Narrow Pulse Transient Scattering Measurements and Elimination of Multi-path Interference

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***Abstract*- Via sub-ns pulse source and sampling oscilloscope, synchronous acquisition of target scattering echo pulse is achieved by adopting the dual-receiving antenna. The target scattering stretch resulted from groud multi-path effect is avoided by adjusting the measurement height. Ultra-wideband (UWB) radar cross section (RCS) distribution of the target is obtained. Compared to the calibration targets' theoretical RCS, the measured results' average error is less than 1 dB, and the time-domain inverse synthetic aperture radar (ISAR) imaging demonstrate the effectiveness of our measurement system and the data processing method.**

I. INTRODUCTION

Ultra-wideband (UWB) narrow pulse transient scattering measurement system mainly consists of UWB pulse emission source, high-bandwidth digital oscilloscope and UWB antenna [1-5]. With the development of UWB pulse power technique, UWB antenna technique and data collection technique, UWB narrow pulse transient scattering measurement technique has gradually matured.

Due to the fine time and spatial resolution of narrow pulse transient scattering measurement, transient scattering echo measurement of complex targets can distinguish the different parts of the scattering echo. For single transient scattering measurement echo contains abundant information of the target from low frequency to high frequency, scattering cross section, impulse response, scattering center, and pole distribution of the target can be extracted. Compared to conventional frequency RCS amplitude and phase measurement technique, UWB scattering time domain measurement technique has a finer resolution and need no requirement of anechoic chamber.

In this paper, via sub-ns pulse source and sampling oscilloscope, synchronous acquisition of target scattering echo pulse is achieved by adopting the dual-receiving antenna. The target scattering stretch resulted from ground multi-path effect is avoided by adjusting the measurement height. Ultra-wideband (UWB) radar cross section (RCS) distribution of the target is obtained. Compared to the calibration targets' theoretical RCS, the measured results' average error is less than 1 dB, and the time-domain inverse synthetic aperture radar (ISAR) imaging demonstrate the effectiveness of our measurement system and the data processing method.

II. TIME DOMAIN SCATTERING MEASUREMENT SYSTEM AND METHOD

Because real-time oscilloscope acquisition data accuracy and bandwidth is relatively low, the target scattering characteristics of the transient measurement commonly used sampling oscilloscope. So sampling oscilloscope is commonly used in transient measurement of target scattering characteristics. The latter requires acquisition trigger signal and the scattering echo signal strict synchronization. Usually people use pulse source to directly provide synchronous trigger signals, but there are still some problems such as trigger timebase jitter and transmit power deterioration in the synchronization method.

UWB narrow pulse transient scattering measurement system introduced in this paper mainly consists of sub-ns pulse source, sampling digital oscilloscope, UWB antenna and other components, as depicted in Fig. 1. To eliminate the effect of groud multipath reflection, the entire measurement system should be appropriately elevated. Generally speaking, to distinguish the echo of a target with a length L and groud multipath, the height from the test target to the ground should be satisfied as below,

$$H > \sqrt{\frac{R_x(2L + c\tau)}{2}} \tag{1}$$

where, R_x is the measure distance, τ is narrow pulse width and c is the light speed. In this measurement, the system height is set as 5m, so the target to be measured can be as long as 1m.

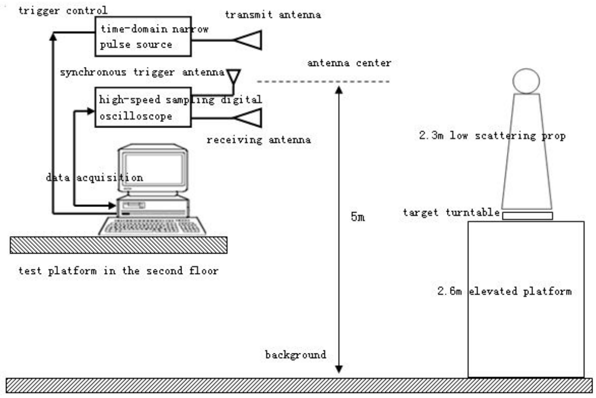


Fig.1 UWB narrow pulse transient scattering measurement system

Meanwhile, to improve the measurement stability and system sensitivity, three antennas is adopted. Besides transmit antenna and receiving antenna, a third antenna is used to provide the oscilloscope trigger signal. Compared to use splitter signal trigger of receiving antenna, the proposed method not only ensure the synchronization of the trigger signal, but also reduce splitter attenuation of the effective signal.

During the process of target scattering measurement, scattering echo time-domain waveform of pulse source signal, target and background are tested, respectively. Background echo interference is offset via the pulse alignment method. Via repeated measure average (32 times) method, the measured data accuracy can be improved.

Relative calibration is adopted in RCS calibration of narrow pulse time-domain scattering measurement. It can be expressed as below,

$$\sigma_{ta}(\theta, f)=\frac{\left|\mathrm{FFT}\left(E_{ta}(\theta,t)\right)\right|^2}{\left|\mathrm{FFT}\left(E_{ca}(\theta,t)\right)\right|^2}\times\sigma_c(\theta, f) \qquad (2)$$

where, E_{ta} is target measured time-domain response versus azimuth and relative time, E_{ca} is measured time-domain response of calibration target and σ_c is theoretical RCS of calibration target.

The target with RCS changing relatively slowly in the whole measured bandwidth is properly chosen as calibration target. Here, the metallic plate with a length of 20cm is chosen as calibration target. Fig. 2 illustrates RCS distribution as a function of frequency (0.5GHz-4GHz) calculated by the method of moment (MoM), which changes relatively slowly.

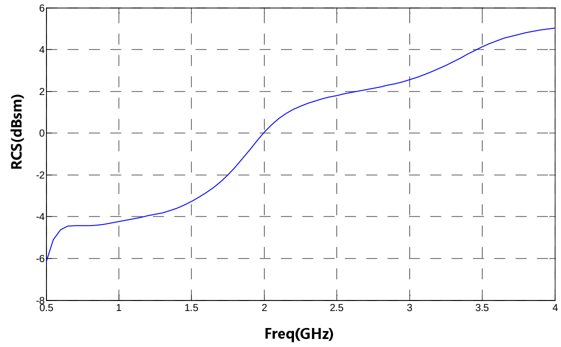
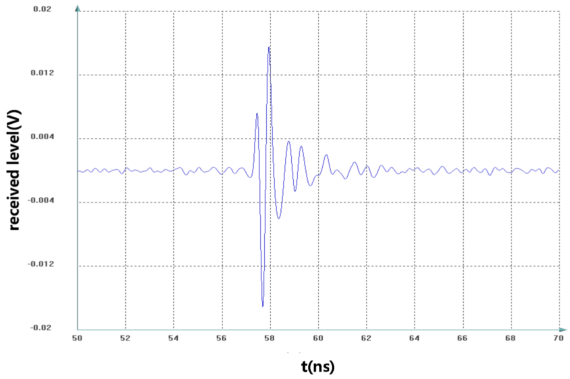


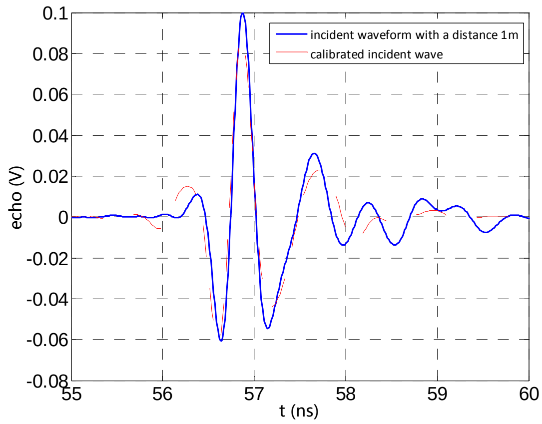
Fig.2 RCS of a 20 cm PEC plate as a function of frequency

III. Time Domain Scattering Measure Result and Comparison

Time-domain echo of a 20 cm PEC plate is measured, as depicted in Fig. 3(a). Via the RCS distribution in Fig. 2, incident waveform of measurement system is obtained by Fast Fourier Transform (FFT) and inverse FFT (IFFT), which agree well with the direct measurement result, as depicted in Fig. 3(b).



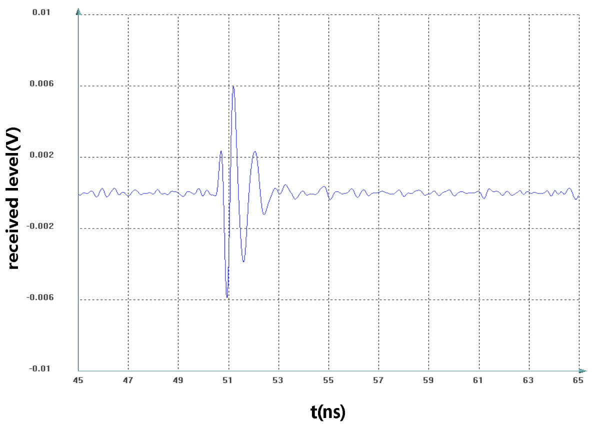
(a) time-domain echo of a 20 cm PEC plate



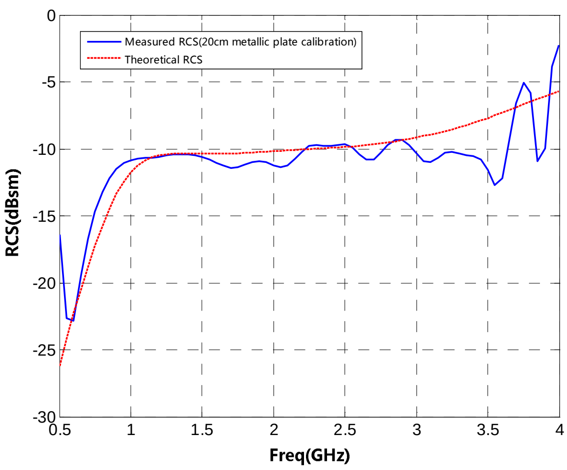
(b) incident waveform of time-domain scattering measurement

Fig. 3 time-domain echo of a 20 cm PEC plate

Fig. 4 shows the scattering echo measurement result of a 10 cm PEC plate. Its UWB RCS is calibrated by the 20 cm PEC plate calibration, and compared with the theoretical computational result.



(a) time-domain echo



(b) UWB RCS Comparison

Fig. 4 Comparison of measured RCS and theoretical RCS of a 10 cm PEC plate

Fig. 4(b) shows that measured RCS agree well with theoretical RCS in the center frequency 1GHz-3GHz, and the average error is approximate 0.5dB. The average error in the remained frequency is approximate 1dB.

Fig. 5 shows the scattering echo measured results of a 10 cm PEC plate and a 20 cm PEC plate. Their down range is 0.44m (X direction) and their cross range is 0.15m (Y direction). The two plates can be distinguished obviously.

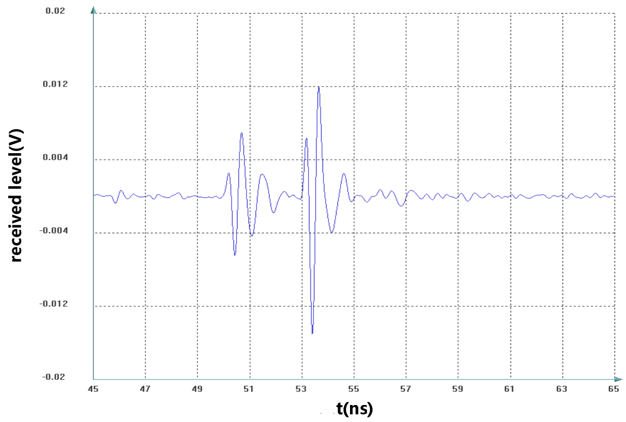


Fig. 5 scattering echo measured results of a 10 cm PEC plate and a 20 cm PEC plate

Fig. 6 is 2-D ISAR imaging[6,7] of the two composite plates using the time-domain scattering echo measured data, where the maximum rotating angle is 20°, the interval angle is 2°. There are two obvious scattering brightness, and their down range is 0.15m and their cross range is 0.45m. They agree well with the actual relative distance of the two composite plates.

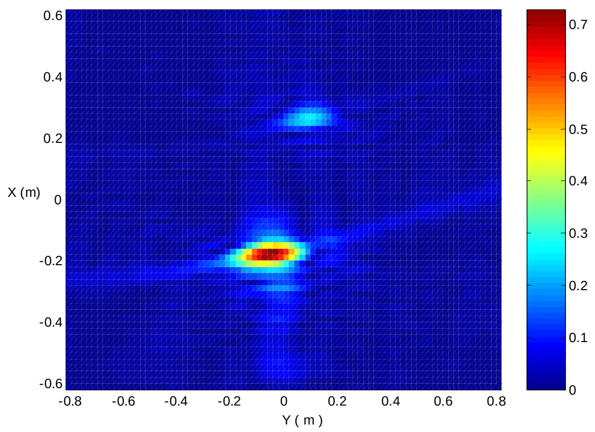


Fig. 6 ISAR of two plates

IV. Conclusion

Ground multipath effect is analyzed and improved by the sub-ns narrow pulse transient scattering measurement system. Synchronous acquisition of target scattering echo pulse with no gain attenuation is realized by adopting the dual-receiving antenna. Time-domain scattering echoes of metallic plate and their composite ones are measured and analyzed. The processed RCS error is less than 1dB compared to theoretical computational RCS, and ISAR of the measured target is obtained. The results demonstrate the effectiveness of our measurement system and the data processing method.

References

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