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RF Receiver Specification of Low-Rate Sensor Network for Coexistence with Various Wireless Devices in 2.4GHz ISM-band

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Abstract

This paper describes the analysis for implementation of a radio frequency (RF) receiver for low-rate wireless personal area networks (LR-WPANs), namely IEEE 802.15.4, for coexistence with various wireless devices in 2.4GHz ISM-band. With IEEE 802.15.4 standard specification, it provides analysis of receiver performance requirements containing the system noise figure (NF), system third-order intercept point (IIP3), local oscillator phase noise and selectivity. With some assumption, it illustrates relation-ship between minimum detectable signal (MDS) and various situations considering for the effects of noise generated from other wireless devices according to communication distance. Here, we can infer the necessity of much tighter specification requirements than standard's that for various communication field environments.

I. Introduction

Recently, the desire for wireless connectivity has led an exponential growth in wireless communication. In particular, wireless sensor networks are potential wireless network application for the following future ubiquitous computing system.

Wireless sensor networks are an emerging research area with potential applications in environmental monitoring, surveillance, military, health and security. Such a network consists of a group of nodes, called sensor nodes, each with one or more sensors, an embedded processor, and a low power radio. Typically, these nodes are linked by a wireless medium to perform distributed sensing tasks [1].

In recent years, the concept of a standardized low rate wireless personnel area network (LR-WPANs) has appeared. Fuelled by the need to enable inexpensive wireless sensor network applications, in December 2000 Task Group 4, under the IEEE 802 Working Group 15, were formed to begin the development of a LR-WPAN standard IEEE 802.15.4. The goal of Task Group 4 is to provide a standard that has the characteristics of ultra-low complexity, low-cost and extremely low power for wireless connectivity [2-3].

The system performance of major specification items required at the standard of IEEE 802.15.4 physical layer is much degraded because of various interferers generated in wireless devices in ISM-band. So, a specification analysis in this frequency band deliberated on interferers' environment according to distance may be required for the solution of coexistence problems.

Section II of this paper presents the analysis and simulation of RF receiver requirements considering for coexistence problems between IEEE 802.15.4 and IEEE 802.11b/802.15.1. Conclusions are presented in Section III.

II. The analysis of RF receiver requirements considering for coexistence problems

A. Derivations of RF receiver specification from Standard

The data of LR-WLAN is coded onto the carrier with direct sequence spread spectrum (DSSS), an inherently robust wireless communication technique of improving multipath performance and receiver sensitivity through signal processing gain (PG). This PG decrease minimum SNR demanded from a baseband demodulator for the achievement of desired BER. The SNR_{min} can be described by (1)

$$SNR_{min} = E_b/N_0 - PG_{despreading} + BB\_margin \qquad (1)$$

The $PG_{despreading}$ can be defined as the ratio of chip rate to data rate and implies spectrum-despreading gain of a baseband demodulator. The E_b/N_0 can be defined as the ratio of traffic channel bit energy to noise density. With considering these effects and baseband implementation loss, a baseband demodulator margin (BB_margin) is defined. In this paper, the *BB_margin* will be assessed by 2dB. The noise figure containing a *BB_margin* is shown (2)

$$\begin{aligned} NF_{required} &= SNR_{in} - SNR_{out} \\ &= P_{signal} - KTB - (E_b/N_0 - PG + BB\_margin) \end{aligned} \qquad (2)$$

The P_{signal} represents the wanted-signal power injected into antenna, and KTB is thermal noise power considering a bandwidth. For example, when a PG is used along with a data rate of 250kbps, the $NF_{required}$ becomes 23dB with a P_{signal} of $-$85dBm, KTB of $-$111dbm, Eb/N0 of 10dB, and BB_margin of 2dB.

Generally, the system-IIP_3 can be derived from inter-modulation distortion (IMD) test condition suggested on any standard specification. This performance parameter indicates an extent of the distortion of an RF/analog-path against strong interferers generated by other user. The IEEE Standard for Part 15.4 [4] doesn't suggest interferer's condition, so the assumption of contribution of receiver noise power for LR-WPAN must be fulfilled. The major noise components inducing the SNR-degradation of a receiver are consisted of normal-noise part and distortion-noise part generated from other systems. The $P_{accept.noise}$ required from a receiver is shown (3)

$$\begin{aligned} P_{accept.noise} &= P_{normal.noise} + P_{distortion.noise} \\ &= P_{signal} - (E_b/N_0 - PG + BB\_margin) \end{aligned} \qquad (3)$$

The distribution of the $P_{distortion.noise}$ is: $P_{CW\text{-}blocking}$, 30 percent of power; $P_{MOD\text{-}blocking}$, 30 percent of power; P_{IMD}, 30 percent of power; and P_{OSC}, 10 percent of power as shown in the Ref. [5].

With the P_{signal} of -82dBm and the SNR_{min} of +1dB, the $P_{Accept.noise}$ will be accepted by -83dBm, the $P_{normal\ noise}$ by -86dBm, and the $P_{distortion\text{-}noise}$ by -86dBm. In this paper, since the P_{IMD} is assumed to 30 percent, the P_{IMD} can be accepted by -91dBm, and the P_{OSC} to 10 percent, the P_{OSC} by -96dBm. The IIP_3 required from a receiver is shown (4)

$$IIP_{3,req.} = P_{signal} + 0.5(P_{signal} - P_{IMD}) \qquad (4)$$