Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Differential detection of IR-UWB PPM symbols]
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Re: [Information and discussion on UWB]

Abstract: [Discussion on different aspects of the IR-UWB PHY in IEEE 802.15.8]

Purpose: [This document is to provide a general review of IR-UWB for PAC]

Differential detection of IR-UWB PPM symbols

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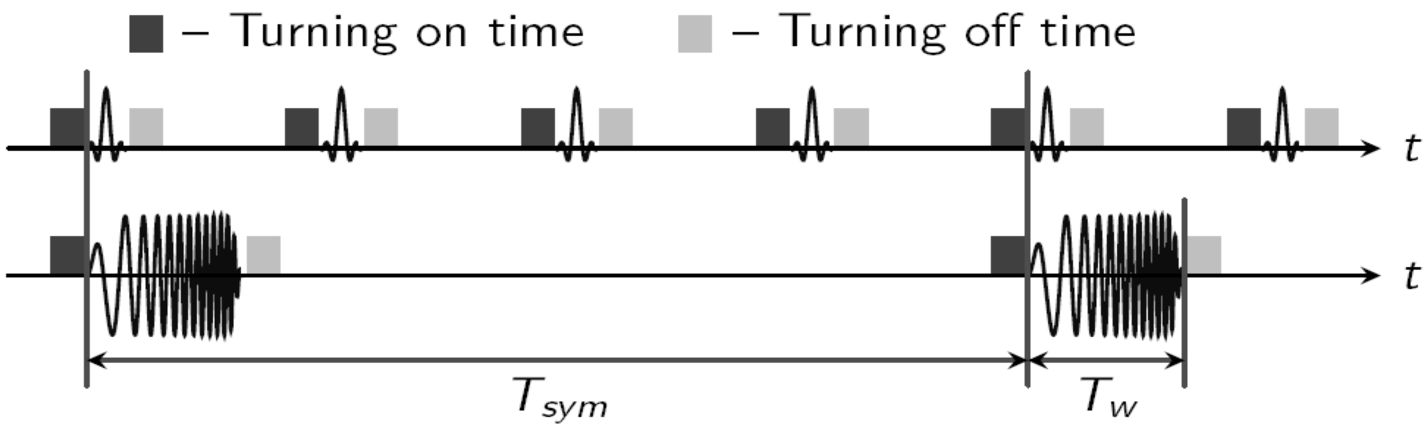
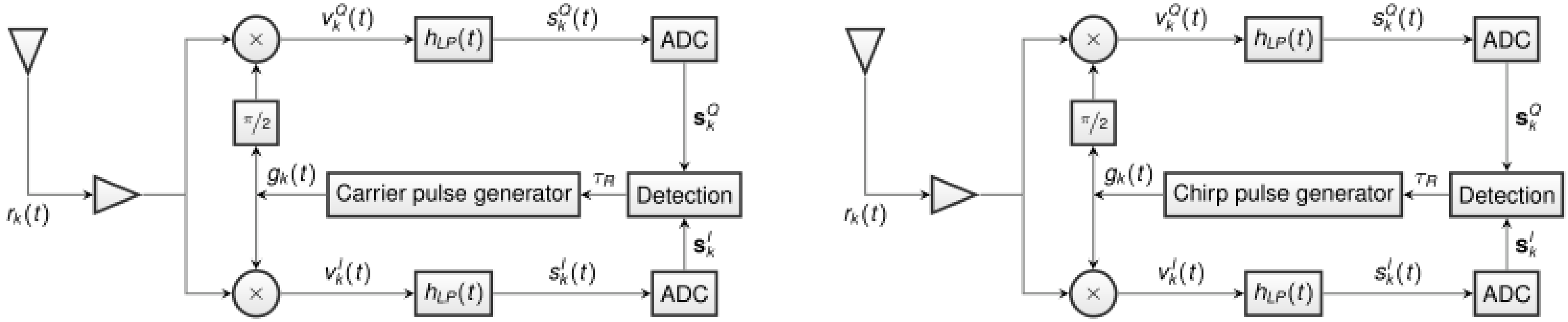
Purpose

To describe differential detection for PPM Impulse Radio Ultra Wideband (IR-UWB) modulation as an alternative to well-known and widespread Energy Detection (ED) and counter .

IR-UWB Signaling symbol structures



- Upper: Classic IR-UWB signaling having several short-pulse chips per symbol.
- Lower: Transmitting one continuous waveform per symbol (used in 15.4a and 15.6).



(a) Sampling receiver. (b) Chirp receiver.

Figure : Heterodyne receiver architectures considered.

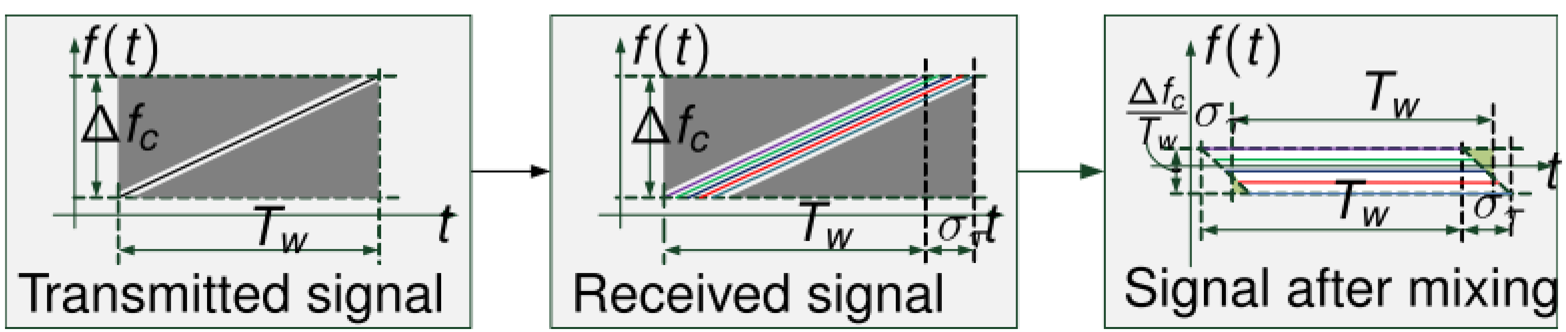


Figure : Principles of the chirp pulse compression.

Signal model

In PPM, there are two positions that receiver needs to discriminate between in order to detect a symbol.

Correct: $\mathrm{s}_k^c = \mathbf{u} + \mathbf{n}_k^c$

Erroneous: $\mathbf{s}_k^e = \mathbf{n}_k^e$

$$b_k = 1 \rightarrow \quad \mathbf{s}_k^1 = \mathbf{s}_k^c, \quad \mathbf{s}_k^0 = \mathbf{s}_k^e$$

$$b_k = 0 \rightarrow \quad \mathbf{s}_k^1 = \mathbf{s}_k^e, \quad \mathbf{s}_k^0 = \mathbf{s}_k^c$$

PPM detection methods

Energy detection

$$d_k = \left\|\mathbf{s}_k^1\right\|^2 - \left\|\mathbf{s}_k^0\right\|^2 .$$

Sample-wise differential detection

$$d_k = \Re\left\{\hat{\mathbf{s}}_{k-1}^H\left(\mathbf{s}_k^1 - \mathbf{s}_k^0\right)\right\} .$$

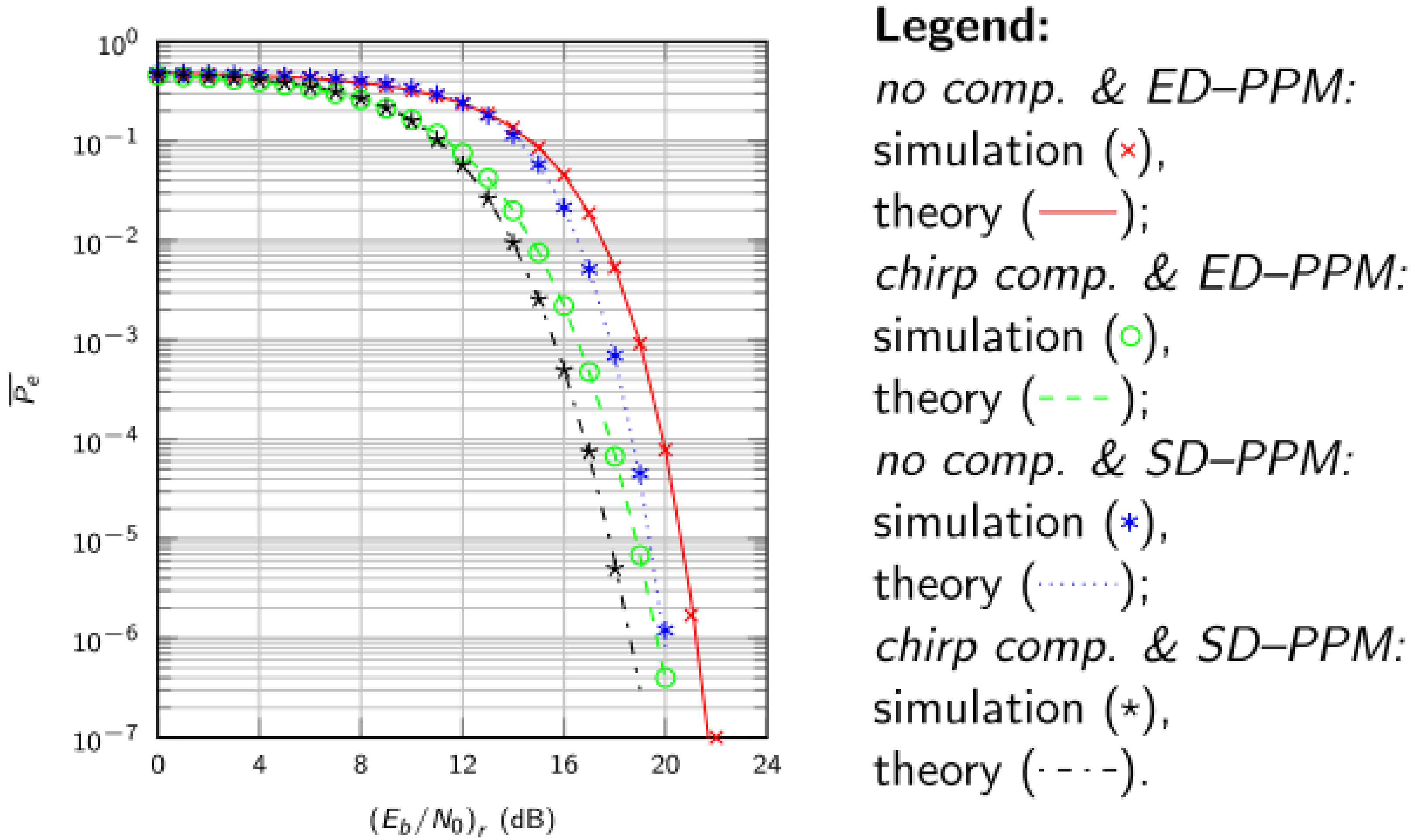
$$\hat{b}_{k-1} = 1 \Rightarrow \hat{\mathbf{s}}_{k-1} = \mathbf{s}_{k-1}^1 \qquad \hat{b}_{k-1} = 0 \Rightarrow \hat{\mathbf{s}}_{k-1} = \mathbf{s}_{k-1}^0$$

SD-PPM detection method is differentially coherent and does not require symbol signature estimation.

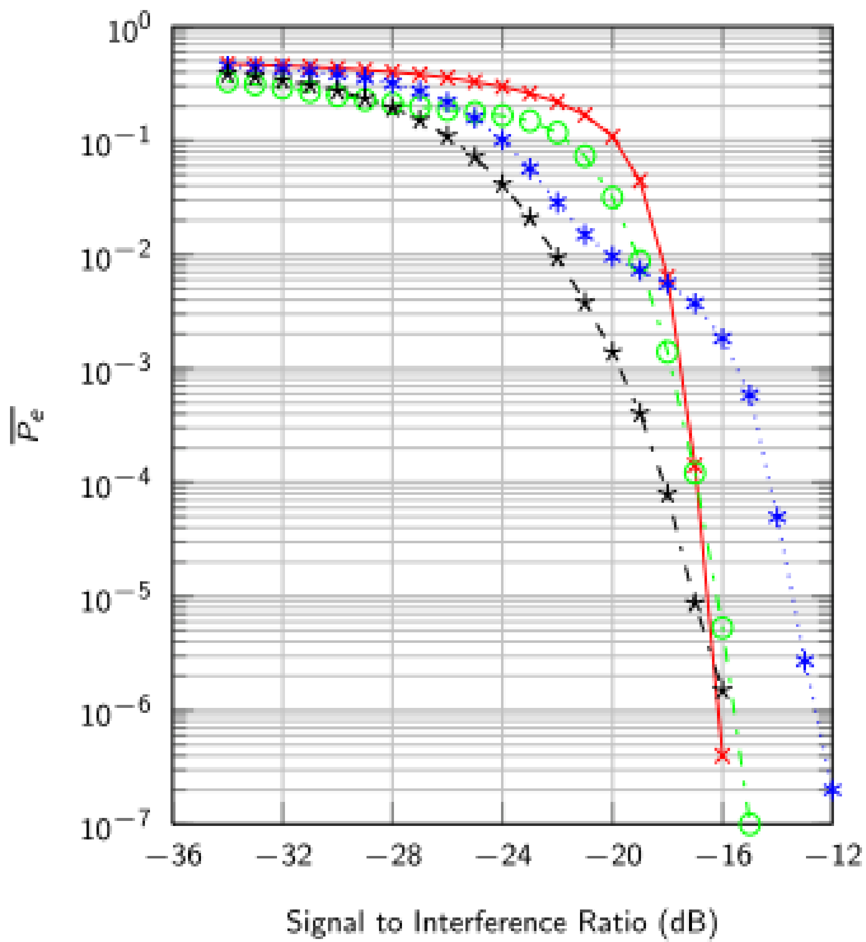
Numerical simulation parameters

- Carrier frequency f_0 = 8 GHz.
- IEEE 802.15.6 Chanel Model CM3.
- T_{sym}=8192 ns
- T_w= 256 ns.
- Chirp pulse is used.
- Time-hopping sequences of IEEE 802.15.6 IR-UWB PPM PHY are used.
- In the sampling receiver signal dimension is M=128.
- In the chirp receiver signal dimension is M=16.
- All simulations were done with 1e4 bits transferred at every of 1e3 scenarios for every point.

Performance in Noise



Performance in FM-UWB interference



Legend:

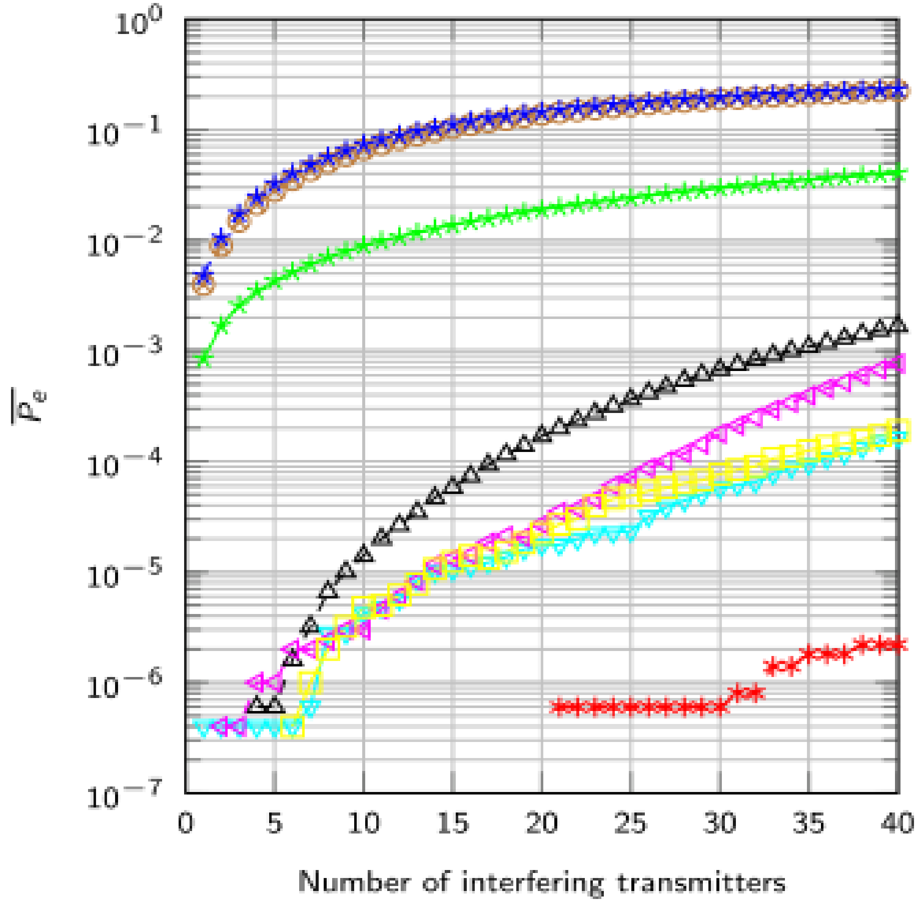
no comp. & ED–PPM (—×—);

chirp comp. & ED–PPM (· ○ -);

no comp. & SD–PPM (····);*

chirp comp. & SD–PPM (· ⋆ -).

Performance in Multiple-Access Interference



Legend:

no comp. & ED–PPM:

chirp interf. (-⊗-),

burst interf. (-★-);

chirp comp. & ED–PPM:

burst interf. (-△-);

no comp. & SD–PPM:

chirp interf. (—▽—),

burst interf. (-◁-);

chirp comp. & SD–PPM:

chirp interf. (—□—),

burst interf. (-✱-).

Conclusions

- The main drawback of ED – poor multiple access interference performance.
- Solution: Use differentially coherent detection.
    - It needs very little channel estimation (no signal signature estimation.)
    - Multiple-access interference performance is considerably better compared to ED.
    - Compared to coherent systems with symbol signature estimation complexity is considerably reduced.