Reuse of 2.4 GHz PHY for the Lower Bands

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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

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 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

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

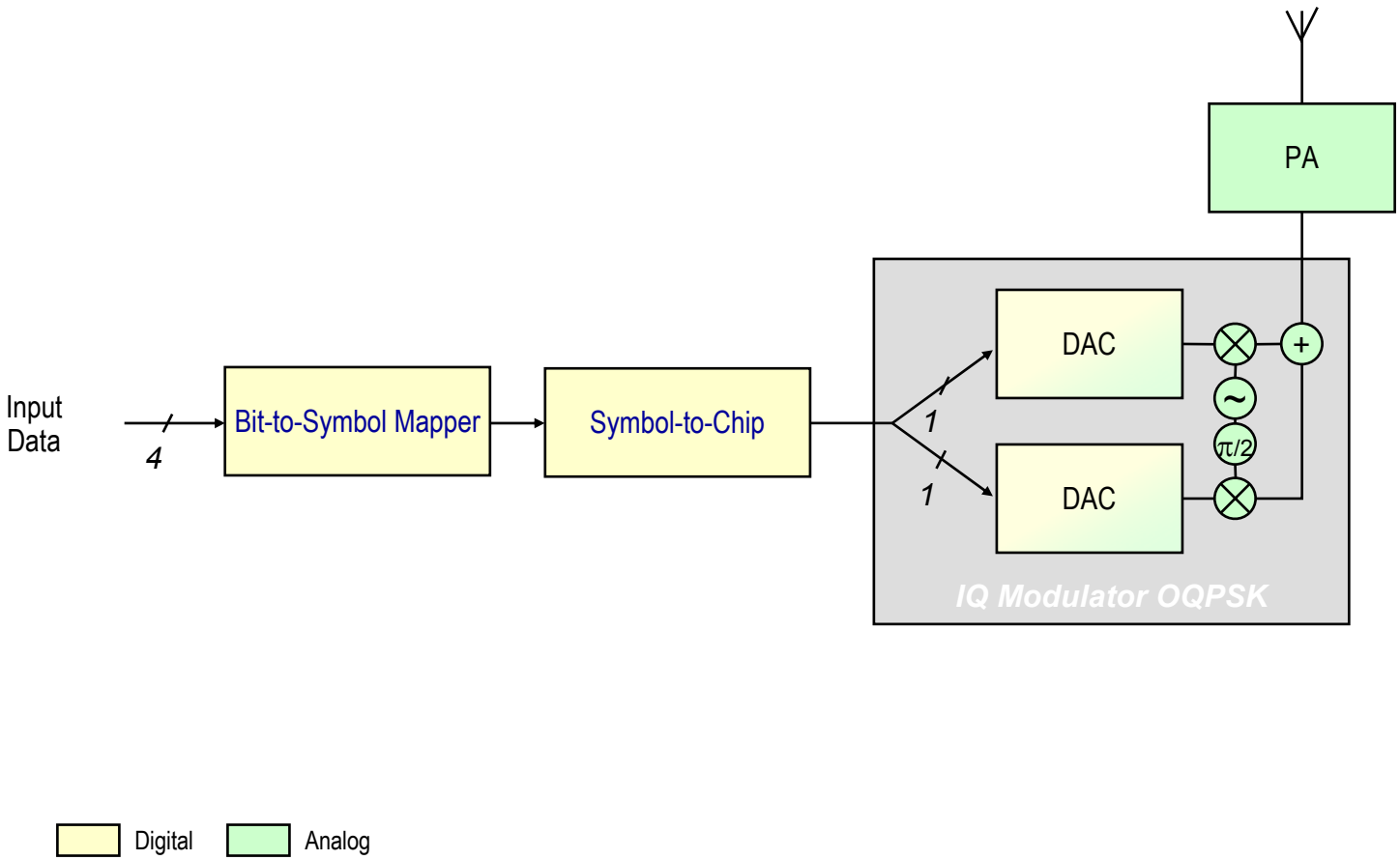
- Bandwidth 600 (1200) kHz
- Chiprate 300 kchip/s (600 kchip/s)
- Data rate: 32*300/32 kbit/s = 300 kbit/s (32*600/32 kbit/s = 600 kbit/s)
- For same data rate more channels at reduced bandwidth
- Spectral efficiency 0.5 Bit/s/Hz

Opportunities

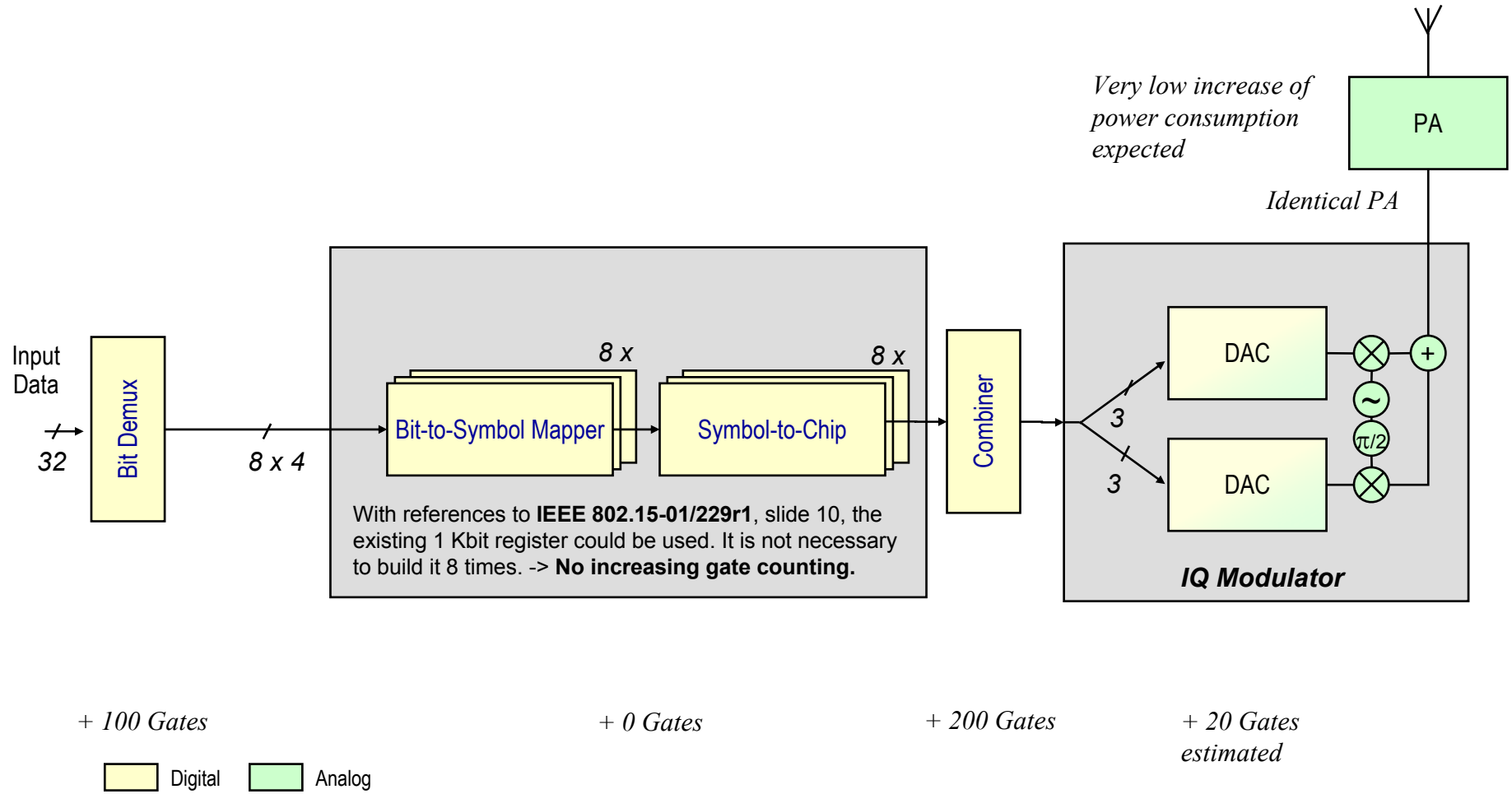
- Tolerates multipath fading up to a delay spread of 1.66 µS (833 ns) or multiple.
- 2 Bit/s/Hz ➔ 1200 (2400) kbit/s and higher possible at very low complexity
- Coding Gain up to 5.5 dB

PSSS: Parallel Sequence Spread Spectrum

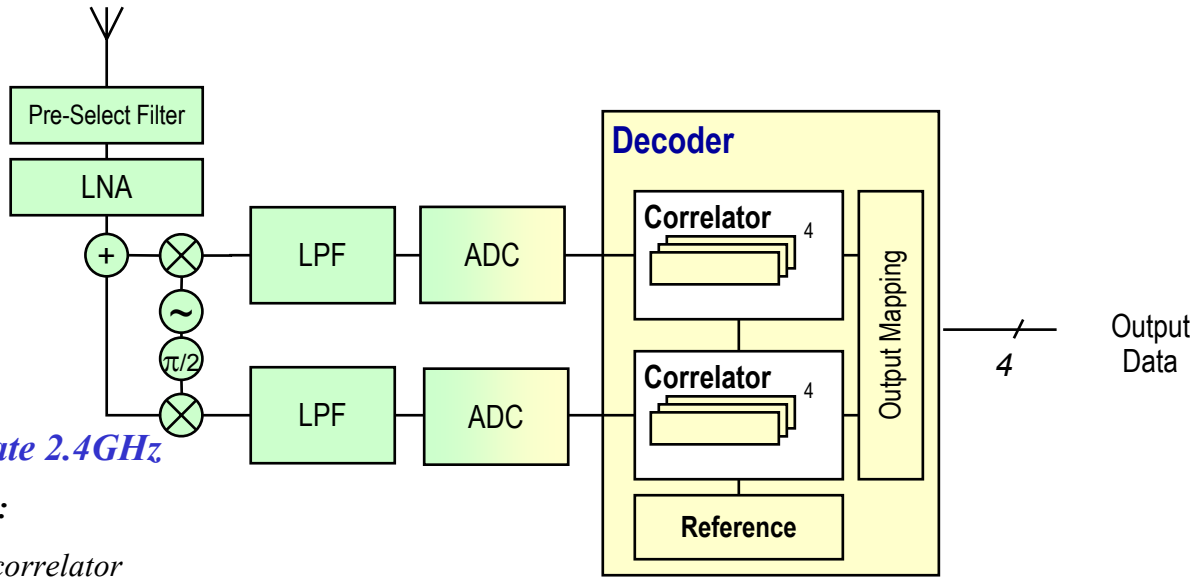
2.4 GHz PHY Tx Architecture (0.0625 Bit/s/Hz)



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



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

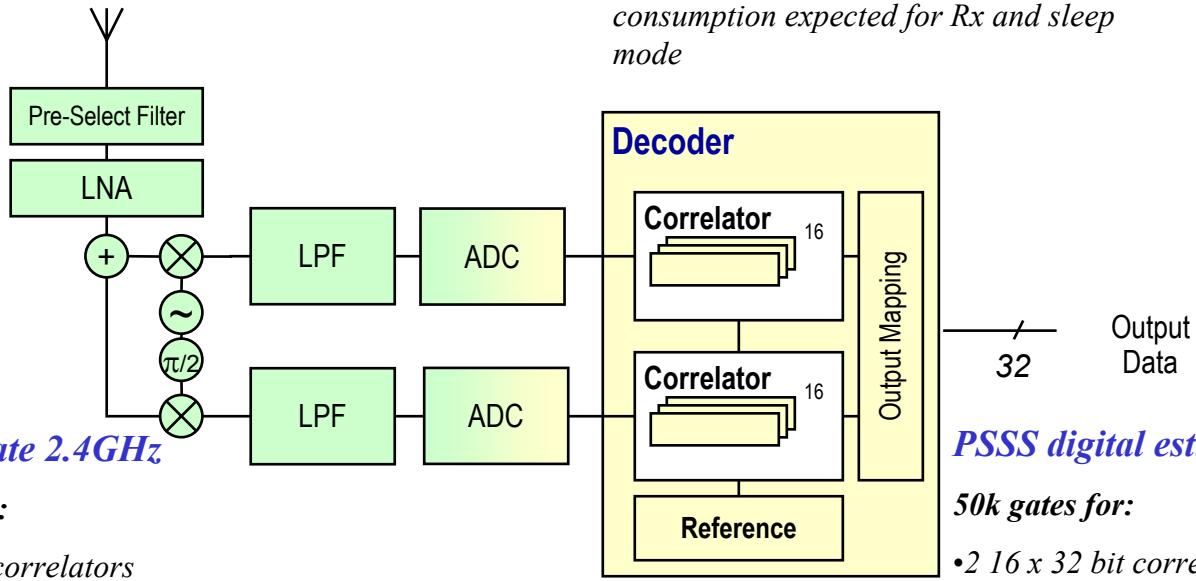
In total 33k gates

Source IEEE 802.15-01/229r1, slide 11

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 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*

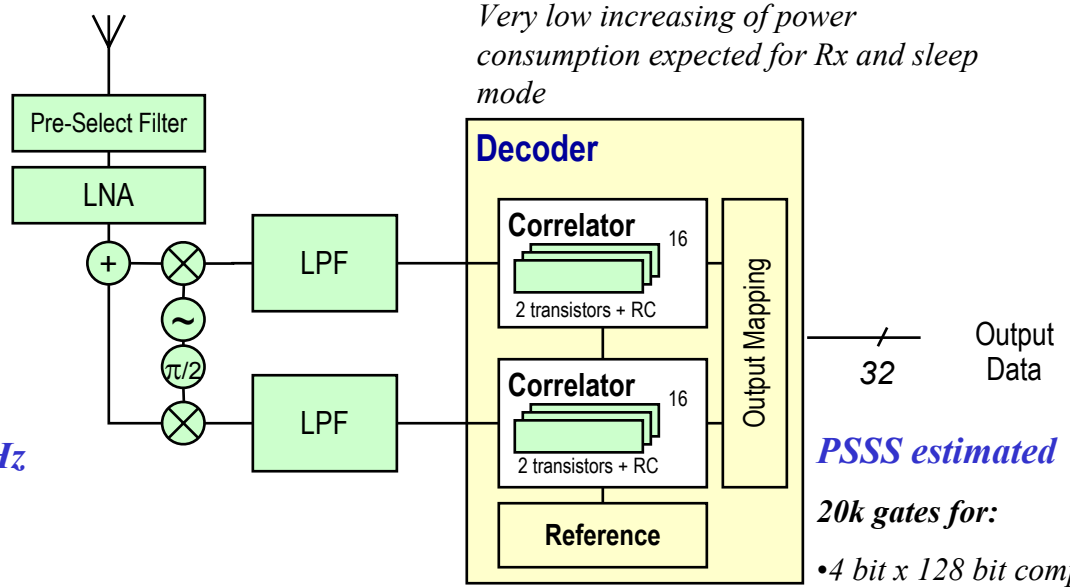
7k gates for data register

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

Digital Analog

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

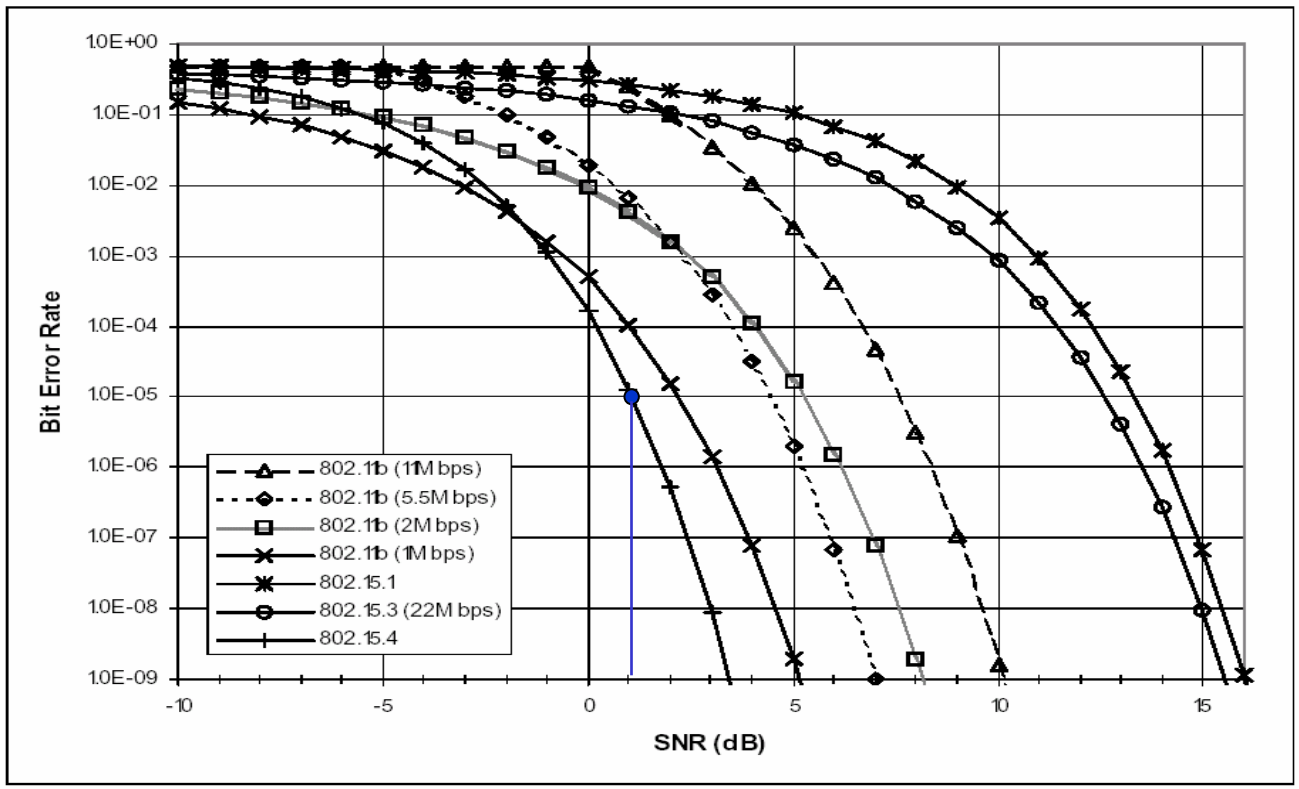
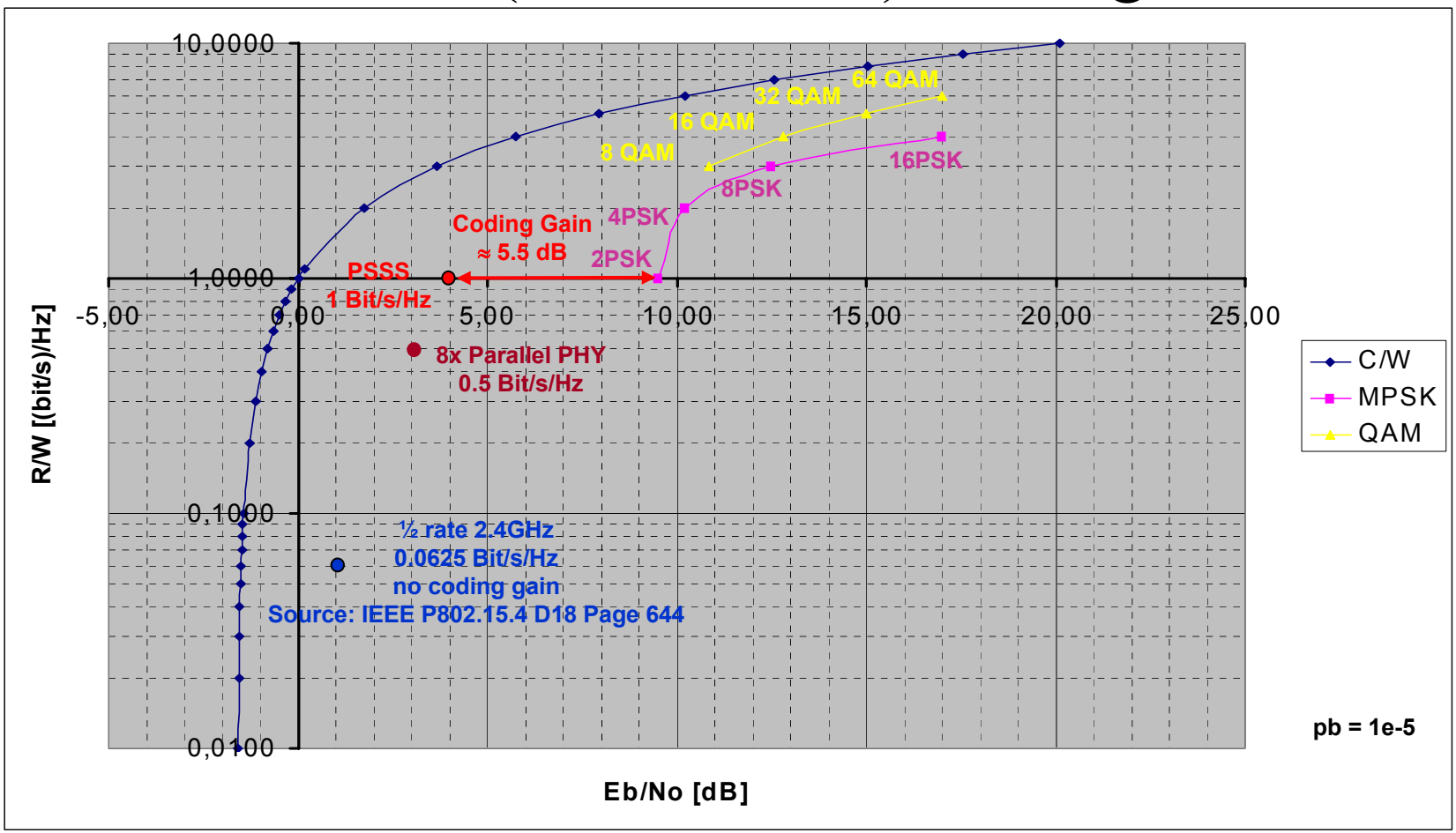


Figure E.2—BER Results for 802.11, 802.15.1, P802.15.3 and 802.15.4

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: 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