# IEEE P802.15
# Wireless Personal Area Networks

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) |
| Title | **Alternative UWB System Physical Layer Proposal for 802.15.4a** |
| Date Submitted | [January 4, 2005] |
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| Re: | [] |
| Abstract | [Preliminary alternative physical layer proposal for 802.15.4a] |
| Purpose | [This document is a response to IEEE 802.15 call for systems proposals] |
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**Contents**

Introduction
Modulation and Coding
Multiple Access
Spectrum
Transmitter
Receiver
Link Budget
Backup Technologies
Example and Performance
Conclusion

## 1. Introduction

This preliminary proposal introduces a UWB system architecture for IEEE 802.15.4a low data rate communications, responding to IEEE 802.15 call for system proposals. The proposed system is an alternative to current narrow band WPAN specifications, and its wide bandwidth and low power spectral density (PSD) enable higher data rate and overlaying with existing wireless systems. Cost and low power are two of main concerns in the system design for IEEE 802.15.4a low data rate applications. A UWB system is an energy limited system. Thus suboptimal reception strategies should be considered to achieve the goal of low cost with low power.

Due to the high resolution of a UWB pulse, the number of resolvable paths is significant [1]. The traditional RAKE structure seems to be too expensive [2-4]. The frequency dependence that was first introduced into a UWB system long ago by one of the authors [1] will cause per path pulse distortion [2-4], thus complicating the system design. If the matched filter that is matched to the composite channel response is used, the optimum detection can be achieved. Again the cost is the limiting factor to eliminate this choice.

In our case for low data rate (IEEE 802.15.4a), inter-symbol interference (ISI) seems not to be a concern. ISI is a concern for IEEE 802.15.3a. We also note that for a UWB system, fading caused by unresolvable multipath is of secondary significance in system design. The major issue is the wide delay spread of the channel.

The so-called transmitted-reference (TR) principle seems to be very promising for IEEE 802.15.4a, as suggested in [2]. A TR system does not need channel estimation and strict timing, which make great sense in terms of system complexity and implementation cost. The underlying technologies for this proposal include differential modulation and autocorrelation detection (ACD) that that can be viewed as a modified version of the TR scheme [5]. The ACD scheme not only eliminates the use of expensive waveform estimator at the receiver.

System framework is proposed with the support of preliminary simulations. Further details regarding pulse shape and spectrum issues, channel control coding, spreading codes, and frame structure, etc., need to be specified in the future.

## 2. Modulation and Coding

Differential binary PSK (DBPSK) is considered as modulation scheme. The main advantages of DBPSK include implementation simplicity, and that it enables to use a simple receiver structure based on differential detection.

To support variable data rates under different channel conditions, the system employs multi-rate channel encoders using convolutional code and/or turbo code. Detailed code structures are to be determined.

## 3. Multiple Access

Direct sequence spread spectrum (DS/SS) based asynchronous CDMA is utilized to support multiple access ability. Theoretically speaking, time hopping spread spectrum (TH/SS) based CDMA and hybrid DS-TH-CDMA work too. However, compared to the TH-CDMA system, the DS-CDMA system does not have to use a large number of precise delay lines for de-spreading purpose at the receiver, and it can be less sensitive to timing since only rough pulse (chip) boundary timing is needed. DS-CDMA in conjunction with CSMA-CA can be an alternative multiple channel access solution to support vast number of users.

## 4. Spectrum

3 dB bandwidth: minimal 500 MHz
Frequency range limits: 800 MHz – 10.6 GHz

## 5. Transmitter

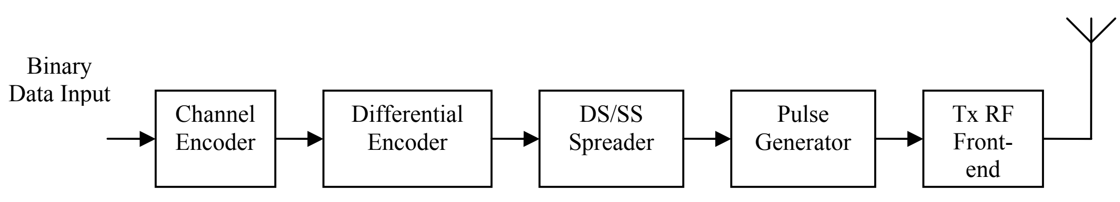


Fig.1. Transmitter structure

## 6. Receiver

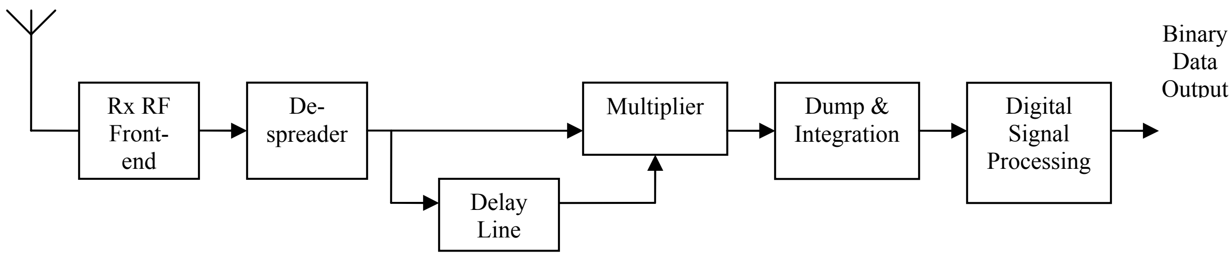


Fig.2. Receiver structure

## 7. Link Budget

| **Parameters** | **Values** |
|---|---|
| Raw bit rate Rb | 1 Mbps |
| Average Tx power | -13.71 dBm |
| Tx antenna gain | 0 dBi |
| Center frequency | 4.125 GHz |
| Path loss at 1 m | 44.75 dB |
| Path loss at 30 m | 74.29 dB |
| Rx antenna gain | 0 dBi |
| Average Rx power | - 88 dBm |
| Thermal noise power per bit: -174 + 10*log10(Rb) | -114 dBm |
| Noise figure | 7 dB |
| Total noise power per bit | -107 dBm |
| Minimal required Eb/No | 12 dB |
| Implementation loss | 4 dB |
| Link margin | 3 dB |
| Proposed minimal Rx sensitivity | - 91 dBm |

## 8. Backup Technologies

Reduced bit quantization
Reference enhancement
Multiple symbol detection
Gating/adaptive integration

### 9. Example and Performance

Raw bit rate: 1 Mbps
Spreading code length: 16 chips
Pulse repetition frequency (PRF): 16 MHz (pulse repetition interval = 62.5 ns)

Noisy demodulation reference takes major responsibility for poorer performance of an autocorrelation receiver. A simple way to reduce the noise on top of the reference and improve the performance is to average over several received waveforms. Shown in Fig. 3 is a performance comparison of ordinary ACD and ACD with reference enhancement based on decision feedback. About 1 dB improvement is obtained at cost of using one more delay line and an addition operation unit (device).

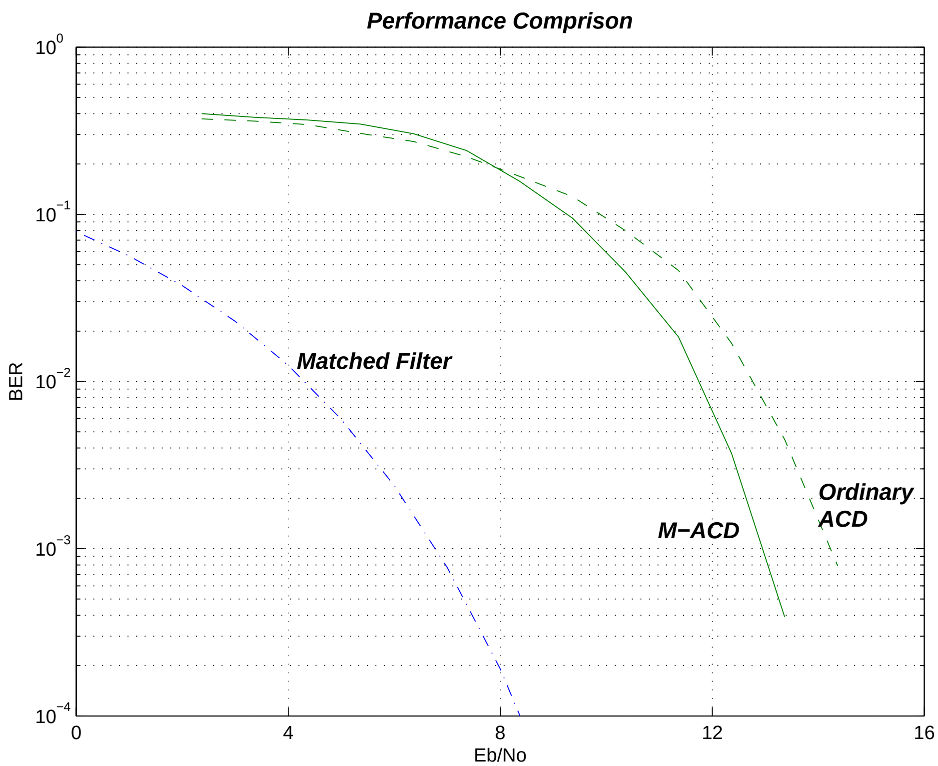


Fig. 3. Performance comparison of ordinary ADC and ACD with reference enhancement based on decision feedback.

Detection based on multiple received symbols is another efficient technique to achieve better performance [5]. The performance is improving as observation window size (or block size) increases Bit error rates (BER) for various block sizes are illustrated in Fig. 4, where $L$ refers to as the number of symbols per block. Trade-off can be made between the performance and complexity that associated with the block size.

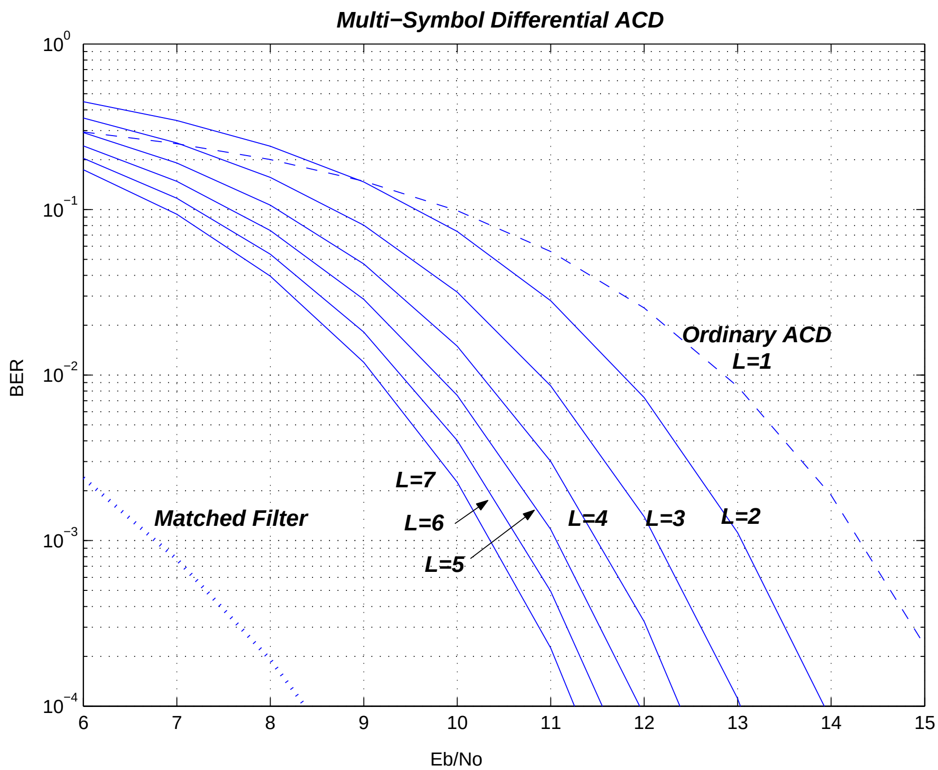


Fig. 4. Performance of multi-symbol differential ACD.

## 10. Conclusion

A physical (PHY) layer architecture for low data rate UWB communications has been proposed. The proposed system has following features:

- No need for channel estimation and waveform estimation
- Make full use of all the multipath energy
- Timing requirement is very low
- Flexible in accommodating variable data rate and multiple users
- Better performance than some of schemes that use suboptimal reception techniques such as square law/envelop detection
- Potential to overlay with existing systems

- Enabling to combining with some enhancement techniques to improve performance further

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