Flat Ferrite RF Absorbers

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INTRODUCTION

Well-known microwave pyramidal foam absorbers have been adapted with moderate success to cover the low frequency range required for EMC measurements. Since the frequencies used in this field are 30 MHz to I GHz, and in some cases 18 GHz, one can quickly determine why the height of such components is at least 1.5 meters with a practical limit of about 2.4 meters.

Pyramid absorber efficiency is mainly determined by the physical geometry together with the electrical conductivity of the impregnated foam material. Unlike large pyramids, ferrite tile absorbers offer comparable performance levels with a thickness of only 5 to 8 mm. The use of ferrite tiles as RF absorbers in anechoic chambers significantly reduces the required overall dimensions of the shielded room while maintaining the same usable volume. They work as broadband magnetic quarter wavelength Salisbury absorbers with an efficiency directly related to the intrinsic properties of the material and to its thickness.

For this reason, ferrite tiles are always mounted on a flat conducting plane (in a shielded room wall or an interior self-supporting structure). They are placed where the magnetic field is at its maximum. With a careful selection of the complex dielectric permittivity $\underline{\varepsilon}$, and of the complex magnetic permeability $\underline{\mu}$ of the material,[1] a low reflection coefficient can be obtained between 30 MHz and 1 GHz.

DEFINING THE REFLECTION COEFFICIENT

Inside an isotropic medium, the wave impedance is defined by

$$\underline{Z}_m = \sqrt{\frac{\underline{\mu}}{\underline{\varepsilon}}} \qquad (1)$$

Experimental data illustrate the close agreement between calculated and measured values for ferrite absorber efficiency.

where $\underline{\varepsilon}$, is the complex dielectric permittivity $\underline{\varepsilon} = \varepsilon' - j\varepsilon''$, which can be written as

$$\underline{\varepsilon}=\varepsilon'(1 - j \tan \delta_\varepsilon) \text{ with } \tan \delta_\varepsilon=\frac{\varepsilon''}{\varepsilon'}$$

$\underline{\mu}$ is the complex magnetic permeability $\mu = \mu' - j\mu''$, which can be written as

$$\mu = \mu' (1 - j \tan \delta_\mu) \text{ with } \tan \delta_\mu = \frac{\mu''}{\mu'}$$

and the propagation factor can be written as

$$\underline{\gamma} = \alpha + j\beta = j\frac{2\pi}{\lambda}\sqrt{\underline{\mu} \cdot \underline{\varepsilon}} \qquad (2)$$

where
α = attenuation constant
β = phase constant
λ = wavelength inside the medium

In the case of an incident plane wave on the medium, a reflection coefficient can be written as

$$\underline{r}_m = \frac{\underline{Z}_m - 1}{\underline{Z}_m + 1} \qquad (3)$$

which, for a flat absorber of thickness d, in the case of normal incidence, can be expressed as[2,3,4]

$$\underline{r} = \frac{\underline{r}_m - e^{2\gamma d}}{1 - \underline{r}_m \cdot e^{2\gamma d}} \qquad (4)$$

Equation 4 clearly shows the different factors which can be optimized by careful selection of the material. They are the thickness d, the complex permittivity ε, and the complex permeability μ.

H. Musal and D. Smith have shown that, after some simple calculations, including a change of coordinates,

$$x = \frac{d}{\lambda} \cdot \mu' \text{ and } y = \frac{d}{\lambda} \cdot \mu'' \qquad (5)$$

One can obtain[3]

$$\frac{d}{\lambda} = \frac{1}{2\pi\mu''} \text{ and } \varepsilon' = 3\,\mu' \qquad (6)$$

In a certain frequency range, a material with these qualities provides a very low reflection coefficient.

$$r_d = 20 \log \frac{1}{\mathrm{Re}\,|r|} \qquad (7)$$

It then acts like a magnetic Salisbury quarter wavelength absorber. The material with high magnetic losses must be placed where the magnetic field is maximum, i.e., against the conducting plane (shielded room wall).

Such an ideal variation of $\underline{\varepsilon}$ and $\underline{\mu}$ with frequency is given in Figure 1. The choice of a particular material permits specifying the maximum dispersion zone anywhere between 30 MHz and 1000 MHz.

The curve of μ'' must follow the law given in Equation (5). A small dielectric loss ε'' can only slightly influence the previous result. In the frequency range where ε'' and μ'' are small, the classical Salisbury equation is valid:

$$\frac{4d}{\lambda} = \frac{1}{\mathrm{Re}\left|\sqrt{\mu \cdot \varepsilon}\right|} \qquad (8)$$

TECHNICAL POSSIBILITIES

Before optimizing absorbers, it is necessary to know the behavior of the material used. A measurement of $\underline{\varepsilon}$ and $\underline{\mu}$ between a few megahertz to several gigahertz is made. This measurement is done with a 50-ohm coaxial cell (7/16 mm) as described in Figure 2.[5] A computer is used to acquire the data from a network analyzer and to calculate ε and μ.[1,6]

An example of such data for a nickel-zinc ferrite absorber is given in Figure 3. The dispersion zone clearly falls in the frequency range of interest (30 MHz - 1,000 MHz) and the resulting absorber can be expected to show a good reflection coefficient in this range.

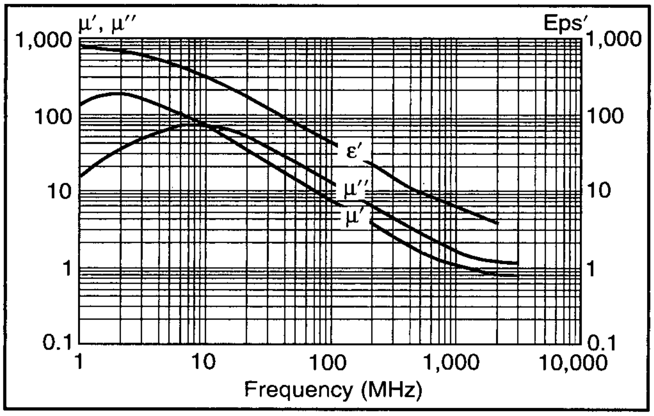

Figure 1. *ε and μ of an Ideal Ferrite Material.*

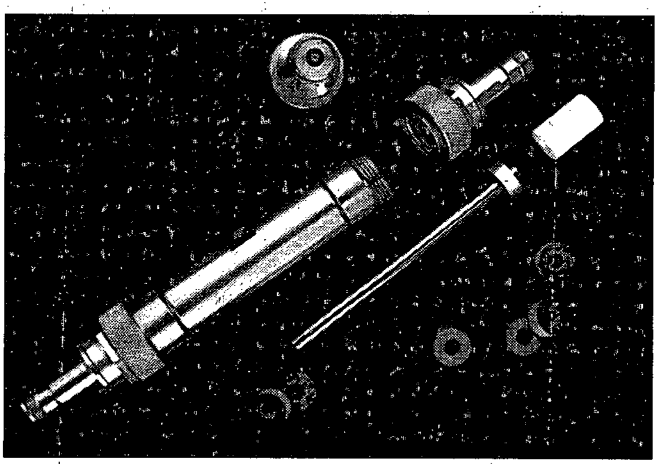

Figure 2. *Sample 7/16 Coaxial Cell.*

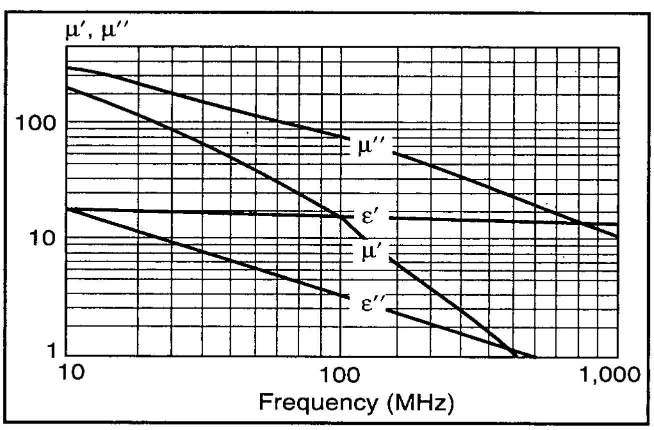

Figure 3. *ε and μ of a Real Ferrite Material.*

PRACTICAL APPLICATIONS OF FLAT FERRITE ABSORBERS

LOW REFLECTION COEFFICIENT

Generally, published absorber performance data are given based on the assumption of an ideal case. For instance, measurements can be made in a 7/16 mm coaxial cell (or a similar system) with metallized samples. In such circumstances, the reflectivity factor is far too optimistic in the middle of the frequency range. Figure 4 shows a typical result in such ideal conditions. The associated phase is illustrated in Figure 5. A steep change of phase of about 360° is clearly visible around 160 MHz and this corresponds to a sharp maximum in the curve of Figure 4.

In practice, such ideal results cannot be obtained. Therefore, it is interesting to compare laboratory measurements against real measurements made on an arrangement of several tiles.

A 100/300 mm square coaxial cell was developed to enable a direct measurement of a 300 x 300 mm absorber panel coming from the production line. Figure 6 shows the transverse section of this coaxial cell. The absorber to be measured is placed on a metallic plate which is then mounted at the end of the coaxial line. Plenty of finger-stock is used to ensure very good HF contacts (low inductance contacts).

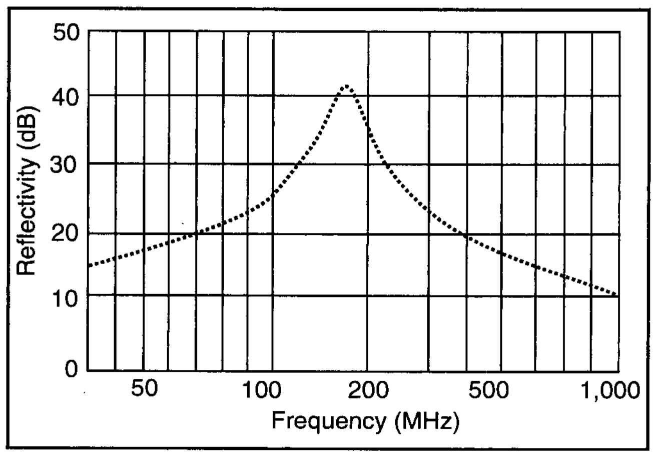

Figure 4. *Reflection Factor of a Nickel-Zinc Material (d = 6.6 mm).*

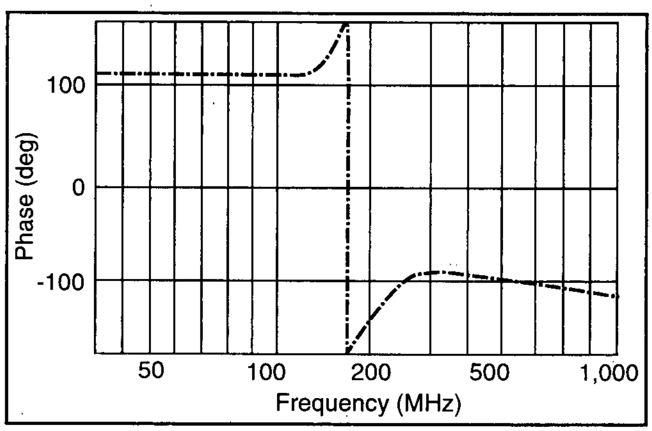

Figure 5. *Associated Phase of Figure 4.*

A comparison between ideal and real cases, measured according to the previously described method, is given in Figure 7. The sharp resonance has disappeared. This can be explained by considering all air gaps introduced into the absorber material where the independent tiles join together.

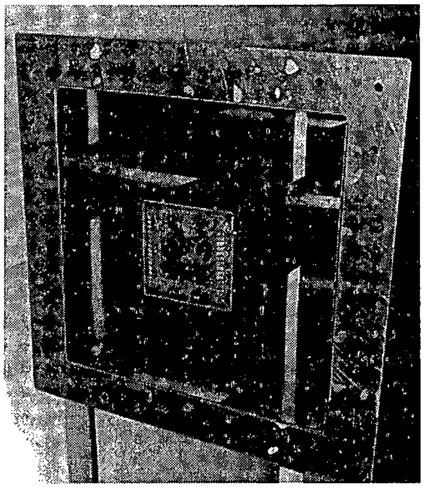

Figure 6. *Sample 100/300 mm Cell.*

OPEN AREA TEST SITE WITH FLAT ABSORBERS*

Special ground plane flat absorbers have been designed to control the ground influence by attenuating the reflected ray and by phase cancellation of both rays at the receiving antenna (Figure 8).

To illustrate, Figures 9 and 10 show both measured and simulated data for a 3-m range site equipped with flat absorber panels. The measured data are obtained in accordance with the ANSI C64.4 standard, while the simulated data are found with a computer code which takes into account all absorber parameters.[7] Horizontal polarization is given in Figure 9 and vertical polarization in Figure 10.

The error margin of the test equipment bay is on the order of ±1 dB minimum. Therefore, the experimental data are in very close agreement with the predicted values.[8]

*It must be noted that, in this configuration, the site is no longer a real OATS. It is better referred to as an AOATS (absorptive OATS).

GROUND ABSORBER FOR SUSCEPTIBILITY MEASUREMENT ACCORDING TO IEC 801-3

An interesting application of ground plane absorbers is to satisfy the requirements of the IEC 801-3 standard (ENV 50140).[9] In order to achieve a calibration plane where a minimum of 12 of 16 predefined points are within a field strength error value of 0 dB/ ±6 dB, absorber panels (Figure 11) are placed on the ground as shown in Figure 12. For both wave polarizations, the 16 calibrations were successful over the whole frequency range.

FULLY ANECHOIC ABSORBER CHAMBER

Small chambers can benefit strongly from the dimensions of flat absorbers. Substantial savings in room dimensions and in total costs are possible by replacing huge pyramids with flat absorbers. Sometimes, due to restricted available volume inside the shielded room, flat absorbers are

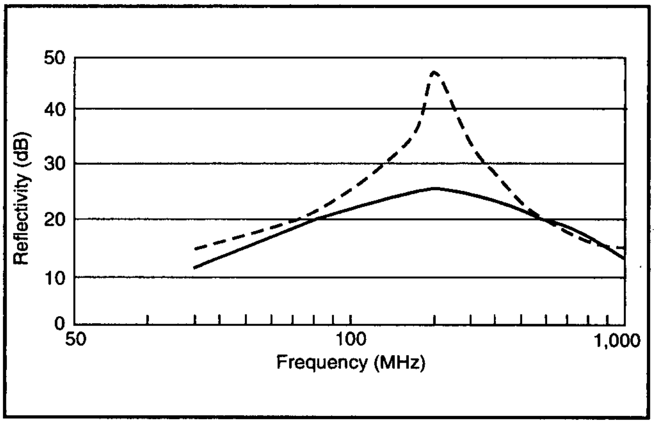

Figure 7. *Reflection Factor. Comparison between 7/16 mm and 100/300 mm Cells.*

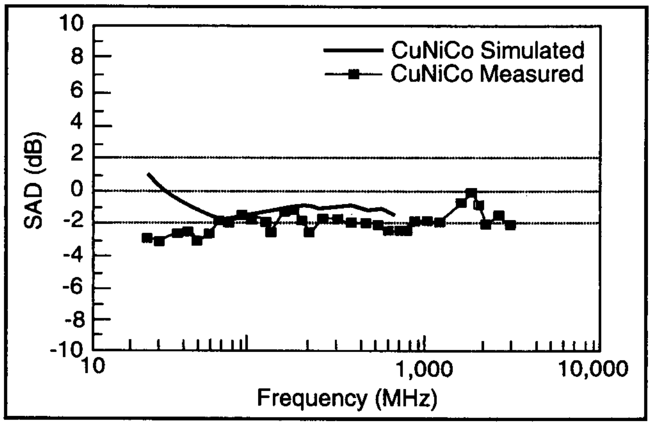

Figure 9. *Site Attenuation Deviation, Horizontal Polarization.*

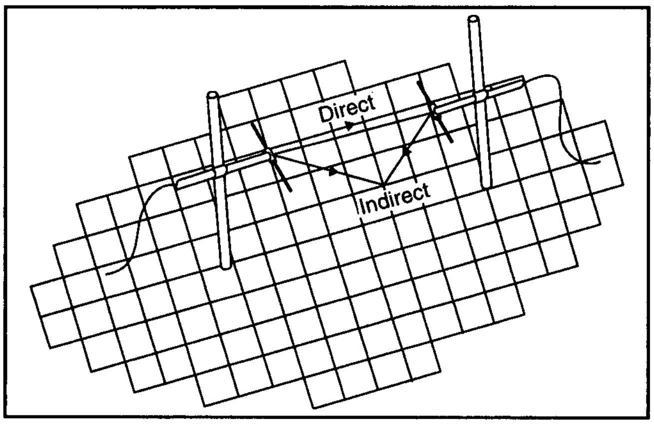

Figure 8. *Open Area Test Site Fitted with Ground Plane Absorber.*

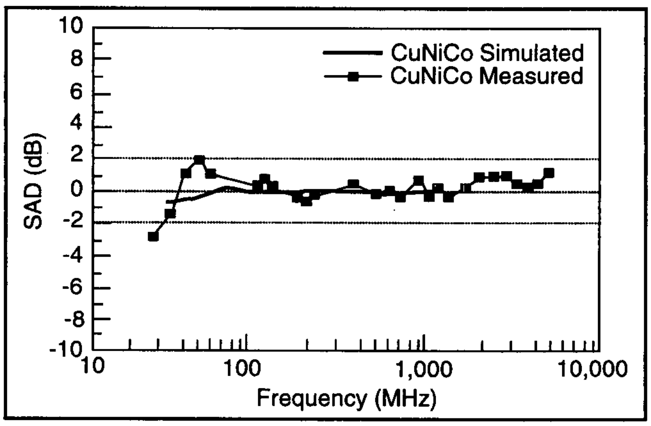

Figure 10. *Site Attenuation Deviation, Vertical Polarization.*

the only possible medium with which to build an anechoic chamber using the existing structure. When height alone is restricted, flat absorbers are used on the floor to transform a semi-anechoic chamber into a fully anechoic one.

As an illustration, consider a semi-anechoic chamber equipped for 3-m range testing using the pyramid approach. The required dimensions are 10.0 m x 7.5 m x 7.5 m. This corresponds to a relatively big surface to cover with pyramidal absorbers.

On the other hand, a shielded room of about 8.5 m x 5.8 m x 5.8 m covered with flat absorbers gives exactly the same performances. A full anechoic version can be made in a shielded room of about 6.8 m x 3.6 m x 3.6 m (Figure 13).

This last configuration also has a site attenuation deviation (SAD)** well within the limit of ± 4 dB. This is shown in Figure 14 for the horizontal polarization and in Figure 15 for the vertical polarization. An official accreditation has been obtained without problem.

**Deviation of the maximum received signal strength between a real site and an OATS reference test site in accordance with ANSI 63.4. An ideal site has a SAD equal to zero at all frequencies.

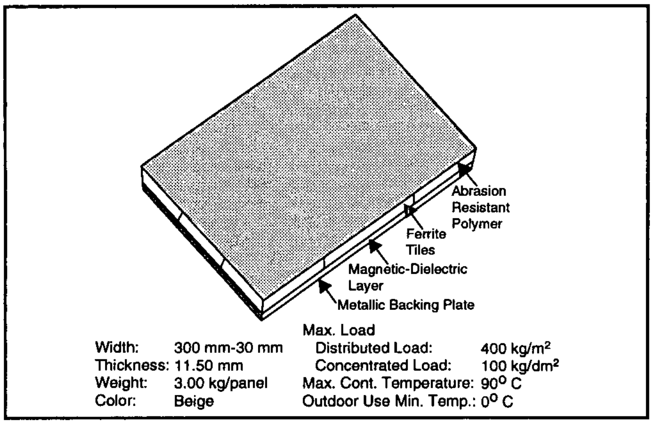

Figure 11. *Multilayer Ferrite Ground Absorber.*

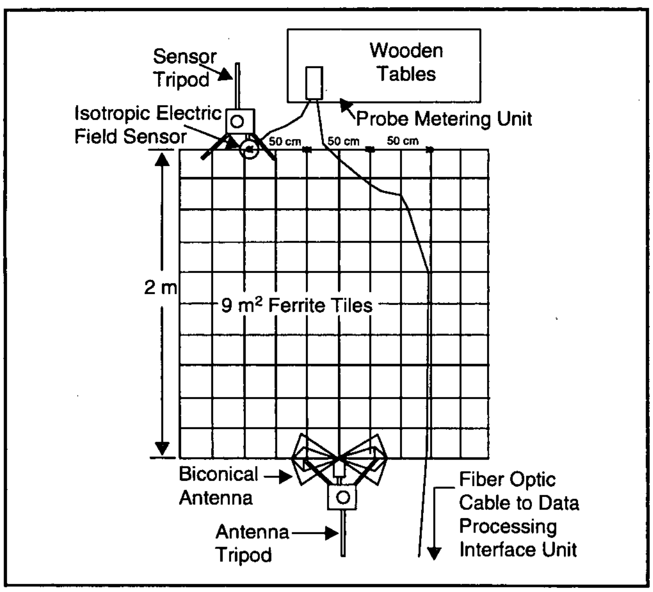

Figure 12. *Test Setup for IEC 801-3 Measurement.*

TEM CELLS WITH FERRITE ABSORBERS

There are two different applications for flat absorbers in TEM structures. The first one is the classical TEM cell or Crawford Cell (Figure 16) which shows a first parasitic resonance at about 200 MHz (depending on cell dimensions). This is due to the fact that higher order models can start to propagate inside the cell (TE and/or TM modes).

A partial covering of the inside walls with a special polymeric matrix flat absorber extends the useful bandwidth to approximately 400 MHz at a low cost.[10] All parasitic resonances are suppressed in this frequency range.

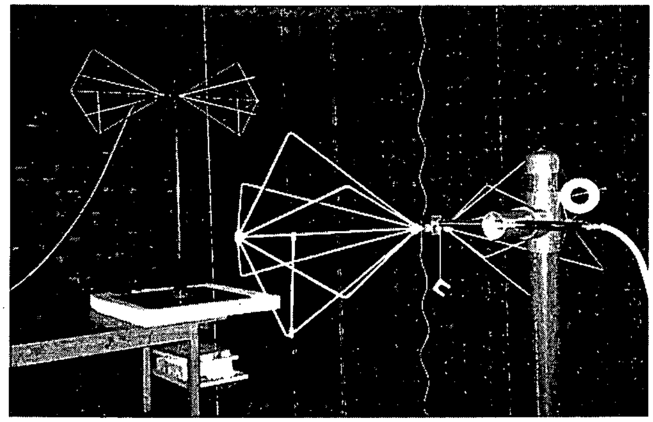

Figure 13. *Fully Anechoic Room.*

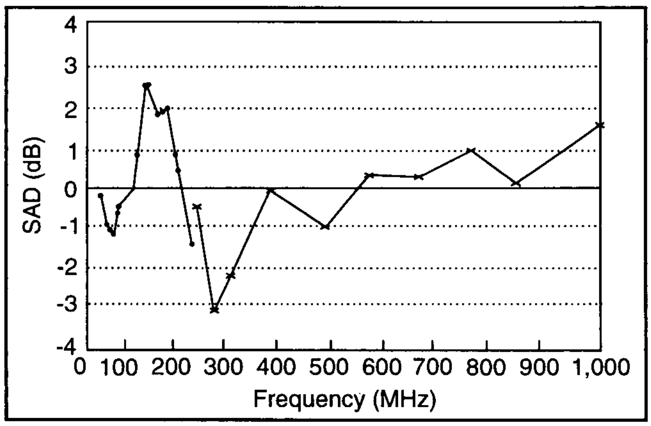

Figure 14. *Site Attenuation Deviation, Horizontal Polarization.*

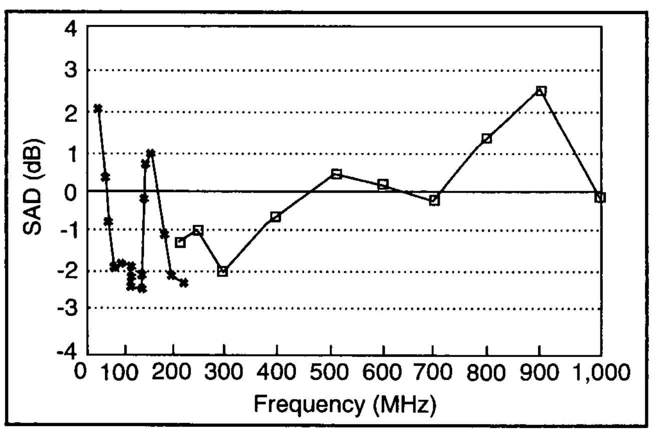

Figure 15. *Site Attenuation Deviation, Vertical Polarization.*

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Again, thanks to flat absorber technology, the volume occupied by the absorbers is reduced to a "thin plate" of flat absorber elements. At the same time, RF performance is increased to above 1 GHz. The terminating 50-ohm load technique used in a broadband TEM cell is clearly visible in Figure 18. The cell is pictured in Figure 19.

An experimental s11 measurement (reflection factor measurement) is given in Figure 20. Over the complete frequency range (dc - 1 GHz), the SWR stays below 1.5:1 and the E field inside the test volume remains stable.

CONCLUSION

Flate ferrite absorber technology is now widely used as an efficient alternative to the classical foam pyramid absorber concept. The advantages of flat ferrites are high performance, stability, total absorber volume reduction and fire resistant properties.

While a classical foam pyramid absorber can be installed without too much performance evaluation, flat ferrite absorber configurations must be examined in order to maximize performance in a particular shielded room. This is normally done with computer simulation and the quality of the anechoic room is then fully known before starting installation.

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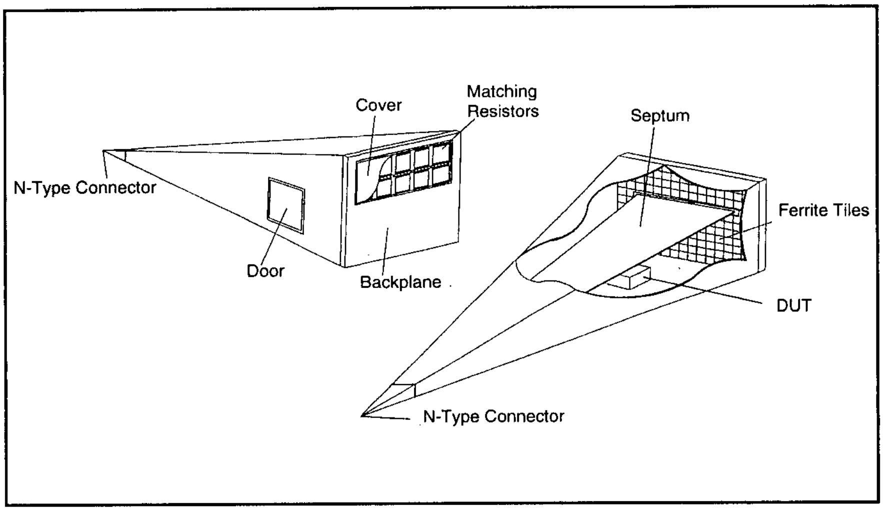

Figure 18. *Broadband TEM Cell with Ferrite Absorbers.*

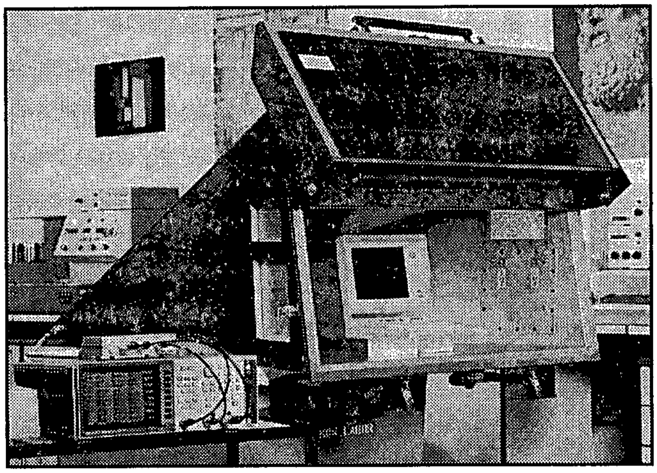

Figure 19. *Broadband TEM Cell.*

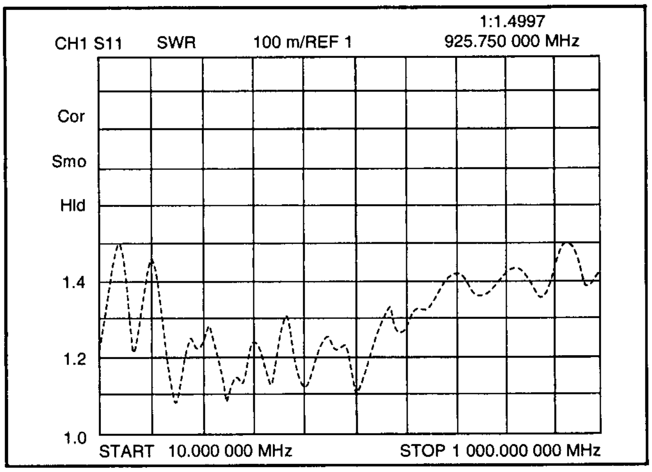

Figure 20. *Broadband TEM Cell, Standing Wave Ratio (SWR).*