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

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**Source:** Andreas Wolf, Dr. Wolf & Associates and Hans van Leeuwen, STS-wireless

Dr. Wolf & Associates GmbH
Tel.: +49 (0)700 965 32 637
aw@dw-a.com, http://www.dw-a.com

STS BV, The Netherlands
Tel: +31 20 4204200, cell +1 858 344 5120
hvl@sts.nl, www.sts-wireless.net

**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

Andreas Wolf
(aw@dw-a.com)
Dr. Wolf & Associates GmbH

Hans van Leeuwen
(hvl@sts.nl)
STS
Presentation Contents

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• Tx and Rx Architecture
• Pb versus $E_bN_0$
• 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
- 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 \textit{derivative modulations yielding higher data rates} 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

<table>
<thead>
<tr>
<th>Actual 868 (915) MHz PHY</th>
<th>Half rate 2.4 GHz PHY adapted for 868 (915) MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Bandwidth 600 (1200) kHz</td>
<td>• Bandwidth 600 (1200) kHz</td>
</tr>
<tr>
<td>• Symbolrate 20(40) ksymbol/s for 868(915) MHz.</td>
<td>• Chiprate 300 kchip/s (600 kchip/s)</td>
</tr>
<tr>
<td>• Chiprate 300 kchip/s (600 kchip/s)</td>
<td>• Data rate: 4<em>300/32 kbit/s = 37,5 kbit/s (4</em>600/32 kbit/s = 75 kbit/s)</td>
</tr>
<tr>
<td>• Data rate: 20 ksymbol/s = 20 kbit/s (40 ksymbol/s = 40 kbit/s)</td>
<td>• Spectral efficiency 1/16 Bit/s/Hz</td>
</tr>
<tr>
<td>• Spectral efficiency 1/30 Bit/s/Hz</td>
<td></td>
</tr>
</tbody>
</table>
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

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.**

**Very low increase of power consumption expected**

**Identical PA**

**IQ Modulator**

+ 100 Gates

+ 0 Gates

+ 200 Gates

+ 20 Gates estimated
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

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 57k gates + 2 x 6 … 8 Bit ADC
PSSS – 8 Times Parallel use of the 2.4 GHz PHY Derivate (0.5 Bit/s/Hz)
Analogue Correlator Rx Architecture

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

Source: IEEE 802.15-01/229r1
BER Results for 802.15.4 (0.0625 Bit/s/Hz)

2.4 GHz. PHY

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

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