Ohio State University Software-Defined Radar Systems
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The OSU software-defined radar group has developed multiple vertically integrated software-defined radar systems that can adapt to user sensing requirements in real-time. An overview of systems is given online at http:/www.ece.osu.edu/~ertine/RFtestbed Adaptation of both transmit waveform and receive signal processing enables the radar to operate in multiple modes including Moving Target Indicator (MTI), High Range Resolution (HRR) MTI, Synthetic Aperture Radar (SAR) and Inverse Synthetic Aperture Radar (ISAR). Multiple phase centers facilitate polarimetric and interferometric operation as well as serve as a test bed to implement and test multi-input, multi-output (MIMO) and waveform adaptive radar concepts.

Although many traditional multi-antenna radar concepts -- such as phased-array, receive beamforming, space-time adaptive processing (STAP), polarimetry, and interferometry -- can be seen as special cases of MIMO radar, the distinct advantage of a multi-antenna radar system with independent transmit waveforms is the increased number of degrees of freedom leading to improved resolution, improved parameter estimation performance, and reduced pulse repetition frequency (PRF) and/or transmit power.

The operational principle of a software-defined radar system is to sample the transmit/receive waveforms using high speed digital/analog and analog/digital converters and to implement key processing stages using programmable digital hardware. The block diagram for our software-defined radar systems is given in Figure 1. A high-speed digital waveform generator is used to construct independent waveforms for a set of transmit antennas, and this digital waveform generator produces a synchronized multi-channel baseband transmit signal which is mixed and amplified for transmission. In the receiver chain, the received signal is filtered, amplified, and down-converted by a RF module, sampled in the baseband bandwidth synchronously across the multiple channels, and passed to an FPGA-based real-time signal processor for multi-channel coherent processing. The adaptive operation of the system is controlled by the information-driven active-sensing layer which allocates system resources to achieve intelligence, surveillance and reconnaissance (ISR) objectives by supplying the user with target recognition primitives (e.g., target detections, target track, and identification).

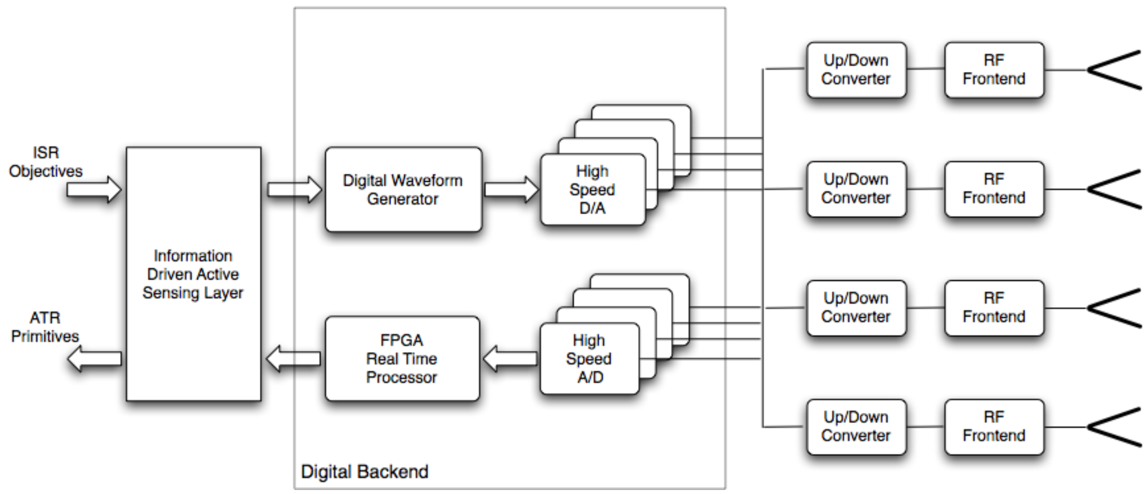

Figure 1: Multi-mode, Multi-channel Software-Defined Radar

The OSU prototype radar systems combine a high-bandwidth digital back-end with a radio frequency (RF) front-end having a variable center frequency over a wide frequency range (covering L, S, C, X, and Ku bands). For the AFOSR Discovery Challenge Thrust program directed by principal investigator Professor Emre Ertin, OSU developed three prototype software defined radar sensors that are fully functioning: the MicroRadar, the UltraWideband MIMO Test Bed, and the Software-Defined MIMO Radar Sensor. These three systems are listed in Figure 2 and detailed below.

1) The OSU **Software-Defined MicroRadar** builds on the Texas Instruments small form factor software-defined radio with a custom wider band RF front end for real-time range-Doppler processing of a 125 MHz instantaneous bandwidth at C band (5.4-6.4 GHz). The MicroRadar consists of a TI DM6446 DSP, a Xilinx Virtex-4 SX35 FPGA, two digital-to-analog converters (DACs), and 2 ADCs. The ADCs sample at a rate of 125 mega samples per second (MSPS). The DACs are given data at a maximum rate of 125 MSPS. The DACs digitally upsample and filter to a rate of 500 MSPS, mitigating frequency domain images when the full 125MHz of bandwidth is used.

2) The OSU **UltraWideband MIMO Radar Test Bed** provides up to 7.5 GHz instantaneous RF bandwidth on 4 Transmit and 4 Receive Channels using Tektronix/Agilent Test Equipment, with MIMO RF down-converters and up-converters operating at an adjustable center frequency 0.1-26 GHz. This system allows flexible data collection campaigns with independent coherent waveforms. The test bed uses two Tektronix AWG7122B dual channel 12GS/s Arbitrary Waveform Generators to generate coherent waveforms on four channels at 10 bit resolution. Two Agilent E8267D PSG vector signal generators with Wideband I/Q Modulators can up-convert baseband

waveforms to higher RF frequencies. These signals are fed to custom wideband antennas with low noise amplifiers (LNAs) on transmit and receive. The custom antenna design provides a low-cost planar printed antenna that can operate in the 2-18 GHz band. On the receive side, a four-channel Agilent N5280A MIMO down-converter (10MHz to 26.5 GHz) is used to down-convert the received signals to baseband; baseband signals are then sampled with a four-channel Tektronix DPO71254 12.5 GHZ Digital Oscilloscope with 50GSPS interlaced sampling rate and 8 bit resolution. An Agilent N5183A MXG analog microwave signal generator is used to generate carrier frequency references for the system.

3) The **OSU Software-Defined MIMO Radar Sensor** combines 4 transmit and 4 receive channels with FGPA/DSP for real-time MIMO radar processing with 500 MHz instantaneous bandwidth at 2-18 GHz. The digital backend uses 1 GSPS ADC (8 bit) and DAC (14 bits) boards from Sundance Multiprocessor Technology. The digitized signals are controlled through Xilinx Virtex-4 SX 35 FPGAs; higher layer signal processing tasks are handled by four TI C6416 32bit fixed point DSPs per channel operating at 1 GHz.

For the MIMO Radar Sensor, OSU developed a wideband (2-18GHz) RF front-end using a standard superheterodyne architecture. The first local oscillator (LO) is at a fixed frequency of 2GHz, enabling RF filter designs with sharp cutoffs. The second LO is tunable for mapping the operating frequency to the fixed frequency of the first LO stage. The second LO filter uses a switchable filter bank on the low frequency band (2-6 GHz) and bandpass yttrium iron garnet (YIG) filters on the high frequency band (6-18 GHz). Fully polarimetric sensing is enabled by an integrated RF switching matrix. The antenna feeds have integrated LNAs to account for cable losses in a MIMO array.

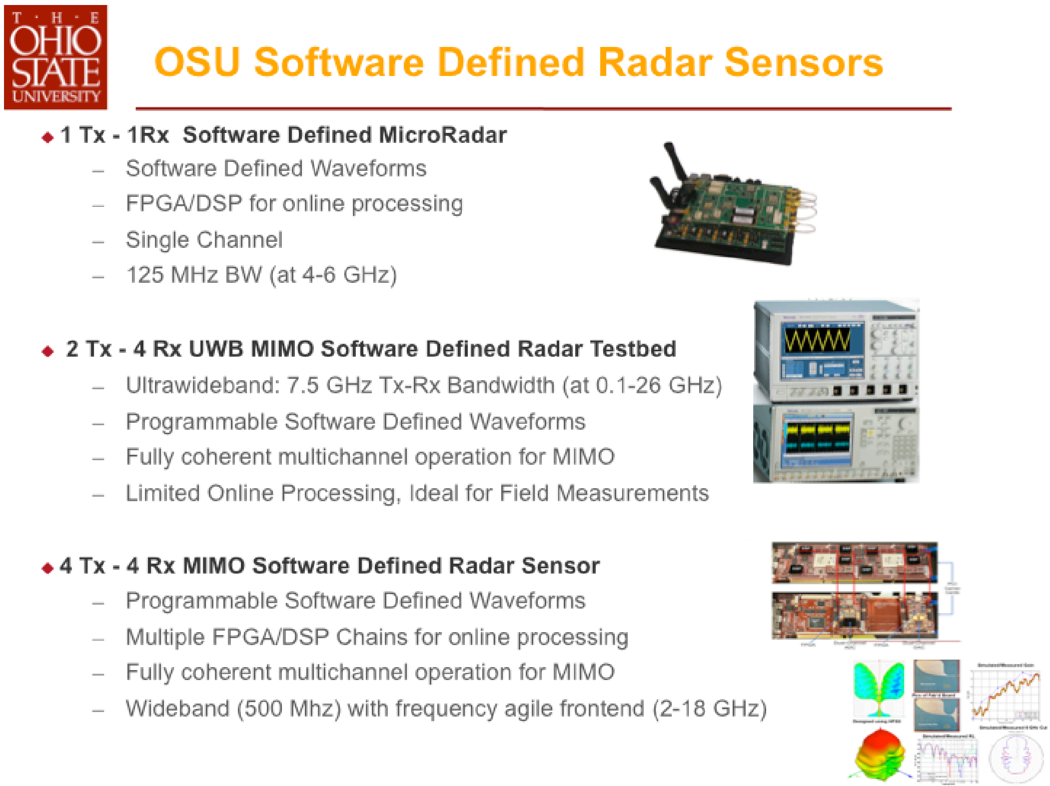

Figure 2: OSU Software Defined Radar Sensors