Ultra-Wideband Radio for High Data-Rate Communication

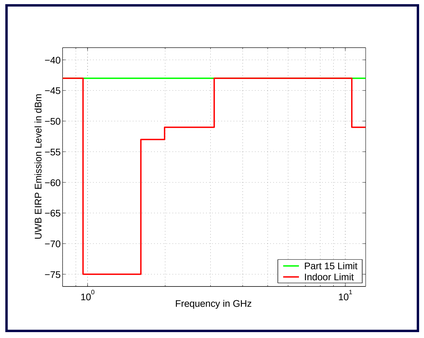
Chris Snow, Dr. Lutz Lampe, Dr. Robert Schober

Department of Electrical and Computer Engineering, University of British Columbia

Introduction to UWB

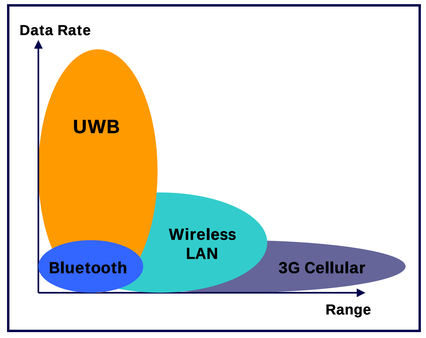
What is UWB?

- UWB stands for Ultra-Wideband
- A low-power, high-bandwidth radio signal
- Bandwidth is *at least* 500 MHz
- Power spectral density limited to –43 dBm/MHz (by U.S. FCC regulation)



Benefits of UWB

- Unlicensed technology (similar to Wi-Fi)
- Reuse of currently allocated spectrum
- Potential for very high data rates (480 Mbps)
- Low transmitter power



Where Will UWB be Used?

- Mainly in short-range applications such as cable replacement (eg: Wireless USB)
- Distribution of audio, video and data
- Low Probability of Detection requirements (for clandestine communication)
- Also has Radar and geo-location applications

Which Groups are Considering UWB?

- IEEE 802.15 (Personal Area Networks) both for high and low data rates
- Wireless USB Promoter Group
- WiMedia Alliance
- Others including designers of radar and geo-location devices

UWB Channel Models

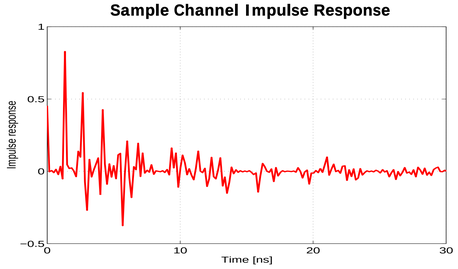
Model Details

- Standard models for UWB developed by IEEE 802.15 Channel Modeling Sub-Committee
- Models consider range of usage scenarios for UWB
- Channel impulse response (see right) modeled as several clusters of arriving rays
- Individual rays are independent log-normally faded
- Clusters also undergo a common log-normal fading

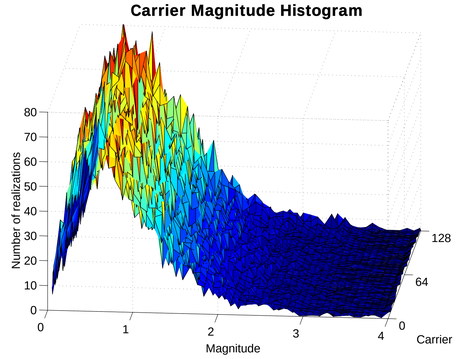
How We Use the Models

- Pre-generate many realizations using MATLAB code
- These realizations are converted to frequency-domain representation (Fourier transform) and stored
- The system simulator inputs channel realizations and uses them to simulate the UWB channel response

Sample Channel Impulse Response



Carrier Magnitude Histogram

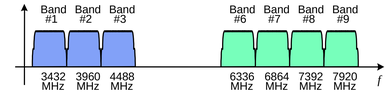


Multiband OFDM Proposed Standard (IEEE 802.15.TG3a)

Technical Details

- An Orthogonal Frequency Division Multiplexing based UWB scheme
- OFDM allows for efficient multi-carrier modulation using FFT/IFFT
- Uses a 528 MHz frequency band in 3.1 – 10.6 GHz range
- Frequency-hopping between different bands part of standard
- QPSK modulation on 128 subcarriers
- Data rates from 55 - 480 Mbps, max range in the order of 10-20 m
- Our research is focusing on this UWB technology

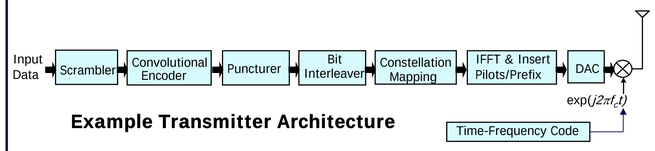
Frequencies Used



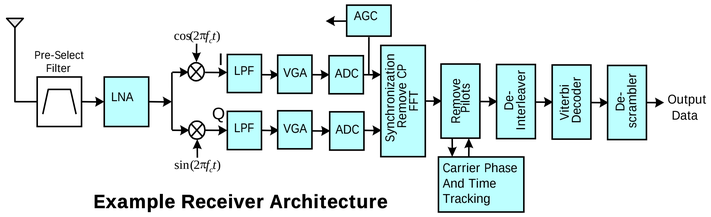
- The standard creates seven 528 MHz bands
- Mode 1 bands (blue) are for first gen. devices
- More advanced radios can use all seven bands

Industry Support of the Standard

- 7 of the world's top 10 semiconductor manufacturers (Intel, Texas Instruments, ST Micro, Infineon, NEC, Philips)
- 100% of the leading consumer electronic companies (eg: Sony, Samsung, Panasonic, Philips, JVC, Sharp, Mitsubishi)
- 5 of 6 USB Implementer Forum Director Companies (Intel, Philips, NEC, HP, Microsoft)



Example Transmitter Architecture



Example Receiver Architecture

Our Research

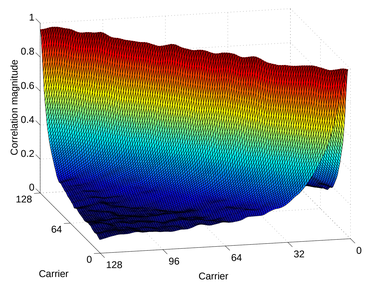
Potential Diversity Gains in UWB

Frequency Diversity

What frequency selectivity is present in the UWB channel?

- Our early results show there is potential for diversity gains
- We can obtain diversity gain by
  - coding across subcarriers
  - increasing frequency-hopping length (currently only 3 symbols)
  - increasing interleaver depth
  - using modulation diversity
- We can analyze the effects and verify via simulations

How OFDM Carriers are Correlated



Spatial Diversity

- We can examine the effects of multiple antennas at the transmitter and/or receiver
- Potential for increased reliability and/or capacity

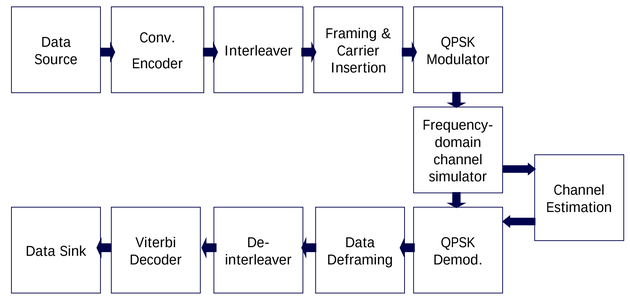
Temporal Diversity

- Given a channel model that considers the time-varying nature of the fading channel, we can determine if there are any potential temporal diversity gains

System Simulator

- High-speed simulator of the Multiband OFDM system
- Written in C++
- Parameters such as data rate and coding scheme are easily changed
- Uses pre-generated frequency-domain channel realizations (MATLAB)
- Allows for addition/replacement of modules to test new schemes
- Used as the basis for simulation/verification of our research findings

Simulator Block Diagram



Information-Theoretic Measures

Why Information Theory?

- Information theory will allow us to determine the maximum theoretical performance achievable by UWB, providing a benchmark with which to compare practical systems

What We Will Do

- Develop expressions for capacity and cut-off rates for the UWB system
- Use these expressions to compare transmitter and receiver schemes and structures

Future Research Directions

- Consider MIMO (Multiple-Input, Multiple-Output) schemes for UWB
- Examine other proposed UWB standards (eg: CDMA-based UWB)
- Consider other channel models and/or develop new channel models

csnow@ece.ubc.ca, lampe@ece.ubc.ca, rschober@ece.ubc.ca