Applications of Time-Gating Method to Improve the Measurement Accuracy of Antenna Radiation inside an Anechoic Chamber

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1. Introduction

In order to obtain accurate measurements on the antenna radiations, anechoic chambers with proper shielding and absorbing structures are generally employed to isolate the undesired interference from external environments. Establishment of an anechoic chamber is very cost cumbersome, and the measurement accuracy highly depends on the quiet zone space and absorber effectiveness in reducing the multi-path interferences, which is generally frequency dependent. In order to increase the quiet zone space, reduce the multi-path interferences and increase the measurement accuracy in an existing chamber, a time gating method (TGM)[1,2] is incorporated into the measurement system. The TGM transforms the frequency domain (FD) response into time domain (TD) and filter out the late time pulses, which are caused by the multi-path interferences, by imposing a gating window. The extracted TD response is then transformed back to provide more accurate FD response. Performance examination is presented in this paper.

2. Fundamental Concepts of Time Gating Method

The concept of TGM transforms the phase difference in FD due to multi-paths into time delayed signals in TD via Fourier transform(FT). The delayed signals can be filtered out by imposing a window function over the dominating signal that is identified to the desired signal. The associated signal in FD can be recovered by utilizing inverse FT.

Initially the measurement is performed over a selected range of frequencies ($f_c - B \leq f \leq f_c + B$ with f_c for central frequency and B for bandwidth). The signal can be expressed by

$$F(f,q,f) = [F_d(f,q,f)e^{-jkr} + \sum_{m=1}^{M} F_m^r(f,q_m,f_m)e^{-jk\ell_m}] \cdot W(f) \qquad (1)$$

where a window function, $W(f)$, is employed to smooth out the effects of finite truncation, and makes the TD pulse more bounded. The first term in (1) is the desired signal while the rest represents the multi-path effects. The phase terms in (1) will

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cause time delays in TD if FT is employed. In TD, (1) can be represented by

$$T(t-r/c,q,f)=T_d(t-r/c,q,f)+\sum_{m=1}^{M}T_m^r(t-\ell_m/c,q_m,f_m) \qquad (2)$$

where each term is associated with that in (1) with time delay factor considered, and c is light speed. Ideally if $r \ll \ell_m$, then the first term, T_d, is isolated from the multi-path contributions, and can be extracted by imposing a window function. Inverse FT is then employed to extract the FD signal.

In realistic applications, the difference between r and shortest ℓ_m (say ℓ_1) determines the bandwidth B that will in turn determine the width of TD signal. In general B has to be sufficiently large in order to get a good resolution since in a realistic chamber the distance difference is usually less than a few meters. As a result, this method tends work better at higher frequency. In a practical application, the windowed signal will still include those multi-path signals that have very short distance differences in comparison with direct distance, which will in general cause ripples. To reduce the impact of this problem, the windowed signal is further smoothed out by removing undesired peaks with large field values in an averaging manner.

3. Performance Examination

To demonstrate the concept, one first numerically considers the radiation of a dipole antenna[3] in a presence of PEC plates. The diffractions of plates will cause interferences and ripples in the patterns as shown in Figure 1. The signals are transformed into TD as shown in Figure 2 following the concepts in section 2. Figure 2(a) shows different delayed pulses with the first pulse being the desired signal. In this case the signals are so isolated so that each signal can be easily extracted. Figure 2(b) and (c) show the extracted signal and ideal signal without PEC plate present, which are both transformed back to FD and also shown in Figure 1. Difference of less than 0.2dB has been achieved. Same concept is applied to the measurement of a horn antenna (EMCO-3115 with operation frequencies of 1~18GHz and 11” (length)x 6.25”x 9.6” (aperture)) inside a chamber ($6m\times 8m\times 4m$). The FD and TD signals are shown in Figure 3 and 4. It is observed from Figure 4(a) and (c) that the multi-path distance differences are very small and some undesired but significant signals are difficult to isolate from the main signals. In this case the signals are first windowed (with 5ns for each side) and smooth out the undesired peaks as shown in Figure 4 and 5. Inverse FT is performed to obtain FD signals as also shown in Figure 3(a) and (b). Smooth curves have been obtained. Finally the measured pattern of the horn antenna is shown in Figure 6 at various dates for reference. Note that data not processed shown uncertainties, while data processed shows stable patterns.

4. Discussion

Utilization of TGM to improve the measurement accuracy inside anechoic chamber is discussed. Significant improvement has been observed. However, due to the limited size of chamber, the TD signals are not well isolated. A smooth-out procedure is thus employed to remove the significant interference signals and further improve the stability of the measurement. The future work would employ techniques of signal processing to further isolate the delayed signals and study the impact of this technique to the expansion of quiet zone.

5. Acknowledgement

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6. References

[1]. *Waiyapattanakorn, C.; Parini, C.G.,* "**Theoretical and experimental investigations of using time domain gating in antenna pattern measurements,**" 8th International Conference on Antennas and Propag., vol. 1, pp. 327 -330, 1993

[2]. *Henderson, A.; James, J.R.; Newham, P.; Morris, G.,* " **Analysis of gating errors in time domain antenna measurements,**" IEE Proc.-Mw., Ant. and Propag., Vol. 136, 4, pp. 311 –320, Aug. 1989

[3]. Constantine A. Balanis, **Antenna Theory**, published by John Wiley & Sons, Inc., 1997, New York, ch16, pp. 839-883.

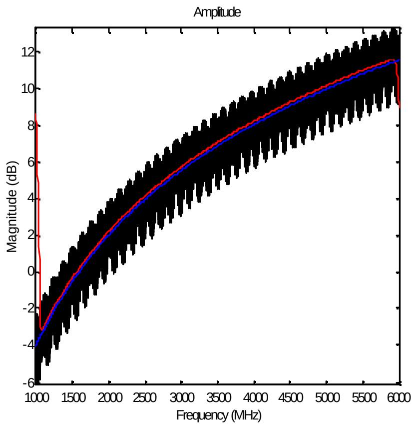


Figure 1: Frequency domain response of a dipole in the presence of PEC plate.

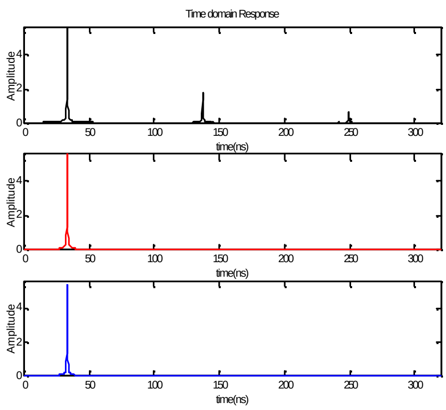
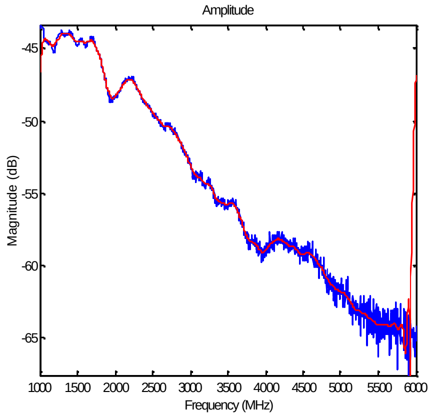
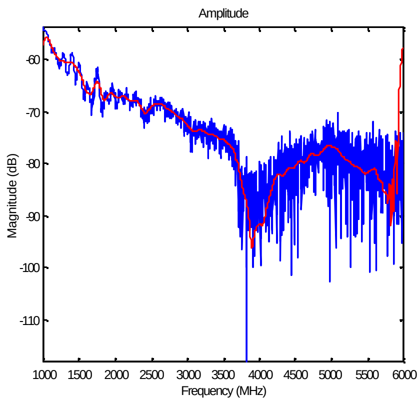


Figure 2: TD response of Fig. 1. (a) complete response, (b) filtered response, and (c) response for a free dipole.



(a) θ=0 degree



(b) θ=180 degrees

Figure 3: FD response of horn antenna at horizontal plane.

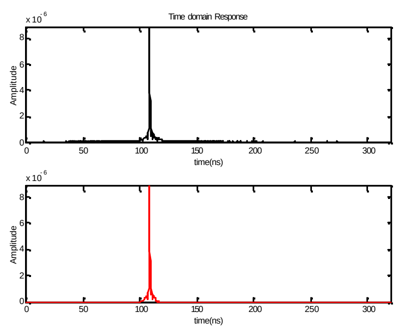


Figure 4: TD response at θ=0 degree. (a) unfiltered response and (b) filtered and smoothed response.

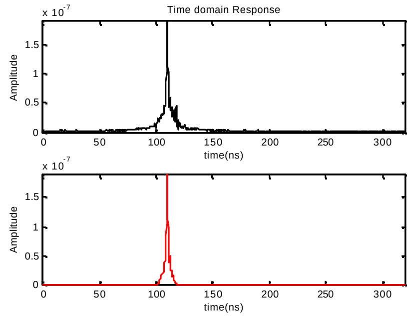
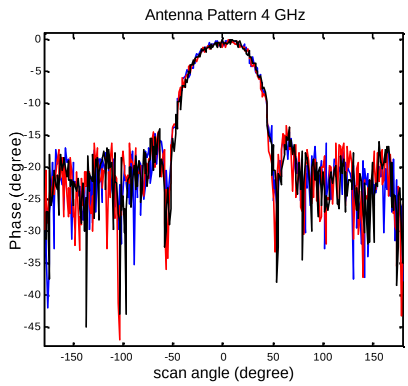
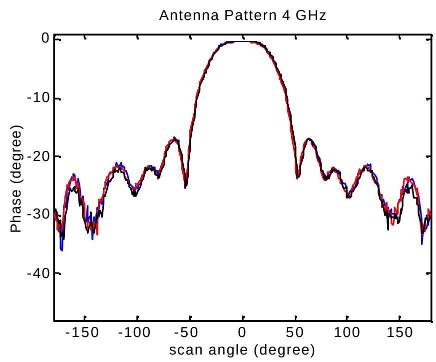


Figure 5: TD response at θ=180 degrees. (a) unfiltered response, and (b) filtered and smoothed response.



(a) Original patterns measured at various dates.



(b) TGM processed patterns.

Figure 6: Radiation patterns of horn antenna measured at various dates.