Multi-Purpose Antenna & EMI/EMC Test Facility Established at G.B. Pant Govt. Engineering College, Delhi.

Kanhiya Lal*, Tarun Sheladiya*, Mamta Jain**, Monika Garg**, Amit Sharma***
*Sahajanand Laser Technology Ltd., E-Mail: kanhiyalal@sahajanandlaser.com
**G.B. Pant Govt. Engineering College, Okhla, New Delhi, 011-26382318, 9871065667
***Amitec Ltd., New Delhi.

Abstract: *The multi-purpose facility was designed for carrying out Far Field Antenna and RCS Measurements, Near Field Measurements covering Planar, Cylindrical and Spherical Near Field Testing, EMI/EMC Measurements per MIL STD 461 E/F etc.*
The test and validation method of Anechoic Chamber was decided based on its design parameters and its intended use and a figure of merit is drawn accordingly. To test and validate the chamber as Far Field Antenna Test Range, its quietness level in the prescribed quiet-zone is required for which Free Space VSWR method is followed. To arrive at figure of merit of the chamber of its use for RCS measurement equivalent RCS of chamber was measured at the designed / intended location.

Five axis antenna positioner has also been installed in the chamber providing three rotations (azimuthal, elevation and polarization) and two linear movements to the device under test. The metallic structure of the positioner has been covered by judiciously selected absorbers lined box to avoid unwanted reflections to reach to quiet-zone. The design and selection of Absorber make this facility suitable / extendable for Near Field and even to a small single reflector compact range, if so required. The test facility is created in a very high quality (shielding effectiveness~100dB) PAN type modular RF shielded structure. Facilities like waveguide air-vents, power line filter, distribution panel and lighting, access panel with RF connectors, CCTV, smoke detector and alarm system have been installed. Since 24- inch thick absorbers are installed at all premier locations, the chamber can be used for EMI/EMC applications as per MIL-STD-461E. Shielding effectiveness of chamber was tested as per MIL-STD-285.

Key words*: Anechoic Chamber, Near Field, Far Field, RCS, & EMI/EMC etc.*

I. *Introduction*

Anechoic chamber: a nearly reflection free , indoor measurement system has been designed, developed and evaluated for different applications and fields like antennas, EMI/EMC, RCS measurement and scattering studies, etc.

This paper shall be described in two parts, firstly: the design, installation and validation of shielded chamber and secondly the Design, Installation and Validation of Far Field/ Near Field / RCS /EMI-EMC test facility in the chamber.

II. *Design, installation and validation of shielded chamber.*

a) *Shielding Effectiveness Specifications /Design parameters*

1. **Chamber Size**: 7.0m X 5.0m X 3.0m (Length X Width X Height).

2. Frequency Region: 14 KHz to 18.0 GHz.

3. Purpose: EMI-EMC Measurements as Per MIL-STD-461E/F

4. Structure Type: Modular PAN Type, self supported, maintenance free total steel structure is installed.

5. Shielding Effectiveness:

Min. -50dB at 14 KHz for H- Field

Min. -80dB at 100 KHz to 1 MHz for H-Field,

Min. -100dB at 100 KHz to 10 MHz for E-Field,

Min. -100dB at 100 MHz to 1.0 GHz for Plane Wave,

Min. -80dB at 2.0 GHz to 18.0 GHz Microwave.

6. Wave Guide Air vents: 04 Nos. wave guide vents of size 300mm X 600mm.

7. Power Line Filter: 1 Phase, 2 Line, 240 V, 32A, 1 Nos.

8. Distribution Panel & Lighting: Power through the Power line filter be connected to 2 Nos Distribution Panels inside chamber.

9. Access Panel: Approx 30cm x 30cm size with 4 No N (F) to N (F) and 4 Nos. SMA (F) to SMA (F) connectors with matched terminations on both ends are to be installed.

10. CCTV Assembly: A CCTV camera is to be installed to monitor the movement inside the chamber. It consist LCD High resolution monitor of Samsung make having 19” size.

b) Design and Installation of shielded chamber.

The shielded chamber has been designed the by PAN design, which is a Total Steel Structure (TSS), an improved design over conventional sandwich type wood core structure (WCS). CAD Design of Chamber as in figure 1.

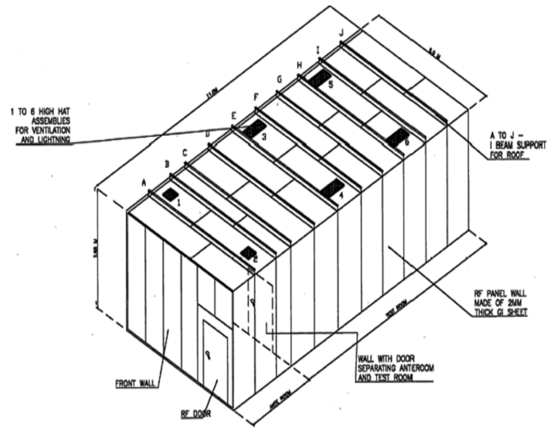

Figure 1: CAD Design of Chamber.

i) Advantages of PAN Type TSS over WCS:

- Superior Attenuation with less weight.
- Easy expandability and relocation using less parts.
- Self supporting upto 12 ft high and 16 ft span while WCS room must have steel supporting members when higher than 8 ft or spanning 8 ft.
- TSS is very desirable in geographic regions with seismic problems. A WCS room can break apart.WCS room has 5 leak points (screws, both surfaces of hat and flat and any joints areas of inter section). TSS has one point of possible leakage (Missing Bolts) and still there is an RF gasket.
- WCS room needs every bolt to be torqued exactly.
- WCS design needs very strict construction practice concerning squareness, plumb, level etc.
- TSS is much more forgiving and very easy to construct.
- TSS is not affected by water and moisture, which play havoc with WCS system.
- TSS allows easy installation of anechoic material without effecting RF Shielding.
- TSS system provides easy inspection contrary to WCS system.

- TSS offers years of maintenance free, high RF attenuation. Moisture / water absorption with thermal expansion or contraction of wood threatens the Shielding Effectiveness of WCS rooms and need to be maintained regularly.

ii) Construction Details

1. 2mm thick hot galvanized sheets indigenously* developed.
2. Computer Aided Designing of parts.
3. Cutting and bending by Laser / CNC machines.
4. Tolerances fabrication of PANs is 0.2mm in length and width wise on inside radii for bending.
5. Radiography quality TIG welding of corners of panels was done.
6. 100% testing of welding by using Iridium (Ir 192) source.
7. Special penetrating solder was used to tin plate the corners to avoid rusting of the welded joints.

iii) Unique Flat Surface Inside/Outside

The walls and the roof are constructed by flat surface inside and the floor was constructed by flat outside, which is the most ideal though difficult to work.

iv) Assembly of PANs

Floor was level to 5mm in 5m for structural integrity of the room and for Shielding Effectiveness. Vapor barrier was used in the form of polyethylene sheet and MDF (medium density fiber) board as a dielectric isolator to keep he chamber insulated from the ground for effective single point grounding of the chamber.

Edges of PANs cleaned of dust, dirt and oil to avoid formation of non linear junctions. Gaskets were thoroughly cleaned with the contact cleaner for the same reason.

Joining of PANs using Rail Road Copper Gasket. The chamber is free standing with no support from parent building. Chamber is housed in a parent building as it is not designed to support loads from weather (storms, rains etc.).

v) Assembly of Door

- Three rows of Copper Beryllium fingers in two pockets were provided for ensuring Shielding Effectiveness.
- 2-point cam locking system.
- Doors are designed to open approx.180°.
- Rail Road gasket used between the door frame and the basic Pan structure.
- Door leaf hanging on the frame by the two hinges mounted in the door frame.

v) 2nd Layer to Get Flat Surface & Better Shielding Effectiveness.

M.S. Square pipe of 40mm x 40mm furring inside the PANs have been put to support the second layer of GI sheet (2mm thick on the floor and 1mm thick else where) to ensure flat surface on the floor and on the side walls and to give extra shielding efficiency.MDF board of 4mm thickness has been used on floor as an isolator /Dielectric insulator.

c) Shielding Effectiveness Evaluation of shielded Chamber.

The chamber has been evaluated in accordance with the MIL STD – 285[1]. Test results[6] for shielding effectiveness are tabulated in table 1.

Type of Wave	Frequency	Designated Specification (dB)	Shielding Effectiveness in dB			
			Loc. 1	Loc. 2	Loc. 3	Loc. 4
Magnetic	14 KHz	≥-50	-51	-51	-51	-51
Magnetic	80 KHz	≥-50	-62	-62	-62	-62
Plane	400 MHz	≥-100	-114	-114	-114	-114
Plane	1.0 GHz	≥-100	-101	-101	-101	-101
Microwave	3.0 GHz	≥-100	-106	-106	-106	-106
Microwave	9.0 GHz	≥-80	-86.6	-86.6	-86.6	-86.6

Table 1: Test results for shielding effectiveness.

III. *Design, Installation and Validation of Far Field/ Near Field / RCS /EMI-EMC test facility.*

a) Specifications/Design Parameters.

1) **Chamber Size**: 7.0m X 5.0m X 3.0m (Length X Width X Height)

2) **Frequency Region:** 80MHz to 40 GHz.

3) **Purpose**: Antenna Near Field/Far Field /RCS/EMI-EMC Measurements.

4) **Intended Measurements:**

i) **Antenna Far-Field Measurements should cover the following:**

a) Azimuth antenna Pattern: 360 degree.
b) Relative/Absolute Gain Measurements of Antenna whose gain range from 0 dBi to +20 dBi or more.
c) Chamber may be used for circular polarization and rotating linear polarization.
d) Bore sight measurements be carried out.
e) Radome error measurements are carried out.

ii) **Antenna Near Field Measurements might cover the following:**

a) Planar.
b) Cylindrical and
c) Spherical Near Field testing.

iii) **RCS Measurements should cover the following:**

a) Both monostatic and bistatic RCS measurements.

b) Bistatic Measurements from +/- 20 degree from monostatic to be carried out from 3 GHz to 40 GHz.

iv) **EMI/EMC Measurements:**

These measurements can be carried out as per MIL STD 461 E/F by removing absorbers on floor. Thus absorbers on floor should be removable.

5) **Transmitting Antenna Gain:**

Transmitting Antenna Gain for antenna measurement should be min. 6 dBi at 500MHz, +10 dBi at 1.0 GHz, min +13 dBi at 3 GHz and min. +15 dBi between 5.0 to 40.0 GHz.

6) **Quiet Zone (QZ)Size / Location / Quietness / Equivalent RCS for antenna Far field/RCS measurement:**

Frequency	Q Z Cylindrical (Length = Diameter)	QZ Locations from Tx Antenna	Quietness	Residual (Equivalent) RCS of Chamber	
				Location	RCS (dBsm)
500MHz	1.0 m	3.0 to 4.0 m	-20 dB	--	--
1.0 GHz	0.8 m	3.2 to 4.0 m	-35 dB	--	--
2.0 GHz	0.6 m	3.4 to 4.0 m	-40 dB	--	--
3.0 GHz	0.5 m	3.5 to 4.0 m	-40 dB	3.0 m	-30
10.0-40.0 GHz	0.3 m	3.7 to 4.0 m	-40 dB	3.0 m	-30

7) **Quiet zone size /Location /Quietness for Antenna Near Field measurements:**

Frequency	Quiet zone size (Centrally located length, width, height wise).	Quietness
2.0 to 40 GHz	4.0m X 2.0m X 1.0m (L X W X H)	-40 dB

8) **Absorber Type* and design details**:

Absorbers should be / were selected and placed to achieve the above performance.

9) **Fire Retardancy of Absorbers[5]:**

As Per NRL USA-8093 Standard complying Tests No.: 1, 2 and 3 with ZERO HALOGEN MEANS.

10) **Smoke Detection System:**

VESDA Laser Focus make fire alarm system is to be / was installed.

*http://www.sahajanandlaser.com/Products.htm

b) Quietness and Equivalent RCS Evaluation/Results :

Quietness evaluation of the designed chamber is done by free space VSWR method. For evaluation of equivalent RCS of designed anechoic chamber a rotating off centric metallic sphere method has been used.

i) Brief of the VSWR Test Method [2] for quietness evaluation: The chamber was illuminated by the transmit antenna of the designated gain at the designed location. The receiving antenna Rx was moved in the quiet zone at various aspect angles (Pattern Levels) with respect of transmit antenna. The standing waves are recorded at these aspects angles by moving Rx either regularly or in a step less then $\lambda/16$ (step movement followed) and the reflected signals are plotted as VSWR curves w.r.t. the separation in the quite zone. The reflectivity level of the chamber is then calculated w.r.t. the direct signal to arrive at the room reflectivity (R).

To arrive at maxima (b) and minima (c) values from the data the standing wave is enveloped.

Two curves one connecting the maxima and other connecting minima are loosely drawn.

The value of (b) and (c) are chosen at that level where maximum value of R is obtained.

Let:

i) Ed-direct signal (0dB) at the Rx location.

ii) Er- reflected signal (To be measured)

iii) Ea- Pattern signal (a dB) which interferes with the reflected signal.

iv) b (dB) and c (dB) are the levels detected in phase and out of phase of Ea and Er thus corresponding to maxima and minima of the interference pattern.

$a = 20 \log_{10} (Ea/Ed)$ ……………………….… . .(1)

$Ea = Ed\ 10^{a/20}$ ……………………………….…. . .(2)

$b = 20 \log_{10} \{(Ea+Er)/Ed\}$ ………… ……….. . (3)

$c = 20 \log_{10} \{(Ea-Er)/Ed\}$ …………………….... (4)

$b-c=\sigma\ (dB) = 20 \log_{10} \{(Ea+Er)/(Ea-Er)\}$…….. .(5)

Quietness or Room reflectivity R (dB) should then be,

$R\ (dB)=20 \log_{10} (Er/Ed)$…………….................. (6)

$R\ (dB) =20 \log_{10} (Er/Ea)\ 20 \text{ logs}_{10} (Ea/Ed)$ …..... (7)

From Eqn. (5) value of $20 \log_{10} (Er/Ea)$ which is reflectivity level below the pattern level can be computed.

Quietness or reflectivity of the chamber can then be found out by adding this value with the pattern level a as per Eqn. (7).

ii) Brief of Rotating off Centric Metallic Sphere Method[3]:

- Considering that coupling between the two antennas is negligible in the bistatic RCS measurement.
- Tx and Rx horn antenna are mounted side by side in Bistatic RCS measurement setup.
- With no target (sphere) in position the resultant electric field vector at the Rx is a component $\sqrt{x} \angle X$ correspond to the signal reflected by the chamber.
- The magnitude of the signal from chamber is assumed as $\sqrt{x}$ so that x can be defined as the RCS of chamber.
- A conducting sphere of known dimensions and therefore known RCS say σ is now mounted on a azimuthal rotator at far field distance (in the prescribed quiet zone) on the line of sight of antenna pair and is rotated eccentrically about a vertical axes thus cover the prescribed quiet zone at a given separation.

The received response is recorded as a function of azimuth rotation at a small angular rotation (used 1 degree rotation step) thus plotting the interference pattern between √x.(amplitude of chamber return) and the amplitude of the sphere return which is √σ which appears in different phase thus creating the interference pattern.

- Thus voltage ratio corresponding to average decibel peak to peak excursions of the curve shall either[4] be,

$$\frac{\sqrt{\sigma}+\sqrt{x}}{\sqrt{\sigma}-\sqrt{x}} \quad \text{Or} \quad \frac{\sqrt{\sigma}+\sqrt{x}}{\sqrt{x}-\sqrt{\sigma}}$$

Considering if √σ is higher then √x or vice versa.

Also in the same setup the metallic sphere is removed and the RCS of empty chamber is noted which is well blow the RCS of sphere noted earlier. In view of this it is imperative that chamber RCS (x) is far below the sphere RCS (σ).

Model Calculation of Chamber RCS:

Frequency: 10GHz

Radius of revolution=250 mm

Sphere diameter: 200 mm (0.2m)

RCS of sphere $\sigma = \pi.\ (0.1)^{2} = 0.03142\ m^{2,}$

$\sigma = -15.03$ dBsm

$\sqrt{\sigma} = 0.17726$

Average excursion= 1.58 dB

Consideration: √σ is higher then √x.

$20 \log_{10} [(\sqrt{\sigma}+\sqrt{x}) / (\sqrt{\sigma}-\sqrt{x})] = 1.58$

$(\sqrt{\sigma}+\sqrt{x}) / (\sqrt{\sigma}-\sqrt{x}) = 1.1995$

$\sqrt{x}/\sqrt{\sigma} = 0.0907$

$\sqrt{x} = 0.0907 \text{ X } 0.17726 = 0.0161$

$x = 0.0002585$

Chamber RCS x = -35.89 dBsm

III) Results:

i) Test results summery of VSWR Method for quietness evaluation of Chamber[7]:

Frequency	Designated Specification of Quietness	Achieved Value of Quietness	Frequency	Designated Specification of Quietness	Achieved Value of Quietness
500 MHz	-20 dB	-28.68 dB	2.0 GHz	-40 dB	-43.76 dB
500 MHz	-20 dB	-29.38 dB	2.0 GHz	-40 dB	-47.89 dB
500 MHz	-20 dB	-33.20 dB	2.0 GHz	-40 dB	-44.52 dB
500 MHz	-20 dB	-35.26 dB	2.0 GHz	-40 dB	-49.27 dB
500 MHz	-20 dB	-33.92 dB	2.0 GHz	-40 dB	-44.80 dB
500 MHz	-20 dB	-35.26 dB	9.0 GHz	-40 dB	-42.48 dB
500 MHz	-20 dB	-24.89 dB	9.0 GHz	-40 dB	-59.93 dB
500 MHz	-20 dB	-38.35 dB	9.0 GHz	-40 dB	-45.71 dB
500 MHz	-20 dB	-49.27 dB	9.0 GHz	-40 dB	-48.55 dB
500 MHz	-20 dB	-44.80 dB	9.0 GHz	-40 dB	-50.82 dB
2.0 GHz	-40 dB	-49.23 dB	9.0 GHz	-40 dB	-53.04 dB
2.0 GHz	-40 dB	-45.41 dB	9.0 GHz	-40 dB	-49.24 dB
2.0 GHz	-40 dB	-58.80 dB	9.0 GHz	-40 dB	-53.16 dB

ii) Test Result Summery for Equivalent RCS of Chamber by Rotating off Centric Metallic Sphere Method[7] :

Freq.	Sphere size (mm)	Quiet zone diameter covered in meter	Designated Value of Equivalent RCS in dBsm	Achieved Value of equivalent RCS in dBsm
10.0 GHz	200	0.5	-30	-35.89

IV) Five axis antenna positioner:

Five axis antenna positioner has also been installed in the chamber providing three rotations (azimuthal, elevation and polarization) and two linear movements to the device under test. The metallic structure of the positioner has been covered by judiciously selected absorbers lined box to avoid unwanted reflections to reach to quiet-zone. An automated various types antenna measurements can be carried out in the designed chamber by utilizing this five axis antenna positioner.

V) Conclusion: On the basis of results obtained for quietness of the chamber by

VSWR method we can sate that the achieved quietness of the chamber much exceeds the designed specifications for specified gain of Tx at all frequencies in the designated quiet zone. And the result of equivalent RCS by Rotating off Centric Metallic Sphere Method shows much better performance then the specified values at 10 GHz. This implies that the chamber can be used to measure very low RCS of target.

This facility is suitable / extendable for Near Field and EMI/EMC Measurements also, thus making it a unique / only facility of its type with any of the Teaching Institution of our country-India.

References:

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