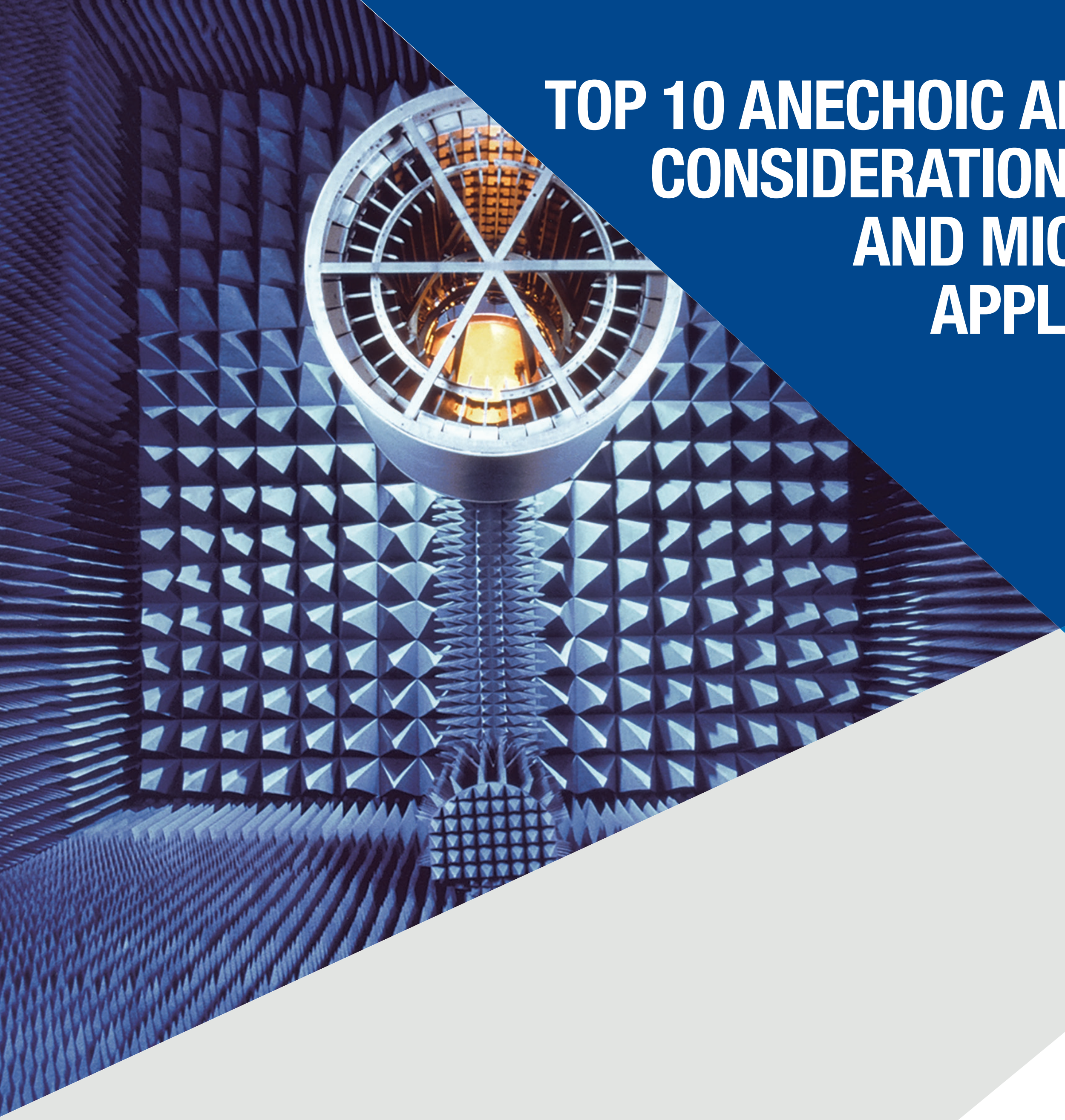

TOP 10 ANECHOIC ABSORBER CONSIDERATIONS FOR RF AND MICROWAVE APPLICATIONS

COMMITTED TO A SMARTER, MORE CONNECTED FUTURE

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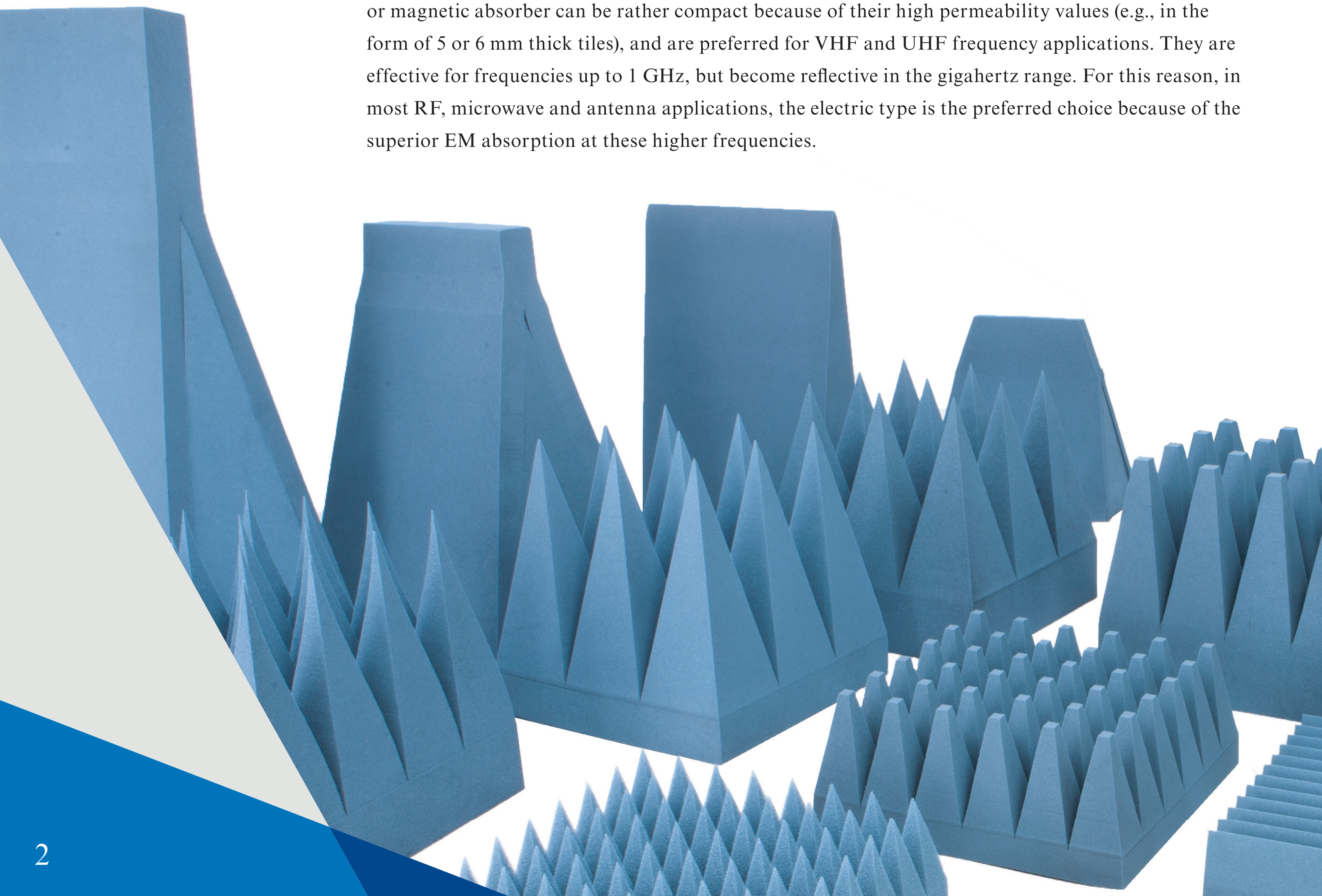
TOP 10 ANECHOIC ABSORBER CONSIDERATIONS FOR RF AND MICROWAVE APPLICATIONS

Following is our Top 10 list of the most important things you need to consider when selecting RF and Microwave Absorber for your test and measurement application. This resource will help you avoid the most common mistakes made in absorber selection as well as educate you about how absorber "works". The result? You'll select optimal absorber for your specific application, save time, and ensure the best measurement results. In addition, you'll appreciate that anechoic absorber is more than just "foam". This quick and concise guide covers many absorber selection considerations, including standards, impact of the device under test, chamber space limitations, and the effect of the installation environment on absorber performance, to name a few.

1. Understand how anechoic absorber works and be aware of the many different types of absorber designs available.

Absorber is designed to reduce reflections from impinging electromagnetic (EM) waves, and "absorb" incident electromagnetic energy. It does so by dissipating the electromagnetic energy inside the absorber and turning it into heat. Absorber is made of materials that can either have electrical loss property, or magnetic loss property. The electrical type is made of lossy dielectric (with complex permittivity). The magnetic type is made of lossy ferrite material (with complex permeability). Ferrite or magnetic absorber can be rather compact because of their high permeability values (e.g., in the form of 5 or 6 mm thick tiles), and are preferred for VHF and UHF frequency applications. They are effective for frequencies up to 1 GHz, but become reflective in the gigahertz range. For this reason, in most RF, microwave and antenna applications, the electric type is the preferred choice because of the superior EM absorption at these higher frequencies.



2. Appreciate the pyramidal shape influence on absorber performance.

Absorber is designed to cover a wide frequency range (with many decades of bandwidth). Broadband absorbers work by avoiding "sudden" changes in impedance for the impinging wave and gradually terminate and absorb the EM wave. Wave impedance is the ratio of the transverse components of the electric (E) and magnetic fields (H). The wave impedance is determined by the material it travels through. It is given by

$$\eta = \sqrt{\frac{E}{H}}$$

Inside a material, it is

$$\eta = \sqrt{\frac{\mu}{\varepsilon}}$$

Where η is the wave impedance, μ is the magnetic permeability, ε is the electric permittivity. In free space, $\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \approx 377\ \Omega$. Electrical absorbers are made of dielectric materials, with negligible magnetic property, so in the absorber:

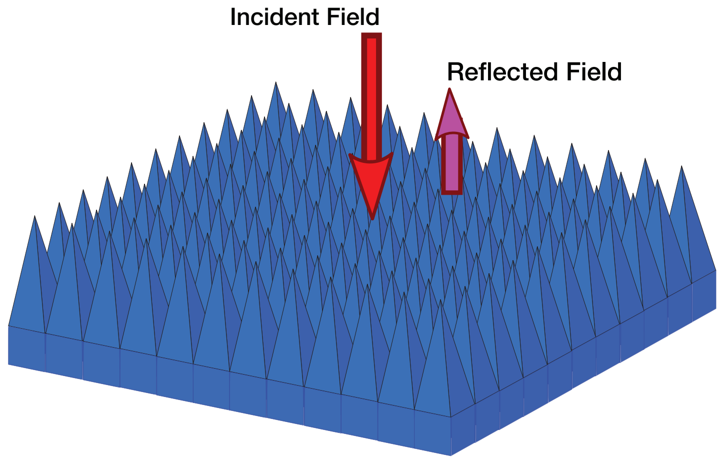
$$\eta = \sqrt{\frac{\mu_0}{\varepsilon_0 \varepsilon_r}} = \frac{377}{\sqrt{\varepsilon_r}}$$

Where ε_r is the relative dielectric constant (relative to free space).

Absorber is typically pyramidal. This is because when the wavelength is long compared to the period of the pyramids (number of pyramids in an area), the wave cannot distinguish the individual pyramid. Instead, it "sees" an average material mixed with dielectric and the surrounding air. When a wave impinges on the pyramidal absorbers, it "sees" a gradual change in the average wave impedance along the length of the absorber. Therefore, reflections are minimized. At the same time, because of the lossy properties of the absorber material, the electric energy is converted into heat loss (due to Ohms law).

3. Become aware of how absorber is specified for RF performance.

Reflectivity is the main figure of merit for RF performance. Reflectivity is defined as the ratio of the reflected field to the plane wave incident field when the absorber is directly placed over a conducting ground. It is usually expressed as a dB value. Since the absorber is measured over a reflecting ground plane, the reflection loss includes a wave traveling through the absorber round-trip. Transmission loss without the ground (through the absorber) is therefore approximately half the reflection loss. Absorber works most effectively when the incident EM wave impinges directly on them (i.e., with an incident angle of 0^{o}, or at a normal angle). Absorber is typically specified for the reflectivity as a function of frequency at normal incident angle. It is important to understand that reflectivity degrades at larger incident angles. Keep in mind that if the absorber is used in an area with the incident wave coming at large incident angles, the specifications for a normal angle can be overly optimistic.



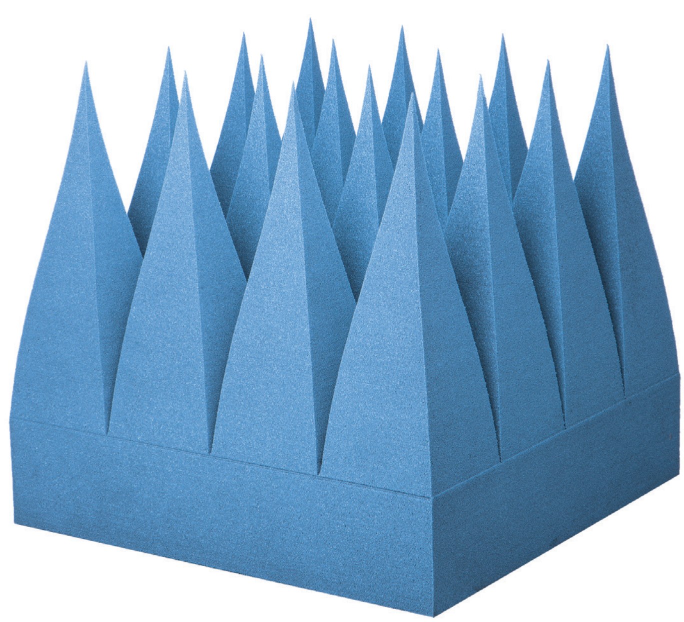
4. Select the correct absorber length and shape for your application.

Pyramidal absorber length determines how well it can work at the lowest frequencies. In general, for normal incidence:

- **To achieve 20 dB reflectivity level, the length of pyramidal absorbers needs to be approximately 0.4 wavelength (0.4λ) or longer**
- **For 30 dB reflectivity, the length needs to be approximately 0.8λ or longer**
- **For 40 dB reflectivity, the length needs to be approximately 1.5λ or longer**

Where λ is the free-space wavelength in meters, which can be calculated from $\lambda = 300/f$, where f is the frequency in MHz. Advanced numerical simulations and precise material property control can be used to achieve optimized reflectivity for the given lengths. One example of an optimized absorber design results in a curvilinear shaped absorber.

With the curvilinear shape, 40 dB reflectivity level is achieved with a length of less than 1λ, compared to 1.5λ for the typical pyramids. For applications with space constraints, curvilinear absorber is an excellent choice.



5. Know the commonly available absorber lengths.

The typical length of most absorber is 3”, 5”, 8”, 12”, 18”, 24”, 36”, 48” or 72”. For ETS-Lindgren absorber, the length of the absorber is identified in the model number, e.g. EHP-24PCL is the 24” pyramidal absorber. Each absorber piece consists of an array of pyramids which covers a 24” x 24” area. The shorter absorber consists of more pyramids. For example, one piece of EHP-3PCL consists of 12 x 12 pyramids, while one piece of EHP-24PCL consists of 3 x 3 pyramids. If you purchase absorber in typical, off the shelf lengths, you will save money and likely receive your absorber quicker. Below please find the typical reflectivity of the different absorber lengths.

Maximum Reflections at Normal Incidence

MODEL NUMBER	80 MHz	120 MHz	200 MHz	300 MHz	500 MHz	L-BAND 1 to 2 GHz	S-BAND 2 to 4 GHz	C-BAND 4 to 8 GHz	X-BAND 8 to 12 GHz	KU-BAND 12 to 18 GHz	K-BAND 18 to 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	-13 dB	-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
EMC-24PCL	-6 dB	-6 dB	-7 dB	-30 dB	-35 dB	-45 dB	-50 dB	-50 dB	-50 dB	-50 dB	-45 dB

6. Pre-determine the maximum power handling capability of absorber.

High quality polyurethane based absorbers can safely handle up to 90ºC temperature without permanent damage. As a rule of thumb, polyurethane absorbers are specified to withstand a maximum power of 0.5 W/in^2 of continuous wave (CW) incident field under room temperature with no additional forced airflow. This is equivalent to 540 V/m of electric field (plane wave/far field condition). For higher power handlings applications, a more porous foam based absorber (using reticulated foam substrates) is available. This type of “filtered foam” absorber is commonly placed over air vents in anechoic chambers. The filtered foam absorber can dissipate heat more efficiently and handle power up to 1 W/in^2 without forced air, and much higher power with forced air through the absorber.

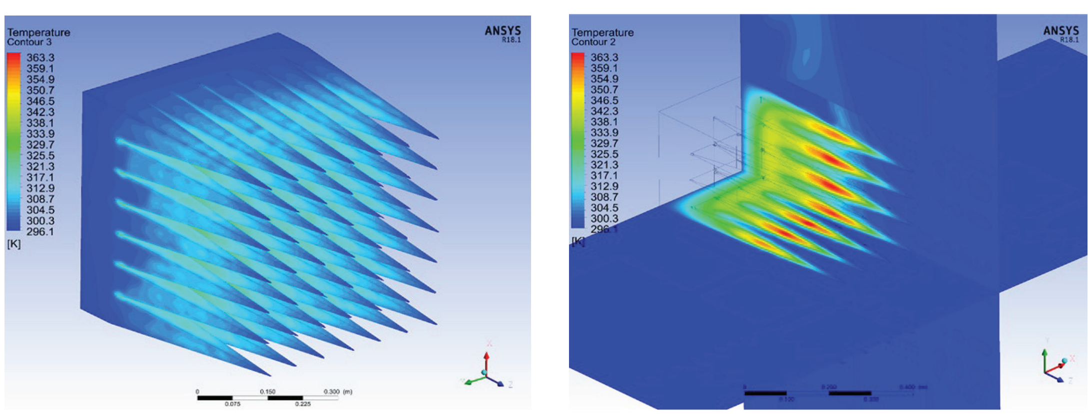
For even higher power applications, high-power absorber with a honeycomb substrate made from a phenolic-based material is recommended. Lossy films are coated on the walls of the honeycomb for effective absorption of incident electromagnetic waves. The hollow honeycomb network allows air to be drawn through them while the phenolic-based material withstands high temperatures. The benefit is that electromagnetic energy flux can be loaded to the absorber at much higher power densities than conventional absorber made with polyurethane material. Quality high power absorber can reach 250ºC without damage, and can handle 2 W/in^2 without forced air. With forced airflow, this absorber can withstand much higher electromagnetic field power densities. Additional expertise in both RF and mechanical engineering is required to enable high power test systems achieve the design goals and safely operate for your specific needs.

As a general rule of thumb, the above description provides a guideline on absorber power handling capabilities. The absorber thermal profile under different power levels is a complicated topic which depends on the RF frequency, near or far field condition, ambient temperature and airflows. Since the safety of personnel and protecting the anechoic chamber investment as well as the equipment under test are critical, verify the absorber manufacturer has the ability to conduct extensive power handling studies using multi-physics simulation tools, such as ANSYS® HFSS (High Frequency Structure Simulator; for electromagnetics) and ANSYS Icepak (for thermal simulations). These simulations have been validated by measurement results, and can be a valuable tool to meet more specific design needs and ensure a safe test environment.

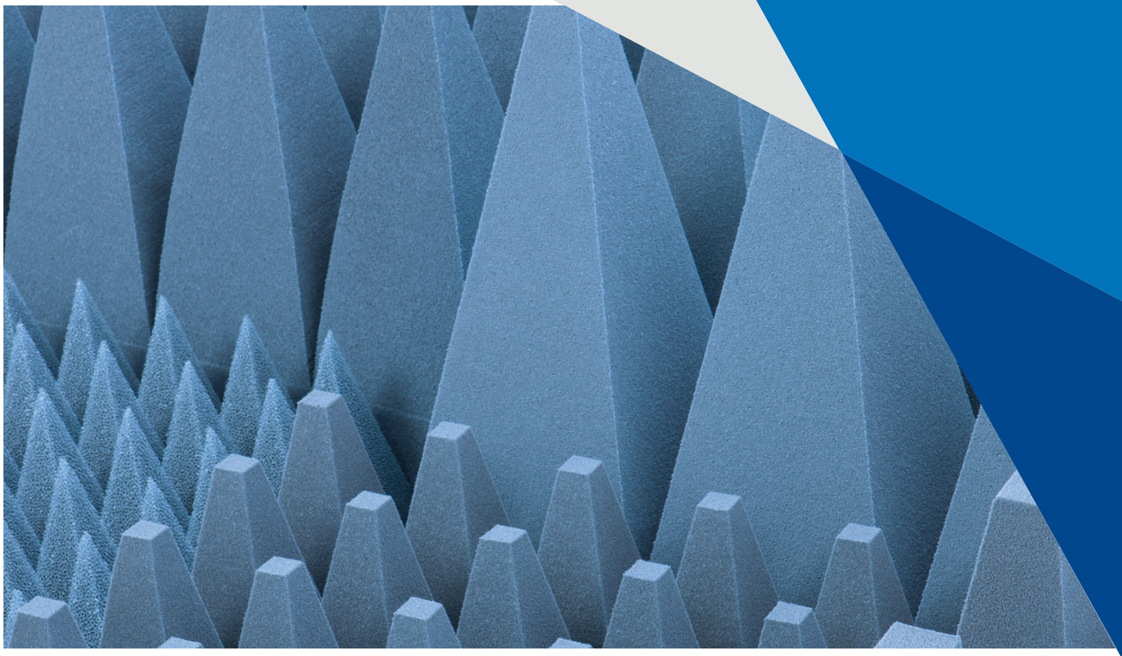
Regarding the absorber flammability rating, verify with your supplier that their absorber contains combustion limiting/fire retardant properties and meets the U.S. Government and commercial flammability specifications shown below. Ensure the results are verified by an independent testing laboratory.

- **NRL Report 8093 (Tests 1, 2, and 3)**
- **MIT Lincoln Laboratory Specification MS-8-21 (Tests I, II, and III)**
- **Raytheon Drawing No. 2693066 (latest revision)**
- **UL 94-5VA and UL 94-5VB**
- **UL 94 HBF**
- **DIN 4102 Class B-2**

For more information, read the paper “Surface and Internal Temperature versus Incident Field Measurements of Polyurethane Based Absorbers in the Ku Band” presented by Zhong Chen at the 2013 Annual Symposium of the Antenna Measurement Techniques Association, Columbus, Ohio, October 6-11, 2013, www.amta.org.



Surface and internal temperature of absorbers under an incident plane wave.

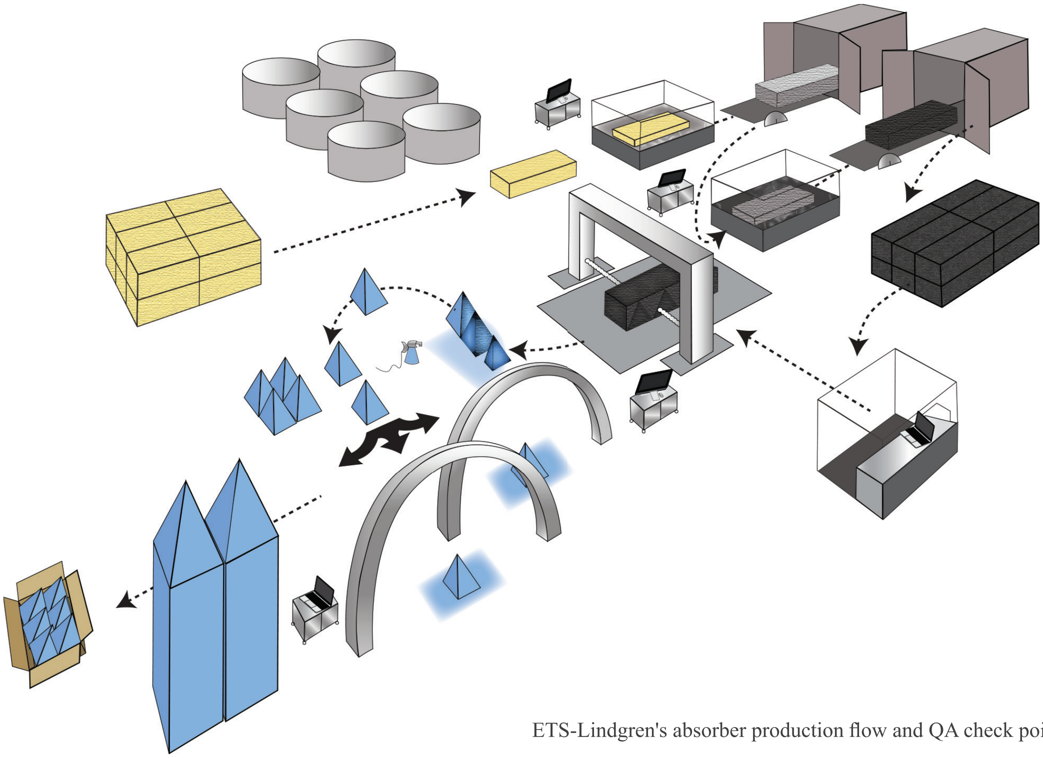


7. Understand the manufacturing process and how this impacts absorber quality.

A high quality manufacturing process is computer controlled that begins with homogeneous blocks of polyurethane foam. The blocks are impregnated with a proprietary solution of lossy agents and dried at an elevated temperature. Next, the blocks are impregnated a second time with fire retardant salts and dried again. This two-step process ensures uniform distribution of both agents and permanently bonds the carbon throughout the foam. The benefit is an absorber that does not release carbon particles which can contaminate delicate electronic equipment in the chamber. In fact, high quality absorbers can be used in clean room environments requiring a Class 100,000 rating.

After impregnation, in a high quality manufacturing process, the foam is shaped using computer-controlled saws maintaining tolerances of ±3 mm (.12 in). Cutting the dried foam into its final shape after the impregnation process avoids shrinkage and warping. The benefit is absorber that may be installed in a chamber with uniform geometric alignment, reducing backscattering, and improving measurement accuracy.

Finally, it is always a good idea to confirm that your absorber manufacturer has a current ISO 9001 certified quality system in place for the fabrication of RF and microwave absorber.



ETS-Lindgren's absorber production flow and QA check points.

8. Take advantage of non-hygroscopic “waterproof” absorber.

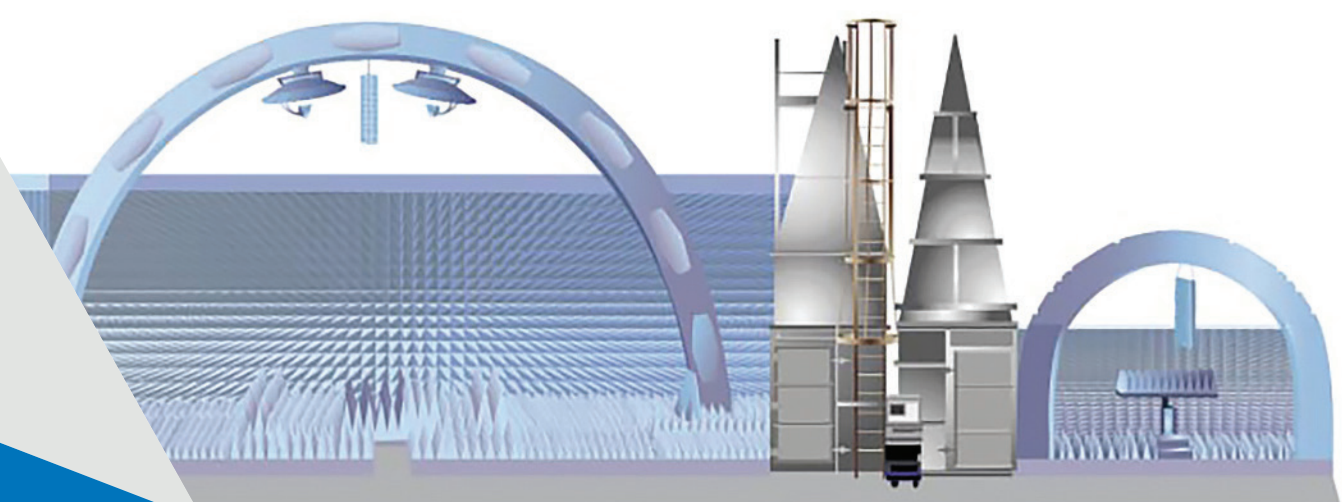
It is essential to maintain a stable absorber electrical property (dielectric constant) regardless of the ambient humidity level. Otherwise, the RF reflectivity will fluctuate. Moisture is known to affect the electrical conductivity (imaginary part of the dielectric constant) significantly. Conventional polyurethane absorber uses hygroscopic fire salts to limit combustion and enhance fire retardancy, but these salts attract moisture in the air, meaning they are hygroscopic, i.e. they absorb moisture from the air.

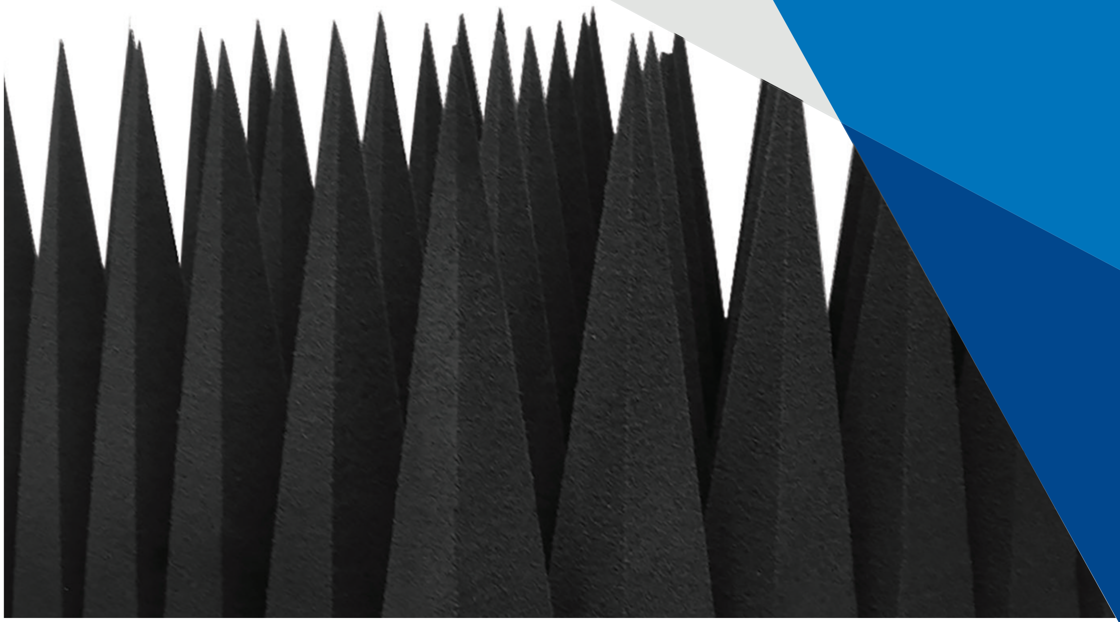
Modern polyurethane absorber is available that is non-hygroscopic and does NOT absorb water, largely due to using non-hygroscopic fire retardants during the manufacturing process. Polystyrene absorber, with its closed cell structure, has the added benefit of being exceptionally non-hygroscopic. The result of using these two types of absorber – modern polyurethane and polystyrene - is a stable absorber electrical property; therefore, the absorber performs better over a longer period of time.

Studies have shown non-hygroscopic absorber had an average increase of mass of 2.3% when exposed under extreme humidity of 95% Relative Humidity (RH) for 240 hours, and average decrease in mass of 0.69% when exposed under an extreme arid condition (20% RH) for 240 hours. In contrast, a conventional absorber was tested under the same conditions. It experienced an average gain in mass by 59.6% for 95% RH, and loss in mass by 7.1% for 20% RH.

9. Confirm the RF performance verification testing of absorber.

Absorbers are either measured in a TEM device (for frequencies < 1 GHz), or in an NRL arch (>1 GHz), as seen below. Both methods are specified in IEEE Standard 1128. A TEM device is essentially a coaxial cable with one end electrically shorted. Both the outer and inner conductors of the coax have square-shaped cross-sections. The difference in measured reflection (S11) with and without the absorber is the reflectivity. When the TEM cell becomes large electrically, higher order modes can distort the TEM wave, therefore it is limited to the lower frequency range. The NRL arch method is a bistatic measurement of the absorber with a transmit antenna illuminating the absorber, while the receive antenna is located at the specular reflection angle. Reflectivity is measured by comparing the reflectivity to a perfect electric conductor (PEC) plate. It is best suited for the higher frequency range because the antenna distance (arch radius) and absorber sample size can get exceedingly large at lower frequencies. With this in mind, ask your supplier how they test their absorber to verify performance reflectivity before shipment. Is every piece of absorber tested or do they sample test one piece per batch? Is each piece of absorber serialized? These are important questions to ask to protect your investment.

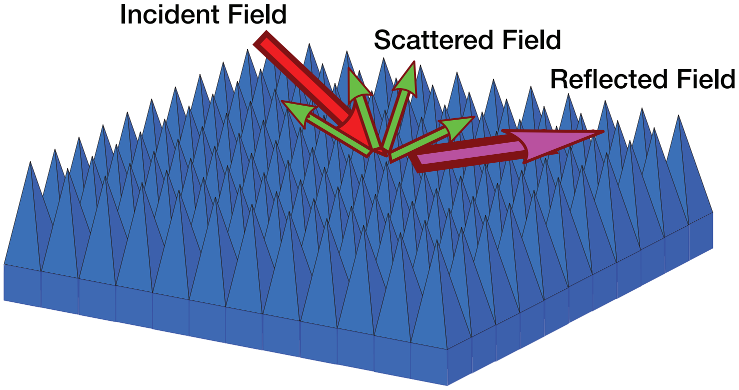




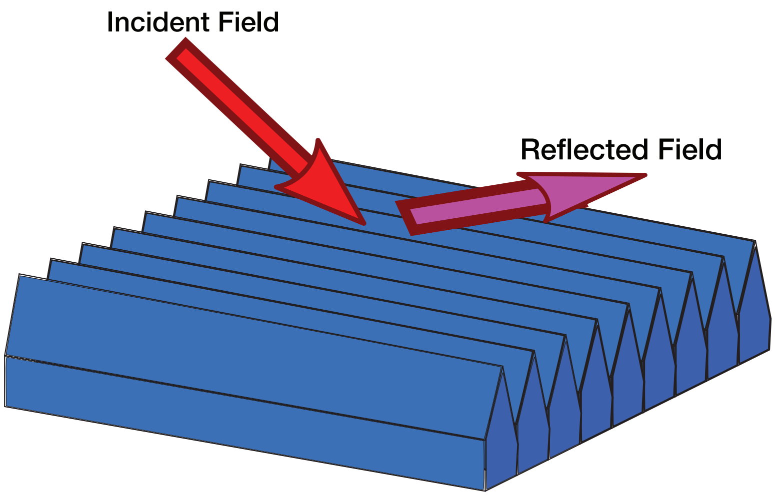
10. Consider the impact of shape, coating and paint on absorber.

EM waves can scatter from the absorber tips and edges, which create scattered fields not only in the specular direction, but in other directions. The desired test zone (quiet zone, or QZ) can be affected by the scattered field from the absorber nearby. For this reason, wedge shaped absorber is often used near the QZ to reduce scattering.

Absorber is naturally black and is usually painted a brighter color for aesthetic reasons. Keep in mind that at millimeter wave frequencies, paint can negatively affect the reflectivity of absorber, sometimes by 5 to 10 dB. Studies have shown that leaving only the tips unpainted (black tips) is insufficient to mitigate the effects. For applications above 40 GHz, absorber should be left unpainted for the best performance.



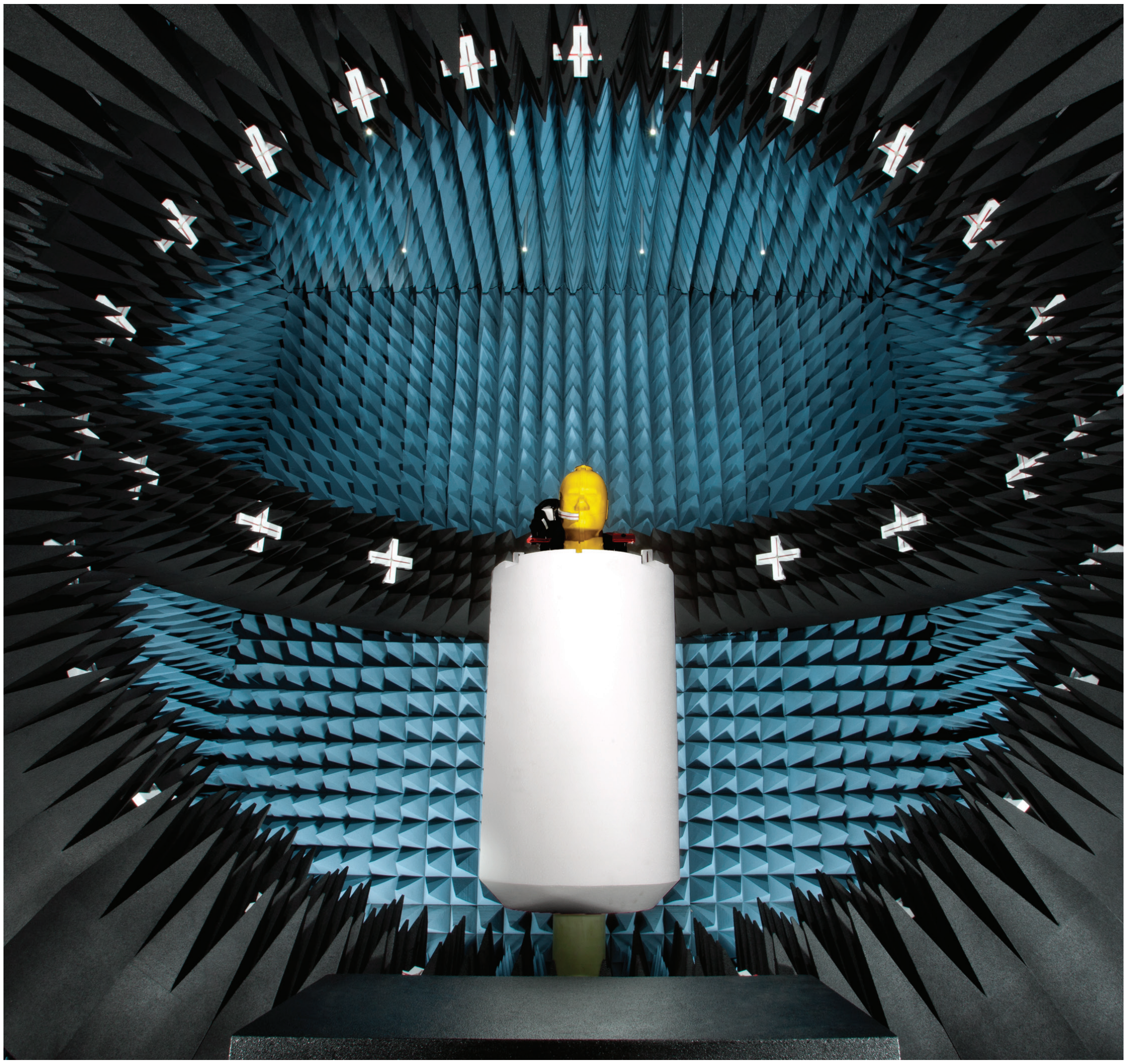
Absorber is also available with a rubberized coating for increased durability. This special absorber treatment is ideal for high traffic areas such as chamber doorways and interior walls, or for tests that require an anechoic floor treatment. The rubberized coating has the additional benefit of minimalizing the possibility of broken absorber tips. Absorber is designed to have a gradual transition from free-space impedance to the termination impedance in the back. Broken tips on absorber affect the impedance transition and matching. Depending on how large the broken tips are and how many pieces, the effects can vary greatly. This risk is reduced with a rubberized coating of the absorber.



Absorber Selector

MODEL NUMBER	FREQUENCY RANGE MINIMUM	FREQUENCY RANGE MAXIMUM	ABSORBER FOOTPRINT	PYRAMIDS PER ABSORBER	BASE HEIGHT	OVERALL HEIGHT	PYRAMID HEIGHT	WEIGHT
EHP-3PCL	4 GHz	40 GHz	61.0 cm x 61.0 cm (24.0 in x 24.0 in)	256	1.90 cm (0.75 in)	8.25 cm (3.25 in)	6.4 cm (2.52 in)	1 kg (2.20 lb)
EHP-5PCL	2 GHz	40 GHz	61.0 cm x 61.0 cm (24.0 in x 24.0 in)	144	2.50 cm (0.98 in)	12.7 cm (5.00 in)	6.4 cm (2.52 in)	1.6 kg (3.53 lb)
EHP-8PCL	1 GHz	40 GHz	61.0 cm x 61.0 cm (24.0 in x 24.0 in)	64	5.10 cm (2.01 in)	21.6 cm (8.50 in)	16.5 cm (6.50 in)	2.8 kg (6.17 lb)
EHP-12PCL	1 GHz	40 GHz	61.0 cm x 61.0 cm (24.0 in x 24.0 in)	36	5.7 cm (2.24 in)	31.1 cm (12.24 in)	25.4 cm (10.00 in)	4.6 kg (10.14 lb)
EHP-18PCL	500 MHz	40 GHz	61.0 cm x 61.0 cm (24.0 in x 24.0 in)	16	5.7 cm (2.24 in)	46.4 cm (18.27 in)	40.6 cm (15.98 in)	4.6 kg (10.14 lb)
EHP-24PCL	200 MHz	40 GHz	61.0 cm x 61.0 cm (24.0 in x 24.0 in)	9	10.2 cm (4.02 in)	61.0 cm (24.02 in)	50.8 cm (20.00 in)	6.1 kg (13.45 lb)
EHP-36PCL	80 MHz	40 GHz	61.0 cm x 61.0 cm (24.0 in x 24.0 in)	4	15.2 cm (5.98 in)	91.4 cm (35.98 in)	76.2 cm (30.00 in)	9.5 kg (20.94 lb)
EHP-48PCL	80 MHz	40 GHz	61.0 cm x 61.0 cm (24.0 in x 24.0 in)	4	20.3 cm (7.99 in)	121.9 cm (47.99 in)	101.6 cm (40.00 in)	11.3 kg (24.91 lb)
EHP-72PCL	80 MHz	40 GHz	61.0 cm x 61.0 cm (24.0 in x 24.0 in)	1	30.5 cm (12.01 in)	182.9 cm (72.01 in)	152.4 cm (60.00 in)	15.9 kg (35.05 lb)
EMC-24PCL	80 MHz	40 GHz	61.0 cm x 61.0 cm (24.0 in x 24.0 in)	9	15.24 cm (6.0 in)	61 cm (24.0 in)	45.72 cm (18.0 in)	4.3 kg (9.50 lb)

80 MHz	120 MHz	200 MHz	300 MHz	500 MHz	L-BAND 1 to 2 GHz	S-BAND 2 to 4 GHz	C-BAND 4 to 8 GHz	X-BAND 8 to 12 GHz	KU-BAND 12 to 18 GHz	K-BAND 18 to 40 GHz	MODEL NUMBER
							-30 dB	-40 dB	-45 dB	-45 dB	EHP-3PCL
						-30 dB	-40 dB	-45 dB	-50 dB	-50 dB	EHP-5PCL
					-30 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB	EHP-8PCL
					-35 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB	EHP-12PCL
				-30 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB	-50 dB	EHP-18PCL
		-20 dB	-30 dB	-35 dB	-40 dB	-50 dB	-50 dB	-50 dB	-50 dB	-50 dB	EHP-24PCL
-11 dB	-13 dB	-25 dB	-30 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB	-50 dB	-50 dB	EHP-36PCL
-15 dB	-20 dB	-30 dB	-35 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB	-50 dB	-50 dB	EHP-48PCL
-20 dB	-30 dB	-40 dB	-40 dB	-45 dB	-50 dB	-50 dB	-50 dB	-50 dB	-50 dB	-50 dB	EHP-72PCL
-6 dB	-6 dB	-7 dB	-30 dB	-35 dB	-45 dB	-50 dB	-50 dB	-50 dB	-50 dB	-45 dB	EMC-24PCL



Did you know ETS-Lindgren provides absorber for 5G and mmWave (W-band) applications? If you need assistance in choosing absorber for your RF, Microwave and W-band applications, ETS-Lindgren can help! Contact your local ETS-Lindgren representative, phone us at +1.512.531.6400, or visit our website at www.ets-lindgren.com.

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