Validation of the Polynomial for RF Absorber Reflectivity for the Prediction of Anechoic Chambers

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***Abstract*— Indoor antenna ranges must have the walls, floor and ceiling treated with RF absorber. The normal incidence performance of the absorber is usually provided by the manufacturers of the materials, however, the bi-static or off angle performance must also be known. In reference [1], a polynomial approximation was introduced that gave a prediction of the reflected energy from pyramidal absorber. In this paper, the approximations are used to predict the quiet zone (QZ) performance an anechoic chambers. These predictions are compared with full wave analysis performed in CST Suite. The results show that the polynomial approximations can be used to give a fairly accurate prediction of the QZ performance of anechoic chambers.**

Keywords—Anechoic ranges, RF Absorber, Numerical Methods

I. INTRODUCTION

RF absorber is used in indoor ranges to reduce reflection from certain areas of the range to create a free space condition for testing. Most manufacturers provide data on the normal incidence reflectivity where the absorber performance is optimized. The pyramidal shape of the absorber helps the electromagnetic (EM) wave penetrate into the absorber where it is transformed into thermal energy and dissipated. In most applications of absorber in indoor ranges, it is important to know its bi-static reflectivity for oblique angles of incidence. In reference [1] a polynomial approximation was developed to provide a prediction of the reflected signal from pyramidal absorber of a given thickness t for a given angle of incidence θ. Figure 1 shows the absorber performance based on the equations presented in [1].

Using these equations and the geometry of the chamber, as well as knowledge of the radiation pattern of the illuminating antenna, it is possible to estimate the highest level of reflected energy arriving into the quiet zone (QZ). That level is known as the QZ level and gives an indication of the quality of the chamber as well as an estimate of the expected measurement errors.

II. SIMPLIFIED RAY-TRACING APPROACH

The presented approach is intended for rectangular anechoic chambers. As it will be shown, the approach is not only valid for far-field measurement ranges, but it is also valid for near-field ranges and, compact ranges.

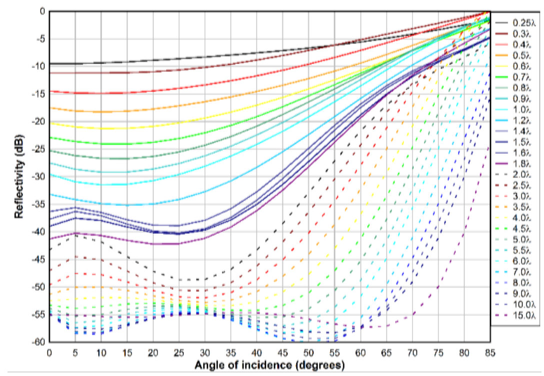

Fig. 1. Plots of the Reflectivity of RF Absorber from the equations presented in [1]

The necessary input parameters are the internal size of the anechoic chamber, length, width and height. The thickness of the absorber used on the side walls, floor, ceiling and end wall are also required parameters. The size of the QZ and the distance from its center to the source antenna are additional parameters.

There are some recommended rules for sizing a rectangular anechoic chamber. Some of these rules are given in [2-4]. A typical rectangular anechoic chamber is given in Figure 2. The chamber has an internal length (L) and height (H). The internal width of the chamber (W) is usually the same as the height (H), but this is not always the case as discussed in [2] and [4].

A simple model can be made in which only the 1st order reflections are considered. This is a very simplistic; but the goal is to achieve a simplified approach to estimate the performance of an anechoic chamber. The 1st order reflections will be the energy reflected from the end wall behind the QZ, and the reflections from the specular point in the side walls, ceiling and floor. It is assumed the source antenna has a front to back ratio high enough that the absorber on the end wall behind the source will reflect a level much lower than the other reflections. From the dimensions above the angle of incidence onto the absorber on the ceiling, floor, and the sidewalls can be calculated using basic trigonometry. This angle θ is the one used in (1) to estimate the reflected energy. For the end wall behind the QZ, equation (2) will provide the level of energy reflected.

Another factor determining the level of reflected energy entering the QZ is related to the level of energy incident onto the side walls compared to the direct path between the source antenna and the QZ. Figure 3 shows the level of the field towards the specular point is about 5dB lower than the level of the direct ray to the QZ.

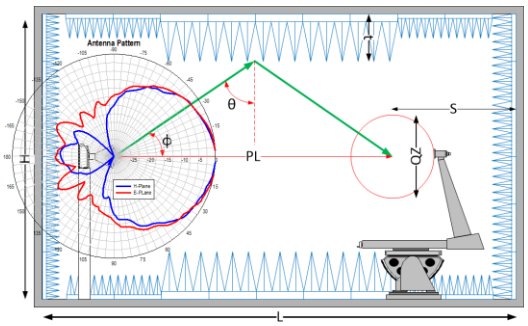

Fig. 2. A pattern of the source antenna superimposed on the chamber diagram showing that the level of energy towards the specular point is lower than the level of the direct ray along the path length PL.

The final factor is the additional path loss as the waves propagate. The difference between the reflected path and the direct path will add some losses that are added to the absorber reflectivity and to the source radiation pattern difference. The path difference given by the QZ location versus the back wall is given by the distance S in Figure 2. It should be noted, when modeling compact ranges using this approach, the plane wave created by the compact range reflector will not attenuate as it propagates along the axis of the chamber.

III. Comparison with Full Wave Models

In the previous section, a very simple approach for modeling a rectangular anechoic range was presented. How good is this model? Is it good enough for estimating the performance of an anechoic range? To answer this question two rectangular ranges will be modelled using this approach and the performance will be compared to the computations from a full wave models. CST was chosen to model the chambers. This is not a very efficient method as the required computer resources limit the highest frequency that can be computed for a given range.

A. A 400MHz Spherical Near-Field Range

For a spherical near-field (SNF) range, a chamber with inside dimensions of 10.40m wide, by 11.78m long and a height of 12.8m was chosen. The QZ is 3.66m in diameter. The distance from the center of the QZ to the open ended waveguide (OEWG) source antenna is 4.57m. The side walls are treated with absorber 1.22m (48 inches) in length with the rest of the surfaces treated with absorber 0.9m (36 inches) in length. The angle of incidence on the walls is 33° and 24.4° for the ceiling and floor.

TABLE I. Reflectivity of the Absorber per Equations on [1]

Thickness	θ=0°	θ=24.4°	θ=33°
t=1.22λ	-34	-35	-32
t=1.63λ	-39	-40	-39

The effects of the illuminating OEWG are about -2dB to -5dB lower than the direct path. The levels depend on the polarization.

For analysis, we can use the highest level of -2dB. If we add the additional path loss, we end up with a highest reflectivity level of -44dB equivalent to an amplitude ripple of ±0.057dB.

TABLE II. Reflectivity at 400MHz

Frequency (GHz)	Source antenna directivity (dB)	QZ level (dB)	Amplitude ripple (dB)
0.4 GHz	8dB	-44	±0.057dB

The chamber model is built within CST. The absorber material properties are provided by the manufacturers of absorber.

The chamber is analyzed at 400MHz and the field distribution is obtained at two orthogonal planes. From the data, we can arrive at the field distribution in the QZ and along the three-main axis of the sphere: the longitudinal, the horizontal transverse and the vertical transverse axes. The data can then be fitted with a 2^{nd} order polynomial and the ripple riding on that polynomial can be determined. From the ripple, the reflectivity in the QZ can be estimated. While the longitudinal field plot showed a 0.055dB peak-to-peak ripple, the transverse horizontal scan shows a much smaller 0.025dB peak-to-peak. The vertical transverse scan shows a ripple of 0.026dB. The ripple for the horizontally polarized probe were all much smaller. This makes sense as the lateral walls are treated with longer absorber and with the OEWG vertically polarized there is lower level of energy illuminating the side walls. From these ripple levels, the reflectivity on the QZ could be estimated to be about -50dB. This is within 6dB of the predictions using equation (1) that are shown in Table II.

IV. Conclusions

The results presented have shown that the simplified ray-tracing approach together with the equations introduced in [1] provide a good approach to estimating the performance of an anechoic chamber. This approach has been validated by comparing it to estimates from full wave analysis performed using commercially available packages. The results further validate the use of the equations introduced in [1] for the prediction of pyramidal absorber reflectivity.

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