Software-Defined Radar for MIMO and Adaptive Waveform Applications

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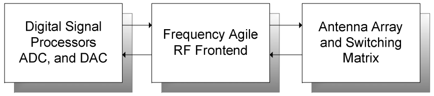
1 Motivation

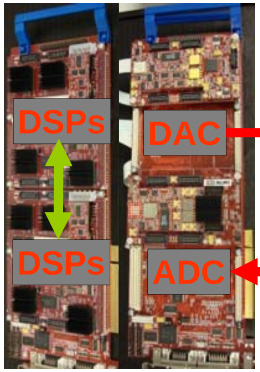
- Modern digital signal processing has motivated new approaches to radar:
  - –Multiple-Input Multiple-Output (MIMO) radar
    - Spatially diverse antennas transmitting independent waveforms may improve target detection statistics over traditional phased arrays
  - –Adaptive transmit waveforms
    - Tailor waveform to target in order to maximize SNR at the receiver, or to aid in target recognition and classification
- Evaluation of these technologies requires a FLEXIBLE RADAR DEVELOPMENT PLATFORM

- Our Software-Defined Radar (SDR) platform provides
  - –500 MHz instantaneous analog bandwidth with center frequency tunable from 2-18 GHz
  - –Arbitrary Pulse Waveform Generator (APWG)
  - –Powerful digital backend to implement real-time processing of radar returns and waveform design
- System Overview:



2 Digital Signal Processing Backend

- Modular platform using components manufactured by *Sundance Multiprocessor Technologies*
- PCI-based system
- 8 Texas Instruments TMS320C6416T fixed-point DSPs
- Dual-channel 8-bit ADC (~6.9 ENOB)
- Dual-channel 14-bit DAC
- Xilinx Virtex-II SX35 FPGAs implement high speed interface to the samplers
- DSPs run *3L Diamond* real-time operating system
- Custom software framework implements radar functionality

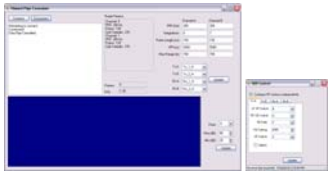


3 RF Frontend Design

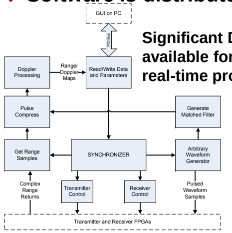
- TWO independent transmit and receive channels
- Super-heterodyne system with one fixed LO and one tunable from 0.5 to 15.5 GHz. (2-18GHz center freq.)
- 500 MHz passband implemented by combination of tunable YIG filters and filter banks
- High speed switching network multiplexes two transmit and two receive channels onto four dual-polarized transmit and four dual-polarized receive antennas
- FCC ultra-wideband (UWB) power requirements

4 Preliminary Software Implementation

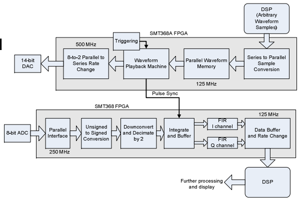
- Graphical User Interface (GUI) running on PC allows the user to easily select operational parameters and control RF frontend



- Software is distributed among a network of DSPs and FPGAs

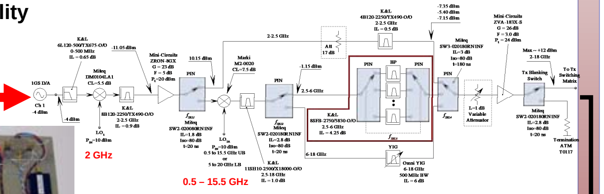


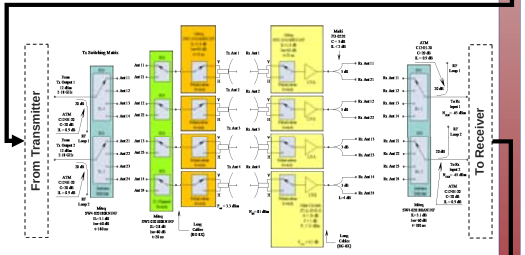
Significant DSP resources available for more advanced real-time processing.

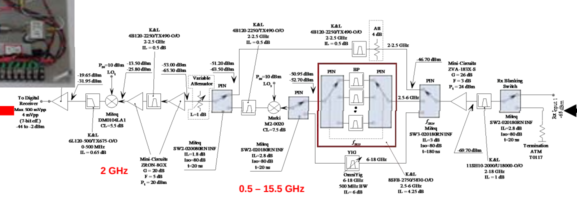


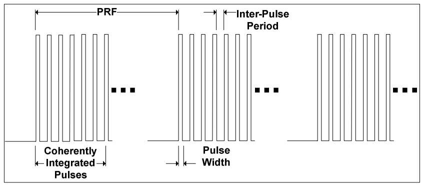
(DSP processing overview) (FPGA processing overview)

- FPGAs provide fine timing control for transmit pulse playback and coherent integration on receive
- DSPs implement bulk of signal processing for maximum flexibility







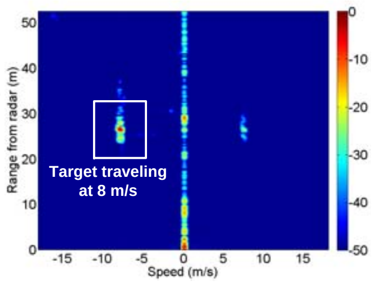


- Pulse properties (width and inter-pulse period (IPP)), the pulse repetition frequency (PRF), and the number of pulses coherently integrated are all programmable

5 Example Measurements

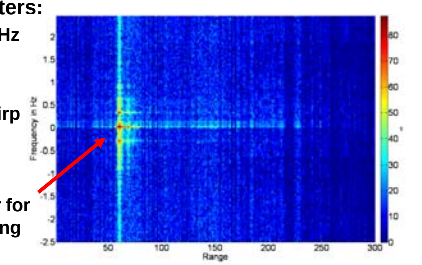
Moving Target Example:

- 128 coherent pulse returns used for Range/Doppler map of S-10 truck (4m in total length) target
- Measurement parameters:
  - –Prototype 6 GHz C-band frontend
  - –800 ns chirp (0 - 500 MHz)
  - –450 MHz bandwidth
  - –128 integrations
- < 2/3m range resolution

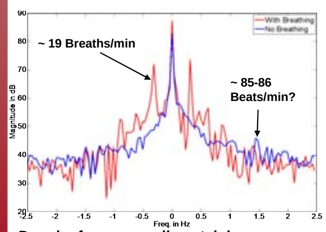


Human Biological Sensing Example:

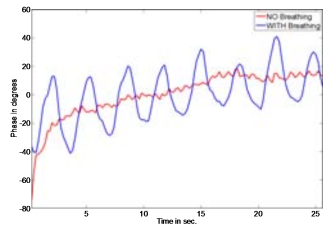
- Three measurements:
  - –Absorber wall only
  - –Human seated in front of absorber wall, breathing normally
  - –Human seated in front of absorber wall, holding breath
- Measurement parameters:
  - –128 pulses @ PRF 5 Hz
  - –25.6 sec duration
  - –8 pulse integrations
  - –600 ns Linear FM Chirp
  - –25 MHz to 450 MHz
  - –EIRP: ~ -40 dBm



Range/Doppler for Human breathing



Doppler for range cell containing person



Phase vs. Time showing breathing motion