Low Complexity Receiver of Pulse Based UWB

— A research of WINLab, USTC

Yin Huarui, *yhr@ustc.edu.cn*

http://staff.ustc.edu.cn/~yhr

University of Science and Technology of China

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Outline

- **About WINLab……**

- **Introduction to UWB**

- **Mono-bit Receiver and its performance**

- **Why we insist on pulse-based UWB?**

- **Conclusion**

- **Related Publications**

Brief Introduction to WINLab, USTC

- **Full Name**
  - *Wireless Information Network Laboratory, affiliated to University of Science and Technology of China*

- **Research Topics**
  - *Technologies about LTE , LTE-A……*
  - *Short range wireless interconnection*

Introduction to UWB

- **Characters of UWB Communication**
  - *Low power spectrum density*
  - *Low power consumption*
  - *Low cost*
  - *High data rates*

- **Impulse radio UWB**

- **Point to point high data rates transmission in short or ultra-short range**

- **Wireless interconnection in a small region, e.g., WPAN**

Specialties of UWB Communication

- **Difference from other wireless communication system**

  - *Inessential to spectrum efficiency*
    - Fast reuse
    - Large bandwidth utilization

  - *Sensitive to power consumption*
    - power consumption of receiver-side signal processing

Traditional UWB Receivers

- **Matched Filter (MF)**
  - *Optimal Receiver in AWGN*
- **Peak Detection (PD)**
  - *Low cost and low power consumption*
- **Transmit Reference (TR)**
  - *Avoid Channel Estimation*

- ## **MF UWB receiver in 2006**
  - *110Mbps @5m, LOS Channel, 2-3 fingers rake combining*

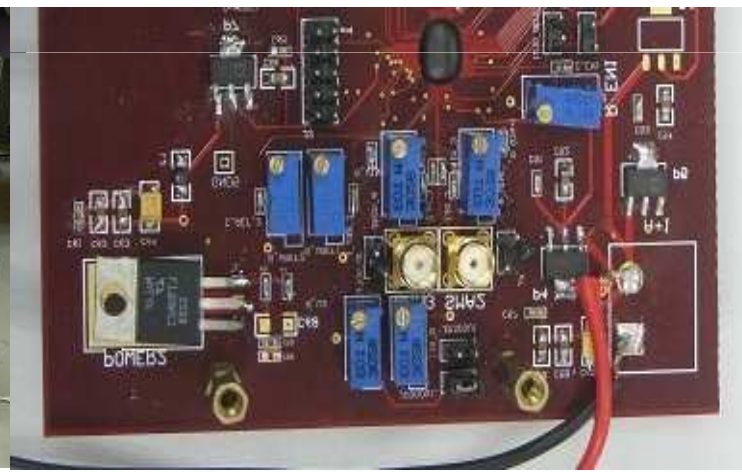Correlation & AD   Baseband

- **PD UWB receiver with discrete devices in 2006 and with integrated circuits in 2009**
  - *200Mbps@1m, strong LOS channel*
  - *20Mbps@5m*

Discrete device   HD Video Trans   Integrated Circuits

Disadvantage of Traditional Receivers

- ## Analog Implementation
  - *MF: High Complexity in multi-path channel*
  - *PD: Poor Performance in multi-path channel*
  - *TR: Low data rate and wideband delay line*

- ## Bottlenecks of Digital Implementation
  - *High Sample rate ADC*
  - *Mass data*

How to achieve high data rates with low complexity UWB receivers?

Specialties of UWB review

- ## Density multi-path fading channel
  - *Analog signal processing is deficient*
    - Digitalized receiver is necessary

- ## Inessential to spectrum efficiency
  - *No need of high order modulation*
    - BPSK is the most case

- ## Signal Pattern of pulse based UWB
  - *Low duty cycle -> Energy concentration -> High Instantaneous SNR*

- ## Decrease the resolution of ADC
  - *ADC power and complexity decreased geometrically*
  - *Amount of data decreased linearly*

- ## Question
  - *How many bits is enough?*
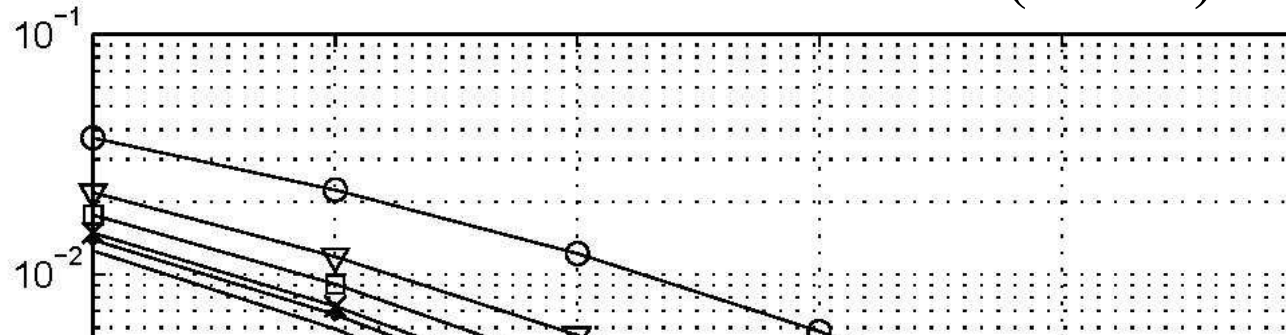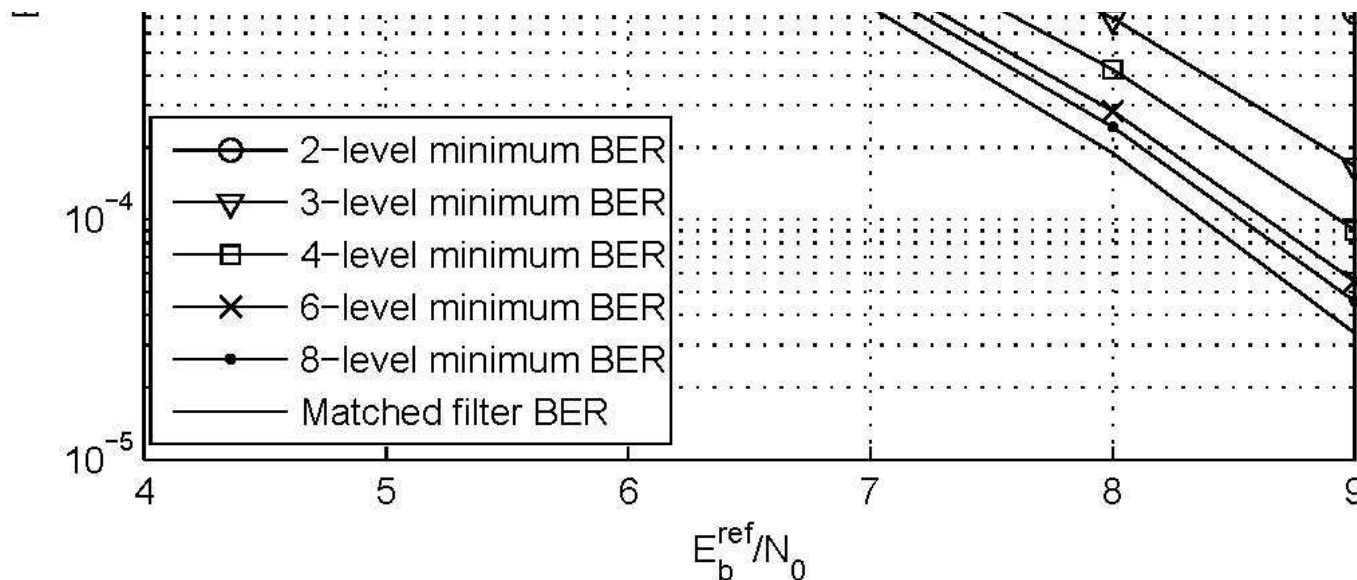
BER bound @diff. ADC bits (BPSK)

Monobit is enough!

Legend:
- ○ 2-level minimum BER
- ▽ 3-level minimum BER
- □ 4-level minimum BER
- × 6-level minimum BER
- • 8-level minimum BER
- — Matched filter BER

E_b^{ref}/N_0

Problems in monobit receivers

- ## Related problems for mono-bit receivers
  - *Reference signal extraction*
  - *Decoding interface of channel coding*
  - *Channel Estimation and equalization*
  - *Synchronization and Timing Recovery*
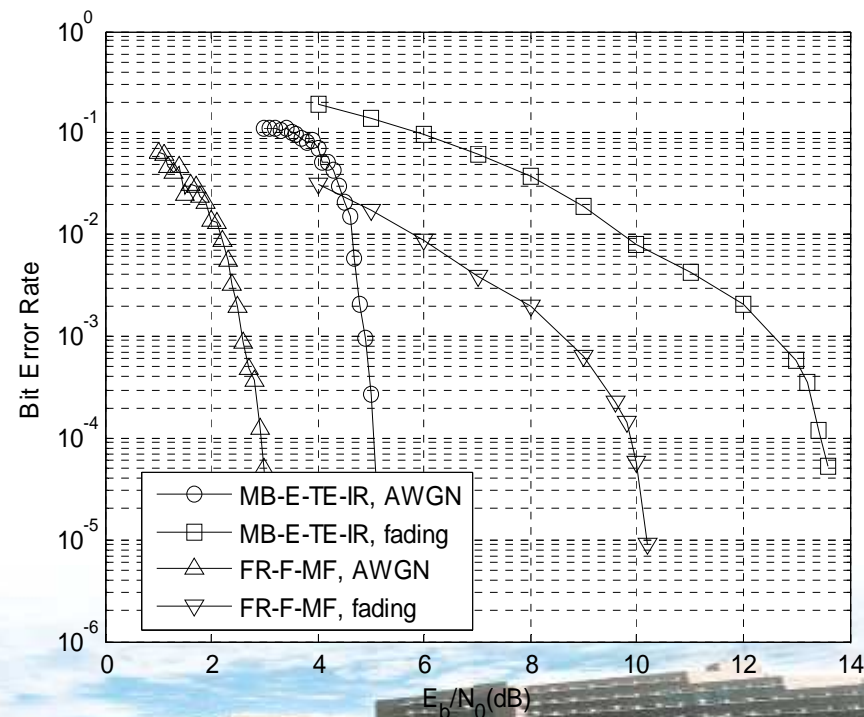- ## Luckily, we have found the solution of these problems and verified the solutions with our test-bed

- **CM-1 fading channel (average with 100 realizations)**
- **Perfect timing**
- **½ LDPC applied**
- **NO ISI assumed**

Conclusion:

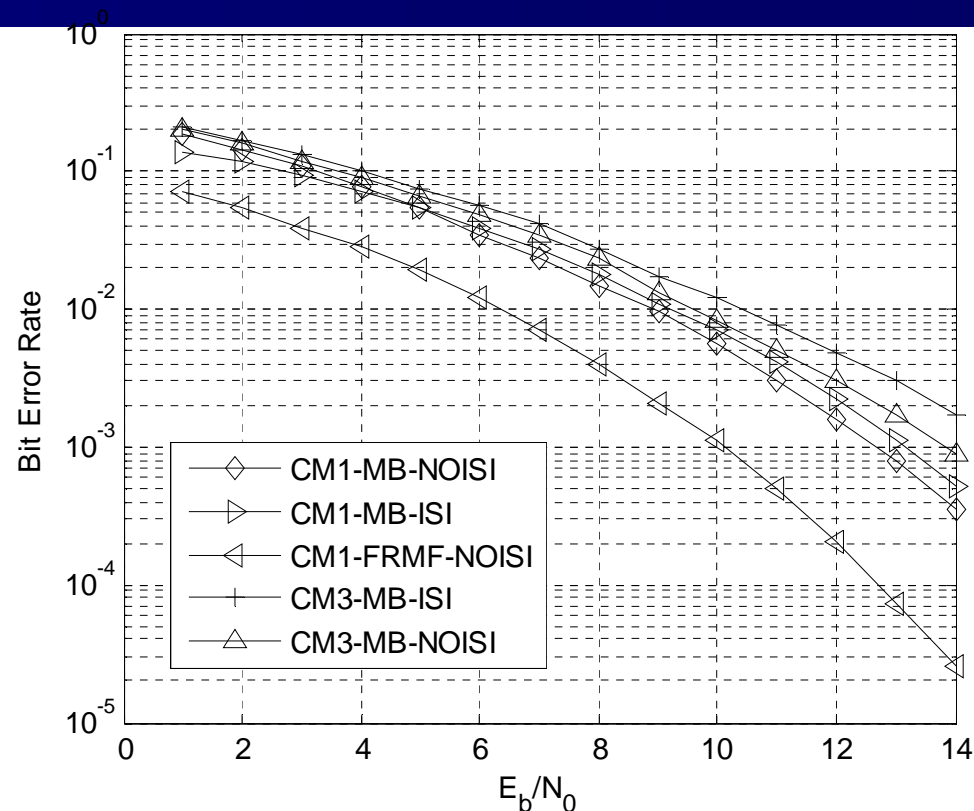*mono-bit receiver incurs only 3.5dB SNR loss in fading channel.*

- **MB: Mono-bit Receiver**
- **FR: Full Resolution ADC Receiver**
- **F : Full Channel Information**
- **E : With Channel Estimated**
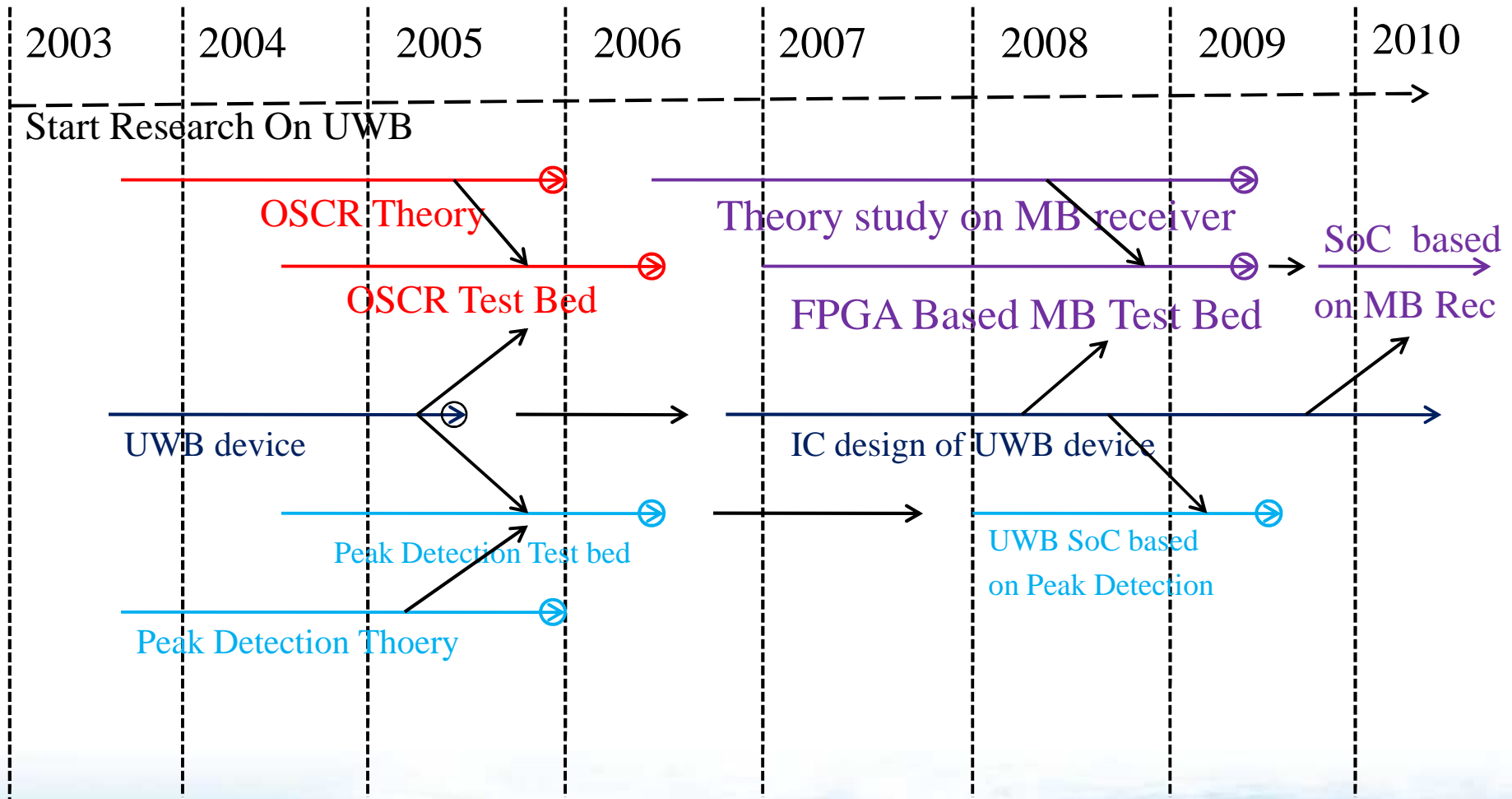- **IR : With Iterative and RSWP**

Bit Error Rate vs E_b/N_0(dB)

Legend:
- MB-E-TE-IR, AWGN
- MB-E-TE-IR, fading
- FR-F-MF, AWGN
- FR-F-MF, fading

- **Data rate is 250Mbps**
- **Perfect timing**
- **With channel estimation and channel equalization**
- **No channel coding**

Legend:
- CM1-MB-NOISI
- CM1-MB-ISI
- CM1-FRMF-NOISI
- CM3-MB-ISI
- CM3-MB-NOISI

X-axis: E_b/N_0

Y-axis: Bit Error Rate

2003	2004	2005	2006	2007	2008	2009	2010

Start Research On UWB

OSCR Theory

OSCR Test Bed

Theory study on MB receiver

SoC based on MB Rec

FPGA Based MB Test Bed

UWB device

IC design of UWB device

Peak Detection Test bed

UWB SoC based on Peak Detection

Peak Detection Thoery

Progress of WINLAB on Monobit Receiver

2006   Started the work, initial results gotten

2007   Work Approved by 863

      Performance Verification with test bed

2008   Started IC design

      Start the work of relative problem

2009   Full Duplex demo FPGA based
      mono-bit tran-ceiver(up to 250Mbps)

      6 nodes demo network

2010   SoC of UWB PHY (expected)
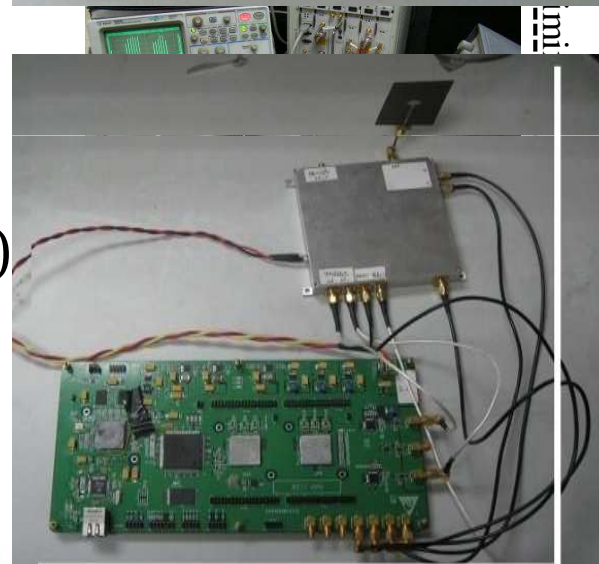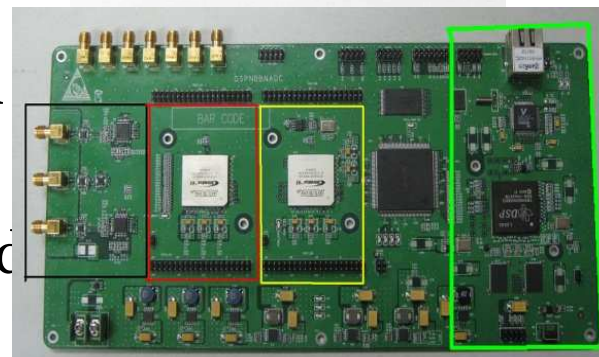
- Advantages of OFDM mechanism
  - *High spectrum efficiency*
  - *Meet the spectrum mask easily*

- Disadvantages
  - *Large PAPR*
  - *High complexity of ADC/DAC module, digital signal processing module*

- What are the most critical problems of UWB?
  - *Power , Complexity, Cost*

- **Receiver-side signal processing becomes the major problem of power consumption in UWB**

- **Monobit receiver is a viable technology for low complexity and low power IR-UWB communication**

- Finite-Resolution Digital Receiver Design for Impulse Radio Ultra-Wideband Communications. (Ke, Yin , Gong and Wang. IEEE ICC 2008, May, 2008. See also : IEEE TWC, Dec, 2008)

- Mono-bit Digital Receivers: Design, Performance, and Application to Impulse Radio. (Yin, Wang, Ke and Wang. IEEE TCOM, 2009, to appear)

- Performance analysis of IR-UWB 1-bit digital receivers. (Gong, Yin, Ke, Fu. 43rd Conference on Information Sciences and Systems, Mar, 2009)

Thanks