Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Ultra-wideband RF-A Tutorial]
Date Submitted: [March 6,2000]
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Re: [UltraWideBand tutorial for 802.]

[If this is a response to a Call for Contributions, cite the name and date of the Call for Contributions to which this document responds, as well as the relevant item number in the Call for Contributions.]
[Note: Contributions that are not responsive to this section of the template, and contributions which do not address the topic under which they are submitted, may be refused or consigned to the "General Contributions" area.]

Abstract: [Presentation on Ultra Wide Band RF]

Purpose: [Tutorial #1, March 6, 2000.]

NOTE: Update all red fields replacing with your information; they are required. This is a manual update in appropriate fields. All Blue fields are informational and are to be deleted. Black stays. After updating delete this box/paragraph.

Ultra-wideband RF
A Tutorial

802 Plenary
Albuquerque, NM
March 2000

Who's Presenting?

- Paul Withington
- Time Domain Corp.
  - Communications
  - Radar
  - Precision positioning & tracking
- Members of the Ultra-Wideband Working Group (www.uwb.org)
- We don't represent the whole industry…

What is UWB?

- Definition
  - Fractional Bandwidth $\geq 25\%$
  - Where:

$$\text{Fractional Bandwidth} = \frac{2(f_H - f_L)}{(f_H + f_L)}$$

  - Source:
    - "Assessment of Ultra-Wideband (UWB) Technology", OSD/DARPA Ultra-Wideband Radar Review Panel, R-6280, Defense Advanced Research Projects Agency (July 13, 1990)
    - See also *Introduction to Ultra-Wideband Radar Systems*, James D. Taylor, ed., CRC Press, at p. 2 (1995)

Rationale

- Achieving linearity is often difficult much beyond 10% relative bandwidth making non-traditional approaches more attractive
- Special characteristics of waveforms with small number of zero crossings become increasingly evident

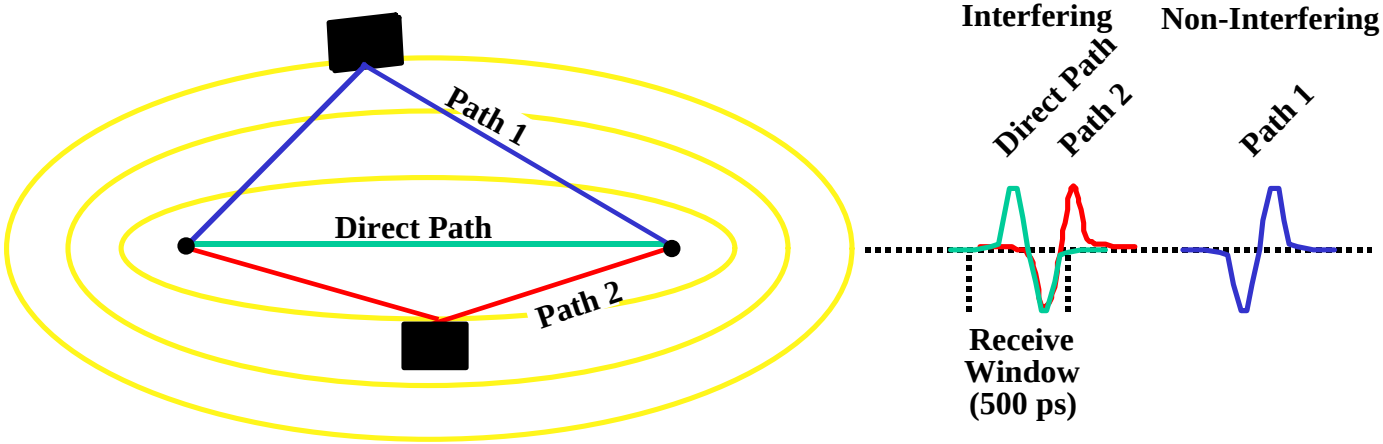
Why Use UWB?

- Promise of processing gain
  - Anti-jam (anti-multipath)
  - Anti-clutter
- Promise of hardware simplicity
  - Avoidance of high chip rate modulation
  - Time domain signal processing
- Potential to fuse functionality
  - Communications
  - Positioning
  - Sensing

Marketplace Interest

- Office of Naval Research has requested proposals for 802.11 “compliant” UWB systems
  - Security
  - Reduction in emissions detectability
  - Performance within ships & submarines
  - Standard interface

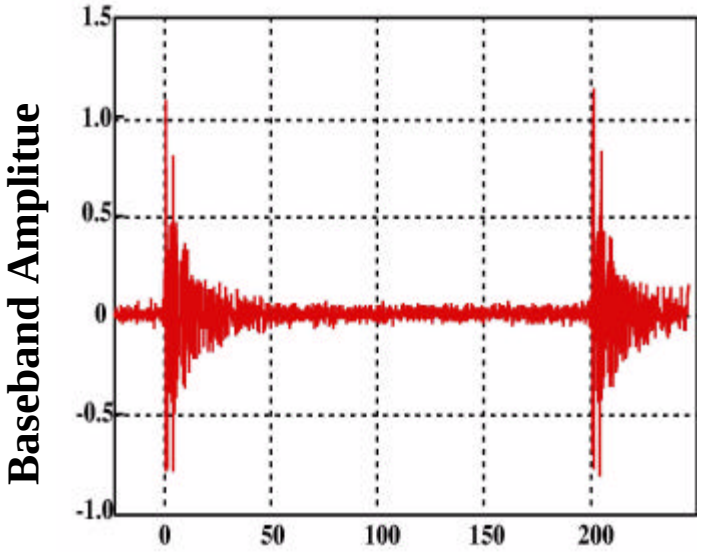
Multipath Advantage



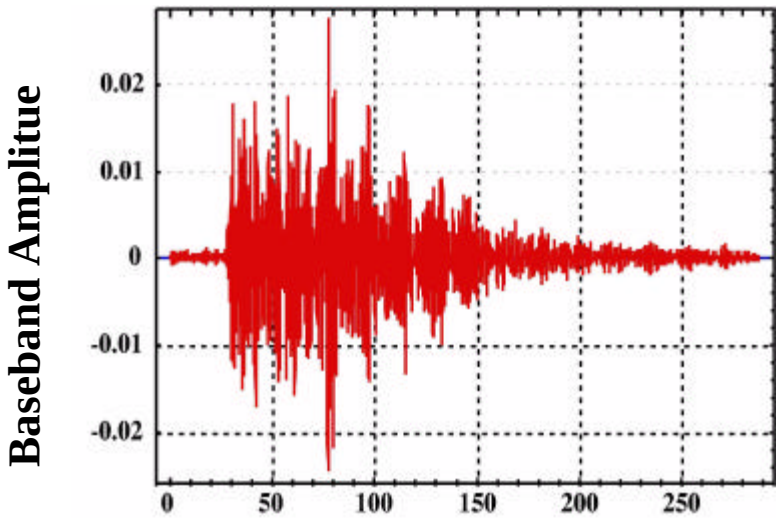
- RAYLEIGH FADING : A Continuous Wave Phenomenon
  - Conventional Radios Overcome Fading with Power
  - High Power Transmitter are Detectable and Consumed Batteries
- TM-UWB Does Not Use Continuous Waves
  - No Rayleigh fading
  - No high power transmission required to overcome Rayleigh fading

Multipath Advantage

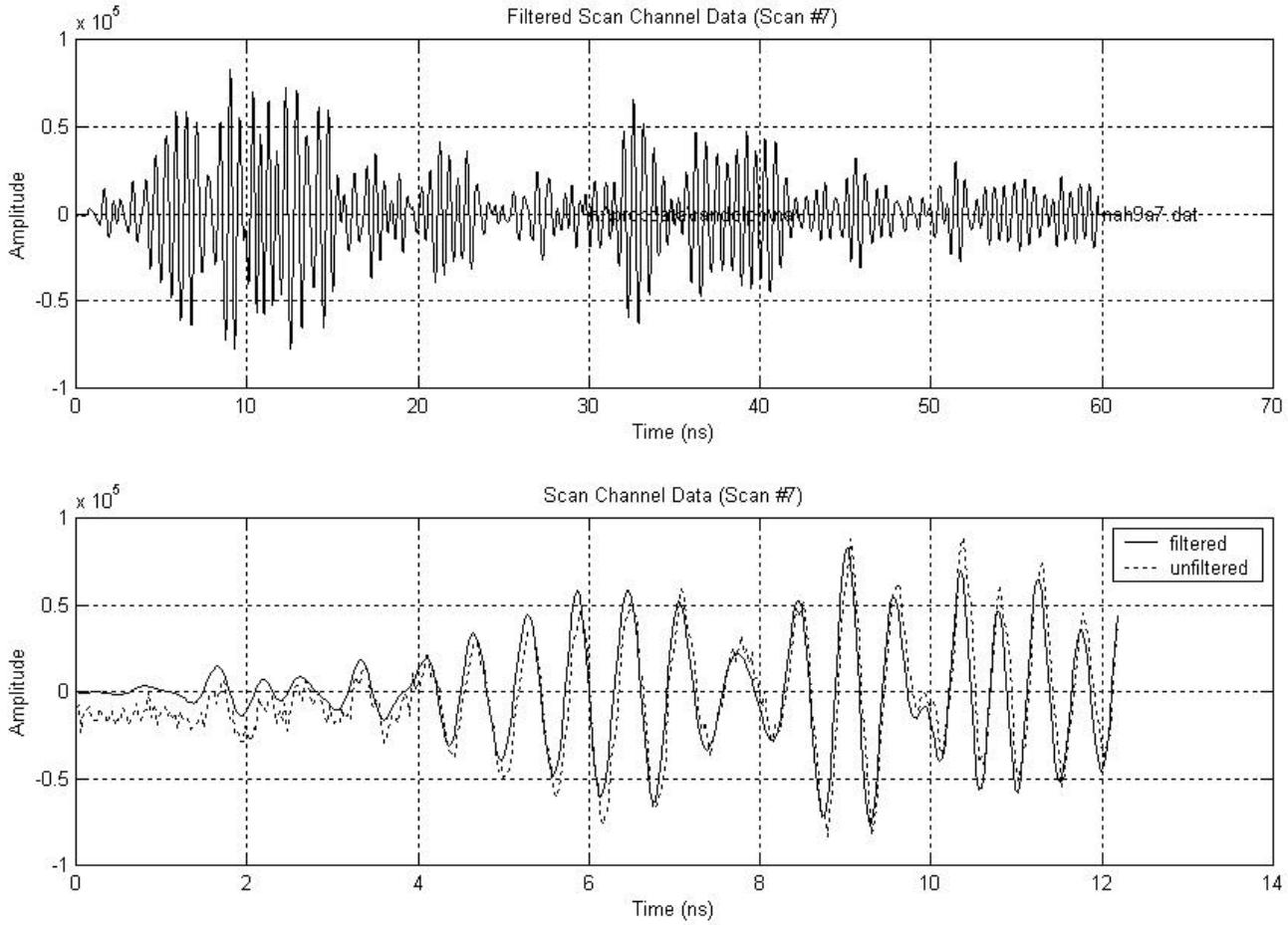
Unobstructed 10 meter LOS Path



Obstructed 8 meter Path

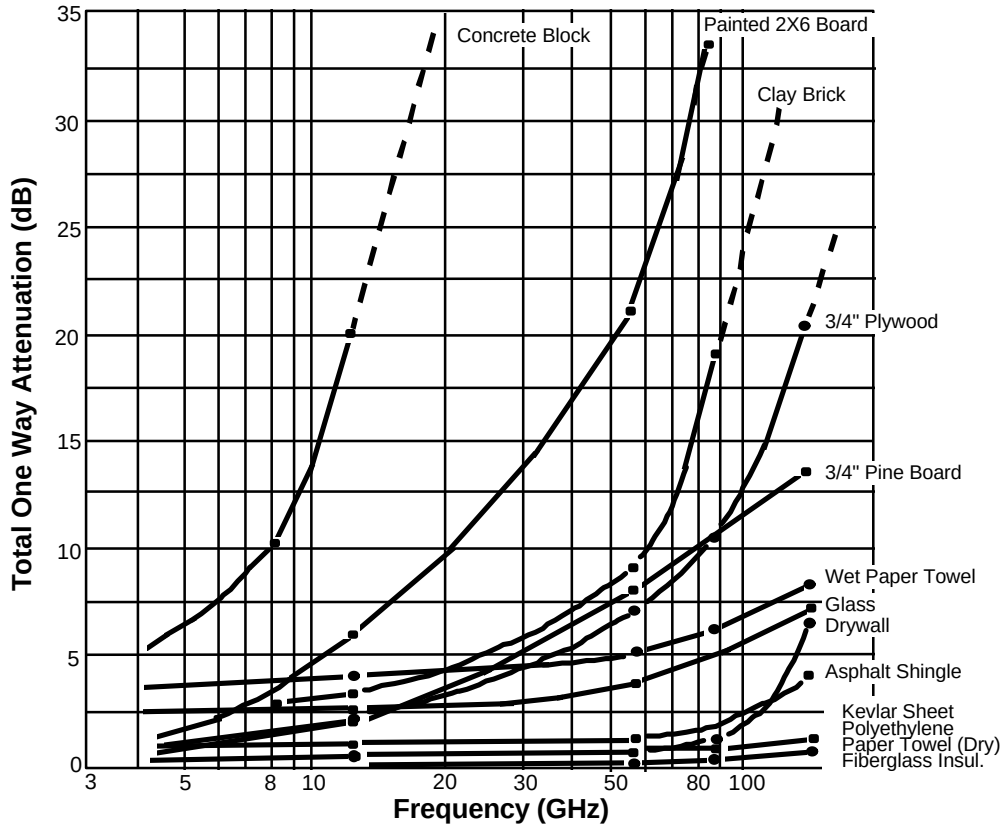


More Multipath Images



Lower vs. Higher Frequencies

- Higher Frequencies Do Not Propagate as Effectively as Lower Frequencies
- Extremely Expensive to Create Sufficient Bandwidth with Narrowband CW Techniques



Source: L. M. Frazier, Hughes, SPIE

Some UWB History

- Ross
  - Radar for ship docking at Sperry
  - Formed ANRO
- Ground Penetrating Radar companies formed
- Big pulse work
- Fullerton issued communications systems patents in mid-80's & forms Time Domain
- 1990's rapid acceleration of UWB R&D

UWB Using Coherent Detection & Time Hopping

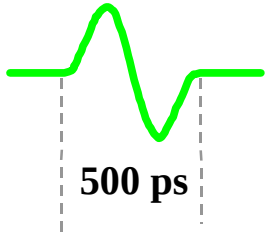
- Primary focus of Time Domain

Technical Characteristics

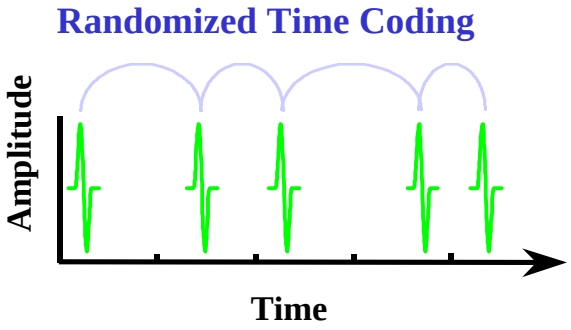
- Extremely large RF bandwidths
  - High performance communications
  - Precision distance measuring
  - High resolution radar
- Maximum performance
  - Coherent Matched Filter Correlating Receiver
  - Minimize transmitted power
- Minimial signal profile
  - Minimize pulse amplitude (high PRF=small pulses)
  - Noise-like Signal (LPI/D)

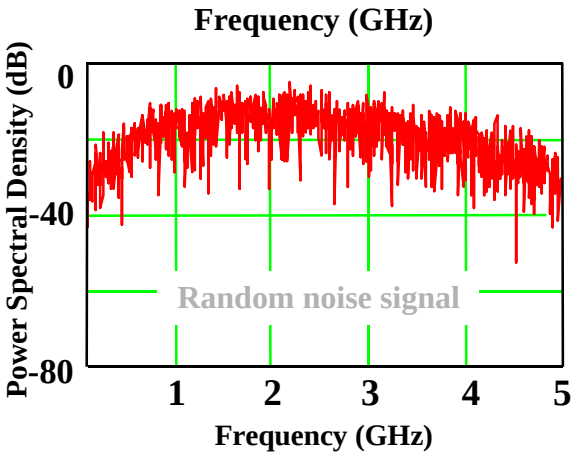
Time Modulated Ultra-Wideband

- Not a sinewave, but millions of pulses per second

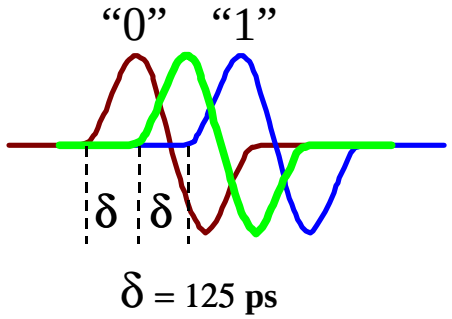


- Time coded to make noise-like



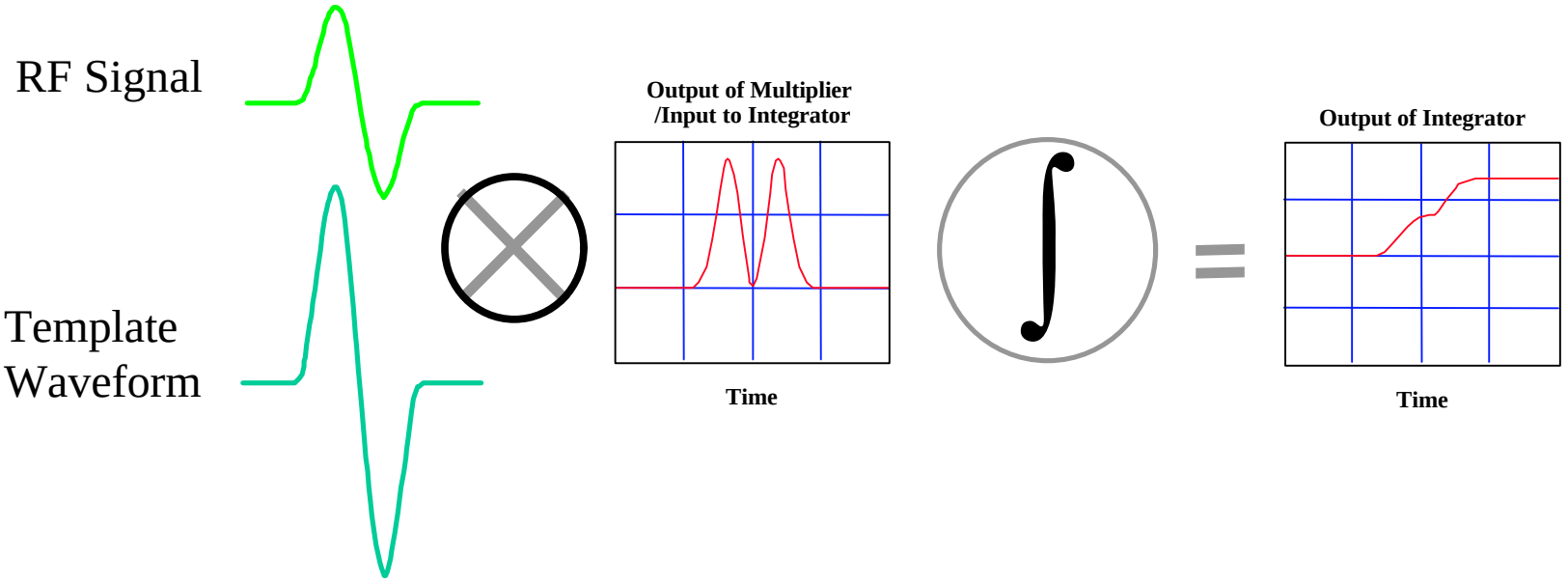


- Pulse position modulation



Cross Correlation Filtering

- An analog process
  - Linear multiplication
  - Integration



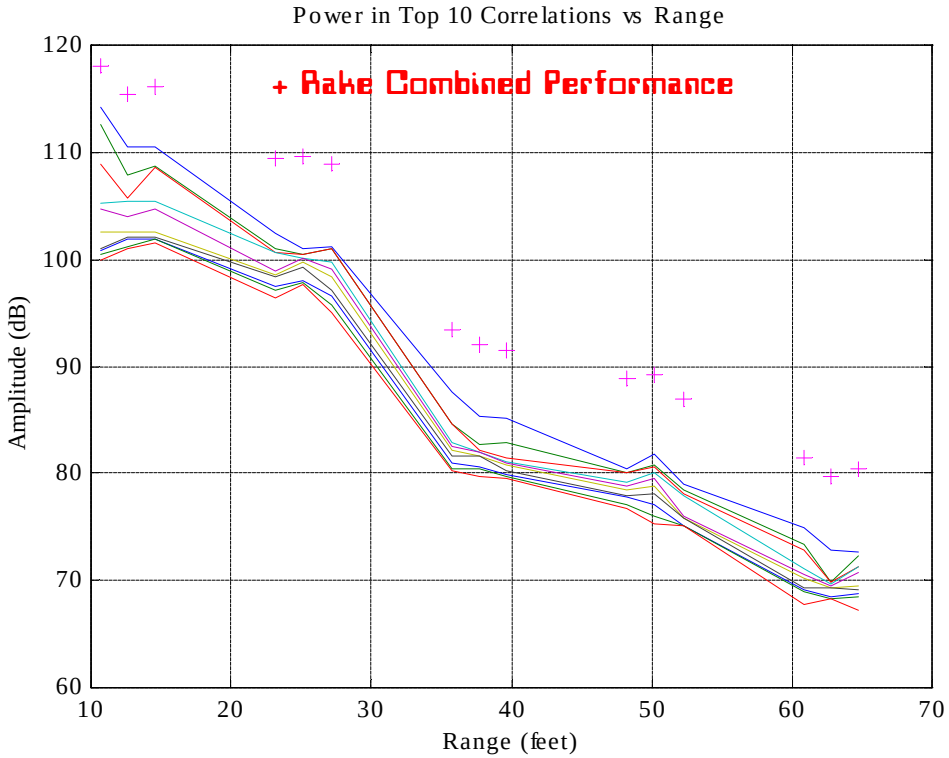
Coherent Pulse Integration

- TM-UWB does not send one symbol per pulse
- TM-UWB depends on coherent pulse integration for additional processing gain
  - For a 2 GHz fc 10 Mpps system transmitting 1 mbps, one symbol is spread over 10 pulses
  - 10 Log (10) = 10 dB additional processing gain
- Total processing gain
  - Duty cycle gain + pulse integration gain
  - 23 dB + 10 dB = 33 dB
- Vary bit rate by changing pulse integration gain

Rake Receiver Performance

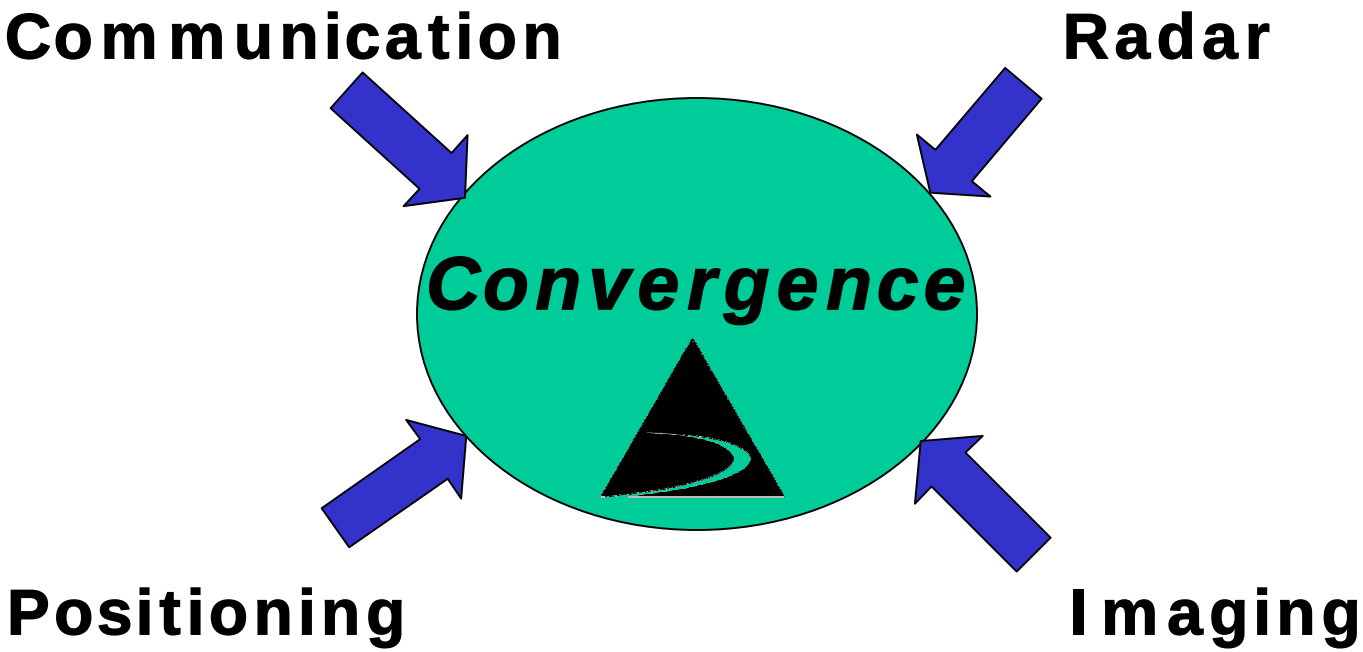
- Five walls
- Non-LOS
- 6 dB rake gain in building

Power In Top 10 Pulses



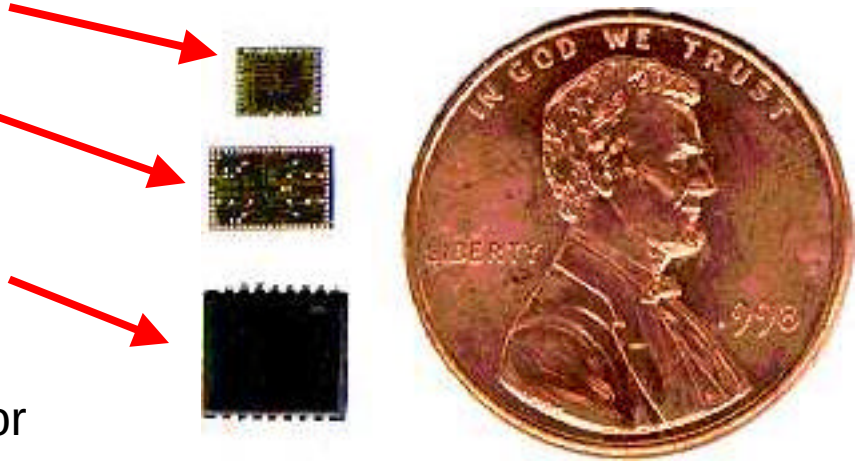
Time Modulated UWB

Fuses 4 Functions



Chip Set Status

- 1st Generation SiGe chips
  - Synchronous programmable time delay
    - 3 ps resolution
  - Multiple correlator ASIC
    - 80 to 90 db dynamic range
    - -93 to –95 dBm sensitivity
- Third chip (in development)
  - DSP/controller is necessary for signal processing and system control
  - Standard CMOS
- 2nd Generation SiGe chips in design



Resources

- www.uwb.org
- Reading:
  - *Introduction to Ultra-Wideband Radar Systems*, James D. Taylor, ed., CRC Press, at p. 2 (1995)
  - "Multiple Access with Time-Hopping Impulse Modulation", R.A. Scholtz, Invited Paper, IEEE Milcom'93, Boston, MA, October 11 – 14, 1993.
  - "On the Robustness of Ultra-Wide Bandwidth Signals in Dense Multipath Environments", M.Z. Win & R.A. Scholtz, IEEE Communications Letters, Vol. 2, No. 2. February, 1998.

Radar Demonstration