Absorbers and Anechoic Chamber Measurements

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SUMMARY

- Absorber Overviews
- Absorber Materials
- Use of Absorbers in chambers
- Chamber RF Testing Methodology
- Chamber designs using absorbers

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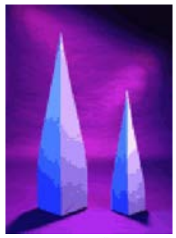
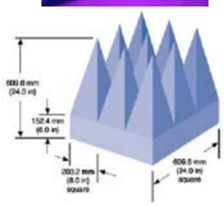
Electrically Lossy Absorbers





Microwave
Pyramidal absorber.
EMC and EHP series

Electric Losses

Preferred technology for High frequencies
It can be used for low frequencies if size (length) is increased

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Magnetically Lossy Absorber

Ferrite Tile .
Magnetic Losses
Preferred technology for Low frequencies (up to 1GHz), it has low profile.

It cannot be used for high frequencies > 1 GHz

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Electric/Magnetic Hybrid

Both Electric and Magnetic Losses

Preferred technology for EMC Applications. Compromise needs to be made to match foam and ferrite tiles at the bottom.

At High frequencies hybrid absorbers typically have insufficient performance compared to MW pyramidal absorbers

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Electric/Flat absorbers

Flat laminate .

Electric Losses

Preferred technology for laboratory set ups. It is a sandwich of different foams.

About 20dB absorption as frequency increases.

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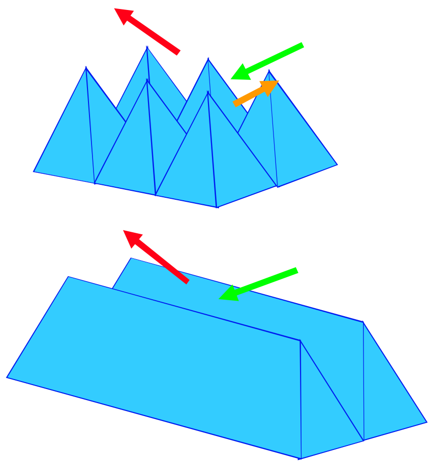
The Absorbers type 5



Wedge and pyramid

Electric Losses

Pyramidal absorbers are superior for small incident angles.

Wedge absorbers show reduced backscattering for large angles. Preferred technology for QZ treatment and for RCS chambers.

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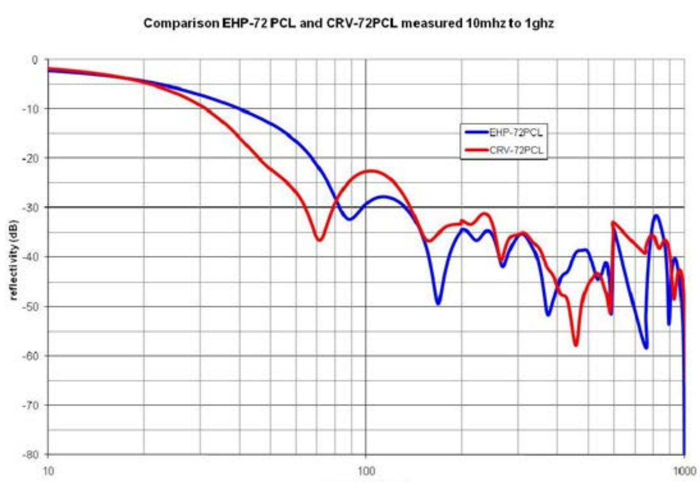
Measured data



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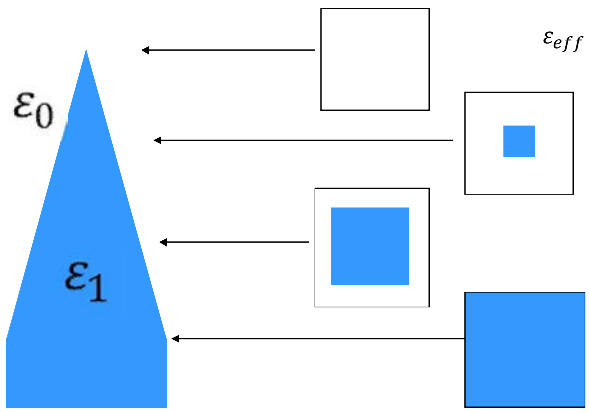
Quasi-Static Homogenization (Maxwell Garnett Mixing Rule)

$$\varepsilon_{eff} = \varepsilon_0 \frac{(1+g)\varepsilon_1 + (1-g)\varepsilon_0}{(1-g)\varepsilon_1 + (1+g)\varepsilon_0}$$

g is the fractional area occupied by the absorber material



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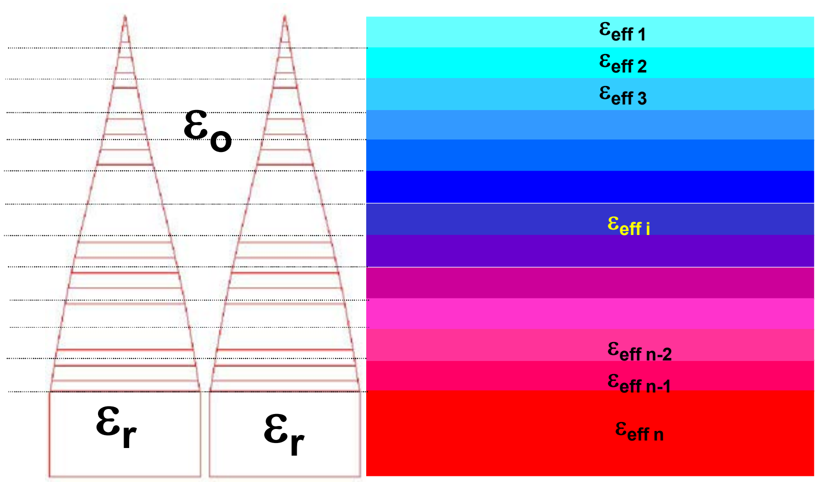
Understanding the absorbers (effective property)



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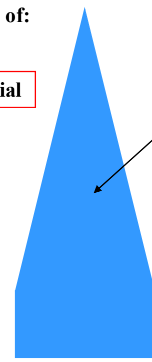
Pyramidal Absorber (Example)

Popular types of absorber have constitutive parameters of:

$\mu_r = 1$ ← **Non magnetic material**

$\varepsilon_r \approx 2 - j1$ ← **Low permittivity with losses**



This material is volumetrically loaded having the same constitutive parameters through the volume of the pyramid

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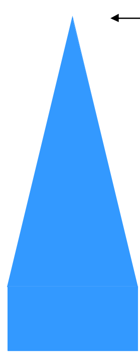
Pyramidal Absorber Theory (Example)



At the tip of the absorber The wave impedance is that of air $Z = 377\angle 0^o$

NO SUDDEN CHANGE IN WAVE IMPEDANCE = LOW REFLECTIVITY

Along the length of the pyramid the wave impedance falls between those two values.

At the base of the pyramid The wave impedance becomes

$$Z = \frac{377}{\sqrt{2 - j1}} = 252\angle 13.3^o$$

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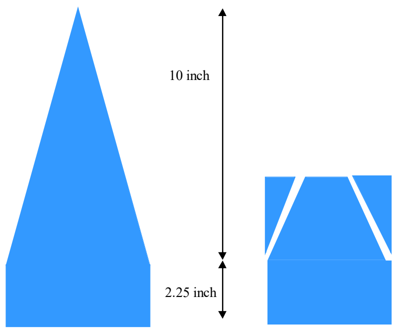
Pyramidal Absorber Theory (Example)



Approximate the pyramid to a solid equivalent volume at 1/3 of the height

For 1GHz

$$\gamma = j\tfrac{2\pi}{\lambda_o}\sqrt{\varepsilon' - j\varepsilon''} = j\tfrac{2\pi}{0.3}\left(1.56 - j0.82\right)$$

$$\alpha = \tfrac{2\pi}{0.3}\left(0.82\right) = 17.1\tfrac{Np}{m}$$

$$\left|\rho\right| = e^{-2\alpha x} = e^{-2\times 17.1\times 0.142} = 0.078 = -42dB$$

Wavelength at 1GHz

Approximate thickness of equivalent solid material

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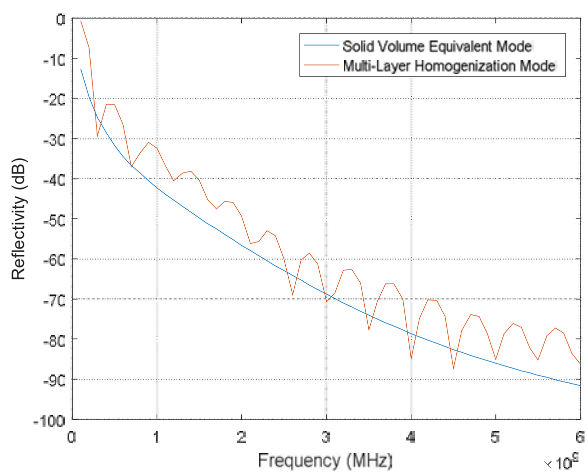
Pyramidal Absorber Theory (Example)



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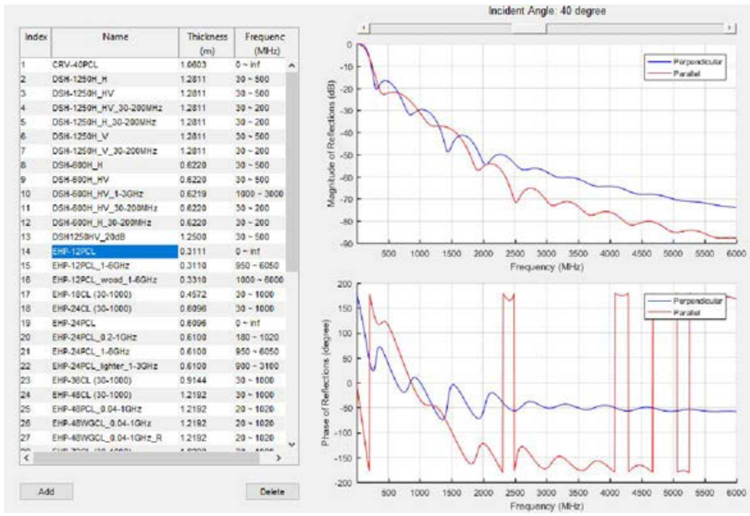
ABSORER Analysis



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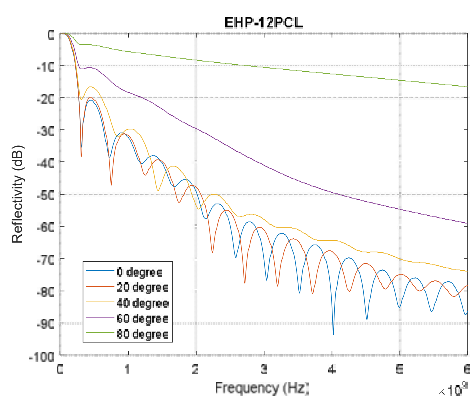
Absorber Reflectivity vs. Incidence Angle



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Typical Absorber Performance Given by Manufacturers

Maximum Reflections at Normal Incidence

Model Number	80 MHz	120 MHz	200 MHz	300 MHz	500 MHz	L Band 1-2 GHz	S Band 2-4 GHz	C Band 4-8 GHz	X Band 8-12 GHz	Ku Band 12-18 GHz	K Band 18-40 GHz
EHP-3PCL								-30 dB	-40 dB	-45 dB	-45 dB
EHP-5PCL							-30 dB	-40 dB	-45 dB	-50 dB	-50 dB
EHP-8PCL						-30 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB
EHP-12PCL						-35 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB
EHP-18PCL					-30 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB	-50 dB
EHP-24PCL			-20 dB	-30 dB	-35 dB	-40 dB	-50 dB	-50 dB	-50 dB	-50 dB	-50 dB
EHP-36PCL	-11 dB	-13dB	-25 dB	-30 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB	-50 dB	-50 dB
EHP-48PCL	-15 dB	-20 dB	-30 dB	-35 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB	-50 dB	-50 dB
EHP-72PCL	-20 dB	-30 dB	-40 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB	-50 dB	-50 dB	-50 dB

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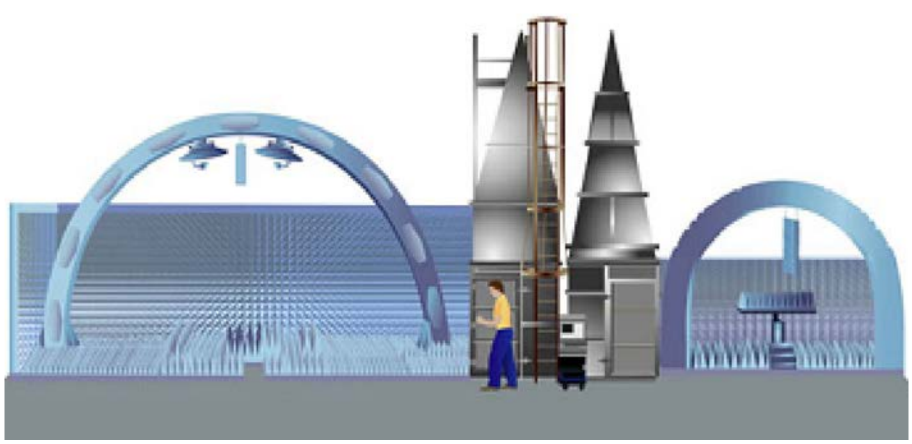
Absorber Reflectivity Measurement Devices from DC to 40 GHz



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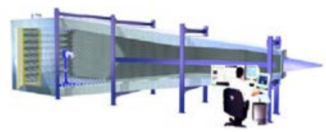
Rectangular and Tapered Chambers

- Rectangular
- Free Space condition
- What Antennas can be measured? Omni-directional and directional.

- Tapered
- Quasi-free Space.
- Absorber treatment is used to create a far field free space behavior of the waves at the location of the antenna under test.
- Lower frequency antenna patterns can be measured
- It can be used for High frequency testing but positioning of the source antenna is critical



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Chamber Measurement Techniques

- **ANSI/IEEE Std 149-1979** (Revision of IEEE Std 149-1965)
- University of Michigan Report 5391-1-F February 1963 (free space VSWR test)

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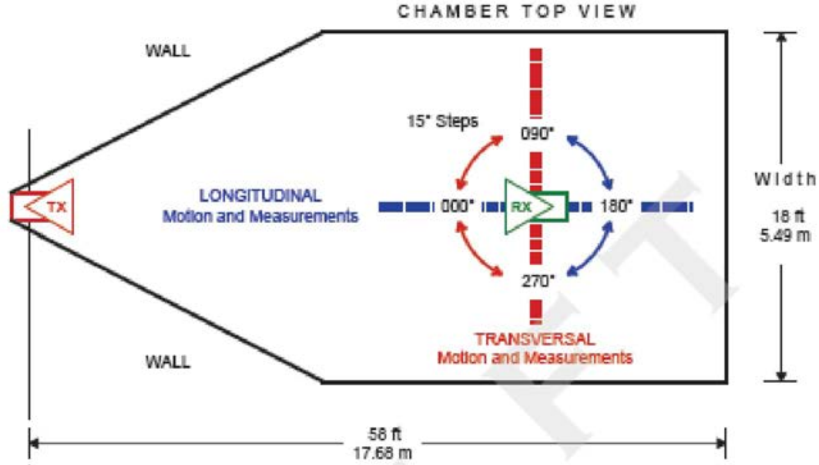
Free Space VSWR



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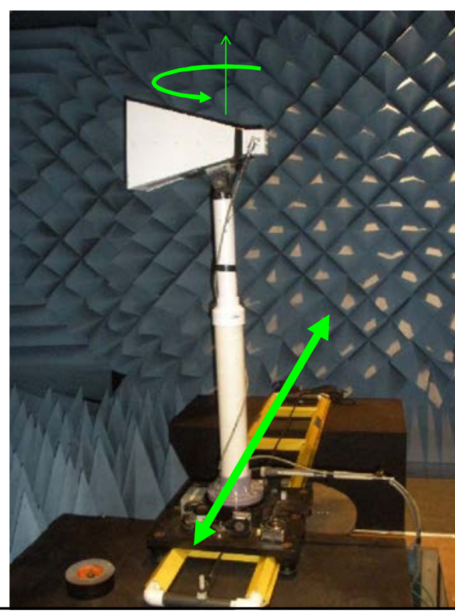
Transverse Scan

The probe antenna is scanned across the QZ
For each scan the antenna points at a different direction from -90 to 90 degrees, commonly every 15 degrees



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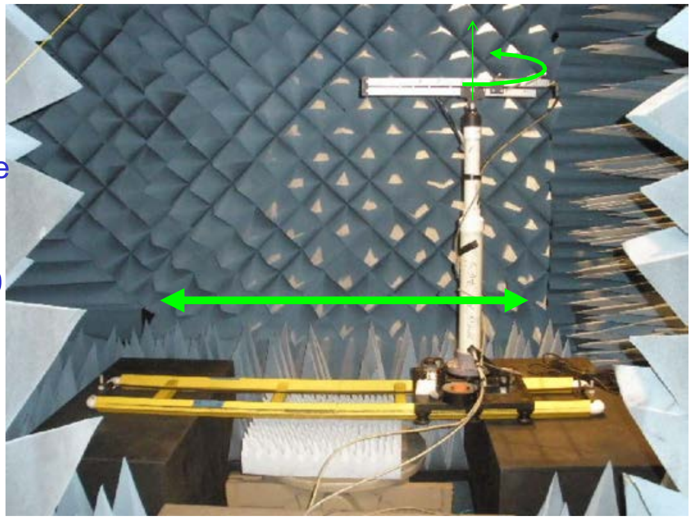
Longitudinal Scan

The probe antenna is scanned across the QZ
For each scan the antenna points at a different direction from -90 to 90 degrees, commonly every 15 degrees



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Definition of the chamber reflectivity R

$$R = \frac{\sum E_r^{'}}{E_d}$$

Prime denotes the E field is measured through a probe antenna

- *R* is defined as the ratio of the sum of all reflections seen by the probe antenna at angle α in the QZ to the incident signal
- Incident signal ***E**d* is a function of the transmit antenna and the chamber, so *R* is a function of the transmit antenna.

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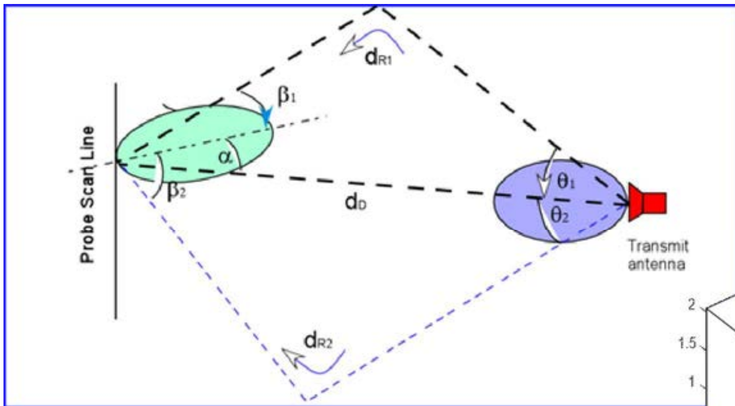

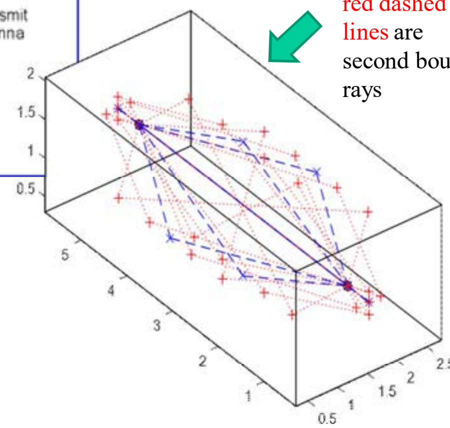

blue dashed lines are first bounce rays; red dashed lines are second bounce rays

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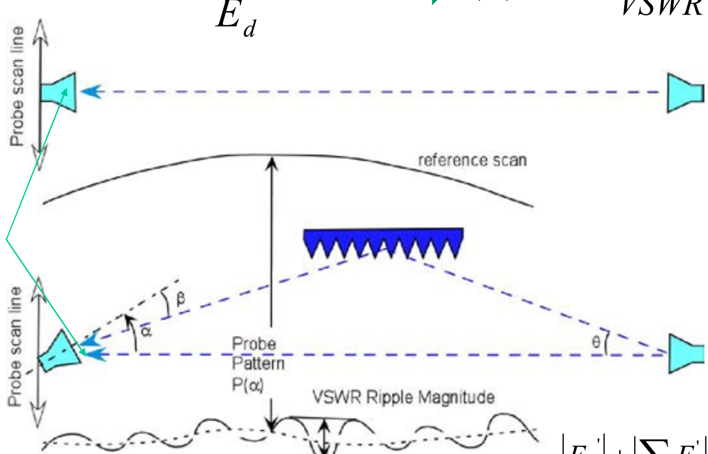
$$R = \frac{\sum E_r^{'}}{E_d} \quad \Rightarrow \quad |R| = P(\alpha)\frac{VSWR-1}{VSWR+1}$$

$$E_d^{'} = E_d \times P(\alpha)$$



$$VSWR = \frac{|E_d^{'}| + |\sum E_r^{'}|}{|E_d^{'}| - |\sum E_r^{'}|}$$

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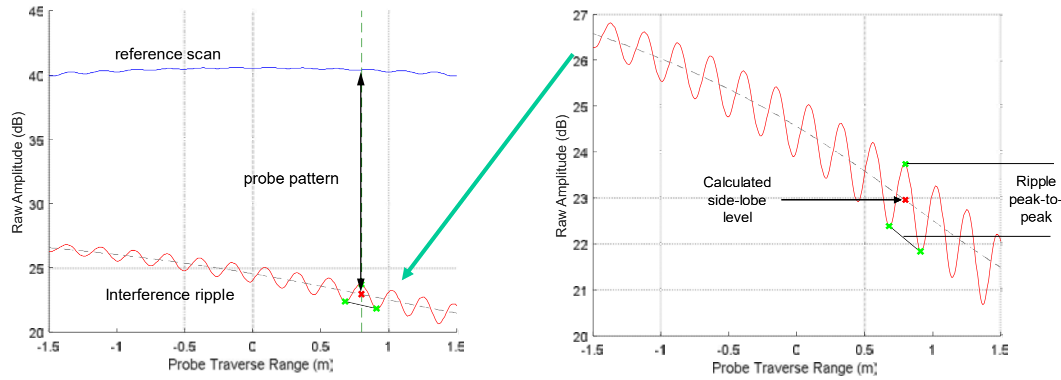
Illustration of Measurements



$$R = P(\alpha)\frac{VSWR-1}{VSWR+1}$$

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R is a function of the probe

- It is often not noted, but by definition, the chamber reflectivity is affected by the antenna pattern of the probe.
- R is a measure of how accurately one can measure the probe antenna pattern at scan angles α.
- If the EUT antenna is dissimilar to the probe, the resulting R may not be representative.

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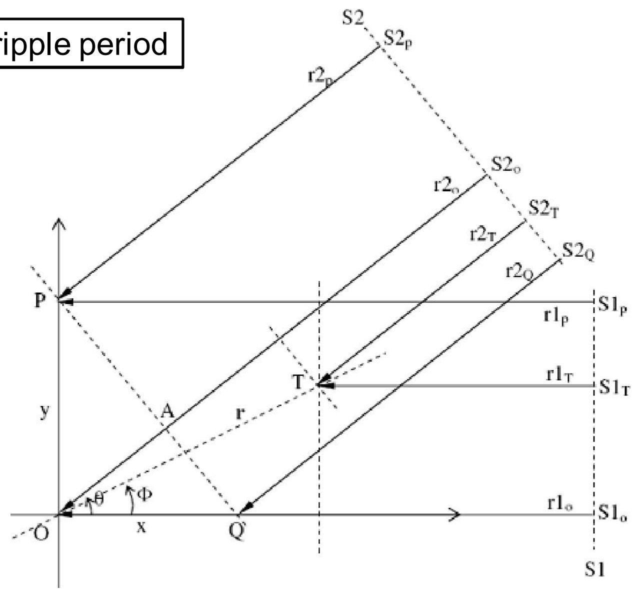
VSWR ripple period



longitudinal

$$d_x = \frac{\lambda}{2\sin^2(\frac{\theta}{2})}$$

transversal

$$d_y = \frac{\lambda}{\sin(\theta)}$$

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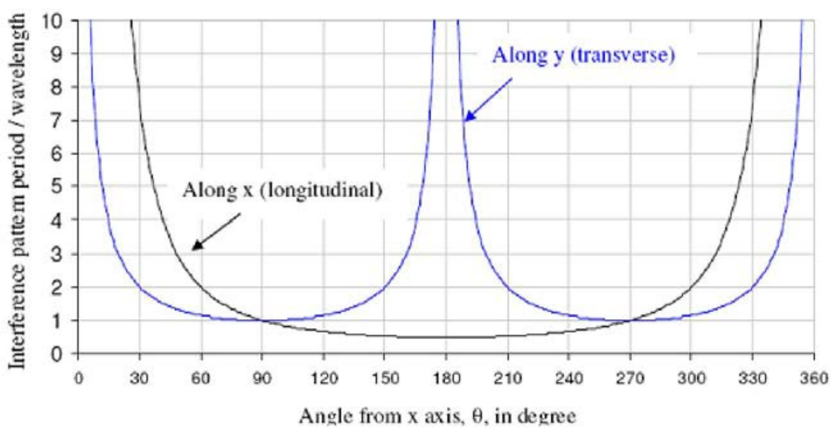

B Tian, “Free space VSWR method for anechoic chamber electromagnetic performance evaluation,” AMTA, Nov 2008.

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Observations of VSWR

- It is better to use a minimal scan distance to see an interference pattern:
  - For small angles, transverse scan is preferred
  - Only longitudinal scan can detect backwall reflections (180 deg)
  - For sidewalls, transverse scan is better
  - The two scans can give a sense of reflection direction

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Free-space VSWR

- Free-Space VSWR is a scalar measurement to measure the standing wave pattern (reflection coefficient, or reflectivity) of an absorber wall
- It attempts to measure one surface at a time using a high gain probe antenna
- CAUTION: In real use, when measuring a low gain EUT antenna in a chamber, the reflectivity level could be worse than indicated by free-space VSWR measurement because reflections can come from multiple surfaces

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Absorber Treatment in a Rectangular Chamber

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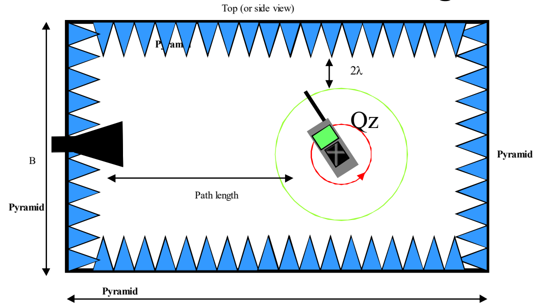
Antenna Chamber Rectangular I



$A = PL + Qz + 2 \cdot (\text{absorber depth})$

$PL = 2d^2 / \lambda_{\text{lowest freq.}}$

$B = 3 \cdot Qz$ or more accuratelly

$B = Qz + 4 \cdot \lambda_{\text{lowest freq.}} + 2 \cdot (\text{absorber depth})$

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Far-Field Rectangular Chamber Design Consideration-II

The Device Under Test (DUT) will determine the QZ dimensions, the pathlength for QZ field incident field uniformity, and the chamber dimensions

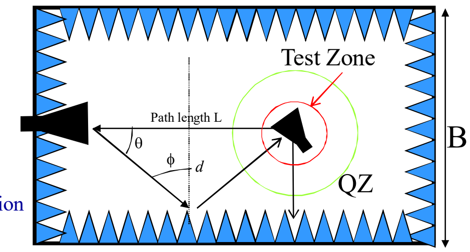
The S/N ratio will determine the absorber treatment

Assume a chamber with: width "B"; path length "L"; absorber depth "a", then

$$\phi = \tan^{-1}\left(\tfrac{L}{2d}\right) \quad or \quad \theta = \tan^{-1}\left(\tfrac{2d}{L}\right)$$

$$d = B/2 - a$$

It is desirable to have ϕ <45° to control degradation of absorber oblique incident performance



The Antenna Under Test (AUT) and the test range will determine the Test Zone dimensions. The Test Zone diameter D_r should meet the following equation:

$$L \geq 2(D_t^2+D_r^2)/\lambda_o$$

Often, the usable Test Zone is a small percentage of the far-field range QZ. As frequency gets higher and the higher the antenna gain, the usable Test Zone get smaller and smaller.

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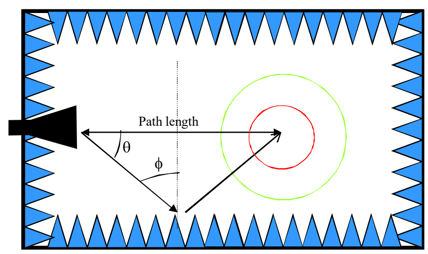
Far-Field Rectangular Chamber Design Consideration-III

With the value of ϕ it is possible (based on the thickness of the absorber in terms of wavelengths) to determine the expected reflectivity.

With the known directivity of the antenna and The knowledge of θ it is possible to compute The gain of the antenna in that direction

The reflected energy entering the quiet zone Can be calculated by:

$$SW_{\text{Reflectivity}} \approx R_{Tx}^{\phi} + G_{Tx}^{\theta}$$



Where R is the absorber oblique incidence reflectivity and G is the sidelobe level the source antenna

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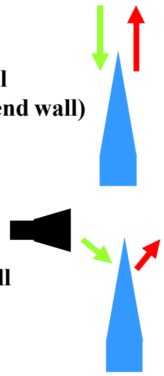
Antenna Chamber: The Absorber Treatment



Back wall
(receive end wall)

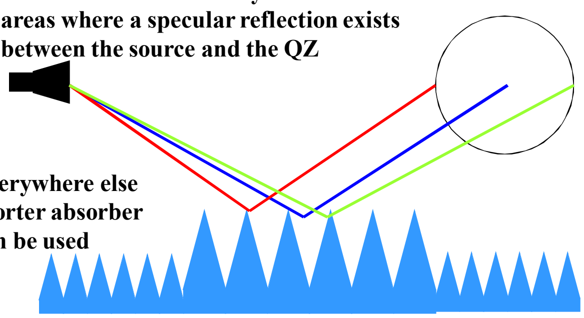
Normal Reflectivity better than QZ level

Side wall

Oblique incidence Reflectivity with off main beam gain better than QZ level

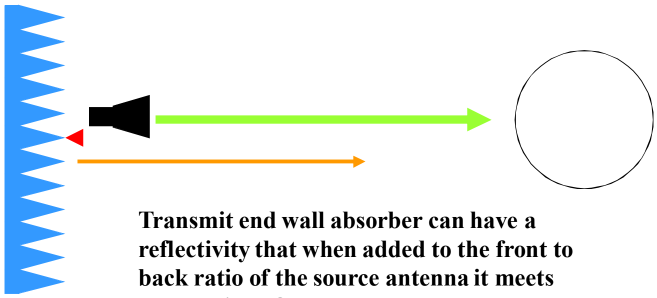
Antenna Chamber: The Absorber Treatment

Side wall absorber is only needed on those areas where a specular reflection exists between the source and the QZ



Everywhere else shorter absorber can be used

Antenna Chamber: The Absorber Treatment



Transmit end wall absorber can have a reflectivity that when added to the front to back ratio of the source antenna it meets the required QZ level

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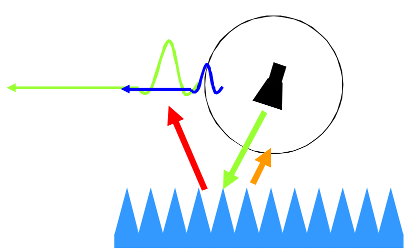
Antenna Chamber: The Absorber Treatment

At high frequencies the antenna under test may re-scattered the backscattered energy from the pyramidal absorber surrounding it



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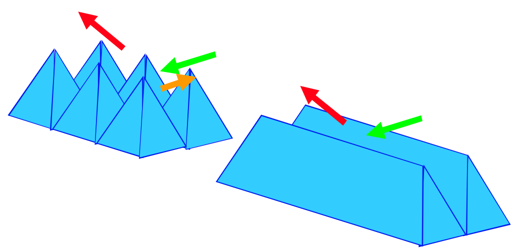
Antenna Chamber: The Absorber Treatment

1. Traditionally in RCS chambers the backscatter of the side walls (and ceiling/floor pair) is to be reduced using Wedge. By using wedge around the QZ section of the chamber we can improve the quality of the measurements at high frequencies



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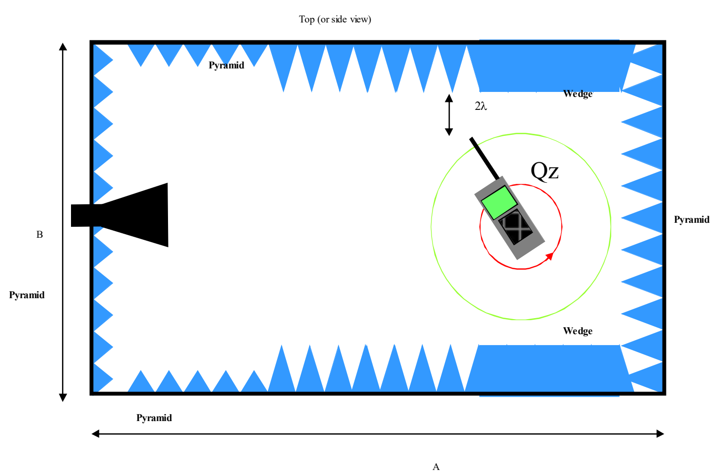
Antenna Chamber: The Absorber Treatment



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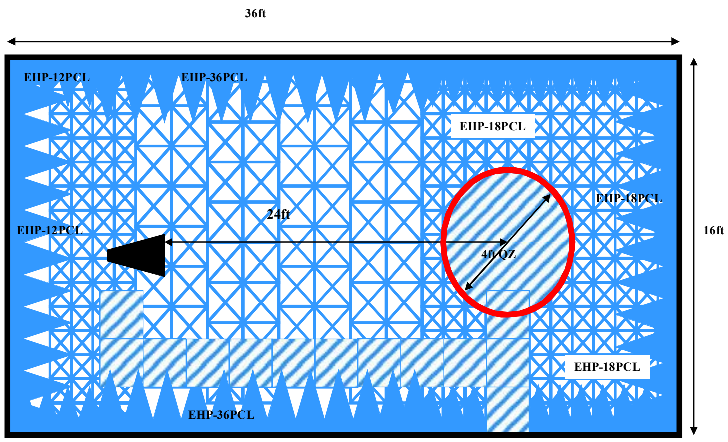
Walkway absorber has a lower absorption so it is placed on the sides or behind the Quiet zone



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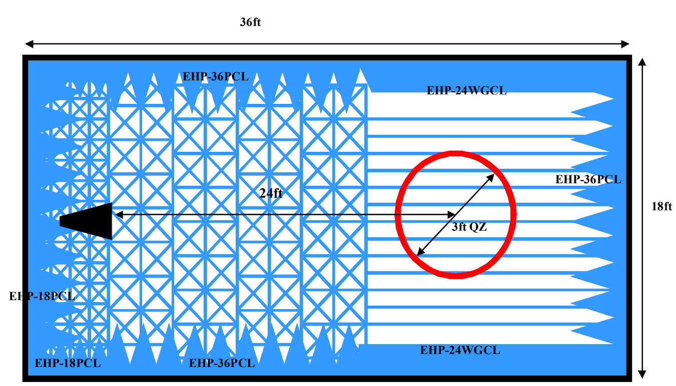
Wedge it is usually used to treat around the QZ



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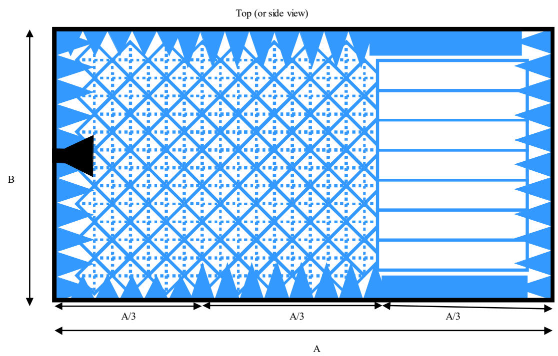
Specular Absorber at 45º



Absorber mounted at 45 degrees (twisted) to reduce the backscattering during RCS Operations

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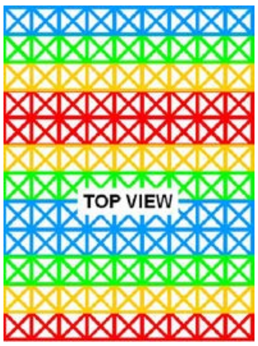
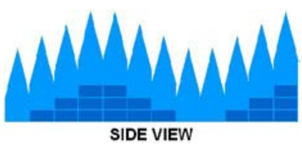
Chebyshev Layout

Analogous to Chebyshev impedance matching transformers in MW circuits. It is possible to have the reflections from the absorber field with different phases so that phase cancellation can be achieved at some frequencies.





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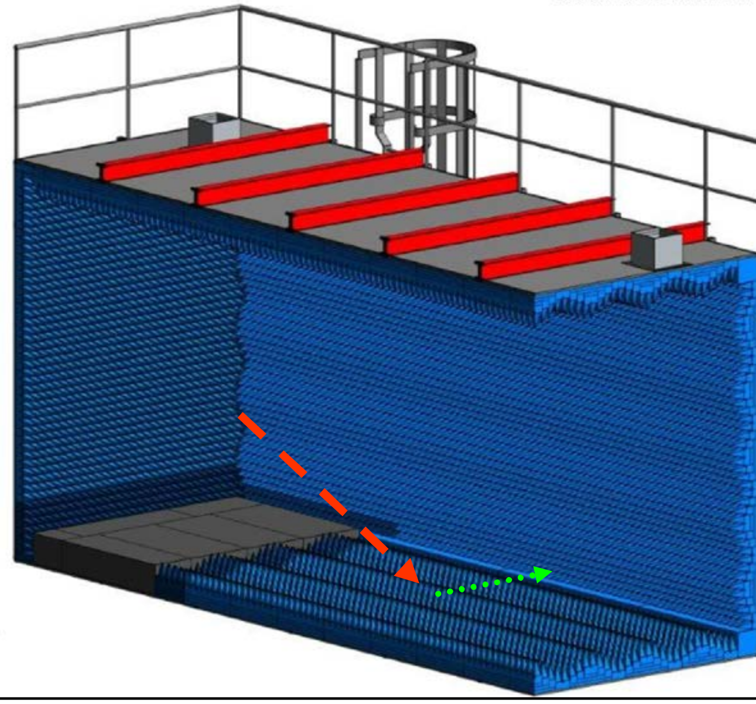
Chebyshev layout in a chamber



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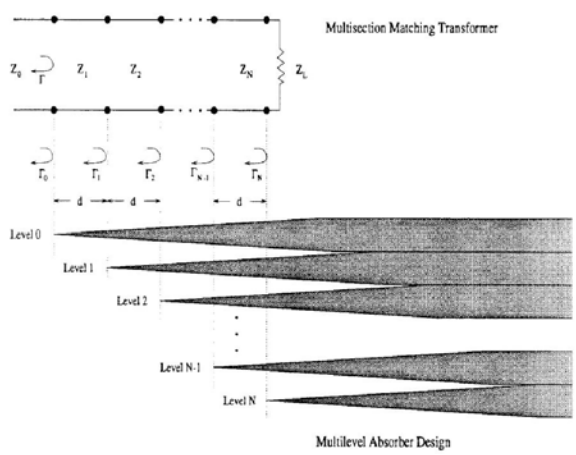

J Gau, etc. "Chebyshev multilevel absorber design concept", IEEE Trans. On AP, Vol. 45, No. 8, Aug 1997

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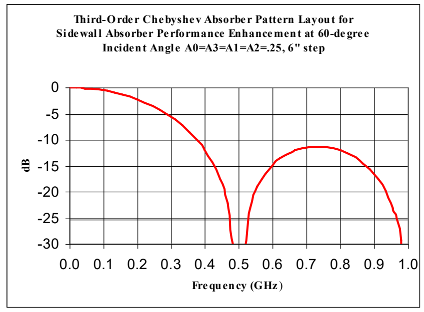
Chebyshev Designs

Choosing the proper step and polynomial weights is possible to improve the performance of the absorber field by a given number of dB.



The improvement shown on is based on ideal plane wave. In actual measurements, for example, 48” absorbers can yield (27dB absorber + 15dB from Chebyshev + 3dB from the source antenna pattern). So overall 40dB is achievable for the side wall treatment.

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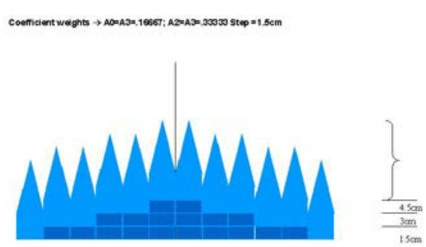
Chebyshev Measurement Sample



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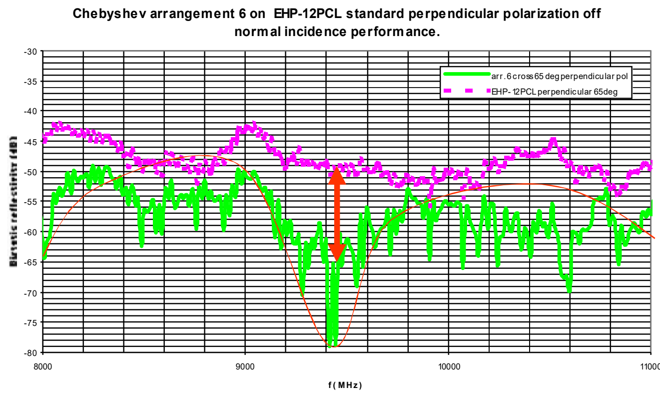
Chebyshev Measurement Sample



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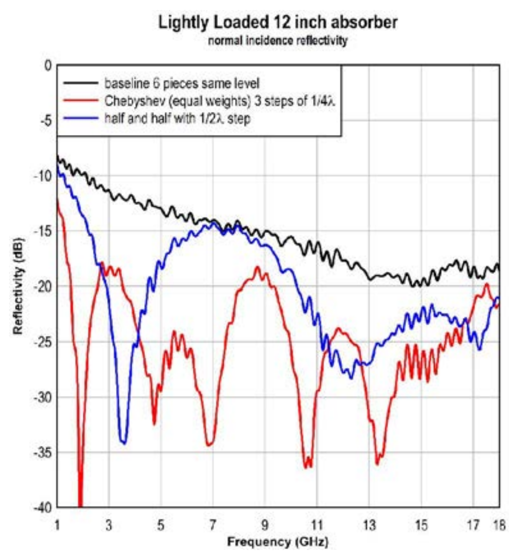

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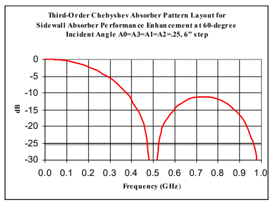
Rectangular Chamber (50x30x30ft) 48 inch /Chebyshev



Anechoic Performance	Frequency	Source directivity	Expected performance	Guaranteed performance
	0.5 GHz	9 dB	< -40 dB	-40 dB
	1 GHz	17 dB	< -45 dB	-42 dB
	2 GHz	17 dB	< -55 dB	-55 dB
	4 GHz	17 dB	< -55 dB	-55 dB
	8 GHz	17 dB	< -55 dB	-55 dB
	12 GHz	17 dB	< -55 dB	-55 dB
	18 GHz	17 dB	< -55 dB	-55 dB
	40 GHz	17 dB	< -55 dB	-55 dB

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Summary

- An overview has been provided on absorbers used in anechoic chambers.
- Free-space VSWR method was discussed for chamber measurements
- Discussions on various chamber design considerations and the use of absorbers to enhance the performances of an anechoic chamber

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