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MICROWAVE ANECHOIC CHAMBERS AND MATERIALS

Timothy M. Abbott
Santa Barbara Research Center
Goleta, California U.S.A.

Development, testing, production and maintenance of microwave antennas and associated systems can be greatly simplified by the use of anechoic chambers.

The location of the boundary between the Fresnel region (transition zone) and Fraunhofer region (far-field) of an antenna, is dependent upon its cross-sectional area and frequency. The separation between the range antenna and the antenna under test to provide far-field conditions generally is expressed as[1]

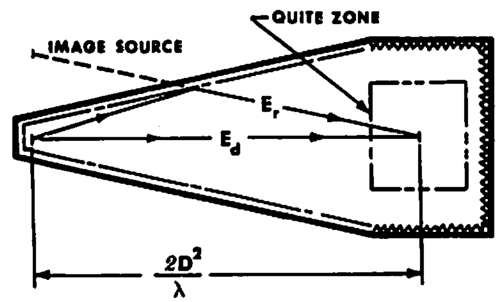
$$R = 2D^2/\lambda \qquad [1]$$

R is the separation between the two antennas (meters), D is the diameter of circular aperture or largest dimension of a non-circular aperture (meters), and λ is the wavelength (meters).

As separation between the range and test antenna is decreased into the transition region, the measured radiation characteristics of an antenna change. Gain decreases, the main lobe broadens, major side lobes increase in magnitude, and nulls between side lobes fill in.

Expanding wall chambers, or tapered chambers, were devised to minimize the variations of signal strength at the test region (quite zone) due to the wall reflections. The basic principle behind the technique is to get the image source as near the real transmitting source as possible.

In the practical operation of a tapered chamber the transmitting antenna aperture is usually placed a small distance from the apex of the chamber. Thus multipath effects also exist inside the tapered chamber as in the conventional rectangular chamber.



By ray tracing techniques one can establish there is little change in path and reflection phase differences among the direct and singly reflected ray at any point in the target area (quite zone) region of the chamber. These rays vectorially add to create a slowly varying spatial interference pattern; whereas, in a rectangular chamber the phase differentials are larger and a more rapidly varying spatial pattern results. This explains the smooth illumination amplitude in the target region of the tapered chamber compared to the rectangular chamber[2].

The presence of multipath effects implies that the chamber does not simulate free-space exactly, since the power density in the chamber will deviate from the $1/r^2$ dependence. The magnitude of the deviation depends upon the path differences and the reflection coefficient at the walls. In a quantitative analysis, one must take into account the reflection coefficient with its accompanying phase, the fact that two of the walls will reflect polarizations in quaduature with respect to the other two walls, and the characteristics of the transmitting antenna[3]. The direct ray and the singly reflected rays will be nearly parallel, resembling more closely those of a uniform plane wave, and free-space transmission.

In establishing the performance characteristics of a microwave anechoic chamber many factors must be considered:

- Quite Zone Requirements
- Frequency Range
- Cross-Polarization Characteristics
- Amplitude Uniformity
- Path-Loss Uniformity

A quite zone of 40 to 50 dB is well within present day capabilities. By definition, the quite zone implies a fictitious antenna, which has a width equal to the diameter of the quite zone. Cross-polarization properties of a chamber are those properties that allow for the purity of polarizations (ϕ,θ) as the wave propagates down the chamber axis. Large measurement errors can exist if the amplitude variation throughout the quite zone is excessive. Vertically and horizontally polarized signals should be transmitted down the chamber with the same transmission loss (path-loss).

The one single most important property that absorbers must have is the ability to absorb electromagnetic energy over the widest range of frequencies possible. The simplest absorber is made by impregnating a piece of cloth with a mixture of carbon until its resistivity measures 377Ω per sq cm and placing it one-quarter wavelength in front of a metal surface. Most modern day absorbers are pyramidal polyurethane base absorbers impregnated with a mixture of carbon black suspended in neoprene. The pyramidal shape has the same effect as varying the density with depth. Under these circumstances, the wave enters the absorber with little reflection, sees a change of material for the first time, and occuring at the boundary, and is absorbed rapidly as it progresses through the material. In general, the absorber must be at least one-quarter wavelength thick for any appreciable absorption to take place.

One of the basic functions of an antenna is to impedance match the transmission line/Transmitter to free-space. Measurement of antenna impedance match in any chamber (by measuring the input VSWR) is critically dependent upon the reflections from the walls of the chamber. Radiated energy emitted by the device under test reflects from the walls and returns to the radiating device through the aperture. The return signal behaves as though it were part of the reflected signal at the input terminals of the device being tested.

If the VSWR measured in the chamber is denoted by a prime, the quantity is related to free-space (or true VSWR) by the expression[4]

$$\mathrm{VSWR}' = \frac{\mathrm{VSWR} + \log_{10}^{-1}\left[\frac{\rho}{20}\right]}{1 - \log_{10}^{-1}\left[\frac{\rho}{20}\right]} \qquad [2]$$

Where: VSWR' is the VSWR when measured in the chamber, VSWR is the VSWR in free-space, or the true value and ρ is the reflectivity from the wall.

REFERENCES

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