

# Short-Range Ultra-Wideband Systems

## UWB Antenna Theory and Design

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- Some recent results of relevance to UWB theory and practice
- Some UWB antenna problems that are outstanding
- Future directions that may be interesting

## Short-Range Ultra-Wideband Systems

### Recent Results: Link Loss for UWB systems

For an UWB radio link, with specific Tx and Rx antennas, and specific UWB waveforms, what is the received energy ?

The answer to this question generally requires full-wave numerical electromagnetics analysis. But for the special case of electrically small dipole or loop antennas, and Gaussian derivative pulses, simple closed-form results are possible. In practice, many realistic antennas are similar to small dipoles or loops, and many UWB waveforms are close to Gaussian pulses or their derivatives. These results therefore are useful in practice, and more accessible to the working engineer.

D. M. Pozar, “Closed-form approximations for link loss in an UWB radio system using small antennas”, IEEE Trans. Antennas and Propagation, vol. 51, pp. 2346-2352, September 2003.

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Recent Results: CAD Software for Modeling Arbitrary UWB Antennas and Links

How can antennas and realistic propagation paths be modeled for UWB systems ?

Using time-domain and frequency-domain integral equation methods with a graphical user interface, a powerful CAD package has been developed and tested extensively for a wide variety of antenna and obstacle configurations.

A.O. Boryssenko and D.H. Schaubert, "Time Domain Integral-Equation-Based Solver for Transient and Broadband Problems in Electromagnetics", AMEREM 2002, Annapolis, MD. Also in Ultra-Wideband Short-Pulse Electromagnetics 6, Kluwer Publishing, 2003, pp. 239-249.

A.O. Boryssenko and D.H. Schaubert, "MEMA-UWB: Massachusetts Electromagnetic Analyzer for UWB Link," Univ. of Massachusetts Antenna Laboratory, January 2005.

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### Recent Results: Optimization of Waveforms for UWB Links

For an UWB link with specified Tx and Rx antennas, what is the optimal waveform that will maximize received voltage amplitude or received energy ?

Using variational methods and full-wave electromagnetics, generator waveforms have been found to optimize received voltage amplitude or received energy (total or within a specified time interval), with constraints on input energy and bandwidth. Resulting waveforms are usually impractical to implement, but these results set an upper bound on UWB radio link performance. Approximate waveforms implemented by using 4-bit quantization result in reasonably good link performance.

D. M. Pozar, “Waveform optimizations for ultra-wideband radio systems”, IEEE Trans. Antennas and Propagation, vol. 51, pp. 2335-2345, September 2003.

A.O. Boryssenko and D.H. Schaubert, “Efficient and practical pulses for dipole antenna UWB link,” 2004 IEEE Int’l Antennas and Propagation Symposium, vol. 2, pp.1283 – 1286.

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### Recent Results: Practical Antenna Designs for UWB Systems

What is the best antenna for UWB radio systems ?

The choice of antennas for UWB radio involves electrical performance (impedance bandwidth, phase linearity, phase center stability), as well as factors such as cost, size, and appearance. Several novel antennas suitable for UWB systems have been developed in recent years. Many of these are conceptually based on small monopoles, dipoles, and loops. Planar UWB antennas occupying less than 10 cm<sup>2</sup> can have low VSWR and omnidirectional radiation for 3-10 GHz.

D. H. Schaubert, "Contoured Triangular Dipole Antenna", United States Provisional Patent Application filed on September 30, 2004, application No. 60/614,865.

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### Recent Results: UWB Radiation from Arbitrary Antennas

What are the optimal characteristics of radiation from an arbitrary UWB antenna ?

Fundamental characteristics of completely arbitrary antennas can be studied by using a spherical mode expansion for the electromagnetic fields radiated outside a mathematical sphere that encloses the antenna. This leads to fundamental limits on the peak amplitude (or energy density) of the electric field that can be radiated by a completely arbitrary antenna, vs. antenna size, for a fixed input energy.

D. M. Pozar, “Optimal radiated waveforms from an arbitrary UWB antenna”, to be submitted for publication.

## Short-Range Ultra-Wideband Systems

### Some UWB Antenna Problems that are Outstanding

- Optimization of arbitrary UWB transmit and receive antennas
- Using arrays of UWB antennas for Direction of Arrival and for Imaging
- UWB antenna designs that operate well in proximity to objects
- Ongoing need to design UWB antennas for specific applications (meeting particular size, shape, manufacturing method, and similar constraints)

## Short-Range Ultra-Wideband Systems

### Future Directions that may be Interesting

- Receive characteristics of an arbitrary UWB antenna bounded in size
- Using an UWB channel with switched beam antennas for secure cryptographic key transmission
- Co-design of antennas, circuits and signals for optimum performance
- Evaluate BER for UWB systems with realistic antennas and propagation channels