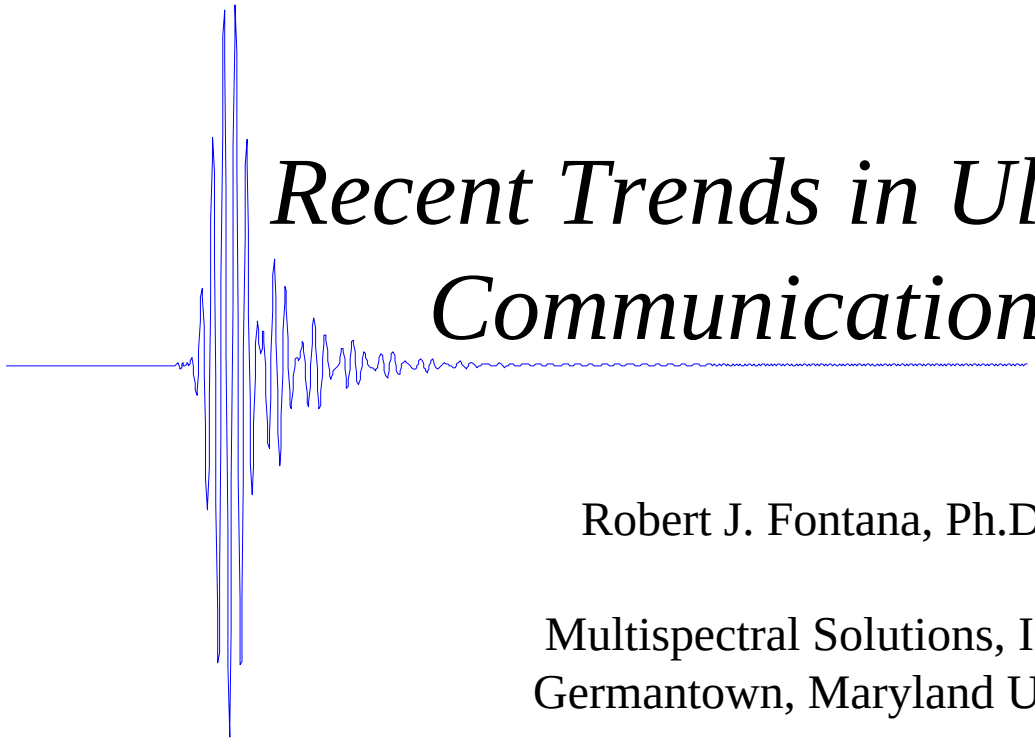

Recent Trends in Ultra Wideband Communications Systems

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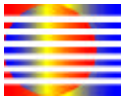

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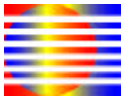
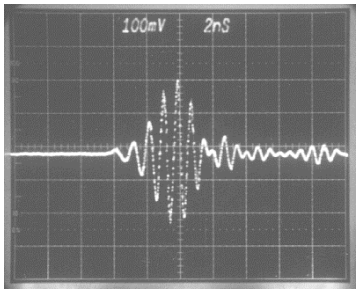
UWB Communications Systems

- What is UWB?
- Brief history of UWB communications
- Examples of recently developed UWB systems
  - Full duplex voice and data communications
  - High-speed video relay
  - Non line-of-sight UWB transceiver for extended ranges (> 60 nmi) over water
  - UWB tags
  - Tactical range, wireless *ad hoc* networks
- Comments on recent controversies over proposed commercial use of UWB technology under FCC Part 15 rules

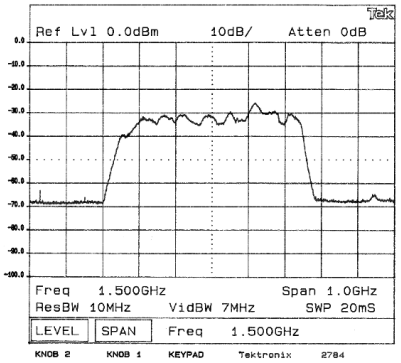


What is Ultra Wideband?

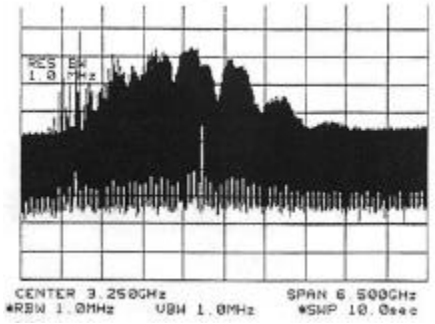
- *Short pulse waveforms*
  - *"Carrier-free","baseband","impulse"*
  - *A few cycles of an RF carrier*
- *Very large fractional bandwidths*
  - *Bandwidth inversely proportional to pulse duration*
  - *Typically > 25% (DARPA 1990 definition)*
  - *Low duty cycles resulting in low average energy densities*
- *Typically produced by "impulse- or step-excited" antennas, filters, etc.*
  - *Not all UWB created equal (Regulatory issues)*
    - *Spectrally filtered*
    - *Spectrally unfiltered*



Time response

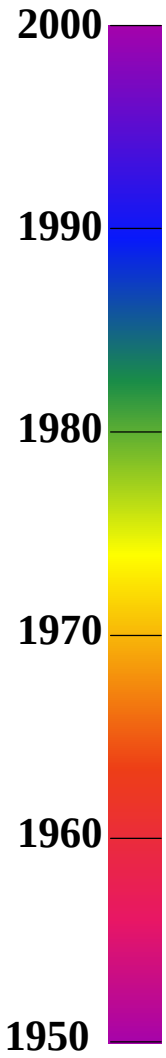


Spectrally filtered



Spectrally unfiltered

UWB Technology Development



2001 MSSI awarded 50th UWB contract

1994 First UNCLASSIFIED UWB communications programs

1990 OSD/DARPA “Assessment of Ultra-Wideband (UWB) Technology”

1986 First fielded “short pulse” UWB Communications system (Ross/Fontana)

Ross et al. – First demonstrated (free space) UWB communications system

1978 Bennett & Ross – “Time-Domain Electromagnetics and Its Applications” – Seminal paper

Morey – Fundamental patent on UWB GPR U.S. Patent No. 3,806,795 (April 1973)

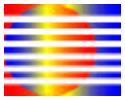
1973 Ross – Fundamental patent on UWB communications U.S. Patent No. 3,728,632 (April 1973)

1972 Robbins – Fundamental patent on single-pulse, quantum tunneling detector

1965 G. Ross – Sperry Research development of UWB technology (1965-1980)

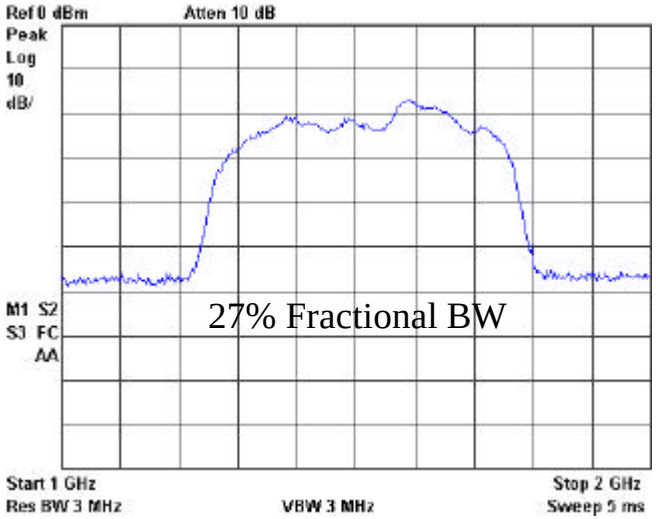
1963 G. Ross – Ph.D. thesis (with A. Papoulis) on time-domain electromagnetics

Late 1950’s Need for impulse response analysis of microwave N-ports (Lincoln Lab, Sperry, others)



UWB Communications

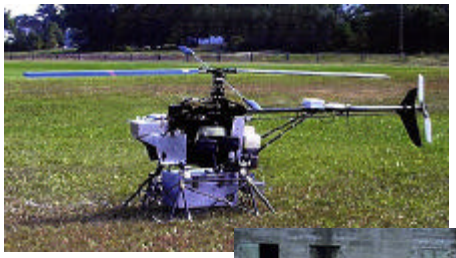
Full duplex voice and data communications



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 (depending upon terrain)
  - 5+ mile performance with higher gain antennas

UWB Communications
High-speed video relay

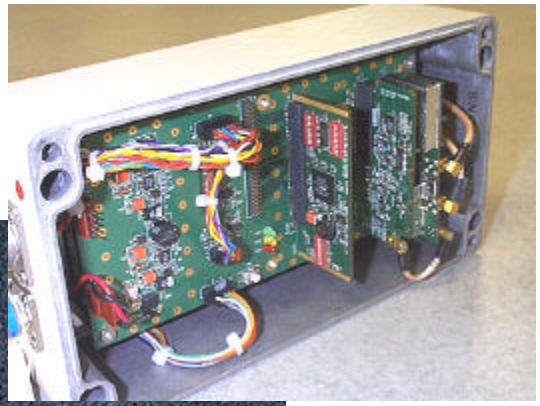


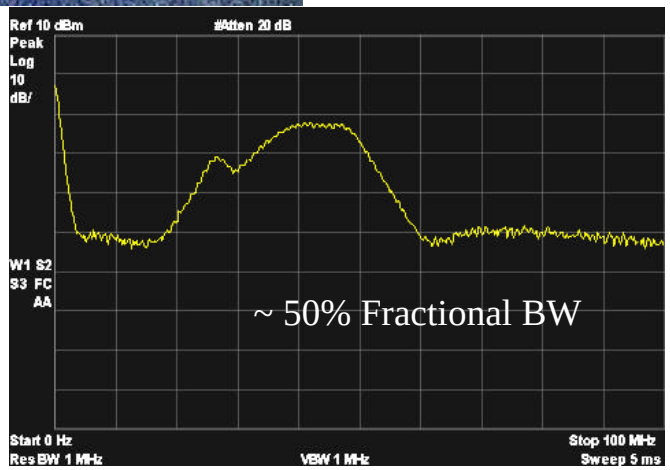
Design Characteristics

- 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 ERP
- 400 MHz instantaneous bandwidth
  - Spectrally shaped waveform design
  - L-band center frequency
    - C-band version developed but not fielded
  - 27% fractional BW (IBW/fo)
- Range
  - 5 miles LOS, omni antennas

UWB Communications

Non line-of-sight UWB transceiver

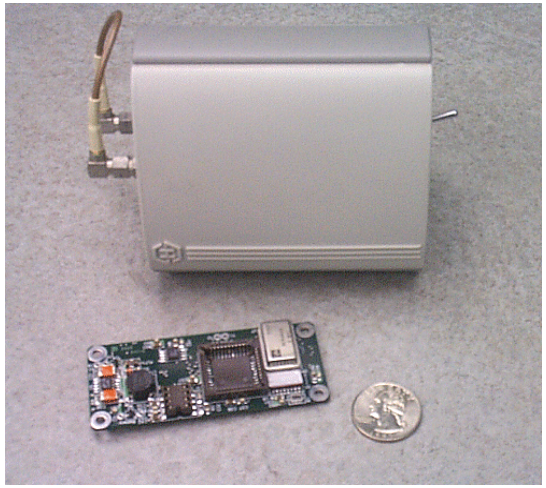




Design Characteristics

- Non-LOS radio using surface/ground wave propagation
- Full duplex voice/video
- 850 kb/s (compressed video)
- 120W peak, low VHF (30-50 MHz)
  - 50% Fractional BW
- Relay mode (packet forwarding)
- Range
  - 60 nmi over sea water
  - On land, range depends upon terrain, ground permittivity & conductivity – typically > 10 miles

UWB Communications
Ultra Wideband Tags

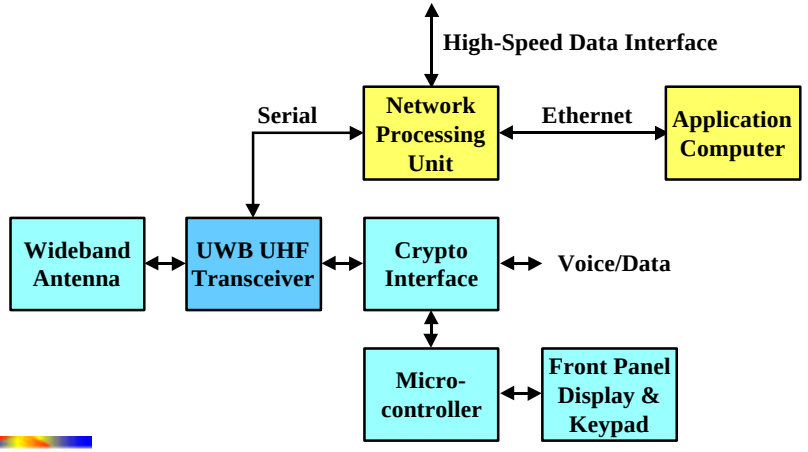


Design Characteristics

- UWB tag for detection and identification of problem drivers
- Vehicle-to-roadside communications of driver & vehicle information (image, data)
- 0.2W peak, 400 MHz instantaneous BW
  - Spectrally shaped waveform design
  - L-band center frequency
  - 27% fractional BW
  - 115.2 kb/s packet burst mode
- Range
  - 800’ range in high multipath environment
  - 2000’+ (line-of-sight)

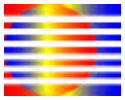
UWB Communications Example

Tactical range, wireless ad hoc networks



Design Characteristics

- Mobile ad hoc Network (MANET)
  - Multi-node, multi-hop
- FDM/TDMA multiple access
  - GLOMO – Rockwell-Collins Orthogonal Domain Multiple Access (ODMA)
- Type 1 encryption
  - Thales Multiband Inter/Intra Team Radio
  - 128 kb/s voice, 115.2 kb/s data
- 1.544 Mb/s (T1) virtual channel
- 10W peak, > 20% fractional BW (VHF/UHF)
- Range
  - 1-2 km (node-to-node) with omni antennas
  - Demonstrated 10-node *ad hoc* network



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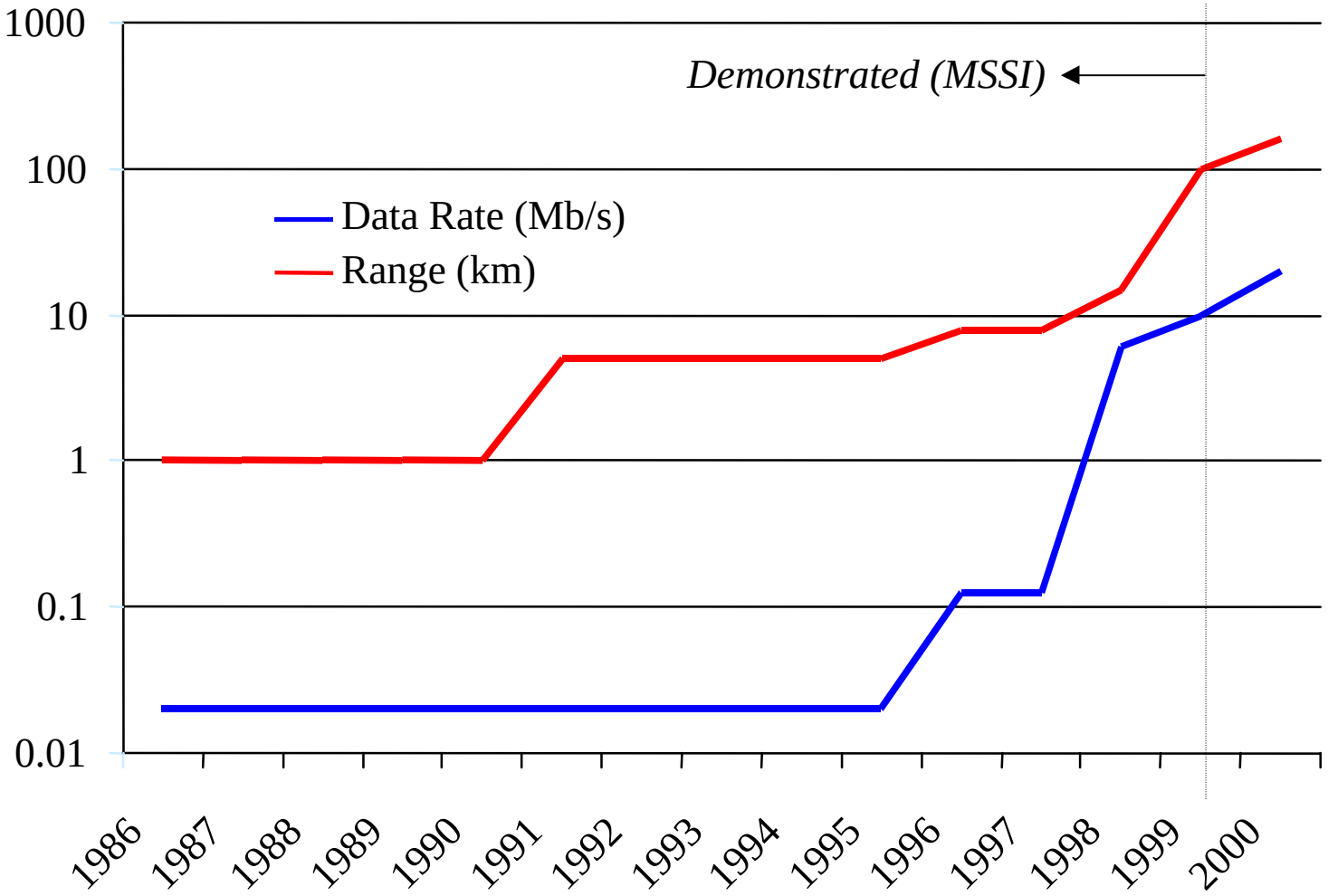
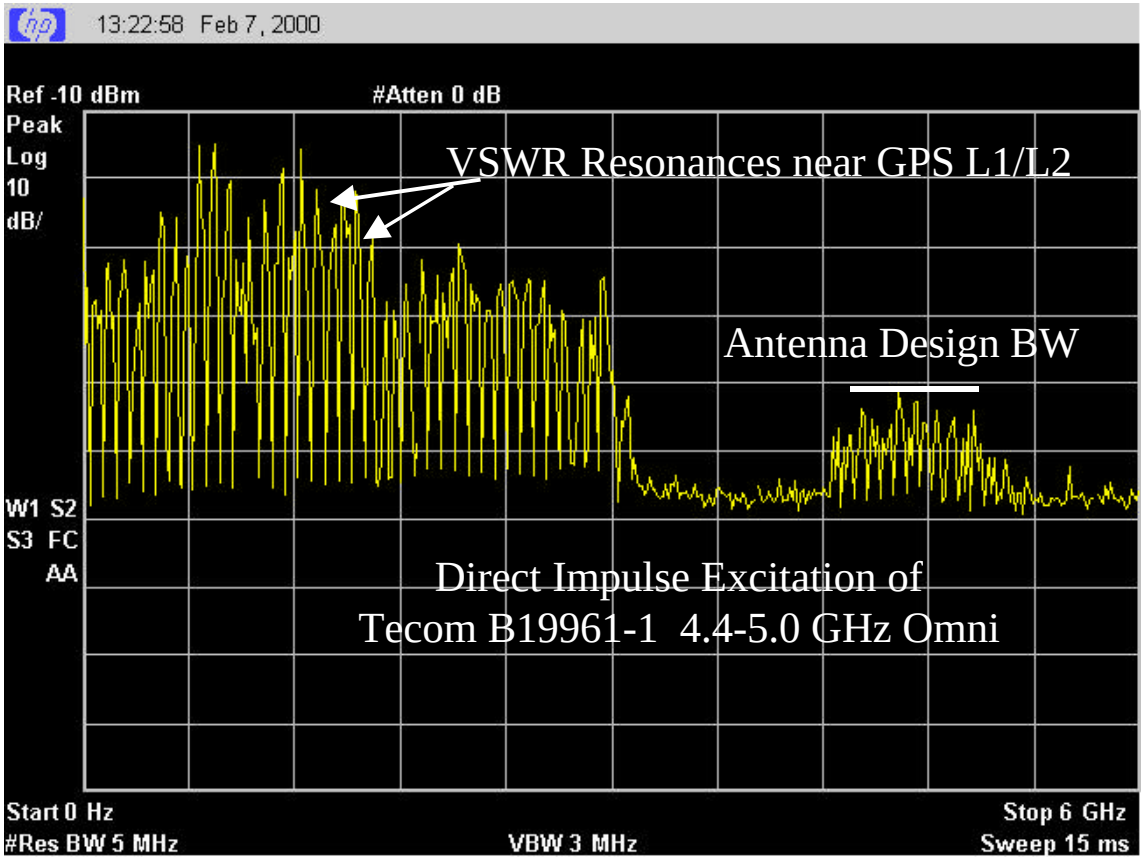
UWB Technology Advances



Regulatory Controversy

- Regulatory Issues
  - ET 98-153 Ultra-Wideband Transmission Systems
    - Notice of Inquiry (NOI) issued September 1998;
    - Notice for Proposed Rule Making (NPRM) issued May 2000
    - Rule making anticipated 4th Quarter 2001
  - UWB proponents desire operation across §15.209 restricted bands
  - Spectral filtering
  - FACT: Interference from UWB has been demonstrated below 3.1 GHz
    - NTIA, Stanford University, Sprint, Time Domain, University of Texas tests show potential interference to Government radars and GPS
    - Interference effects aggravated by high pulse repetition frequency (PRF) and use of multiple UWB transmitters
- Recommendations
  - *NTIA* – operation below 3.1 GHz is "problematic" except for lower (<20 Mpps) PRF applications
  - *ATA et al. (40+ companies)* – stay above 5.46 GHz safety-of-life band
  - *MSSI* – Stay above 3.1 GHz
    - Part 15 emission levels (500 μV/m @ 3 meters)
    - 3.1 - 5.46 GHz – limit PRF to 20 Mpps
    - > 5.46 GHz with no PRF limits
    - Enables benefits of UWB technology for all potential applications, including high speed wireless LANs, *without interference to existing services*

Direct Impulse Excitation
Why is Spectral Filtering Needed?



Direct impulse excitation of an antenna cannot adequately control radiated bandwidth

Spectrally Filtered UWB Systems