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PX-1000: A Solid-State Polarimetric X-Band Radar

Non-Linear Frequency Modulation Waveform Optimization and Time-Frequency Multiplexed Waveform for Blind Range Mitigation

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The PX-1000

A solid-state polarimetric X-band radar has been developed at the Advanced Radar Research Center (ARRC) at the University of Oklahoma (OU). This radar has been referred to as the PX-1000, as the original idea was conceived in 2008, in which the binary representation of 08 would be 1000. It is designed and developed to be transportable and autonomous using a software defined radio approach.

The PX-1000 radar has been successfully deployed at various locations in the vicinity of Norman, Oklahoma for different field experiments. It can be monitored and operated from a remote location. The system requires only a power input at the inlet of the housing and has its own wireless system for internet communications, which facilitates the remote access. An internally developed software is used for signal processing, system controls, communications and user interface. During operations, when an internet connection is available, the latest snapshots of the collected data can be viewed via the live software or the web portal at http://arrc.ou.edu/px1000

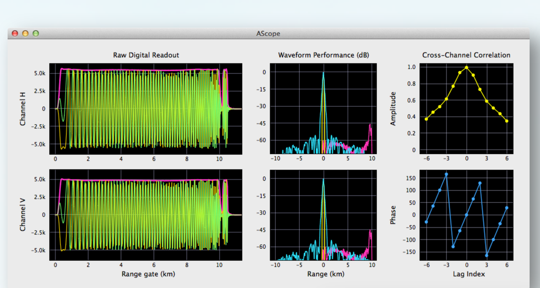
In order to maximize the power efficiency of the transmit pulse, a non-linear frequency modulation (NLFM) waveform is used for the long pulse, with virtually no amplitude tapering. We use a genetic algorithm optimization framework for waveform parameter search.

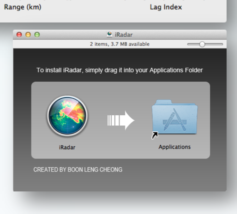
To mitigate the blind range of a pulse compression radar, a time-frequency multiplexed (TFM) waveform was developed. Initial results are promising.

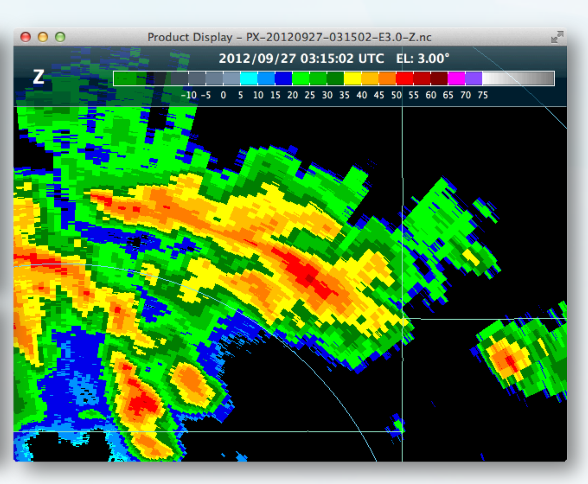
The PX-1000 radar in the field. The entire trailer with the radar system weights approximately 4,500 lbs., which can be easily towed by a full-size pickup truck.

Each up-down-conversion unit is housed in a custom-made 1U enclosure (0.75").

Frames on the side support all the RF components, i.e., IF transceiver, up-down-conversion units and amplifiers



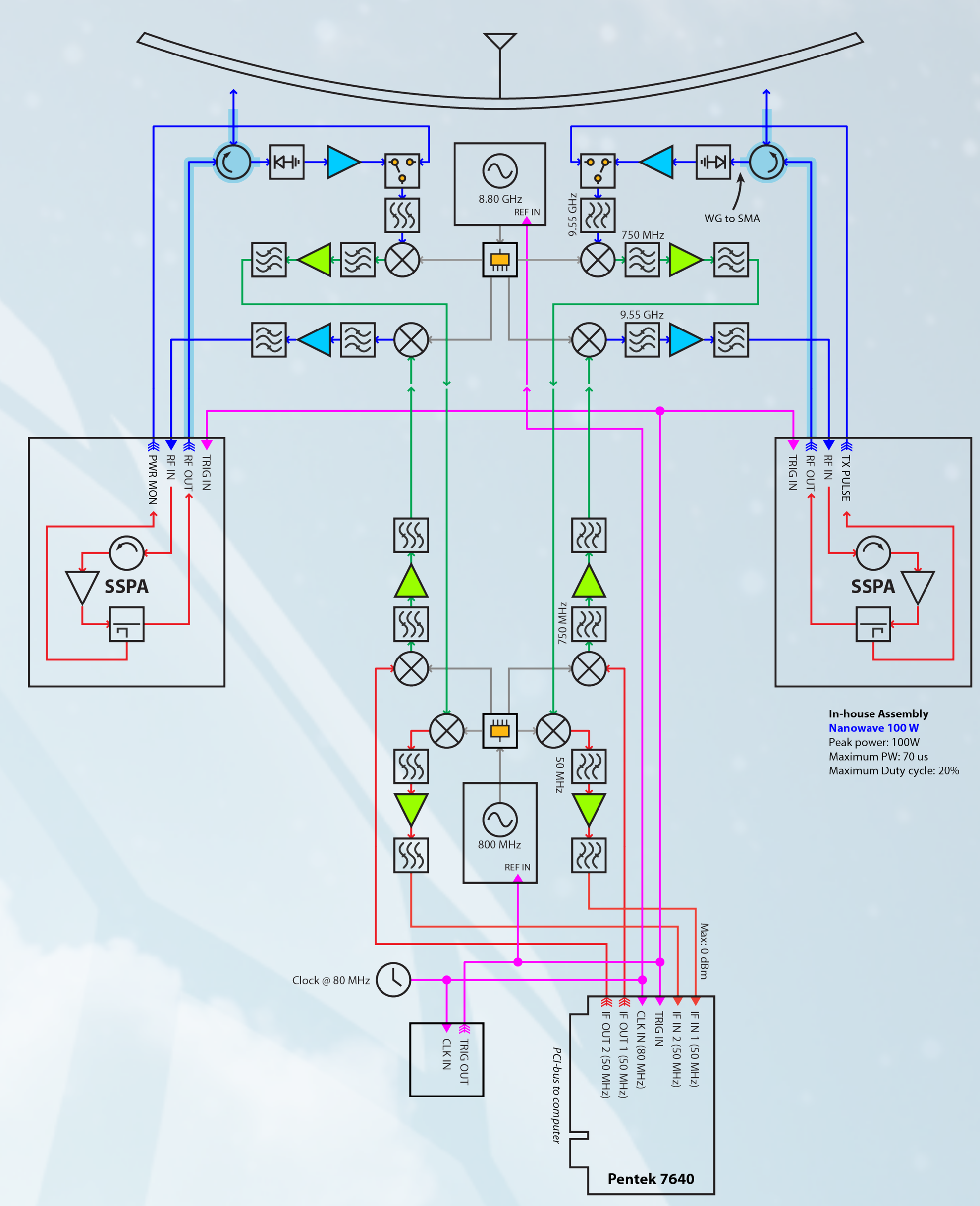




A software framework was developed for radar operations

System Overview

The system features a pair of 100-W solid-state amplifiers, with identical but independent transmit-receive waveform generator and up-down conversion for each channel, which allows for the use of independent transmit waveform. It also uses a 1.2-m parabolic reflector dish with a dual-polarization prime focus feed and the majority of equipment is supported by an azimuth-over-elevation pedestal. As mentioned earlier, the radar is designed in a software-defined radio approach for system versatility. Long transmit pulse length of up to 70-us can be applied to compensate for the low transmit power while pulse compression technique is applied to recover range resolution and radar sensitivity.



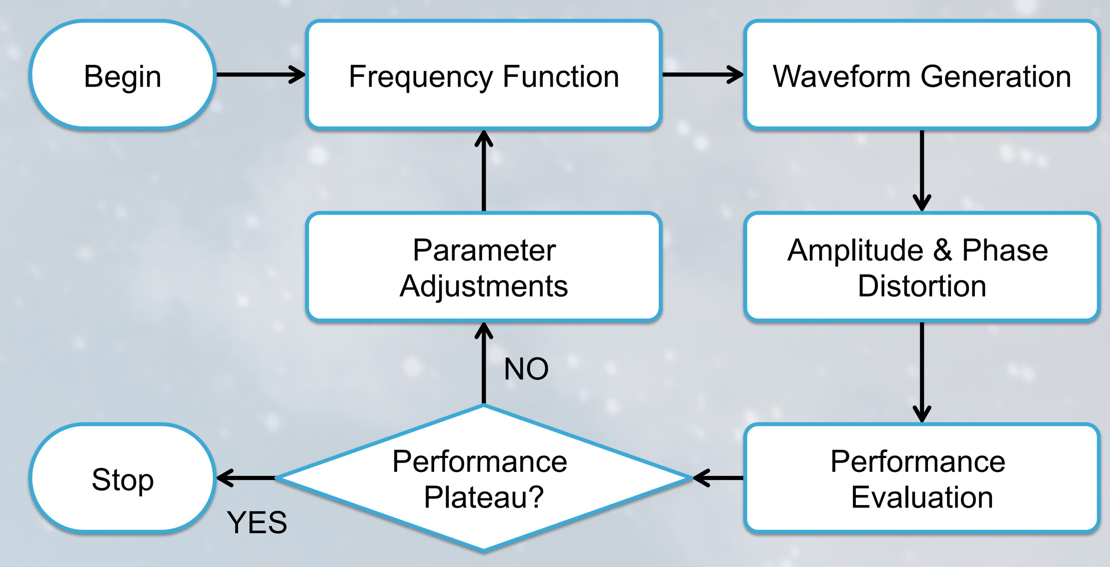
There are two independent transmit-receive chains providing the potentials for channel waveform design for improving isolation and/or polarimetric data quality.

General	
Operating Frequency	9550 MHz
Sensitivity	< 20 dBZ @ 50 km
Observation range	> 60 km
Antenna	
Antenna gain	38.5 dBi
Diameter	1.2 m
3-dB beamwidth	1.8°
Polarization	Dual linear
Polarimetric isolation	26 dB
Pedestal	
Contiguous rotation	Yes
Maximum payload	260 lbs
Maximum angular velocity	50°s⁻¹
Pointing precision	0.25°
Angular feedback resolution	0.01° in 16 bit
Transmitter	
Peak power	100 W
Pulse width	1-70 us
Maximum duty cycle	20%
Receiver	
Minimum gate spacing	30 m
Maximum data throughput	320 Mbps

System characteristics of the PX-1000

NLFM Waveform Optimization

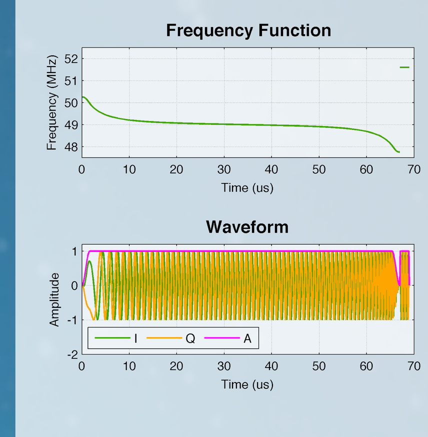
A flexible frequency function with multiple parameters and variable degrees of freedom was used in our waveform optimization scheme. A genetic-algorithm based framework is used to search for an optimum NLFM waveform where optimality is defined as high range resolution, narrow mainlobe width, low integrated sidelobes.

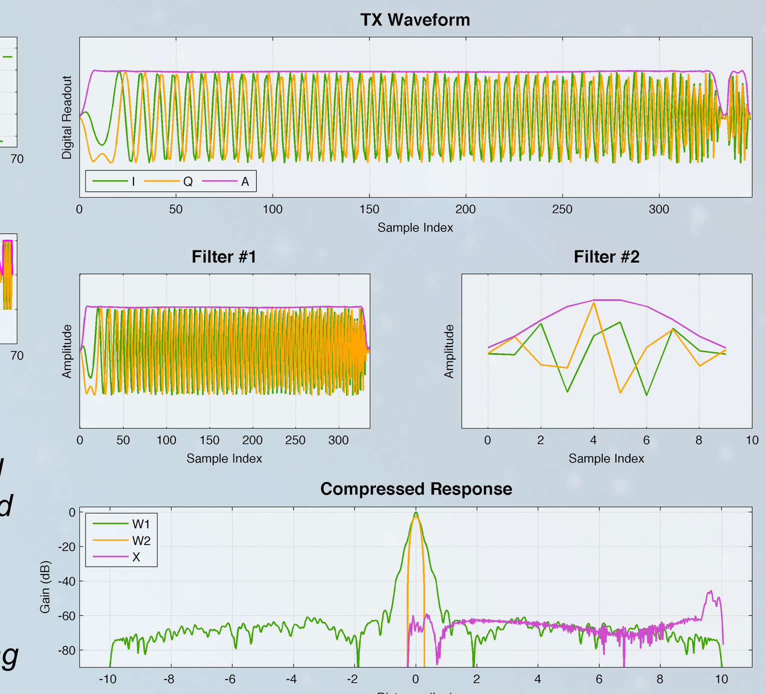


A flow chart of the waveform optimization scheme

Time-Frequency Multiplexed Waveform

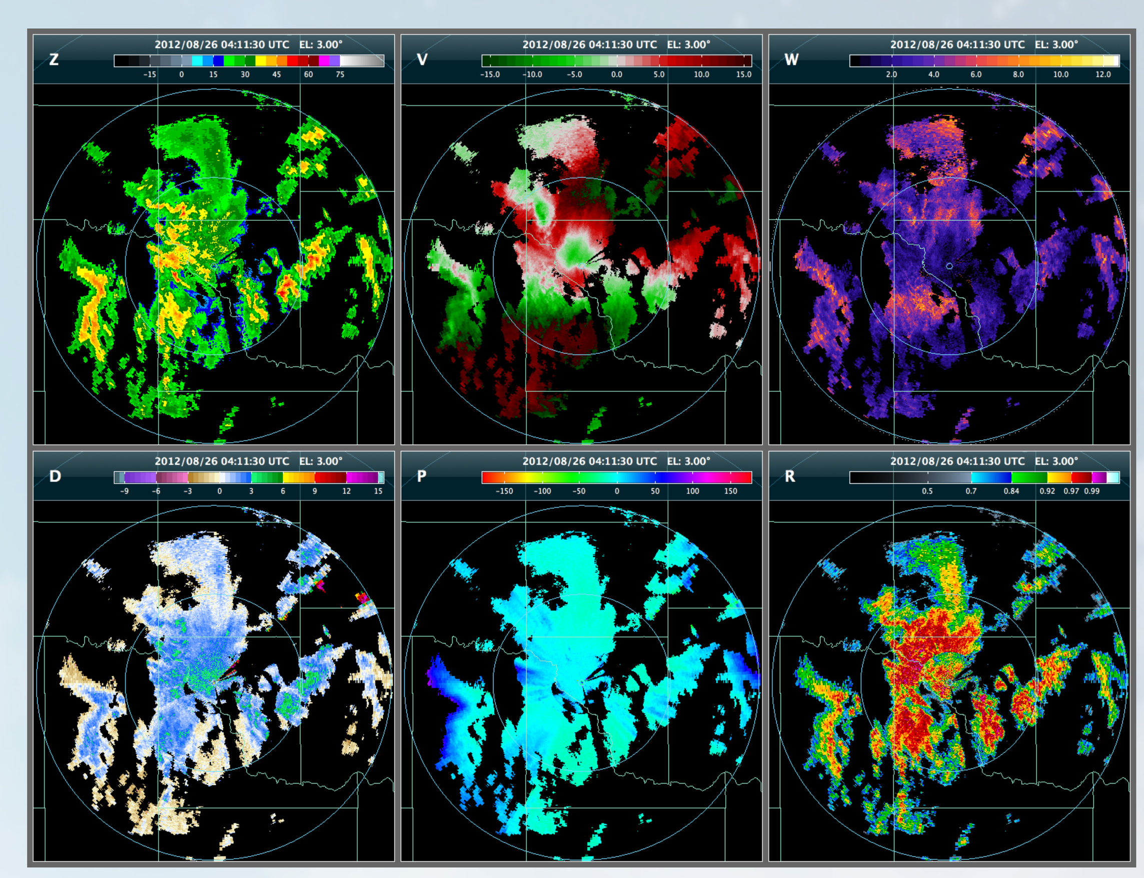
The TFM waveform is a multiplexed of two sub-waveforms where each occupies a different frequency band. The digital waveform generator needs not know the content of this TFM waveform. It transmits the entire waveform just like an ordinary pulsed radar. On the receive end, the signal processor demultiplexes the waveform by applying match filtering twice on the time series to extract radar signals from each sub-waveform. Using the TFM waveform, there is no need to interleaved a short pulse, i.e., no loss in the PRT and, thus, the Nyquist velocity.





Two frequency-separated waveforms are multiplexed in time as a single pulse.

The waveforms are then separated in match filtering



After merging radar returns from each waveform, only a single raw I/Q stream is produced. Standard pulse-pair method can then be applied to derive moment data.

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http://arrc.ou.edu