Signal Processing with Low-Precision A/D Conversion

A Framework for Low-Cost Gigabit Wireless Communication

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Motivation

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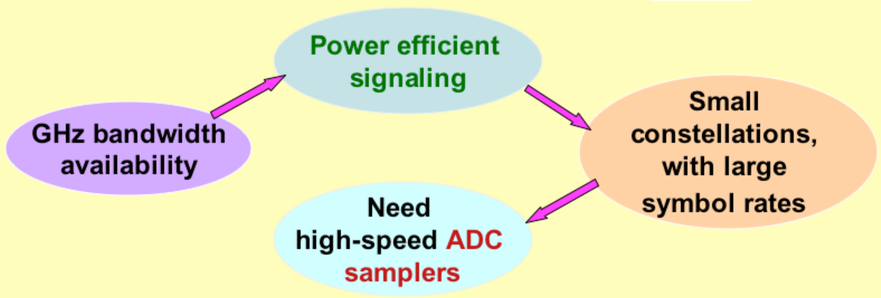
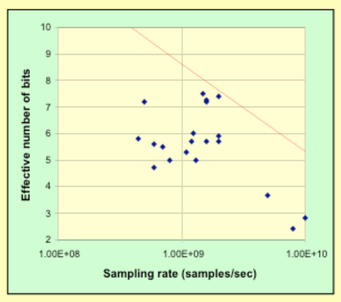
Communication systems scale up in speed and bandwidth

- 7 GHz of unlicensed spectrum in the 60 GHz mm wave band
- Feb 2002 : FCC opened up the 3-10 GHz band for UWB communication

Huge Potential for WLAN/WPAN Applications

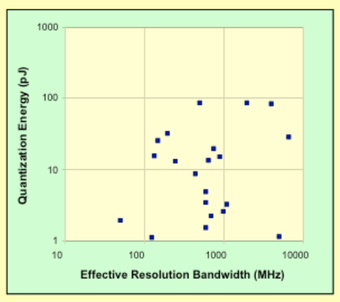


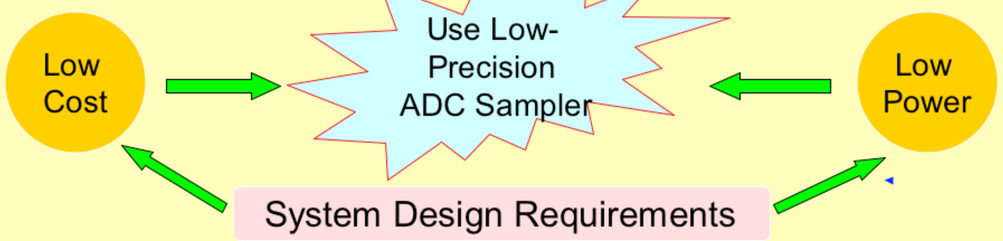
ADC State of the Art



Major limiting factors

- Aperture Jitter
- Transistor mismatch
- Device parasitics





Issues to be Explored

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Single Carrier Systems

- Shannon theoretic limits for low precision ADC
  - For Nyquist sampling : Joint optimization over the quantizer and the input constellation
  - Does oversampling help ? Optimal choice of pulse shapes ?
  - Can dithering provide some gains ?
- Synchronization and Parameter Estimation with imperfect ADC
  - Must revisit the conventional approaches
    - Carrier synchronization
    - Channel estimation
    - Timing estimation
    - Equalization

⇩ **Non-linear Channel model**

Focus will be on developing DSP-based solutions [despite sloppy ADC]

Moore's Law

Low cost digital-centric implementations

Multi Carrier Systems

- OFDM Systems : FFT / IFFT operations assume perfect ADC
  - How does finite precision effect performance ?
  - Role of time-interleaved ADCs to improve the precision

Initial Results

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Shannon limits for the extreme case of 1-Bit ADC Precision

Assumptions

- Linear modulation
- Real baseband AWGN channel
- Nyquist criterion satisfied

Channel Model : $y(t) = \text{sign}[x(t)+n(t)]$

Non-spread system

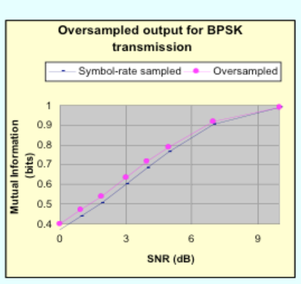
- For symbol rate sampling [$Y = \text{sign}(X+N)$]

  BPSK is optimal

- Symbol rate sampling is not optimal !

  Oversampling provides some additional information about the input

Can we generalize ?
Intuitive thought : N-point constellation will be optimal for N-level quantizer



Initial Results

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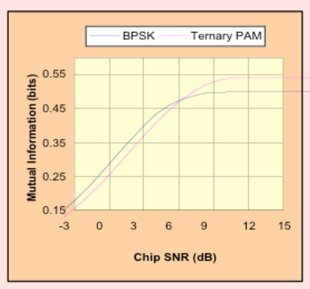
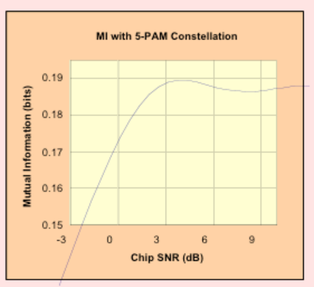
Spread-spectrum system

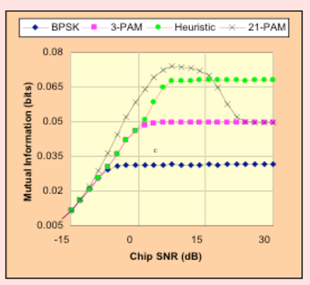
Symbol rate sampling : [$Y_k = \text{sign}(X_k+V_k)$]



BPSK not optimal



Mutual Information may be non-monotonic with SNR !



CLT based heuristic constellation design

Summary

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- Low-precision ADC : Could be a promising paradigm for low cost, ultra-high speed wireless communication
- Preliminary insights : Results that are taken for granted need to be revisited if ADC is not perfect. Complete rethink of transceiver design required