

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]

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Differential detection of IR-UWB PPM symbols

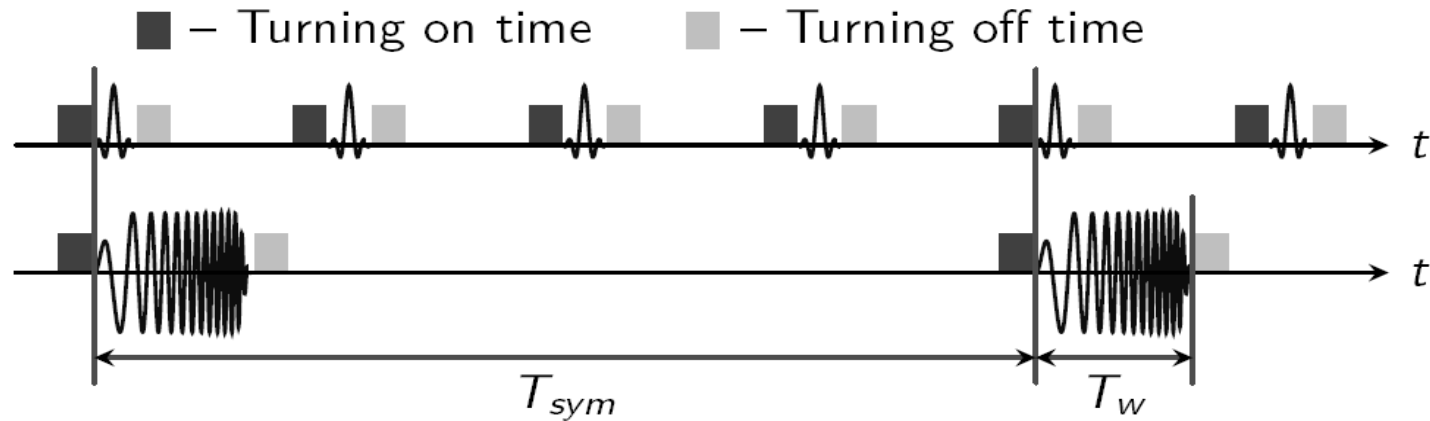
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Purpose

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

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).

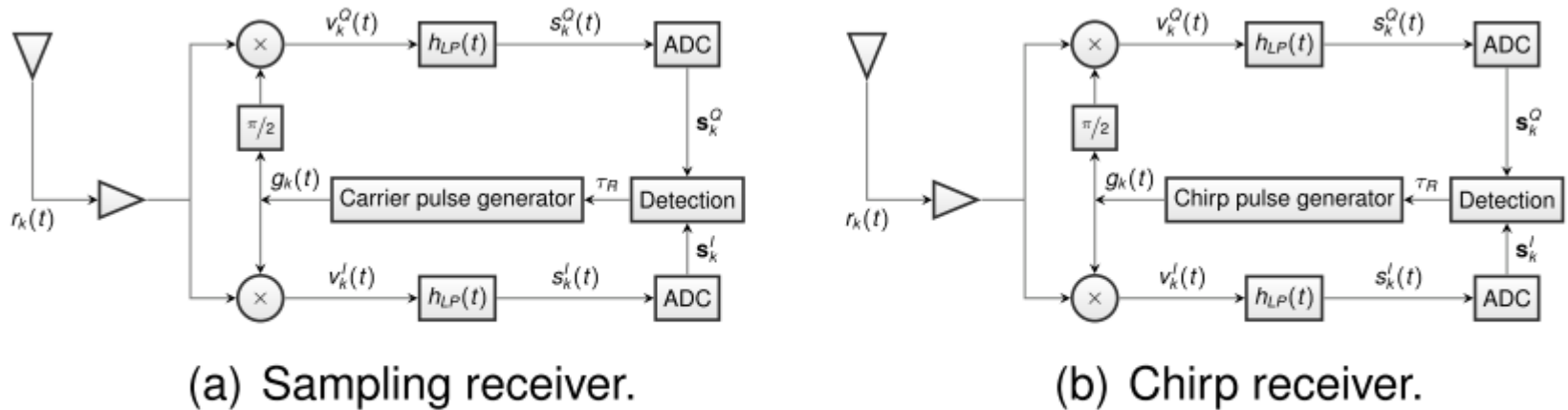


Figure : Heterodyne receiver architectures considered.

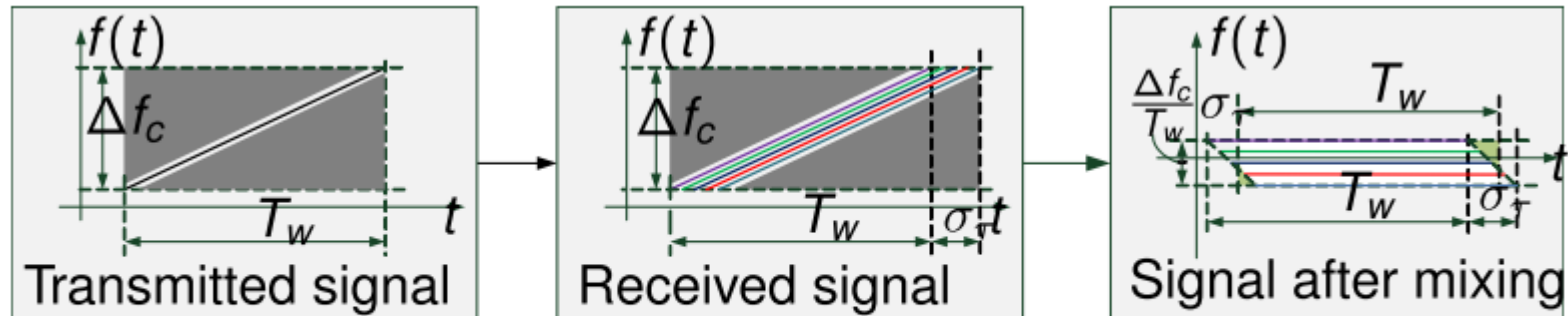


Figure : Principles of the chirp pulse compression.

Signal model

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

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

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

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

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

PPM detection methods

Energy detection

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

Sample-wise differential detection

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

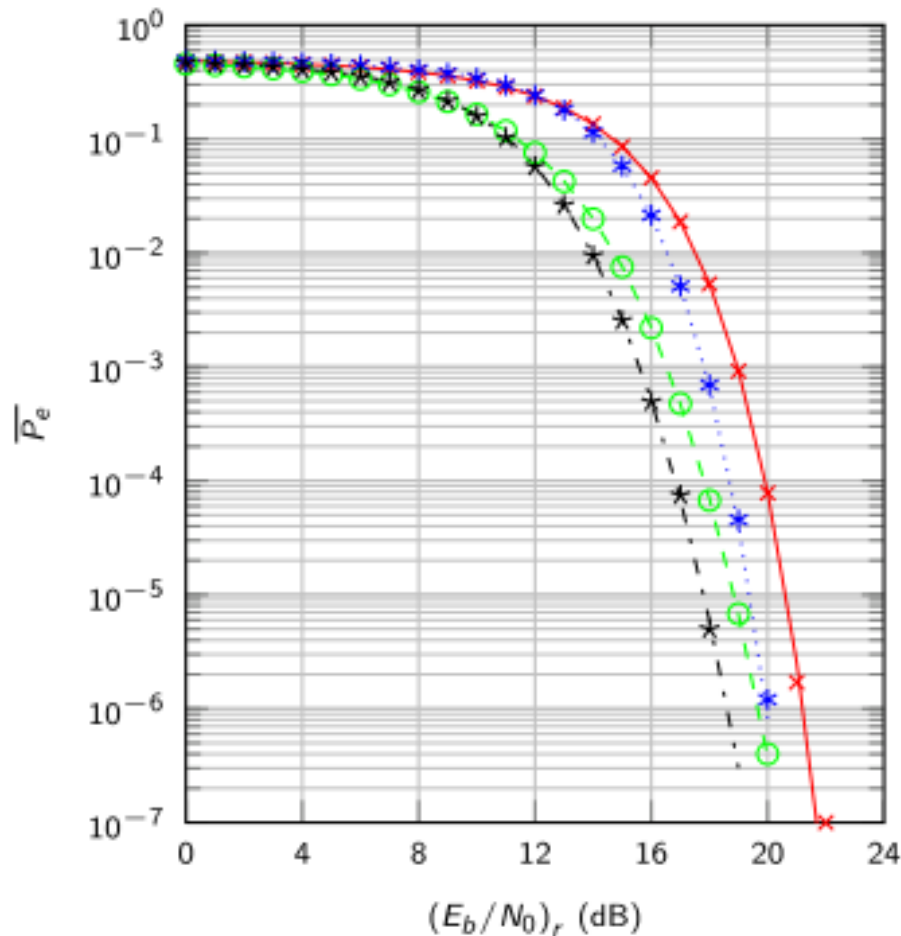
$$\hat{b}_{k-1} = 1 \Rightarrow \hat{\mathbf{s}}_{k-1} = \mathbf{s}_{k-1}^1 \quad \hat{b}_{k-1} = 0 \Rightarrow \hat{\mathbf{s}}_{k-1} = \mathbf{s}_{k-1}^0$$

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 Channel 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.

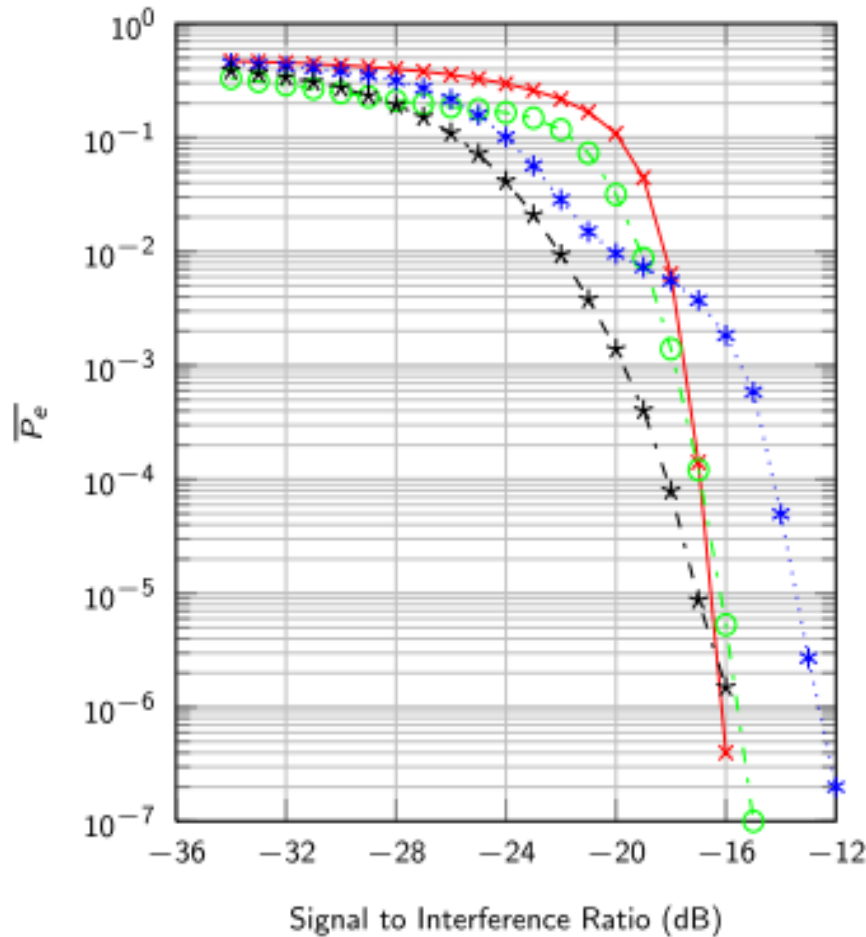
Performance in Noise



Legend:

- no comp. & ED-PPM:*
simulation (×),
theory (—);
- chirp comp. & ED-PPM:*
simulation (○),
theory (---);
- no comp. & SD-PPM:*
simulation (*),
theory (.....);
- chirp comp. & SD-PPM:*
simulation (*),
theory (·-·-·).

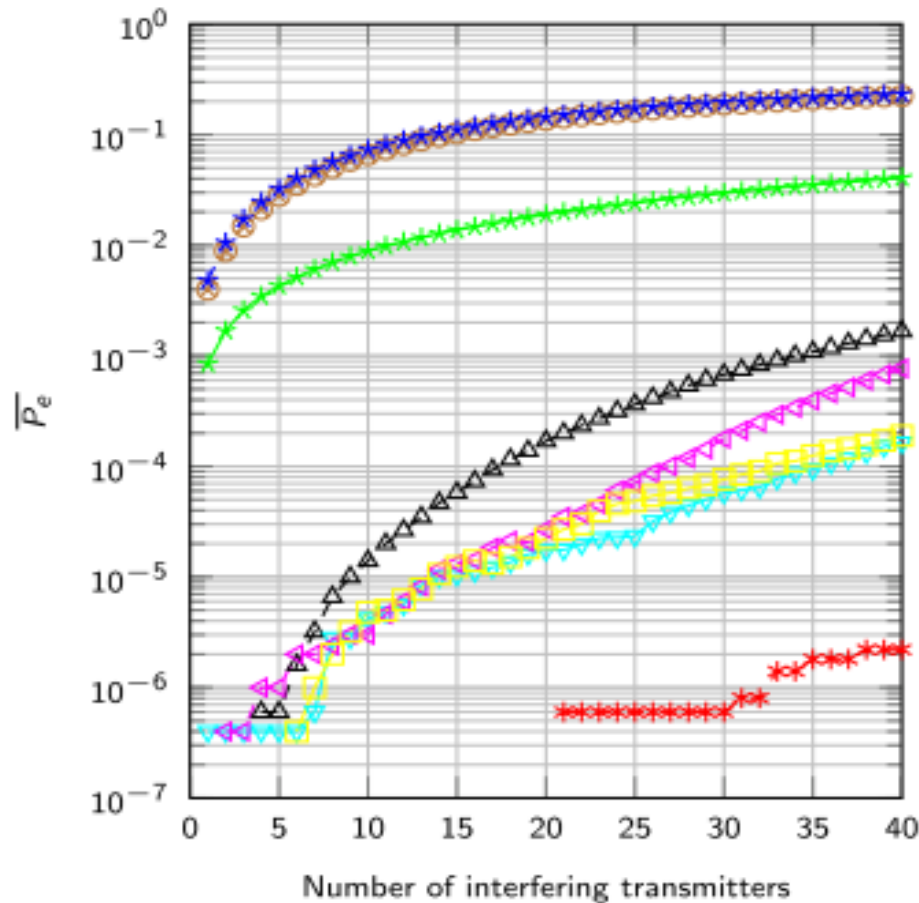
Performance in FM-UWB interference



Legend:

no comp. & ED-PPM (—x—);
chirp comp. & ED-PPM (-o-);
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.