Ultra Wideband Radio (UWB)
An Introduction

Chris Snow
csnow@ece.ubc.ca

Overview of the talk

- What is ultra-wideband?
- Regulatory environment for UWB
- Different Implementations
- Standardization
- Future directions

An Introduction to UWB

- Transmit with very low power at extremely large bandwidths
- This allows operation over currently allocated spectrum
- Application: low-power, short-range, high-speed wireless (wireless desktop, Personal Area Network)
- Also can be used for locationing (ie. radar)
- Multipath mitigation (resolvable paths proportional to bandwidth)
- Cost of Bluetooth, better performance than 802.11 WLAN
- (Nice introductory paper in September 2003 IEEE Spectrum)

FCC Definition of UWB

"an intentional radiator that, at any point in time, has a fractional bandwidth equal to or greater than 0.20 or has a bandwidth equal to or greater than 500 MHz, regardless of the fractional bandwidth."

FCC Regulations about UWB

- Frequency allocation: 3.1 to 10.6 GHz
- Low radiated power (max -40 dBm)
- Some roll-off allowed at min, max freqs
- Stringent requirements for interference with GPS (at ≈ 1.5 GHz)

UWB Spectral Mask

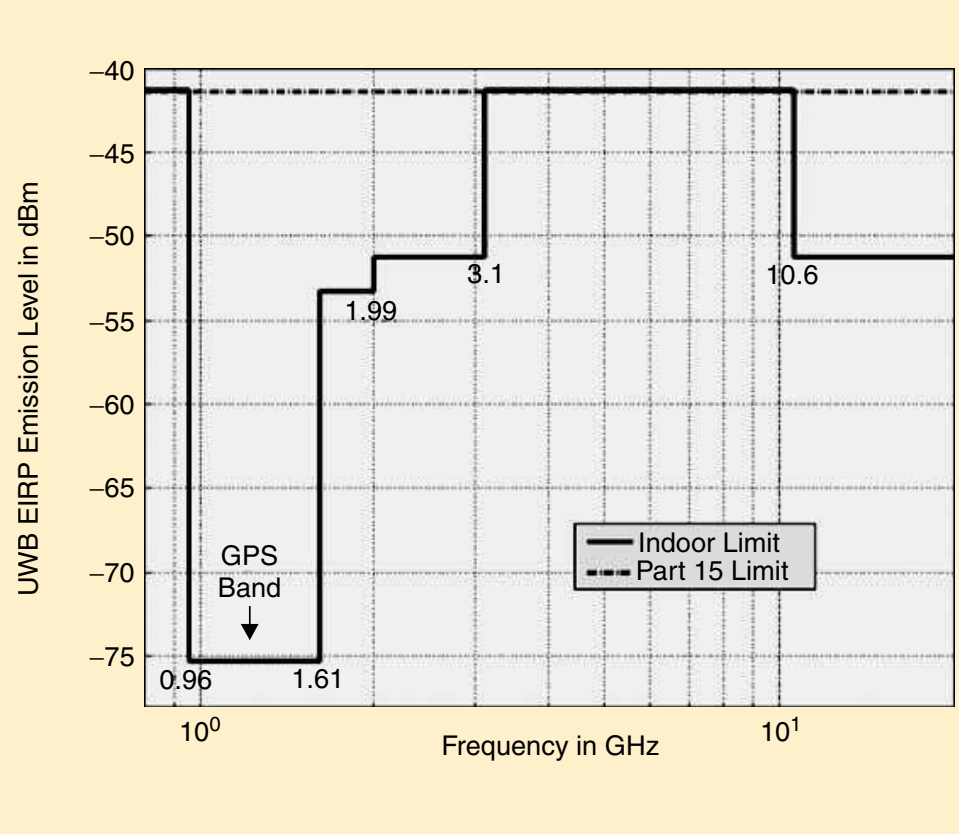


Image from G.R. Aiello and G.D. Rogerson "Ultra-Wideband Wireless Systems", *IEEE Microwave Mag.*, June 2003

Regulations in other countries

- Some other countries have different regulations on UWB
- In general, there may be regulations preventing radiation in some small bands between 3.1 and 10.6 GHz.
- So, although FCC says -40 dBm from 3.1 to 10.6 GHz, we may need to limit that in some bands...

Implementations — General

Implementations must:

- Meet FCC requirements (spectral masks, bandwidth)
- Be fairly cheap to implement (we'll see about this)
- Provide good performance
- Minimize interference
- (we would like good multiuser performance too)

Implementations being considered

The following are the main implementations that are (were) being considered by the IEEE for standardization (for PAN physical layer):

- Impulse radio
- DS-CDMA
- OFDM ("Multiband OFDM")

Considerations

The choice of implementation will impact:

- Hardware complexity, scalability
- Interference to others
- Radio performance
  - Range, data rate
  - Multi-user performance
  - Robust to RFI, MAI

Impulse Radio

The first UWB system was developed about 100 years ago!

- First experiments in radio were spark-gap generators (Hertz, Marconi)
- Signal produced was wideband and carrierless
- Once we figured out how to generate sinusoids, we abandoned these techniques...
- Now, we return to the past

Impulse Radio (cont'd)

- Idea: Use short baseband pulses, with pulse-position modulation (PPM)
- Spectrum of these signals will be very wide
- Transmit with a low duty cycle, send several pulses for each data bit
- Multiple users can be supported with some additional codes (changing pulse position)

Form of Impulse signal

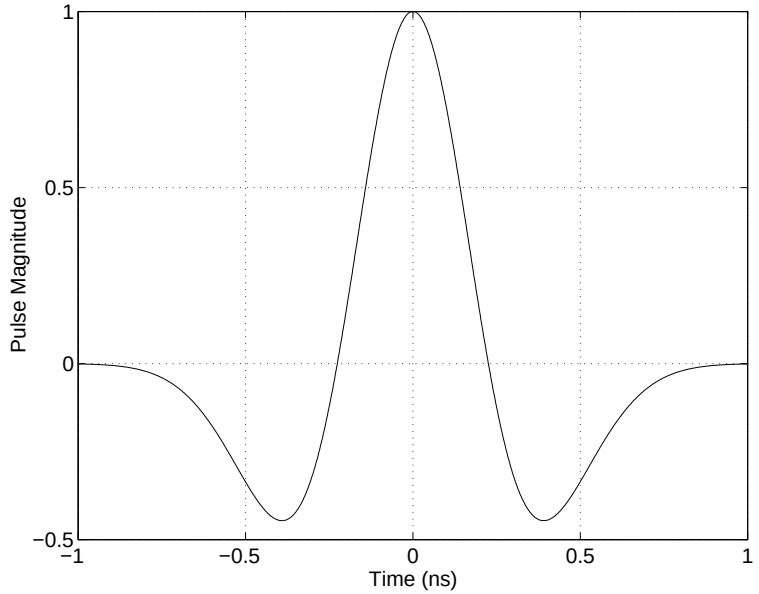
$$s_{\mathrm{tr}}(t) = \sum_{j=-\infty}^{\infty} \omega_{\mathrm{tr}}(t - jT_f - c_j T_c - \delta d_{\lfloor j/N_s \rfloor}) \tag{1}$$

$\omega_{tr}(t)$	pulse waveform (often a Gaussian monocycle)
T_f	pulse repetition time
c_j	j^{th} time shift of the time-hopping sequence
T_c	the duration of addressable time delay bins
δ	modulation index
N_s	number of repetitions per data bit
d	data bit being transmitted

Gaussian Monocycle

$$s_{\text{pulse}}(t) = \left[1 - 4\pi\left(\frac{t - t_d}{\tau_m}\right)^2\right] \exp\left[-2\pi\left(\frac{t - t_d}{\tau_m}\right)^2\right] \qquad (2)$$

t_d is the location of the pulse center in time and τ_m is the parameter which determines the temporal width of the pulse



Impulse Radio Summary

- Most research papers in UWB systems consider the impulse radio system.
- However, UWB is now a general class of systems, rather than a specific implementation
- We will discuss briefly two alternative UWB implementations

CDMA Approach

- Can use standard DS-CDMA with high chip rate to get very wide spreading
- CDMA proposal to IEEE standards group splits spectrum into low and high bands (at about 5 GHz) with a gap (licensing problems there...)
- Claim is that RX/TX design is easier than the Multiband OFDM design (don't need high-speed AD/DA, FFT, etc), and can scale for different performance requirements
- High symbol rate $\Rightarrow$ high ISI, need equalization
- Use RAKE receiver to deal with multipath
- Multiple access by standard CDMA techniques (codes)

Multiband OFDM

- Split the large bandwidth into 500 MHz subbands
- Frequency-hop between them (can avoid MAI, etc)
- In the 500 MHz band, use OFDM with 4 MHz carriers
- OFDM is used in new WLAN standards (802.11g), DSL (called DMT)
- Can turn off some carriers if there are licensing problems
- Requires some advanced electronics (FFT/IFFT, A/D, etc)
- Multipath mitigation from FEC (bits lost due to narrowband fading can be corrected from FEC bits on other carriers)
- Multiple access by time and frequency division

The future of UWB

- Being studied by IEEE 802.15 TG3a (Alternate PHY layer for PAN)
- Multiband OFDM was chosen, needs 75% "confirmation vote"
- Hasn't happened yet...
- DS-CDMA supporters very worried about Multiband-OFDM and FCC compliance (how is power of a FH system measured?)...

Research Issues

Some research issues pertaining to UWB:

- Channel models
- Theoretical limits of wideband channels (information theory)
- Improving performance (equalization, reciver, etc)
- Multiuser aspects

Conclusions

- UWB is a "hot topic"
- First commercial products should be out in about a year
- Lots of unexplored research areas to consider

(I have lots of literature, if you are interested please ask...)