

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

Submission Title: Reuse of 2.4 GHz PHY for the Lower Bands

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Re: Proposal and Discussion of equal higher data rates for PHY for 900 and 2400MHz bands

Abstract: Proposal of scaleable The proposed parallel reuse of the 2.4 GHz 802.15.4 modulation technology in PSSS offers highly attractive performance improvement increasing market opportunities. Scaleable data rate up to 300 or 600kbps in 868/915MHz is backward compatible with current BPSK and OQPSK modulation. Increase complexity measured in number of gates is very small. A preferred linear implementation is proposed as well. In addition the solution is more robust for multipath fading (up to 1.6us delay spread).

Purpose: Increased data rate to reduce total system power and reduce marketing difference with 900/2400

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Reuse of 2.4 GHz PHY for the Lower Bands

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Presentation Contents

- Introduction
- New Specifications for Low Bands
- Current PHY for 868/915 MHz versus adapted 2.4 GHz PHY
- Adapted 2.4 GHz PHY versus PSSS – 8 Times parallel reused 2.4 GHz PHY derivate
- Tx and Rx Architecture
- Pb versus $E_b N_0$
- Coding Gain
- Summary

Why do we want higher data rate

- (no order)
- 868 duty cycle issues
- more simple MAC
- marketing
- power consumption reduction (if done well)

What is important for the technical selection

- higher data rate enabling lower power consumption
- and good sensitivity (link budget>)
- small implementation
- backward compatible
- multipath robust
- scalable

New Specifications for the Low Bands

- We can expect new frequency bands specifications for the low ISM bands (868, 915 MHz) in Europe and Asia with increasing bandwidth
 - However, it will take years until the changed SRD band specifications form CEPT are adopted by all countries
-
- Therefore 3 forms of *derivative modulations yielding higher data rates¹* are desirable:
 - Higher rate in new, upcoming European 862-868 MHz band
 - Higher rate in 915 MHz band
 - Higher rate in existing European band

1: Scope as defined in PAR

Key Features Actual PHYs

Actual 868 (915) MHz PHY

- Bandwidth 600 (1200) kHz
- Symbolrate 20(40) ksymbol/s for 868(915) MHz.
- Chiprate 300 kchip/s
(600 kchip/s)
- Data rate:
20 ksymbol/s = 20 kbit/s
(40 ksymbol/s = 40 kbit/s)
- Spectral efficiency 1/30 Bit/s/Hz

Half rate 2.4 GHz PHY adapted for 915 MHz

- Bandwidth 2000 kHz
- Chiprate 1000 kchip/s
- Data rate:
 $4 \cdot 1000 / 32$ kbit/s = 125 kbit/s
- Spectral efficiency 1/16 Bit/s/Hz

Key Features for Parallel Reuse

Half rate 2.4 GHz PHY adapted for 915 MHz

- Bandwidth 2000 kHz
- Chiprate 1000 kchip/s
- Data rate:
 $4 * 1000 / 32 \text{ kbit/s} = 125 \text{ kbit/s}$
- Spectral efficiency 1/16 Bit/s/Hz

PSSS – e.g. 8 parallel half rate 2.4 GHz PHY Derivate adapted for 868 (915) MHz

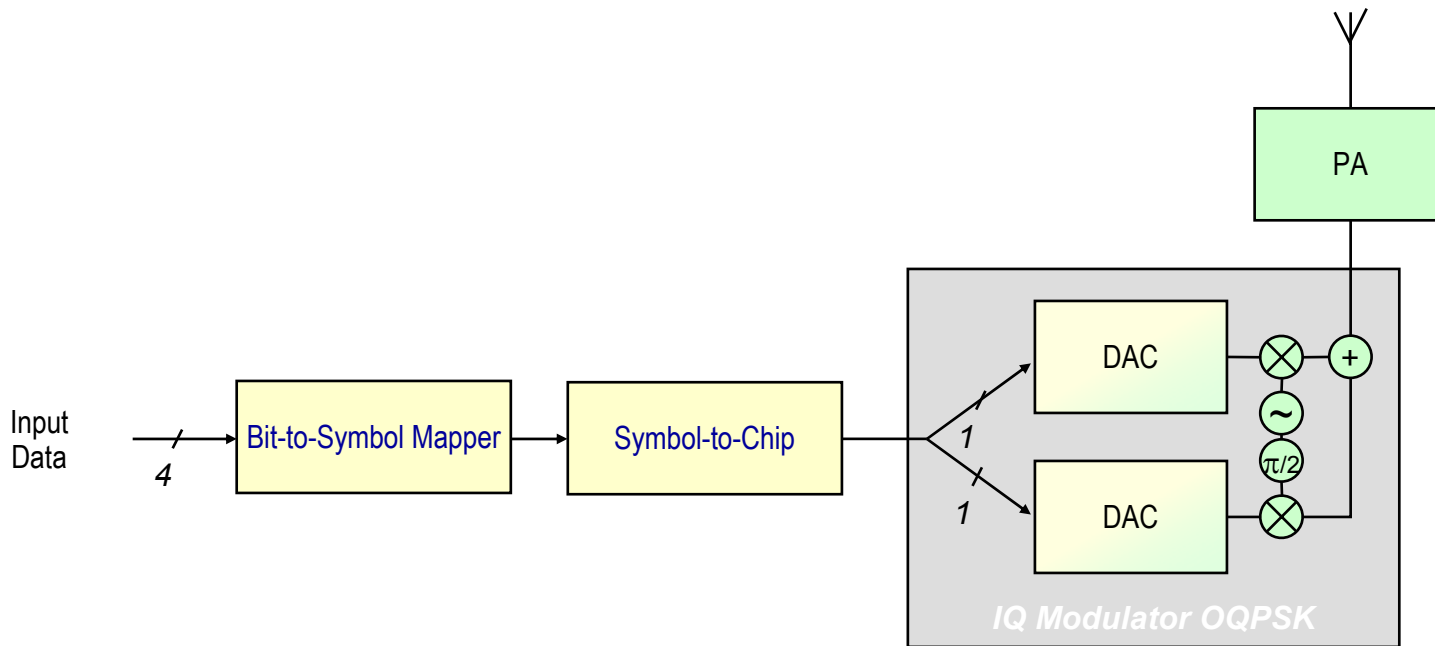
- Bandwidth 600 (2000) kHz
- Chiprate 300 kchip/s
(1000 kchip/s)
- Data rate:
 $32 * 300 / 32 \text{ kbit/s} = 300 \text{ kbit/s}$
($32 * 1000 / 32 \text{ kbit/s} = 1000 \text{ kbit/s}$)
- For same data rate more channels at reduced bandwidth
- Spectral efficiency 0.5 Bit/s/Hz

Opportunities

- Tolerates multipath fading up to a delay spread of 1.66 μs (500 ns) or multiple.
- 2 Bit/s/Hz \rightarrow 1200 (4000) kbit/s and higher possible at very low complexity
- Coding Gain up to 5.5 dB

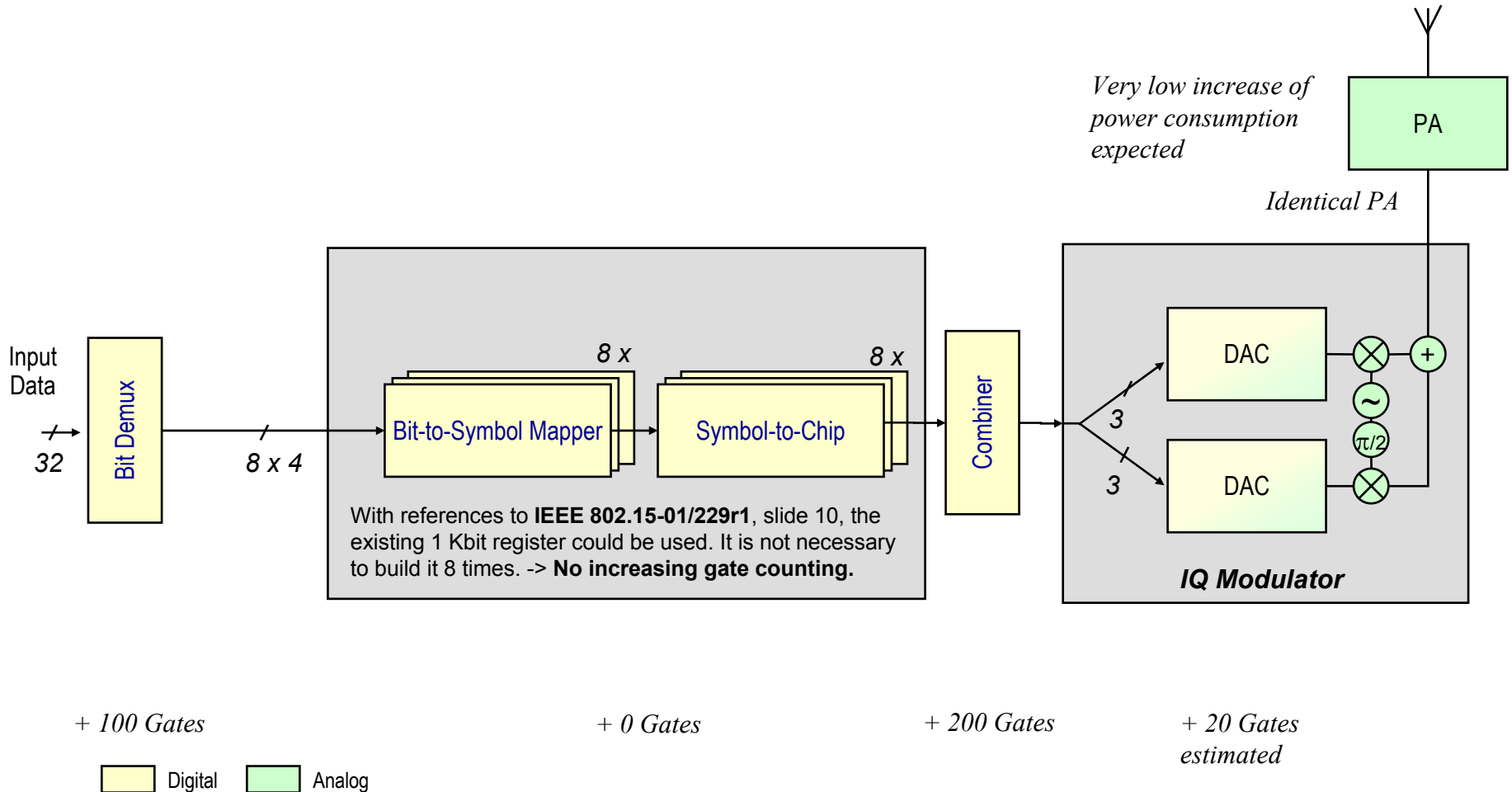
PSSS: Parallel Sequence Spread Spectrum

2.4 GHz PHY Tx Architecture (0.0625 Bit/s/Hz)



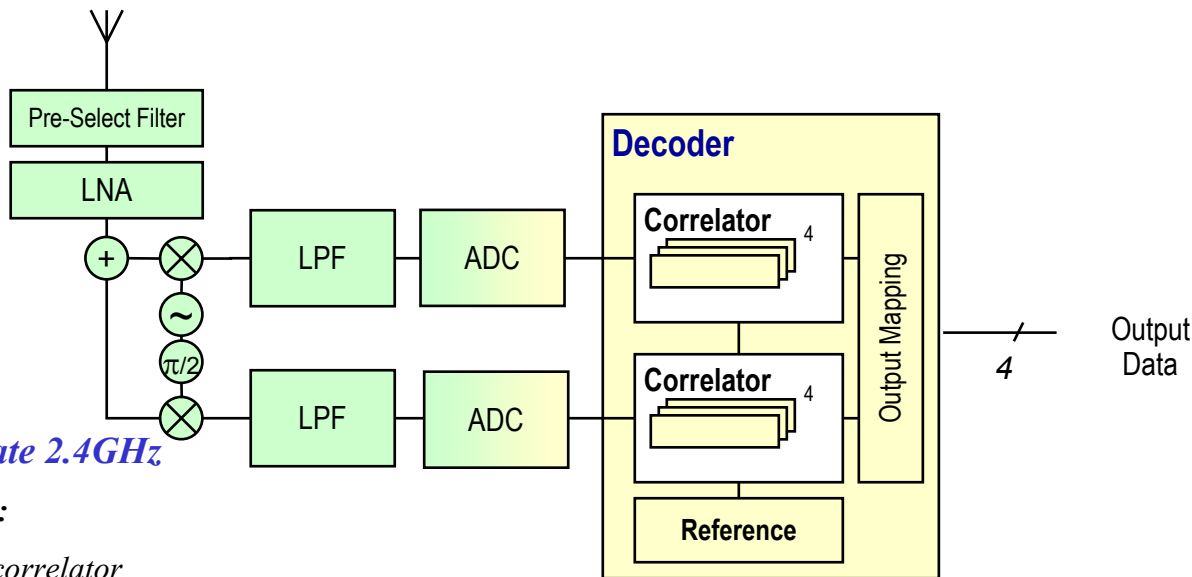
Digital
 Analog

PSSS - 8 Times Parallel use of the 2.4 GHz PHY Derivate (0.5 Bit/s/Hz) Tx Architecture



2.4 GHz PHY (0.0625 Bit/s/Hz)

Rx Architecture



Actual 1/2 rate 2.4GHz

26k gates for:

- 2 4 x 32 bit correlator
- 4 bit x 128 bit complex correlator for preamble
- Clock recovery and timing control

7k gates for data register

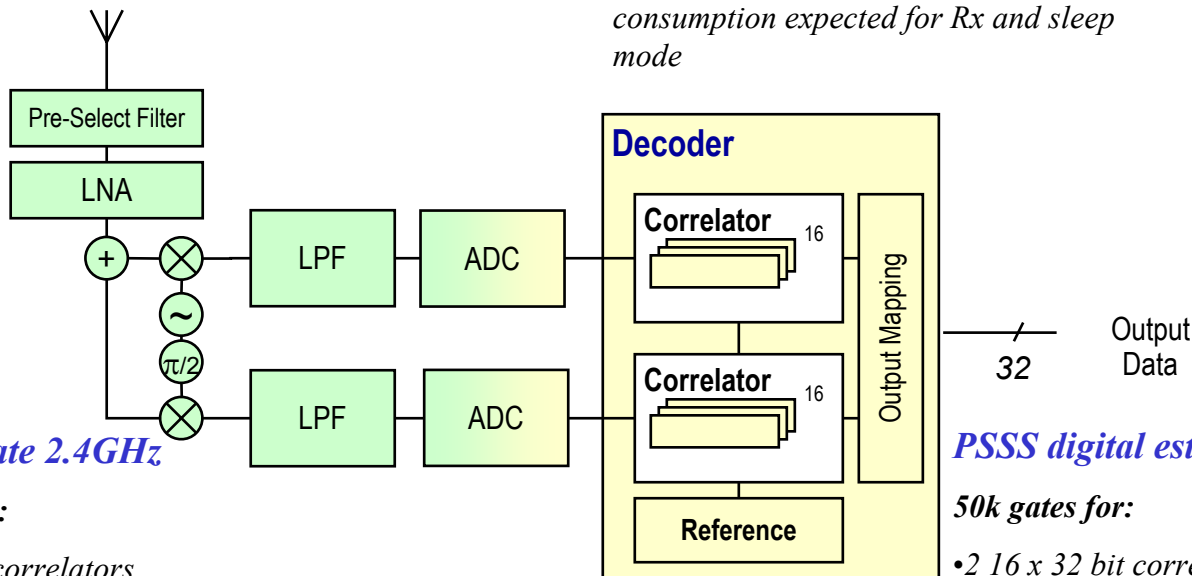
In total 33k gates

Source IEEE 802.15-01/229r1, slide 11

Digital
 Analog

PSSS – 8 Times Parallel use of the 2.4 GHz PHY Derivate (0.5 Bit/s/Hz) Rx Architecture

Very low increasing of power consumption expected for Rx and sleep mode



Actual 1/2 rate 2.4GHz

26k gates for:

- 2 4 x 32 bit correlators
- 4 bit x 128 bit complex correlator for preamble
- Clock recovery and timing control

7k gates for data register

In total 33k gates

Source IEEE 802.15-01/229r1, slide 11

PSSS digital estimated

50k gates for:

- 2 16 x 32 bit correlators
- 4 bit x 128 bit complex correlator for preamble
- Clock recovery and timing control
- Output Mapping

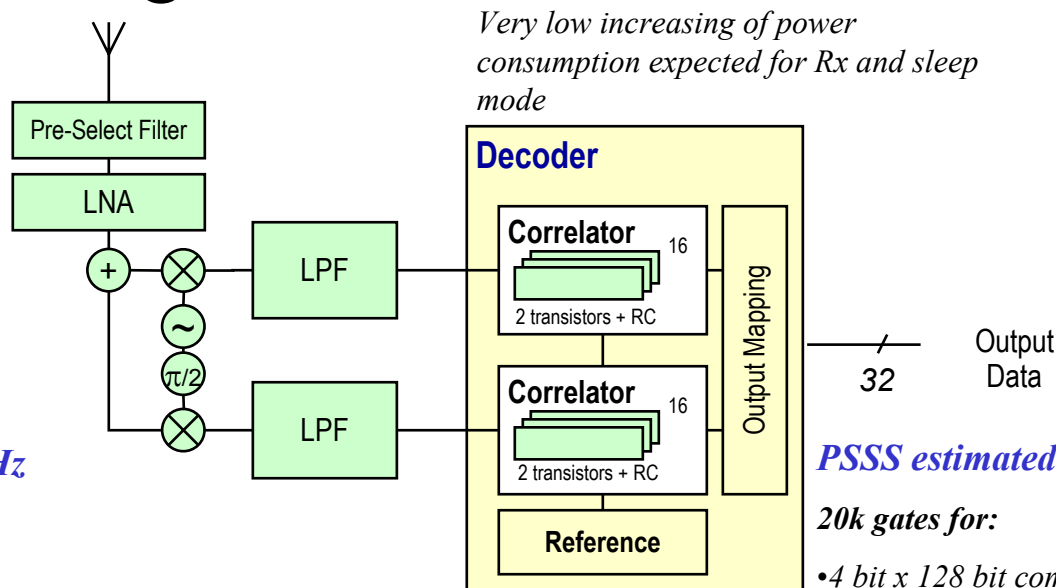
7k gates for data register

In total 57 k gates + 2 x 6 ... 8 Bit ADC

Legend: Digital Analog

PSSS – 8 Times Parallel use of the 2.4 GHz PHY Derivate (0.5 Bit/s/Hz)

Analogue Correlator Rx Architecture



Actual 1/2 rate 2.4GHz

26k gates for:

- 2 4 x 32 bit correlators
- 4 bit x 128 bit complex correlator for preamble
- Clock recovery and timing control

7k gates for data register

In total 33k gates

Source IEEE 802.15-01/229r1

PSSS estimated

20k gates for:

- 4 bit x 128 bit complex correlator for preamble
- Clock recovery and timing control
- Output Mapping

7k gates for data register

In total 27 k gates + 32 analogue integrate & dump

Legend: Digital Analog

BER Results for 802.15.4 (0.0625 Bit/s/Hz) 2.4 GHz. PHY

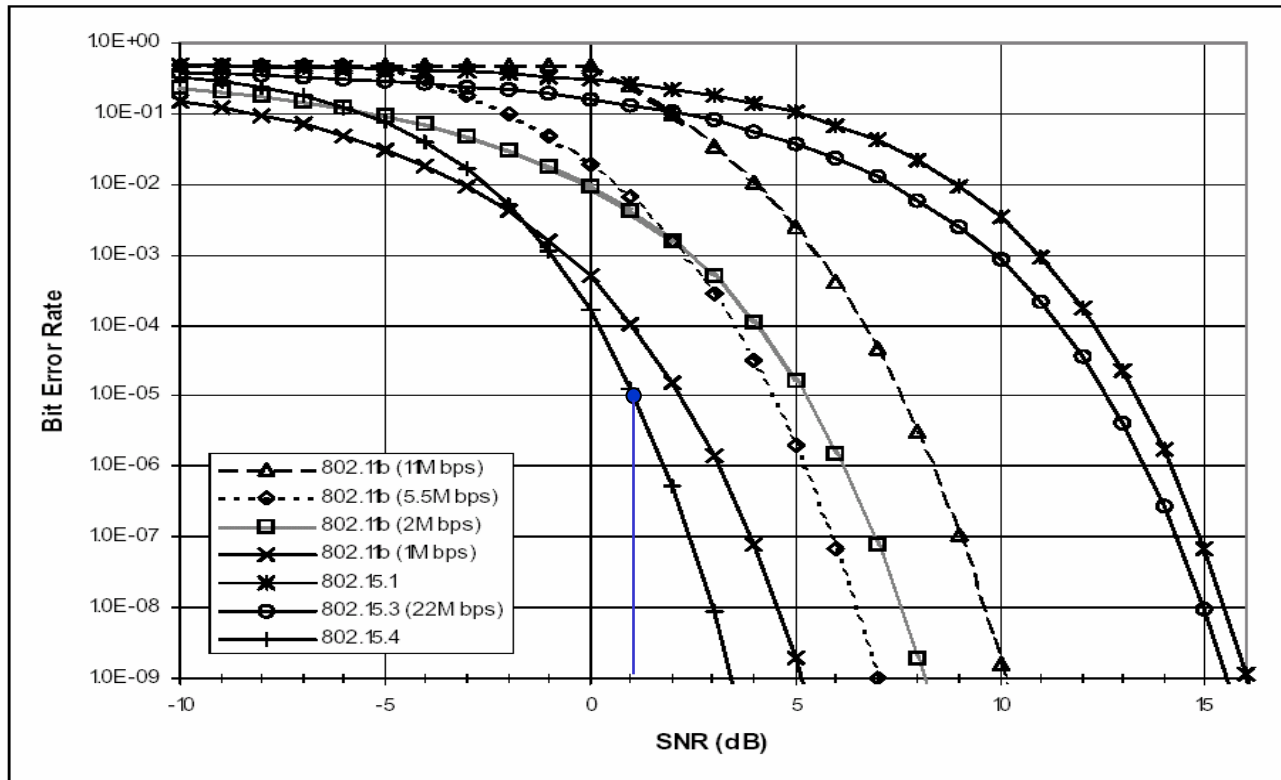
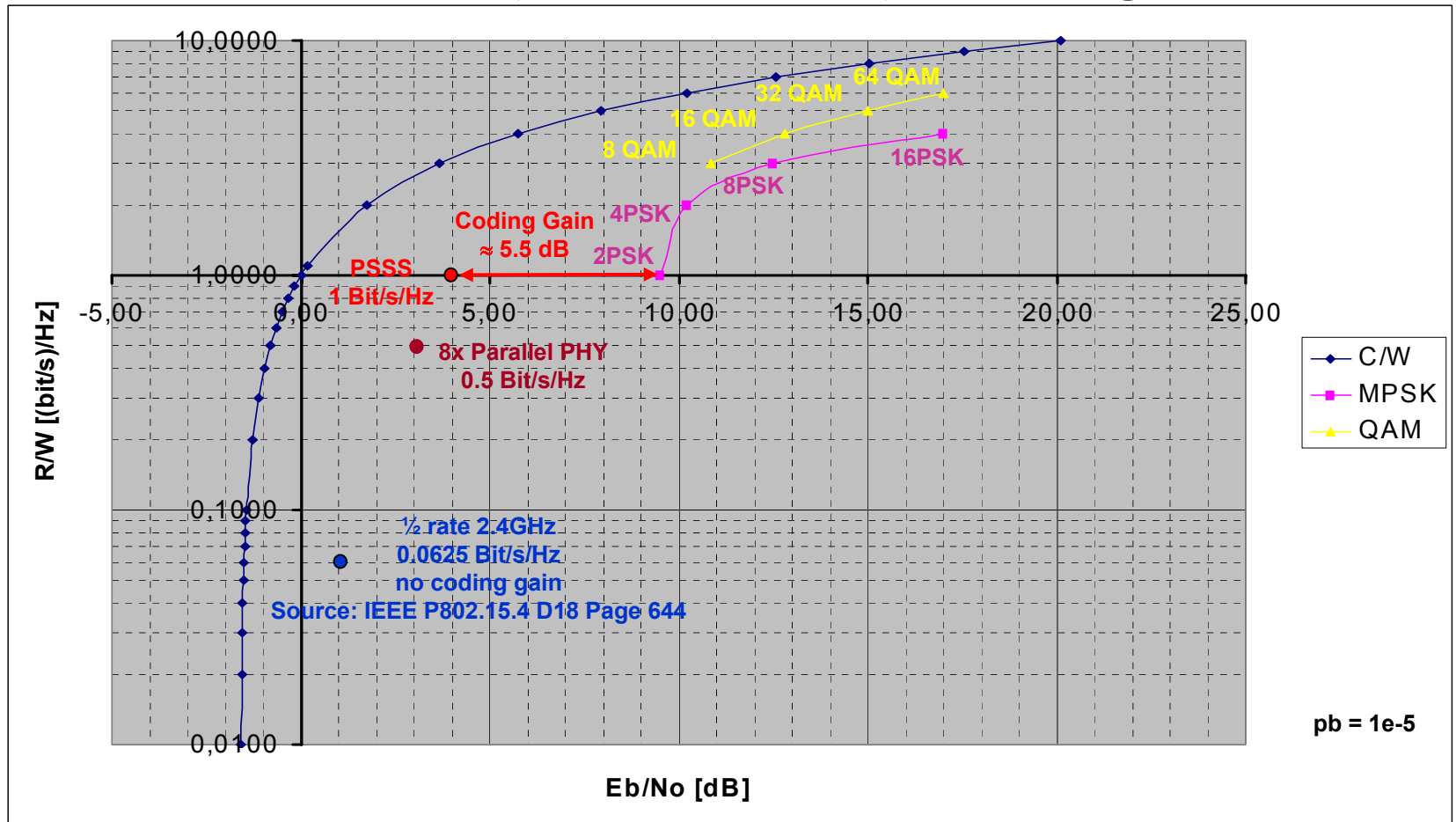


Figure E.2—BER Results for 802.11, 802.15.1, P802.15.3 and 802.15.4

Reference: P802.15.4D18, Figure E.2, page 654

PSSS – 8 Times Parallel use of the 2.4 GHz PHY Derivate (0.5 Bit/s/Hz) Coding Gain



Source for MPSK and QAM: John G. Proakis, Digital Communications 4th edition, McGrawHill, Boston et. al. 2001, page 282.

Summary

- The proposed parallel reuse of the 2.4 GHz 802.15.4 modulation technology in PSSS offers highly attractive performance improvement increasing market opportunities
- Higher data rate and multiple channels possible in both current *and* upcoming European band (and certainly also in 915 MHz band)
- 15x higher spectral efficiency through PSSS compared to the current PHY for 868/915 MHz
(8x higher over “½ rate 2,4GHz” proposal for new European band)
 - Data rate or number of channels could be increased
 - More efficient use of spectrum and resulting better coexistence
- Significantly stronger multipath fading robustness in PSSS
 - Visibly higher range in many attractive, high volume target areas
- Very easy backward compatibility to the 2.4 GHz PHY, also easy adaptation to current 868/915 MHz designs
 - PSSS is derivative superset of current 2,4 GHz PHY technology
 - Scalable data rate and automatic fallback to current standard possible