WAVEFORM DESIGN FOR CASA DUAL-POLARIZED X-BAND SOLID STATE WEATHER RADARS

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The Center of Collaborative Adaptive Sensing of the Atmosphere (CASA) has been successfully deploying and operating its first generation network of four low-power, short range, X band dual-polarized Doppler weather radars in Oklahoma. This first generation CASA radar system are magnetron based system that has some limitation on duty cycle and supported waveforms. For example, at the maximum peak of power (25 kW) the maximum PRF is 1 kHz when a pulse width of 1μs is used. Reducing the peak power allows a higher PRF but loses the system sensitivity. In addition, the use of a magnetron transmitter limits the ability of using phase coding for second trip echo suppression on the transmitted waveform. Only random phase coding scheme is available.

In order to overcome the limitation of the first generation radars, the next generation of CASA X-band radar system uses solid state transmitters is being developed (George, 2010). These transmitters with phased array antennas are main updates for the second generation CASA radar system. The use of solid state transmitters promises to improve the data quality and reliability of the system. The major drawback of a solid-state transmitter is that its peak power is very low compared to that of a magnetron transmitter. However, it has almost no restriction on the duty cycle; therefore it allows transmitting a waveform with long pulse duration and high PRF. In order to achieve a comparable sensitivity and resolution to a magnetron system, pulse compression technique is used.

At X-band, the weather radars require the use of non-uniform pulsing scheme to obtain sufficient unambiguous velocity and maximum operational range. There are two common schemes to be used, namely dual-PRF and staggered PRT techniques. The dual-PRF scheme has been successfully designed and implemented in the first generation CASA network (Bharadwaj et al 2005). When compared to dual-PRF schemes, staggered PRT techniques show some advantage. For example, to attain the same performance, staggered PRT techniques require less number of samples; therefore it allows the system to provide faster update time. However, clutter filtering is the main problem that prevents staggered PRT technique being implemented in operational weather radar systems. Recently, Nguyen et al. 2008 proposed a time domain GMAP (GMAP-TD) clutter filter that can be used for staggered PRT 2/3 scheme. The method is successfully tested with actual staggered PRT 2/3 measurements; and more important, it can be implemented for real time operation.

The emergence of new hardware technology and advance clutter filter opens a new space for waveform design. This paper presents a waveform design for solid-state X-band weather radars that meets the requirement of unambiguous range-velocity problem, is able to sufficiently suppress second trip echo, and achieves good performance in case of clutter contamination. The next generation CASA radars require operation in two transmitting modes: simultaneous transmitting mode and alternating transmitting mode. The staggered PRT 2/3 scheme for simultaneous transmission mode is described in figure 1. The two spacing T_1 and T_2 are chosen as multiples of a base unit time T_u, i.e. $T_1=2T_u$ and $T_2=3T_u$.

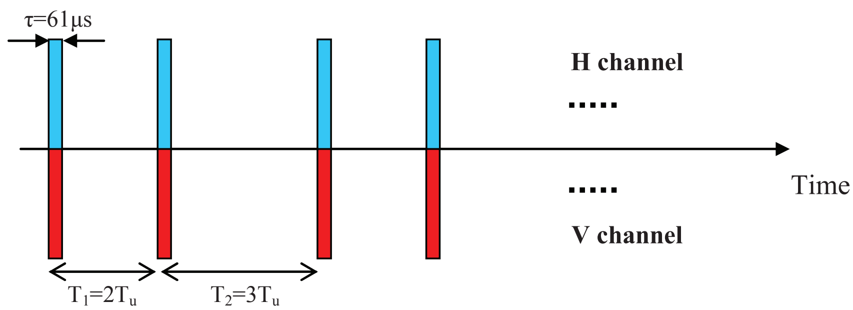


Figure 1. Transmission scheme for simultaneous mode

For example, the waveform with option 1 in Table 1 is able to achieve a maximum range of 53 km and a maximum velocity of 38 m/s.

Table 1: Waveform parameters

Waverform parameters	T_u (ms)	$T_1=2T_u$ (ms)	$T_2=3T_u$ (ms)	v_a (m/s)	r_a (km)
Option 1	.208	.416	.624	38	53
Option 2	.138	.276	.414	57	32

In the case of simultaneous transmitting mode, the spacing between two co-polar samples is about 50 km. Normally, for weather target, this is not sufficient enough to avoid the effect of second trip echo. To mitigate this problem, a random phase coding technique is applied to the staggered PRT sequences.

$$S_r(k) = \left[V_1(k)e^{j\psi_k} + V_2(k)e^{j\psi_{k-1}}\right] e^{-j\psi_k}$$
$$= V_1(k) + V_2(k)e^{j(\psi_{k-1}-\psi_k)}$$

The simulation study shows that the random phase coding provides good results even in the extreme case where the second trip echo power is only 5dB below the first trip echo power.

While the design of the staggered PRT 2/3 waveform for the simultaneous transmitting mode is straightforward, the staggered PRT 2/3 for alternating transmitting mode is more complicated. Figure 2 shows a waveform for this mode where the H channel sequence is staggered PRT 2/3 while the V channel sequence is uniform.

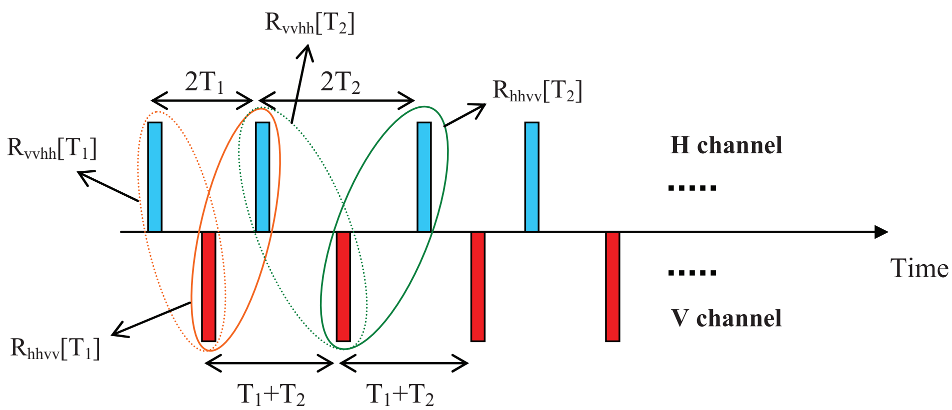
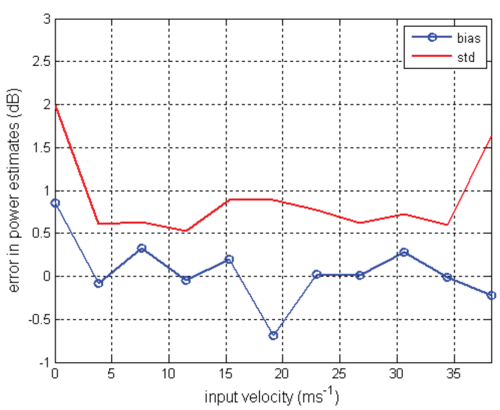
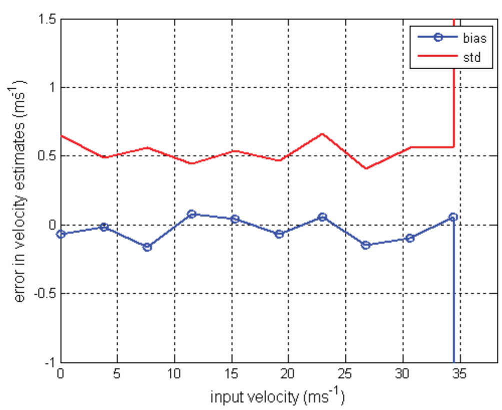


Figure 2. Transmission scheme for simultaneous mode

The waveform in figure 2 remains the advantage of the staggered PRT 2/3 scheme, e.g. meeting the requirement of unambiguous range-velocity. However, the clutter filtering needs a special attention due to the different sampling schemes at two polarization channels. For this typical waveform, estimation of mean velocity and co-polar correlation coefficient is the most difficulty. The GMAP-TD filter is modified to accommodate this situation. Figure 3 shows results of GMAP-TD for alternating mode using simulated radar data. In overall, GMAP-TD is able to deliver good performance even in case of strong clutter contamination.



(a)



(b)

Figure 3. GMAP-TD clutter filtering performance for alternating waveform: SNR=15dB; CSR=25dB, phase noise 0.5 deg for X-band transceiver. (a) power estimation; (b) mean velocity estimation

In summary, this paper will present waveform options for CASA solid-state X-band weather radars for both simultaneous and alternating transmitting modes. The waveforms meet the system hardware limitation as well as operation requirements. The waveforms are designed to be a balance between providing good values of maximum range/velocity and parameter estimation accuracy. It also allows the implementation of ground clutter filtering procedure to ensure the correct functioning of the systems.

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