Radar Techniques for Locating Non-cooperative Radio Receivers

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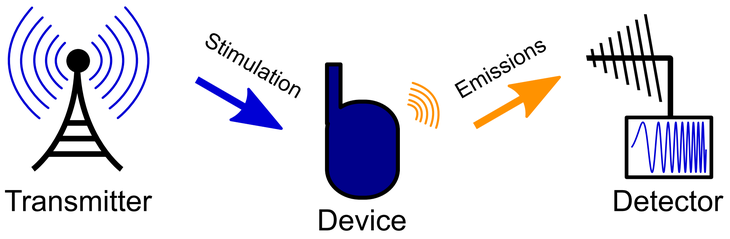
Introduction



- Superheterodyne receivers can initiate explosive devices
- Can detect with stimulated emissions [1]:
  1. Device interaction
  2. Unintended emissions retransmission
  3. Emissions detection
- Cannot estimate location (i.e., range)

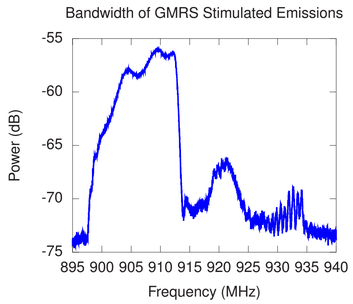
Ranging with Time of Arrival

$$\delta R = \frac{c\sqrt{3}}{2\pi B(2E/N_0)^{1/2}}$$

A Superheterodyne Receiver

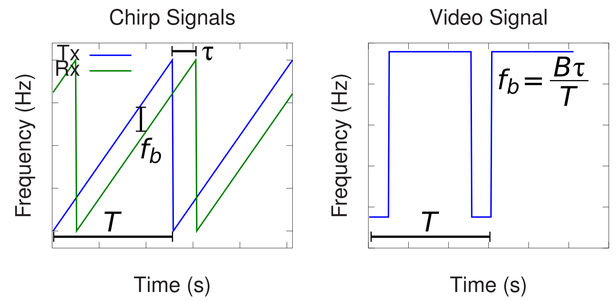
- Maximum Time of Arrival (ToA) resolution is δR [2]
  - More bandwidth $\rightarrow$ higher resolution
  - Existing stimulation signal insufficient
- Limiting factor is image rejection filter

Bandwidth Measurements



- Measured stimulated emissions bandwidth
- 3 dB bandwidth approximately 10 MHz
- Sufficient bandwidth for ToA

FMCW Radar



- Frequency-Modulated Continuous Wave (FMCW)
  - Transmits linear, frequency-modulated chirp
  - Multiplies echoes with conjugate chirp
  - Resolution $\Delta R = \frac{c}{2B}$ [3]

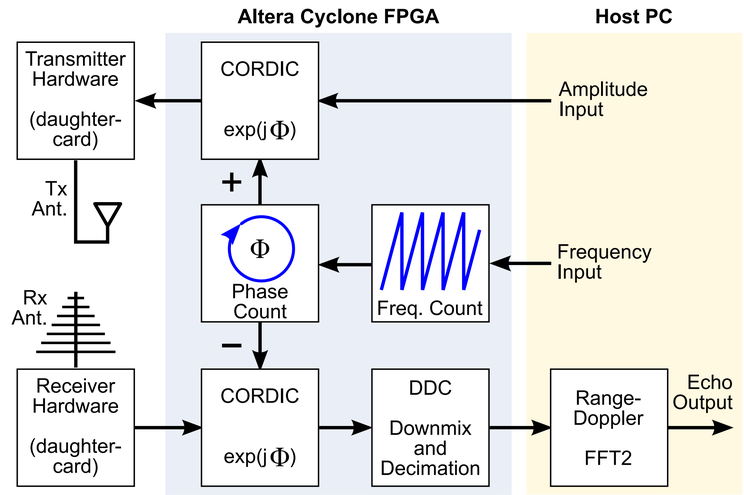
USRP Modifications

- Universal Software Radio Peripheral (USRP)
- Radar requirements:
  - High-speed signal processing
  - Hard real-time synchronization
- Implemented FMCW radar in software

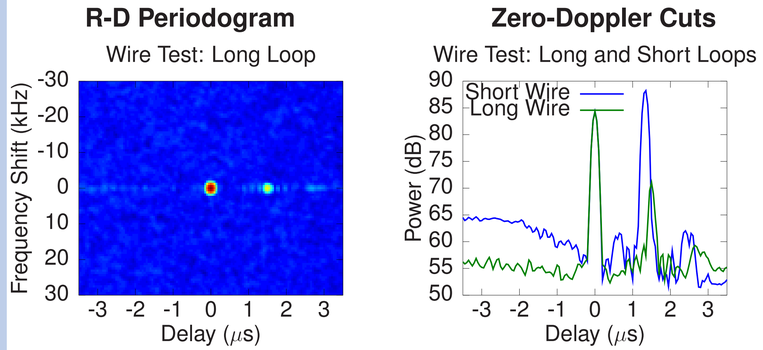
  FPGA: Modified bitstream performs chirp/de-chirp

  Host PC: Range-Doppler processing

Firmware Block Diagram

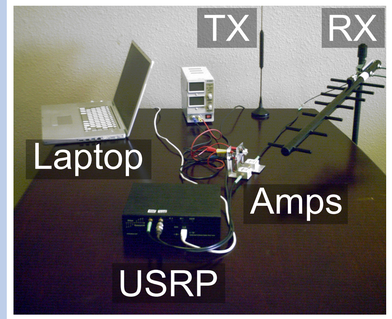


Validation Testing



- Tested system using a long wire for delay
  - Belden RG-58a, 40 m long, VF $\approx 0.75c$
  - Compared with short wire, $< \frac{1}{2}$ m long
- Successfully estimates length of the wire
  - Estimated length is 33.7 m (0.15 μs delay)
  - Within resolution ΔR
- Simulates superheterodyne receiver
- Radar is functional and ready for field trials

Research to Reality



- Functional design of deliverable field unit
  - Software-defined radar
  - Non-line-of-sight detection
- Potential commercial product for locating IEDs
  - Battery-powered handheld
  - Low cost

References and Acknowledgments

(1) C. Stagner, A. Conrad, C. Osterwise, D.G. Beetner, and S. Grant, "A Practical Superheterodyne-Receiver Detector Using Stimulated Emissions," *IEEE Trans. Instrum. Meas.*, vol. 60, no. 4, pp. 1461 – 1468, 2011.

(2) M. Skolnik, "Theoretical accuracy of radar measurements," *IRE Trans. Aeronautical and Navigational Electronics*, no. 4, pp. 123–129, 1960.

(3) N. Levanon and E. Mozeson, *Radar Signals*. Wiley, 2004, ch. 10, pp. 318–323.

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