Low Power Radio Receiver Specifications of Ubiquitous System 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 require-ments 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.

Index terms – ubiquitous system, coexistence, ISM-band

1. Introduction

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].

2. THE ANALYSIS OF RF RECEIVER REQUIREMENTS

In PHY-layer standard specification of IEEE 802.15.4, the channel selection methods are introduced with channel clear assessment (CCA) and energy detection / link quality indication (ED / LQI). This methods are that don't communicate and wait or move into other channels when exist strong interferers. With these situations, the more appearance of application devices using a 2.4GHz ISM-band will lead the less probability of call-success. So, in this paper, we will extract the proper specification of RF/analog-path of PHY-layer for the probability of call-success against coexistence problems.

Unfortunately, the blocker profiles don't be minutely specified in unlicensed frequency band of 2.4GHz with various wireless communications. Really, the possible strong blockers will considerably degrade performances of RF-receiver system.

The communication block-diagram of LR-WPAN against interferers generated from various communication systems in 2.4GHz ISM-band is shown in Fig.1. In this Fig.1, the receiver of FFD1 does only want to communicate with the transmitter of RFD2. But it does simultaneously receive transmitters' signals from a UE1 and UE4 of NT2-network (IEEE 802.11b) and NT3-network (IEEE 802.15.1), respectively. In this case, the FFD1 receives unwanted blockers' signals: Pb1 and Pb2 according to distance d1 and d2, respectively. In example, with worst-case field environment for very short distance, i.e. one meter, and transmission of allowable maximum power, the sensitivity of receiver is rapidly degraded because of inter-modulation distortion products and reciprocal mixing products generated by strong interferers.

The SNR-degradation of a receiver containing inter-modulation distortion (IMD) and reciprocal mixing effects by interferers is shown in Fig.2. To reduce the SNR-degradation by strong interferers, there are two solutions. One method is to decrease noise components, which get in a wanted in-channel, by the reduction of interferers' signal power. By using the transmitter's power control algorithm of other communication standard, this method is the most efficient. But, this is not a good solution because of problems beyond our standard category. The other method is to increase requirements of the receiver performance parameters. In this paper, we will calculate the major parameters of receiver performance: system-IIP3, phase-noise, and selectivity, with a consideration of worst-case interferers environment. The receiver sensitivity according to system-IIP3 and strength of blockers is shown (1)

$$Sensitivity = NF + 10\log(KTB + P_{IMD}) + SNR_{de\,mod}$$
$$[\,where,\ P_{IMD} = 3\sum(P_{max.blocker}) - 2IIP_3,\ SNR_{de\,mod} = SNR_{min},\ P_{max.blocker} \cong P_{max} - 20\log(4\pi \cdot distance \cdot f/c)\,] \quad (1)$$

The receiver sensitivity according to phase noise of local oscillator and strength of blockers is shown (2)

$$Sensitivity = NF + 10\log(KTB + P_{OSC}) + SNR_{de\,mod}$$
$$[where,\ P_{OSC} = \sum P_{max.bloc\,ker} + Phase\ noise + 10\log(BW),\ P_{max.bloc\,ker} \cong P_{max} - 20\log(4\pi \cdot distance \cdot f/c)] \quad (2)$$

The selectivity for in/out of-band channel selection must be determined for the specification of RF/IF/baseband filters. The selectivity of a receiver against blockers generated from other communication system is shown (3). In this equation, we can see that the selectivity of receiver is decided by a signal power of blockers [4-5].

$$Selectivity = P_{max.bloc\,ker} - (MDS - SNR_{de\,mod})$$
$$(SNR_{de\,mod} = E_b/N_0 - PG_{despreading} + BB\_margin) \quad (3)$$

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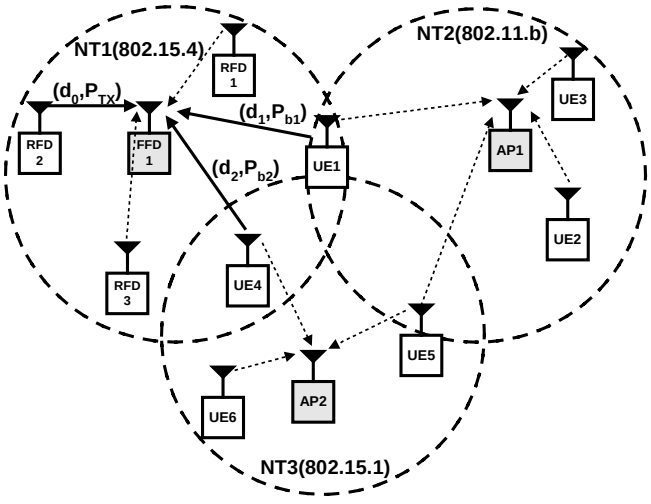

Fig.1 Communication block-diagram of LR-WPAN against interferers generated from various communication systems in 2.4GHz ISM-band.

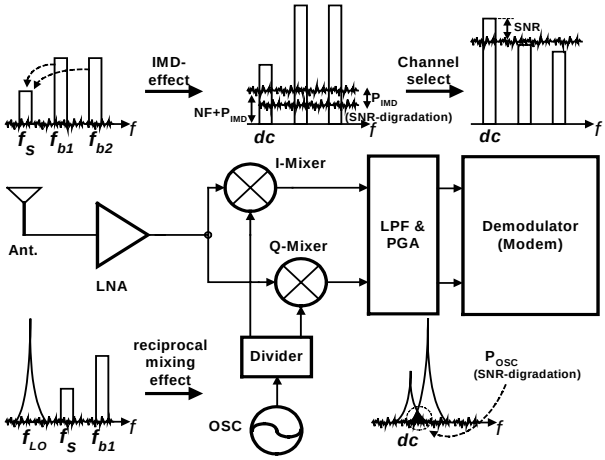

Fig.2 SNR-degradation of a receiver containing IMD and reciprocal mixing effects by interferers.

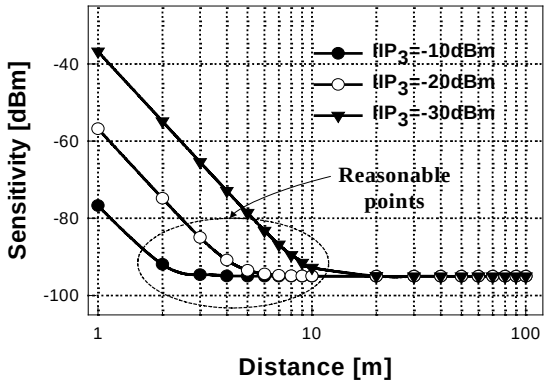

Fig.3 Sensitivity vs. distance according to various system-IIP_3

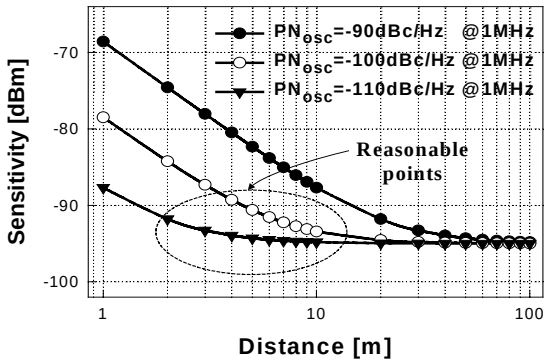

Fig.4 Sensitivity vs. distance according to various LO PN

TABLE I
RF-SYSTEM PARAMETER FOR LR-WPAN

Requirements	Standard Spec. (IEEE802.15.4)	Reasonable Spec. (this paper)
NF / Sensitivity [dB/dBm]	25 / -85	14 / -95
IIP3 [dBm]	-32.4	-10.8
Phase noise (LO) [dBc/Hz, @1MHz]	87	-110
Selectivity[@5MHz]	1	52
Selectivity[@10MHz]	31	58