Comparison of Measurements and Simulations of Tapered Anechoic Chambers

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***Abstract*—Recently the author presented two papers on the use of full wave numerical methods for the prediction of anechoic chamber performance. In the first paper [1] the author argued that full wave analysis while accurate is still dependent on the accuracy of the input parameters, one of which may be the material properties of the RF absorber. On the second paper [2] presented the author stated that full wave analysis should be reserved to evaluating the potential effects of defective absorber of location of lights in different areas of the range. In this paper the author compares the full wave analysis of a taper anechoic range with the measured performance of the implementation of said tapered range.**

***Index Terms*—anechoic range design, numerical methods, range measurements.**

I. Introduction

Anechoic ranges for electromagnetic measurements are a challenging problem to simulate. Simple approaches can be used that provide an approximate result to predict the behavior of the range [1]. Ranges can be simulated as it was shown in [2] and [3]. As it was done in [3], this may involve separate simulations to get a full wave solution of the absorber behavior or of the region around the range antennas and a different simulation using asymptotic methods to solve for the full range using the output of the other simulations [3]. However, even these approaches have assumptions, the most common assumption is that the absorber is homogeneous, which is not the case as was reported on [1] and as early as 35 years ago by Burnside and Peters in [4].

Recently two tapered ranges have been constructed and their quiet zone performance measured. The first range, referred to in this paper as Range A, is a 1.52 m (5 ft) spherical QZ range having a rectangular section that is and the other is a 4.88 m (16 ft) tall, 4.88 m (16 ft) wide by 8.54 m (28 ft) long with a tapered section being 9.6 m (31.5 ft) long including the feed section. For this range only the amplitude was measured as part of the free space VSWR test.

The second range, referred to in this paper as Range B, has a cubical section being 4.88 m (16 ft) per side with a tapered section being 9.3 m (30.5 ft) in length. This is the range that is analyzed in [2] for a 1.82 m (6 ft) diameter spherical QZ.

II. Analysis and Measurements: Range A

Range A is an unusually shaped tapered range since the traditionally cubically-shaped section has a rectangular footprint. The reason for this approach was the desire by the user to do additional testing unrelated to the tapered range geometry. The range was treated with 1.82 m (72 inch) long pyramidal absorber on the end wall and 0.61 m (24 inch) long pyramidal absorber on the lateral surfaces of the rectangular section. The floor was treated with 30.5 cm (12 inch) pyramidal absorber to allow for the antenna under test (AUT) positioner to rotate freely without hitting the absorber. The balance of the range was treated with 45 cm (18 inch) wedge absorber. The taper section had the 45 cm wedge trimmed down to 7.62 cm (3 inches) thickness at the interface with the feed section that was treated with 7.62 cm thick lossy foam block. Figure 1 show the numerical model built in CST suite and a picture of the implemented range during the testing.

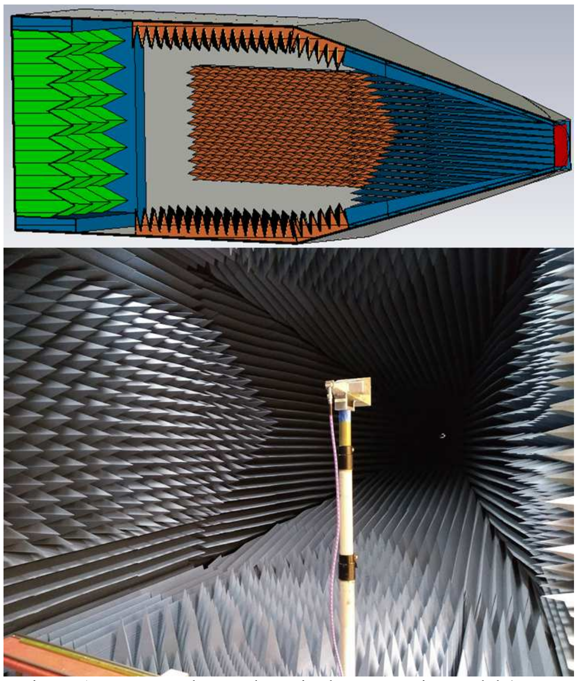

Figure 1. Range A shown above in the CST Suite model (some absorber and the conical feed hidden for clarity) and below a picture of the implemented range.

The absorber properties were supplied by the absorber manufacturer or measured form samples by a third-party lab. The average of these measurements was taken as the homogeneous loading of the entire absorber piece.

In addition to the assumption of the absorber being homogeneously loaded, the other assumption is the illumination. To reduce the complexity of the model a circular aperture at the interface between the conical feed section and the taper section was used in [2]. In the present paper, for Range A instead of using an assumed illumination a lower frequency range model using a dipole feed was done (see Figure 2). The dipole modeled has the same size

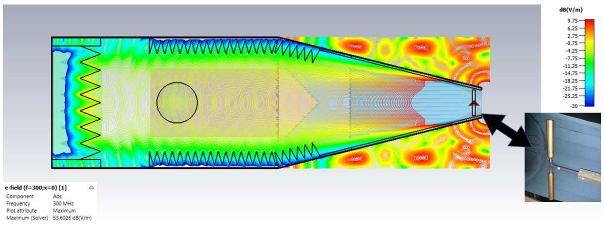

Figure 2. Model of the tapered range showing the dipole excitation, the inset picture shows the dipole used as a range antenna at the 100 to 300 MHz range. Because the conical feed section is not present the structure is "unshielded"

elements as the dipole antenna used during the measurements. The antenna was an A. H. Systems SAS-530. The inset on Figure 2 shows a picture of the dipole in the feed section of the tapered chamber. Figure 3 shows the results of this analysis at 300MHz.

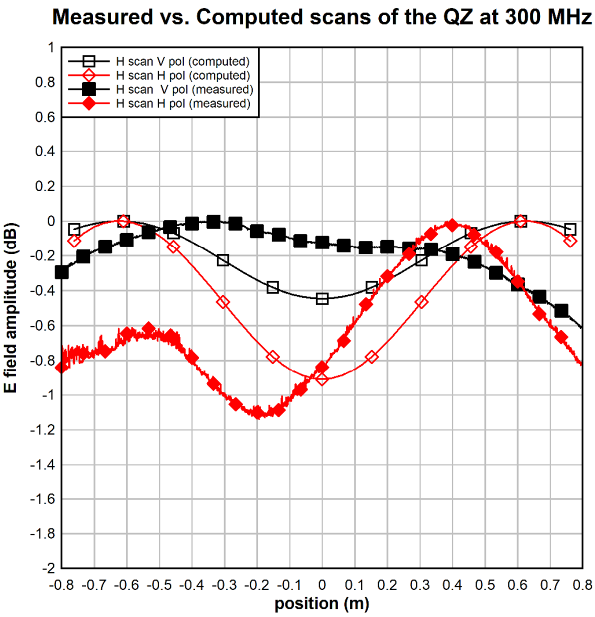

Figure 3. Measured and Computed scans for two orthogonal polarizations of the range antenna at 300 MHz.

The data is normalized to the highest value across the scan and plotted in decibels for comparison. Clearly, the predicted results are not close to the measured results. The measured results are clearly asymmetric. This asymmetry was shown in the numerical results presented in [2] and can be easily caused by variations on the absorber loading around the feed section. There are some similarities, the Horizontal polarized results for this transverse horizontal scan are the ones with a larger ripple. Additionally, all the scans show a slight dip in the centerline of the QZ. An additional frequency was simulated and measured using the dipole as the range antenna. Figure 4 shows the results for 200 MHz. As was the case with data at 300 MHz there are very few similarities. The asymmetry in the measured data is present. This asymmetry is not seen in the perfect model. In this case the only similarity is that the overall shape with a peak near the center and the magnitude of the field decreasing as the edges of the QZ are approach is similar in both the modeled data and the measured data, but for the measured data, the amplitude taper is smaller for the vertical polarization compared to the horizontal polarized case. The opposite appears in the computed data where the vertical polarization has a larger amplitude taper than the horizontal polarized case.

The data measured for range A only shows the

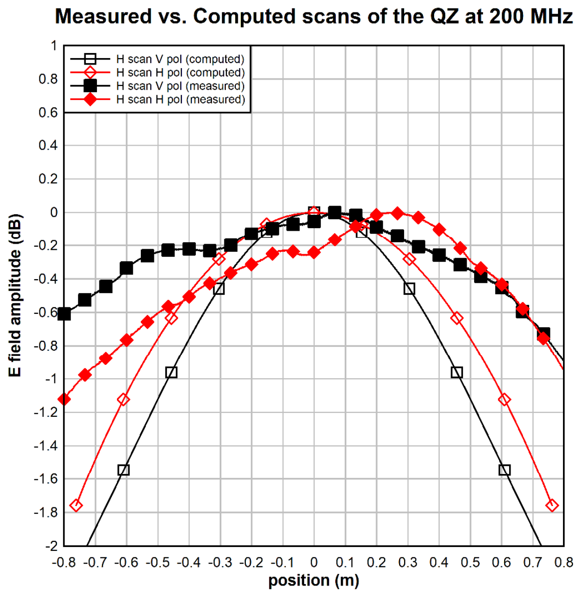

Figure 4. Measured and Computed scans for two orthogonal polarizations of the range antenna at 200 MHz.

amplitude. This was due to the instrumentation used in performing the free space VSWR test. It is of interest to see the phase distribution across the QZ, but a means to measure phase are required. This was done during the testing of Range B.

III. Analysis and Measurements: Range B

The taper chamber performance was computed and measured for range B.

Range B is the same range that was analyzed in [2]. The absorber treatment is 1.82 m (72 inch) pyramidal absorber on the end wall. The lateral surfaces of the cubical section are treated with 45 cm tall pyramidal absorber (18 inch) with the balance of the areas being a 20 cm (8 inch) wedge absorber. The tapered section extending into the conical feed section is also 20 cm (8 inch) wedge absorber. The QZ is a sphere with a diameter of 1.82 m (6 feet). For range B, the data was measured from 500 MHz to 40 GHz. The computed data was obtained from 100 MHz to 1 GHz as mentioned in [2]. To allow for computing efficiently at these higher frequencies a circular aperture port was used at the location of the range antenna aperture. The range antenna used to illuminate the taper was an ETS-Lindgren 3164-10 open-boundary quad-

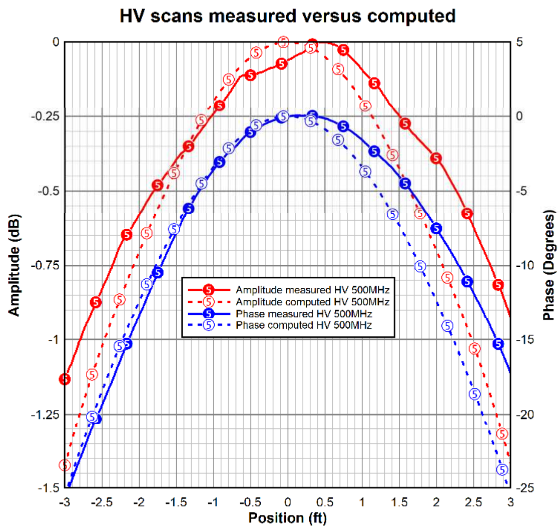

Figure 5. Computed and measured amplitude and phase at 500 MHz for range B.

ridge horn. Although data was taken in both polarizations, vertical and horizontal and in two scanning directions, a horizontal scan and a vertical scan, in this paper we concentrate on the horizontal scan with the vertically

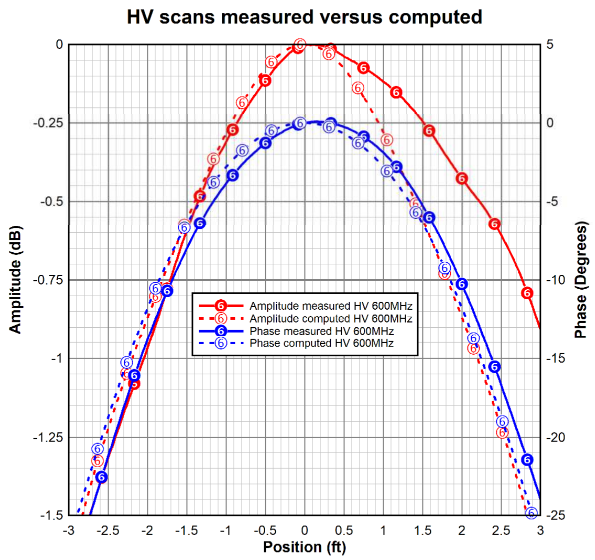

Figure 6. Computed and measured amplitude and phase at 600 MHz for range B.

polarized range antenna.

Figure 5 shows the computed and measured amplitude and phase distributions across the QZ. The computed data had been reported in [2].

The data shows that the amplitude taper is less pronounced in the measured results than in the computed ones. However, the difference is less than 0.5 dB. The phase distribution shows an asymmetry. Given the assumptions about the absorber and the range antenna the predictions are very close.

Figure 6 show the computed and measured results at 600 MHz. Here the asymmetry o the amplitude is more pronounced, However the phase behaves very close to the computed results. Is of interest that on the negative end of the scan, the amplitude follows the predicted results very closely. one side of the scan. This could be a case where, as it was shown in [2], variations on the absorber, or compressing the foam more on one side than the other during installation has yield an asymmetry in the illumination as it was shown on [2].

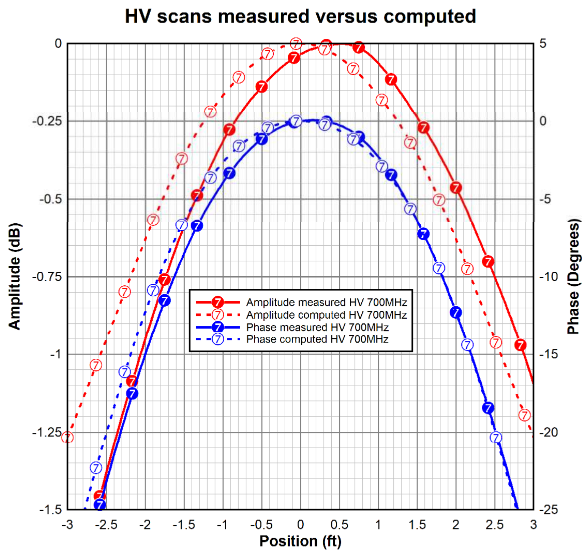

Figure 7. Computed and measured amplitude and phase at 700 MHz for range B.

Figure 7 shows the amplitude and phase, both computed and measured at 700 MHz. The measured phase distribution follows very closely the computed results. The measured amplitude, while slightly shifted to one side also has a very similar profile to the computed results. This is very interesting given that the actual illuminating mechanism is different, a circular aperture port versus an open-boundary quad-ridge horn.

Figure 8 shows the measured and computed amplitude at 1 GHz, The results also shows that the predicted and measured phase are very similar with differences on one side of the center smaller than 5 degrees. The amplitude is interesting because it shows good agreement on the negative side of the scan but on the positive side there is a 0.3 to 0.4 dB difference. While it is true that there is an asymmetry on the actual range created by the presence of the door which is

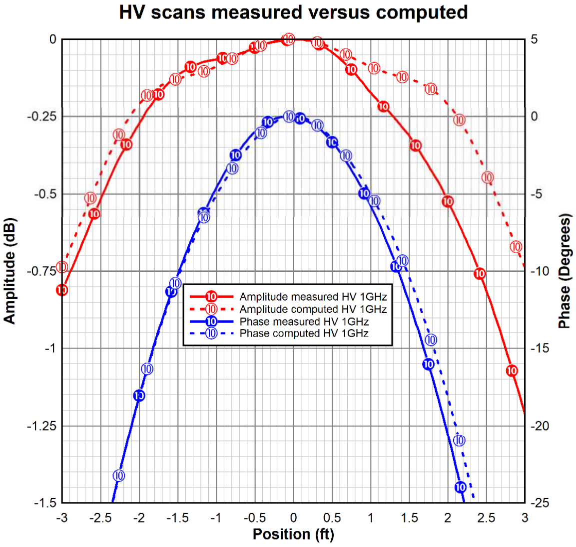

Figure 8. Computed and measured amplitude and phase at 1 GHz for range B.

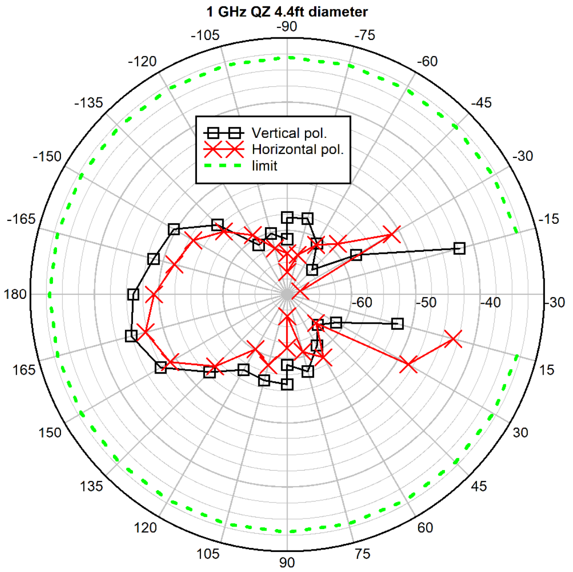

Figure 9. Measured reflectivity per the free space VSWR for Range A.

treated with rubberized coated polyurethane foam absorber. free space VSWR plots at these sub 1 GHz frequencies have shown that there is not much difference in the reflectivity from the rubberized absorber on the door and the opposite wall with standard absorber. Figure 9 shows the free space VSWR results for range A at 1 GHz. The door is at 90 degrees, and the range antenna at 0 degrees. The end wall is at 180 degrees.

The last analysis was to compare the span of the 22.5 degrees phase variation (the lower boundary of the far field per the $R=2D^2/\lambda$ equation) to the expected QZ size based on the distance from the scan plane to the aperture of the feed antenna. Figure 10 shows that there is excellent agreement between the prediction from $R=2D^2/\lambda$ to the measured data.

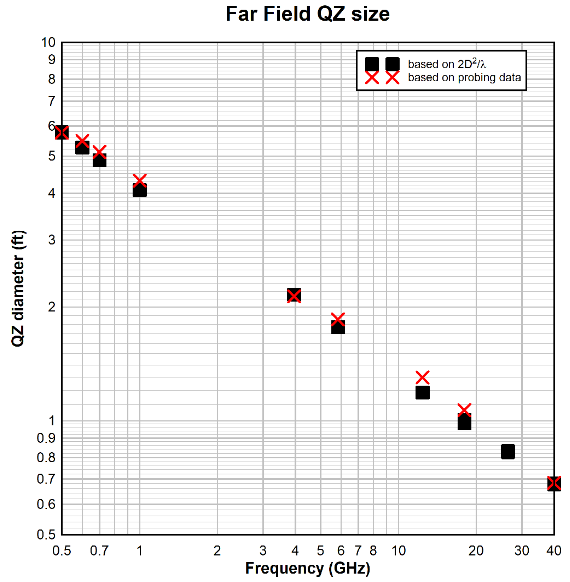

Figure 10. Computed and measured far field illuminated QZ for range B.

IV. Conclusions

The data does support that at the present time there are limitations to the accuracy of numerical solutions using full wave analysis for the simulation of anechoic ranges. The asymmetry found in the measured data was not predicted by any of the perfect homogeneous modeled absorber simulations. The possibility of asymmetry due to the variations in loading of the absorber was predicted in [2] and indeed the measured data shows that it does occur.

This is not to say that simulations of anechoic ranges are a futile exercise. Simulations can help identify areas of concern to the range designer prior to the implementation of the range, but the engineer using numerical tools should understand the limitations and the assumptions made. Even with these assumptions the numerical results can be used to give close predictions of performance provided that the engineer performing the simulations understands the potential for deviations from the modeled results and accounts for them in the predicted results.

Seeing how far the ability to run these complex simulations have evolved in the previous 20 years it is possible that in the future faster computers and simulations using multiple methods can help in the design of anechoic rooms, however the user has to always understand any potential limitations and never expect that the actual performance will match exactly the simulated results.

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