FREQUENCY CHARACTERIZATION OF REVERBERATION CHAMBERS

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Abstract

A series of measurements to investigate the modal structure of a reverberation chamber were conducted at the Dahlgren Division of the Naval Surface Warfare Center, Dahlgren, Virginia. These measurements were Phase I of a project to determine the frequency dependent characteristics of the fields in a reverberation chamber.

Measurements were taken to compare the modal structure excited by both CW and band limited white gaussian noise.

Measurements were also obtained to determine the required step size for collecting field characterization data using discrete frequency data.

The measurements were taken over frequency bands ranging from 1 MHz to 100 MHz using frequency steps from .1 to 100 kHz. The frequency bands selected covered frequencies from below the first chamber resonance to 18 GHz. Each frequency band was evaluated for multiple boundary conditions (i.e. independent positions of the paddle wheel tuner). The data collected were analyzed to determine the width of the peaks that occur within the chamber as a function of frequency. The results of the analysis yielded the uncertainty of obtaining the true peak (i.e. independent positions of the paddle wheel tuner). The data collected were analyzed to determine the width of the peaks that occur within the chamber as a function of frequency. The results of the analysis yielded the uncertainty of obtaining the true peak (i.e. independent positions of the paddle wheel tuner). The data collected were analyzed to determine the width of the fields in the chamber as a function of the frequency step size. The results of the analysis yielded the uncertainty of obtaining the true peak (i.e. independent positions of the paddle wheel tuner). The data collected were analyzed to determine the width of the fields in the chamber as a function of the width of the frequency band and size of the frequency step. NOTE: To keep this paper to the length allowed, only a portion of the data is presented.

Introduction

Use of reverberation chambers to conduct electromagnetic (EM) effects testing is increasing as the technology matures. Inclusion of the test technique into such documents as RTCA DO-160D which covers the testing of aircraft avionics, the FAA HIRF Users Guide for certification of commercial aircraft to High Intensity Radiated Fields, SAEJ551, and GM-9120P has led to many manufacturers and commercial test houses acquiring reverberation chambers.

Recent investigations into the use of band limited white gaussian noise (BLWGN) to excite the modal structure of reverberation chambers [1,2] have yielded some interesting findings. Results of EM effects testing [2] show that BLWGN yielded comparable results to those obtained using CW excitation and mechanical stirring. However, other investigations [3] show large variations in upset levels when utilizing BLWGN. These variations lead to the need for direct comparison of the modal structures excited by CW and BLWGN excitations. The first set of measurements addresses this issue.

Further investigations conducted by the authors and others suggest that the effective electromagnetic test environment for a device under test (DUT) when utilizing BLWGN is affected not only by the bandwidth of the noise as reported in [1], but also by the susceptibility bandwidth of the DUT. The implications of these observations is that the effective electromagnetic test environment is determined by the susceptibility bandwidth of the DUT as well as the field characteristics of the reverberation chamber. Data show that this applies to swept CW excitation as well as BLWGN.

The observations on the role of the DUT in defining the effective test environment indicate the need to understand the electromagnetic environment in a reverberation chamber to a level of detail not currently available. The field characteristics include the statistical distribution of the three field components at an arbitrary location in the chamber. Also required is the chamber uniformity, which is a comparison of the field components for multiple locations within the chamber. Since test results appear to depend on the susceptibility bandwidth of the DUT, the chamber field characteristics must be known as a function of frequency for bandwidths equal to the susceptibility bandwidths of the DUT. The detailed field characteristics described above will require collection of a significant data base. A major factor in determining the size of the data base is the number of frequencies, i.e. the frequency step size, required to adequately characterize the chamber with a reasonable level of uncertainty. As the frequency step size decreases the total number of data points increases and, in the limit, could become unmanageable. Conversely, as the step size increases the expected uncertainty in determining the characteristics of the peak field components also increase. Thus it is necessary to determine an optimum frequency step size before the full characterization measurements can begin. The second set of measurements addresses this issue.

Approach

Two sets of data were collected for this report. The first set of data were used to compare the modal structure generated using CW and BLWGN excitation. Data were collected using BLWGN and swept CW illumination of the NSWCDD reverberation chamber at a common center frequency using multiple positions of the paddle wheel tuner.

The second set of data were collected to determine the optimum frequency step to be used to characterize the chamber as a function of frequency. Data were taken over frequency bands ranging from 1 MHz to 100 MHz in width, and using frequency steps from .1 to 100 kHz. Each frequency band was evaluated for multiple boundary conditions (i.e. independent positions of the paddle wheel tuner). The data collected were analyzed to determine the "minimum" width of the peaks that occur within the chamber as a function of frequency.
Experimental Procedure

To compare the modal structure excited by CW and BLWGN, the chamber was configured as shown in Figure 1. The CW mode of excitation was accomplished by disconnecting the noise source input from the mixer. The set-up allowed the excitation mode of the chamber to be changed without effecting the chamber in any other way. The fields in the chamber were monitored using a spectrum analyzer set to the "peak and hold" mode with the resolution bandwidth (RBW) set to 30 kHz. The spectrum analyzer RBW was much less than the noise BW. This allowed the spectrum analyzer to capture the "peak envelope" of the field pattern generated by each excitation method.

For BLWGN excitation, the spectrum analyzer was left in the "peak and hold" mode while multiple sweeps of the spectrum analyzer were collected. The RF synthesizer was set to the frequency of interest and "mixed" with a fixed bandwidth of white gaussian noise as shown in Figure 1. When the rate of change of the peak and hold trace, which was capturing the peak envelope of the rapidly changing noise excitation, had diminished such that no appreciable change occurred to the additional sweeps, data collection was stopped.

For CW excitation, the spectrum analyzer was again left in the "peak and hold" mode while a single 200 second sweep of the spectrum analyzer was collected. The RF synthesizer was set to sweep over the interval of interest (equivalent to that generated by the BLWGN) at a rate of 20 milliseconds per sweep.

To determine the optimum frequency step to be used to characterize the chamber as a function of frequency the test set-up was changed as shown in Figure 2. Data were collected by stepping through multiple frequency bands up to 100 MHz in width using frequency steps ranging from .1 to 100 kHz. For each band the synthesizer was stepped through the frequency band while the spectrum analyzer was used as a receiver to measure the amplitude of the signal received at each frequency. The process was repeated for five (5) positions of the paddle wheel tuner.

Results

The data collected to compare the modal structure excited by CW and BLWGN for fixed boundary conditions are shown in Figures 3A and 3B. The two Figures show the data for 200 +/- 10 MHz and the delta between the two excitation techniques for two different boundary conditions (paddle wheel tuner conditions). As expected the modal structures in Figures 3A and 3B vary by as much as 25 dB at some frequencies but the peak values are essentially the same. The two traces in each Figure show that both CW and BLWGN excite the same modal structures.
Figure 4A. 500 - 510 MHz Frequency Stepping Data.

Figure 4B. Peak data from each trace in figure 4A normalized to 0 Hz and 0 dBm received power.

Figure 5A. 500 - 501 MHz Frequency Stepping Data.

Figure 5B. Peak data from each trace in Figure 5A normalized to 0 Hz and 0 dBm received power.

Figure 6A. 4000 - 4001 MHz Frequency Stepping Data.

Figure 6B. Peak data from each trace in Figure 6A normalized to 0 Hz and 0 dBm received power.
The data collected to define an optimized frequency step as a function of frequency are shown in Figures 4A - 7A.

In order to determine the frequency interval to use in collecting the Phase II data, it was necessary to replot the data normalizing both the peak amplitude of each trace to 0 dBm and the frequency at which the peak occurred to 0 Hz. These plots are shown in Figures 4B - 7B.

Figures 4, 5, and 6 show the data collected at 500 MHz. Figure 4A shows the data for 500 - 510 MHz collected using 1 kHz frequency steps. Figure 4B shows that the normalized peak for Figure 4A is approximately 30 kHz wide. Figure 5 shows the data for 500 - 501 MHz collected using 0.1 kHz frequency steps. Again the normalized peaks show that the peaks are approximately 30 kHz wide. These data show not only the approximate width of the peaks, they also show that a 1 kHz frequency step is more than adequate for collecting the data needed. Similar data are shown in Figure 6 for 4 GHz and Figure 7 for 18 GHz.

Conclusions

The boundary effects data show that the modal structure which is excited in a reverberation chamber for a fixed boundary condition is the same for both CW and BLWGN excitation methods.

The modal structure data show that below 4 GHz a frequency interval of 25 kHz should detect the peak within 0.25 dB and a frequency interval of 50 kHz should detect the peak within 1 dB. Data above 4 GHz show that a frequency interval of 25 kHz should detect the peak within 0.2 db and a frequency interval of 50 kHz should detect the peak within 0.4 dB.

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References

