MURI Review Agenda (Afternoon)

1:15 PM: Circuit Design

Panel: Bob Brodersen, Won Namgoong, Mike Chen, Ian O'Donnell, Stanley Wang

Topics: UWB Low Noise Amplifier Design in CMOS, low Power Integrated UWB Transceivers, CMOS Implementation Design for UWB Acquisition, Tracking and Detection

2:30 PM: Break

2:40 PM: Future Goals

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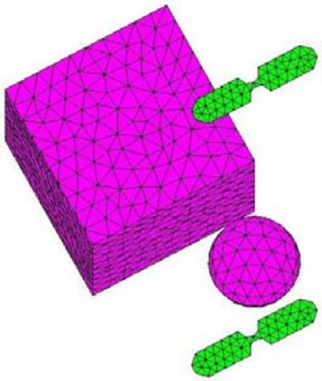
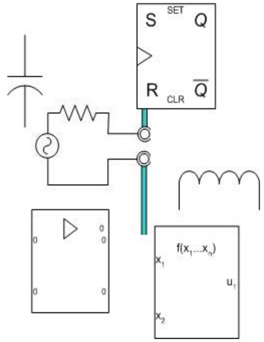
Long Range Goals

- Derive the fundamental limits for optimal transient radiation for arbitrary antennas.
- Demonstrate complete control of the received UWB waveform in an anechoic chamber environment.
- Develop multipath-embracing models and algorithms for UWB time transfer in links and networks.
- Quantify the effect of CMOS impairments on UWB system performance.
- Assemble a complete asset tracking system using real-time emulation and CMOS implementation.

Future Plans for UWB Link Simulator



- **Extend analysis to dielectric materials**
  to treat realistic scenarios with penetration/ attenuation through walls, packages, etc.



- **Waveform optimization with constraints**
  incorporate multipath effects and transmitter/ receiver circuitry limitations while approaching as closely as practical to the ideal result.

- **Antenna/Circuit/Waveform/Spectrum codesign**
  new and existing antennas combined with transmitter/receiver circuits to produce desired waveforms and or spectral characteristics.

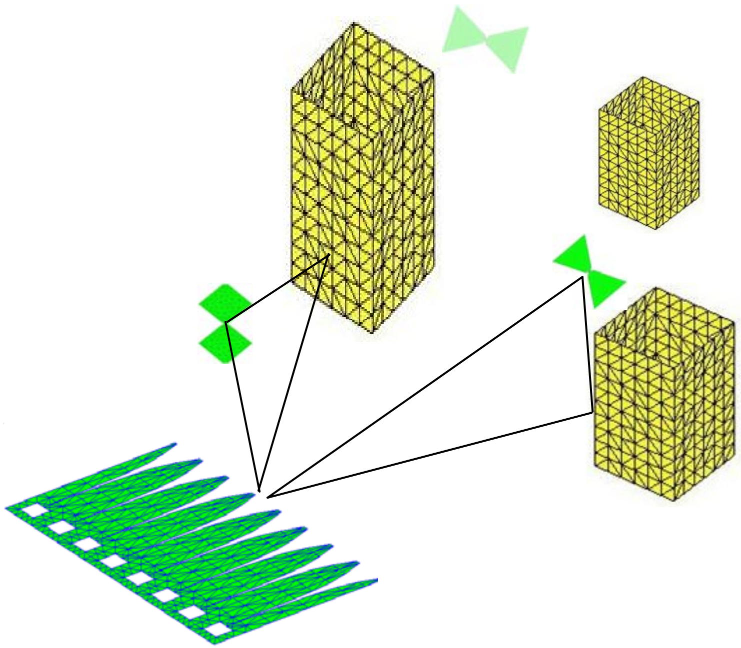
Future Plans for UWB Link Simulator

- **UWB antenna array performance**

UWB signal dispersion and DOA for base stations/interrogators.

- **Position location**

quantitative simulation of position location scenarios with realistic propagation, interference, etc.



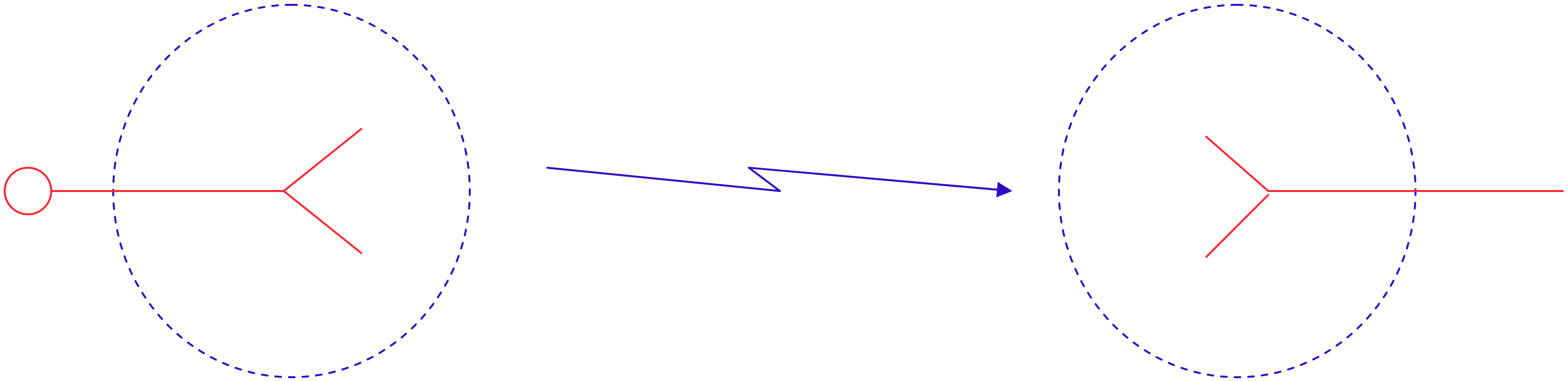
Topics for Future Work

- Fundamental limits on UWB links for arbitrary antennas
- Further performance evaluation of UWB antennas (biconical horns, TEM horns, LTSAs, Vilvaldi, and more)
- Experimental confirmation of UWB antenna evaluations
- Antenna matching using active negative inductance elements
- Modeling of multipath propagation

Future Work on Fundamental Limits for UWB Radio

Above results required specification of particular antennas for transmit and receive. After many analyses and optimizations, the question arises:

What is the BEST that can be done with ANY antenna ?



arbitrary transmit antenna enclosed by mathematical sphere of radius *a*

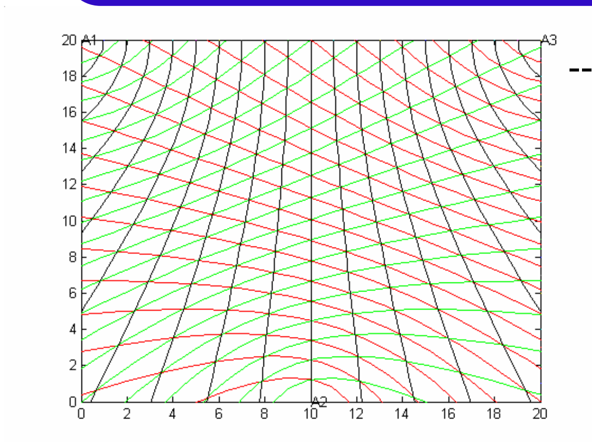
arbitrary receive antenna enclosed by mathematical sphere of radius *a*

Dave Pozar

Developing Research Emphases

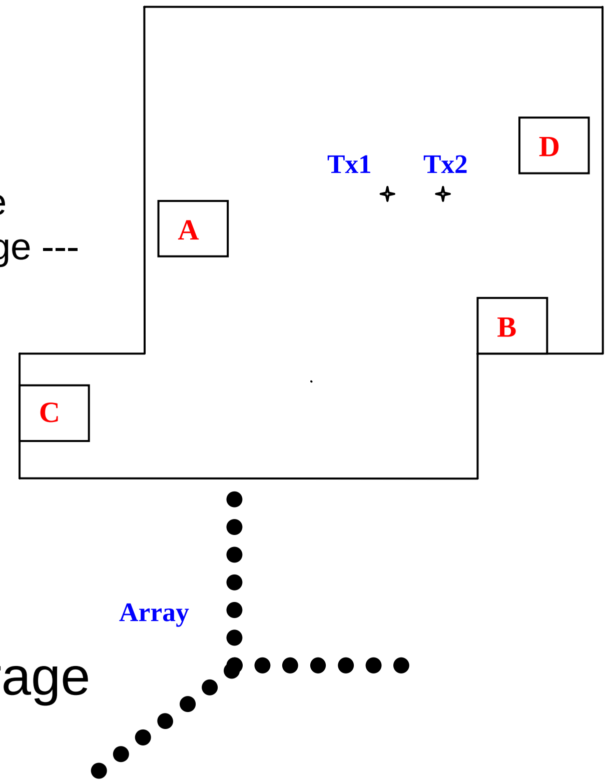
- **Cross-Polarization Measurements** – to assess the richness of multipath polarization diversity.
- **Control of the UWB Received Waveform** – via transmitted signal synthesis to optimize system efficiency and performance.
- **Frequency Domain Processing** – for lower work factors in multicorrelator implementations, a possible BEE related effort.
- **UWB Time Transfer** – distinguished by time multiplexed signaling, very high delay spreads relative to time resolution of signal.

Positioning with UWB Signals



--- Uncertainty regions

Siting for adequate
direct path coverage ---



Key problems:

- Finding direct path signals
- Placing measurement antennas for
    - adequate unobstructed direct path coverage
    - minimum worst-case uncertainty region volumes
- Wireless time transfer to measurement receivers

Generalized TR-UWB Techniques

- Develop signal/code design techniques for this unknown UWB channel technique
- Performance limits
  - Can it compete with “standard” UWB at a much lower complexity?
  - What is the optimal bandwidth?
- Revisit hardware implementation aspects (note that GE has a functioning TR-UWB system.
- What kinds of adaptivity/learning can be added to TR systems without adding significantly to complexity?
- What is the effect of interference on TR UWB systems? How can interference be mitigated?

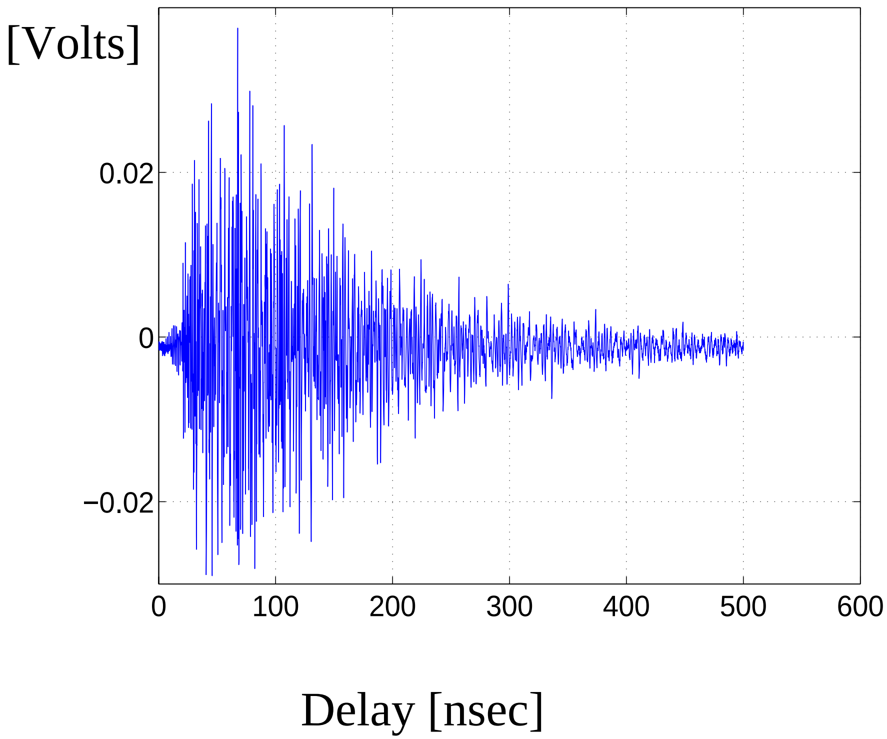
Dennis Goeckel Bob Scholtz

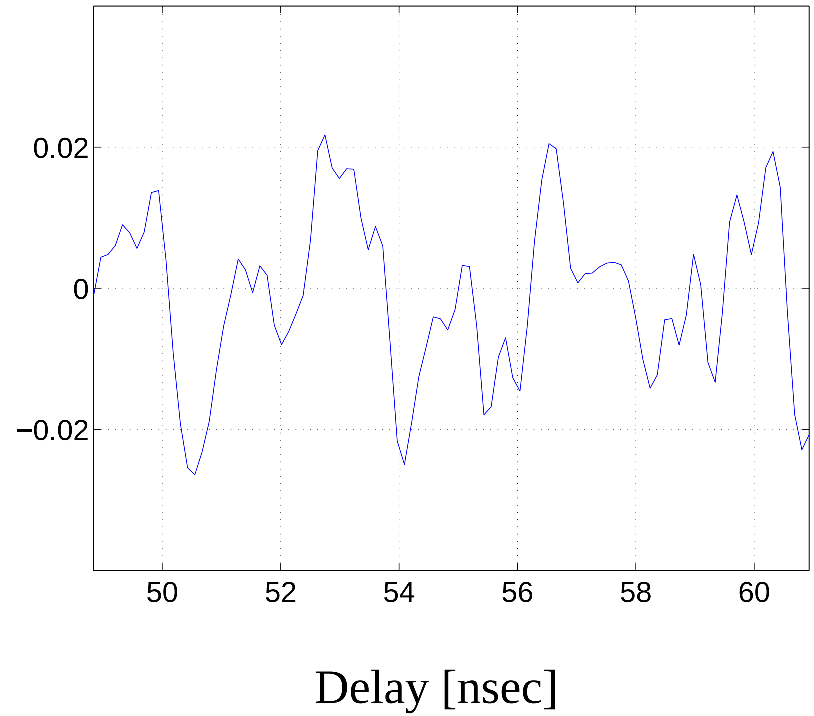
Propagation-Centric Network Capacity Limits

1. Leverage current UMass-Amherst NSF project (Janaswamy/Goeckel) on the asymptotic (large number of antennas) capacity of networks with MIMO links
   - Propagation models are analytic (bandwidth scalable)
   - Propagation models include multiple scattering
2. Validate for finite bandwidths using available propagation data
3. Extend to the multi-user network environment

Channel Uncertainty in Real Environments

Channel measured at USC UltRa Lab





Dana Porrat, David Tse

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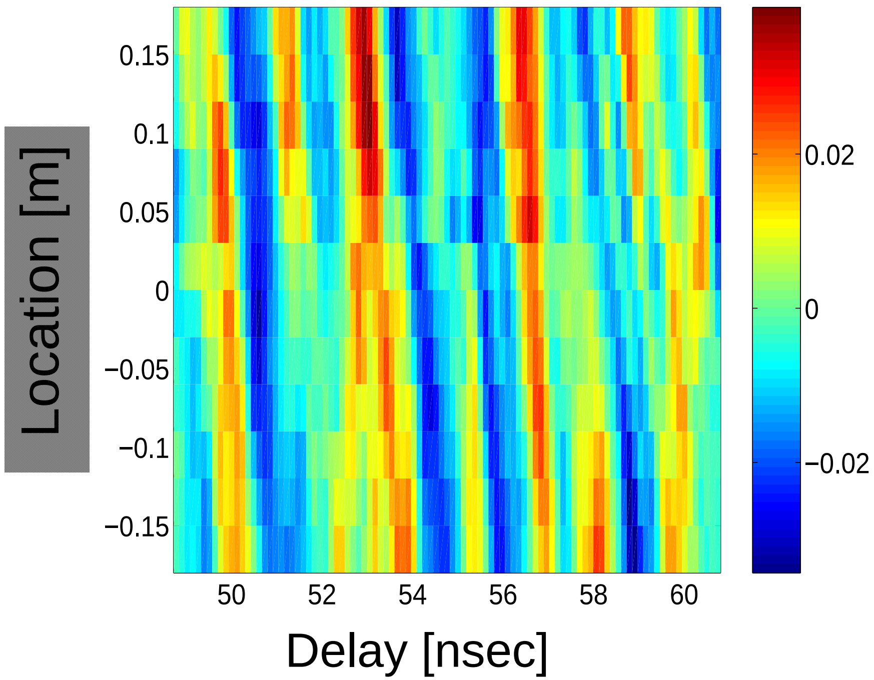
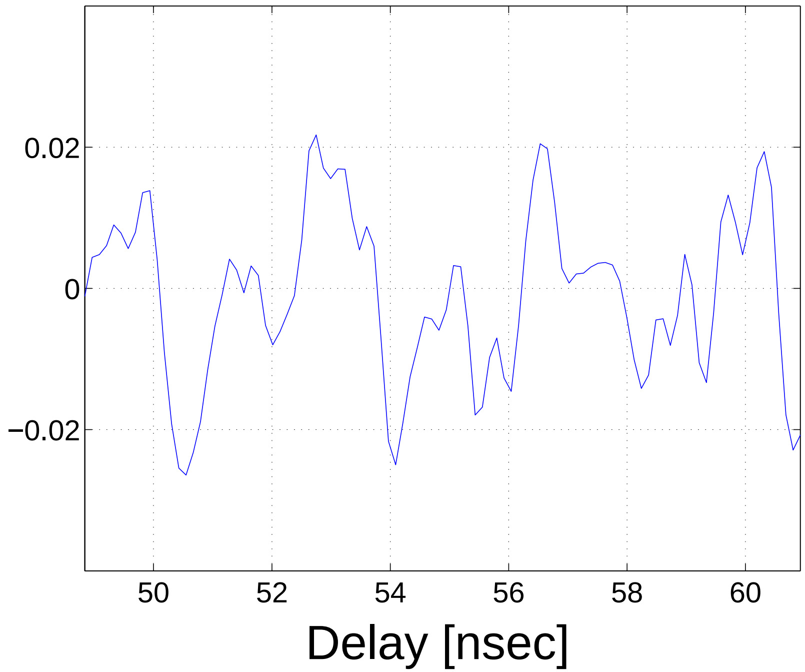
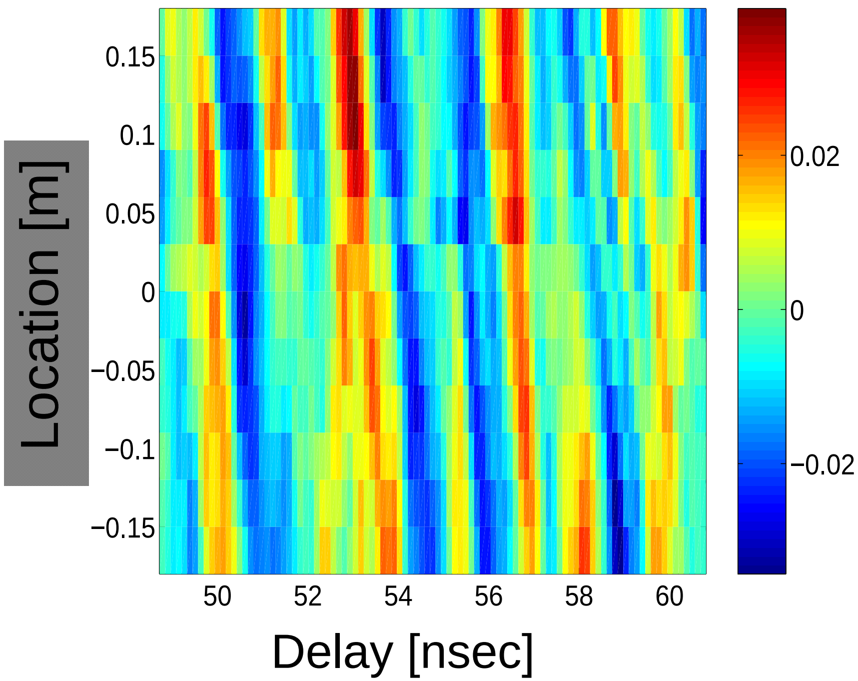




Channel Uncertainty in Real Environments

Channel model: must include essential uncertainties of channel, be realistic but not too complicated.



Clusters of paths due to rough surfaces. Effect of roughness on high end of frequency band.

High bandwidth channel models contain many taps, but their weights are correlated.

Channel is complex, but uncertainty limited.

Can estimate span of paths, need more experimental verification.

Dana Porrat, David Tse

Radio Design Work

Overall objective: Develop circuits and systems that support wideband communications in CMOS.

- Study fundamental design tradeoffs in wideband CMOS LNA.
  - Explore novel wideband LNA architectures.
- Validate effectiveness of frequency channelized receivers.
  - Algorithm development.
  - Hardware implementation.
- Demonstrate a CMOS UWB radio that operates efficiently in the 3.1-10.6 GHz band.

Parallel PN Acquisition Research

- Further Algorithm Development
  - Verification routine
  - Include channel estimation
    - Capture multipath delays thru parallel search
- Coordinate w/ Hardware Prototyping
  - Enable “long-code” solutions with reasonable similar circuit complexity and better acquisition time

Clock Tracking using Iterative Decoding

- Incorporate clock drift as well as jitter
  - Incorporate BWRC specs and complexity sensitivity
  - Goal: enable integrated solutions with relatively poor clock sources (cost, power reduction)
- Include multipath channel effects
  - Track group delay (fast) and channel variations (slow)
- Integrate with acquisition mode solution

Future Implementation Research

- Develop and Implement localization algorithms
  - Convex optimization
  - Pseudo inverse of overdetermined matrix
- Demonstrate complete system with localization using CMOS ULP-UWB chip
- Design radios that work at higher frequency bands with minimal power increase
  - Sub-sampling mixing
- Reduce requirements on analog processing
  - Sampling at the rate of innovation (reduces A/D rate)
  - Conversion to analytic signal (reduces timing sensitivity)
  - Implement USC advanced baseband processing

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