ANECHOIC MATERIALS FOR CONDUCTING EMC TESTS IN SHIELDED ROOMS

Introduction

This presentation is a brief review of the principles involved in the design of the anechoic lining of an EMC test facility for 25 to 1000 MHz testing. Because it is difficult to simulate all the possible electromagnetic environments to which a test item might be exposed, it is desirable to test the item under a set of standard conditions, i.e., a plane wave testing environment. This environment consists of exposing the test item to a field which is uniform in phase and amplitude. Long wave lengths, however, account for the difficulty in achieving field uniformity.

Amplitude Considerations

In any testing situation, the uniformity of the illuminating wave front is a function of the source antenna's pattern and the separation distance. It is desirable that the source antenna have a broad beam width. However, this leads to distortions in the test region due to interactions with the surrounding physical environment. This is demonstrated by considering a single source of reflections, such as in the case of an elevated test facility as shown in Figure 1.

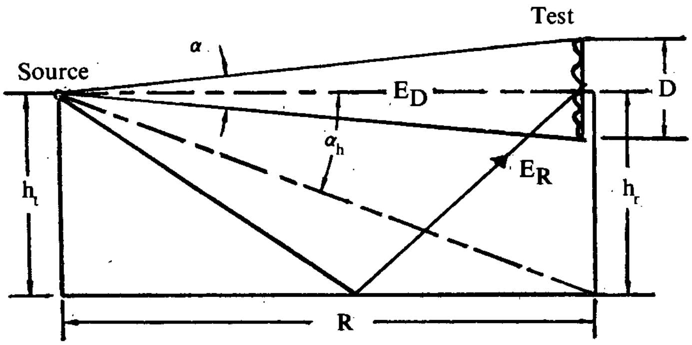

Figure 1. Field Variation due to Range Reflections—Elevated

A field strength variation in the test region results, the degree of which depends on the relative amplitude of the direct path signal and the reflected path signal. The ripple rate is a function of the operating frequency and the geometrical relationships involved. In an enclosed facility, there are six simultaneous interactions to consider.

Phase Considerations

Though it is desirable that the phase front be planar, this is a function of geometry and is fixed for any given testing situation. For example, the time-honored expression,

$$R \geqslant 2D^2/\lambda$$

is based on the assumption that an acceptable phase variation across the unit under test is 22.5° from the center of the UUT to either edge. When $R \leqslant 10\lambda$, other considerations apply, such as coupling interaction. When $R \leqslant 1\lambda$, the coupling becomes inductive. In this region, you are clearly in the near field and the test conditions become difficult to interpret from the plane wave assumptions that are normally assumed.

Radio Frequency Absorbing Material Performance

When a radiated measurement is performed inside the confines of a room, particularly a shielded room, it is necessary to dampen the reflections and interaction from the walls. The standard procedure is to use pyramid-shaped foam loaded with lossy materials to absorb this extraneous energy. The pyramid is chosen because it provides an excellent broadband termination for the electromagnetic wave as it proceeds from free space into the wall. The actual amount of energy reflected from the terminations is a function of its length in wavelength and the RF loss per unit length of the termination, with minor consideration as to the physical geometry of the termination. This relationship is depicted in Figure 2.

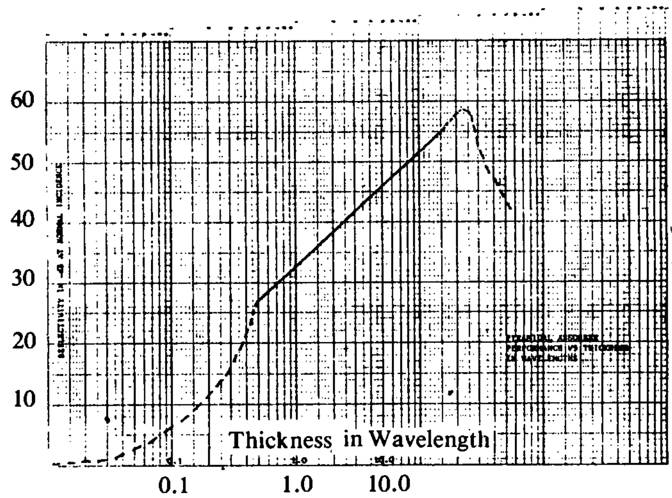

Figure 2. Pyramidal Absorber Performance vs. Thickness in Wavelength.

Another important consideration is the effect of energy arriving to the face of the material at angles other than normal. This relationship is shown in Figure 3. Note that the curve breaks sharply in the 60-degree region.

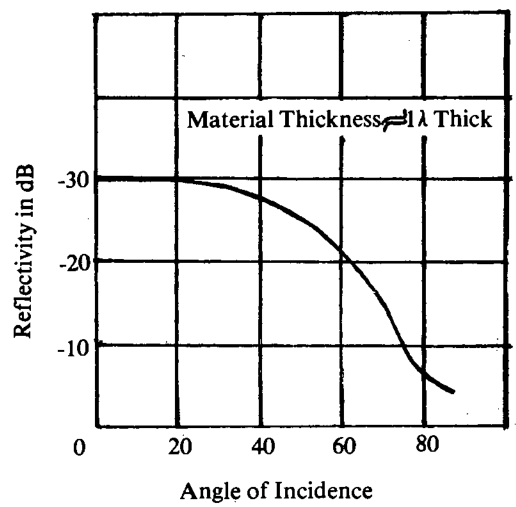

Figure 3. Typical wide angle. Performance of Pyramidal Absorbing Materials.

Shielded Room Considerations

When radiated measurements are conducted within a shielded room, various radiation modes are possible, depending on the room size, operating wavelength, and geometrical relationship of the antennas within the room. These factors are discussed below.

Room Size (Volume)

When RF energy is injected into a metal cavity, resonating modes of various complexities are possible, depending on the geometry of the cavity and the exitation wavelength. The relationship for a rectangular cavity is as follows.

$$F_{MHz} = 150 \sqrt{\frac{k^2}{l} + \frac{m^2}{h} + \frac{n^2}{w}}$$

Where l = length of enclosure in meters
h = height of enclosure in meters
w = width of enclosure in meters
k,m,n, = a positive integer 0,1,2,3, . . ., etc.

These are for T_E modes. For example, a one-foot cubed box has a cutoff frequency of 696 MHz.

Moding Activity With Respect to Wavelength

As a rough estimate of the effect of wavelength within a given enclosure geometry, based on experience, the following has been found useful. From λ_c to λ (i.e., the width and height of the are on the order of a wavelength), the room acts somewhat like a waveguide. That is, the amplitude variation within the room is sinusoidal, with zero amplitude at the walls and maximum in the center. The wavelength is so large that little phase interaction occurs and the test region variation is basically a function of the end wall absorbers, in much the same way that standing waves are terminated in a waveguide system. The ceiling-to-floor and wall-to-wall variations are pure sine wave variations, and thus can not be doctored very much.

From about λ to 5-10 λ, multimoding occurs and the field variations are a function of the cavity dimensions and equipment placement. Even a small movement of personnel in the space will change equipment readings. Careful design is required to properly control variations in the test region, since the volume is limited and most absorbing materials need to be somewhat thick in λ to achieve high suppressions, especially at wide angles of incidence. Some additional suppression is possible, using a directional antenna.

Above 10 λ, the room acts somewhat like free space. Directional antennas are used, and the problems are controlled. Test facilities are routinely built using high-performance pyramidal materials for all types of electromagnetic testing, achieving excellent results.

Basic Rectangular Room Concepts

This section provides a brief treatment of rectangular anechoic design concepts, so that the designs proposed can be interpreted in terms of basic principles.

Chamber Design Considerations

The basic principle used in the design of a rectangular anechoic chamber is the suppression of extraneous energy reaching the test region (quiet zone) by means of energy absorption and source antenna selection. The principle source of extraneous energy is from the source antenna, which is reflected from the internal surfaces of the room. When the room aspect ratio exceeds 2:1, diffraction (blockage of direct path energy) becomes a problem. Due to the geometry required by economics, conventional anechoic chambers are narrow. Consequently, the sidewall represents the chief source of extraneous energy.

Consider Figures 4 and 5. Figure 4 represents a ray path taken in a room which has a length/width (height) aspect ratio of 1:1. Thus, the reflected energy has a nominal incident angle of 45°. As shown in Figure 6, this means the absorber placed on that wall has a loss which is nearly that of normal incidence. On the other hand, refer to Figure 5 and note that for an aspect ratio length/width (height) of 2.5:1, the angle of arrival for the unwanted energy of 68°, which from Figure 6 means that the sidewall absorber is considerably less effective.

Figure 7 represents the amount of surface area a box has. The aspect ratio is varied from 1:1 to 3:1, with width and height equal and variable, and the length held fixed. The curve is normalized at an aspect ratio of 2:1. This demonstrates the relative costs involved in chamber construction, since the costs are directly proportional to the surface area of the facility. Note that the curve starts back up in cost above 2:1. This is to indicate that extraordinary costs are involved in absorber design and source antennas needed to overcome the poor aspect ratio, and consequent poor performance of the facility. However, it generally means that the Quiet Zone size must be reduced, due to the use of thicker sidewall materials.

Thus, it can be seen that for a given performance level the designer and chamber buyer must be aware of what the performance/cost trade-offs are prior to specifying the aspect ratio of a given test facility.

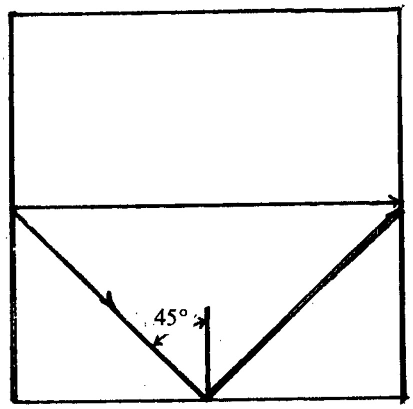

Figure 4. 1:1 Room Aspect Ratio.

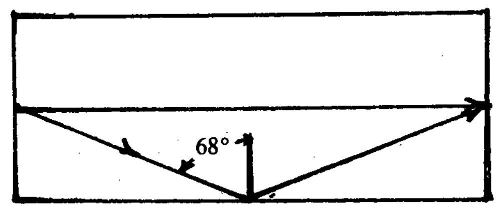

Figure 5. 2.5:1 Room Aspect Ratio.

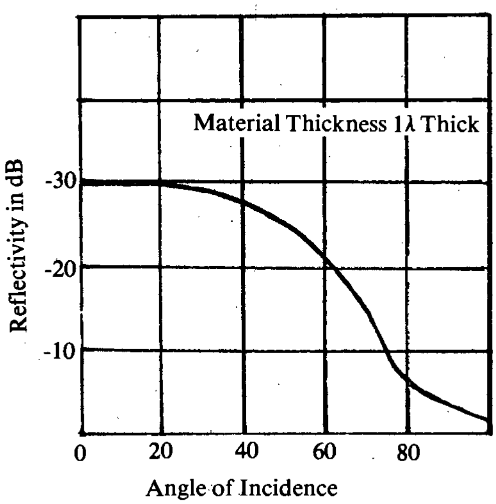

Figure 6. Typical Wide Angle Performance of Pyramidal Absorbing Materials.

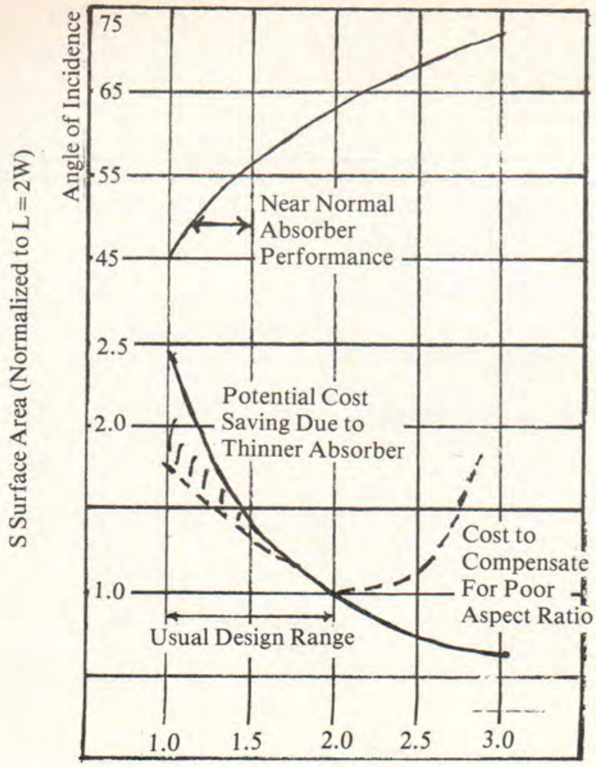

Figure 7. L/W Aspect Ratio.

A secondary but important consideration in the design of rectangular chambers is the selection of the proper source antenna. This trade-off can be seen in Figures 8 and 9.

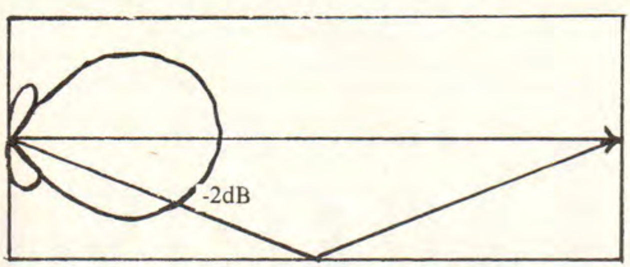

Figure 8. Low Gain Source Antenna 8dB.

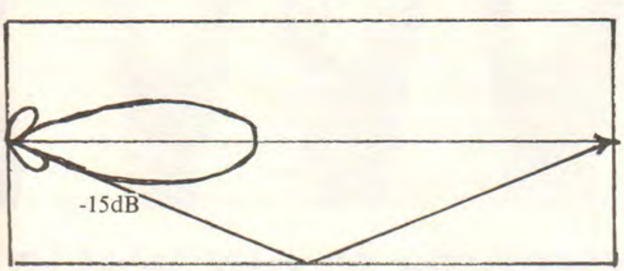

Figure 9. Moderate Gain Source Antenna 15dB.

Note that the beam geometry controls the amount of extraneous energy reaching the sidewalls, consequently reaching the test region. The beam geometry also determines the level of energy blocked by the sidewall material. Lower illumination means a lesser possibility of diffraction effects. The limitations placed on antenna selection are:

- amount of amplitude taper permitted in the test region;
- cost;
- operating frequency;
- size of transmitting wall;
- thickness of absorber on the sidewalls;
- chamber aspect ratio;
- the type of test being conducted.

The third design consideration is the absorber selection and layout on the chamber walls. These are selected on the basis of operating frequency versus specified performance, chamber aspect ratio, type of testing to be conducted in the chamber, and economics, since the material is extremely expensive.

Generally speaking, the size of the Quiet Zone in a chamber is approximately ⅓ of the chamber's cross section. It is specified as a sphere, since a cube really implies the Quiet Zone to be a large sphere. Also, test items sweep out a sphere during pattern testing, not a cubic volume.

It can be seen that the entire chamber design problem for a given specified performance is based on the proper selection of the chamber's basic aspect ratio. If possible, the width of the room between the tips of the absorber should be equal to the path length from the source antenna to the farthest point in the test region. Note that Figure 7 is offered as an illustration of the trade-off concept between absorber thickness and chamber aspect ratio. Actual cost projections must be used to properly evaluate the trade-off's between different design approaches.

Selection of Anechoic Materials

Assuming that the room geometry is fixed and that the aspect ratio relationship is such that the energy illuminating the walls and ceiling is arriving at approximately 45°, the question remains: what thickness of material should be used?

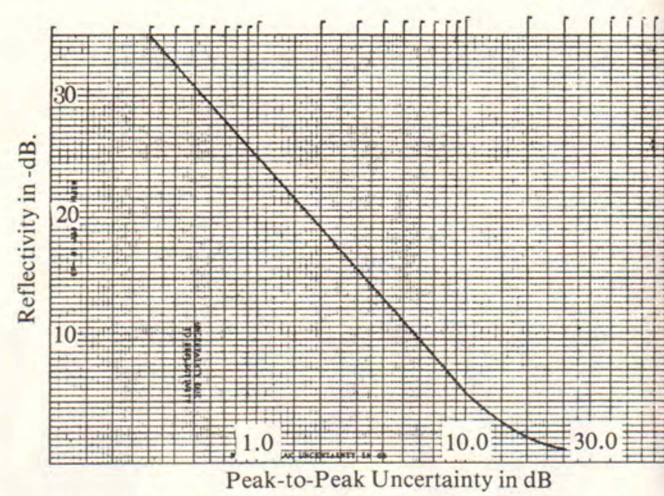

Figure 10. Worst Case Uncertainty due to Reflectivity.

Measurement Uncertainties

Figure 10 relates the peak-to-peak field variation in dB that can be expected (worst case) in the test region of the shielded anechoic room. This may be treated as the uncertainty which may be experienced in the measured data, should a device under test be moved about in the test environment. For example, if the test engineer wishes to be able to repeat his radiated measurements within± 2dB, then the reflectivity of the anechoic material should be on the order to -15dB. If he wished to perform this measurement to 100 MHz, the thickness of the material (See Figure 11 through 15) would have to be on the order of 30 inches thick. Thus, the key to the type of thickness of the absorber is the measurement tolerance the test engineer can tolerate, and the geometry of the room.

Note that all of the above considerations ignore the effect of the ground plane normally present in open field FCC tests. Should full free space conditions be desired, then special floor treatments are available.

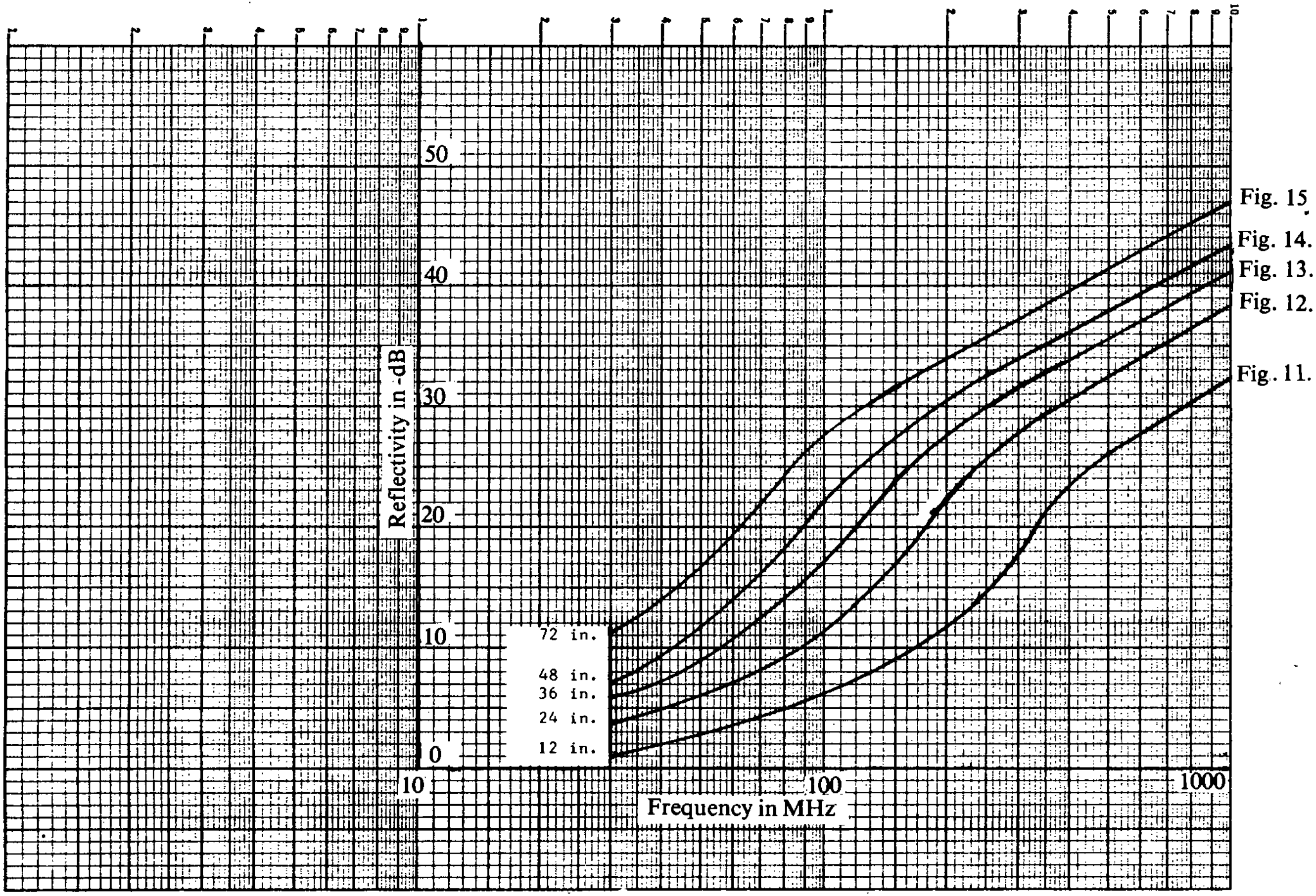

Figure 11. Typical Performance of 12-inch Pyramidal Absorbers.
Figure 12. Typical Performance of 24-inch Pyramidal Absorbers.
Figure 13. Typical Performance of 36-inch Pyramidal Absorbers.
Figure 14. Typical Performance of 48-inch Pyramidal Absorbers.
Figure 15. Typical Performance of 72-inch Pyramidal Absorbers.

Design Example

Because of the many trade-offs associated with shielded anechoic chambers, no single solution is possible. The purchaser needs to review needs and constraints with an experienced supplier, and develop room specification to meet requirements. The following is given as a typical example of what should be considered when developing a shielded anechoic facility:

Assume the following:

Path Length: 3 meters
Test Region Size: 2 meters
Clearance: 1 meter
Transmit Antenna Allowance: 1 meter

Thus, the overall path length is 8 meters. Allowing 1 meter for absorber, the room length should be about 10 meters. The Room width should have an aspect ratio of 1:1 from the transmit antenna to the back of the test region via the tips of the absorber, making the room 7 meters wide. Room height (assuming a metal floor and a transmitter height of 1.5 meters) should be 5 meters. Converting these dimensions to convenient dimensions in feet, the room should be on the order of 34 feet long, 22 feet wide and 15 feet high. Since 15-foot clearances are not generally available, the height could be reduced to 12 feet, although further reduction is not recommended.

A 22-foot wide room implies that the cut-off wavelength is 44 feet, or 22 MHz. Thus, the end walls set the room performance up to 44 MHz. Assume that the degree of uncertainty permitted is ± 3dB at 30 MHz. From Figure 10, the absorber requirement is 10dB. The standard 4-foot material will provide about 7dB, and the EM series, 10dB.

As discussed in Section 4.3, the room performance from 25 to 1000 MHz is a function of all the wall absorbers. If at 100MHz it is desired that the uncertainty be less than ± 1dB, then the loss required is on the order of 20dB. Noting that a standard 36-inch material would meet this requirement, this material should be used on the sidewalls. The ceiling should be composed of material to compensate for the lack of height discussed above. Room reflectivity versus frequency can be expected as follows:

Frequency in MHz	Reflectivity in -dB	Measurement Uncertainty Peak to Peak
30	10	6
50	16	3
100	20	1.8
200	25	1.0
400	31	0.55
800	37	0.3
1000	39	0.2

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