AN RF TIME DOMAIN REFLECTOMETER NOT IN REAL TIME*

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Abstract

A nanosecond radar system was developed, in which each line of the pulse spectrum was radiated in turn, their reflections measured and stored in a computer, and finally added up to compute the echo.

Introduction

An RF TDR that operates like a short-pulse radar was designed and constructed. Several versions of such a system were investigated. The final system is an unusually versatile tool that can be used in various ways.

The application called for a bandwidth of 3000 MHz centered near 2000 MHz. To cope with the problems of generating such a wide-bandwidth pulse, an unconventional approach was used whereby separate but coherent CW oscillators were used to generate the frequencies of the pulse spectrum. After appropriate amplitude and phase adjustments, these signals were combined to form a pulse train. This approach is referred to as the synthesized-spectrum technique.

Some of the potential advantages of the synthesized spectrum approach to the generation of short pulses are as follows.

(1) Very-wide-bandwidth signals can readily be synthesized.

(2) The amplitudes and phases of the spectral lines can be individually controlled to obtain a pulse shape with the optimum tradeoff between (a) short pulse length, (b) small ringing on the baseline between pulses, and (c) the total bandwidth covered by the spectrum. (By optimum is meant the shortest possible pulse for given spectrum bandwidth and baseline ringing.) Baseline ringing 40 dB below the pulse peak is illustrated here, but even lower ringing is possible.

(3) The spectrum occupies a specific frequency band, and has no energy outside of that band. Bandpass components, such as antennas and mixers, must operate only over that definite spectral bandwidth. This is contrasted with pulses obtained using snap diodes, whose spectrum only gradually decays away as frequency increases. Cutting off these upper frequency spectral lines in passing the signal through a bandpass component distorts the pulse.

(4) The amplitudes and phases of the spectral lines can be trimmed from their initial theoretical values to compensate for dispersion within the passband of the system components. By dispersion is meant deviation of the amplitude-versus-frequency response from a constant value, and deviation of the phase-versus-frequency characteristic from a straight line (i.e., constant group delay). Such dispersion would distort a pulse even though the pulse spectrum was limited to the passband of the components. (Examples of components with wide passband but significant phase distortion are antennas of the log-periodic and equiangular-spiral types.)

(5) It might be possible to introduce some pre-distortion of the pulse to correct for pulse distortion introduced by the signal environment.

(6) Corrections for several system errors can be made at each frequency within the spectrum when the system is automated, such as will be described in this paper. These correctable errors include mismatch errors due to reflections from connectors, transitions, etc. When radiating into space and receiving echoes, errors due to finite isolation between the transmitting and receiving antennas can be corrected. The corrections are accomplished by first measuring the error parameters under standard conditions, storing these parameters in the computer, and later subtracting them from the target data during the data processing.

Implementation

One use of the system is as a high-resolution radar, as will be described. The system block diagram is shown in Fig. 1. The RF signal generator of the Hewlett-Packard Automatic Network Analyzer serves as the transmitter on a discrete-frequency CW basis. An external frequency-stabilizing circuit was added so that the frequencies selected by the network analyzer are harmonically related. Using this particular circuitry, any spectrum within the 400-to-3560-MHz band that is made up of spectral lines harmonically related to 40 MHz can be selected. The RF sampler and analyzer sections of the network analyzer serve as the receiver.

*This work was sponsored by the Mine Detection Division, Counter-Mine/Counter-Intrusion Department, U.S. Army Mobility Equipment Research and Development Center, Ft. Belvoir, Virginia 22060

These sections measure the amplitude ratio and phase difference of the received signal (Port B) and the transmitted signal (Port A)

The network-analyzer computer both controls the transmitted spectrum and processes the received data. This processing includes correcting the data for system errors in obtaining the net transfer function between the antennas, which is due to reflections off the target. The system errors include the reflections and losses inherent in the cables, the wideband amplifier gain fluctuations, and the antenna cross coupling.

With the network analyzer used as it is here, it can be thought of as being very similar to a conventional radar system operating in the frequency domain. The equivalent of transmitting any arbitrary analog waveform (within the bandwidth constraints) was obtained by appropriately weighting the received-signal spectrum in the frequency domain and Fourier transforming the information into the time domain.

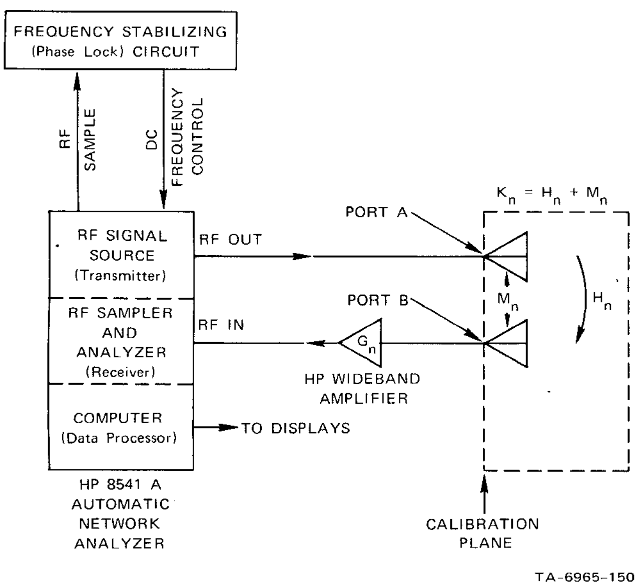


FIG. 1 MICROWAVE TDR AS SHORT-PULSE RADAR, USING THE HEWLETT-PACKARD AUTOMATIC NETWORK ANALYZER AS TRANSMITTER AND RECEIVER

Results

Figure 2 shows the antenna geometry. Figure 3 shows the transmitted pulse waveform, and Fig. 4(a) and 4(b) show the echo waveforms off a flat metal plate and a metal sphere, respectively. The later echo clearly shows the creep-wave component resolved from the specular component. The waveforms shown are the RF carrier cycles. Detected video would be the envelope of these waveforms.

Conclusions

A versatile and well-calibrated tool has been developed for high-resolution measurement of target radar signatures. In addition to the above application, this tool has been used for applications ranging from measuring antenna patterns to measuring complex dielectric constants.

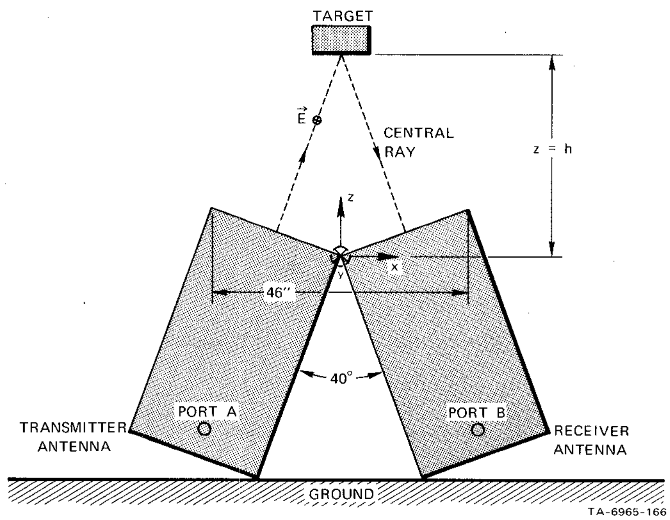


FIG. 2 ANTENNA GEOMETRY FOR FREE-SPACE MEASUREMENTS. Aperture width = 46 inches; aperture depth (i.e., y-dimension) = 24 inches.

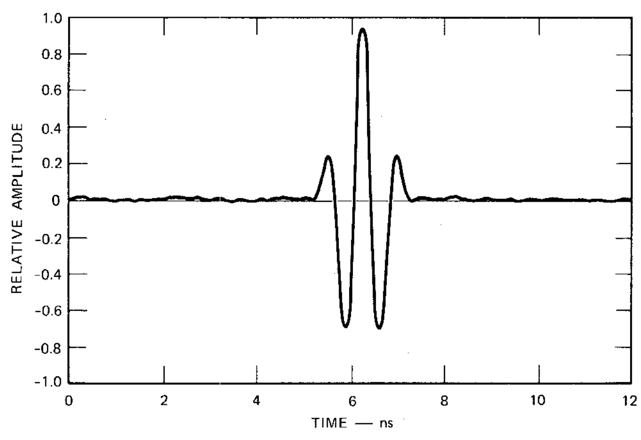
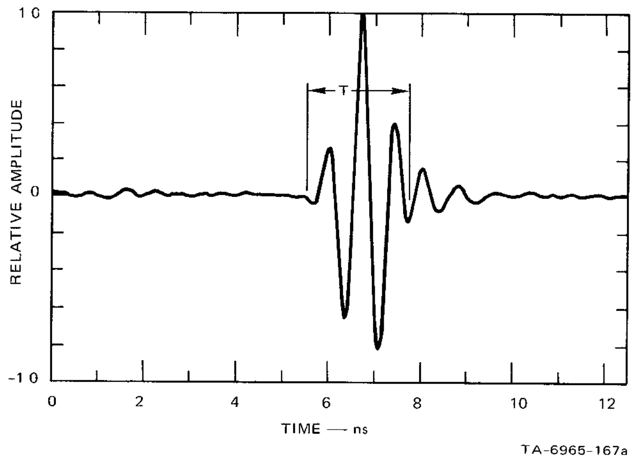
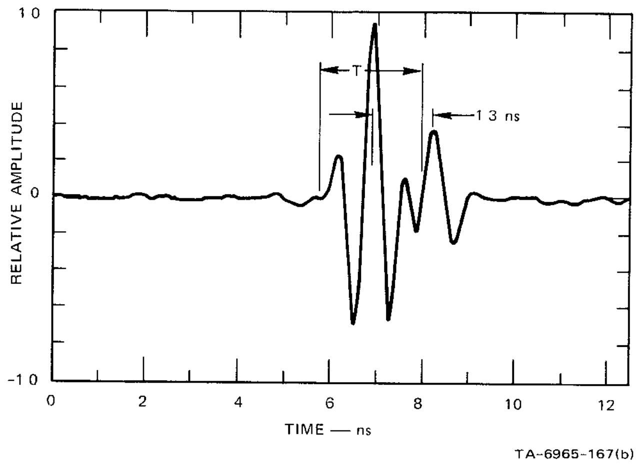


FIG. 3 PULSE WAVEFORM TRANSMITTED THROUGH A NON-DISPERSIVE, LOW-LOSS COAXIAL LINE APPROXIMATELY 6 ft LONG. Spectrum of 480 to 2000 MHz with 80-MHz line separation and weighting for post-pulse ringing down 40 dB from the pulse peak.



(a) 12-BY-12-INCH METAL PLATE



(b) 6-INCH DIAMETER SPHERE

FIG. 4 PULSE RETURNS FROM TARGETS IN FREE SPACE. Targets centered over antenna pair, 3 ft high. Spectrum of 480 to 2000 MHz with 80-MHz line separation. Equivalent transmitted pulse width T = 2.2 ns, with post-pulse ringing down 40 dB from the pulse peak.