IEEE P802.15
Wireless Personal Area Networks

Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)	
Title	TG4k Coexistence Document	
Date Submitted	May 2012	
Source	Qing Li [InterDigital, USA] Steve Jillings [Semtech, USA]	Voice: [1 610-878-5695] E-mail: [Qing.Li@InterDigital.com] Voice: [1 805-498-2111] E-mail: [SJillings@semtech.com]
Re:		
Abstract	Analysis on coexistence of 802.15.4k with other 802 systems within the same spectrum bands	
Purpose	To address the coexistence capability of 802.15.4k	
Notice	This document has been prepared to assist the IEEE P802.15. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.	
Release	The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15.	

Contributors of the CA document are sorted by alphabetical order of the last name:

1. Introduction

1.1. Bibliography <NOTE: need to check with the latest version of the standards.>

[B1] IEEE Std. 802.15.1™ – 2005, IEEE Standard for Information Technology – Telecommunications and Information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15.1: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Wireless Personal Area Networks (WPANs).

[B2] IEEE Std. 802.15.2™ – 2003, IEEE Recommended Practice for Information Technology – Telecommunications and Information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15.2: Coexistence of Wireless Personal Area Networks with Other Wireless Devices Operating in Unlicensed Frequency Bands.

[B3] IEEE Std. 802.15.3™ – 2003, IEEE Standard for Information Technology – Telecommunications and Information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15.3: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for High Rate Wireless Personal Area Networks (WPANs).

[B4] IEEE Std. 802.15.4™ – 2011, IEEE Standard for Information Technology – Telecommunications and Information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs).

[B5] IEEE Std. 802.15.4e /D8 – 2011, IEEE Standard for Information Technology – Telecommunications and Information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) Amendment to the MAC sub-layer.

[B6] IEEE Std. 802.15.4k /D1 – 2012, IEEE Draft Standard for Information Technology – Telecommunications and Information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs) – Amendment x: Physical Layer Specifications for Low Energy, Critical Infrastructure Monitoring Networks.

[B7] IEEE Std. 802.15.4g /D8 – 2011, IEEE Draft Standard for Information Technology – Telecommunications and Information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15.4: Wireless Medium

Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs) – Amendment 4: Physical Layer Specifications for Low Data Rate Wireless Smart Metering Utility Network.

[B8] IEEE Std. 802.15.4g TG4 Coexistence Assurance Document (IEEE 802.15-10-00668-05-004g)

[B9] IEEE Std. 802.11™ – 2007, IEEE Standard for Information Technology – Telecommunications and Information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

[B10] IEEE Std. 802.11n™, IEEE Standard for Information Technology - Telecommunications and Information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications - Amendment 5: Enhancements for Higher Throughput.

1.2. Acronyms

2. Overview

2.1. Overview of the frequency Bands of IEEE 802.15.4k

The allocated frequency bands for the 802.15.4k are given as below:

Table 1 Frequency Bands for 802.15.4k PHYs

Frequency Band (MHz)	802.15.4k PHY(s)	Channel Spacing / Bandwidth (MHz)
169 (Europe)	FSK	0.050
433 (Europe, US, AUS, NZ)	FSK	0.1 / 0.2
470–510 (China)	FSK DSSS	0.1 / 0.2 1.99??
779–787 (China)	FSK DSSS	0.1 / 0.2 1.99??
863–870 (Europe)	FSK DSSS	0.1 / 0.2 ~~0.25/0.3/0.6~~0.650/0.575
902–928 (US ISM)	FSK DSSS	0.1 / 0.2 1.99
915–928 (AUS)	FSK DSSS	0.1/0.2 1.99??

917–923.5 (South Korea)	FSK DSSS	0.2 1.99??
920–928 (Japan)	FSK DSSS	0.2 2.0??
921–928 (NZ)	FSK DSSS	0.1/0.2 1.99??
2400–2483.5 (Worldwide)	FSK DSSS	0.2 1.99

2.2. Overview of Coexistence Mechanism in 802.15.4 and 802.15.4k

The importance of coexistence mechanism in the LECIM is two-fold. The LECIM specified two alternative PHYs shall be able to coexist with each other if operating co-locatedly in the same frequency band. The LECIM also has to share multiple frequency bands and coexist with dissimilar 802 systems.

The coexistence mechanisms specified in 802.15.4 (6.9.x and 7.5.x [B4]), 802.15.4g (5.2b [B6]), and 802.15.4k (xxx [B5], are applicable to both homogeneous (among different LECIM PHYs) and heterogeneous (across other 802 systems) coexistence.

3. Dissimilar Systems Sharing the Same Frequency Bands with 802.15.4k

This clause presents an overview on other 802 systems which are specified to operate in the same frequency bands that are also specified for the 802.15.4k. The present co-locating dissimilar systems with reference to respective frequency bands is listed in Table 2.

Table 2 Dissimilar Systems Co-exist with 802.15.4k

Frequency Band (MHz)	802.15/11 System	802.15/11 System's PHY(s)	802.15.4k PHY(s)
169 (Europe)	802.15.4g	FSK	FSK
433 (Europe, US)	802.15.4f	FSK	FSK
	802.22	FSK	FSK
470–510 (China)	802.15.4g	MR-FSK, MR-O-QPSK, MR-OFDM	FSK DSSS: BPSK/O-QPSK
779–787 (China)	802.15.4c (keep?)	DSSS O-QPSK	FSK DSSS: BPSK/O-QPSK
	802.15.4g	MR-FSK	
		MR-O-QPSK	

		MR-OFDM	
863–870 (Europe)	802.15.4	DSSS BPSK	FSK DSSS: BPSK/O-QPSK
		DSSS O-QPSK	
		PSSS ASK	
	802.15.4c (keep?)	DSSS BPSK	
	802.15.4g	MR-FSK	
		MR-O-QPSK	
		MR-OFDM	
902–928 (US ISM)	802.15.4	DSSS BPSK	FSK DSSS: BPSK/O-QPSK
		DSSS O-QPSK	
		PSSS ASK	
	802.15.4g	MR-FSK	
		MR-O-QPSK	
		MR-OFDM	
	802.11ah	Currently in progress, specification not available <NOTE:check current status>	
917–923.5 (South Korea)	802.15.4g	MR-FSK MR-O-QPSK MR-OFDM	FSK DSSS: BPSK/O-QPSK
920–928 (Japan)	802.15.4g	MR-FSK MR-O-QPSK MR-OFDM	FSK DSSS: BPSK/O-QPSK
2400–2483.5 (Worldwide)	802.11b	DSSS CCK	FSK DSSS: BPSK/O-QPSK
	802.11g	OFDM BPSK	
	802.11n	OFDM QPSK	
	802.15.1	FHSS GFSK	
	802.15.3	SC D-QPSK	
	802.15.4	DSSS O-QPSK	
	802.15.4g	MR-FSK	
		MR-O-QPSK	
		MR-OFDM	

	802.15.4f		FSK DSSS: BPSK/O-QPSK
	802.16		

4. Coexistence Scenario and Analysis

4.1. PHY Modes in the 802.15.4k System

<NOTE: need PHY parameter values here.>

In this sub-clause, each frequency band is discussed referring to a table listing all the coexisting systems from other standard specifications. The contents of the tables are formatted as below:

(a) Standard specification: the name of the 802 system with which 802.15.4k system is coexisting

(b) PHY specification: the PHY design of the above 802 system specification

(c) Receiver bandwidth: the receiver bandwidth of the above 802 system specification

(d) Transmit power: the transmit power of the above 802 system specification

(e) Receiver sensitivity: the receiver sensitivity of the above 802 system specification.

(f) Involved 802.15.4k system: the particular PHY in 802.15.4k that is coexisting with the above 802 system specification

Note: The data rate modes, including receiver bandwidth, transmit power and receiver sensitivity listed in the columns of the following tables, are only a part of the complete list from the respective standard specifications. These data rate modes are chosen for the purpose of coexistence analysis in this coexistence document.

4.1.1. Parameters for 802.15.4k PHY Modes

Table 3 shows the PHY modes chosen from each of the FSK, and DSSS PHYs and their corresponding parameters. The path loss is typical -120dB.

Table 3 Main Parameters of 802.15.4k PHY Modes

System	PHY Spec.	Receiver Bandwidth (MHz)	Transmit Power / Power Spectral Density	Receiver Sensitivity (dBm)	PHY Mode

802.15.4k	FSK	~~0.2/0.1~~??	up to +30 dBm	Down to -120	25kbps
	DSSS	1MHz	??dBm/KHz	Down to -120	~~100 /1000kcps?~~ O-QPSK

4.1.2. BER/FER Calculations for 802.15.4k PHY modes

The BER/FER calculations are detailed in 4.1.2[B8].

Figure 1 and Figure 2 show the BERs of FSK and DSSS (O-QPSK) with different spreading factors, simulated with uncoded AWGN channel.

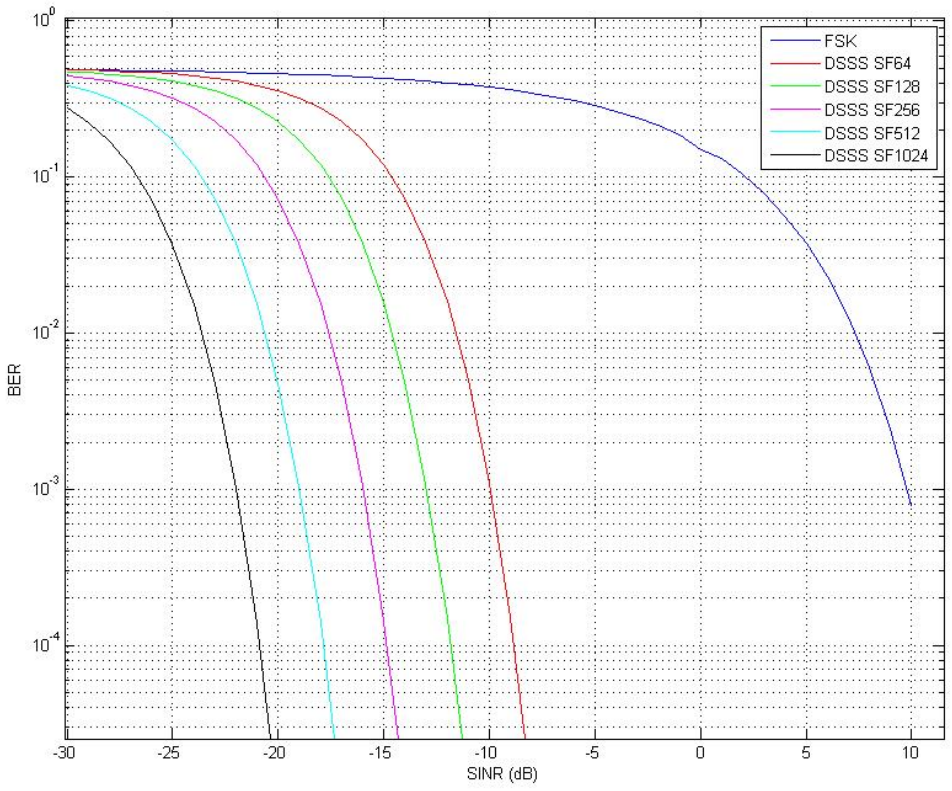

Figure 1. BER of 802.15.4k FSK and DSSS (O-QPSK)

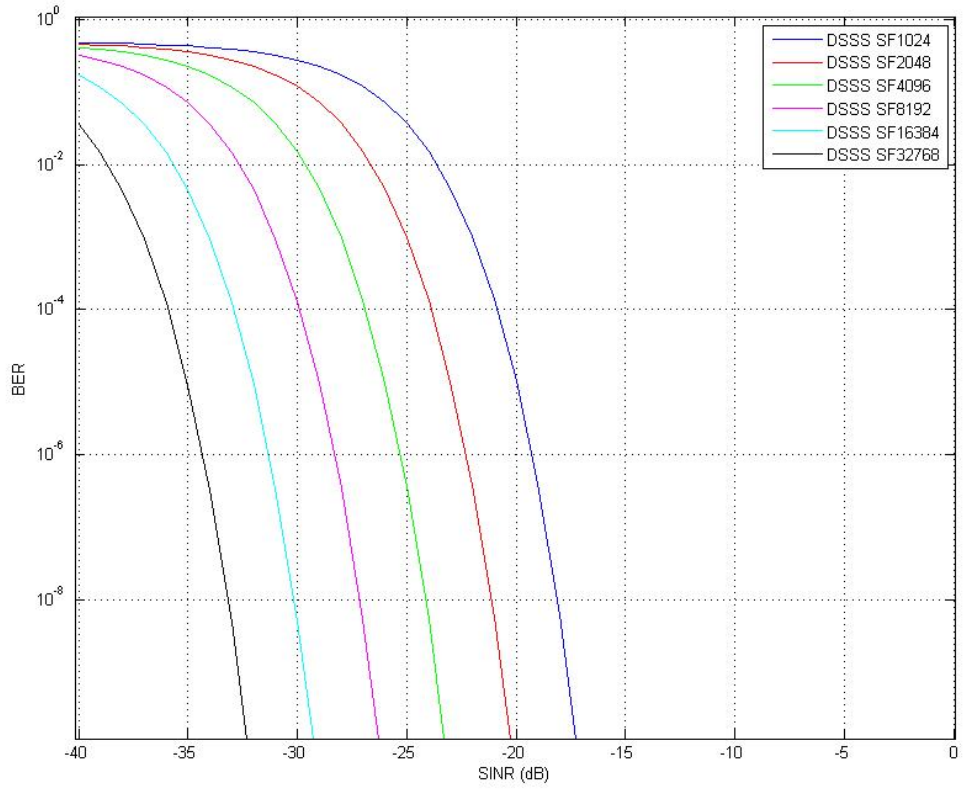

Figure 2. BER of 802.4k DSSS (O-QPSK)

Figure 3 shows the BER comparison between 802.15.4k and other 802.11x and 802.15.x systems.

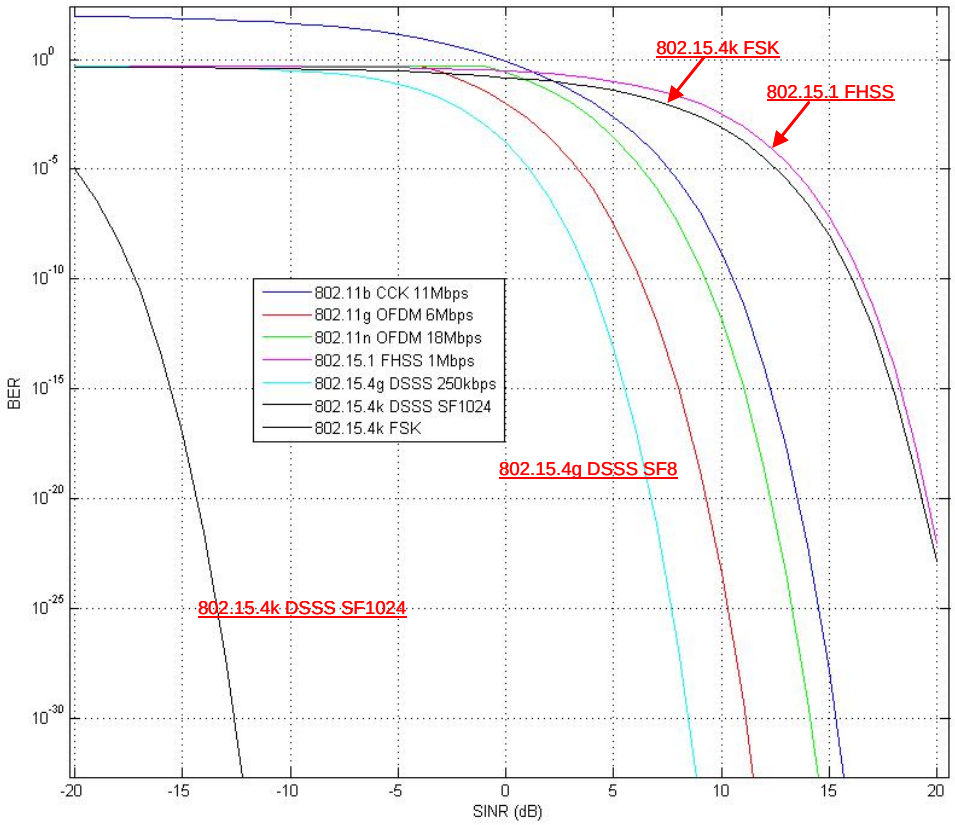

Figure 3. BERs of 802.11b, 802.11g, 802.15.1, 802.15.4g, 802.15.4k

4.2. Interference Modeling

The interference Modeling is detailed in 4.2[B8].

Figure 4 shows how the interferer 802.11b/802.11g affects the victim 802.15.4k FSK's performance within certain distance at difference Tx power levels.

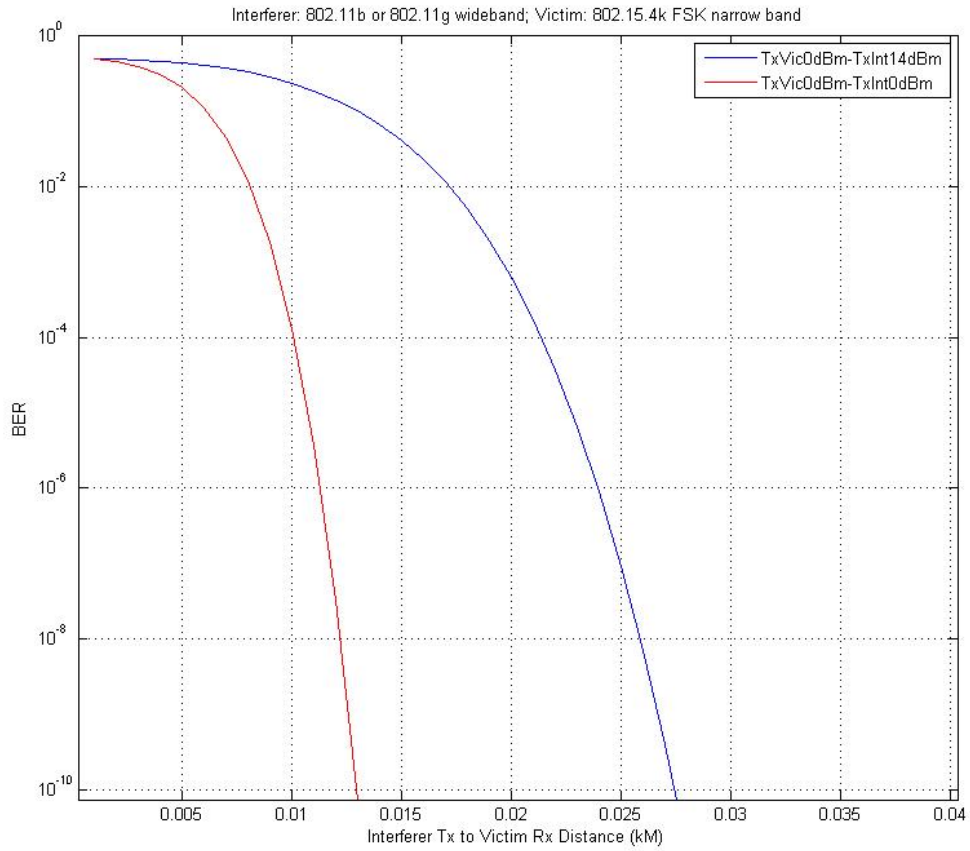

Figure 4. 802.15.4k FSK as Victim and 802.11b/802.11g as Interferer

4.3. Coexistence Performance

5. Detailed Coexistence Analysis and Interference Avoidance/Mitigation Techniques

6. Discussions and Conclusion

Annex A