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Ultra Wideband (UWB) Technology

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University of California
Lawrence Livermore
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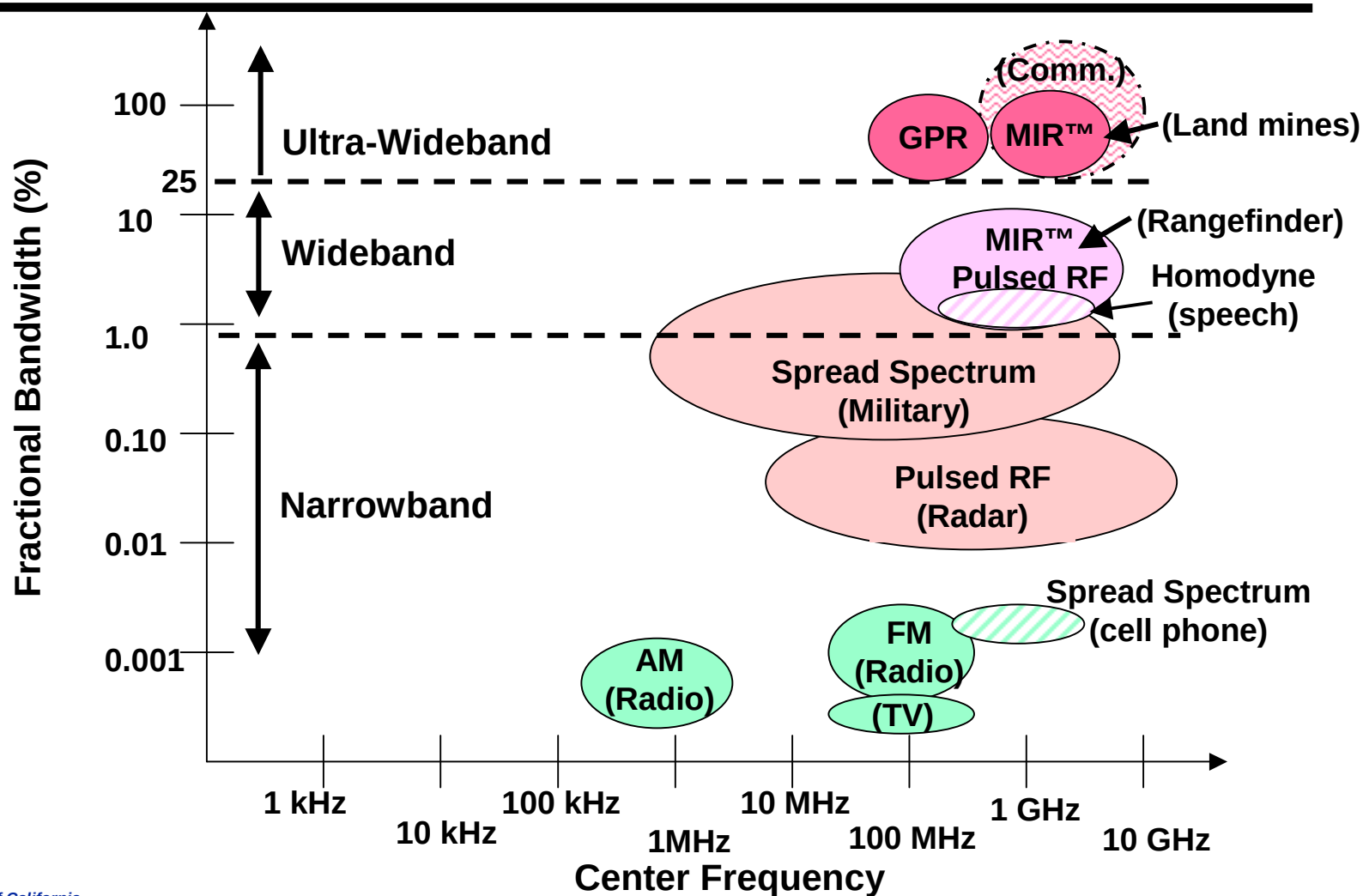
Agenda

- Background
- UWB: Time and Frequency
- Technologies and Applications
- Hardware Examples
- FCC Issues and Status
- Summary

Background: UWB Electromagnetics

- 1960's to Present - DOE National Laboratories continue a long history of research on UWB/impulse electromagnetics
- 1962 - The Nuclear Electromagnetic Pulse (EMP) caused a power failure in a Hawaiian city
- 1960's - LLNL and LANL directed to study EMP and impulse technology, and its threat to weapons systems
- 1964 - Hewlett-Packard and Tektronix sell time-domain instruments
- 1970's - Patents on "impulse" technology: G. Ross (1973) and Morey (1974)
  - LLNL laser-based applications research in pulse diagnostics
- 1986 - First book published, "Time-Domain Measurements in Electromagnetics", edited by Dr. E. K. Miller, LLNL scientist
- 1990's - LLNL develops and patents Micropower Impulse Radar

RF Technologies (Applications)



$$F.\ B.(\%) = 100\left[\frac{(freq_{high} - freq_{low})}{\frac{(freq_{high} + freq_{low})}{2}}\right]$$

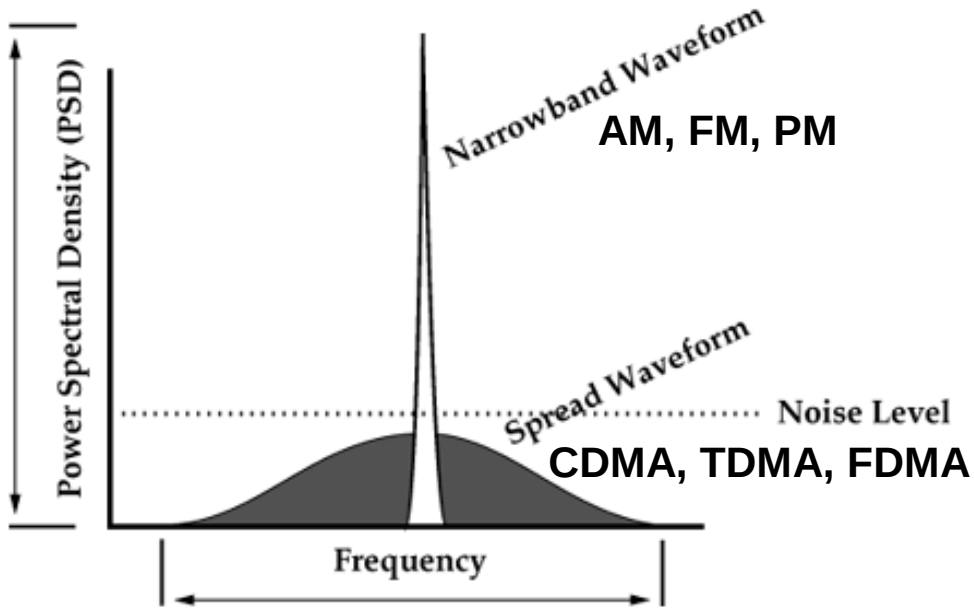
(MIR™ is UC/LLNL I.P.)

Spread Spectrum (SS) Techniques

The transmitted signal is spread over a wide frequency band, much wider than the minimum required bandwidth to transmit information.

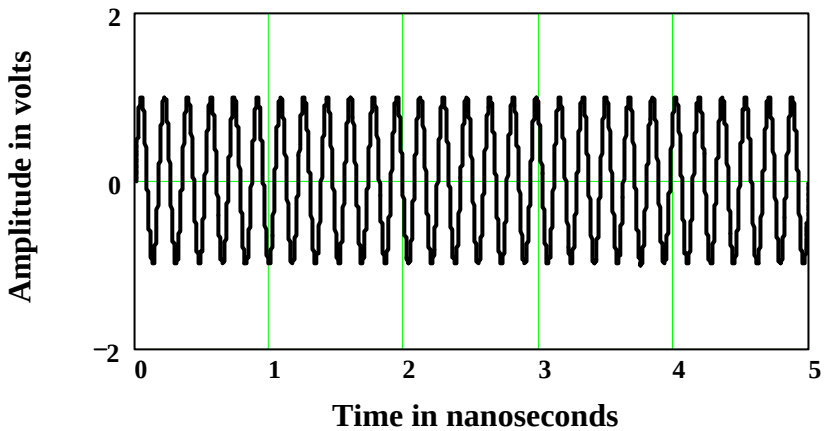
SS Techniques:
- Direct Sequence SS
- Frequency Hopping SS
- Time Hopping SS
- Pulsed FM (Chirp) SS
- Hybrid Systems
- Ultra Wideband??

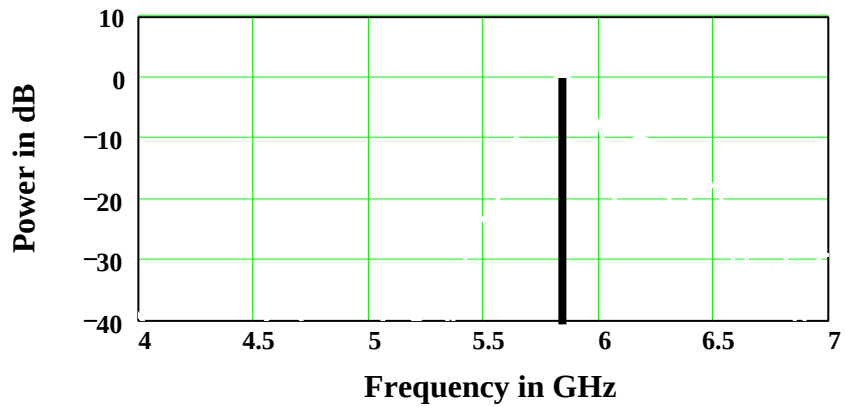
Advantages of SS:
- Resists Interference
- Alleviates Multipath
- Share Same Frequencies



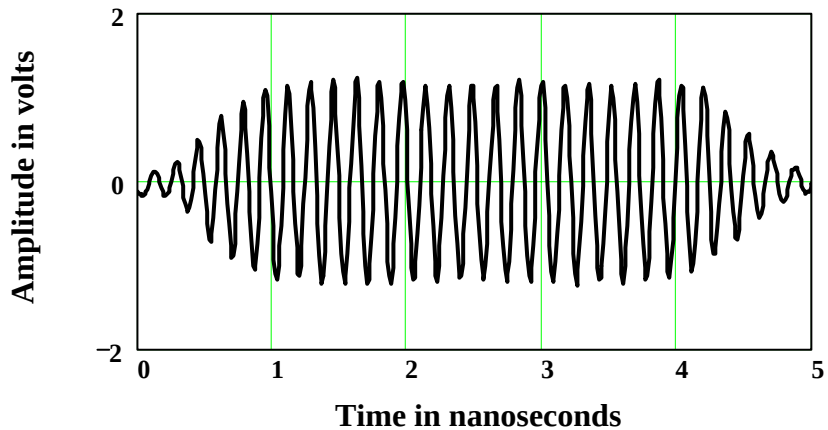
Motivation: Allows more users access to a limited amount of scarce frequency spectrum. Multi-billion $$ industry.

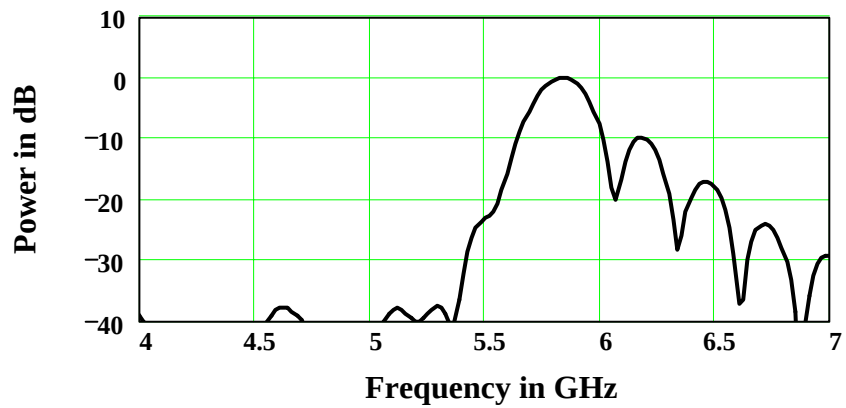
Time and Frequency Domain Signals (1)





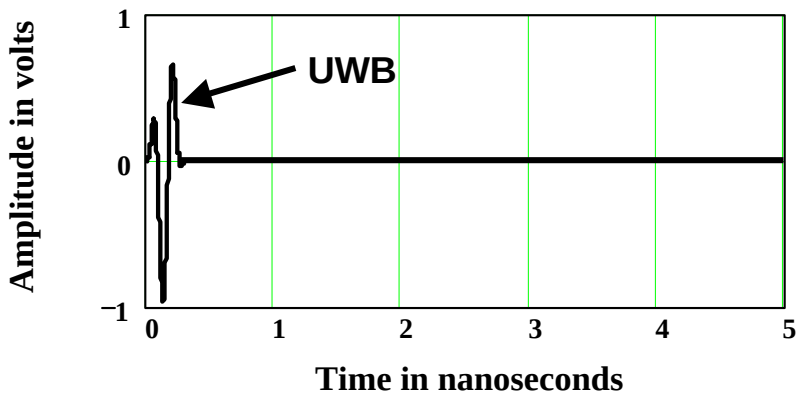
Narrow band (NB) Continuous Wave (CW) Signal

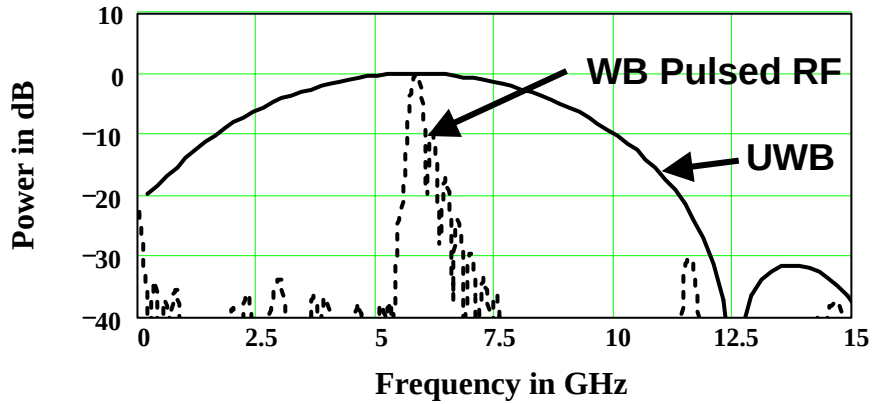




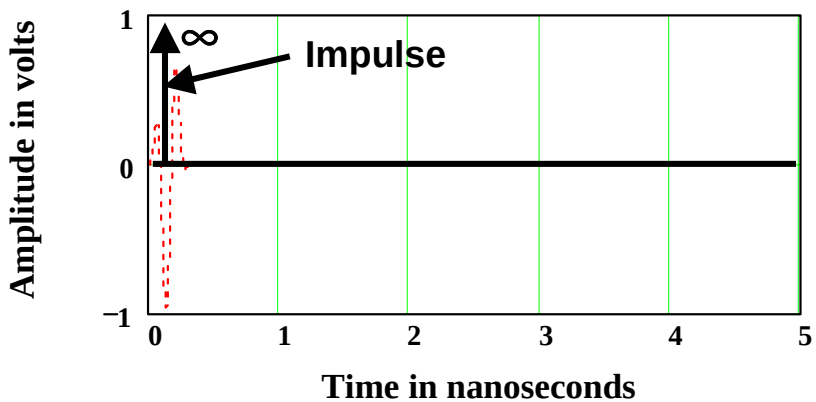
Wideband (WB) Pulsed RF Signal (approved by FCC)

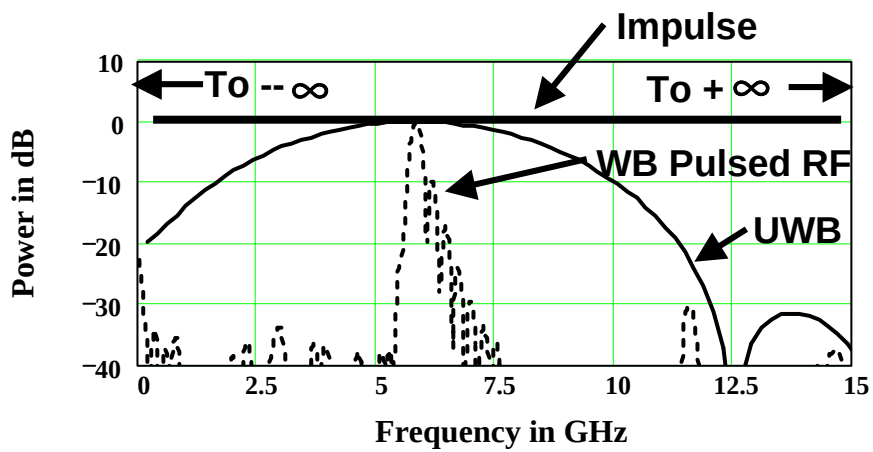
Time and Frequency Domain Signals (2)





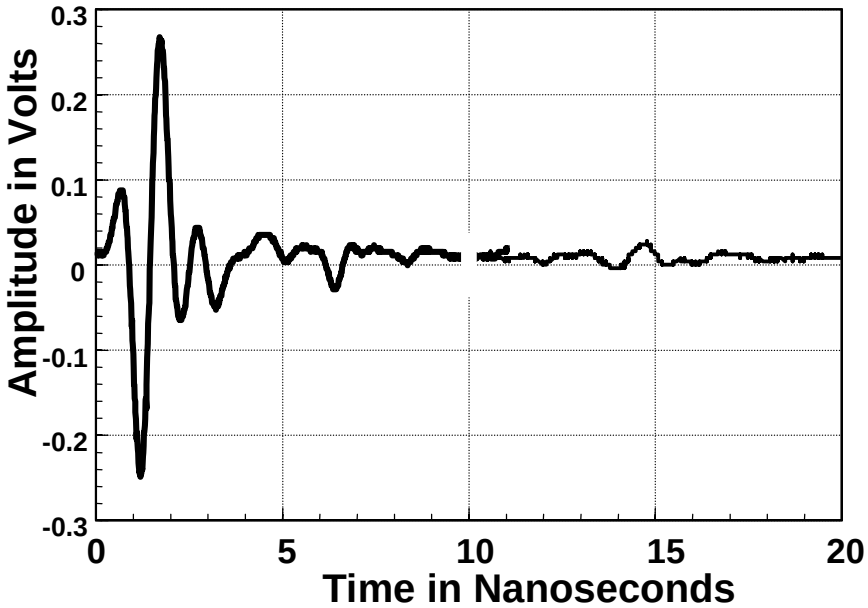
Ultra Wideband (UWB) Signal (not approved by FCC)





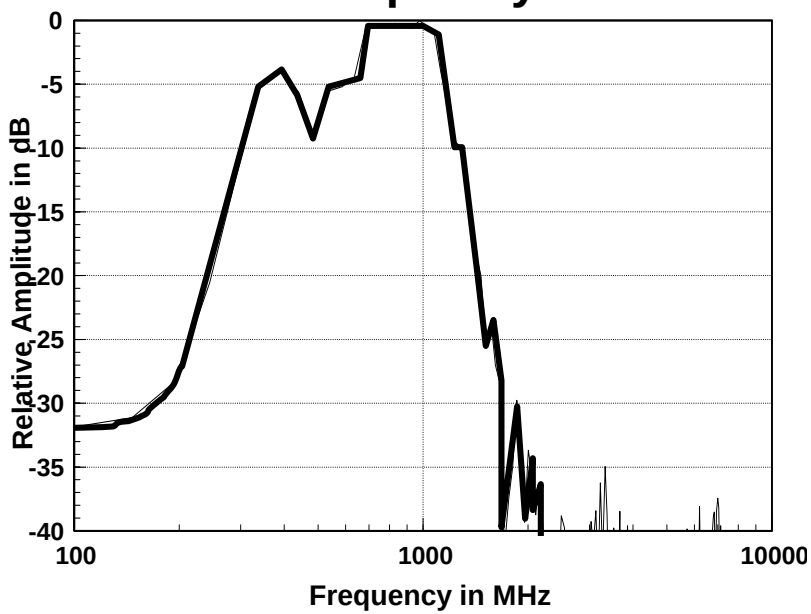
Impulse Signal (not realizable)

Ultra-Wideband Signal

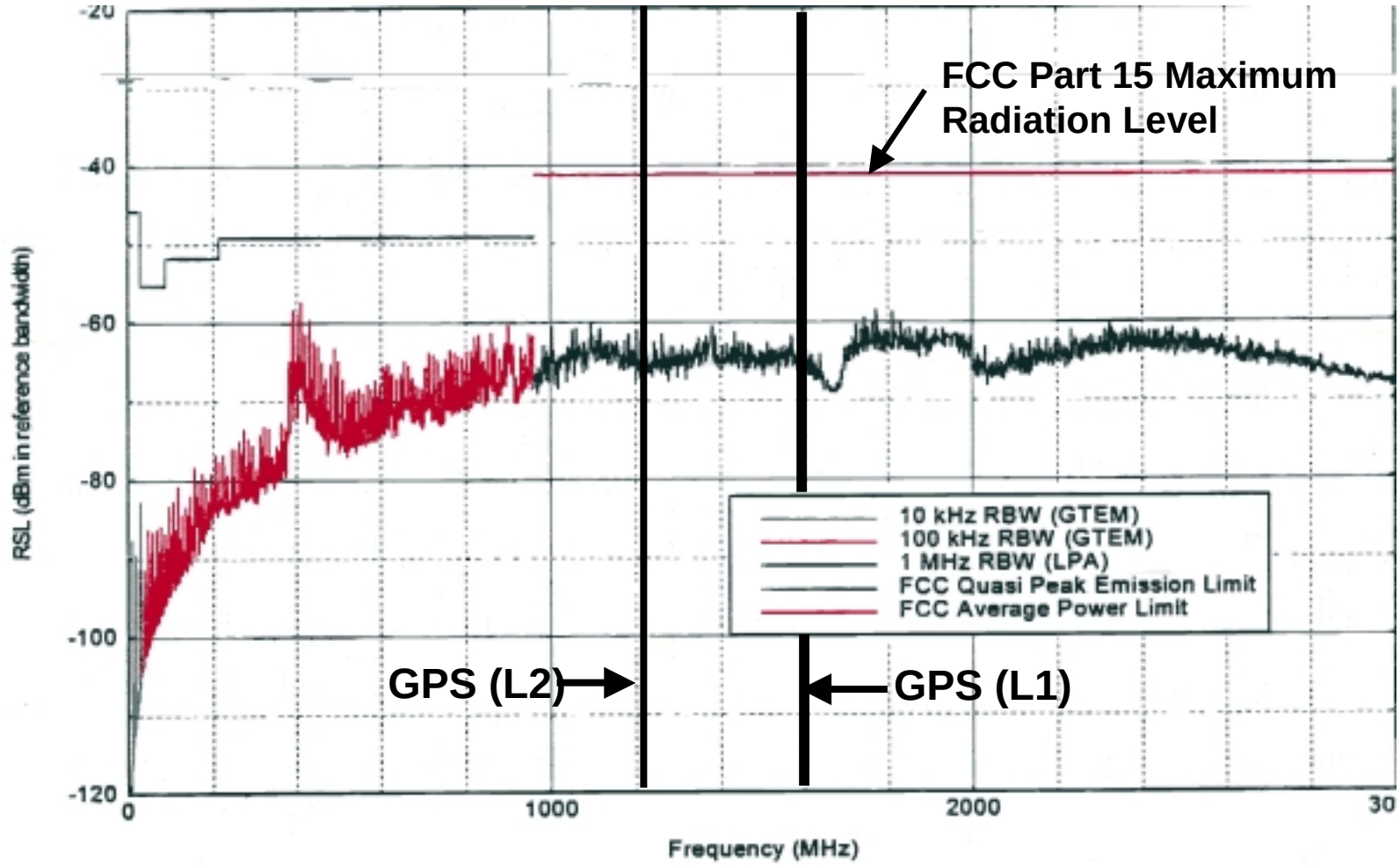


Time Domain

Frequency Domain



UWB Device Spectrum: EIRP (dBm) vs. Frequency

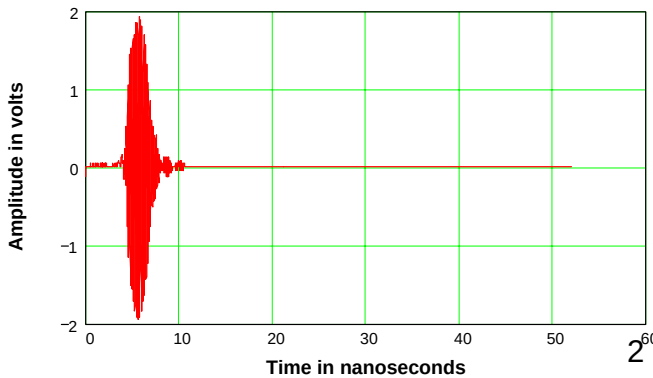


Note: FCC measured spectrum of Zircon, Inc. UWB device. Zircon received a FCC waiver to Part 15 on June 29, 1999 to market an UWB device.

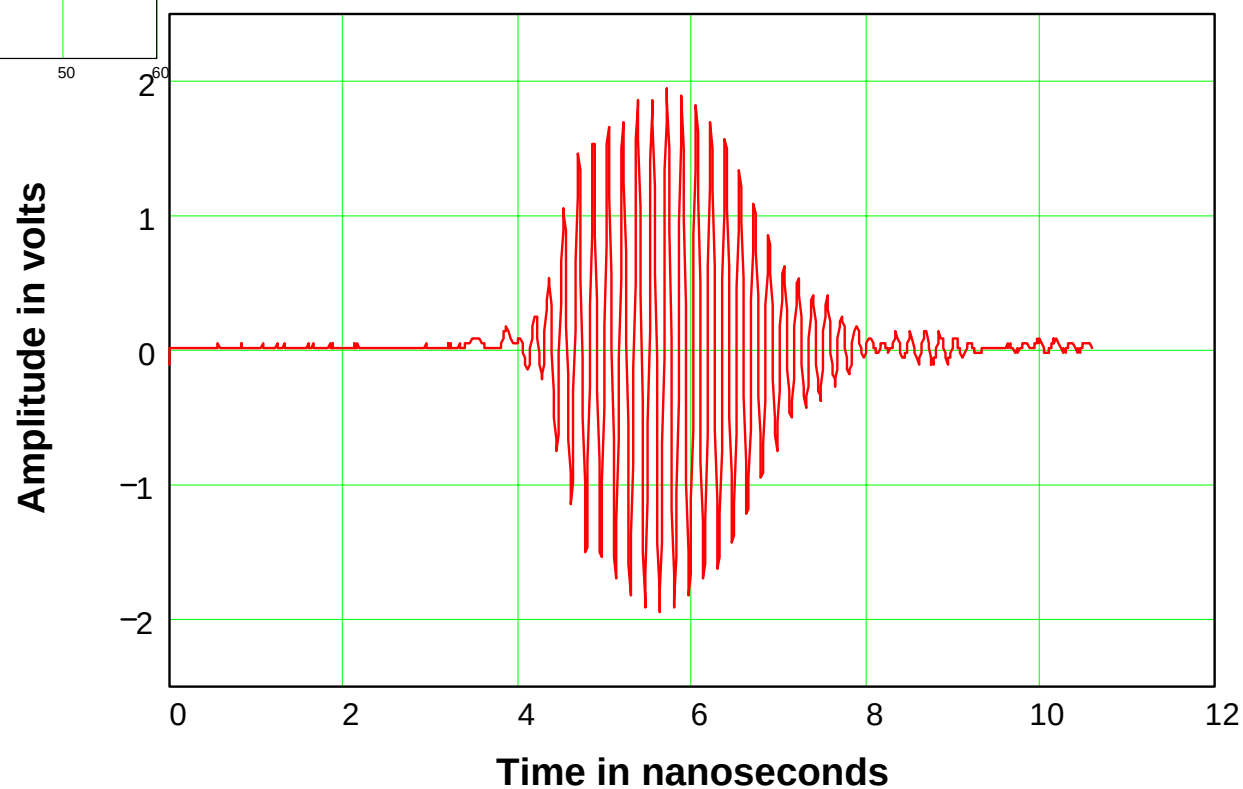
Examples of Ultra Wideband

• Natural Lightening	~20 ns
• EMP: Nuclear Atmospheric Detonation	>10 ns
• Nuclear EMP Simulators	~2 ns
• Ground Penetrating Radars	~10 ns
• Foliage Penetrating Radars	~5 ns
• Pulse-Pos. Modulation Communications	~0.4 ns
• Area Intrusion Detectors for Security	~1 ns
• Liquid Level Control Devices (TDR)	~0.2 ns

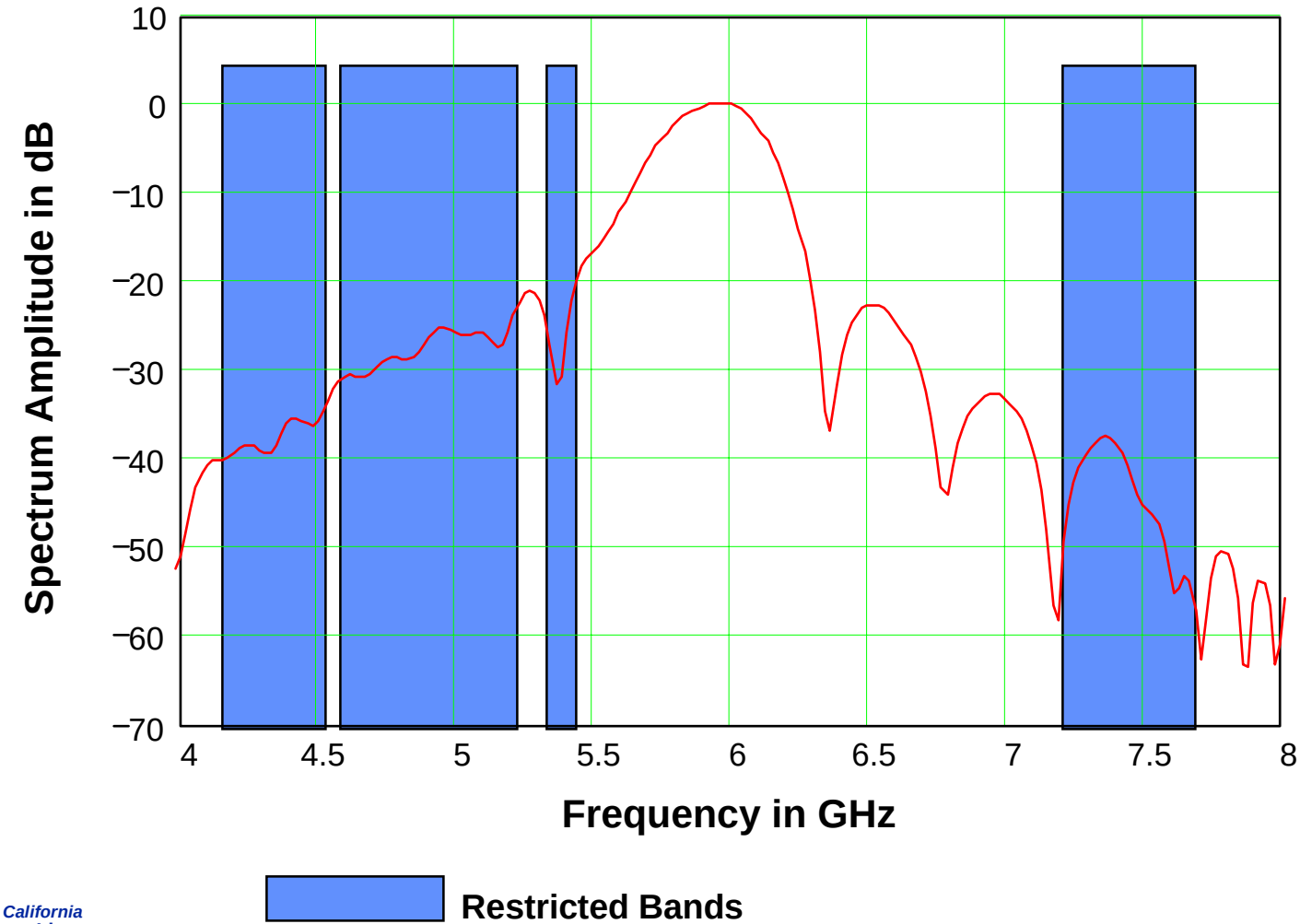
Wideband (WB) Pulsed RF



Expanded



5.8 GHz Pulsed RF



UWB Technologies and Applications

- **Penetrating/Identification Radar**
  - Ground Penetrating Radar (GPR)-- Geophysics
  - Detects and identifies targets hidden in foliage, buildings or beneath the ground
- **Very Low Power, Short Range Radar**
  - Liquid level monitors
  - Conduit and rebar imaging in concrete walls
- **UWB Radio Systems**
  - Intra-home and intra-office communication
  - Stealthy communications--law enforcement

Each technology may need different spectrum management.

Penetrating/Identification Radar

- **Relatively high power and large bandwidth:**
  - Large bandwidth for image quality and resolution
  - Operating range: 100 to 1000 MHz
  - Relatively high power for penetration depth
- **Engineering considerations:**
  - Maximize radiation into the ground or material
  - Minimize radiation into the air with shielding
- **Spectrum management:**
  - Control emission level into free space in operating mode
  - Control sale of these radar systems
  - Control where used relative to existing users
  - Wall penetrating units may be a problem

Very Low Power, Short Range

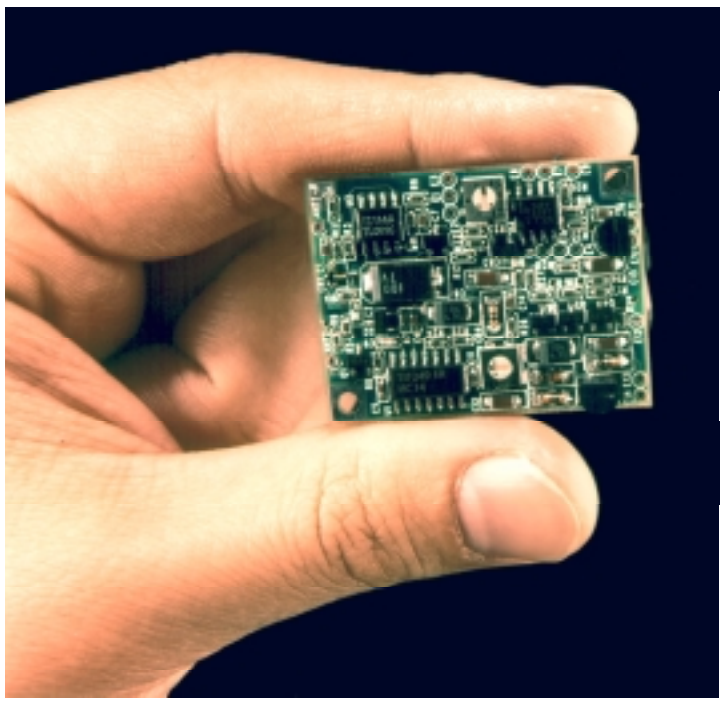
- **Range less than 10 feet**
- **FCC Part 15 devices**
  - Motion sensors
  - Liquid level monitors
  - Stud finders
- **Spectrum management issues:**
  - Determine level of harmful interference to existing users -- FAA, GPS, cell phones
  - Assess aggregate effect of multiple UWB devices.
  - Once allowed under Part 15, spectrum control is lost

UWB Radio Systems

- **Radio transmission uses the airways**
  - Communication networking requires multiple users
  - Potential for creating harmful interference
- **Engineering considerations:**
  - Move spectrum up and away from FAA restricted bands
- **Spectrum management issues:**
  - Assess aggregate effect of multiple UWB users
  - Does the level of harmful interference increase?
  - Are there other wireless technologies that will work?
  - Move operating frequencies to unoccupied part of the spectrum
  - Once allowed under Part 15, spectrum control is lost

UWB Radar Grew from LLNL's Extensive Laser Diagnostics Research

Based on pulse generation technology originally developed for Laser Fusion at LLNL

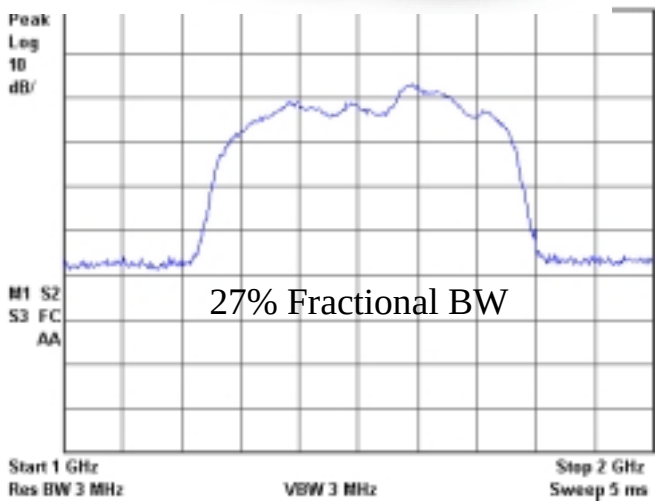


Complete MIR* motion sensor (minus battery and antenna)

- **Unique, patented technology**
  - — **Compact**
  - — **Inexpensive**
  - — **Wideband pulsed radar**
  - — **Low power**
- **Applications in:**
  - — **Short-range motion sensing**
  - — **Distance/light measurements**
  - — **High-resolution Imaging**
- **On-going government programs in:**
  - — **Bridge inspection**
  - — **Mine detection**
  - — **Security**
  - — **Explosives diagnostics**
  - — **Aircraft safety**

(*Micropower Impulse Radar)

UWB Communications (MSSI)



Ultra Wideband Handheld Radios

Design Characteristics

- **LPI/D digital voice/data radio**
- **Full duplex**
- **Packet burst, CSMA-CD**
- **128 kb/s (CVSD voice), 115.2 kb/s (data)**
- **1W peak**
- **400 MHz instantaneous bandwidth**
  - **Unique, spectrally shaped waveform design**
  - **L-band center frequency**
  - **27% fractional BW (IBW/fo)**
- **Range**
  - **1-2 km with low profile, omni antennas**
  - **Multiple mile performance with higher gain antennas**

(Multispectral Solutions, Inc., Gaithersburg, MD)

UWB Communications (MSSI)

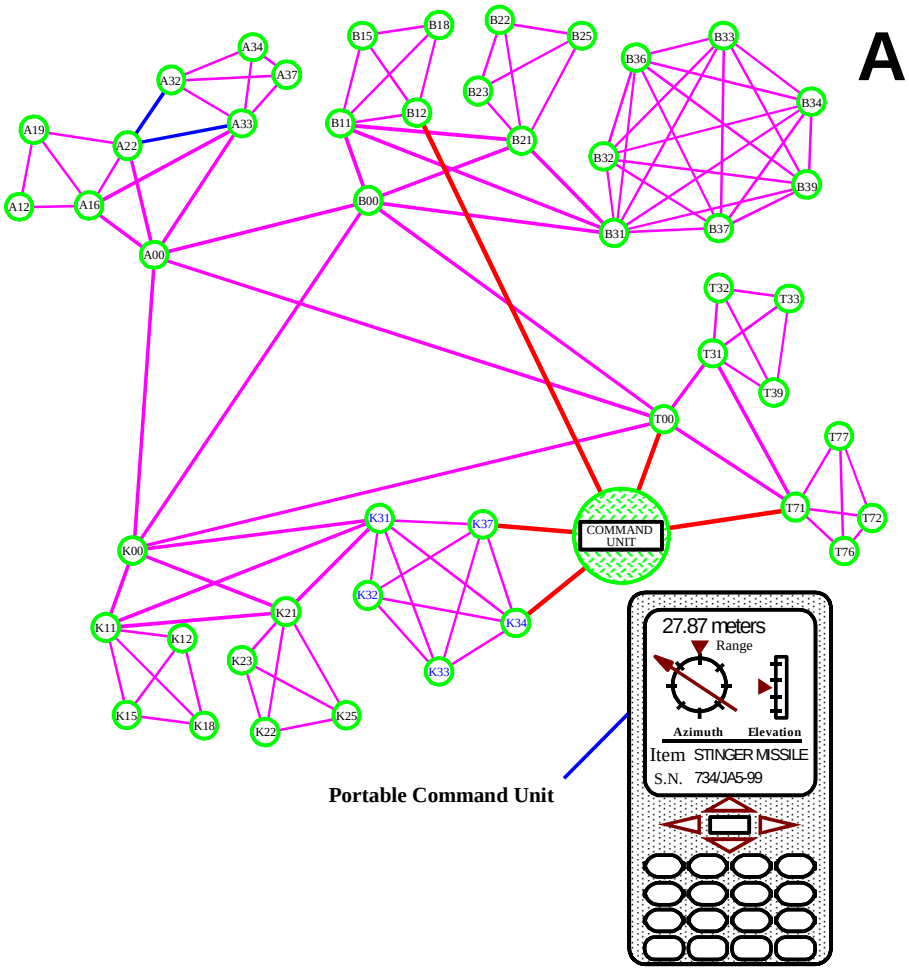
High-speed UWB Radios

Design Characteristics

- **LPI/D command & control uplink and video downlink for UAVs and ground robots**
- **Full duplex TDMA packet burst**
  - **C&C uplink (115.2 kb/s)**
  - **Video downlink (1-25 Mb/s compressed)**
- **2W peak**
- **400 MHz instantaneous bandwidth**
  - **Spectrally shaped waveform design**
  - **L-band center frequency**
    - **C-band version also developed**
  - **27% fractional BW (IBW/fo)**
- **Range**
  - **Up to 5 miles LOS, omni antennas**

(Multispectral Solutions, Inc., Gaithersburg, MD)

UWB Localizer Network*



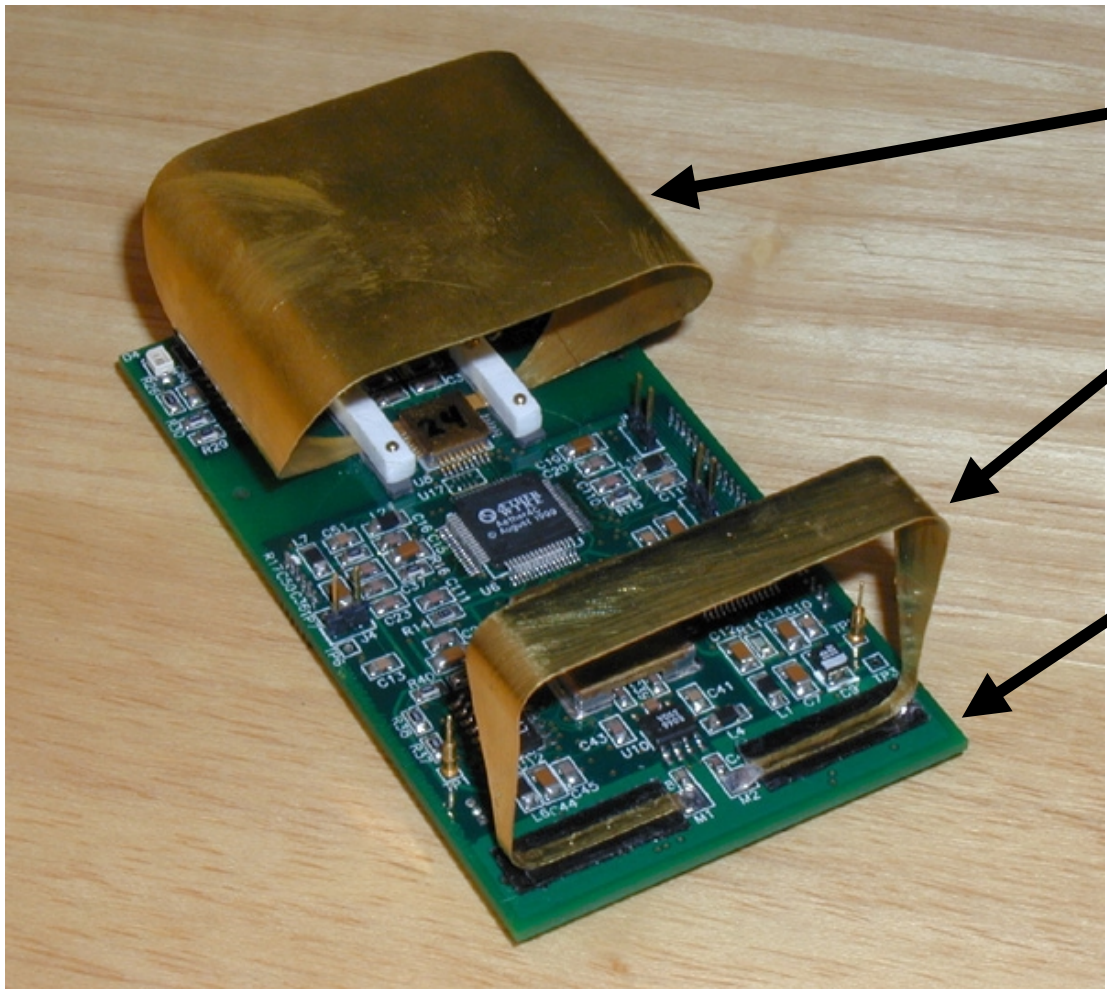
Azimuth, Elevation & Range

Design Characteristics

- Integrated, low-power, UWB transceivers for distributed position location and communication
- Determines azimuth, elevation and distance of nodes to centimeters
- Concise common clock for each node
- Two-way communication between each node for data flow

*(Aether Wire & Location, Inc., Nicasio, CA)

UWB Localizer Unit*



Transmit antenna

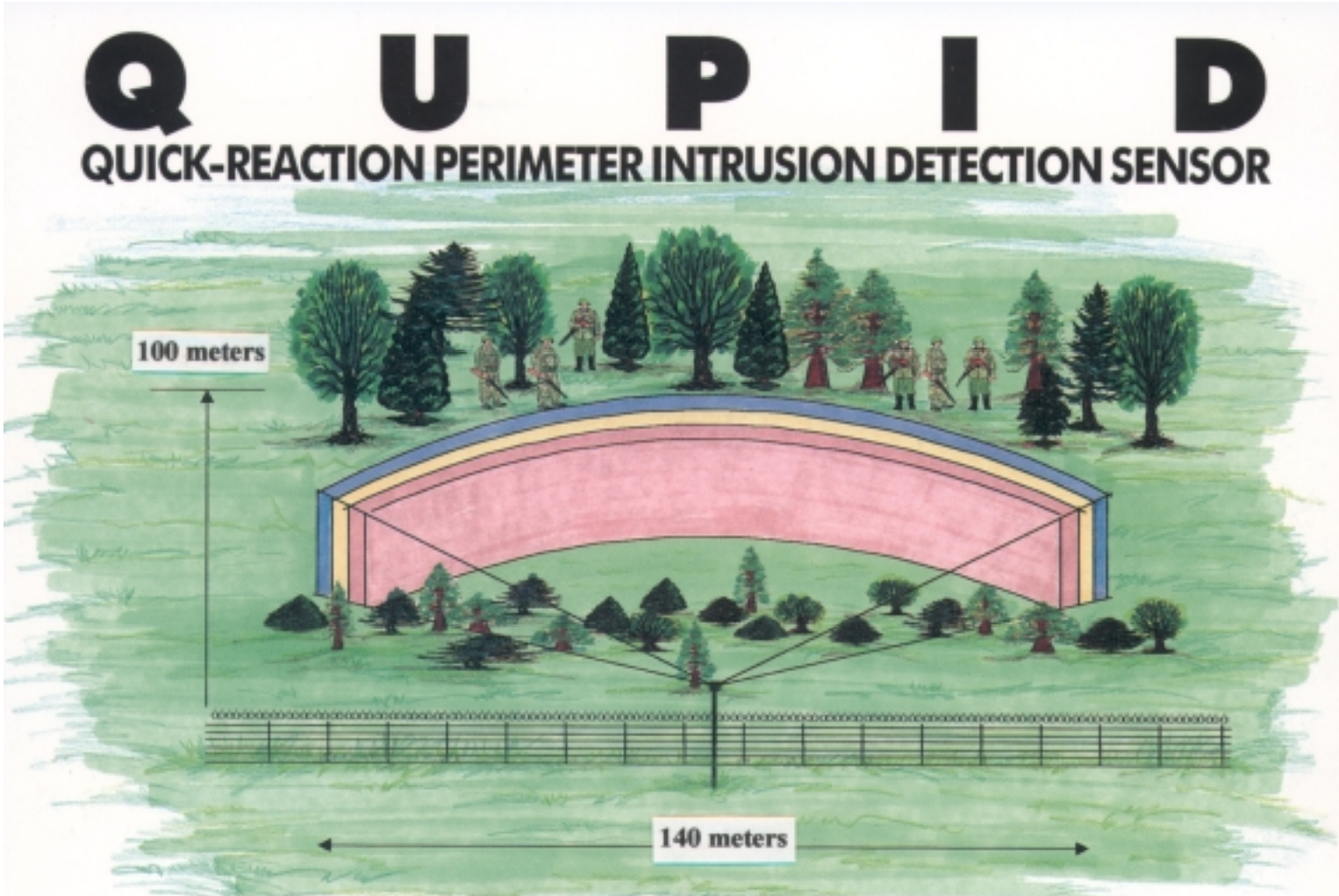
Receive antenna

Board dimensions 2.0" x 3.6"

Fourth generation Localizer prototype.

*(Aether Wire & Location, Inc., Nicasio, CA)

UWB Intrusion Sensor*



*(ANRO Engineering Inc., Sarasota, FL)

FCC/NTIA Issues/Status on UWB (1)

- FCC received UWB waiver requests from three companies in early 1998:
  - U. S. Radar, Inc. for ground penetrating radar
  - Time Domain Corp. for communications
  - Zircon, Inc. for wall scanning radar
- FCC released UWB Notice of Inquiry Sept. 1998
- FCC released Notice of Proposed Rule Making (NPRM) In the matter of Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems on May 11, 2000

FCC/NTIA Issues/Status on UWB (2)

- FCC received comments on the UWB Notice of Proposed Rule Making (NPRM) in October 2000
- Stanford University test results show that some UWB devices interfere with GPS
- NTIA tested UWB devices for harmful interference during last half of 2000
- NTIA releases two UWB test reports: January and March 2001
- Potential of harmful interference to GPS receivers by UWB systems, operating below 3 GHz, will likely delayed Part 15 use of these frequencies by UWB devices

Summary of UWB/GPS Test Results

Test	Min. Range	Max. Range	Average	Criteria
Stanford Univ. (Funded by DOT)	1 meter	100 meters	33 meters over all modes tested	Distance for loss of first satellite
NTIA				Distance at maximum allowable system tolerance
Aviation	185 meters	1556 meters	633 meters	
Terrestrial	28 meters	78 meters	41 meters	
Surveying	102 meters	103 meters	102.5 meters	
NASA/ Time Domain	0.33 meter	4.5 meters	0.67 meters	Distance when fewer than 5 of 11 satellites tracked
Johns Hopkins	3 meters	3 meters	3 meters	Distance for loss of lock on all satellites
U of Texas (Funded by Time Domain)	3 meters	>25 meters	~ 20 meters	Distance for loss of first satellite

From: Reply Comments of Multispectral Solutions, Inc. to FCC on March 16, 2001.

Summary

- Long history of R&D in impulse and UWB technology
- UWB is an extension of Pulsed RF where the pulse contains a few RF cycles and has a large instantaneous bandwidth
- A monocycle (single RF cycle) is the shortest possible radiated pulse
- Practical UWB pulses are on the order of a nanosecond
- Intentionally radiating UWB signals requires FCC approval and Part 15 rules changes

UWB WEB References

- http://www.aetherwire.com/ (Good historical material)
- http://www.sedona.net/service/anro/
- http://www.fantasma.net/
- http://www.getradar.com/
- http://www-lasers.llnl.gov/lasers/idp/mir/
- http://www.multispectral.com
- http://www.time-domain.com/
- http://ultra.usc.edu/ulab/
- http://xtremespectrum.com/