PMCW Automotive Radar Testing Exploiting Orthogonal Waveforms & Joint Radar & Communication Capabilities

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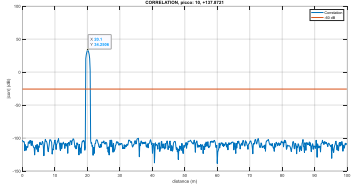
Motivations for PMCW orthogonal waveforms

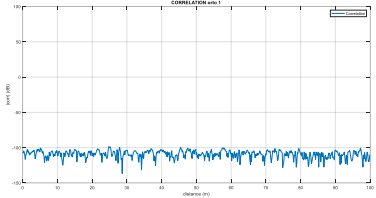
- Binary PMCW radars benefits: better HCR, larger maximum velocity, interference mitigation thanks to code orthogonality, easy integration of communication and sensing, etc.
- FMCW radars use Time Division Multiplexing technique to achieve orthogonality and exploit MIMO advantages. This technique has the main drawback of limiting the maximum unambiguous velocity of the radar.
- Zero Correlation Zone sequences allow to transmit orthogonal signals simultaneously, have no sidelobes inside a determined range and do not require complementary pair.

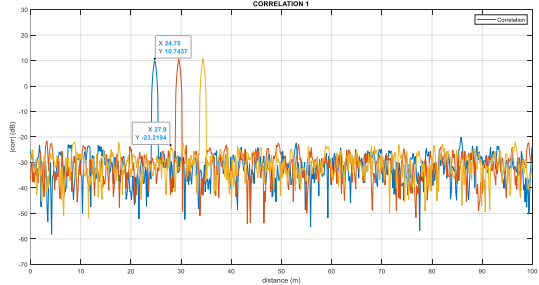
Simulation of ZCZ sequences

Autocorrelation



Crosscorrelation with orthogonal sequence



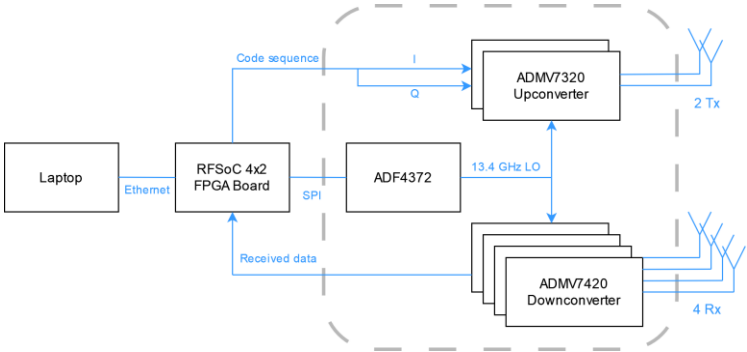


Scenario with three orthogonal sequences simultaneously scattered by three targets at different range at 0 dB SNR

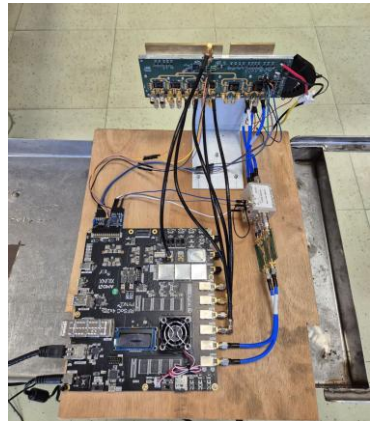
Radar parameters

Bandwidth	250 MHz
T sequence	2 µs
Nchip in a sequence	512
Number of sequences per frame	64
Modulated carrier	250 MHz
Upconverted carrier	80 GHz
Sampling frequency	2 GHz
Frame repetition rate	100 ms
Range resolution	60 cm
Range accuracy	7.5 cm
Max velocity (PRI = 48 µs)	40 m/s
Velocity resolution	0.6 m/s

PMCW radar block diagram



Integrated in PCB



Real Digital AMD FPGA board

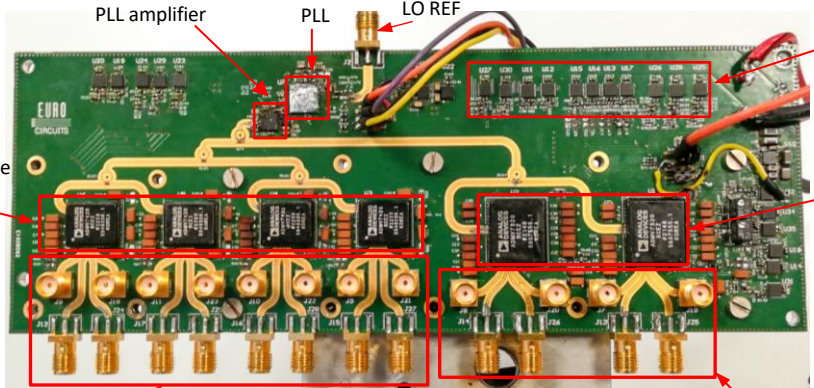
- Xilinx Gen 3 Zynq UltraScale+ RFSoC ZU48DR
- Quad core ARM Cortex-A53, Dual core ARM Cortex–R5F
- Programmable Logic with 930K logic cells, 4272 DSP slices, 38Mb block RAM
- 4x 5GSPS RF ADCs SMA ports
- 2x 9.85GSP RF DACs SMA ports
- External clock and sync ports
- 4 GB 64-bit 2400MHz Processing System memory
- 4 GB 64-bit 2400MHz Programmable Logic memory
- 10/100/1000 Mbps Ethernet
- 100G Ethernet MAC/PCS w/RS-FEC (QSFP28)

Implemented FPGA firmware

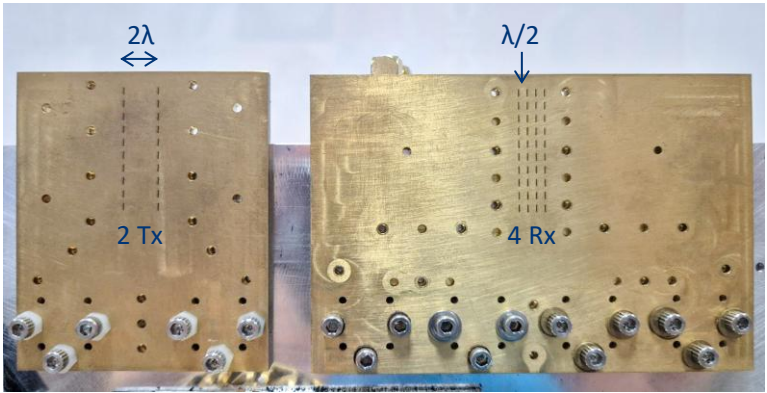
FPGA real-time processing steps:

- Generation of custom digital sequence to be transmitted
- 250 MHz modulated signal generation for radar front-end
- Sampling of received signal from radar front-end
- Digital demodulation from 250 MHz to baseband
- Correlation with transmitted sequence
- Doppler FFT calculation and range-doppler map generation
- Data transfer to laptop PC through 1 Gb Ethernet

Custom designed MIMO 2-Tx 4-Rx radar front-end

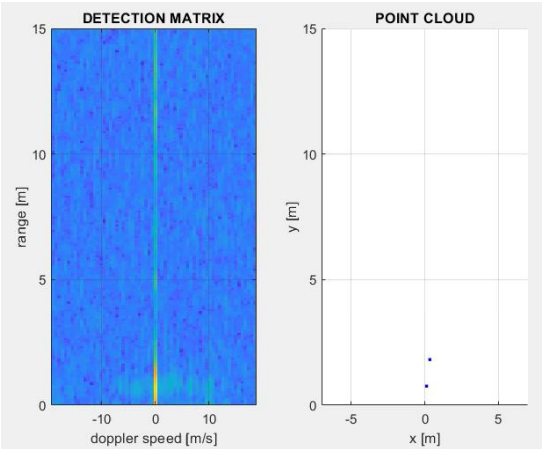


Custom designed MIMO radar high efficiency antennas

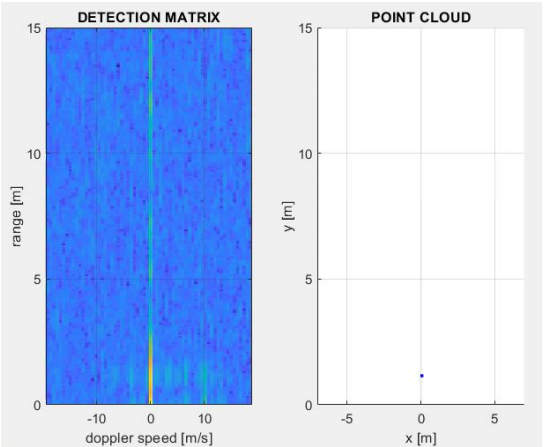


- 2 CNC-machined halves
- Tin soldered
- Completely characterized with VNA in anechoic chamber
- Directly connected to chips' Launcher-on-Package

Initial test and validation: walking pedestrian



Initial test and validation: walking pedestrian 2



Conclusions and next steps

Conclusions:

- Full exploitation of PMCW benefits
- High flexibility of the system (sequences and parameters managed via laptop PC)
- Easy integration of communication payload
- Interference mitigation

Next steps:

- Extensive validation of communication and sensing in real-life scenarios
- Advanced antennas configuration for improved MIMO capabilities
- Integration on a single chip

Thank you for your attention

Any questions?

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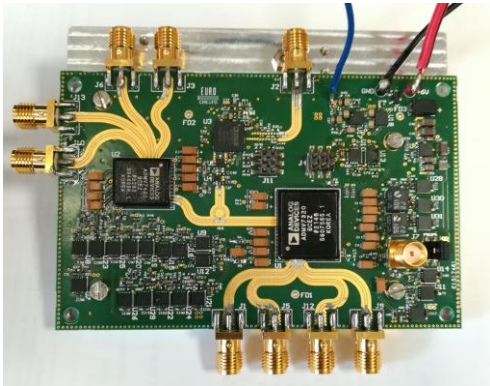
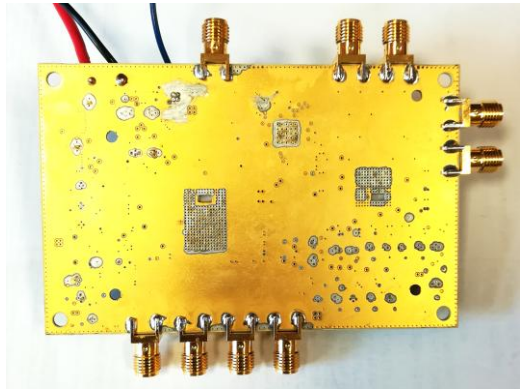
PMCW radar front-end PCB



Top view



Bottom view