# SOFTWARE-DEFINED RADAR TESTBED FOR MIMO SAR APPLICATIONS

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## 1. INTRODUCTION

Spaceborne SAR systems for remote sensing and urban surveillance applications demand both wide swath coverage and high azimuth resolution. Traditional single-antenna SAR systems pose a trade-off between these two capabilities by offering greater azimuth resolution at the expense of swath coverage or vice versa. This is a result of compromises in antenna design and fundamental properties of SAR systems such as the pulse repetition frequency (PRF) and the total transmitted power. Recent SAR systems have attempted to overcome these limitations through the utilization of multiple real apertures, digital beamforming, and waveform diversity techniques.

The use of displaced phase center (DPC) antennas is one multiple-aperture technique for improving unambiguous swath coverage [1]. This technique utilizes a single transmit aperture with multiple receive apertures in the along-track direction, each illuminating the same swath on the ground. The range returns from a single transmit pulse are measured by the multiple receive apertures simultaneously, thereby creating several elements of the synthetic array at once. Because of this, the PRF required to generate a properly sampled SAR array is decreased by a factor equal to the number of elements in the real array. This lower PRF corresponds directly to a larger achievable unambiguous swath width.

The DPC technique can be expanded through the utilization of a two-dimensional receive array. If each element in the array has its own receiver, digital beamforming on receive can used to effectively steer the receive beam in elevation to follow the radar returns along the ground. This is particularly important in wide swath applications where the required signal-to-noise ratio (SNR) at the furthest range may be difficult to achieve. Since no information in the along-track direction is lost through beamsteering in elevation, the DPC technique can still be applied thereby lowering the PRF and enabling larger swath widths [2].

Other advanced techniques have been proposed which utilize the same two-dimensional array for transmission in addition to reception [3]. Krieger *et al.* propose using multidimensional waveform encoding in addition to steering a transmit beam in elevation as a function of time [2]. In this manner, very large swaths are illuminated with the high-gain synthesized beam thereby improving the SNR or equivalently decreasing the required total transmit power. The resulting radar returns are then further separated spatially by beamsteering on receive which provides an additional processing gain before forming the SAR image.

MIMO radar has been studied recently for its application to target detection and target parameter estimation [4, 5] but can be applied to SAR as well. Multiple-input multiple-output (MIMO) SAR utilizes orthogonal waveforms for each transmit element so that the scattered returns from each transmitter can be unambiguously separated at each receiver. This configuration offers several options for processing the data. If the individual transmit and receive elements observe the entire swath, then digital beamforming on both transmit and receive can be applied *a posteriori* to provide a two-way processing gain. Alternatively, a method has been proposed which utilizes an Alamouti space-time coding scheme to provide an additional processing gain and better azimuth ambiguity performance [6].

A software-defined radar (SDR) is being constructed to provide the opportunity for real-world analysis and verification of the previously described SAR techniques as well as other advanced radar techniques. The SDR has been designed as a multi-channel, low-power radar testbed based on an extremely powerful digital signal processing system. This system offers two independently configurable transmit and receive channels coupled to a tunable radio frequency (RF) front end capable of coherently transmitting and receiving waveforms with up to 500 MHz of instantaneous bandwidth. The center frequency of the radar is also digitally controllable and can be tuned in of the range of 2 to 18 GHz.

## 2. DESCRIPTION OF WORK

To fully investigate the types of SAR techniques outlined previously, the SDR must be capable of transmitting and receiving arbitrary waveforms with wide bandwidths. A modular digital signal processing platform has been assembled based on components commercially available from *Sundance Multiprocessor Technology Ltd.* [7] providing dual-channel 1 giga-samples per second (GSPS) digital-to-analog (DAC) and analog-to-digital (ADC) converters and a network of eight DSPs. The system is PCI-based and is contained in a standard PC. Figure 1(a) shows the layout of the digital components which are distributed across two PCI carrier cards.

To leverage the power and flexibility of the SDR digital back end, a software framework is being developed which implements a multi-channel arbitrary pulsed waveform radar. This framework allows the user to quickly prototype transmit waveforms of arbitrary length, adjust the radar's PRF, control the amount of coherent integration performed, and receive the complex-valued range returns without having to program the FPGAs. An overview of the framework for a single transmit and receive channel is given in Figure 1(b). This framework primarily utilizes resources in the ADC and DAC FPGA modules, leaving the DSP network largely free for higher-level signal processing tasks required for SAR.

The SDR digital back end will be discussed with particular attention being given to the software framework currently under development. Details of the RF front end capable of tuning from 2 to 18 GHz will also be presented along with measurements illustrating the potential range and Doppler resolution of the system. Finally, prototyping advanced SAR techniques using the SDR will be addressed.

## 3. REFERENCES


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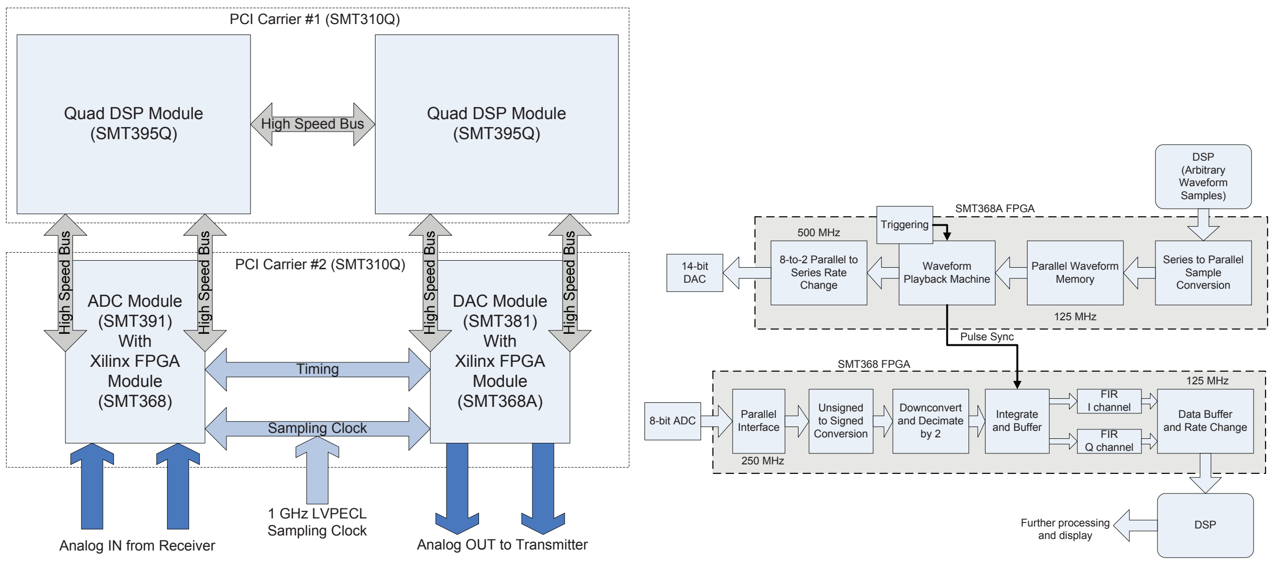


(a) The SDR digital back end.

(b) Software framework.

**Fig. 1**. Diagrams of the SDR digital back end and the SDR software framework which are used to easily prototype complex radar techniques.


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