A MULTIPURPOSE WIDEBAND ANECHOIC CHAMBER

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ABSTRACT

A multipurpose anechoic chamber has been designed to operate over a very wide frequency range from 30-MHz through 18-GHz. It can be used for EMC tests, antenna measurements, radar cross-section measurements, and other electromagnetic research experiments. The geometry of the chamber is asymmetrical, consisting of a combination of rectangular and tapered volumes. Less expensive absorbers can be used to achieve the required wideband performance due to the unique geometry of the chamber. Simplicity of the structure is preserved for ease of construction as well as lining of electromagnetic wave absorbers so that the actual quietness is comparable to theoretical simulation result.

INTRODUCTION

The common geometrical shapes of anechoic chambers in the world are generally rectangular, tapered, quasi-tapered, or dome. Vast majority of them is of rectangular shape due to the simplicity in constructing the chamber structure and ease of lining the absorbers. One deficiency of this simple design, however, is that the absorbers on the walls, ceiling and floor scatter a considerable amount of waves that are approaching at large angle of incidence with respect to the normal direction of the absorbers. These wide-angle reflections are especially crucial at low RF frequencies where the absorbers are less effective in absorbing the incident waves. As a consequence, the reflected waves add with the direct path signal at the test region and form an interference field (with sharp peaks and nulls) that degrades the measurement accuracy.

An increasing number of low-frequency (30 - 1000 MHz) anechoic and semi-anechoic test chambers have been designed and manufactured in recent years due to the rapid growth in multimedia and telecommunication industries. Products must meet both emission and immunity requirements of electromagnetic compatibility (EMC) regulations before they can be marketed. A fully anechoic chamber is commonly used to determine the immunity of products to impinging electromagnetic field. As for the emission limit, RF emissions from electronic products are referenced to measurements performed on an ideal open area test site (OATS) having a perfectly conducting infinite ground-plane. Thus, a semi-anechoic chamber in which the floor is not covered with wave absorbing materials is commonly used.

Anechoic chambers that are built specifically for EMC tests are usually not suitable for radar cross-section (RCS) and antenna measurements. Similarly a microwave anechoic chamber using pyramidal foam absorbers with thickness less than a meter is usually not suitable for EMC tests. In this project, an innovative technique has been used in the design of a multipurpose anechoic chamber to operate over a very wide frequency range from 30-MHz through 18-GHz. It can be used for EMC tests, antenna measurements, radar cross-section measurements, RF transceivers testing, calibration of scatterometer, and other electromagnetic research experiments. It is suitable for both industrial use and basic research.

ABSORBER CONFIGURATIONS

Pyramidal shape absorber is usually used for frequency range from 1-GHz to 40-GHz. Optimum performance of the electrically-thick foam absorber, with less than -60 dB reflectivity at normal incidence, is obtained by adjusting the carbon loading of the foam. For frequencies below 1-GHz, the required taper length of the pyramid will become too bulky and difficult to be installed in an anechoic chamber. To achieve small reflectivity using electrically-thin absorber, a different carbon loading for the foam pyramids must be used. This may give an optimum reflectivity of -20 dB for the 200 - 1000 MHz range [1], but it may not be optimum for higher frequencies where the typical applications are for antenna and radar cross-section measurements (which require much better quietness). On the other hand, ferrite tile or grid with a thickness of about 6-mm performs very well from 30 to 600 MHz but the reflectivity deteriorates rapidly as the frequency goes higher. In order to obtain an extremely wide operating frequency range from 30-MHz to 1-GHz, combination of pyramidal foam absorber on ferrite tile is necessary. This configuration is called a hybrid absorber. The matching of the material properties is very critical. For example, the taper length and the carbon loading of the pyramidal absorber must not be too low or too high.

Research and measurement results have shown that the reflectivity of ferrite tiles and grids can be improved by adding a dielectric layer between the ferrite and the metal chamber wall [1]. The dielectric layer can be commercial plywood with dielectric constant of about 2.0. However, the thickness of the dielectric must be properly chosen in order to give an optimum performance. Combining hybrid absorber with a dielectric layer will give a wideband performance. However, good hybrid absorber alone does not guarantee good performance for the anechoic chamber. The lining of the absorbers must be done carefully to minimise the discontinuity between the neighbouring absorber panels. Gaps and misalignment of the pyramids may give rise to a much poorer reflectivity than the manufacturer specification.

Small and medium size foam absorbers are conventionally glued onto the chamber wall using rubber-based contact adhesive. Absorbers longer than 1 m are usually supplied with metal base plate (with hook) to be installed onto a rail-and-clip mounting system on the chamber wall in order to ensure the installation reliability. Ferrite tiles can be installed using glue. However, due to the weight and sharp-edges of the tile, overhead net must be installed as safety measure to prevent fallen tile from injuring or killing the personnel that enters the chamber room. A more secure method is to install a plywood panel onto the wall and then fasten the ferrite tile (which comes with a centre hole) onto a plywood panel using self-tapping screws. In addition, the gap between adjacent tiles can be precisely controlled to give better reflectivity performance in contrast to using adhesive in which some glue may get in between the tiles.

The calculations of the interference field in an anechoic chamber are often inaccurate due to the lack of a proper model to characterise the scattering behaviour of absorbers when they are lined up on the chamber walls [2]. Absorber manufacturers usually specify only the reflectivity at normal incidence due to the limitation of the large fixtures that are currently used to carry out the measurement. In actual fact, the reflectivity at oblique incidence may deteriorate rapidly with increasing incident angle. The reflectivity as a function of incident angle is required for determining the sum of waves propagating directly towards the receiver and those reflected from the chamber walls and ceilings. In addition, wave energy incidents on the absorber will be scattered in virtually all directions much like a rough surface. A ray-tracing method of theoretical simulation that assumes specular reflection may not give a result that can compare well with measurement data. The only reliable method to give a good prediction of the performance, prior to chamber construction, is to perform a complete 3-D solution of Maxwell's equations throughout the interior of the chamber. This method is very laborious in terms of specifying the exact dimensions of the chamber structure and fixtures, absorber material properties, and it involves extremely long computation time. In all practical cases, it is next to impossible to characterise the chamber fixtures (such as antenna mast, turntable, lighting, CCTV camera, "honeycomb" waveguide vents, penetration panels, etc.) and imperfection in lining the absorbers for an exact simulation. Hence, it justifies the use of ray-tracing method to predict the quietness performance of the chamber if we take into account the wave scattering behaviour of the absorber. Each and every ray originating from the transmitter will reach the receiver with different field strength and phase. However, if a finite number of "ray-cone" instead of infinite number of rays is used, the required simulation time can be reduced dramatically.

Due to the cost constraint, and considering the required absorber installation skill and quality control, 610-mm microwave foam absorbers have been chosen. Wedge shaped absorbers are used at selected surfaces where the wave directions are nearly parallel to the ridge of the wedge to obtain better absorbing characteristic. For treatment of the corners, 305-mm pyramidal absorber and flat foam absorber are cut to fit the angle of the corners.

MODELLING OF THE CHAMBER WALL

Based on the general guidelines of [1], the absorber reflectivity at normal incidence must be at least -20 dB throughout the frequency range of 30 - 1000 MHz to achieve the performance criteria of 10-m emission test chamber. At 45^o oblique incidence, the reflectivity must be at least -15 dB.

For the 610-mm microwave foam absorber, the manufacturer's data specifies only the reflectivity for frequencies above 300 MHz. Based on the trend of the frequency characteristic curve, the absorber reflectivity degrades exponentially as the frequency goes lower. A similar response is observed on a plane-boundary of lossy material on which a portion of the incident wave is reflected and the rest is attenuated as it propagates into the material. By modelling the chamber wall with this kind of lossy material and assume the thickness extends to infinity, a value of equivalent dielectric constant together with the equivalent conductivity (representing the loss factor) is to be assigned. Based on the mathematical expression for reflectivity of electromagnetic wave at a plane boundary, a mean-square error between the calculated value and the available manufacturer data can be evaluated. An iterative process is carried out to adjust the value of dielectric constant and conductivity until the mean-square error is minimal. For the 610-mm absorber, the suitable value for dielectric constant is 1.0 while the value for conductivity is 0.003 S/m. The calculated absorber reflectivity at 30 MHz is -9 dB.

The absorber reflectivity above 1000 MHz is better than -40 dB. If the chamber geometry is designed in such a way that no first-order and second-order reflections (except those reflected from the floor) will get to the quiet zone, we can be sure that the quietness will be acceptable. Hence, a good strategy is to concentrate on the low-frequency performance where the absorber reflectivity is poorer.

DESIGN OF THE CHAMBER GEOMETRY

A ray-cone beam tracing technique is use in the prediction of site attenuation based on the plane-boundary chamber wall model. The major advantage of beam tracing over ray tracing is the field strengths at multiple receiver locations can be calculated simultaneously as oppose to running a ray tracing simulation for each receiver location one at a time. As a result, the computing time is greatly reduced. The computer program simulates an impulse transmitted from a dipole antenna and it propagates in all directions in the form of polygon-shaped beams. The possible paths for the beams to reach the receivers are recorded. When the beam hits a wall, the reflected wave energy is calculated based on the equivalent dielectric constant and conductivity. Since the absorber reflectivity is poorer at lower frequency, the reflectivity (magnitude and phase) at 30 MHz is used in calculating the interference field strength at the receiver. The wall is assumed to have a flat frequency response of -9 dB throughout the frequency range 30 - 1000 MHz in an attempt to assess the worst-case condition. The received impulses resulting from various multipath propagation (with different time-delays) are combined to give a time-domain impulse response. A Fast Fourier Transform (FFT) is performed to get the desired interference pattern in frequency domain.

EMC standard specifies that a radiated emission test site shall be validated by means of a set normalised site attenuation (NSA) measurements [3]. A measurement site is considered acceptable for compliance test purposes if the measured NSAs are within ±4 dB of the theoretical NSA for an ideal site. For a 10-m range, the horizontal distance between the transmit antenna and receive antenna shall be 10 m. The receiving antenna scans in height from 1-m to 4-m and the maximum signal voltage measured from this scan is recorded. Site attenuation is basically the ratio of the signal generator voltage to the received voltage measured at the receiver, taking into account the antenna factors of both the transmit and receive antennas. For an anechoic chamber, a single-point NSA measurement is insufficient to pick up possible reflections from the construction and RF absorbers. The transmitting antenna shall be placed at various points within the test region in the process of evaluating the test site.

An asymmetrical-shaped chamber geometry has been designed and constructed. It consists of a combination of rectangular and tapered volumes. The size of the chamber is about 19.5m × 9.75m × 7.3m height. The floor plan is shown in Fig. 1, and Fig. 2 is a photograph of the Anechoic Chamber. Simplicity of the structure is preserved for ease of construction as well as lining of electromagnetic wave absorbers so that the actual quietness is comparable to theoretical simulation result. An antenna mast is setup to carry the appropriate type of antenna to move from 1-m to 4-m height. A sample of the NSA simulation and measurement results is shown in Fig. 3. The results conform to the limits of ANSI C63.4 standards on the alternative test site requirements over the frequency range 30 - 1000 MHz.

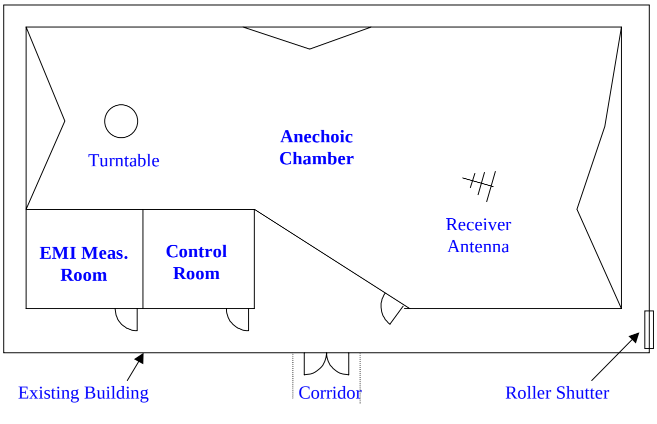

Fig. 1. Floor plan of the Asymmetrical-shaped Chamber.

Fig. 2. Configuration of pyramidal- and wedge- shaped absorbers in the Anechoic Chamber.

CONCLUSION

A multipurpose anechoic chamber has been designed and constructed to operate over an extremely wide frequency range from 30 MHz through 18 GHz. A plane-boundary model has been used to model the walls and ceiling that are covered with microwave absorbers. A ray-cone beam tracing technique is use in the prediction of Normalised Site Attenuation. The desired wideband performance is achieved with the use lower-cost wave absorbers and the unique asymmetrical-shaped chamber geometry.

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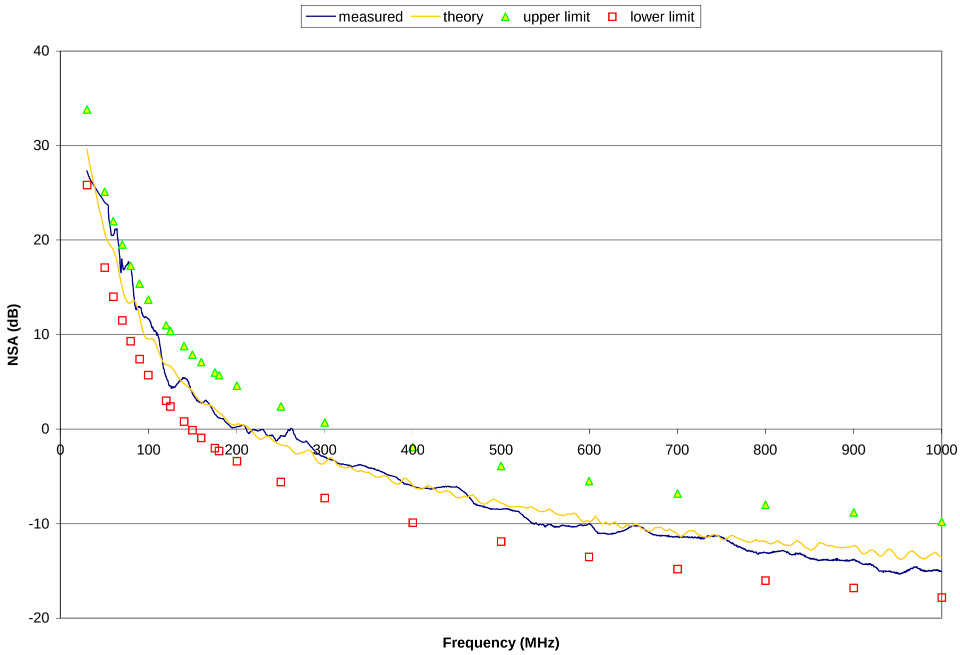

Fig. 3. Comparison between measured and calculated NSA (horizontal polarisation).