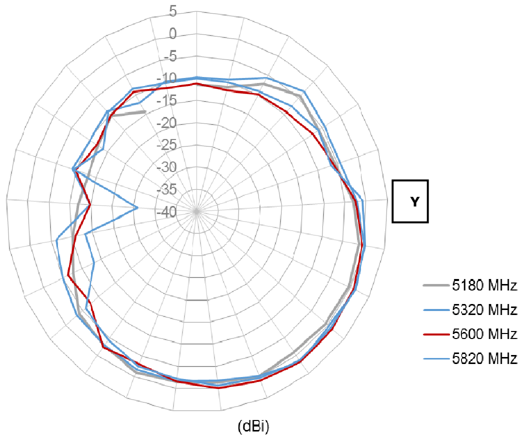
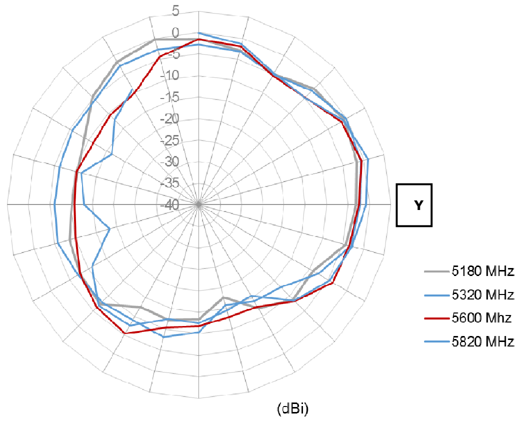




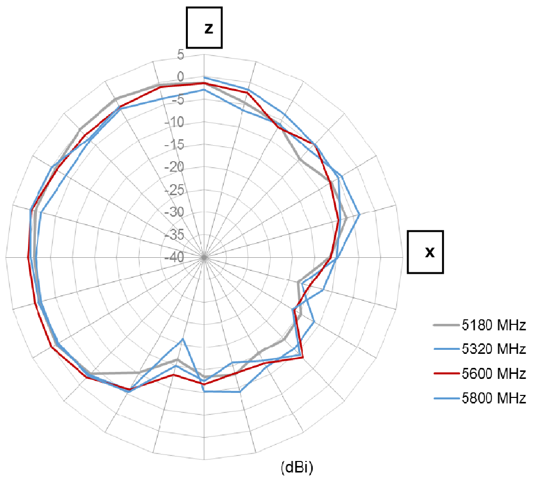
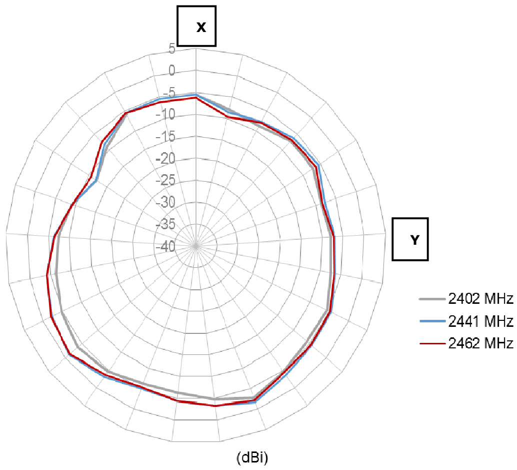
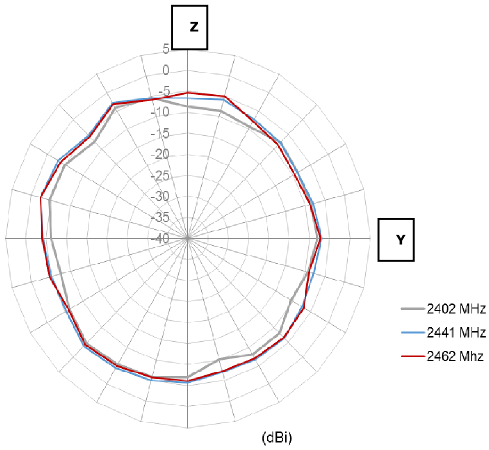


Figure 30. *2D radiation patterns WLAN at 5.0GHz Port 1.*





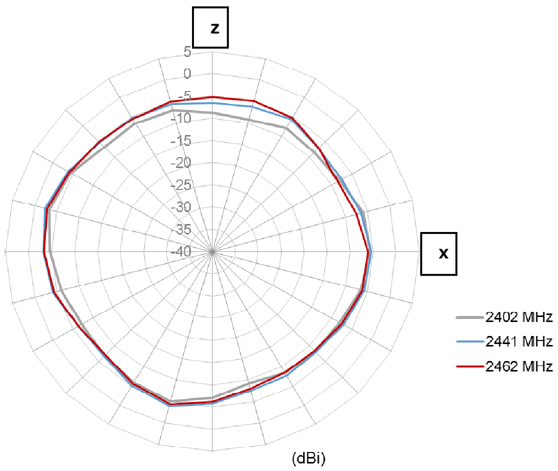


Figure 31. *2D radiation patterns WLAN at 2.4GHz Port 2.*

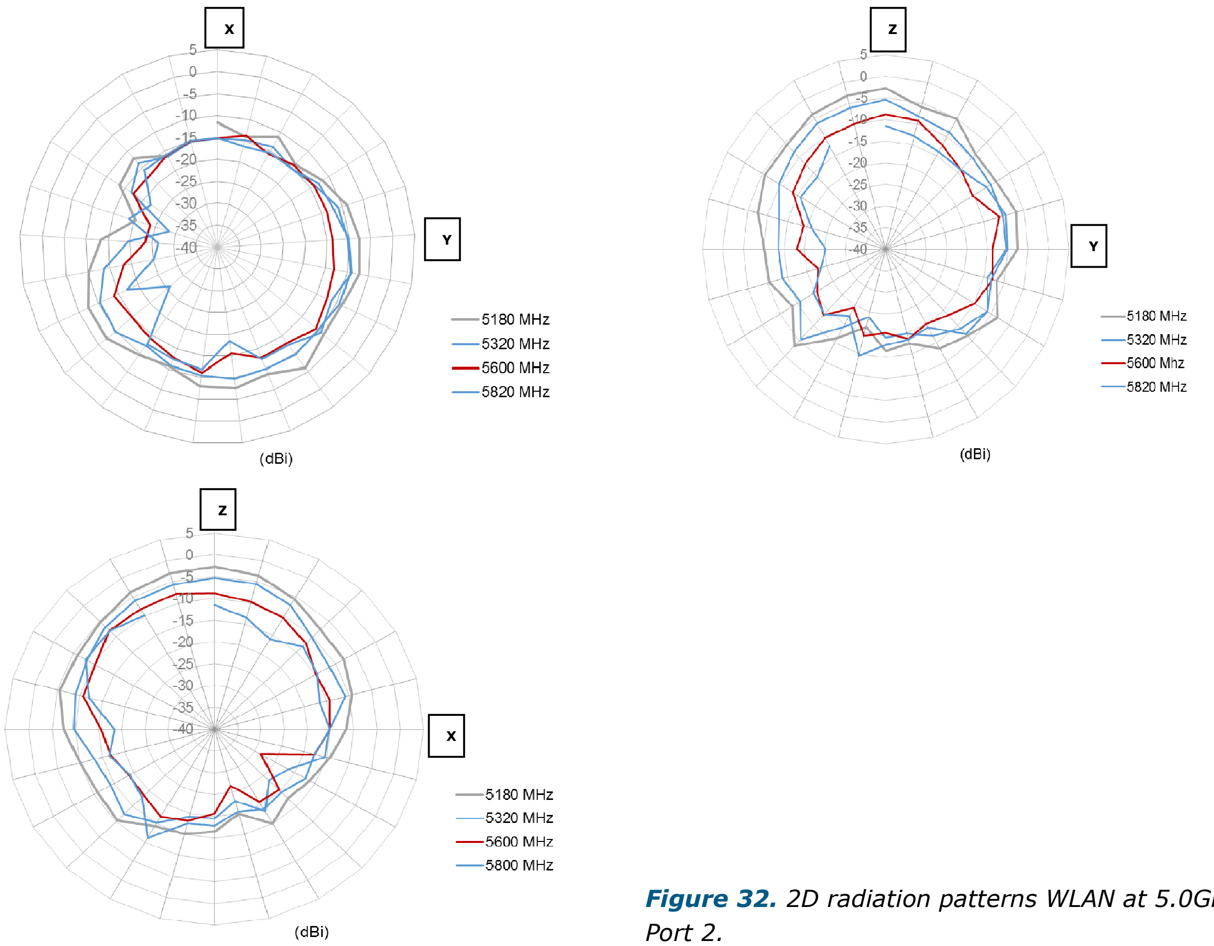


Figure 32. *2D radiation patterns WLAN at 5.0GHz Port 2.*

6 Conclusions

This report presents the antenna characterization of the Harman internal antenna.

Anex A

Basic Definitions of the antenna parameters

A.1 Antenna Impedance and Bandwidth

The antenna is essentially a transducer between the characteristic impedance of the radio system (nominally 50 ohms) and the impedance of free space. As such, the antenna impedance and the radio frequencies over which that impedance is maintained are critical. It is essential that the antenna present an acceptable impedance match over the frequency band(s) of operation.

Antenna impedance and the quality of the impedance match are most commonly characterized by either Return Loss (represented by the scattering parameter S_{11}) or Voltage Standing Wave Ratio (VSWR); these two parameters are simply different formats of exactly the same impedance data. The Return Loss, is typically measured on a logarithmic (dB) scale, while the VSWR is a unit-less ratio.

These impedance parameters measure how much of the power supplied to the antenna reflects back from the antenna terminals. Ideally, but impossible to achieve if the antenna is perfectly matched to the system, all of the power supplied to the antenna will be radiated with no reflection.

It is important to note that the return loss measured at the antenna terminals is relevant for both receive and transmit operation. In transmit mode, compromised S_{11} will reflect power back into the final output amplifier, while in receive mode the power is reflected back into the antenna.

Table A.1. *Return Loss (S11) and VSWR Relationship*

S11 (dB)	VSWR	Reflection Loss (dB)	Comment
-6.0	3:1	1.2	Marginal
-9.5	2:1	0.5	Acceptable (and typical Antenna Specification)
-15.0	1.4:1	0.15	Good

Some shifting of the frequency response will also occur during normal use when the device is near other objects, a secondary or temporary enclosure, the user's hand or head and so forth. Therefore, excess bandwidth should be designed in from the beginning of the product design.

The bandwidth of an antenna over which the return loss is acceptable is directly proportional to the volume the antenna occupies, so very small antennas can produce inadequate bandwidth, especially in the 700 MHz band where the effective volume is smallest relative to the frequency of operation.

A.2 Efficiency

The antenna efficiency is arguably the most important performance parameter, assuming the antenna produces an acceptable return loss and Peak Gain over the band of interest.

Efficiency is simply a measure of what portion of the power supplied to the antenna, including any reflection loss, is actually radiated by the antenna.

The efficiency of small antennas that are tightly integrated into a small product can be affected substantially. Nearby grounded conductors and dielectric materials (like a typical plastic housing) will constrain and absorb the near-fields of the antenna and cause significant losses. below illustrates the efficiency concept.

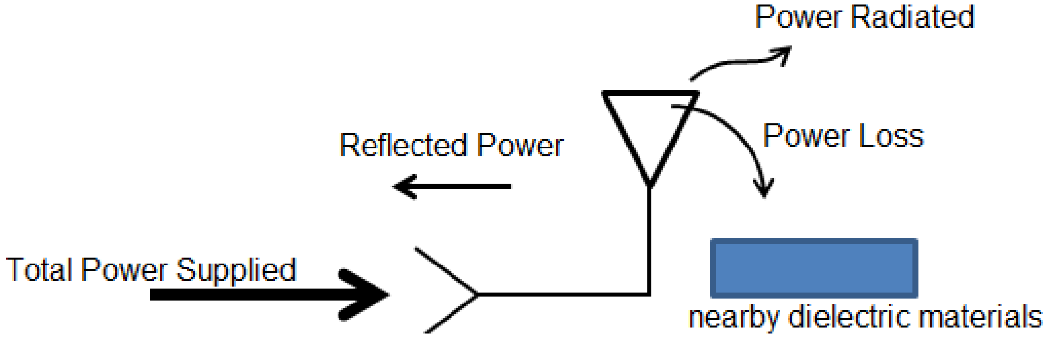


Figure A.1. *Efficiency Concept*

Common plastic materials, like polycarbonate or ABS (Acrylonitrile Butadiene Styrene), can become significant absorbers of RF energy when very close to an antenna. Energy loss will occur during both receive and transmit operation.

The efficiency of a typical embedded antenna can range from about 40 to 75%. Greater than 75% efficiency is challenging to obtain from a fully embedded antenna and lower than 40% efficiency will typically cause certification failures but this depends on the TRP(Total Radiated Power) and TIS(Total Isotropic Sensitivity) limits from the network provider. In most cases, the efficiency goal should be 60%, with 40% as an absolute minimum.

It is important to understand that good return-loss performance can be inadvertently achieved at the expense of efficiency. An extreme example of this concept is a 50 ohm resistor: the resistor has an excellent return loss but has virtually 0% efficiency, and is obviously not an antenna. Therefore, an understanding of the return loss and efficiency concepts is critical to good antenna design.

A.3 Average Gain

Efficiency is typically expressed as a percentage, but it is helpful to translate efficiency into the same logarithmic scale used in other antenna performance parameters, when the antenna efficiency is represented in logarithmic scale is named Average Gain. Next table shows the relationship between the Antenna Efficiency in % and the Average Gain in dB

Table A.2. *Efficiency (%) and Average Gain (dB) Relationship*

Efficiency (%)	Average Gain (dB)
90	-0.5
75	-1.2
50	-3.0
25	-6.0

As shown in the table above, antenna efficiency in percentage can be converted to a dB scale (Average Gain) by a 10 log (%) function.

A.4 Peak Gain

Peak Gain is the maximum energy radiated by the antenna in one direction. The peak Gain is usually referred to an isotropic antenna and with the designation dBi.

A.5 Radiation Patterns

An antenna is a physical device that radiates energy, almost always with some directional dependence. An antenna radiation pattern or antenna pattern is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far field region. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization." The radiation property of most concern is the two- or three-dimensional spatial distribution of radiated energy as a function of the observer's position along a path or surface of constant radius

An isotropic radiator is defined as "a hypothetical lossless antenna having equal radiation in all directions".

A directional antenna is one "having the property of radiating or receiving electromagnetic waves more effectively in some directions than in others".
The omnidirectional antenna has a no directional pattern in a given plane and a directional pattern in any orthogonal plane." An omnidirectional patterns then special type of a directional pattern".

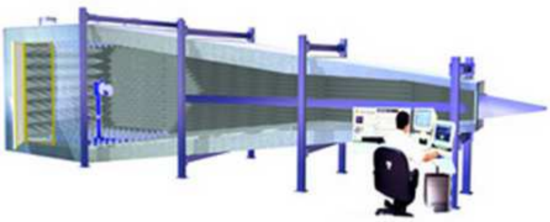
Anex B

Anechoic ("No echo") chambers

A radio frequency "anechoic chamber" is a shielded room whose walls have been covered with a material that scatters or absorbs so much of the incident energy that it can simulate free space.
Electromagnetic wave measurements involving very low signal levels are commonly performed in laboratory facilities that provide high isolation from external electromagnetic environment. Shielded enclosures with isolation performance in excess of 100 dB prevent extraneous energy from masking measurements of the intended signals. However, electromagnetic wave generally propagates in all directions and waves reflected by the walls, ceiling, and floor of the shielded enclosure will give rise to a complex wave front at the test region where the test antenna is to be placed. As it is desirable to provide an environment for electromagnetic energy to propagate between the test antenna and the device-under-test (DUT) in a simple and well defined manner, waves propagating towards the walls, ceiling, and floor of the enclosure must be absorbed using a suitable absorbing material. A shielded enclosure with the entire inner surfaces covered with wave absorber to create a non-reflecting environment equivalent to free space is known as Anechoic Chamber.

B.1 Kinds of anechoic chambers

B.1.1 Tapered Anechoic Chamber



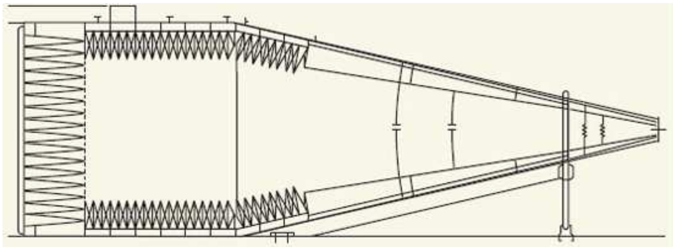


Figure B.1. *Tapered Anechoic Chamber*

- The tapered chamber actually uses the reflections off the walls to its advantage. It was found that suppression of reflections for low frequency broad-beamed antennas was almost impossible.

- Tapering one end of the chamber would cause the chamber to act like an indoor ground reflection range. The reflections off of the chamber walls actually add together to form an almost uniform plane wave at the test region. The shape of this chamber and the wave front emanating from it is reminiscent of horn antenna.

- The cost of a tapered chamber is usually less than a rectangular chamber.

- The tapered chambers are used mostly for low frequencies in the VHF(30-300 MHz) / UHF(300 MHz a 3 GHz) range.

B.1.2 Near Field Anechoic Chamber

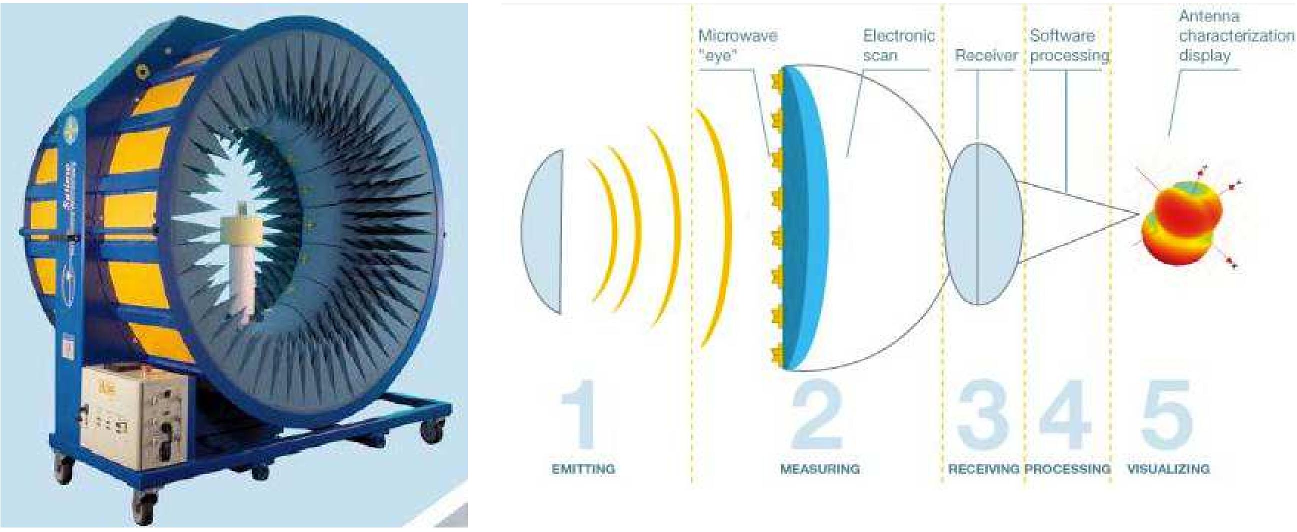


Figure B.2. *Near Field Anechoic Chamber*

- The test antenna is measured in the near-field and a near-field to far-field transform is used to obtain the far-field pattern.

- The disadvantage of this method is that points in different planes are needed to get an accurate far-field calculation.

- Other disadvantage is that this method is very math intensive and requires more equipment to get a complete scan of the antenna.

B.1.3 Rectangular Chamber

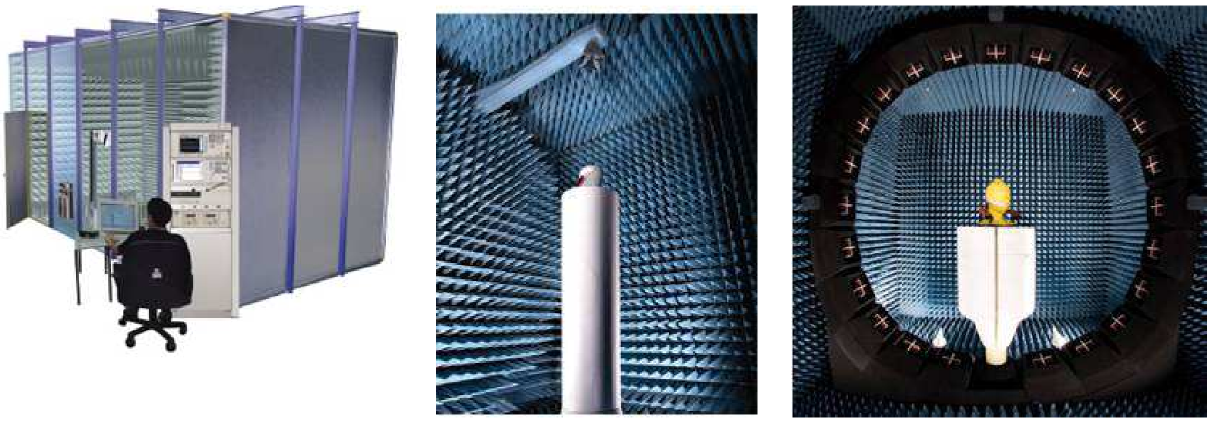


Figure B.3. *Rectangular Anechoic Chamber*

- Most common type of chamber because they are easy to build and easier to design than other types of chambers.
- These chambers range in size depending on what the operating frequency is and also on what is being tested. The major specification is that the chamber must be long enough so that the antennas under test are in the far-field.
- The chamber to be deep enough so that we don't get a skipping effect of the electromagnetic wave off the floor of the chamber.

B.2 Chamber coordinate systems

The chambers utilize the spherical measurement system, and can be distributed or combined. Each of the two referenced chamber setups have different coordinate system orientations This is due to the difference in implementation of the chamber axes. However, the EUT coordinate systems will apply independent of the physical orientations of the EUT inside the chamber. Figure B.4 shows the typical setup using a combined axis system. In addition to the pictured Theta axis rotation, the EUT will have to be rotated about the Z-axis (Phi rotation) in order to perform the full spherical scans. Figure B.5 shows the typical setup using the distributed axis system. In this configuration, the Phi and Theta angles are traversed separately by the distributed positioners in the chamber.

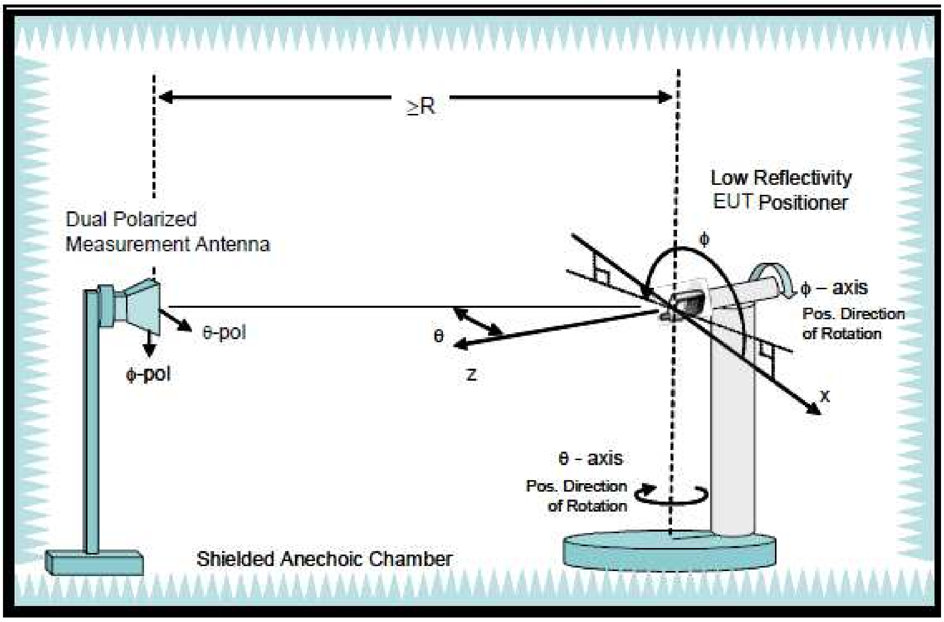


Figure B.4. *Shows the typical setup using a combined axis system. In addition to the pictured Theta axis rotation, the EUT will have to be rotated about the Z-axis (Phi rotation) in order to perform the full spherical scans.*

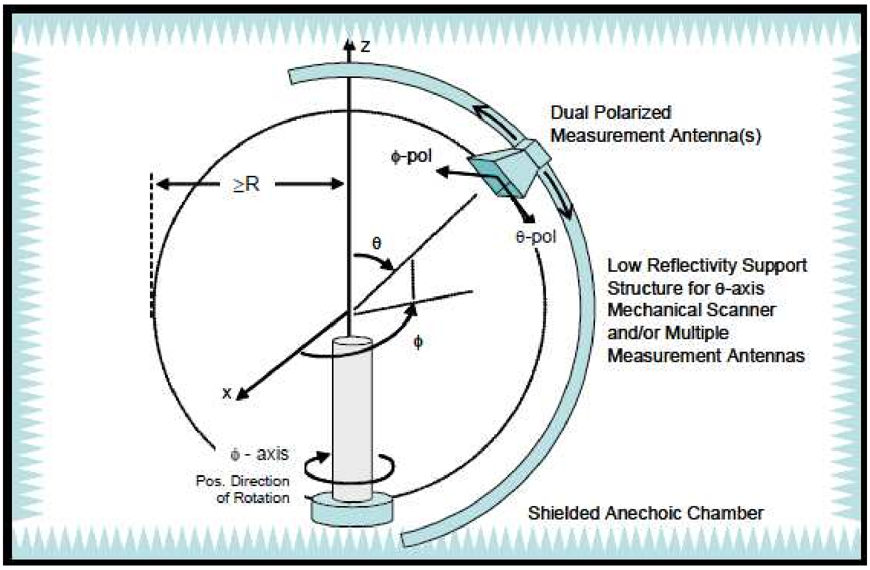


Figure B.5. *Shows the typical setup using the distributed axis system. In this configuration, the Phi and Theta angles are traversed separately by the distributed positioners in the chamber.*

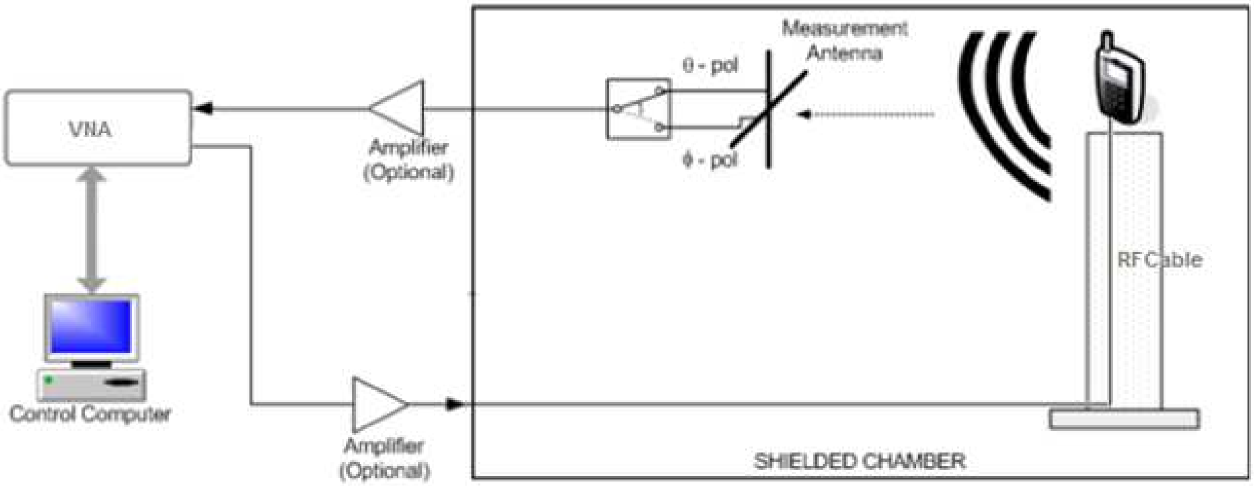


Figure B.6. *Simplified block diagram showing the common configuration for the passive antenna measurement*

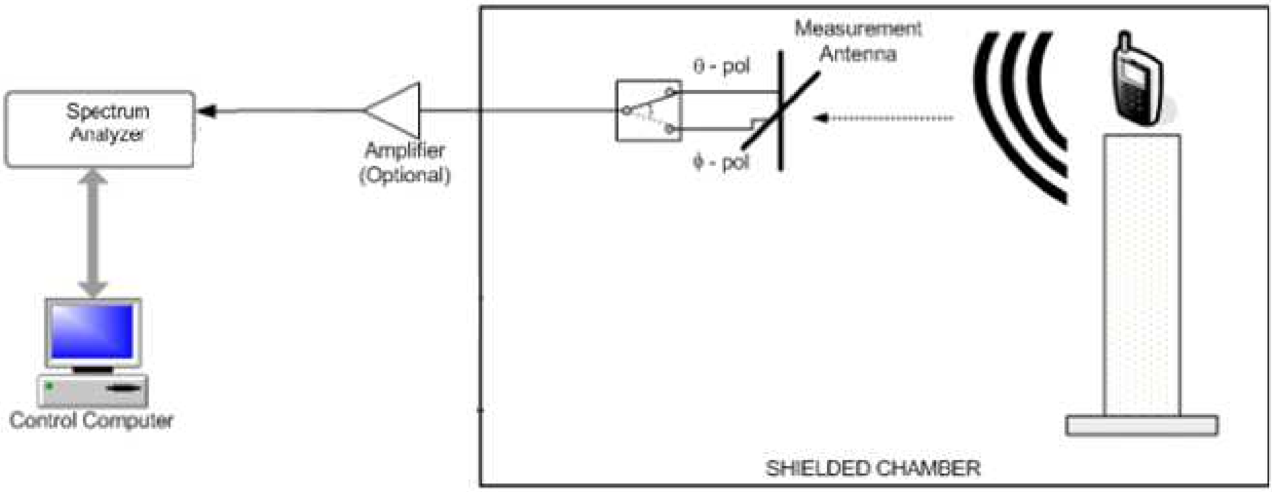


Figure B.7. *Simplified block diagram showing the common configuration for the TRP, in TX power mode antenna measurement*

End of Report