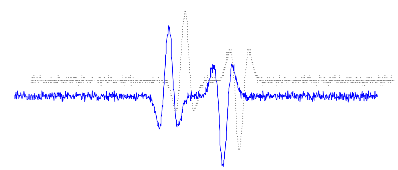
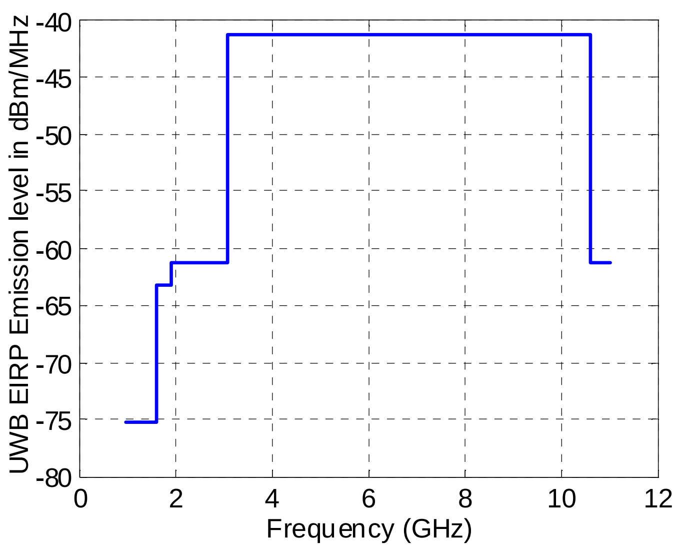
Architectures for Energy-Aware Impulse UWB Communications

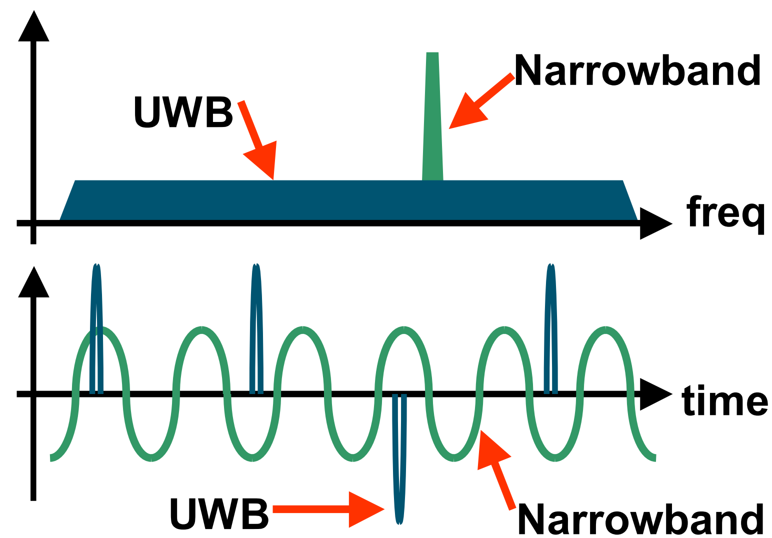


Raul Blazquez, Anantha P. Chandrakasan

Massachusetts Institute of Technology

UWB Radio



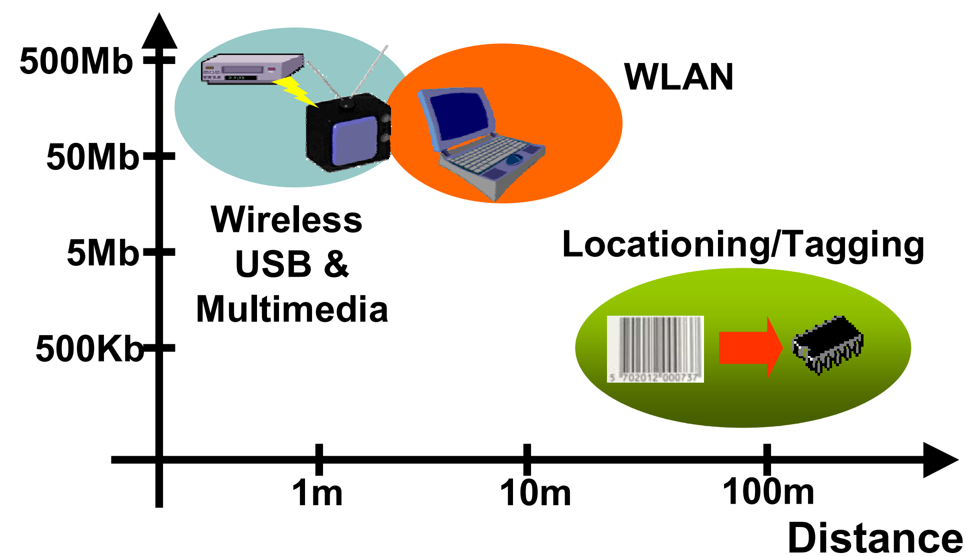


7.5GHz of free unlicensed spectrum

High Data Rate

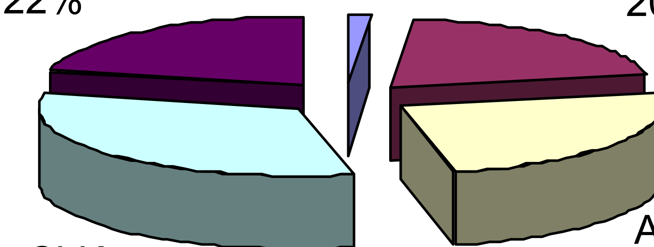
Excellent Multipath Resolution

Low Interference to other systems



Power Budget for a UWB Transceiver

- MB-OFDM :
  - Front-end: 117.5 mW (Bergervoet et al. ISSCC'05)
  - Clock and carrier: 73.44 mW (Leenaerts et al. ISSCC'05)
  - Digital Back-end: 523 mW (Liu et al. ISSCC'05)
  - Estimated for 90nm CMOS (MBOA White paper): 93mW Tx, 169mW Rx

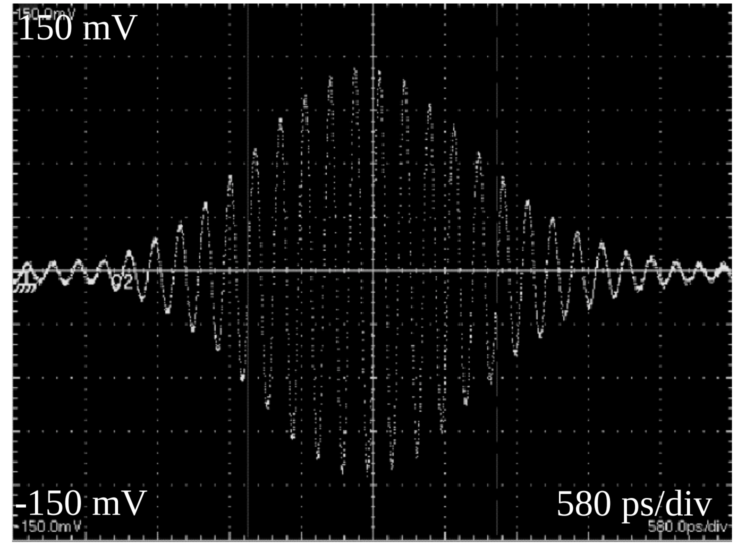


- Pulse UWB (DSSS)
  - Total: 280mW (Iida et al. ISSCC'05)

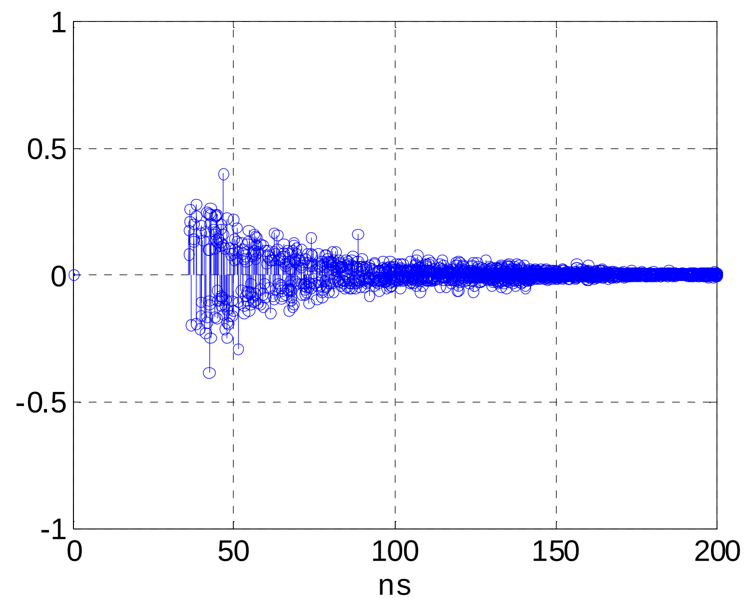
ADC and Digital baseband dominate the receiver

Transceiver Specification

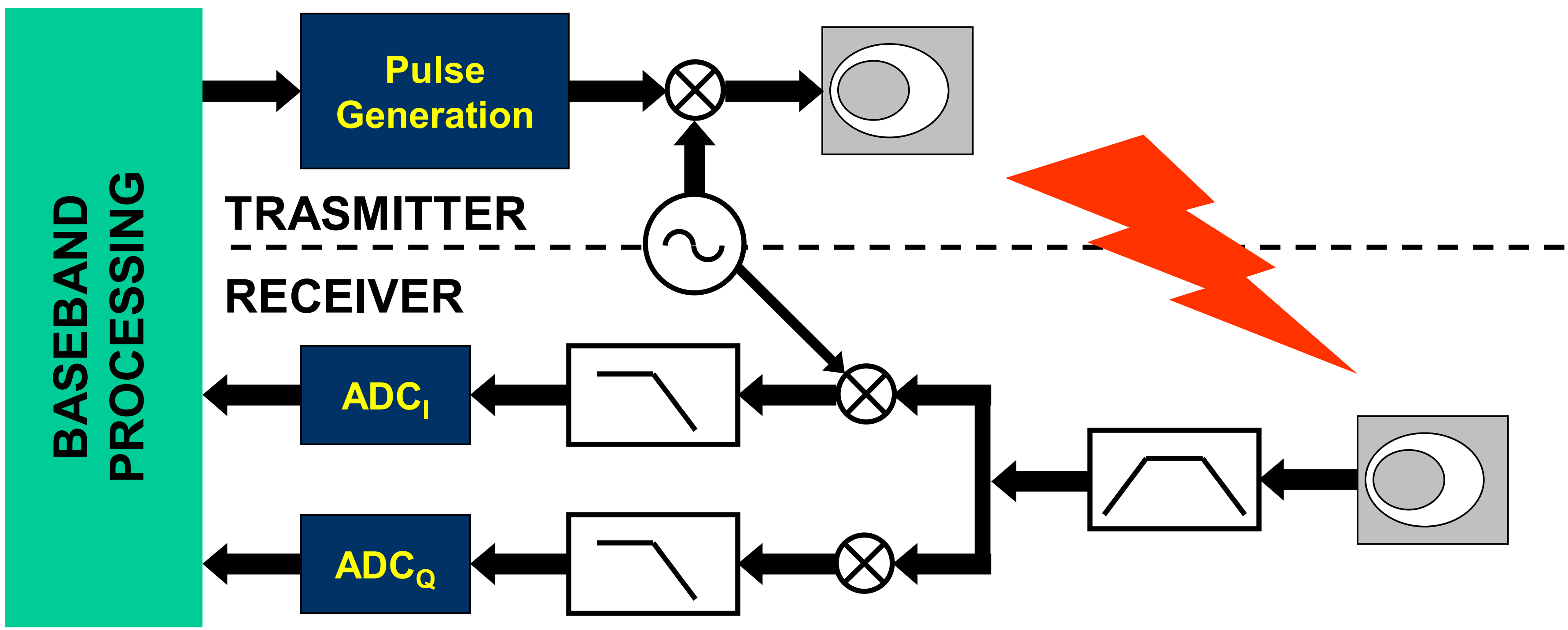
- 100 Mbps
- $BW_{min} = 500$ MHz
- Limitations:
  - Interferers (802.11a)
  - Multipath.



	Description	RMS Delay
CM1	LOS 0-4m	5.3ns
CM2	NLOS 0-4m	8.0ns
CM3	NLOS 4-10m	14.3ns
CM4	Extreme NLOS	25ns

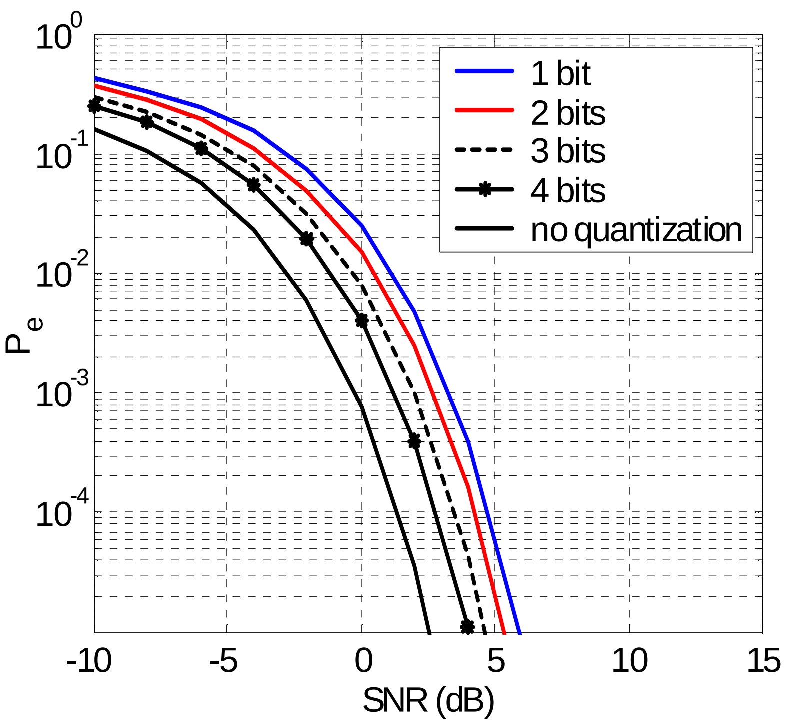


Direct Conversion Architecture

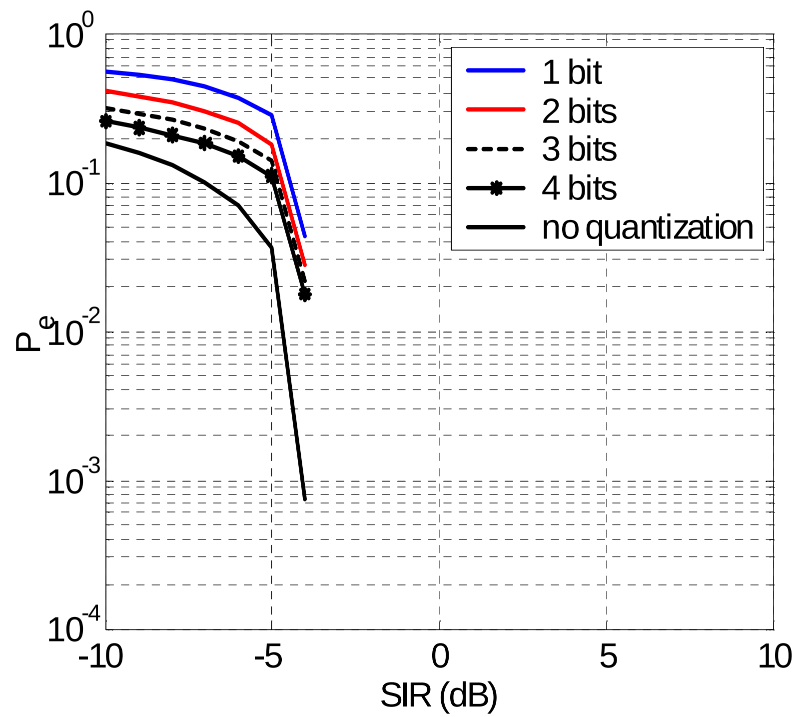


Sampling Rate: 500 Msps

Specification of the ADC



Noise Limited Case

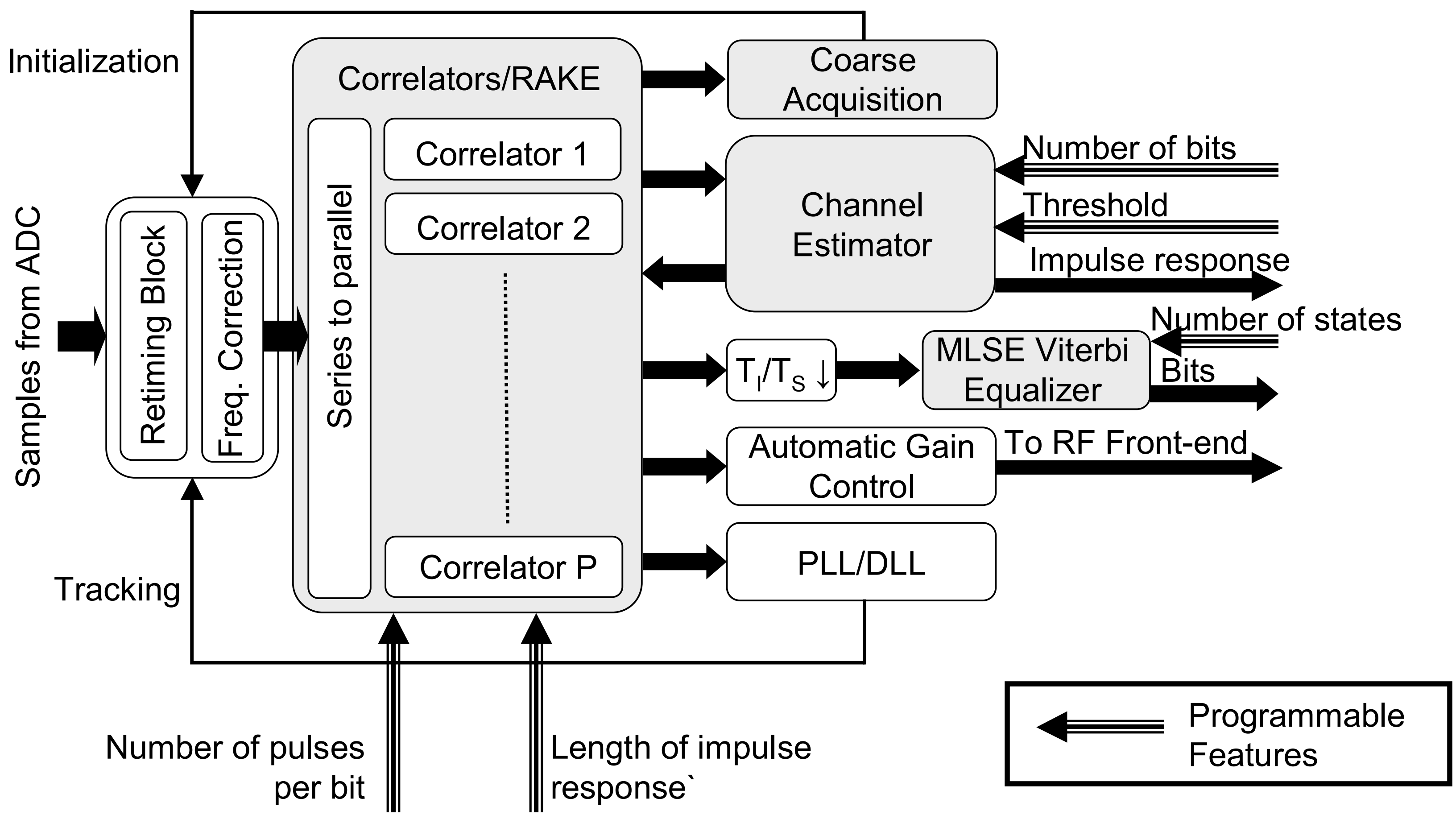


Interference Limited Case

4 bits sufficient for reliable UWB detection

Scale down number of bits to safe power

Energy Aware Baseband



Estimate Channel Quality ⇒ Adapt to minimize power

Parallellization

- **<u>Wider integration window?</u>**

  2 samples per pulse

  N_c pulses per bit

<u>Case 1:</u> 1window ⇒ Width N

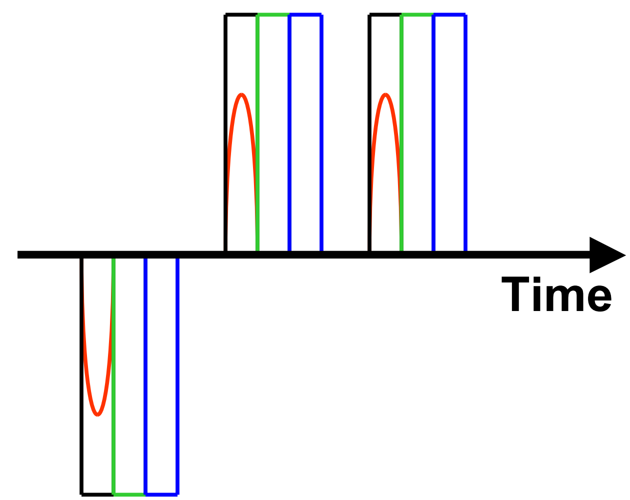
  $2N_cN$ multiplications

  $2N_cN$-1 additions

<u>Case 2:</u> N windows ⇒ Width 1

  $2N_cN$ multiplications

  $2N_cN$-N additions



Number of trials ∝ N_c/Duty cycle

Correlators

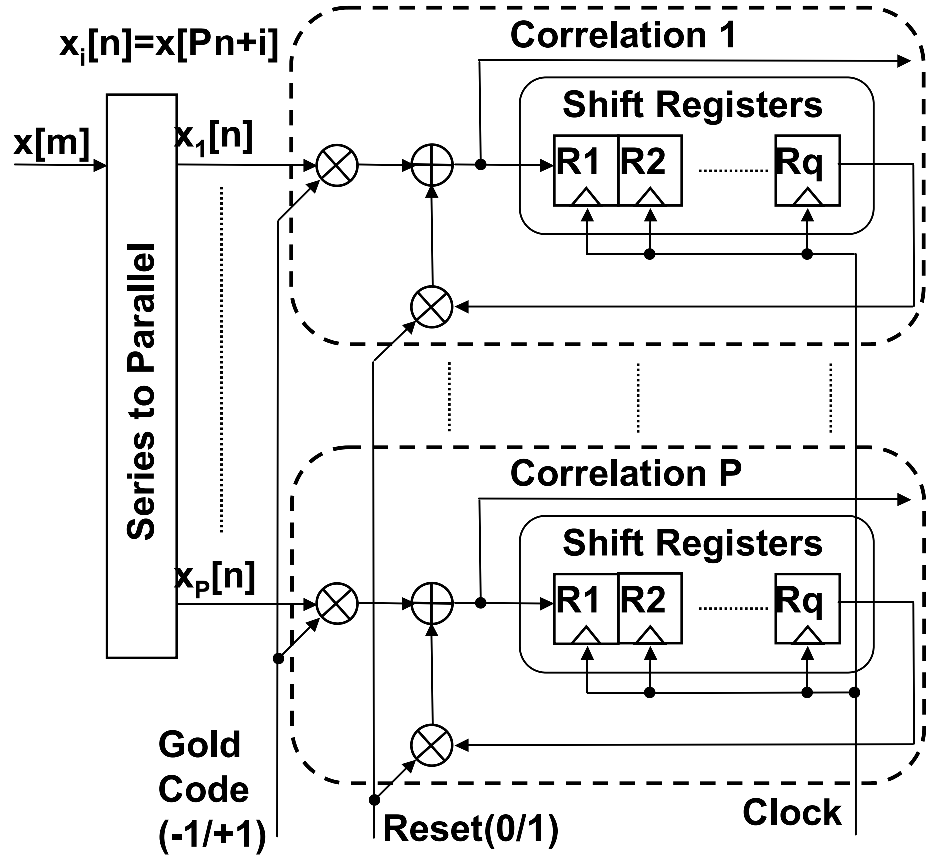
- P Correlators
- Each correlator time-shared with q correlations.

Advantages

- Faster packet acquisition
- Clock frequency
- Dynamic Voltage Scaling

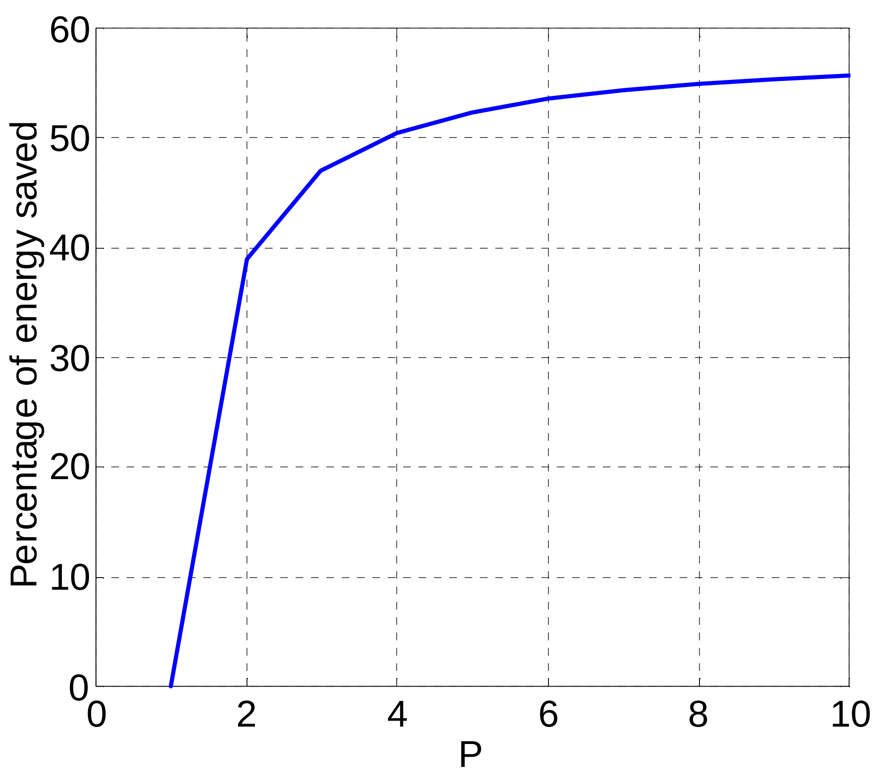
  Power $\propto (V_{DD})^2$

Channel estimation for free

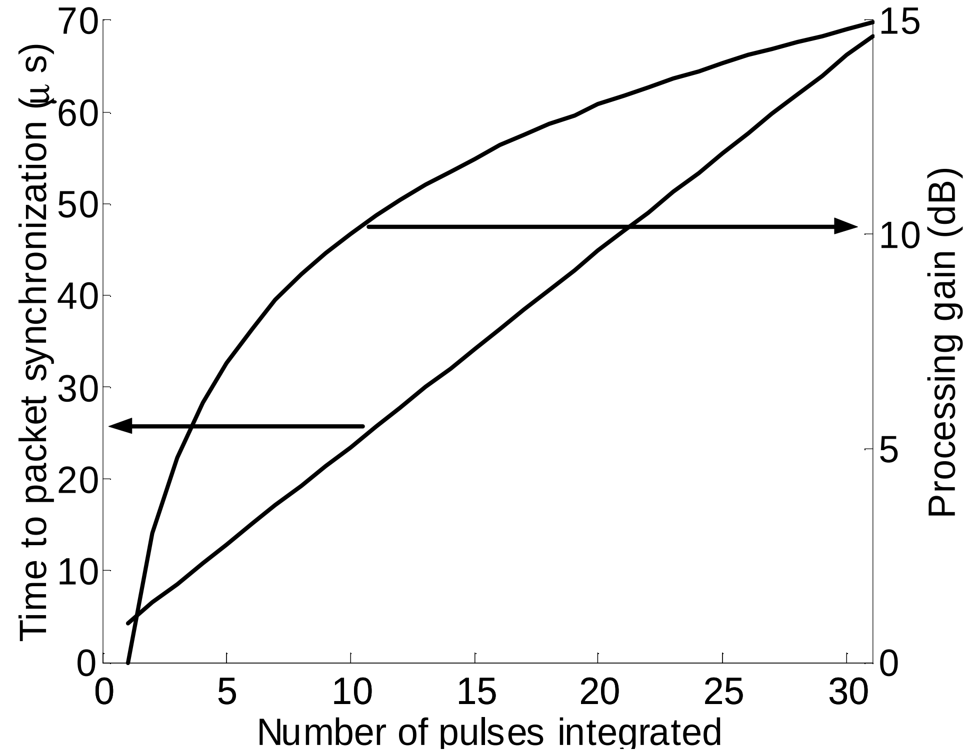


Correlators Architecture

Coarse acquisition

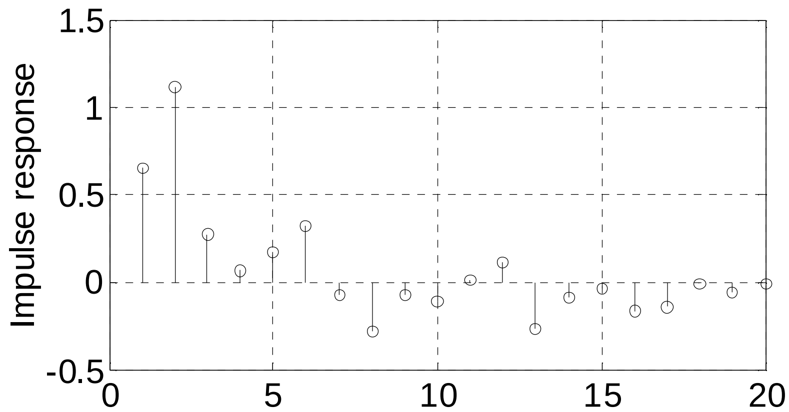


Parallellization Savings



Length of correlation trade-off

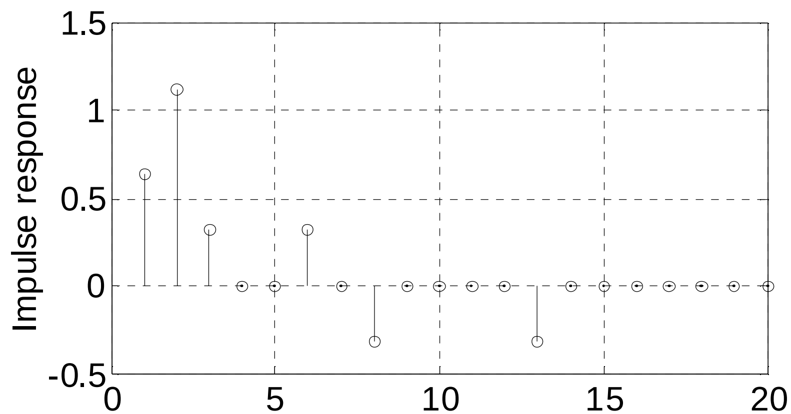
Rake Receiver



Channel Impulse Response (with multipath effects)

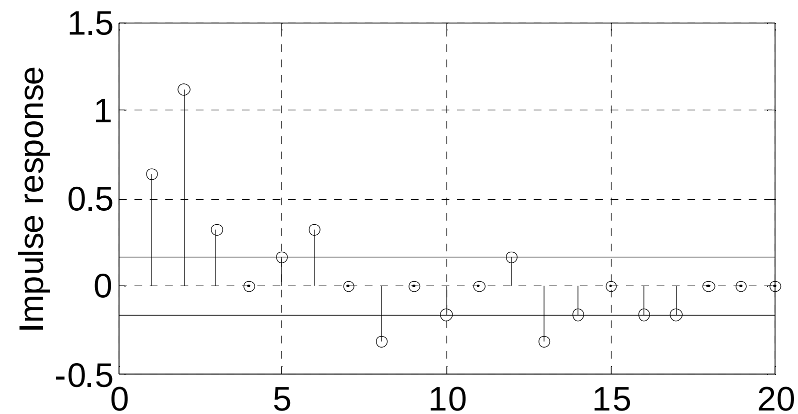
6 finger RAKE

Number of fingers fixed

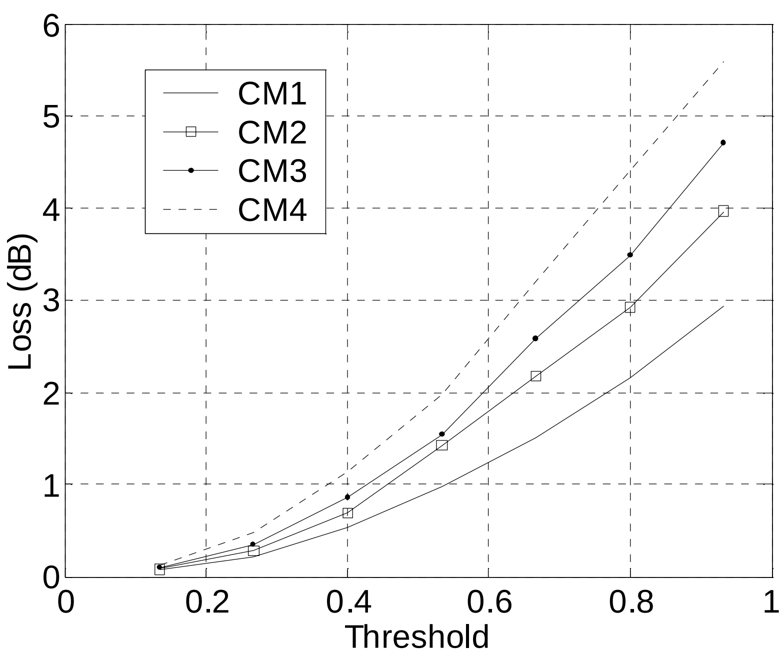


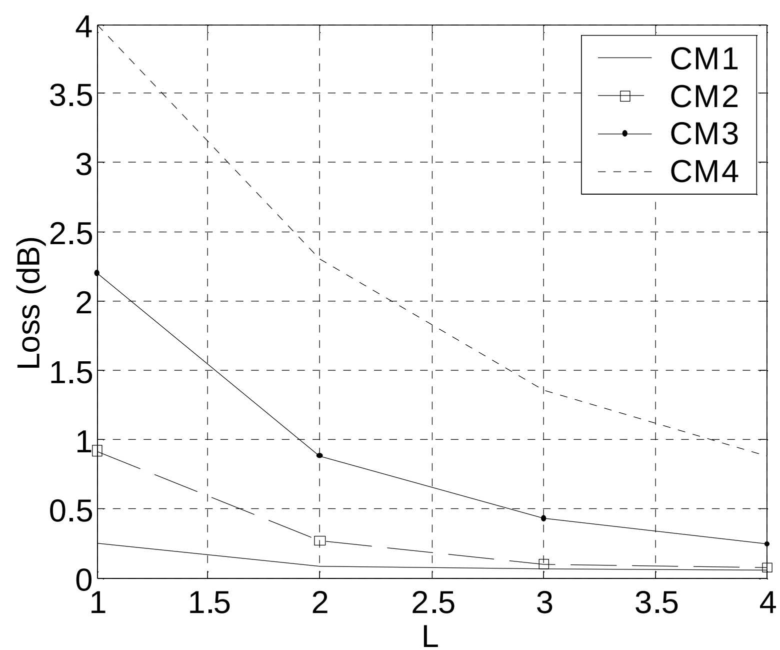
Method implemented

Variable number of fingers based on relative amplitude of response.



Programmable Baseband





MINIMUM POWER OF ECHOES

Energy $\propto$ 1/Threshold

NUMBER OF STATES OF MLSE EQ.

Energy $\propto$ exp(L)

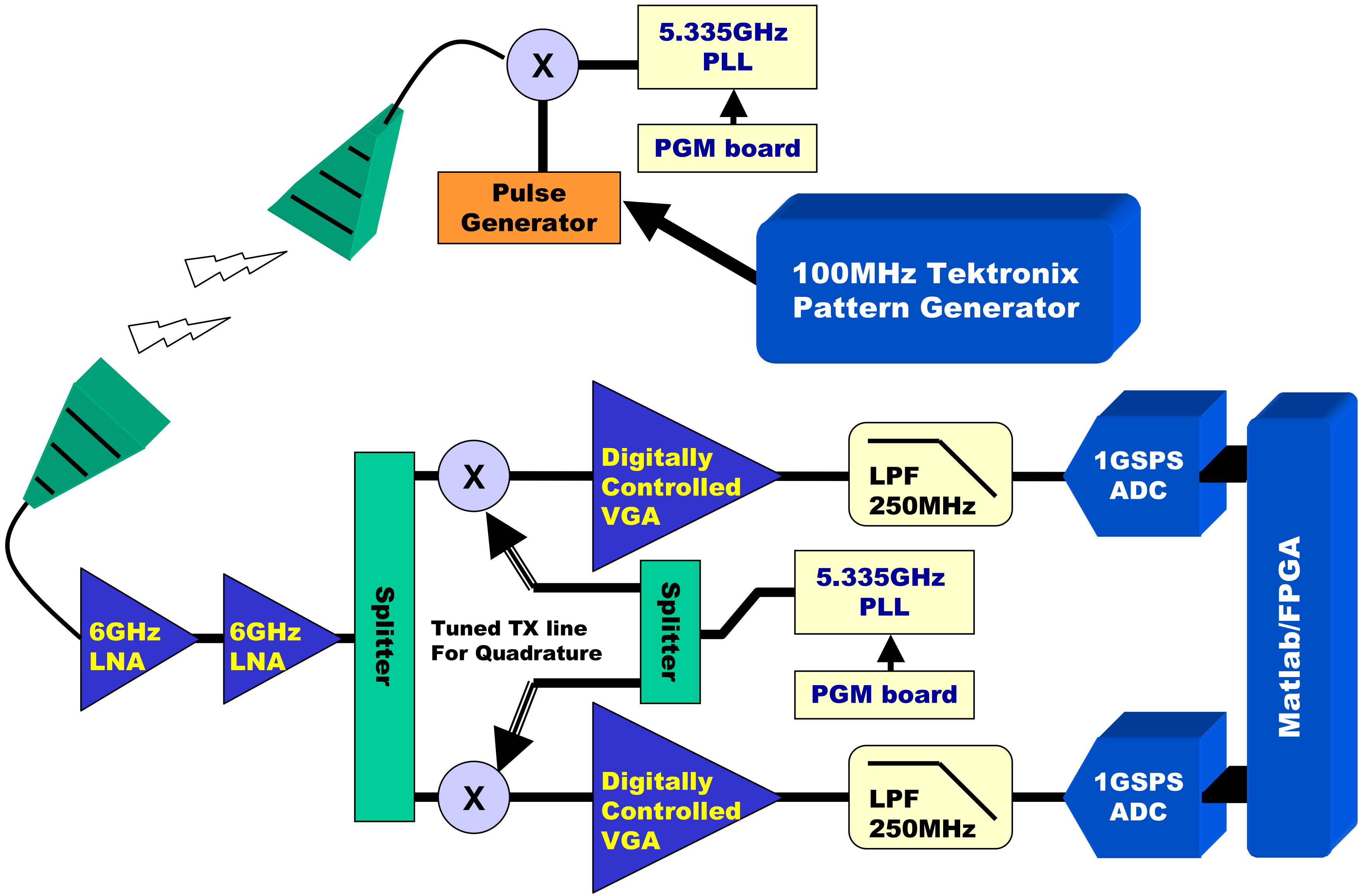
Adapting to the Channel

- Digital baseband estimates channel properties:
  - Multipath (Impulse Response)
  - Signal power

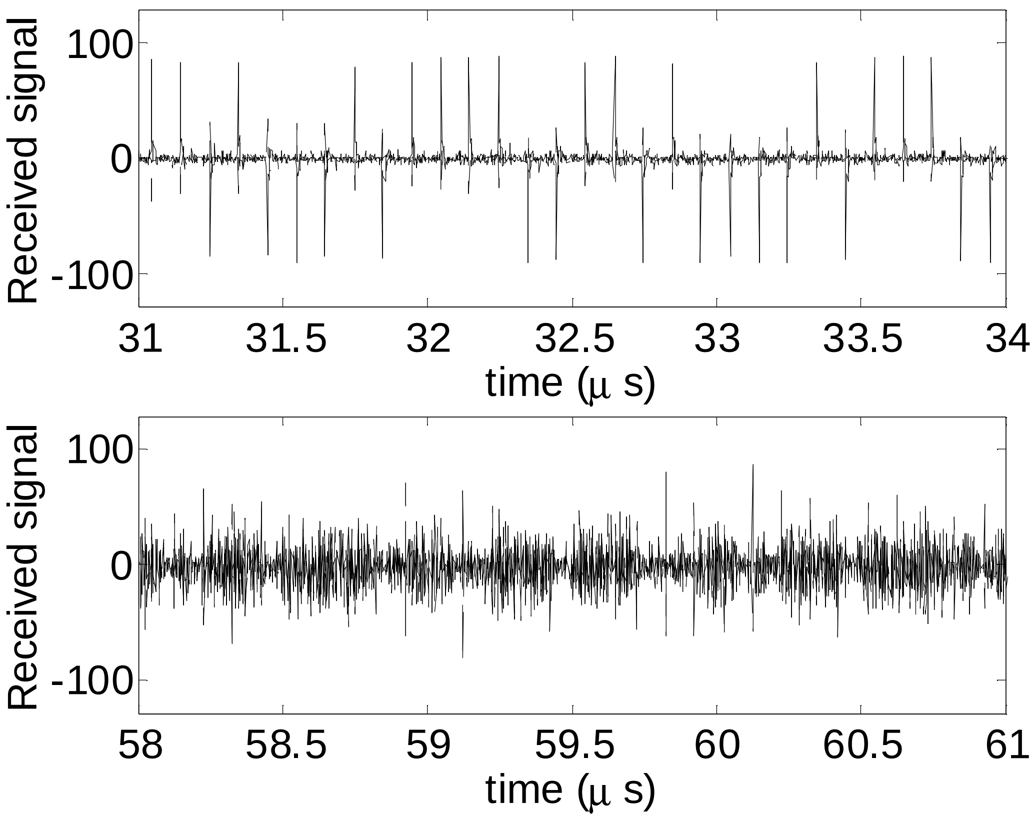
- Controls over signal processing:
  - Number of states of equalizer.
  - Number of bits of ADC.
  - Threshold of the channel.

TRADE OFF SIGNAL PROCESSING ENERGY WITH QUALITY OF SERVICE

Flexible Discrete Prototype



Testing Using the Discrete Prototype



No Interference

SIR = -11 dB

Demonstrated 100Mbps wireless link, packets 10000 bits payload

Conclusions

- Higher data rate implies complexity.
- Parallellization reduces acquisition time and allows power reduction.
- Signal processing energy is traded off with quality of service and data rate.
- A discrete platform was designed, achieving 100 Mbps, wireless.