemented with the source and AUT site on local terrain peaks with a valley in-between, which minimizes any contribution from ground reflections.

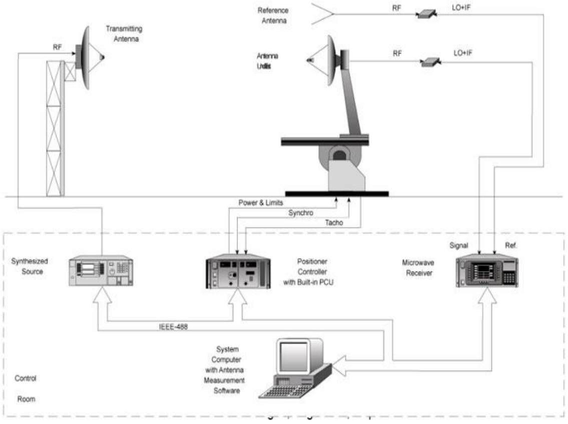

Figure 10: Elevated Range Configuration

4.2.3 Slant Range: A slant range is one in which the source antenna is located close to the ground and the AUT is mounted on a tower. The source antenna points toward the center of the AUT and its first null points toward the tower base. It is desirable that the tower that supports the AUT be constructed of non-conducting materials to reduce reflections. Slant ranges, in general, require less real estate than elevated ranges.

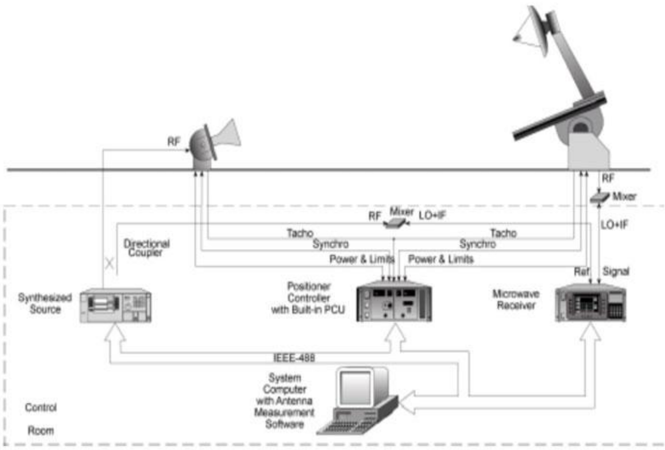

Figure 11: Slant Range Configuration

4.2.4 Compact Range: Antenna measurements require that the AUT be illuminated by a uniform plane wave. This requirement is approximately achieved in the far field for a range length $r > 2D^2/\lambda$, which in many cases dictates large distances. A compact range creates a plane wave field at distances considerably shorter than those required using the conventional Far-Field criteria. The plane wave produced by a compact range is generated by a large parabolic reflector.

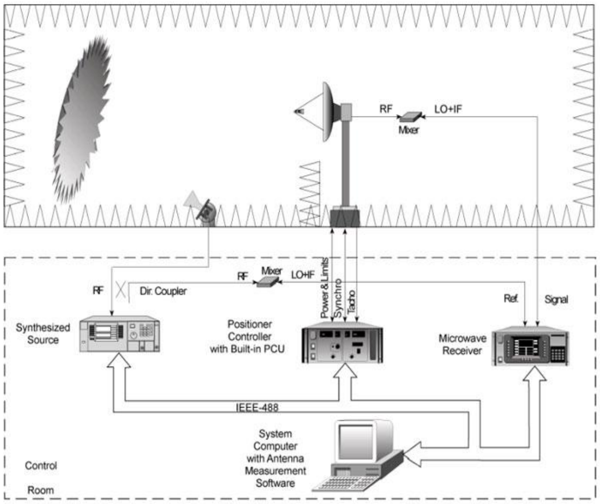

Figure 12: CAR Configuration

The parabolic reflector converts a spherical phase front from the illuminating feed into a planar phase front close to its aperture. There are several major factors which affect the compact range performance: aperture blockage and edge diffraction. The aperture blockage is reduced by utilizing an offset reflector system. The edge diffraction is reduced by using serrated or rolled edges.

Out of these test ranges, far field and anechoic chambers are widely used for antenna measurements. It should be understood by now that the radiation pattern can be measured using this test facilities. Some of the advantages and disadvantages of the above facilities are tabulated below.

4.2.5 Anechoic chamber specification: The typical anechoic chamber shall be defined using following parameters.

Parameter	Specifications
Chamber type	Rectangular with opening door
Chamber size	10M x 5M x 4.1M (Max)
Frequency range	500 MHz to 40 GHz
Purpose of chamber	Antenna measurements (Omni and directional)
Size and location of quiet zone	a) 1.4 M x 1.4M x 1.4 M at 500 MHz b) 0.5 M x 0.5 M x 0.5 M at 18 to 40 GHz
Quietness	a) At 500 MHz with antenna gain of ≥6 dBi: -27 dB or better b) For 2-40 GHz with antenna gain of ≥12 dBi : -60 dB or better
Shielding effectiveness with door closed	500-2000 MHz >50 dB 2-8 GHz >30 dB
Quietness & shielding effectiveness	As per IEEE standard procedure
Absorber type	Zero halogen type
Fire retardancy	As per IEEE standard specification
Grounding	Resistance less than 1 ohms
Walk on	Near Tx and Rx
Testing of individual absorbers	As per IEEE standards
Validation of chamber	Electrical evaluation for quietness using VSWR method and shield effectiveness as per MIL-STD-285
Warranty	5 years
Max weight on Tx	50 Kgs
Max weight on Rx	150 Kgs
Polarization positioners	At Tx and Rx
Patterns	Rectangular, Polar and 3-D Patterns
Software for patterns	Midas by Orbit FR, Israel
Receiver type	Network analyzer
Maximum dimension of antenna	600 mm

Figure 13: Specification of typical anechoic chamber

Figure 14: Comparison of antenna test facilities

Anechoic chamber	Open antenna test ranges	Near field test ranges	Compact antenna test ranges
Widely used for smaller and medium size antenna measurement	Generally used for larger antennas	Suitable for only for directional antennas	Widely used for smaller and medium size antenna measurement
Simple to construct	Slightly complex	Very complex	Complex and major problem is aperture blockage
Cost is less	Cost is medium	Very costly	Very costly
Measurements are accurate	Minor errors are expected due to noise in the environment	Measurements are accurate but depends on analysis software	Measurements are accurate
No effect due to weather	Errors are expected due influence of weather	No effect due to weather	No effect due to weather
Suitable for all seasons	Disturbances are expected in rainy seasons	Suitable for all seasons	Suitable for all seasons
Repeatability is ensured	Repeatability is ensured in most of the applications	Repeatability is ensured	Repeatability is ensured

4.2.6 Test Equipment:

Following test equipment is required at Transmitting side

- Transmitting tower for mounting of transmitting antenna
- Azimuth, Elevation and polarization positioner
- Signal generation equipment or network analyzer
- Transmitting antennas
- Cables and accessories
- Amplifiers if required

Following test equipment is required at receiving side

- Receiving tower for mounting of Antenna Under Test
- Azimuth, Elevation and polarization positioner
- Microwave receiver or Network analyzer
- Cables and accessories
- Single or multiple position controller for controlling transmission/receiver antenna position in Azimuth, Elevation and Polarization
- Computer with antenna test software
- Printer/plotter

4.2.7 Radiation pattern measurements

- Antenna Under test and Transmitting antenna (typically a standard gain antenna) shall be mounted on towers in LOS (suitable test jigs can be used, preferably made with wood)
- Set all the required parameters like frequency, polarization, receiver parameters, etc
- Select the measurements required like 3-dB beam width, 10 dB beam width, Axial ratio, FBR, SLL, Omni variation etc.,
- Run the software to capture the radiation pattern either in rectangular or polar or 3-D patterns as per the requirement

Note: Presently, the measurements are fully automatic and very fast)

4.2.8 Gain measurements: Gain of an antenna (always measured as peak gain) is measured in following two ways.

4.2.8.1 By comparison: The gain of the standard antenna (gain values are known) is compared with respect to the gain of the AUT as follows

a) In the anechoic chamber, measure the power level received at beam peak of the standard gain antenna and AUT
b) Compare the power levels measured and with the help of the gain values of standard antenna. Compute the gain of the AUT
c) This shall be measured for all frequencies
d) This is widely used method and the accuracies are depend on the gain values of standard gain antenna and measurement accuracy of the chamber

4.2.8.2 By three antenna measurement. This method is suitable for smaller antennas like Cavity Backed Spiral Antenna, Log Periodic Antenna, high frequency horns etc.,

a) Minimum three similar antennas are required
b) Signal generator and spectral analyzer is sufficient for measurements (Alternately Network analyzer may be used)
c) Anechoic chamber may not be required. However suitable absorbing panels may be used between TX and Rx antennas
d) Mount the AUTs, one on transmitting side (A1) and the other on receiving side (A2). Ensure bore sight for both the antennas
e) Measure the power received at frequency (P12)
f) Repeat the procedure for other antennas by interchanging antennas between transmitter and receiver. Thus we get P23 and P31 for each frequency.

g) Since the distance between the transmitting and receiving antennas is known and frequency of operation is available one can easily measure the gain of all three antennas by solving the path loss equation.

Note: Presently software is available for calculation of gain in this method.

The measurement of the remaining parameters i.e., VSWR measurements and antenna Impedance can be easily measured by using Network analyzer set up.

4.2.9 Polarization measurement: Two methods are commonly used for polarization measurement. One is called the "spinning linear" method, where a linear source is rotated through all linear polarization states, thus yielding a direct measurement of the antenna under test axial ratio. The second common method is the dual polarization method, where the response of the antenna under test is measured for two source illuminations characterized by orthogonal polarizations (typically linear vertical and linear horizontal). In this case, measuring the complex (amplitude and phase) response of the AUT in systematic way yields the axial ratio, tilt angle, and sense of the antenna.

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