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.]

Re-capturing PAR & 5C and Introduction

[Excerpt from PAR & 5C]

This (950MHz PHY ammendment) 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

(MHz)					10mW	1mW
Freq. 951.0	Ch# 1	RFID Licensed 4W EIRP	RFID Light-Licensed 4W EIRP	RFID License-exempt 10mW	WPAN License Exempt	WPAN License Exempt
951.2	2					A, B, C
951.4	3					A, B, C
951.6	4					A, B, C
951.8	5					A, B, C
952.0	6					A, B, C
952.2	7	A	A	A		A, B, C
952.4	8	A, B	A	A		A, B, C
952.6	9	A	A	A		A, B, C
952.8	10	A	A	A		A, B, C
953.0	11	A	A	A		A, B, C
953.2	12	A	A	A		A, B, C
953.4	13	A	A	A		A, B, C
953.6	14	A, B	A	A		A, B, C
953.8	15	A	A	A		A, B, C
954.0	16			A		A, B, C
954.2	17			A	A	A, B, C
954.4	18			A	A	A, B, C
954.6	19			A	A	A, B, C
954.8	20			A	A	A, B, C
955.0	21					A, B, C
955.2	22					A, B, C
955.4	23					A, B, C
955.6	24					A, B, C

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

A: Carrier Sense 5ms @ -74dBm
Tx duration 4 s max
w/t Cease-TX 50ms

A: CarrierSense 10ms@-64dBm
Tx duration 1 s max
w/t Cease-TX 100ms

A: Carrier Sense10ms@-75dBm
Tx duration 1 s max
w/t Cease-TX 100ms

A: CarrierSense 10ms @ -75dBm
Tx duration 1 s max
w/t Cease-TX 100ms
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

Relevant Rules to this amendment

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}

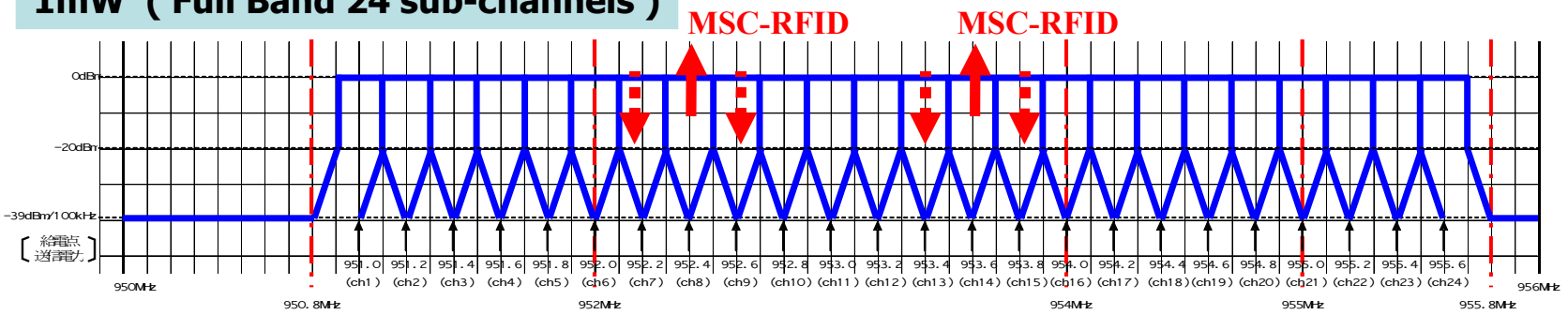
Channel Plan

Channel Plan & Sub-channels

As RFID system 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.

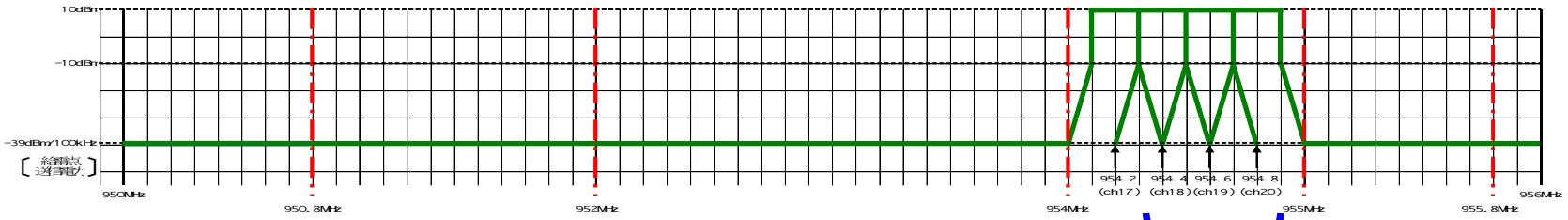
600kHz Channelization ↔ 3 Sub-channels bonding [Page 0 or page 3 (new)]

1mW (Full Band 24 sub-channels)



Bonded Channels → Ch.1 Ch.2 Ch.3 Ch.4 Ch.5 Ch.6 Ch.7 Ch.8

10mW (Specific sub-channels [17,18,19,20 sub-channel])



Bonded Channels → Ch.9 Ch.10

“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

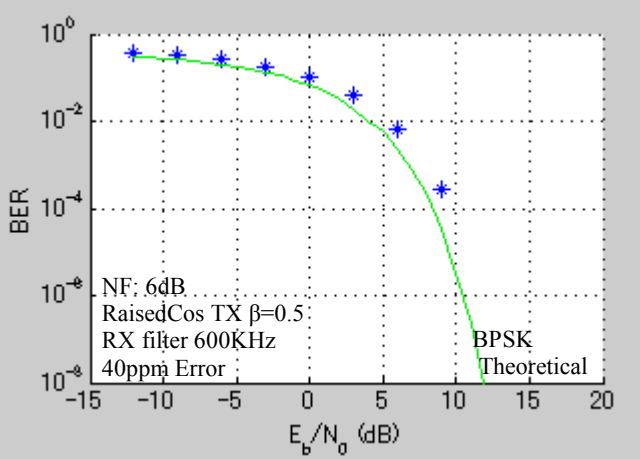
TX Power : 0dBm (3dBmEIRP) for Ch.1-8
or 10dBm (13dBmEIRP) for Ch.9-10

TX PSD Limit

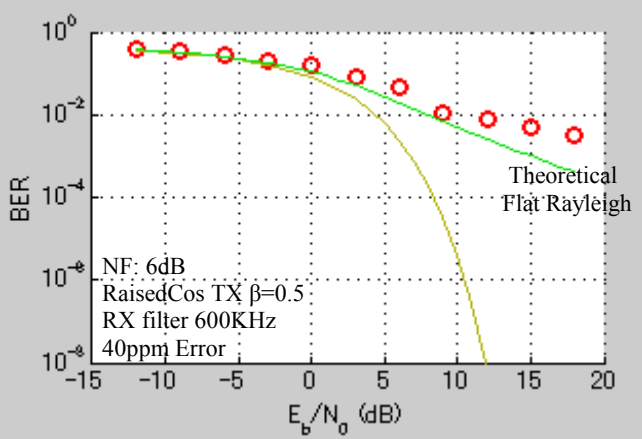
Channel Aggregation	Frequency	Relative Limit	Absolute Limit
3 Sub-channels [Ch.1-8]	$\|f-f_c\| \geq 300$kHz	$-20dB_c$	-20dBm
	$\|f-f_c\| \geq 400$kHz	---	-39dBm/100kHz
3 Sub-channels [Ch.9-10]	$\|f-f_c\| \geq 300$kHz	$-20dB_c$	-10dBm
	$\|f-f_c\| \geq 400$kHz	---	-39dBm/100kHz

BPSK modulation schemes

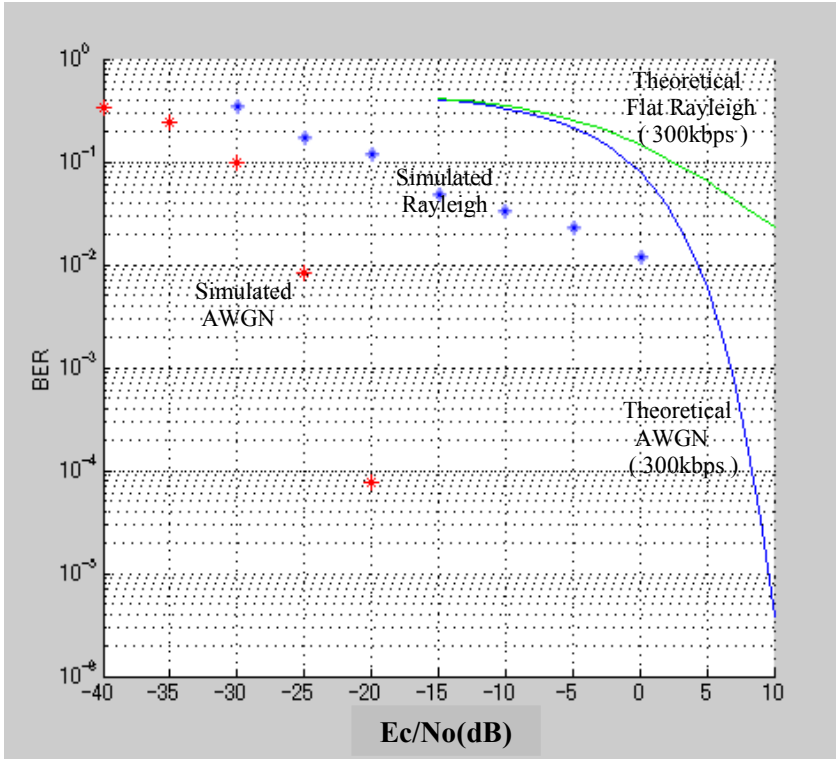
•AWGN channel (300kbps)



•Rayleigh Channel (300kbps)

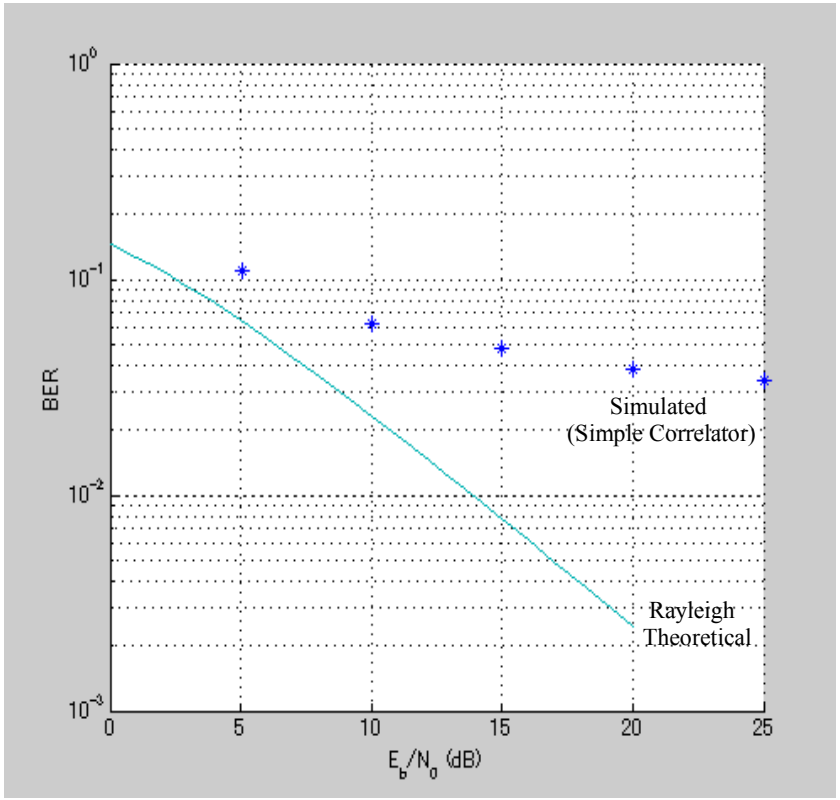


•15 chips DSSS Processing Gain (20kbps)

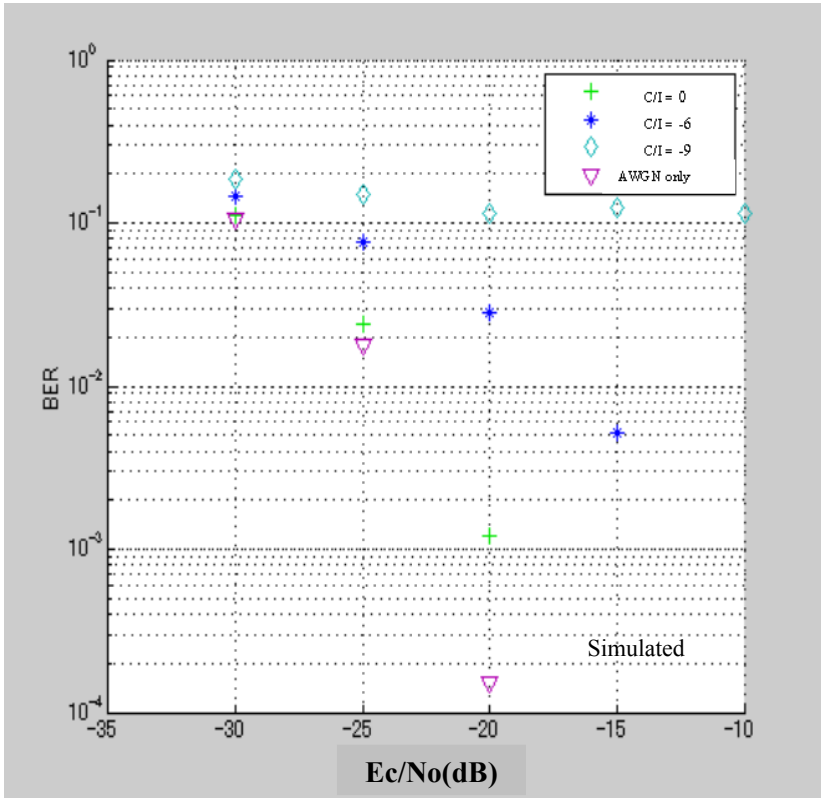


BPSK-DSSS modulation scheme

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



- Narrow Band Interference (C/I+AWGN)

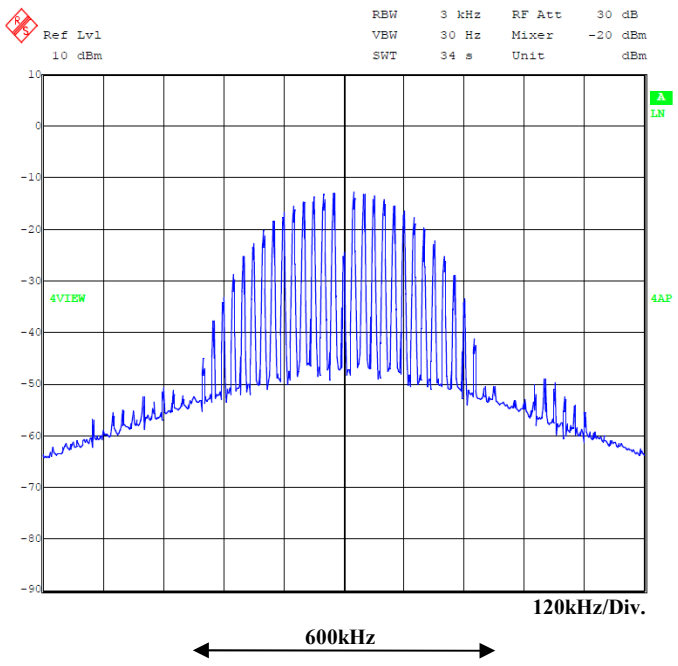


* Because of 300kHz chip-rate, 3taps model with 1'st tap of Rician k=12dB is substituted and used.

No flooring in case of C/I= -6dB or better.

BPSK DSSS modulation scheme

•TX PSD



[Excerpt from specification of commercially available chip]

•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.

DSSS-BPSK as a baseline modulation scheme

Band width : 600KHz

→ Identical as current European 868-868.6MHz PHY

Table Frequency bands and data rates

PHY (MHz)	Frequency band (MHz)	Spreading parameters		Data parameters		
		Chip rate (kchip/s)	Modulation	Bit rate (kb/s)	Symbol rate (ksymbol/s)	Symbols
868/915	868–868.6	300	BPSK	20	20	Binary
	902–928	600	BPSK	40	40	Binary
950	**950.9-955.7 (1mW)** / **954.1-954.9(10mW)**	**300**	**BPSK**	**20**	**20**	**Binary**
868/915 (optional)	868–868.6	400	ASK	250	12.5	20-bit PSSS
	902–928	1600	ASK	250	50	5-bit PSSS
868/915 (optional)	868–868.6	400	O-QPSK	100	25	16-ary Orthogonal
	902–928	1000	O-QPSK	250	62.5	16-ary Orthogonal
2450	2400–2483.5	2000	O-QPSK	250	62.5	16-ary Orthogonal

[Page 0 or page 3 (new)]

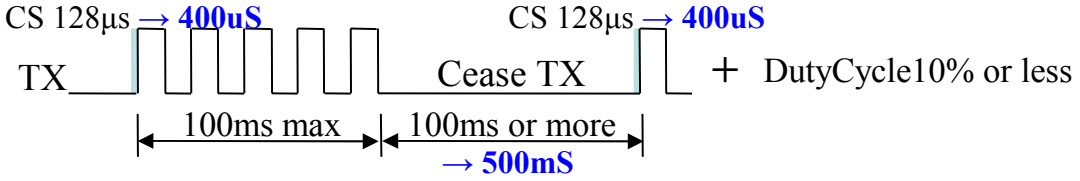
Relevant Transmission Control Rules

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)

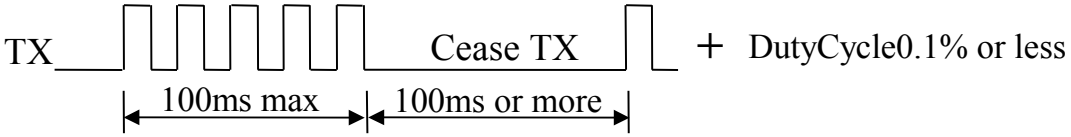
In case of DSSS-BPSK

<Carrier Sense 128us or more>



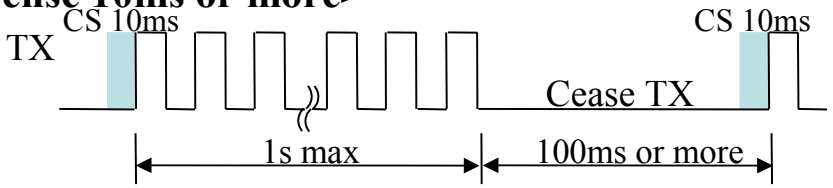
<No Carrier Sense>

Relevant in case of ACK transmission



1mW (Full Band Ch.1 - Ch.8) or 10mW System (Specific Channels Ch.9 or Ch.10)

<Carrier Sense 10ms or more>



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

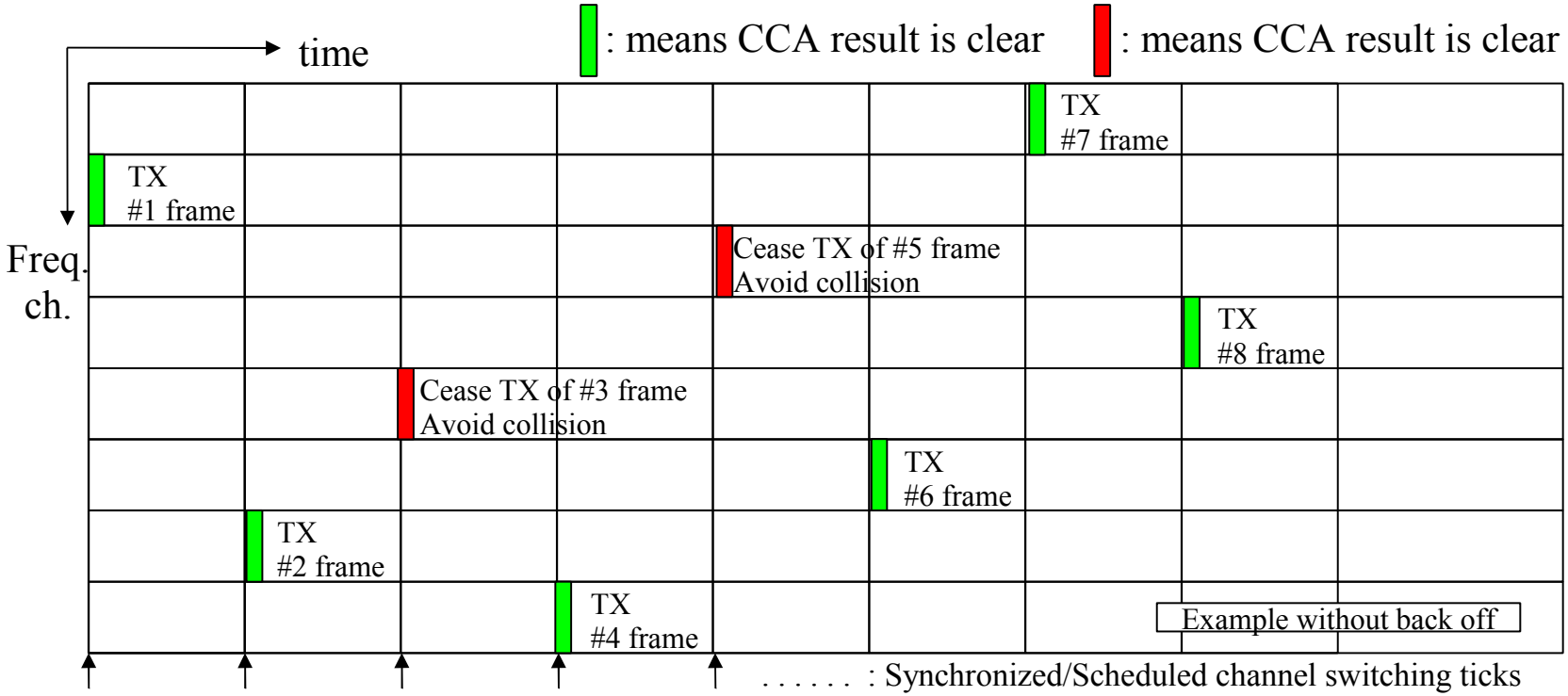
- Channel Scan using CCA and transmission of resulting information are network independent function in PHY/MAC

  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.

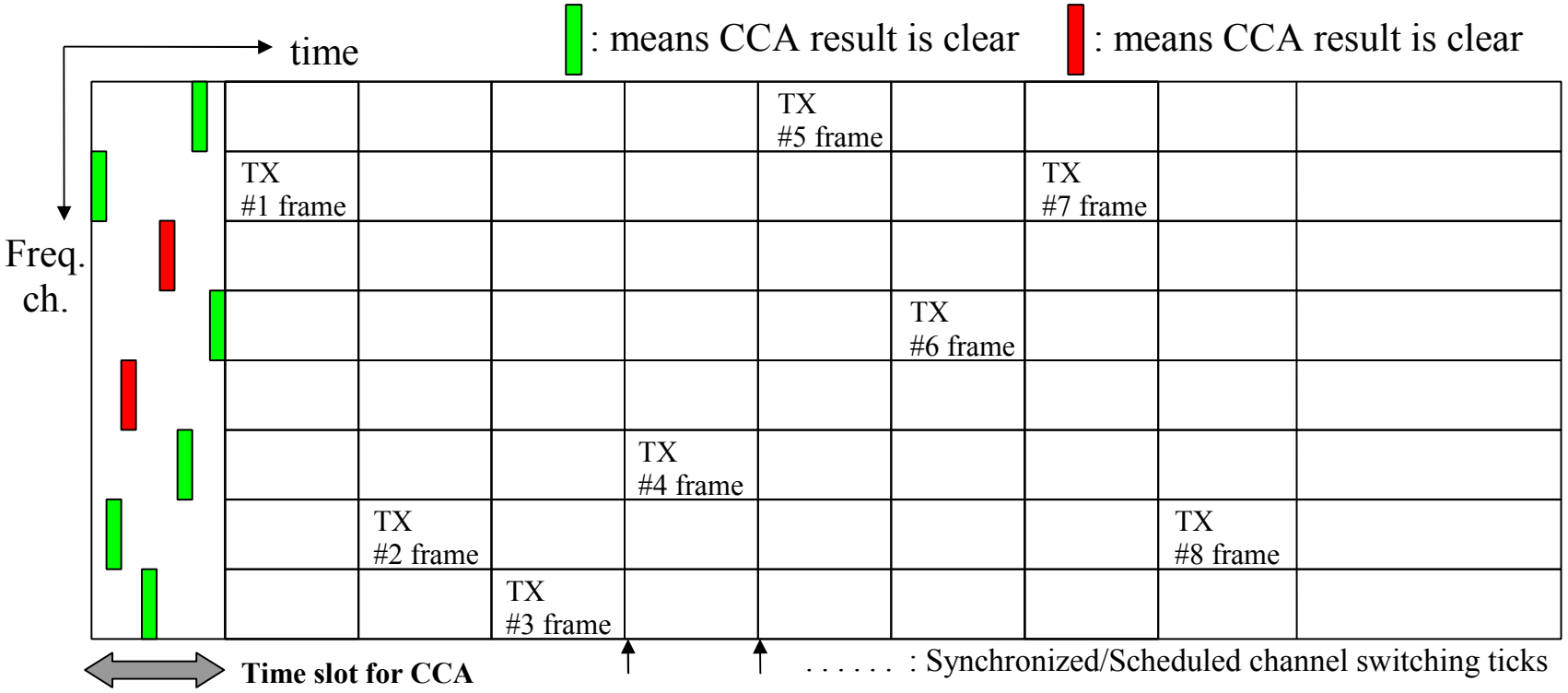


Then TX node must follow the pre-defined TX channel order to send. In this case, AFA means just CA, i.e., collision avoidance.

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

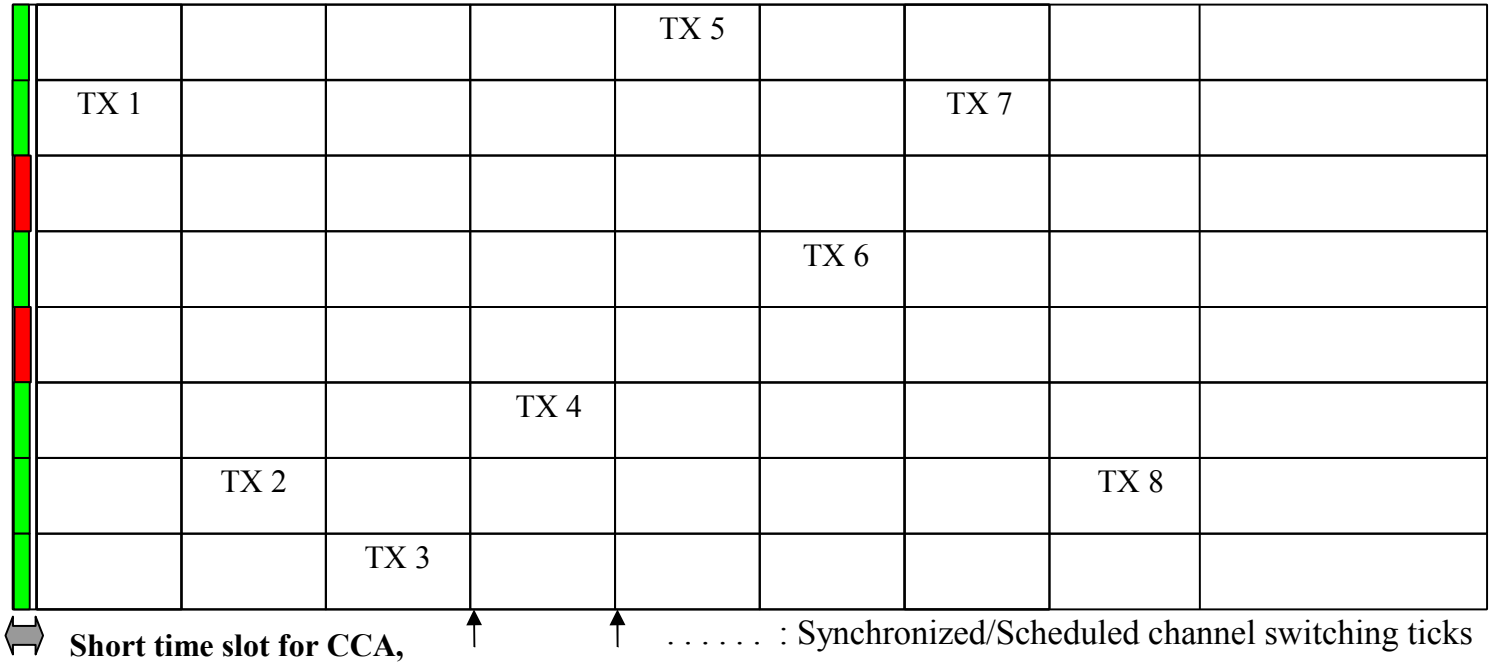
TX node to decide the transmission of each channels and its order to send.



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 >

		Octets				
		1		3	1	variable
Preamble	SFD	Frame length (7 bits)	Extension Exist (1 bit)	TX Ch. Table **24 Ch. x (1 bit)**	Control bits (8)	PSDU
SHR		PHR		**PHR Extension**		PHY payload

- 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							
Sub-channel 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
Clear/Busy	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit	1bit

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

Std. Control field (1bit)	Control bits (6bit)	Reserved (Further Extension Exist)
0	Standard definition	(1 bit) Usually "0"
1	Reserved	

Control bits	Meaning
0	Channel clear/Busy
1	Scheduled TX
2	Acknowledged
3-63	Reserved

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 using sub-channels
→ Type: array
→ Value: Arbitrary combination of channels, specified by number 0-24

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

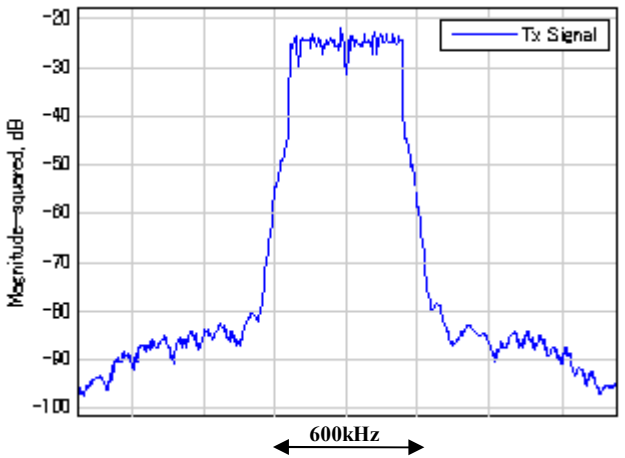
FFT number of points : 256pts
Sampling Rate : 5.12MHz
Sub-carrier Spacing 20kHz
Bandwidth : 4.8MHz
Number of Sub-carrier within band : 240
GI : Short 2.5uS, Long 5.0uS
Modulation : BPSK, QPSK, 16QAM
Coding Rate : 1/3
Instantaneous Signal bandwidth : 600kHz
Symbol Rate : 19.0476 k symbol/S (2.5uS GI),
18.1818 k symbol/S (5.0uS GI)
Effective number of sub-carrier in 600kHz : 24

Condition		Data Rate (bps)		Remarks
Modulation	Coding Rate	GI=2.5uS	GI=5uS	
BPSK	1/3	152.38k	145.45k	8bits/symbol
QPSK	1/3	304.76k	290.91k	16bits/symbol
16QAM	1/3	609.52k	581.82k	32bits/symbol
16QAM	2/3	1.2191M	1.1636M	64bits/symbol

{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.



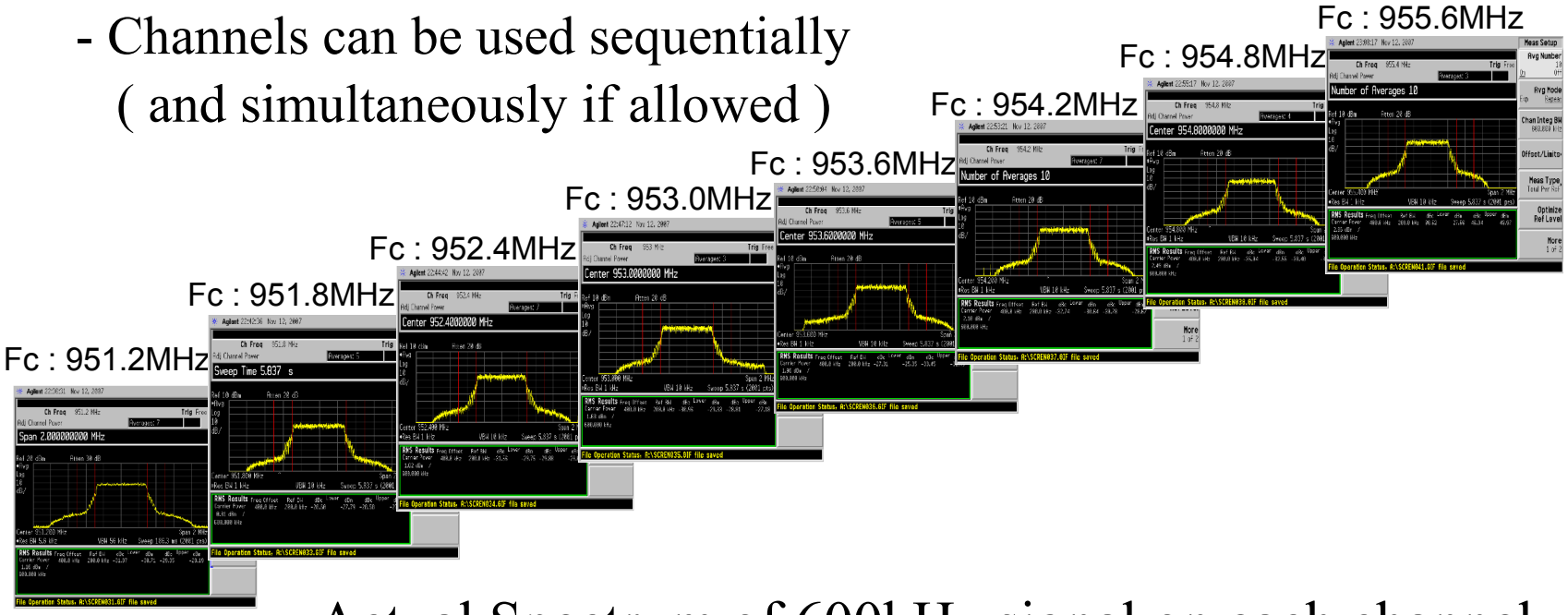
[Simulated PSD example of signal]

[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.**

{Provisioning for future 802.15.4 PHY with AFA functionalities}

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



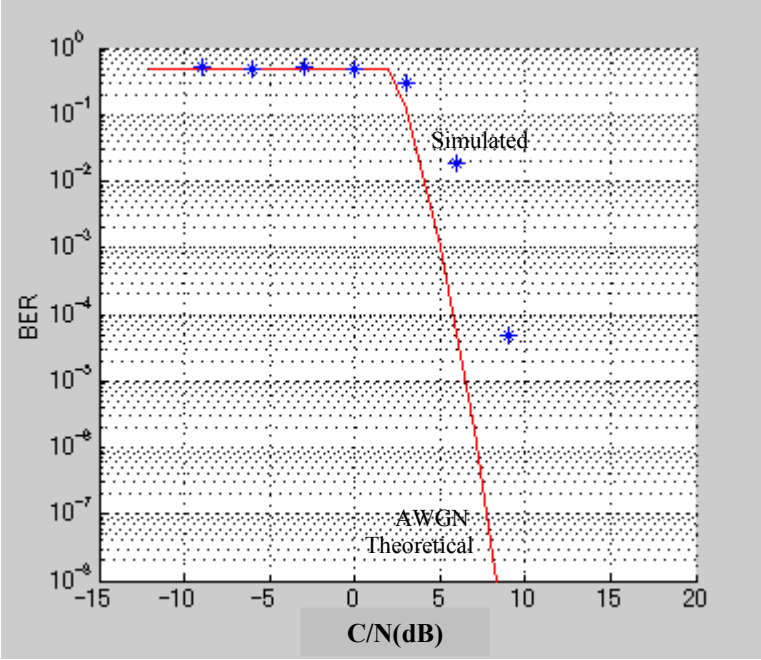
Actual Spectrum of 600kHz signal on each channel
(Actually measured)

{Provisioning for future 802.15.4 PHY with AFA functionalities}

- AWGN Channel

Raised Cosine Window β≈0.2

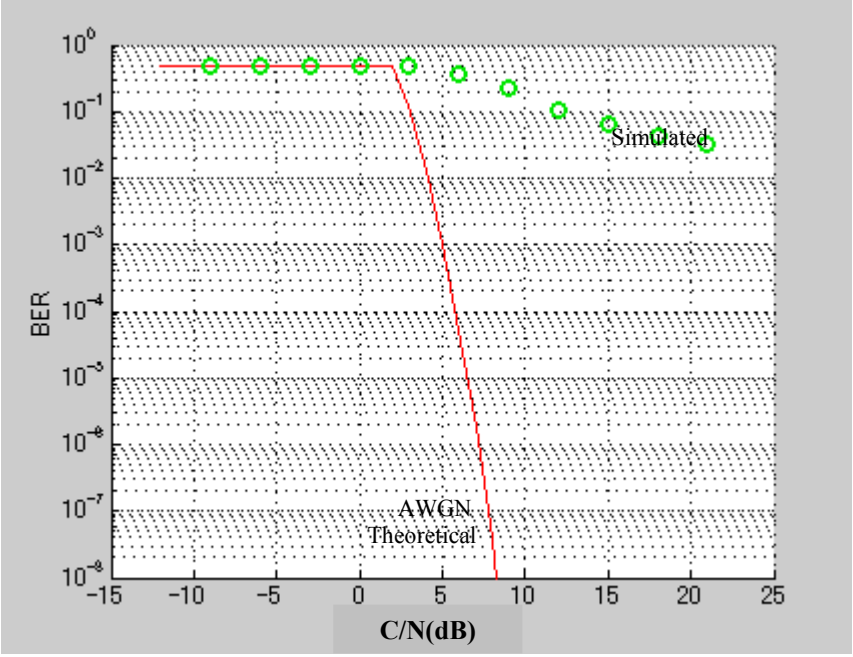
FEC (Hard Decision) within 600kHz Band
NF=6dB



- Rayleigh Channel

Raised Cosine Window β≈0.2

FEC (Hard Decision) within 600kHz Band
NF=6dB

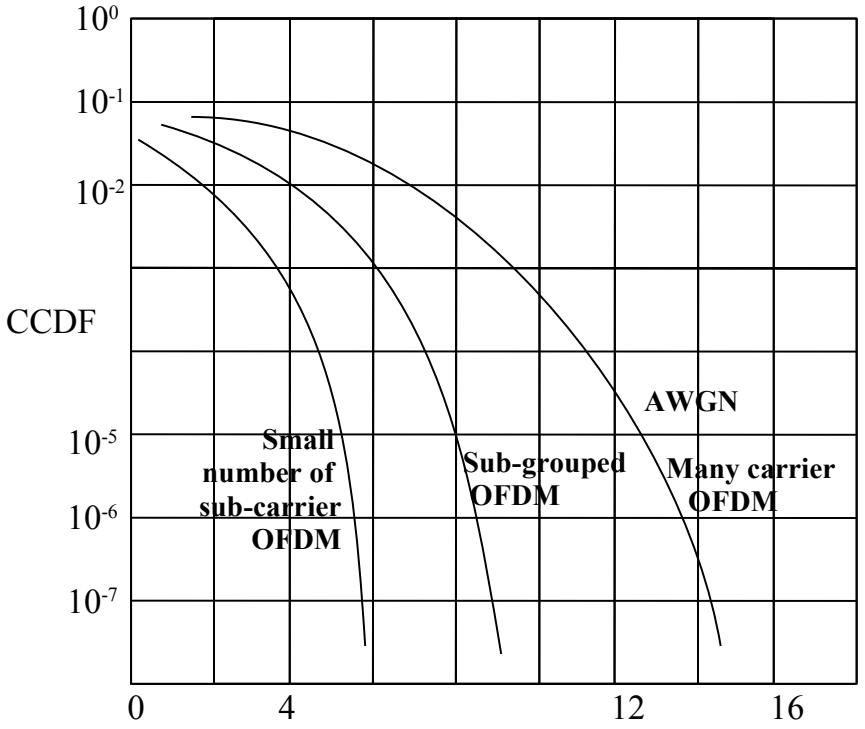


Because of limited availability of instantaneous TX bandwidth, it is crucially important to distribute the signal to entire allowed bandwidth in order to alleviate the impediment of multipath fading.

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)



[Conceptional CCDF of sug-grouped OFDM signal]

[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 propotional with the number N.**
- **In the sense of PAPR control, sub-grouping of OFDM sub-carrier means controlling PAPR of OFDM signals.**

References

IEEE Doc 15-08-0006-01-004d-preliminary-proposal-ww-bpsk-with-afa-provisioningCall-for-Proposal

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

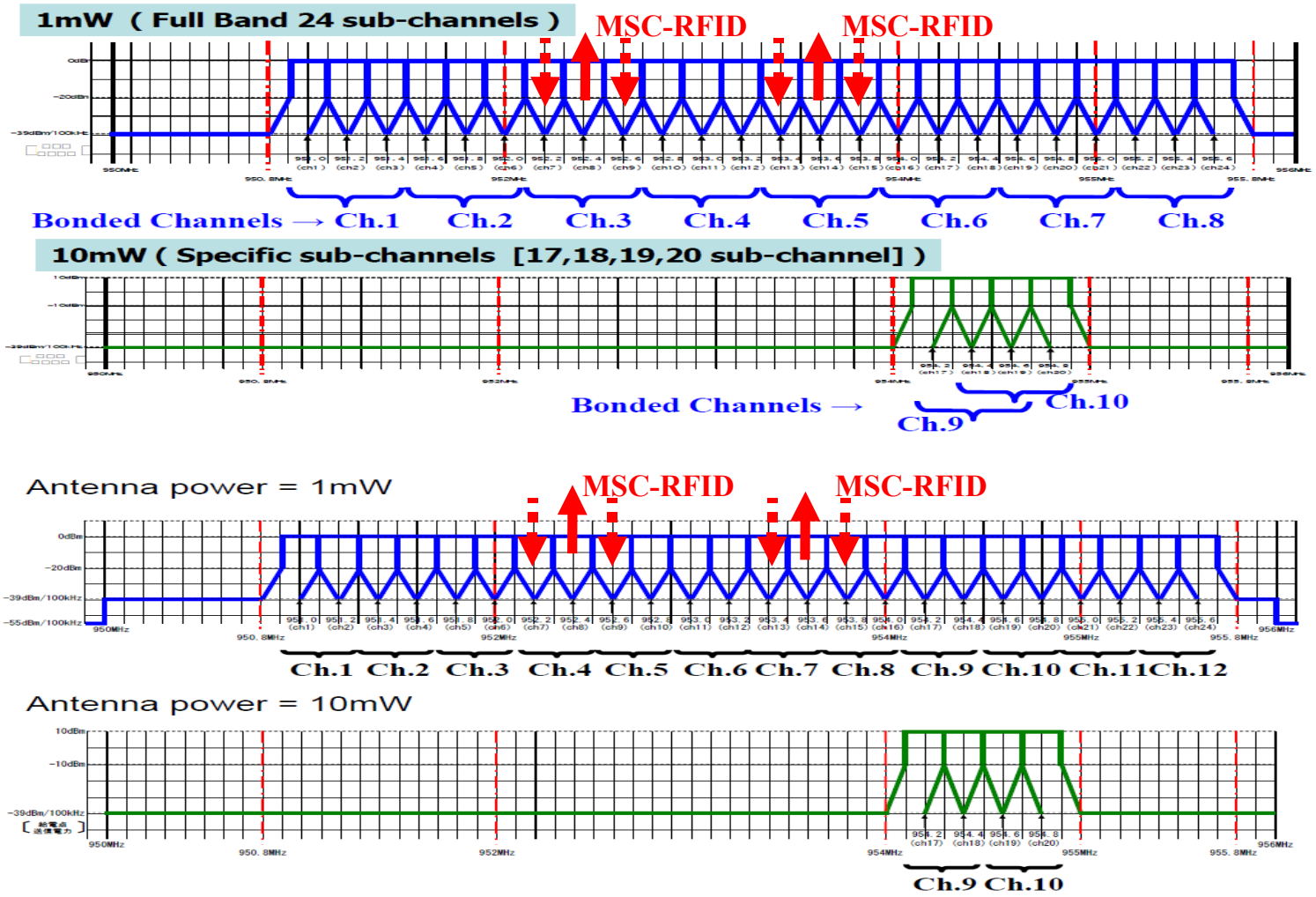
Annex

Tentative Comparison of Two Proposals

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

15-08-0007-02-004d-
response-to-call-for-preliminary-proposal-in-ieee802-15-4d-task-group

Channel Plan (1)



Channel Plan (2)

Submission Number of Proposal	Channel Bandwidth (% of max.)	Number of 1mW Channel	Number of 10mW Channel	Number of non-overlapping 10mW Channel	LBT on MSC-RFID	Commonality with Existing 15.4 Std.
15-08-0006	600kHz	8 ch.	2ch.	1ch.	Inherent	Same as current EU mandatory
15-08-0007	400kHz	12 ch.	2ch.	2ch.	Difficult or Prohibit MSC-RX Ch.	Unique
EU 868MHz in IEEE802.15.4-2006	600kHz	1 ch.	1ch.	1ch.	---	Mandatory 20kbps on 600kHz
US 915MHz in IEEE802.15.4-2006	2MHz	10 ch.	10 ch.	10 ch.	---	Mandatory 40kbps Using 600kcps

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

Submission Number of Proposal	Bit Rate	Bandwidth	Modulation	Spreading /Factor /Coding	Robustness / Coexistence with Narrow Band System including MSC-RFID	Remarks
15-08-0006 Part 1	20kbps	600kHz	BPSK	300kcps 15chip Sequence	Better Best with AFA	SHR/PHR with Periodicity to facilitate CCA
EU 868MHz 802.15.4 2006 Mandatory	20kbps	600kHz	BPSK	300kcps 15chip Sequence	Better	SHR/PHR with Periodicity to facilitate CCA
US 915MHz 802.15.4 2006 Mandatory	40kbps	2MHz	BPSK	600kcps 15chip Sequence	Better Best with AFA	SHR/PHR with Periodicity to facilitate CCA

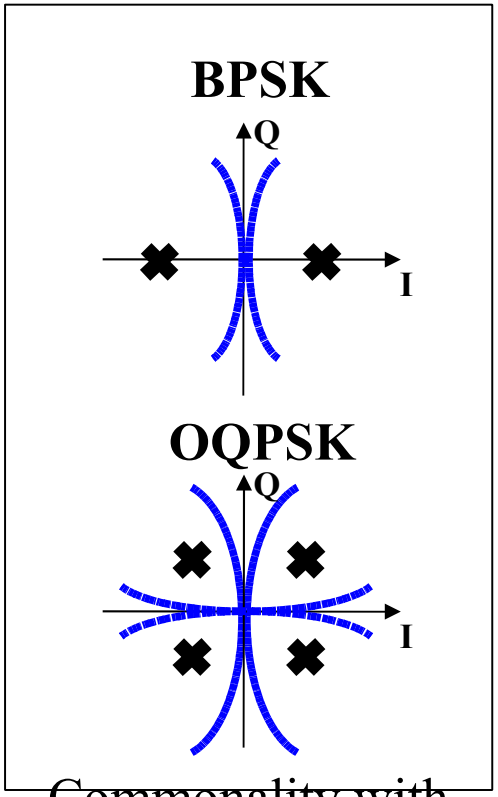
Modulation Scheme (2)
Baseline Rate

Submission Number of Proposal	Bit Rate	Bandwidth	Modulation	Spreading /Factor /Coding	Robustness / Coexistence with Narrow Band System including MSC-RFID	Remarks
15-08-0007	100kbps	400kHz	GFSK	BT = 0.5 Mod. Index = 1.0	Uncertain	SHR/PHR with No Periodicity
EU 868MHz 802.15.4 2006 Option 1	100kbps	600kHz	16-ary Orthogonal	400kcps 16chip Sequence	Good	SHR/PHR with Periodicity to facilitate CCA
US 915MHz 802.15.4 2006 Option1	250kbps	2MHz	16-ary Orthogonal	1Mcps 16chip Sequence	Good	SHR/PHR with Periodicity to facilitate CCA
EU 868MHz 802.15.4 2006 Option 2	250kbps	600kHz	PSSS-ASK	20bit PSSS	Uncertain	SHR/PHR with Periodicity to facilitate CCA
US 915MHz 802.15.4 2006 Option1	250kbps	2MHz	PSSS-ASK	5bit PSSS	Uncertain	SHR/PHR with Periodicity to facilitate CCA

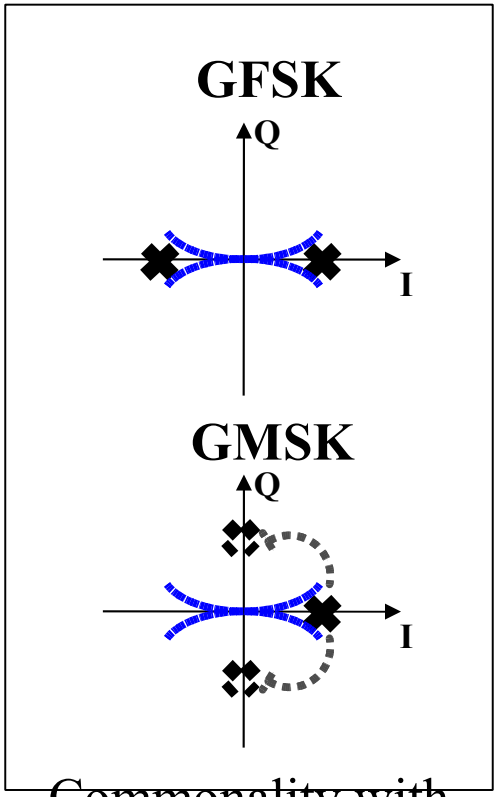
Modulation Scheme (3)
Baseline Rate

Submission Number of Proposal	Bit Rate	Bandwidth	Modulation	Spreading /Factor /Coding	LBT on MSC-RFID	Commonality with Existing 15.4 Std.
Partly Spread Mode DSSS-BPSK	300kbps Pay Load / 20kbps (PHR)	600kHz	BPSK	300kcps 15chip Sequence / No Spreading on Pay Load	Better with AFA	Highly Similar
15-08-0006 Part 3	GI= 2.5uS/5uS 152/145kbps 305/291kbps 610/582kbps 1219/1164kbps	24 of 600kHz Sub-carriers	OFDM BPSK QPSK 16QAM 16QAM	FEC 1/3 1/3 1/3 2/3	Excellent (Inherent AFA)	Completely Different But Good Co-existence

Modulation Scheme (4)



Commonality with 15.4



Commonality with 15.1

END