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SHORT PULSE RESPONSE OF RADAR TARGETS

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The current interest in high resolution radar for the identification of targets has stimulated interest in the investigation of scattered waveforms that result when a short pulse (i.e., an approximate electromagnetic impulse) illuminates the target. From the resulting pulse response, the response due to other incident waveform shapes can be calculated by a convolution operation. In this paper a technique for measuring the electromagnetic pulse response is presented and the results are compared with exact results obtained by solution of the time domain integral equation.

The functional block diagram of the measurement system is shown in Fig. 1. The system signal source is a high voltage switch which generates a 300 V step function with a risetime less than 100 psec. The signal is radiated, virtually undistorted, from a wire transmitting antenna protruding through a circular ground plane (20 ft. diameter). This wave is then reflected by a target and the scattered waveform is received on a coaxial horn antenna, which essentially differentiates the signal and thus provides the pulse response of the target. The received waveform is sampled by a 12 GHz oscilloscope and is subsequently processed by a laboratory instrumentation computer.

The salient characteristics of the range are the speed and simplicity with which multi-octave frequency domain data can be obtained. These advantages accrue because the time domain scattering range yields an "uncontaminated" interval of time between the arrival of the direct wave and the arrival of unwanted reflections. This is most easily explained by considering the photographs in Fig. 2, which show the range response as it appears at the sampling oscilloscope. The transmitted signal travels outward from the base of the wire antenna and is received at time \( t_0 \), which is marked by the pulse at the left end of the trace in Fig. 2. The outgoing wave reaches the target, is reflected, and arrives at the receiver at a later time. The targets are usually located anywhere from 2 to 5 ft. from the transmitting antenna and the target returns lie in the region marked by the doublets at \( t_1 \) and \( t_2 \) in the lower photograph. The response at the right edge of the trace which occurs after \( t_3 \) marks the arrival of the pulse reflected by the ground plane edge and the effects of the pulse radiated from the tip of the transmitting antenna.

The feasibility of accurately measuring the pulse response on the time domain scattering range has been demonstrated quantitatively. The measured incident pulse is shown in Fig. 3 along with the incident pulse used for the theoretical time domain calculations. The measured sphere response in the backscatter direction...
is shown in Fig. 4 along with the theoretical results. The agreement between these results is excellent. The initial pulse in the response corresponds to the return from the nose of the sphere (the specular return). Next, a negative swing occurs in the response. The character of this negative swing is influenced only by the shape of the target in the vicinity of the specular point. The timing of the second positive pulse in the response indicates it is due to a wave "traveling" around the rear of the sphere (often called the creeping wave). These results illustrate the close relationship between the approximate impulse response and the geometry of the scatterer.

In Fig. 5 the measured end-on response of a finite cylinder with a length-to-diameter ratio of two is compared with the theoretical result. Again one can see good agreement between the theoretical results and the measured results. The initial response is clearly the return from the nose of the cylinder and closely approximates the derivative of the incident pulse, as would be expected. The response then becomes small, indicating there is little return from the sides of the cylinder. The following negative swing may be interpreted as the direct return from the rear of the cylinder. Finally, the second positive pulse may be attributed to a wave traveling around the rear of the cylinder. Note again the close relationship between the approximate impulse response and the target geometry.

The electromagnetic pulse responses for a number of other target geometries and orientations, including thin wires and cylinders at various aspect angles, are also presented and discussed.

FIG. 1 Functional block diagram of time domain scattering range.
FIG. 2. Response of time domain scattering range showing incident pulse and time window. (Horizontal scale: 2 nsec/cm; vertical scale: 200 mV/cm.)
FIG. 3 Comparison of measured and theoretical incident pulse.
Measured sphere response

( Horizontal scale approximately one sphere radius per div. )

Theoretical response of sphere with radius \( a \)

FIG. 4 Comparison of measured and theoretical time domain sphere response.
FIG. 5 Comparison of measured and theoretical end-on response of cylinder with flat ends.