IEEE P802.15
Wireless Personal Area Networks

Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)	
Title	TG4f Coexistence Assurance Document	
Date Submitted	11, November 2010	
Source	802.15 TG4f Task Group	Voice: E-mail:
Re:	802.15 Plenary Meeting in Dallas, Texas (November 2010 session)	
Abstract	Analysis on coexistence of 802.15.4f with other 802 systems within the same spectrum bands.	
Purpose	To address the coexistence capability of 802.15.4f	
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Release	The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15.	

1. TG4f PHYs

A 433 MHz PHY employing minimum phase-shift keying (MSK) modulation

A UWB PHY employing On Off Keying (OOK) modulation

A 2450 MHz narrow band PHY employing minimum phase-shift keying (MSK) modulation

In further additions to the rates supported in IEEE Std 802.15.4-2006, IEEE Std 802.15.4a - 2007, IEEE Std 802.15.4c – 2009 and IEEE Std 802.15.4d – 2009 additional, rates have been added. These include rates in the bands located at 433 MHz, UWB-OOK, as well as a narrowband 2.4 GHz. These PHYs have their rates tuned to require minimum energy per transmission.

1.1 Operating Frequency Range and Rates

PHY (MHz)	Frequency band (MHz)	Chip Rate (kchp/s)	Modulation	Bit Rate (kb/s	Symbol Rate (ksymbol/s)	Symbols
433	**433.05 – 434.79**	**N/A**	**MSK**	**250**	**250**	**Binary**
				31.25	**31.25**	
2400	**2400 – 2483**	**N/A**	**MSK**	**250**	**250**	**Binary**
OOK-UWB	**6289.6 – 9185.6**	**1000**	**OOK**	**1000**	**1000**	**Binary**
		1000	**OOK**	**250**	**250**	**Binary**
		2000	**Manchester PPM**	**31.25**	**31.25**	**Binary**

1.2 List of regulatory documents:

Europe:

— Approval standards: European Telecommunications Standards Institute (ETSI)

— Documents: ETSI EN 300 328-1, ETSI EN 300 328-2, ETSI EN 300 220-1, ETSI EN 302 500-1, ETSI EN 302 500-2, ETSI EN 302 065.

ERC Recommendation 70-03

Approval authority: National type approval authorities

Japan:

— Approval standards: Association of Radio Industries and Businesses (ARIB)

— Documents: ARIB STD-T66, ARIB STD-T96, ARIB STD-T92, ARIB STD-T91

— Approval authority: Ministry of Public Management, Home Affairs, Posts and Telecommunications

(MPHPT)

United States:

— Approval standards: Federal Communications Commission (FCC), United States

Documents: FCC CFR47, Sections 15.247, 15.249, 15.250, 15.517, 15.231(e), 15.519,

Canada:

— Approval standards: Industry Canada (IC), Canada

— Document: GL36, Document: IC RSS210

2 UWB PHY

This document details simulations performed to demonstrate coexistence between the proposed OOK-UWB PHY and 802.15.4a. The OOK-UWB PHY is an ultrawideband PHY which can operate in three bands. The following frequencies are defined in the standard:

Frequency	**PSD Limit**
Band 0 (f_n = 6489.6 MHz)	
< 5620.0 MHz	-18 dBr
5620.0 MHz to 5783.1 MHz	-10 dBr
5783.1 MHz to 7196.1 MHz	0 dBr
7196.1 MHz to 7359.2 MHz	-10 dBr
> 7359.2 MHz	-18 dBr
Band 1 (f_n = 7488.0 MHz)	
< 6588.8 MHz	-18 dBr
6588.8 MHz to 6663.8 MHz	-10 dBr
6663.8 MHz to 7813.0 MHz	0 dBr
7813.0 MHz to 7888.0 MHz	-10 dBr
> 7888.0 MHz	-18 dBr

Band 2 (f_n = 8985.6 MHz)	
< 8086.4 MHz	-18 dBr
8086.4 MHz to 8161.4 MHz	-10 dBr
8161.4 MHz to 9310.6 MHz	0 dBr
9310.6 MHz to 9385.6 MHz	-10 dBr
> 9385.6 MHz	-18 dBr

It should be noted that Band 0 has been chosen to have the same centre frequency as 802.15.4a Bands 5 and 7. Similarly, Band 1 has the same centre frequency as 802.15.4a Band 8 and deliberately avoids mandatory Band 9 of 802.15.4a to allow 802.15.4a devices to interwork without interference from the OOK-UWB PHY. Band 2 of the OOK-UWB PHY was chosen to have the same centre frequency as 802.15.4a Band 12.

2.1 Simulation Setup

The simulation setup consisted of an OOK-UWB PHY transmitter and an 802.15.4a compliant victim receiver. The transmit level of the OOK-UWB PHY was set to simulate a transmitter that was transmitting at full FCC regulatory power 1 metre from the victim receiver. The OOK-UWB transmitter was setup for 500MHz 3dB bandwidth. The centre frequency of the OOK-UWB transmitter was set to 6489.6 MHz and it was started transmitting preamble in basic mode, i.e. with a PRF of 1MHz. The 802.15.4a victim receiver was configured for a centre frequency of 6489.6 MHz, i.e. exactly the same as the OOK-UWB transmitter. It was configured to try to detect an 802.15.4a compliant preamble at a PRF of 15.6MHz.

2.2 Simulation Results

The 802.15.4a compliant receiver’s preamble detector did not get triggered by the OOK-UWB transmitter.

2.3 Conclusion

This test simulation shows that the presence of an OOK-UWB transmitter does not erroneously trigger an 802.15.4a victim receiver despite them both operating in the same band.

3 2.4 GHz PHY

This document details experiments performed to demonstrate coexistence between the proposed 2.4 GHz MSK PHY and 802.11.g. The 2.4 GHz MSK PHY is a narrowband PHY which can operate on multiple frequencies in the 2.4 GHz band so as to coexist with other services. The following frequencies are defined in the standard:

Table 1- 2.4 GHz MSK PHY channels

Channel Number	Center Frequency(MHz)	Data Rate (kb/s)
13	2422.50	250
14	2423.25	250
15	2442.00	250
16	2447.50	250
17	2462.00	250
18	2477.75	250

Additionally 13 further channels may be defined by the application on a case by case basis using any of 341 possible center frequencies. In this way devices can operate on frequencies which interleave with other services. The results in this document demonstrate the effectiveness of this coexistence strategy using a typical MSK channel selection (13 and 14) for use with WiFi channel 1.

3.1 Experimental Setup

A laptop was placed inside an anechoic chamber, together with a 2.4GHz MSK device operating at maximum output power on channels 13 and 14.

A WiFi access point operating using 802.11g on WiFi channel 1 was placed outside the chamber, and its antenna port routed via a cable to an omni-directional antenna inside the chamber.

The laptop inside the chamber was connected to the WiFi access point (AP), and an 833MB file was transferred via SCP from the laptop to a remote computer via the WiFi AP, and vice-versa. The average file transfer throughput (averaged over four file transactions) in both directions (‘put’ and ‘get’) was recorded.

The use of an anechoic chamber ensured that no interference was caused by other 2.4GHz radio systems in the environment.

3.2 Experimental Results

A baseline throughput analysis was performed with no interference to the WiFi link. All results are presented relative to the normalized transfer time in the no-interference case. The baseline measurements established the experimental error at ±5%.

Two sets of experiments were performed, both with a laptop to AP antenna spacing of 4m. In the first set of experiments, the 2.4 GHz MSK device was placed 0.4m from the AP antenna, and in the second the MSK device was collocated with the AP antenna.

Table 2- Experimental results for 0.4m device spacing

Channel: Frequency (MHz)	'Put' throughput (relative to ideal case)	'Get' throughput (relative to ideal case)
13: 2422.50	0.98 ±5%	0.95 ±5%
14: 2423.25	1.04 ±5%	1.01 ±5%

Table 3- Experimental results for collocated devices[1]

Channel: Frequency (MHz)	'Put' throughput (relative to ideal case)	'Get' throughput (relative to ideal case)
14: 2423.25	1.03 ±5%	1.01 ±5%

3.3 Conclusion

Table 2 and Table 3 clearly show that, within the experimental error, there is no discernable impact on the throughput of a WiFi data link in the presence on a 2.4 GHz MSK device operating in the default channels.

As specified, the 802.15.4f draft standard defines six channels for the MSK PHY which have been chosen to interleave in with 802.11 and 802.4 devices. Additionally, 13 further channels selected from 341 possible options can be written by the application in order to accommodate unforeseen 2.4 GHz legacy systems. This might be done during installation based on the results of an RF survey, or in real time, based on regular CCAs. The narrowband nature of the MSK waveform and the abundance of channel frequency selections in the 2.4 GHz band assure coexistence with both IEEE and non-IEEE in-band devices.

4 433 MHz PHY

No other 433 MHz PHYs exist in currently released IEEE 802 standards therefore there is no other interference for this coexistence assurance document to consider.

[1] Only the worst case 2.4 GHz MSK PHY channel from the 0.4m spacing was evaluated with the devices collocated.