A TEST TARGET GENERATOR FOR WIDEBAND PULSED DOPPLER RADARS

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ABSTRACT

A test target simulator (TTS) based on a fiber-optic delay line (FODL) has been designed for realistic testing and characterizing of wideband pulsed Doppler radars. The TTS can simulate one or two targets at different radar cross sections (RCS's), different Doppler, and different ranges in the presence of uncorrelated noise or interference. With one target, clutter and multipath effects can also be simulated. In a closed-loop test of a pulsed Doppler radar transceiver, the variable control of the RCS can be used to test the radar's dynamic range. Simulating two targets and varying the range and Doppler of each target in the closed-loop test can evaluate the radar's range and Doppler resolution, respectively.

1. INTRODUCTION

The fiber-optic delay line (FODL) based test target simulator (TTS) can generate one or two returned targets and independently control simulations of the range and range separation between them, their Doppler frequencies, and their absolute radar cross sections (RCS's) in the presence of variable uncorrelated noise. Since FODL is nondispersive and very broad band, very wideband exotic modulations can be evaluated in closed-loop testing. In addition, these capabilities would benefit radar testing, allowing low-cost complex target simulations for a radar system's initial evaluation and calibration.

2. TTS CONFIGURATIONS

Figure 1 is a functional block diagram showing the implementation of the TTS functions. The TTS operates between 16.0 and 16.6 GHz. The radar's waveform out of the power amplifier of the radar transmitter is attenuated and coupled to the input of the TTS. It is then down-converted to the frequency range of the optical delay line, which provides two outputs, one with

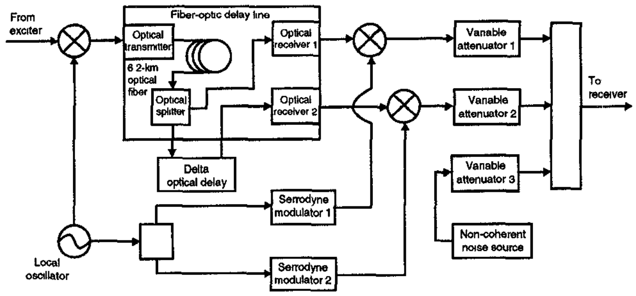

Figure 1. TTS functional block diagram.

a nominal delay of 30 μs and the other with a delay of 30 μs, plus a short incremental delay. Independently, a digital phase shifter serrodyne modulates each of two signals that are split from the local oscillator (LO) to produce a frequency-shifted version of the LO. The frequency translation is accomplished by a linear shift in the phase of the input signal at a given rate. The rate at which the phase is shifted determines the Doppler shift of the target. Direct serrodyning has the advantage of producing a single-sided (either positive or negative) Doppler shifting, which is the same result obtained in the real world [1]. Then each of the signals is mixed with the outputs of the FODL to construct the original carrier frequency offset by the Doppler. To represent variations in RCS over a 30-dB range, a variable attenuator is used for each of the two delayed signals. After this stage, the two outputs are then combined with a third signal, an incoherent noise source that can represent varying interference. This combined signal is then reintroduced into the radar receiver.

Conventional delay techniques that use coaxial cable or microstrip produce delays that are frequency dependent, have limited time-bandwidth products, suffer from high losses, or are susceptible to electromagnetic interference (EMI). Acoustic techniques, which can provide significant delay time, have high losses [2]. The TTS overcomes these disadvantages by using nondispersive wide-bandwidth, single-mode fiber-optic links that can provide the required delays at microwave frequencies, with the advantages of wide bandwidth, low loss, small size and weight, and immunity to EMI [3]. A portion (upper left quadrant) of figure 1 shows a functional block diagram of the FODL. This FODL consists of a laser diode that is amplitude modulated at microwave frequencies, a long single-mode optical fiber, an optical splitter, short lengths of optical fiber, and two optical receivers. The fiber-optic dual delay line operates over a frequency range of 3.0 to 3.6 GHz, with a low transmission loss, providing a fixed delay of 30 μs nominal and an additional incremental delay of 2, 6, 60, 100, or 200 ns for the line with the delta optical delay. These delays correspond to a target at a fixed range of about 4.5 km and range separations of about 0.3, 0.9, 9, 15, and 30 m, respectively. An important aspect of the FODL design is the optimization of the insertion loss and return loss of the fiber-optic link by reactive impedance matching of its optic transmitter and receiver [4].

3. TTS CAPABILITIES

It is advantageous to test and characterize a radar system with the TTS in the laboratory before expending the effort and cost of field testing. The TTS can be used in all tests of pulsed Doppler radar performance. Combinations of settings can be used to exercise the radar at many points on its performance envelope. Variations in delay, amplitude, and frequency shift of the TTS will provide the radar target returns with variations in range, RCS, and Doppler, respectively. By adjusting the amplitudes of the target returns individually, we can evaluate the ability of the radar to detect a small target in the presence of a large target and thus demonstrate the dynamic range of the radar receiver within the 30-dB limit. Since target range separation can be measured down to 0.3 m, we can determine the radar's ability to resolve targets in range. Further, two target outputs can be separated in Doppler space to a resolution of 50 Hz (in the existing hardware implementation). One available option is that one can set one target return to zero Doppler (to simulate the clutter) and the other target return, at the same range, to a finite Doppler. Thus, we can simulate a moving target in the presence of clutter. Various levels of signal-to-clutter ratio can then be simulated. To present a multipath problem to the radar, we can set two target returns at the same Doppler, but with different ranges and RCS's. Incoherent noise can be added to the returns so that we can evaluate the performance of the radar in the presence of interference or jamming.

4. CLOSED-END RADAR TESTING OF A Ku-BAND PULSE DOPPLER RADAR

A developmental radar testbed, as shown in figure 2, was used to exercise the functions of the TTS. The testbed uses an HP8770 arbitrary waveform synthesizer (AWS) for generating, for example, a 10-MHz chirp with a 5-μs pulse width and a pulse repetition interval (PRI) of 50 μs. A single-sideband modulator and a second LO up-convert the initial waveform to 16 GHz. The waveform passes through the TTS to the testbed receiver. The testbed's receiver consists of a low-noise amplifier at 16 GHz and a dual down-converter. Data are then collected by a Tektronix 602 dynamic signal analyzer (DSA). The collected data were processed off-line to form the range-Doppler mapping. Digital pulse compression techniques and fast Fourier transform processing were used to extract the Doppler and range information from the simulated return(s). Figures 3 to 6 illustrate some of the capabilities of the closed-loop radar testbed. Figure 3 shows the mapping of amplitude to range and velocity of a slowly moving target in

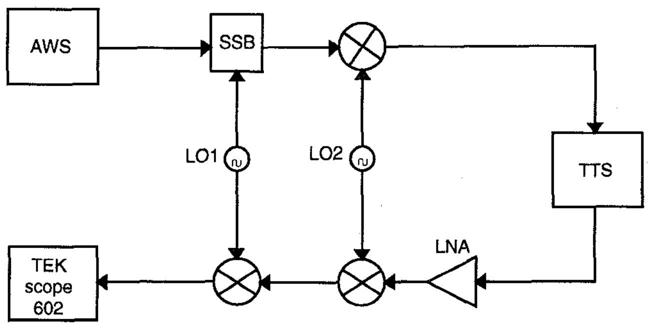

Figure 2. Closed-end radar testbed employing TTS.

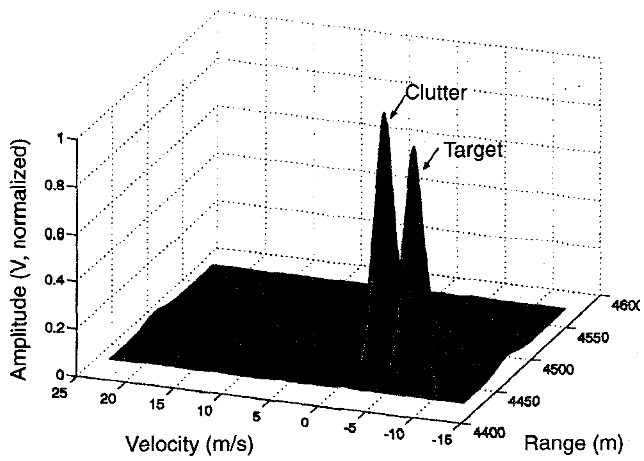

Figure 3. One target in presence of large clutter.

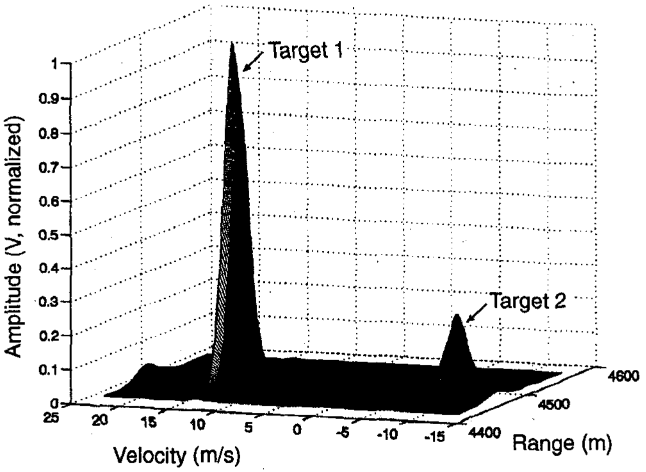

Figure 4. Two targets separated in range and velocity.

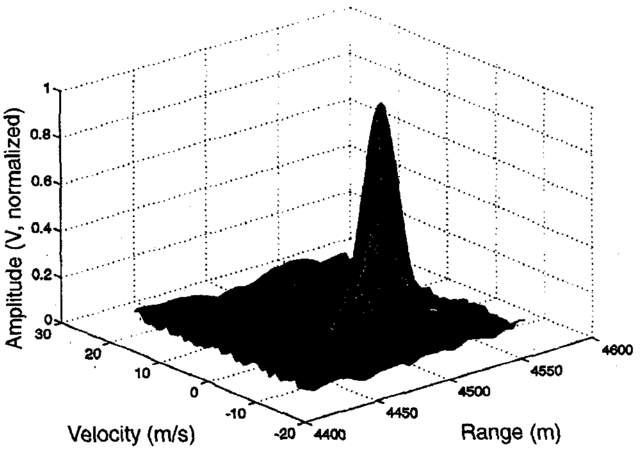

Figure 5. One stationary target in presence of interference.

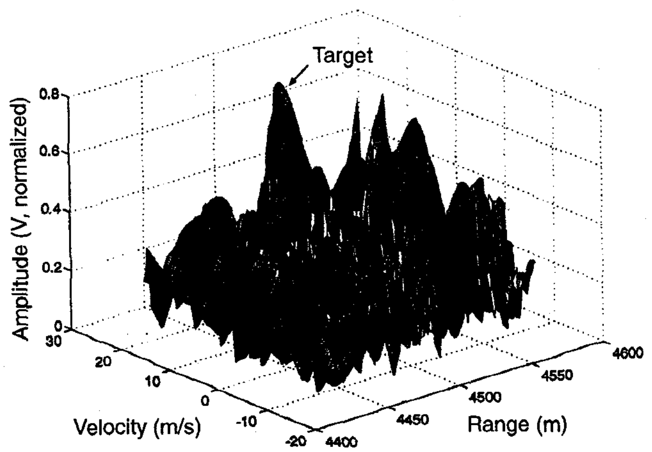

Figure 6. One target in presence of strong jamming.

the presence of strong clutter. For a delay time of 30 µs and a target Doppler frequency of 320 Hz, the target and clutter are located at 4500 m with velocities of –5 and 0 m/s, respectively. Figure 4 shows two simulated targets that are 30 m apart in range but are moving in different directions, with velocities of 12 and 10 m/s, respectively. Figure 5 shows a detection of a stationary target at a range of 4500 m in the presence of interference. Lastly, figure 6 shows a moving target (30 m/s) at a range of 4530 m in the presence of strong jamming.

5. CONCLUSIONS

The TTS offers, at low cost, the opportunity to fully test and characterize radars, especially pulsed Doppler, for the purpose of acceptance, calibration, and performance evaluation. The TTS design is extremely flexible, allowing for simulations of one or two targets undergoing complex maneuvers involving different RCS's, radial velocities, and ranges, while either in a benign environment or in the presence of noise (interference or jamming).

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