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1 Introduction

The University of Nebraska has developed a random noise radar system which transmits an ultrawideband random noise waveform with a uniform power spectral density (PSD) in the 1-2 GHz frequency range. Simulation studies and controlled laboratory tests confirm the system's ability to preserve the instantaneous phase of the received signal [1, 2]. The potential of the system to characterize the Doppler shift of moving targets exhibiting varying linear and rotational velocities was clearly demonstrated [2].

This paper provides with the results of recent field experiments at a range of about 200 m which confirm the ability of the system to be used as a Doppler radar in operational scenarios.

2 Radar System Description

A simplified block diagram of the random noise Doppler radar is shown in Fig. 1. The noise source OSC1 produces a signal with a Gaussian amplitude distribution, constant PSD, and average output level of 0 dBm (1 mW) in the 1-2 GHz frequency range. The noise source output is split into two equal in-phase components in power divider PD1. A 10 Watts transmit power is achieved through a TWT broadband amplifier AMP1 and transmitted via a horn antenna ANT1. The second output of PD1 is connected to a combination of a fiber optic (FO) fixed delay line DL1 and a digitally controlled variable delay line DL2. The fixed delay line provides 1.5 μsec delay, while the variable delay line can be programmed for delays from 0 to 19.968 ns in 0.156 ns steps. The delay line output is mixed with the output of a 160 MHz phase-locked oscillator OSC2 in a lower sideband upconverter MXR1, whose outputs feed each receive chain via PD3.

A 1-2 GHz signal received by antenna ANT2 provides the second input to mixer MXR2. the mixing operation. The 160 MHz output of MXR2 is filtered in a 160 MHz bandpass filter FL1 and split in power divider PD5. One of the outputs of PD5 is amplified in logarithmic amplifier AMP7 to yield the signal amplitude, and the other output is fed to I/Q detector IQD1 to yield the in-phase (I) and quadrature (Q) components of the received signal. A similar receiver is used for the second receive chain connected to antenna ANT3. The E/H plane beamwidths and gain of all antennas at 1.5 GHz are 23°, 34°, and 17 dB respectively.

3 Theoretical Considerations

The transmit waveform of the system can be modeled as [1, 2]:

$$v_t(t) = a(t) \cos \{2\pi \left(f_0 \pm \delta f\right) t + \psi_t\} \tag{1}$$

where $a(t)$ represents the Gaussian amplitude distribution, f_0 is the center frequency at 1.5 GHz, δf is uniformly distributed over the ± 0.5 GHz frequency range, and ψ_t is the arbitrary transmitter phase.

If the target is in motion, the in-phase I and quadrature Q components of the received waveform can be shown to be [2]:

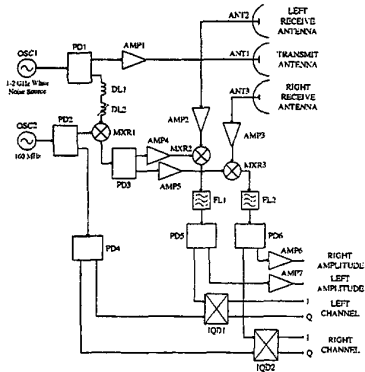$$I = k_I \cos \left\{ -\frac{4\pi V}{\lambda} t + \psi_s \right\} \tag{2}$$

Figure 1: Block diagram of coherent ultrawideband random noise radar.

$$Q = k_Q \sin\left\{-\frac{4\pi V}{\lambda}t + \psi_s\right\} \tag{3}$$

where k_I and k_Q represent the amplitudes of the I and Q components respectively, and the instantaneous wavelength $\lambda = c/(f_o \pm \delta f)$. Note that Doppler frequency is not constant, but varies due to the varying nature of the instantaneous wavelength λ.

4   Experimental Setup

A large corner reflector with 45.7 cm sides with a radar crossection (RCS) value of 6.6 $dBsm$ at 1.5 GHz mean frequency was chosen as the target. Since each radar range bin is 15 cm long, a linear array of such corner reflectors was mounted at a height of 3 meter atop a van.

The radar system was mounted inside another van, and the antennas were mounted on top of the 10-m high telescopic boom. The distance between the stationary radar van and the moving target van was approximately 200 m. The overall geometry of these experiments is shown in Figure 2.

5   Experimental Results

The target van approached the radar van along the boresight direction with approximate uniform velocities of 4.5 m/sec and 9 m/sec with corresponding mean Doppler frequencies of 45 Hz and 90 Hz, respectively. Each experiment was also repeated at 1.5 GHz fixed frequency, and using 1.4-1.6 GHz random frequency. At each speed, ten trials were carried out and final results are depicted in Figures 3 and 4. These figures show the individual trials along with the extracted mean Doppler. The solid line is the averaged Doppler from ten individual trials (dotted).

It can be seen that:

(1) the Doppler frequency associated with a moving target can be extracted using the UWB random noise system developed by UNL,

(2) the estimated Doppler using comparatively narrow bandwidth (i.e. 200 MHz) is almost identical to that using fixed frequency, and

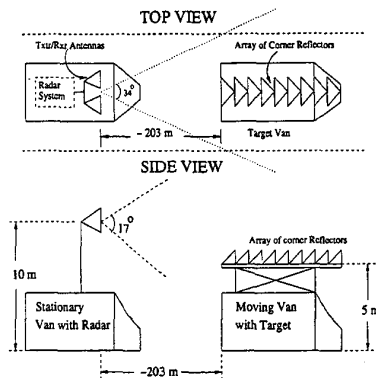(3) the Doppler spread increases at higher bandwidths and higher target velocities.

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Figure 2: Geometry of field experiments for Doppler measurements.

6 Conclusions

The experiments demonstrate the potential of random noise radar to be used as a Doppler radar. The radar's unique concept synergistically combines the advantages of random noise transmission with the power of coherent signal processing to yield a powerful technique for velocity tracking and scanning applications. The advantages of random noise radar, such as its small size, low power and immunity from interference, make it a promising candidate for civilian and military applications.

Acknowledgments

References

[1] R. M. Narayanan, R. D. Mueller and R. D. Palmer, "Random noise radar interferometry", *Proc. SPIE Conference on Radar Processing, Technology, and Applications*, (W. Miceli, Ed.), Volume 2845, pp. 75-82, August 1996.

[2] R. M. Narayanan, M. Dawood, R. D. Mueller and R. D. Palmer, "Doppler estimation using a coherent ultrawideband random noise radar", *Proc. SPIE Conference on Radar Processing, Technology, and Applications II*, (W. Miceli, Ed.), Volume 3161, pp. 70-76, August 1997.
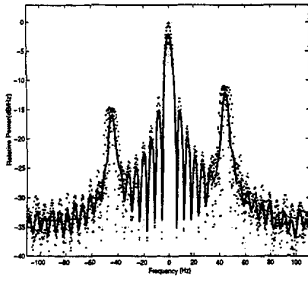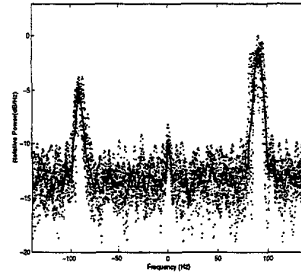
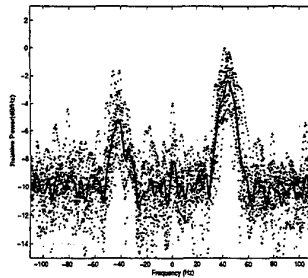(a) Transmit Frequency 1.5 GHz (fixed)
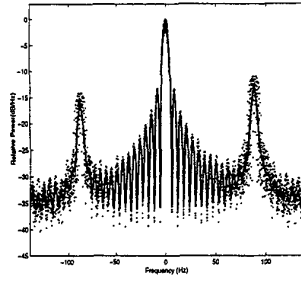
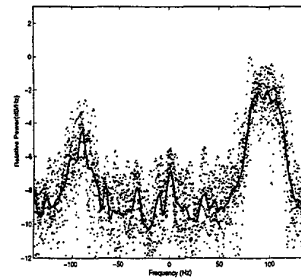(a) Transmit Frequency 1.5 GHz (fixed)
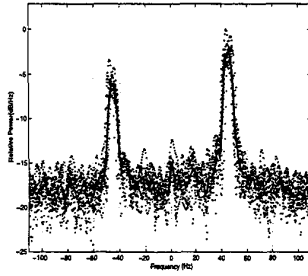
(b) Transmit Frequency 1.4-1.6 GHz (random)

(b) Transmit Frequency 1.4-1.6 GHz (random)

(c) Transmit Frequency 1-2 GHz (random)

(c) Transmit Frequency 1-2 GHz (random)

Figure 3: Doppler spectra of target moving at 4.5 m/sec

Figure 4: Doppler spectra of target moving at 9 m/sec

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