Project: IEEE 802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [ Part of P802.15.4.d Consolidated Proposal of Japanese 950MHz WPAN PHY: WW-BPSK with AFA provisioning ]

Date Submitted: [13 May., 2008]

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Re: [ IEEE P802.15-15-07-0860-02-004d-Call-for-Proposal ]

Abstract: [ To enhance world wide commonality, BPSK-DSSS as a baseline modulation scheme with additional AFA(Adaptive Frequency Agility) functionalities, and Reliable & Simple OFDM option for future provisioning of IEEE802.15.4 PHY, are considered as well as GFSK. ]

Purpose: [ This submission is a proposal of Japanese sub-GHz PHY responding to CFP of IEEE802.15 TG-4d. ]

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Re-capturing PAR & 5C and Introduction

[ Excerpt from PAR & 5C ]
This (950MHz PHY amendment) makes it appropriate for many applications for which 2.4GHz is not appropriate, due to improved range and reliability.

Currently 802.15.4 supports 906-928 MHz band in the US and the 868MHz band in Europe. This amendment will allow for similar operation in the sub 1GHz band in Japan for applications benefiting from better propagation characteristics – such as automatic metering, industrial control and monitoring. Japan is a large and important market which makes undertaking a project like this worthwhile.

[ Introduction ]
The purpose of IEEE802.15 TG4d is to provide Japanese 950MHz PHY in addition to existing US and Europe sub-GHz PHY, so that such the applications utilizing the propagation characteristics of Sub-GHz are facilitated widely around the world wide market.
Therefore, this proposal was devised through both the world wide commonality enhancements and the regional requirements such as the coexistence with passive RFID systems, and furthermore novel PHY technology in IEEE802.15.4 as the future provisioning for adaptive frequency agility.
(1) As per Japanese regulatory rule, 200kHz sub-channelization and its bundled usage are defined so that the designated sub-channels for Miller sub-carrier type RFID reader/writer are aligned centre on each 600kHz channels.
(2) To avoid interference with other systems sharing same frequency band and to increase reliability and robustness, TX side frequency band selection and sequencing are supported by the extension of PHR through which the channel sequence information are provided at RX PHY.
(3) For future provisioning, simultaneous multiple bands reception using Simple, Adaptive and Reliable OFDM scheme may be included.
## Regulatory Rules

<table>
<thead>
<tr>
<th>Freq</th>
<th>Ch#</th>
<th>RFID Licensed 4W EIRP</th>
<th>RFID Light-Licensed 4W EIRP</th>
<th>RFID License-exempt 10mW</th>
<th>WPAN</th>
<th>License Exempt</th>
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<td>A</td>
<td></td>
<td>A</td>
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<td>A, B, C</td>
</tr>
</tbody>
</table>

- **A:** Carrier Sense 5ms @ -74dBm
  - Tx duration 4 s max
  - w/t Cease-TX 50ms
- **B:** No Carrier Sense
  - No TX duration Control

### Relevant Rules to this amendment

- **A:** Carrier Sense 5ms @ -74dBm
  - TX duration 4 s max
  - w/t Cease-TX 50ms
- **B:** CarrierSense 128us @ -75dBm
  - Duty Ratio Control 10%
  - TX duration 100ms max
  - w/t Cease-TX 100ms
- **C:** No Carrier Sense
  - Duty Ratio Control 0.1%
  - TX duration 100ms max
  - w/t Cease-TX 100ms

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**Submission**

Shusaku Shimada, Yokogawa Co.
Summary of Proposal
3 way Proposal on 600kHz channel plan

- DSSS-BPSK as a baseline modulation scheme
  ** “Baseline” means: A device which provides the 15.4d BPSK-DSSS PHY functionality should be capable of same PHY functionalities for EU 868 and US 915MHz bands as well.

- PHY Header Extension for AFA provisioning
  PHR extension (1)
  Channel utilization PIB (2)

  ** This PHY header extension is useful especially in every Sub-GHz multichannel circumstances.

- Simple, Agile and Reliable OFDM
  ** {Provisioning toward future AFA functionalities}
Channel Plan
Channel Plan & Sub-channels

As RFID systems are based on the sub-channel selection function using LBT, WPAN also is to be able to search and select the unused bonded sub-channels which are up to 600kHz maximum (three sub-channels of 200kHz), i.e., a sort of adaptive frequency agility.

600kHz Channelization ↔ 3 Sub-channels bonding [ Page 0 or page 3 (new) ]

1mW ( Full Band 24 sub-channels )

10mW ( Specific sub-channels [17,18,19,20 sub-channel] )
“Baseline” BPSK scheme
BPSK-DSSS as a baseline modulation scheme

Band width : 600KHz
→ Identical as current European 868-868.6MHz PHY

Frequency : 950.8MHz-955.8MHz
→ Frequency accuracy of ± 20ppm

Chip Rate : 300cps, 15-chip PRBS
→ Current Base Line scheme of sub-GHz PHY is maintained

Data rate : 20kbps
→ To achieve better robustness than 2.4GHz PHY.

Pulse Shaping : Raised Cosine Filter with 100% of Excess Band.
→ Identical as current European 868-868.6MHz PHY

TX Power : 0dBm (3dBmEIRP) for Ch.1-8
 or 10dBm (13dBmEIRP) for Ch.9-10

TX PSD Limit

<table>
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<tr>
<th>Channel Aggregation</th>
<th>Frequency</th>
<th>Relative Limit</th>
<th>Absolute Limit</th>
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<td></td>
<td></td>
<td>f-f_c</td>
<td>≥ 300kHz</td>
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<tr>
<td></td>
<td></td>
<td>f-f_c</td>
<td>≥ 400kHz</td>
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<tr>
<td>⑨</td>
<td>Sub-channels [Ch.1-8]</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>f-f_c</td>
<td>≥ 300kHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>f-f_c</td>
<td>≥ 400kHz</td>
</tr>
</tbody>
</table>
BPSK modulation schemes

- **AWGN channel (300kbps)**

- **Rayleigh Channel (300kbps)**

- **15 chips DSSS Processing Gain (20kbps)**
BPSK-DSSS modulation scheme

- Modified* Multipath 4b-Model (10 taps)

- Narrow Band Interference (C/I + AWGN)

* Because of 300kHz chip-rate, 3 taps model with 1st tap of Rician k=12dB is substituted and used.

No flooring in case of C/I = -6dB or better.
**BPSK DSSS modulation scheme**

- **TX PSD**

![TX PSD Diagram]

- **Narrow Band Interference**

  DSSS Processing Gain(11dB) effectively suppresses various narrow-band interference, especially RFID energizing signal emitted by Reader/Writer devices, as long as adequately separated and controlled for co-existence.

- **Multipath Fading Channel**

  600kHz bandwidth is not sufficiently wide to overcome the fading condition. Wider band utilization like adaptive frequency agility, need to alleviate the impediments due to propagation environment.

  Usually, BPSK-DSSS will facilitate to utilize better propagation characteristics of sub-GHz band and the good penetration as well.

[Excerpt from specification of commercially available chip]
DSSS-BPSK as a baseline modulation scheme

Band width: 600KHz
→ Identical as current European 868-868.6MHz PHY

<table>
<thead>
<tr>
<th>PHY (MHz)</th>
<th>Frequency band (MHz)</th>
<th>Spreading parameters</th>
<th>Data parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Chip rate (kchip/s)</td>
<td>Bit rate (kb/s)</td>
</tr>
<tr>
<td>868/915</td>
<td>868–868.6</td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>902–928</td>
<td>600</td>
<td>40</td>
</tr>
<tr>
<td>950</td>
<td>950.9–955.7 (1mW)</td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>954.1–954.9 (10mW)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>868/915</td>
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<td>250</td>
</tr>
<tr>
<td>(optional)</td>
<td>902–928</td>
<td>1600</td>
<td>250</td>
</tr>
<tr>
<td>868/915</td>
<td>868–868.6</td>
<td>400</td>
<td>100</td>
</tr>
<tr>
<td>(optional)</td>
<td>902–928</td>
<td>1000</td>
<td>250</td>
</tr>
<tr>
<td>2450</td>
<td>2400–2483.5</td>
<td>2000</td>
<td>250</td>
</tr>
</tbody>
</table>
Relevant Transmission Control Rules

Fairness between License-Exempt low power WPAN and Licensed high power RFID system is reflected in TX duty ratio control and maximum duration of transmission followed by the cease-TX time enforced.

1mW (Full Band Ch.1 - Ch.8)

1mW (Full Band Ch.1 - Ch.8) or 10mW System (Specific Channels Ch.9 or Ch.10)
PHY Header Extension for AFA
Channel Scan Operation using CCA

- Distributed CCA during series of transmission or CCA at designated time slot is a part of AFA and its base function

- Channel Scan using CCA and transmission of resulting information are network independent function in PHY/MAC

But the frequency channel selection is correlated issue
(1) Depend on network topology and interference
(2) Cross Layer issue with PHY, MAC and NWK

- Due to inevitable congested frequency usage, channel scan operation and resulting peer CCA information are crucially important in every forms of AFA implementations.
AFA with distributed CCA in each time slot

TX node to decide the transmission of each channels using CCA.

Then TX node must follow the pre-defined TX channel order to send. In this case, AFA means just CA, i.e., collision avoidance.

In case of the reliability conscious APP, it's better for TX node to inform the decision of transmission regarding entire channels to RX nodes.
AFA with congregated CCA in a designated time slot
TX node to decide the transmission of each channels and its order to send.

TX node must ensure at least a frame is following the previously scheduled channel and time slot unchanged to inform the new transmission channels and its order to send. Adaptive utilization of channels according to CCA is possible.
AFA with Simultaneous CCA in a designated time slot

As a future provisioning, it may be considered TX node decide the channel usage more adaptively based on wider band receiver like OFDM transceiver. Even in this uncertain future scenario, TX node is supposed to include at least TX side information of channel usage by which RX node is able to be ensured if intended frame transmission have succeeded or failed. Simultaneous reception of multichannel at RX node would greatly improve the reliability of AFA.
Channel Coordination Functions (1)
< PHR extension >

Modification of PHR Length Field

Current : Length 7 bits + Reserved 1 bit
Modification : Length 7 bits + PHR Extension 1 bits

Addition in PHR structure

TX Channel Table
→ Length : 4 Octets
→ 24 Entry for each 200kHz 1mW/10mW sub-channel
→ 1 bits for each entry
→ Value: 1bit, indicating
   Clear/Busy, or AFA scheduled TX channel, or other

Favourable Usage

→ Inform AFA schedule or status on other TX channels to Peer nodes
Channel Coordination Functions (1)

< PHR extension >

<table>
<thead>
<tr>
<th>Octets</th>
<th>1</th>
<th>3</th>
<th>1</th>
<th>variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preamble</td>
<td>SFD</td>
<td>Frame length (7 bits)</td>
<td>Extension Exist (1 bit)</td>
<td>TX Ch. Table 24 Ch. x (1 bit)</td>
</tr>
<tr>
<td>SHR</td>
<td>PHR</td>
<td>PHR Extension</td>
<td>PHY payload</td>
<td></td>
</tr>
</tbody>
</table>

- TX Channel Table: In case of Japanese 950MHz PHY, sub-channel number indicates a 200kHz BW channel as the way shown Slide 3, e.g. number increasing number means increasing frequency.

| Octet Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|--------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Sub-channel Number | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit |
| Clear/Busy | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit | 1 bit |

- Control Field: Define the meaning of TX ch. Table, or other messages.

<table>
<thead>
<tr>
<th>Control bits</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>・</td>
<td>Channel clear/Busy</td>
</tr>
<tr>
<td>1</td>
<td>Scheduled TX</td>
</tr>
<tr>
<td>4</td>
<td>Acknowledged</td>
</tr>
<tr>
<td>3-24</td>
<td>Reserved</td>
</tr>
</tbody>
</table>

(" bit) Usually “・”
Channel Coordination Functions (2)

< Channel utilization PIB >

PHY Management Services
PLME-Peer-AFA-TX ; Perform CCA on each channel & TX
PLME-Peer-AFA-RX ; Collect AFA information in PHR

PIB
phyChannelsActivated
  → Type: array ; Indicates Peer Transmitting Channel
  → Value: Scheduled(F/H), Simulcast, DuplicateTX
phyChannelsOccupied
  → Type: array ; Indicates CCA history of performed LBT
  → Value: Ratio and latest time stamp of Clearance
phyCurrentChannel ; Currently 0-26
  → Type: array
  → Value: 0-26 or 3 combined value of 100-108
Simple, Adaptive and Reliable OFDM for Future AFA provisioning
{Provisioning for future 802.15.4 PHY with AFA functionalities}

This part of proposal have to consider how to conform with European 863-868MHz band which is expected to accommodate SRD systems abide by ETSI recommendation and open for further discussions.

Simple, Agile and Reliable OFDM PHY

FFT number of points : 256pts
Sampling Rate : 5.12MHz
Sub-carrier Spacing 20kHz
Bandwidth : 4.8MHz
Number of Sub-carrier within band : 240
GI : Short 2.5uS, Long 5.0uS
Modulation : BPSK, QPSK, 16QAM
Coding Rate : 1/3
Instantaneous Signal bandwidth : 600kHz
Symbol Rate : 19.0476 k symbol/S (2.5uS GI), 18.1818 k symbol/S (5.0uS GI)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Data Rate (bps)</th>
<th>Remarks</th>
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<td>Coding Rate</td>
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<td>1/3</td>
<td>152.38k</td>
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<tr>
<td>QPSK</td>
<td>1/3</td>
<td>304.76k</td>
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<td>16QAM</td>
<td>1/3</td>
<td>629.02k</td>
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<td>16QAM</td>
<td>2/3</td>
<td>1.1191M</td>
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</table>
Provisioning for future 802.15.4 PHY with AFA functionalities

- PSD of instantaneous signal (600kHz BW in Japan)

In order to conform with 600kHz bonded channel mask, 24 of 30 sub-carrier is used and time domain windowing of Raised Cosine shape is applied.

Further possibilities

- With 600kHz bonded channel mask, 24 of 30 sub-carrier is used and rest is nulled out. Time domain windowing of Raised Cosine shape is applied to achieve required PSD mask of regulatory rules.

- Active edge cancellation in addition to nulling out may be applicable in some cases.

- Avoid usage of specific 200kHz channels interfered by alien systems sharing identical band.

- Pre-determined sub-carriers for active PAPR reduction.

[ Simulated PSD example of signal ]
{Provisioning for future 802.15.4 PHY with AFA functionalities}

- Channels can be used sequentially
  ( and simultaneously if allowed )

Actual Spectrum of 600kHz signal on each channel
( Actually measured )
Because of limited availability of instantaneous TX bandwidth, it is crucially important to distribute the signal to entire allowed bandwidth in order to alleviate the impediment of multipath fading. AFA may be used to ensure the coded multi-carrier forward error correction scheme even in flat fading sub-band of 600kHz, in addition to adaptive co-existence strategies to alien systems in identical band.
{Provisioning for future 802.15.4 PHY with AFA functionalities}

- **PAPR of Sub-grouped OFDM signal**
  (e.g. 24 carriers within 600kHz band)

[ General Rule ]

- As number of OFDM sub-carrier increases, PAPR is getting closer to AWGN statistics.

- So PAPR of AWGN like OFDM is Rayleigh distributed and infinite peak in theory.

- In reality, as number of sub-carrier decreases, ratio of PAPR is reduced and the factor is proportional with the number N.

- In the sense of PAPR control, sub-grouping of OFDM sub-carrier means controlling PAPR of OFDM signals.

[ Conceptional CCDF of sug-grouped OFDM signal ]
References

IEEE Doc 15-07-0860-02-004d-Call-for-Proposal
IEEE Doc 15-07-0959-00-004d-PHY-System-Parameters
IEEE Doc 15-07-0918-00-004d-technical-requirements-950mhz-low-power-active-radio-systems
IEEE Doc 15-07-0789-00-004d-japanese-950mhz-regulation(2)
IEEE Doc 15-07-0788-00-004d-japanese-950mhz-regulation
IEEE Doc 15-07-0712-00-wng0-Supplement-Commonality-Enhancement-for-Sub-GHz-WPAN
IEEE Doc 15-07-0621-03-wng0-Commonality-Enhancement-for-Sub-GHz-WPAN

Proposed Consultation document of 950MHz frequency band usage rules for public comment Solicitation issued by MIC in Japan
Annex
Tentative Comparison of Two Proposals

15-08-0006-01-004d-p802-15-4-d-preliminary-proposal-ww-bpsk-with-afa-provisioning

Channel Plan (1)
## Channel Plan (2)

<table>
<thead>
<tr>
<th>Submission</th>
<th>Channel Bandwidth ( % of max. )</th>
<th>Number of 1mW Channel</th>
<th>Number of 10mW Channel</th>
<th>Number of non-overlapping 10mW Channel</th>
<th>LBT on MSC-RFID</th>
<th>Commonality with Existing 15.4 Std.</th>
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<tbody>
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<td>٦٠٠٠-٨٠-٥١</td>
<td>٦٠٠kHz</td>
<td>≥ ch.</td>
<td>≥ ch.</td>
<td>≥ ch.</td>
<td>Inherent</td>
<td>Same as current EU mandatory</td>
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<tr>
<td>٦٠٠٠-٨٠-٥١</td>
<td>٦٠٠kHz</td>
<td>≥ ch.</td>
<td>≥ ch.</td>
<td>≥ ch.</td>
<td>Difficult or Prohibit MSC-RX Ch.</td>
<td>Unique</td>
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<tr>
<td>EU 868MHz in IEEE802.15.4-2006</td>
<td>٦٠٠kHz</td>
<td>≥ ch.</td>
<td>≥ ch.</td>
<td>≥ ch.</td>
<td>---</td>
<td>Mandatory 20kbps on 600kHz</td>
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<tr>
<td>US 915MHz in IEEE802.15.4-2006</td>
<td>٦MHz</td>
<td>≥ ch.</td>
<td>≥ ch.</td>
<td>≥ ch.</td>
<td>---</td>
<td>Mandatory 40kbps Using 600kfps</td>
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</table>
Channel Plan (3)

• Selecting 600kHz
  Pro: Consistent with existing 15.4 sub-GHz PHY
  Con: Not to be optimized for 400kHz PHY

• Selecting 400kHz
  Pro: Optimized for 400kHz PHY
  Con: Alienate 600kHz PHY

• Not to define any channel plan
  Pro: No restriction
  Con: Less coexisting strategies
       & more legacy problems in future
       & many narrow-band proprietary systems participate
## Modulation Scheme (1)
### Baseline Rate

<table>
<thead>
<tr>
<th>Submission Number of Proposal</th>
<th>Bit Rate</th>
<th>Bandwidth</th>
<th>Modulation</th>
<th>Spreading / Factor / Coding</th>
<th>Robustness / Coexistence with Narrow Band System including MSC-RFID</th>
<th>Remarks</th>
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</thead>
<tbody>
<tr>
<td>15-08-0006 Part 1</td>
<td>16kbps</td>
<td>200kHz</td>
<td>BPSK</td>
<td>300kcps 15chip Sequence</td>
<td>Better Best with AFA</td>
<td>SHR/PHR with Periodicity to facilitate CCA</td>
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<tr>
<td>EU 868MHz 802.15.4 2006 Mandatory</td>
<td>16kbps</td>
<td>200kHz</td>
<td>BPSK</td>
<td>300kcps 15chip Sequence</td>
<td>Better</td>
<td>SHR/PHR with Periodicity to facilitate CCA</td>
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<tr>
<td>US 915MHz 802.15.4 2006 Mandatory</td>
<td>64kbps</td>
<td>1MHz</td>
<td>BPSK</td>
<td>600kcps 15chip Sequence</td>
<td>Better Best with AFA</td>
<td>SHR/PHR with Periodicity to facilitate CCA</td>
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</table>
# Modulation Scheme (2)

## Baseline Rate

<table>
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<th>Submission Number of Proposal</th>
<th>Bit Rate</th>
<th>Bandwidth</th>
<th>Modulation</th>
<th>Spreading /Factor /Coding</th>
<th>Robustness / Coexistence with Narrow Band System including MSC-RFID</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU 868MHz 802.15.4 2006 Option 1</td>
<td>100 kbps</td>
<td>400 kHz</td>
<td>GFSK</td>
<td>BT = 0.5 Mod. Index = 1.0</td>
<td>Uncertain</td>
<td>SHR/PHR with No Periodicity</td>
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<tr>
<td>EU 868MHz 802.15.4 2006 Option 2</td>
<td>85 kbps</td>
<td>800 kHz</td>
<td>16-ary Orthogonal</td>
<td>400kcps 16chip Sequence</td>
<td>Good</td>
<td>SHR/PHR with Periodicity to facilitate CCA</td>
</tr>
<tr>
<td>US 915MHz 802.15.4 2006 Option 1</td>
<td>85 kbps</td>
<td>2 MHz</td>
<td>16-ary Orthogonal</td>
<td>1Mcps 16chip Sequence</td>
<td>Good</td>
<td>SHR/PHR with Periodicity to facilitate CCA</td>
</tr>
<tr>
<td>EU 868MHz 802.15.4 2006 Option 2</td>
<td>85 kbps</td>
<td>800 kHz</td>
<td>PSSS-ASK</td>
<td>8-bit PSSS</td>
<td>Uncertain</td>
<td>SHR/PHR with Periodicity to facilitate CCA</td>
</tr>
<tr>
<td>US 915MHz 802.15.4 2006 Option 1</td>
<td>85 kbps</td>
<td>2 MHz</td>
<td>PSSS-ASK</td>
<td>6-bit PSSS</td>
<td>Uncertain</td>
<td>SHR/PHR with Periodicity to facilitate CCA</td>
</tr>
</tbody>
</table>
## Modulation Scheme (3)
### Baseline Rate

<table>
<thead>
<tr>
<th>Submission Number of Proposal</th>
<th>Bit Rate</th>
<th>Bandwidth</th>
<th>Modulation</th>
<th>Spreading /Factor /Coding</th>
<th>LBT on MSC-RFID</th>
<th>Commonality with Existing 15.4 Std.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partly Spread Mode DSSS-BPSK</td>
<td>300kbps</td>
<td>700 kHz</td>
<td>BPSK</td>
<td>300kps 15chip Sequence / No Spreading on Pay Load</td>
<td>Better with AFA</td>
<td>Highly Similar</td>
</tr>
<tr>
<td>15-08-0006 Part 3</td>
<td>152/145kbps, 305/291kbps, 610/582kbps, 1219/1164kbps</td>
<td>24 of 600kHz Sub-carriers</td>
<td>OFDM BPSK QPSK 16QAM 16QAM</td>
<td>FEC 1/3 1/3 1/3 2/3</td>
<td>Excellent (Inherent AFA)</td>
<td>Completely Different But Good Co-existence</td>
</tr>
</tbody>
</table>

- **Bit Rate**: 300kbps
- **Bandwidth**: 700 kHz
- **Modulation**: BPSK
- **Spreading/Factor/Coding**: 300kps 15chip Sequence / No Spreading on Pay Load
- **LBT on MSC-RFID**: Better with AFA
- **Commonality with Existing 15.4 Std.**: Highly Similar

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**Note**: The table above provides a comparison of different modulation schemes for baseline rates, including bit rates, bandwidths, modulations, spreading factors, coding rates, and compatibility with existing standards.
Modulation Scheme (4)

Commonality with 15.4

Commonality with 15.1
END