Digital Architecture for an Ultra-Wideband Radio Receiver

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UWB Flavors

Multicarrier. 500 MHz from 3.1 to 10.6 GHz

Pulsed UWB

OFDM UWB

Digital Approach ⇒ Programmability and Scalability
Antenna Requirements

Impedance Matching Requirements
- VSWR < 2
- $10\log|S_{11}|^2 = -\text{Return Loss} < -10 \text{ dB}$

Wave Reception
- Constant Group Delay
- High Radiation Efficiency
- Target Omnidirectional Radiation Pattern (Non-directive)

Physically Small
Current Design: 1.0 x 1.9in.
Analog Front-End
A/D Converter

- 500+Msps ⇒ FLASH converters or FLASH interleaved converters.

- Power scales exponentially with the number of bits:
  - Maximum number of bits
  - Adaptation of the number of bits to the environment.
Back-End Processing

- Synchronization
  - Coarse acquisition
  - Fine tracking

- Signal demodulation
  - Channel estimation
  - AGC
Coarse Acquisition

- A wider integration window?
  - Loss in processing gain.
  - Same number of operations.
  - Less comparisons to a threshold
Coarse Acquisition (II)

- $N_c = 31$, duty cycle $= 2\%$, $\Delta$delay = pulse width $\Rightarrow N = 1550$
- $P_{fa} << 1/N$

<table>
<thead>
<tr>
<th>$P_{fa}$</th>
<th>$P_{cd}$</th>
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<tbody>
<tr>
<td>$10^{-3}$</td>
<td>0.42</td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>0.87</td>
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<tr>
<td>$10^{-5}$</td>
<td>0.98</td>
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- 20 ppm, width = 2ns $\Rightarrow$ 25$\mu$s for static users.
Signals with Same Bit Rate

- **Target bit rate:** 100Mbps
- **Options:**
  - Pulses of 2ns width separated 10ns from one another. BPSK.
  - OFDM with 256 carriers, prefix of 54 ns. Duration of the symbol: 310 ns. Each carrier modulated using BPSK. 31 bits per symbol.
- **Assumptions:**
  - Time and frequency synchronization achieved.
  - No need for channel equalization
  - Instantaneous AGC.
Demodulation of UWB Signals

Pulsed UWB:
- Samples
- Slicer
- Integrate & Dump

OFDM UWB:
- Samples
- S/P
- Prefix removal
- FFT
- Slicers
- P/S
- Bits
Noise Limited Case

Pulsed UWB

OFDM UWB
Why the Difference?

- **Pulsed UWB:**
  - 2 samples
  - Function of the noise.

- **OFDM UWB:**
  - 256 samples. CLT.
  - Function of other bits in the OFDM symbol.

\[ \text{SNR} \propto 2^{2^b} \]
Interference Limited Case

Pulsed UWB

OFDM UWB
Conclusions

- Digital architecture ⇒ programmability and scalability.

- Synchronization and demodulation process are signal dependent.
  - Parallel process.
  - A low probability of false alarm is required.

- Number of bits: adaptive to signal and environment. 3 or 4 bits enough for most situations.