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Performance Analysis of Bluetooth Zigbee and Wi-Fi Protocols in 2.4 GHz Multi-standard Zero-IF Receiver

***Abstract**. This paper presents a system-level modeling of a multi-standard receiver, which satisfies Bluetooth, Zigbee and Wi-Fi protocols. An analysis of different wireless receivers suited for multi-standard purposes is performed. The multi-standard Zero-IF receiver was modelled and simulated in MATLAB/SIMULINK environment. The simulation result exhibits better performance of multi-standard wireless receiver for these three protocols. The signal spectrum is verified by simulation model through the receiver for each standard and concluded that Zero-IF is the adequate topology for multi-standard receivers.*

***Streszczenie.** Przedstawiono odbiornik pracujący w wielu standardach – ZigBee, Bluetoot i WiFi. Modelowano taki odbiornik i symulowano. Stwierdzono że odbiornik typu zero IF ma najlepsza topologię dla pracy wielostandardowej. (**Analiza właściwości odbiornika typu zero IF pracującego przy częstotliwości 2.4 GHz w różnych standardach**)*

Keywords: Multi-standard, Zero-IF receiver, RF front-end.
Słowa kluczowe: odbiornik, Zigbee, WiFi, Bluetoot.

Introduction

With the significant growth of wireless communication, challenges are continuously being posed on enabling technologies to handle requirements that are more demanding. Communication systems organize to simplify communication between one or more devices, according to a pre-determined signaling process. The signaling processes often conform to a standard, whether the standard is proprietary or determined by an industry consortium. For example, wireless communication systems involve communication between a base station and a mobile unit through radio frequency (RF) transmission. The baseband section in a receiver receives baseband analog signals and performs subsequent processing before generating digital output. Analog signals coming into the baseband receiver usually undergo a filtering operation to attenuate unwanted frequencies or noise, followed by an analog-to-digital conversion (ADC) [1]. Recently wireless communication system has a great evolution in cellular phones, wireless local area networks or wireless sensor networks terminal been widely feast for comfortable living.

Last few years wireless communication system being developed for achieving higher data rates. Technology development requires new architecture of transceiver capable of adjusting more standards through the generation of cellular system evaluation. Only a few years ago, mobile technology has simply voice transmission functionality. It was first generation (1G) mobile phone with analog modulation scheme. Increasing the operation and functionality with digital modulation pattern predominantly used in GSM standard in second generation (2G) mobile terminals. Last few years third generation (3G) mobile technologies become a revelatory change in multimedia application digital video transmission, Short-range connectivity using Bluetooth, Wi-Fi as well broadband internet connectivity with data rates up to 2 mbps with WCDMA/UMTS standards. High-speed wireless communication technology like 4G involves a straightforward linear extension of the capabilities of 3G. Data rates around 100 Mbps intend to catch up by near 2015 [2]. Table I illustrates a variety of potential communication standards specification. However, next generation wireless communication system are expecting in convergence in a single chip platform [3-4]. In this context Bluetooth (IEEE802.15.1), Zigbee (IEEE802.15.4) and Wi-Fi (IEEE802.11b) standards will give a simulation result that allows validation of multi-standard receiver.

Receiver architecture for multi standard operation

Nowadays, the availability of different wireless standards enforced many areas of communication applications. As shown in Table I associated with continuous emergence of latest wireless technologies suggests the use of a reconfigurable multi standard baseband receiver.

Table 1. Summary of wireless communication standards [2]

Standards	Frequency band T_x/R_x (MHz)	Channel spacing (MHz)
GSM	890-915/935-960	0.2
EDGE	1930-1990	0.2
GPRS	880-915/925-960	0.2
WCDMA(UMTS)	1920-1980/2110-2170	5
HSDPA	1920-1980/2110-2170	5
BLUETOOTH	2400-2483.5	1
ZIGBEE	2402-2480	5
ULTRA WIDE BAND	3100-10600	500
WI-FI IEEE 802.11a	5000	20
IEEE 802.11b	2400-2483.5	16.25-22
IEEE 802.11g	2400-2483.5	22
IEEE 802.11n	2400, 5000	22
GPS	1575.42,1227.60	24
WIMAX IEEE 802.16	2000-11000	1.25-28

The use of such reconfigurable design simply can be achieved through the use of software defined radio (SDR) [5]. This term refers to a radio receiver, programmable by software system, that defines the radio parameters and that will upgrade to face the necessities of recent forthcoming protocols. The goal of SDR is to perform the signal digitalization as near as possible to the antenna, hence permitting the use of digital programmable hardware, such as digital signal processors (DSPs), field programmable gate array (FPGA) [5]. An ideal SDR would consist in an analog to digital conversion right after the antenna, an ADC with bandwidth about 6GHz and up to 14 bits of resolution. This part deals with the receiver architecture with emphasizes high integration and multi-standard baseband capabilities. To achieve high integration utilizing multi-standard receiver architecture that performs baseband channel filtering on chip. However, according to state-of-the-art of analog-to-digital converters this possibility is still unfeasible.

Consequently the digitalization of the signal has to be performed in baseband frequency, since that result is more reasonable requirement for the ADC. Consequently, an analysis on the architecture of these receivers is performed, specifically their multi-standard and integration capabilities, described in Table II. The most conventional configuration that used in RF receiver is the superheterodyne receiver, based on its performance in terms of sensitivity and selectivity, achieved largely due to its separate filters. Therefore, the use of a radio frequency (RF), image rejection (IR) and intermediate frequency (IF) filters turns this design unsuitable for integration and consequently for multi-standard functions that would need even additional off-chip filters.

Table 2. Receiver architecture characteristics

Architecture	Discrete filters	Integrati on Level	Multi-standard ability	Power
Superheterody ne	RF, IF,IR	Low	Low	High
Zero-IF	RF	High	High	Low
Low-IF	RF	High	Medium	Medium
Wide-Band IF	RF	High	High	Medium

Fig. 1 illustrates several architectures of receivers. The direct conversion receiver or Zero-IF receiver uses solely a separate RF filter; suppressing the others, off-chip filters [6].

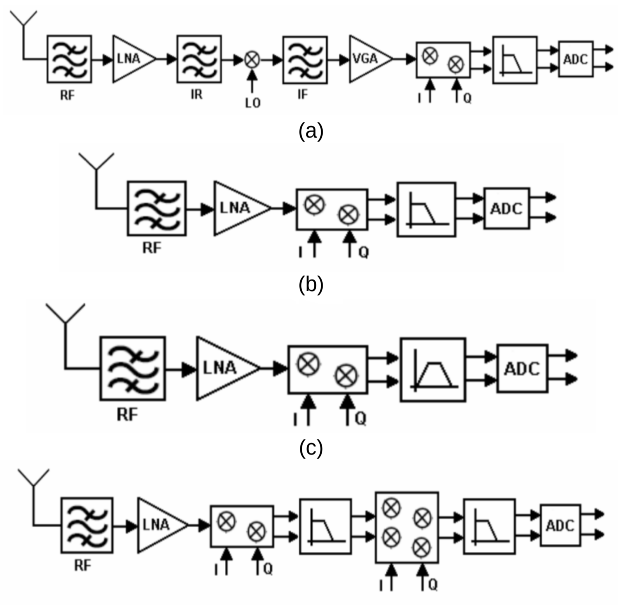


Fig.1. Architecture of (a) Superheterodyne (b) Zero-IF (c) Low-IF and (d) Wide-Band IF double conversion receiver.

This is performed using a single mixer stage translating the signal directly to baseband. Thus, integration capability is improved like as multi-standard, since channel selection is performed in baseband by a low pass filter that could be programmable to support diverse standards. In a Low-IF topology the RF signal is translated to intermediate frequency closer to the baseband frequency [7]. Besides maintaining the same level of integration as the Zero-IF, multi-standard ability is affected, since the more severe constraints are posed on band pass filter and ADC for wide channel bandwidth, leading to an increase in consumption. Wideband IF double conversion receiver performs the carrier translation to baseband in a similar manner that superheterodyne solution [8].

However, this topology allows a higher level of integration since it uses only the discrete front- end RF filter. This topology requires six high linear mixers that increases the overall power dissipation of the receiver. Multi-standard configurability is still possible since channel filtering perform in baseband like in zero-IF approach. A zero-IF architecture is therefore the solution that presents more advantages regarding a multi-standard implementation. Such architecture proposes on reinforcing the use of this topology for multi-standard wireless applications.

Reconfigurable multi-standard analog baseband front-end

The project outcome is to implement a reconfigsurable solution for analog baseband signal processing. It must be able to cope with the standards previously defined. Therefore, the most efficient solution, able to cope with the standards, is the implementation of reconfigurable blocks, digitally controlled. The control of the analog blocks performs through a digital processor. This solution adopts in, where the analog baseband blocks are generally interleaved voltage gain amplifiers (VGAs) and low pass filters (LPFs) [9-10]. For instance, two VGA blocks and a LPF composed the multi-standard analog baseband chain proposed in, where the first VGA switches according to the selected standard. Fig. 2 shows a generalized version of the analog baseband front-end. Low pass filter is used to select the desired channel and therefore to reject the adjacent channels. Bandwidth specifications vary according to selected standards and thus this parameter must be reconfigurable. The following analog block, the VGA that uses to increase the signal's amplitude has an adjusted gain also digitally controlled.

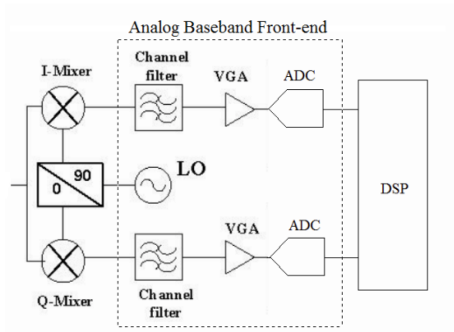


Fig.2. Analog baseband front-end circuit

Results and discussion

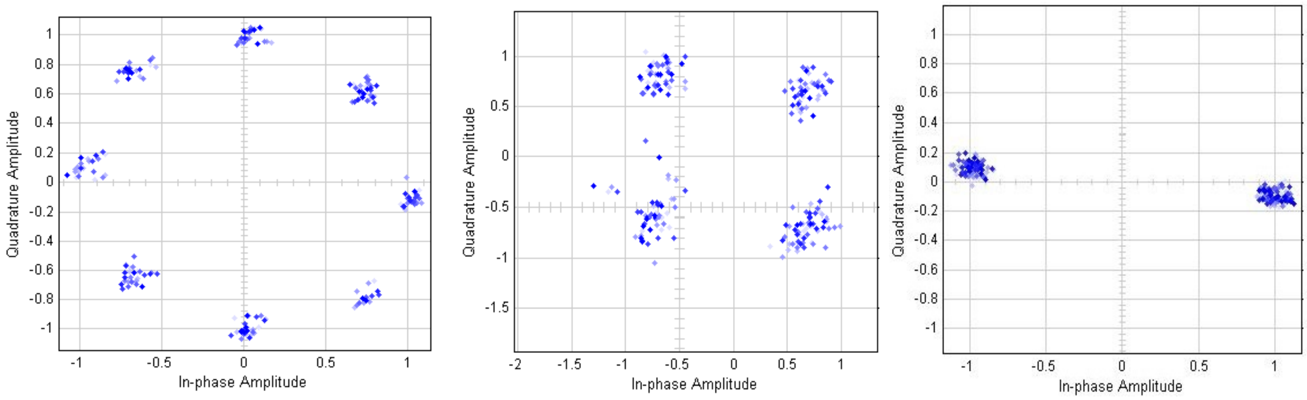
The Zero-IF receiver was implemented using MATLAB/SIMULINK software to perform a behavioral simulation to get the well set of specifications and therefore the requisites for analog block. This receiver architecture commonly uses in multi standard applications. Using Simulink block set several non-idealities properties of receiver be simulated like clock jitter, dc gain, bandwidth, thermal noise, slew rate [11]. However, for this simulation the model was designed for three popular communication standards namely Zigbee, Bluetooth and WLAN (802.11b) operate at 2.4 GHz ISM band. Equivalent baseband simulation was employed by well-known RF toolbox in Simulink. The input signal was changed to digitally modulated signal. RF modulated carrier directly demodulates to baseband frequencies in the Zero-IF receiver, while it detects the signal directly and the information recovered. The Bluetooth system operates in the 2.4 GHz ISM band in 1 MHz channel bandwidth. For this simulation Bluetooth 2.0 specification was considered with 8 differential phase-shift keying (DPSK) modulation format. For Zigbee specification offset quadrature phase-shift keying (OQPSK) that transmits two bits per symbol with a channel spacing of 5 MHz. In addition, IEEE802.11b channel bandwidth of 22 MHz is identified quadrature phase-shift keying **(**QPSK) modulation. For Bluetooth channels of 1MHz, with the desired RF channel power at receiver input was set to -27 dBm. The output power in the receiver was 15.9dBm. Similarly, for Zigbee specification the input power at receiver was -43.35 dBm results an output power of 1.548 dBm. Wi-Fi 802.11b had an input power at the receiver was -25.06 dBm and the receiver output power is 20.04 dBm.

The Zero-IF RF receiver has a frequency conversion stage and two gain stages. Each of the blocks captures RF impairments relevant to this design. Table III sums up the several parameters optimizing the simulated blocks of the receiver, which is good agreement with the specifications. The nonlinear blocks were specified by noise figure. The LNA non-linearity was specified by IP3 is 10 dBm, and the nonlinearity in the IF amplifiers are specified by both IP2 and IP3. The mixer nonlinearity is specified by IP2. A single LO and a phase shift block provide the cosine and sine terms to In-Phase and Quadrature-Phase, respectively.

In Fig. 3 the constellation diagram represents the value actually received. With this constellation arrangement, it is less likely that distortion of the signal will result in a less transmission error. In this simulation the multi-standard receiver, accomplish the performance requirements of three standards: Bluetooth, Zigbee and Wi-Fi 802.11b. Fig. 4 illustrates the frequency spectrum of the signal generated for the standards mentioned.

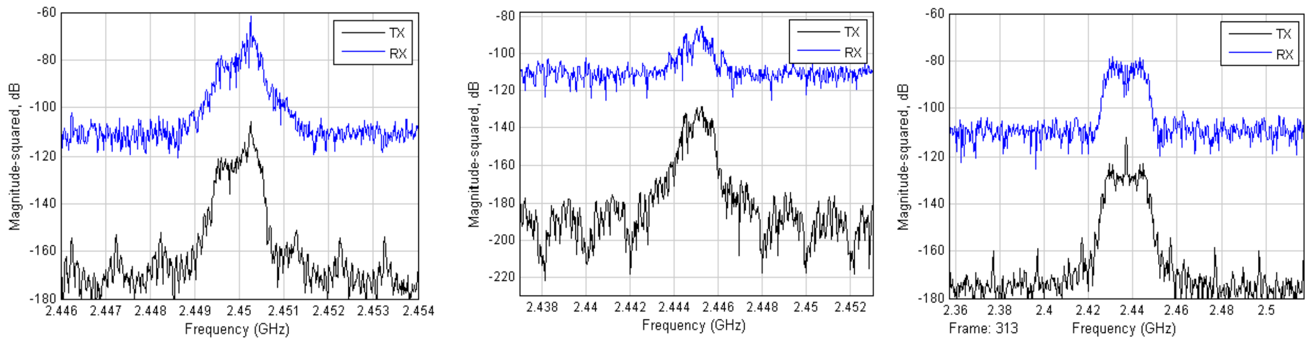
Table 3. Parameters of Zero-IF receiver block

Block	Gain(dB)	IP2(dBm)	IP3(dBm)	Noise Figure(dB)
BPF	-3	0	0	0
LNA	18	Inf	10	3
Mixer	10	7	Inf	10
LPF	0	0	0	20
VGA	20	25	0	15



(a) (b) (c)

Fig.3. Constellation diagrams of (a) Bluetooth (b) Zigbee and (c) WLAN (802.11b)



(a) (b) (c)

Fig.4. Frequency spectrums of (a) Bluetooth (b) Zigbee and (c) WLAN (802.11b)

Conclusion

In this paper the design issue relating multi-standard baseband RF receiver front-end capable of associating a wide range of standards are simulated. The proposed implementation of multi-standard specifications reduces the hardware and computational effort while dealing with multiple standards. Potential standards for the next generation of wireless systems are selected and analysis on existent wireless receiver is performed. The signal spectrum is verified by simulation model through the receiver for each standard. Hence, the research concluded that Zero-IF receiver is the adequate network topology for multi-standards.

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