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

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
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- Pb versus E_bN_0
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- 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

- scaleable

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 rates*[1] 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

**Half rate 2.4 GHz PHY
adapted for 868 (915) MHz**

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

- Bandwidth 600 (1200) kHz

- Chiprate 300 kchip/s
   (600 kchip/s)

- Data rate:
  4*300/32 kbit/s = 37,5 kbit/s
  (4*600/32 kbit/s = 75 kbit/s)

- Spectral efficiency 1/16 Bit/s/Hz

Key Features for Parallel Reuse

Half rate 2.4 GHz PHY
adapted for 868 (915) MHz

- Bandwidth 600 (1200) kHz

- Chiprate 300 kchip/s
  (600 kchip/s)

- Data rate:
  4*300/32 kbit/s = 37,5 kbit/s
  (4*600/32 kbit/s = 75 kbit/s)

- Spectral efficiency 1/16 Bit/s/Hz

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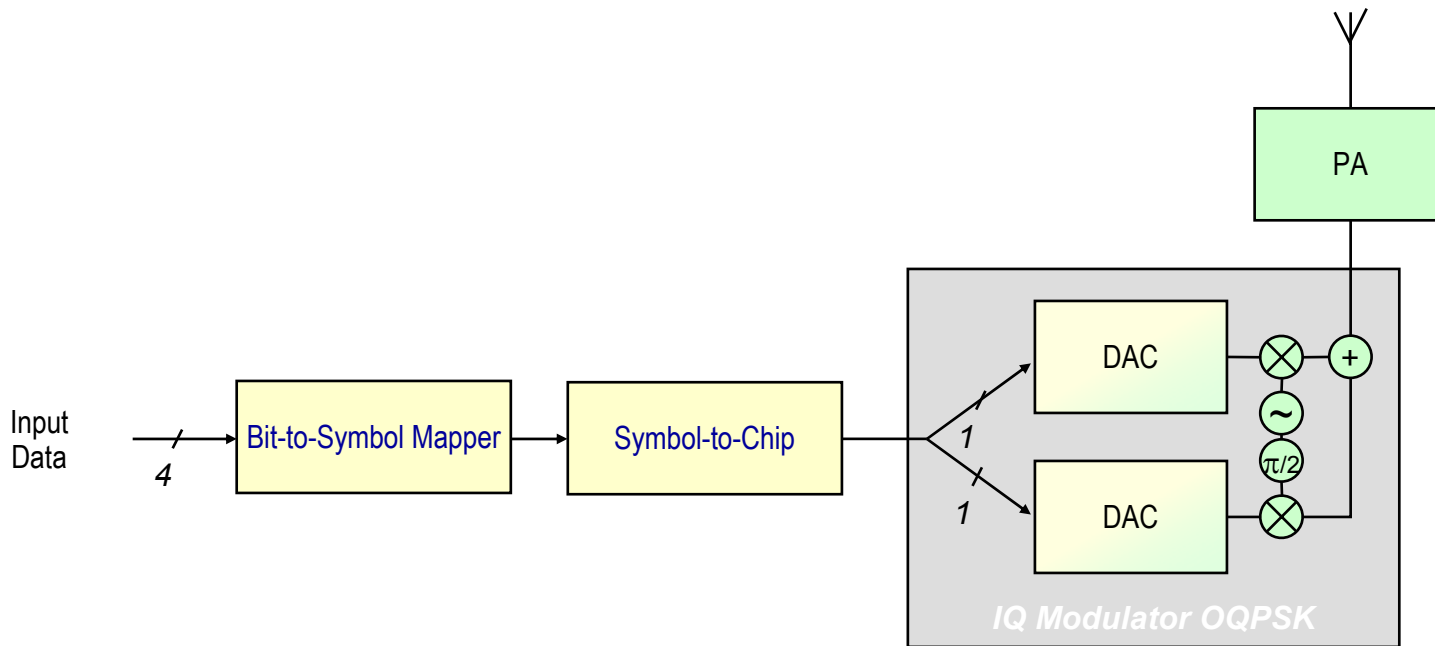**Derivate adapted for 868 (915) MHz**

- Bandwidth 600 (1200) kHz

- Chiprate 300 kchip/s
  (600 kchip/s)

- Data rate:
  32*300/32 kbit/s = 300 kbit/s
  (32*600/32 kbit/s = 600 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 (833 ns) or multiple.

- 2 Bit/s/Hz ➔ 1200 (2400) kbit/s and
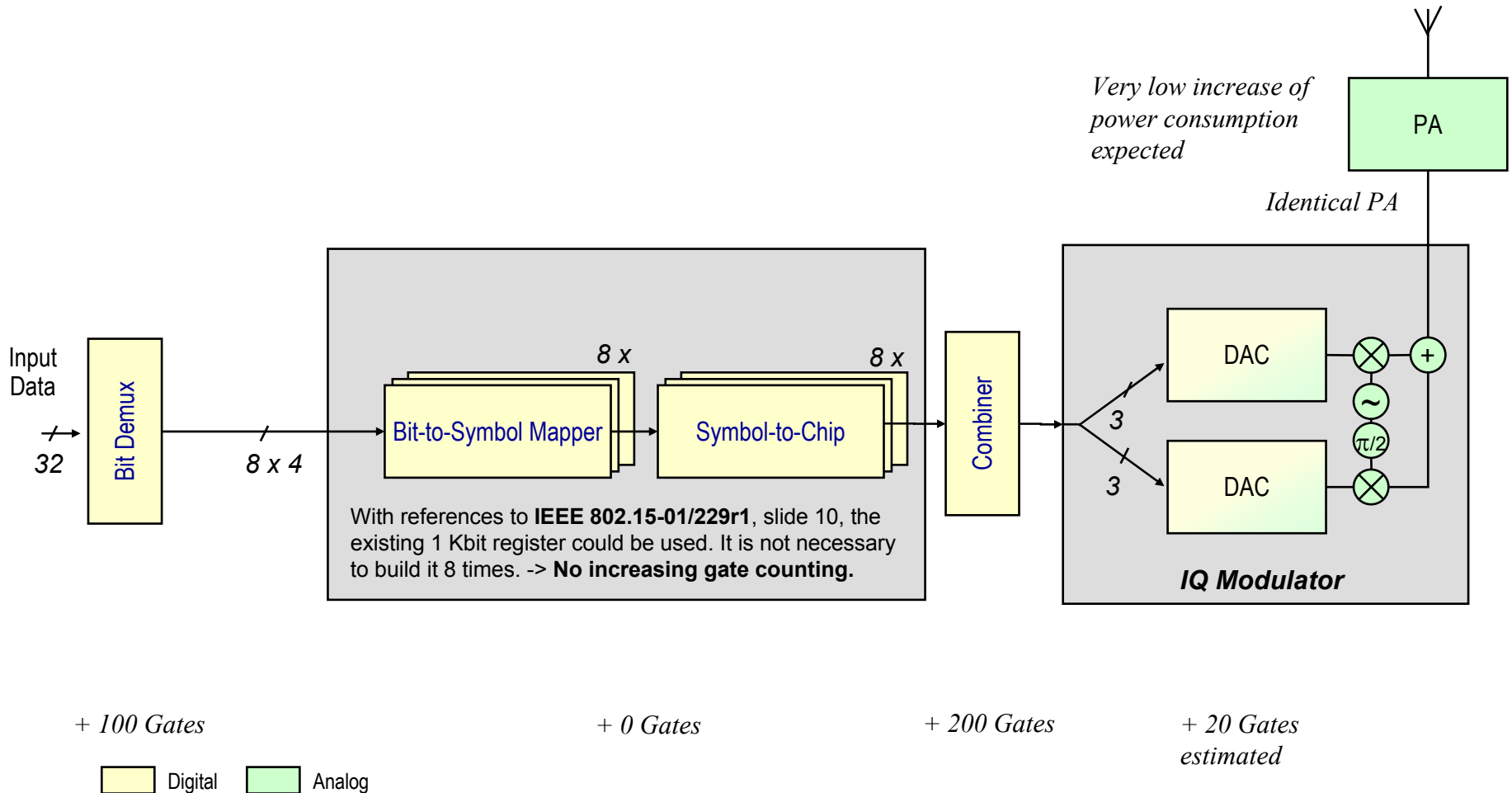 higher possible at very low complexity

- Coding Gain up to 5.5 dB

PSSS: Parallel Sequence Spread Spectrum
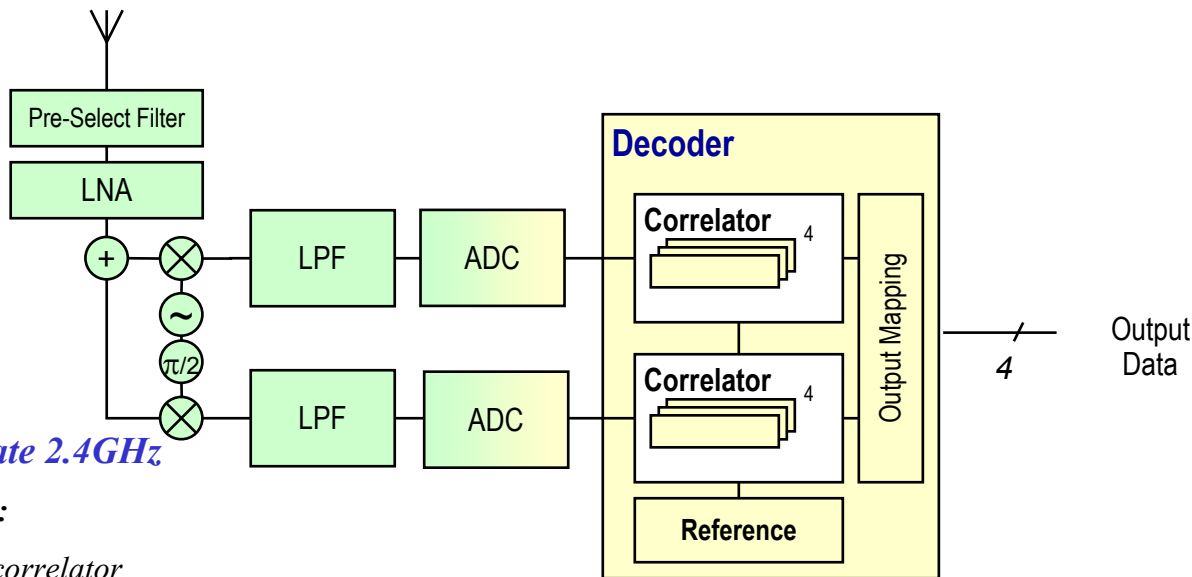
2.4 GHz PHY Tx Architecture
(0.0625 Bit/s/Hz)

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

Very low increase of power consumption expected

PA

Identical PA

Input Data

Bit Demux

32

8 x 4

8 x
Bit-to-Symbol Mapper

8 x
Symbol-to-Chip

Combiner

3

3

DAC

DAC

π/2

IQ Modulator

With references to **IEEE 802.15-01/229r1**, slide 10, the existing 1 Kbit register could be used. It is not necessary to build it 8 times. -> **No increasing gate counting.**

+ 100 Gates

+ 0 Gates

+ 200 Gates

+ 20 Gates estimated

Digital   Analog

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

Actual ½ rate 2.4GHz

26k gates for:

• *2 4 x 32 bit correlator*

• *4 bit x 128 bit complex correlator for preamble*

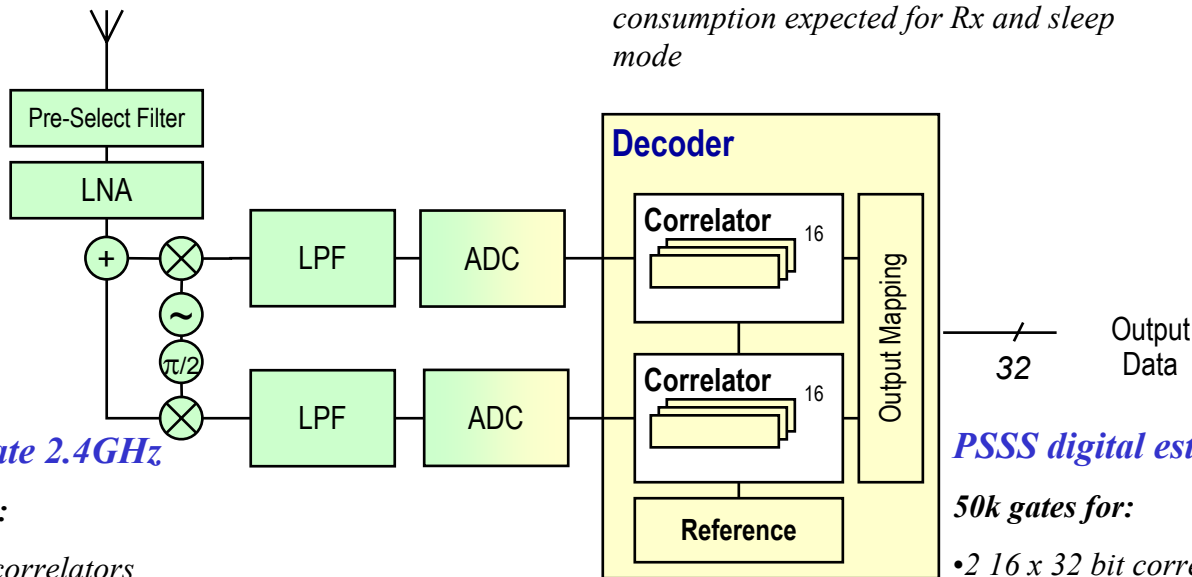• *Clock recovery and timing control*

7k gates for data register

In total 33k gates
Source IEEE 802.15-01/229r1, slide 11

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

Pre-Select Filter

LNA

+ ⊗ ~ π/2 ⊗

LPF — ADC

LPF — ADC

Decoder

Correlator 16

Correlator 16

Output Mapping

Reference

32 — Output Data

Actual ½ 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
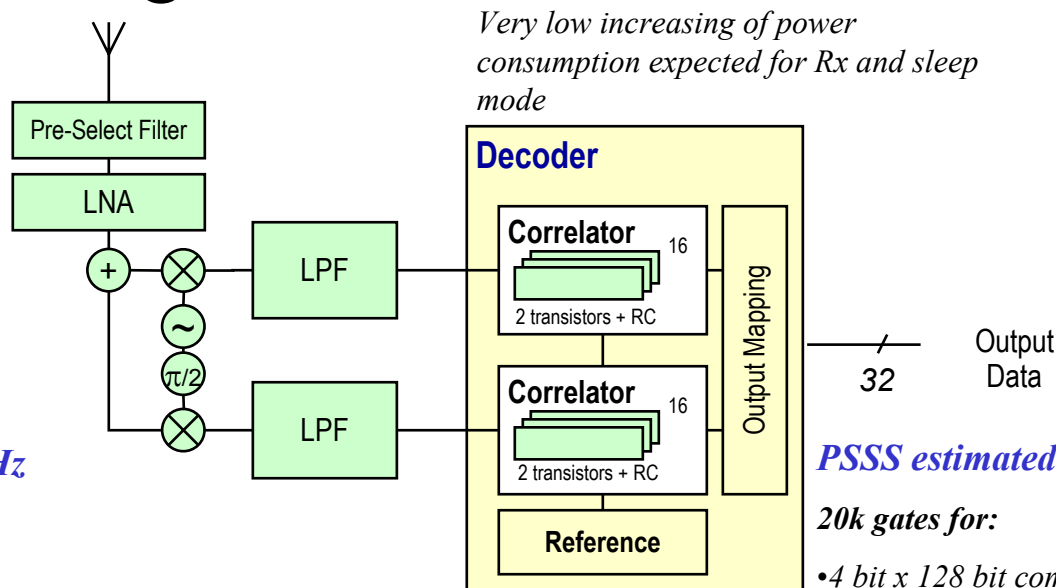
• Clock recovery and timing control

• Output Mapping

7k gates for data register

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

Digital   Analog

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

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

Actual ½ 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

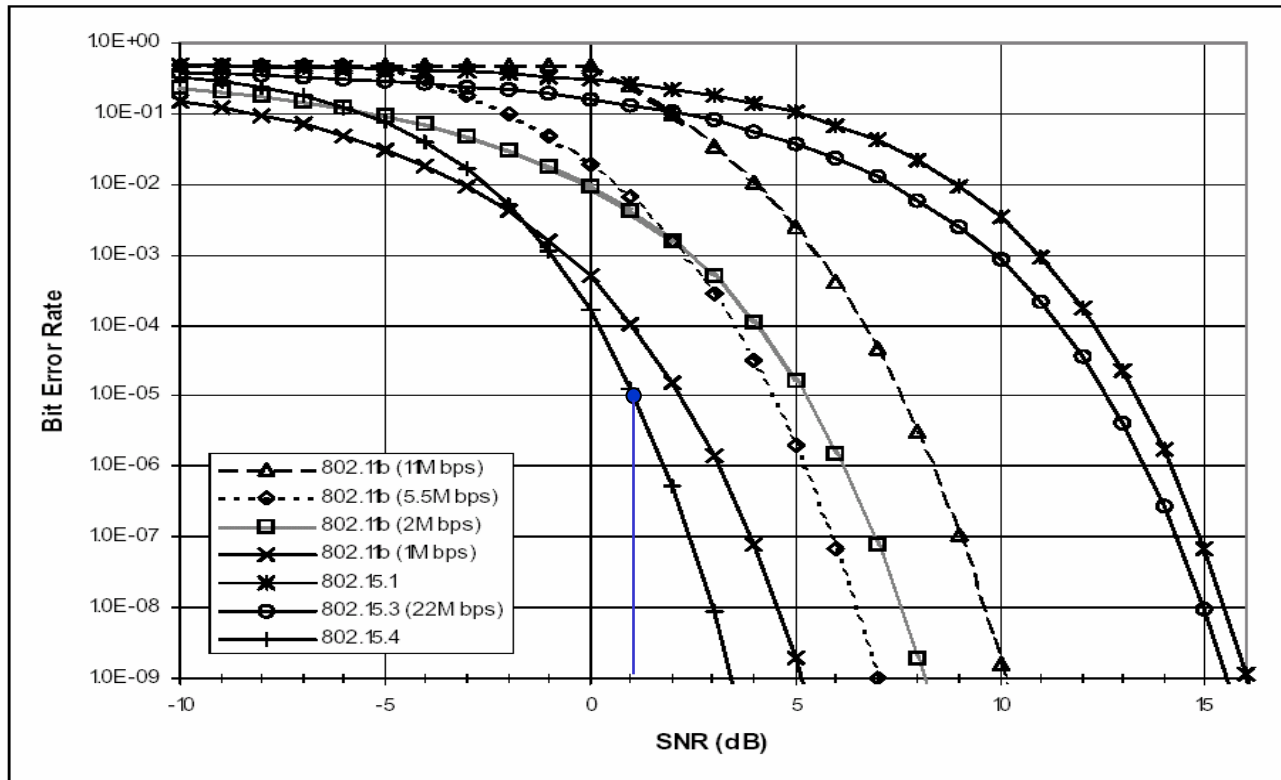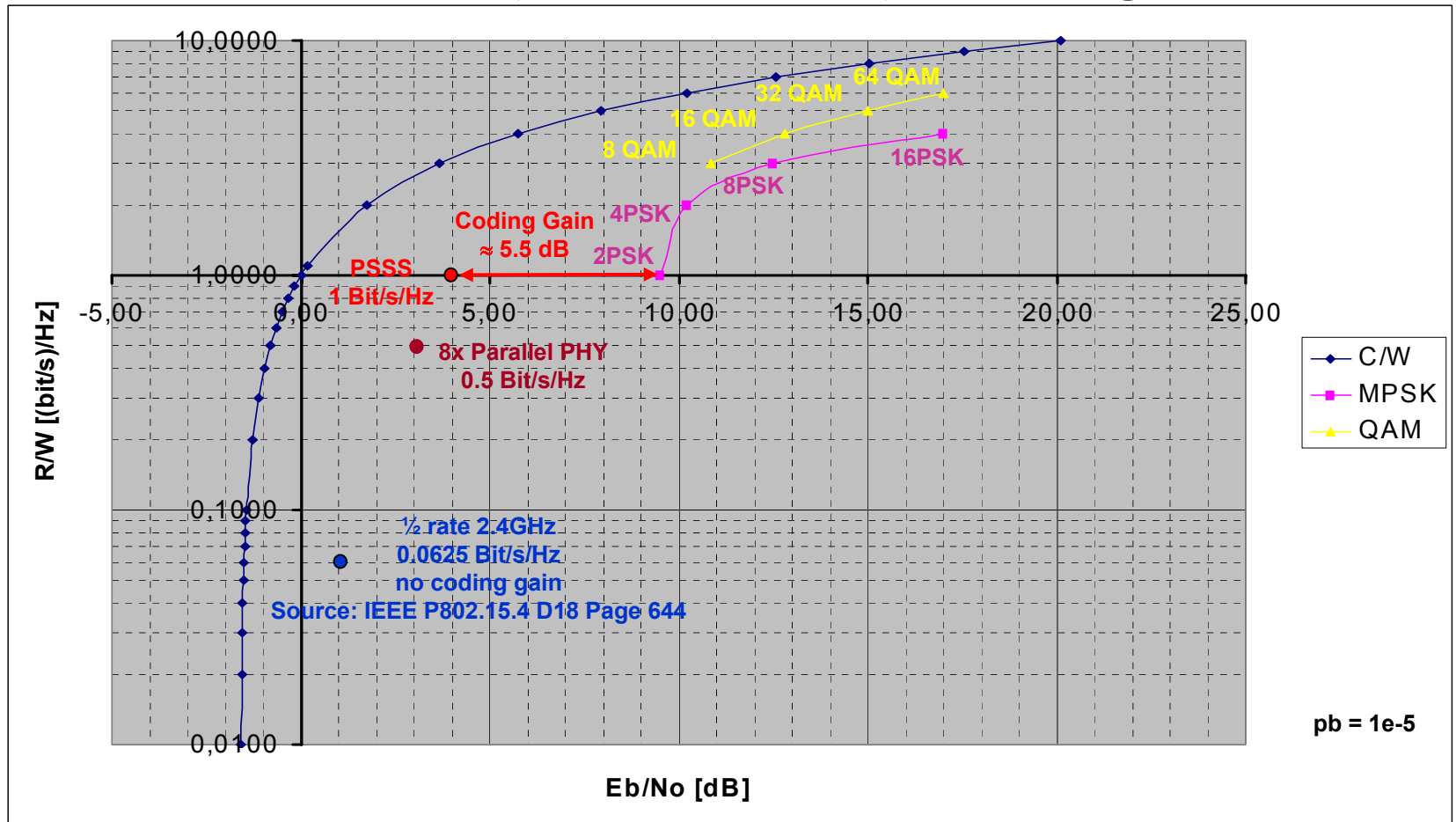# BER Results for 802.15.4 (0.0625 Bit/s/Hz) 2.4 GHz. PHY

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 date 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