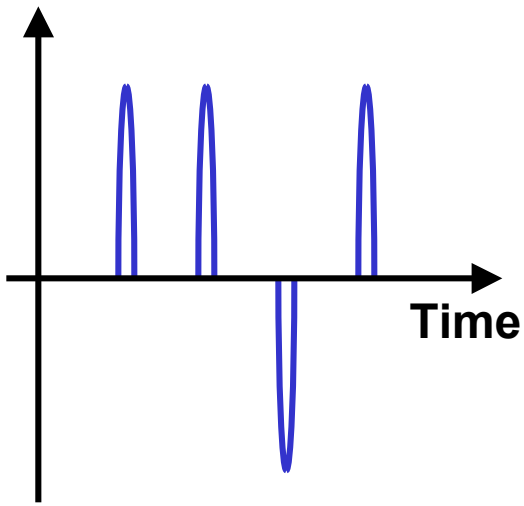
Digital Architecture for an Ultra-Wideband Radio Receiver

Raul Blazquez, Fred S. Lee, David D. Wentzloff,
Puneet P. Newaskar, Johnna D. Powell,
Anantha P. Chandrakasan

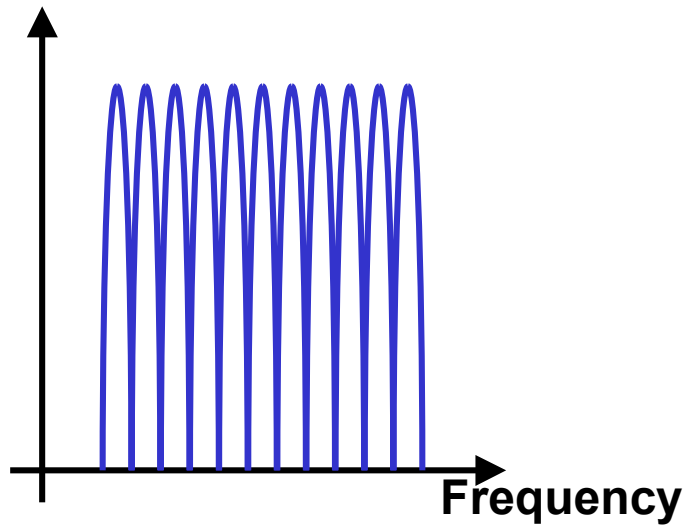
Digital Integrated Circuits and Systems
Massachusetts Institute of Technology

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

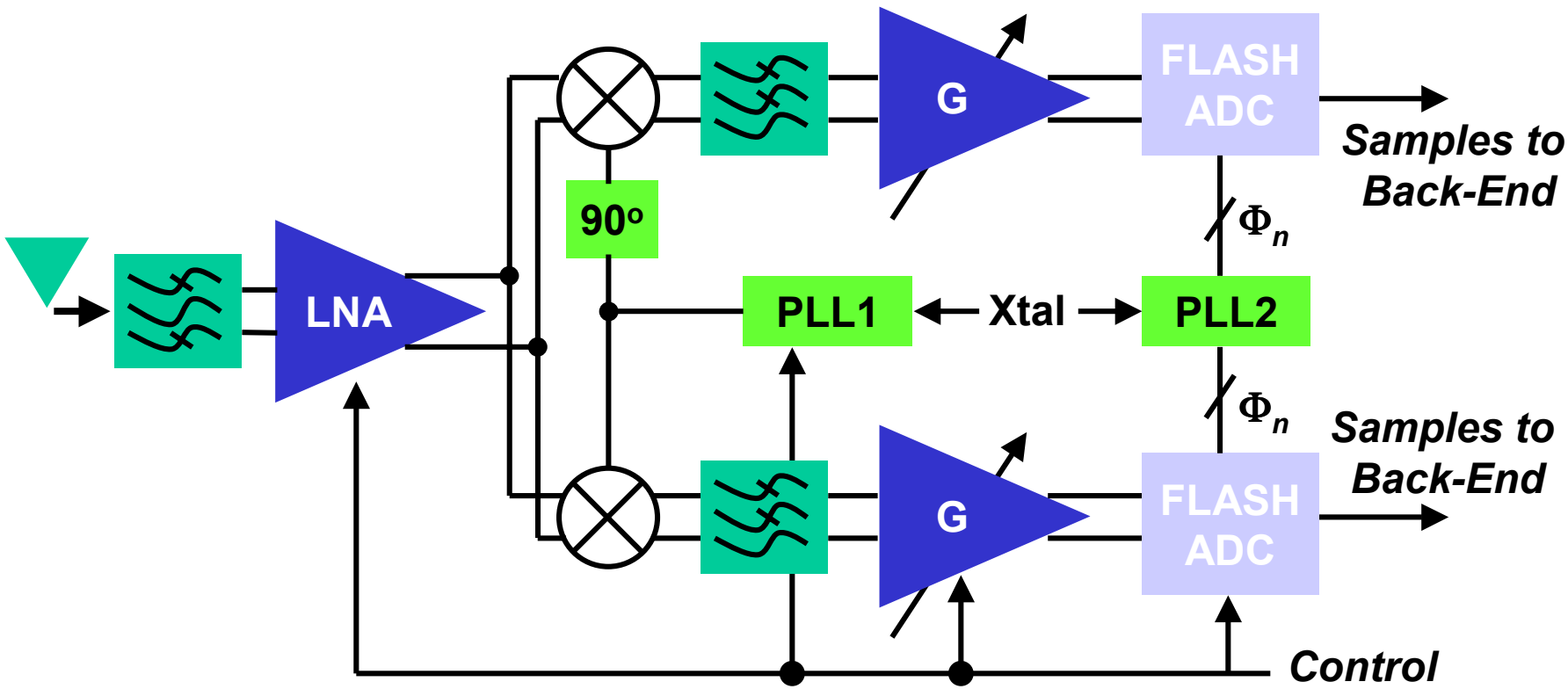
- VSWR < 2
- $10\log|S_{11}^2|$= -Return Loss < -10 dB

Physically Small
Current Design:
1.0 x 1.9in.

Wave Reception

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

Analog Front-End



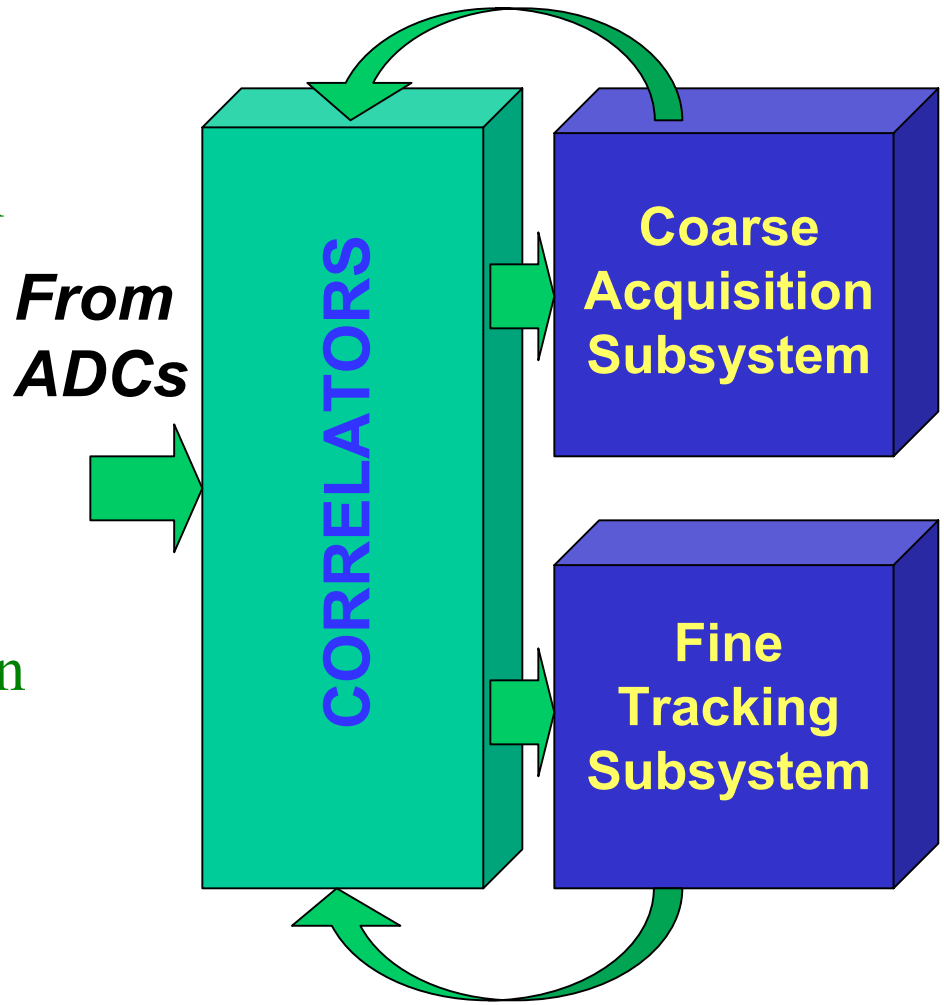
A/D Converter

- 500+Msps $\Rightarrow$ FLASH converters or FLASH interleaved converters.

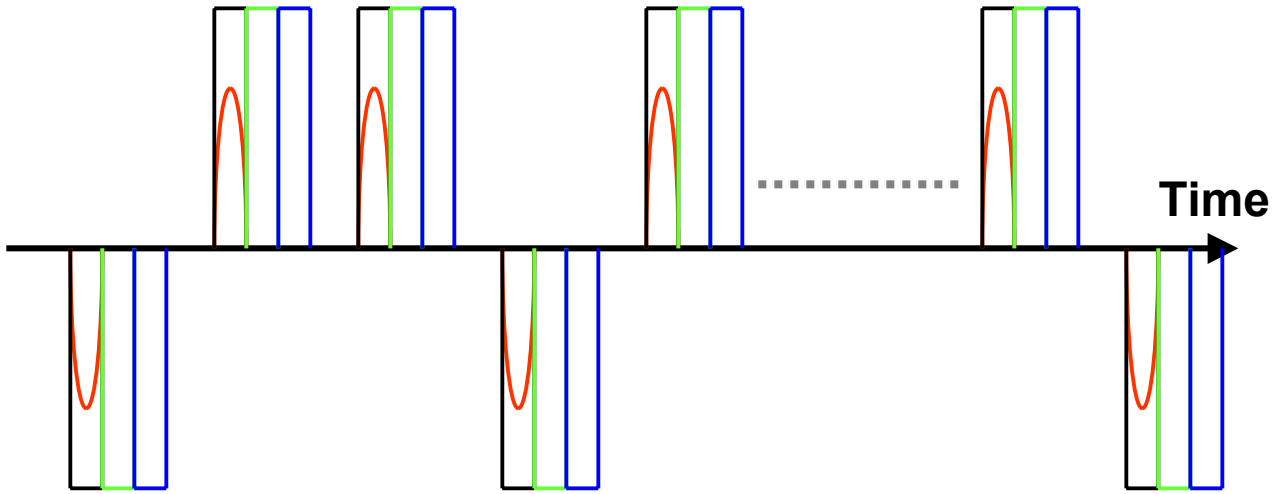
- Power scales exponentially with the number of bits:
  - Maximum number of bits
  - Adaptation of the number of bits to the environment.

Back-End Processing

- Synchronization
  - Coarse acquisition
  - Fine tracking
- Signal demodulation
  - Channel estimation
  - AGC

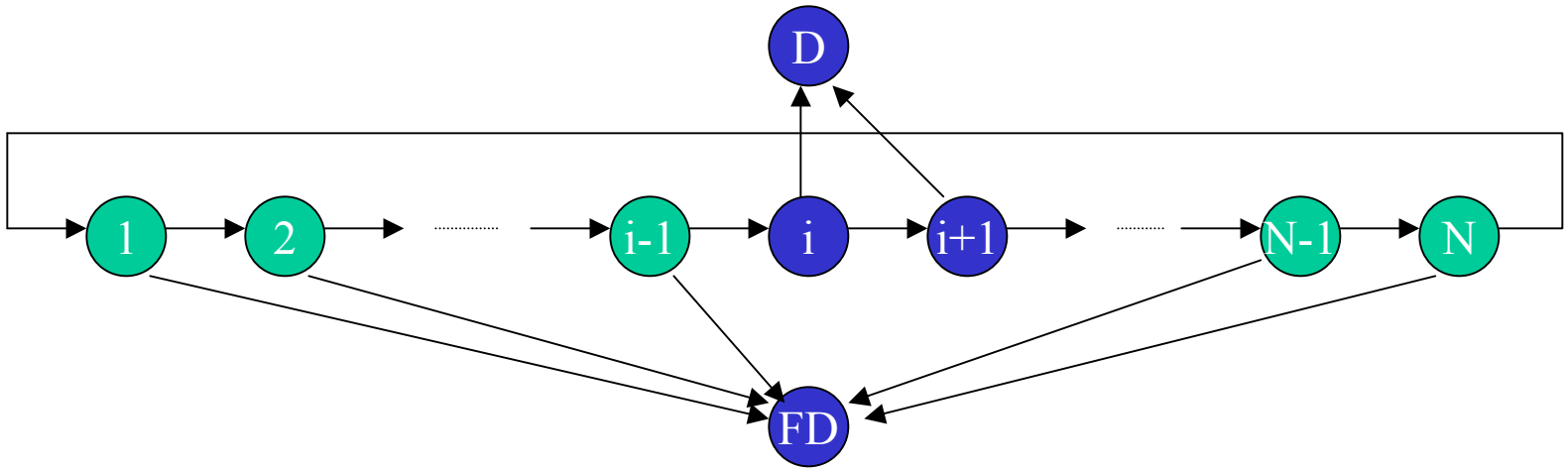


Coarse Acquisition



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

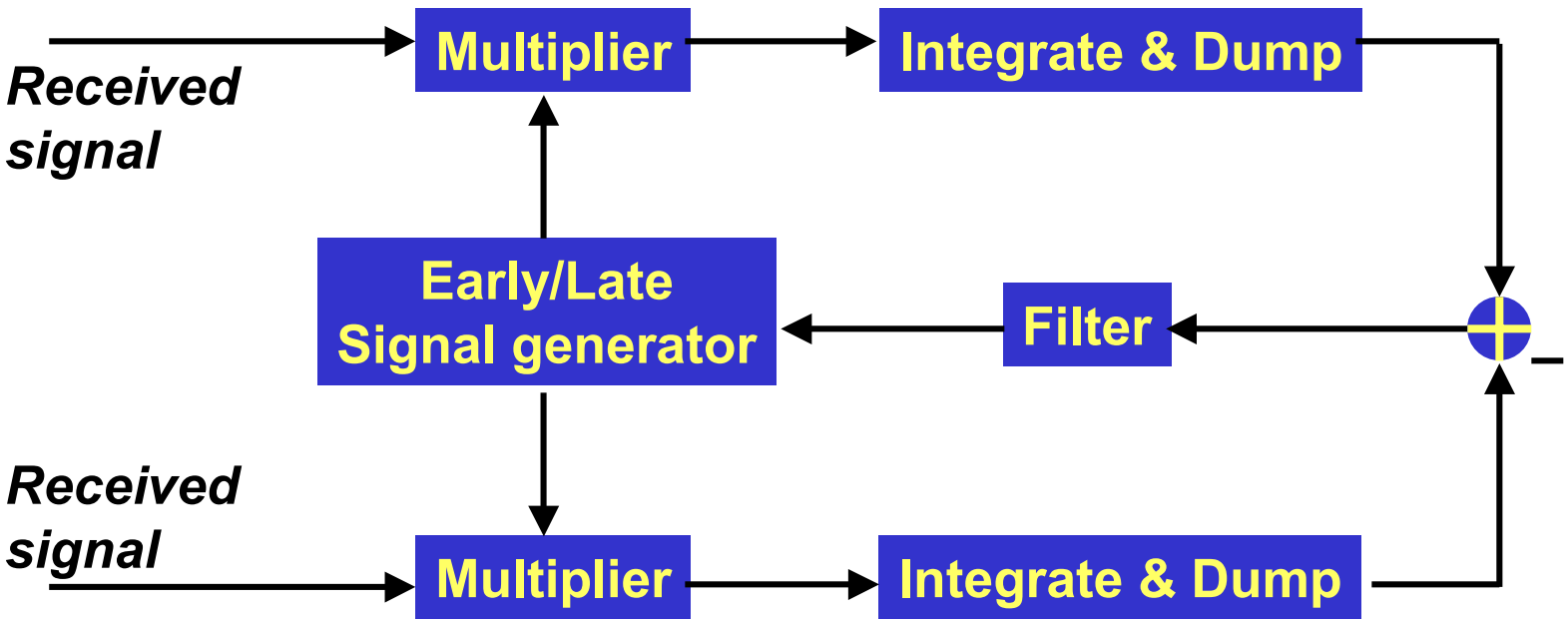
Coarse Acquisition (II)



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

P_{fa}	P_{cd}
10^{-3}	0.42
10^{-4}	0.87
10^{-5}	0.98

Fine Tracking

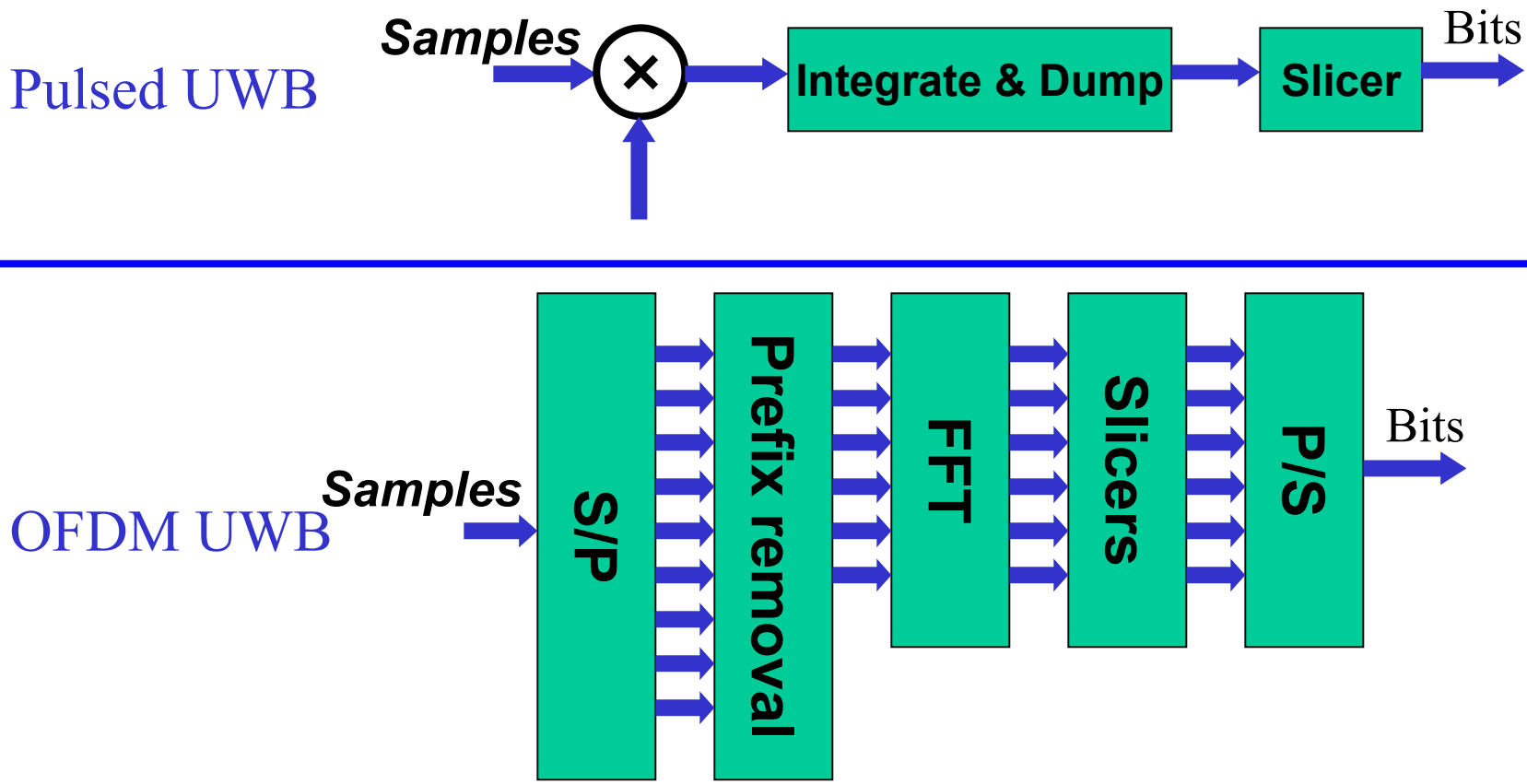


- 20 ppm, width = 2ns ⇒ 25μs for static users.

Signals with Same Bit Rate

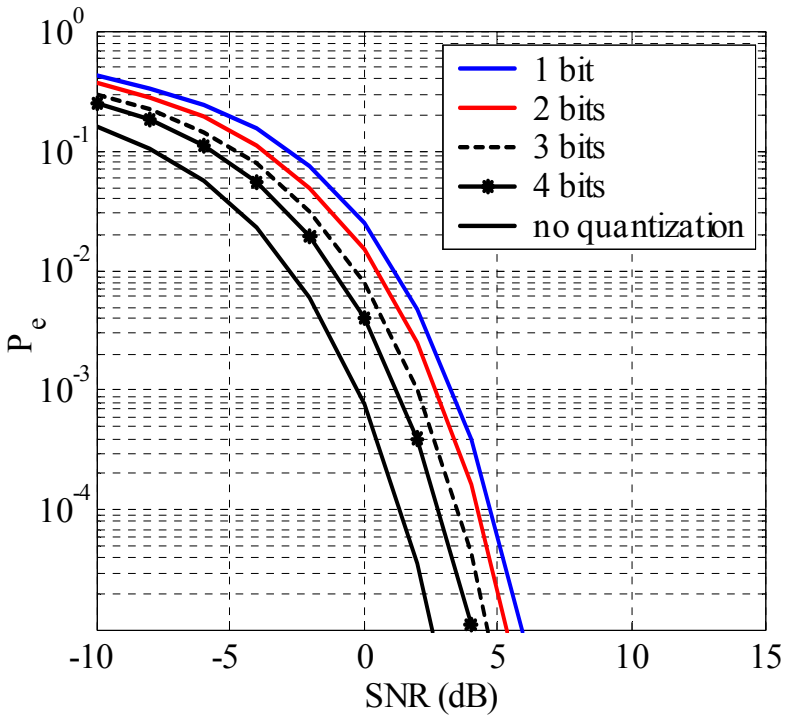
- Target bit rate: 100Mbps
- Options:
  - Pulses of 2ns width separated 10ns from one another. BPSK.
  - OFDM with 256 carriers, prefix of 54 ns. Duration of the symbol: 310 ns. Each carrier modulated using BPSK. 31 bits per symbol.
- Assumptions:
  - Time and frequency synchronization achieved.
  -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

Demodulation of UWB Signals

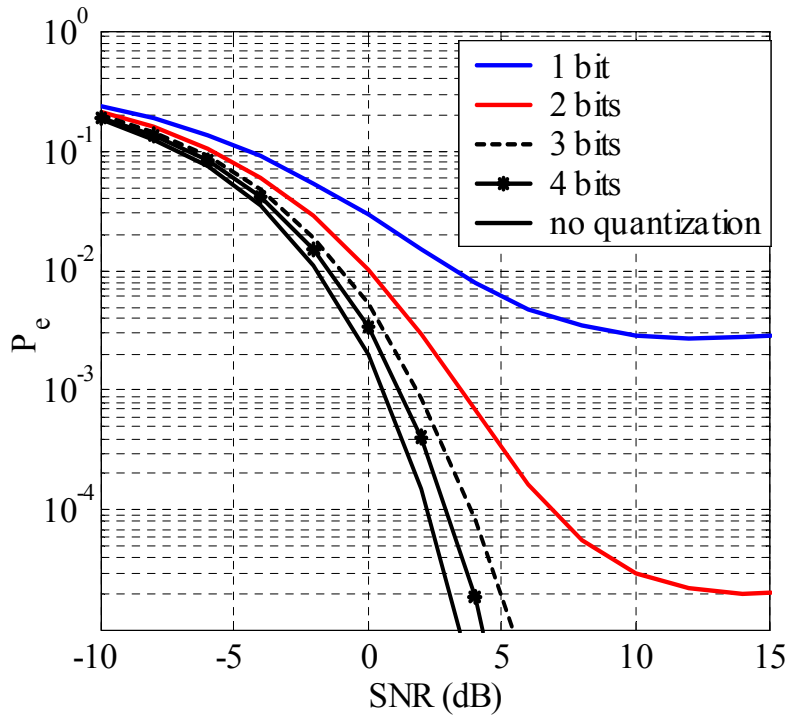


Noise Limited Case

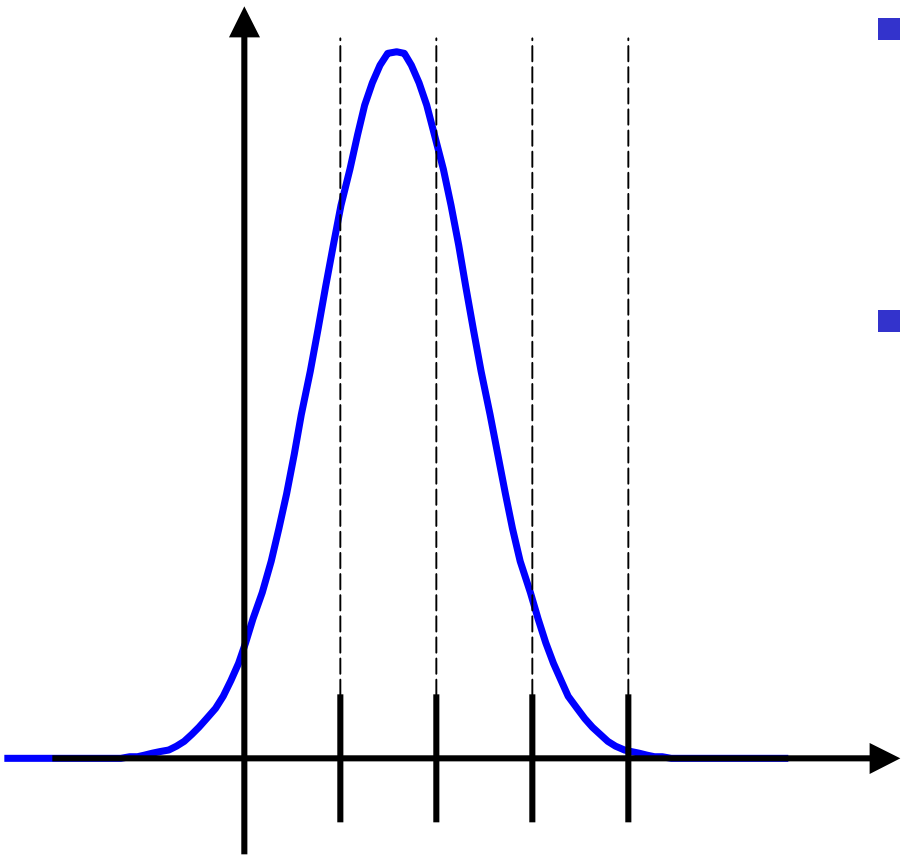
Pulsed UWB



OFDM UWB



Why the Difference?

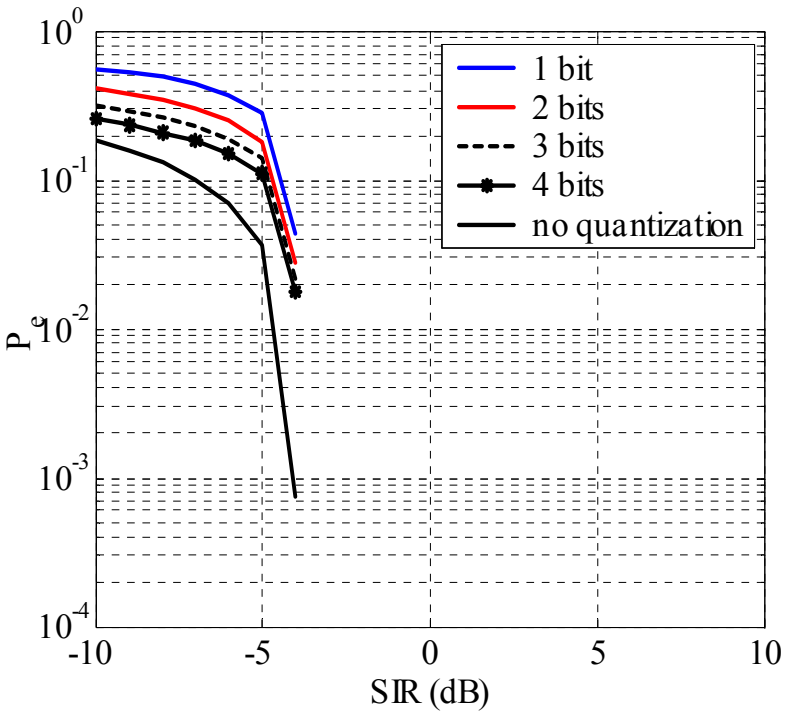


- Pulsed UWB:
  - 2 samples
  - Function of the noise.
- OFDM UWB:
  - 256 samples. CLT.
  - Function of other bits in the OFDM symbol.

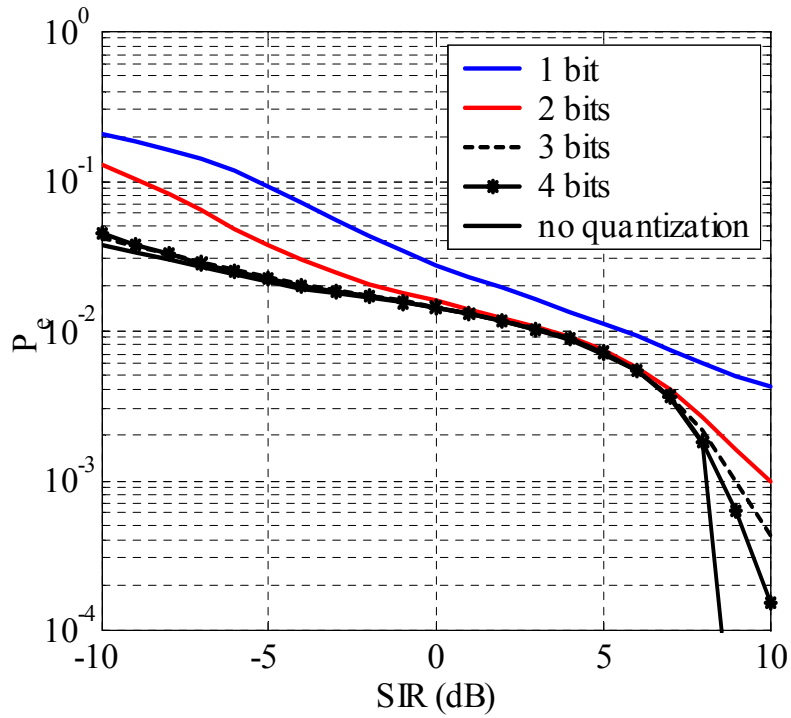
$$SNR \propto 2^{2b}$$

Interference Limited Case

Pulsed UWB



OFDM UWB



Conclusions

- Digital architecture $\Rightarrow$ 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.