XIX IMEKO World Congress
Fundamental and Applied Metrology
September 6–11, 2009, Lisbon, Portugal

BASIC CHARACTERISTICS OF ZIGBEE AND SIMPLICITI MODULES TO USE IN MEASUREMENT SYSTEMS

L. Skrzypczak[1)], *D. Grimaldi*[2)], *R. Rak*[3)]

[1)] Department of Electronics, Computer and System Sciences, University of Calabria, Rende – CS, Italy, slk@data.pl
[2)] Department of Electronics, Computer and System Sciences, University of Calabria, Rende – CS, Italy, grimaldi@deis.unical.it
[3)] Institute of the Theory of Electrical Engineering, Information and Measurement Systems, Electrical Engineering Faculty, Warsaw University of Technology, Warsaw, Poland, rrak@okno.pw.edu.pl

Abstract – The main goal of this paper is to experimental examine some of the properties of two different wireless communication modules, ZigBee and SimpliciTI, which are employing two different transmission standards. This paper is a part of wider research aimed to examine and evaluate the different wireless transmission standards to use in distributed measurement systems.

Keywords : ZigBee; SimpliciTI; Distributed Measurement Systems

1. INTRODUCTION

The use of new wireless transmission standards in measurement systems is described by some requirements of industrial applications such those presented in [1] which are (i) integration into existing measurement systems, (ii) coordination of the advanced and traditional monitoring structures, and (iii) design of innovative measurement systems. This paper is an attempt to examine two different wireless transmission standards named ZigBee and SimpliciTI in order to meet those requirements.

SimpliciTI is Texas Instruments proprietary network protocol [2] for low-power radio frequency wireless communication. Main properties of SimpliciTI are [2]:
Low cost which means that SimpliciTI network protocol can be implemented in systems with small memory capacity. According to [2] as low as 8 kB of ROM and 1 kB of RAM is needed to implement SimpliciTI.
Flexibility which is achieved by multiple network topologies namely star and peer-to-per (p2p) [2].
The basic Application Programmers Interface (API) makes SimpliciTI *simple* to be used.
Wide selection of transceiver chips made to work with SimpliciTI operating in sub-1GHz frequencies and in 2.4 GHz band [3] makes this protocol versatile.
Finally very low current consumption in sleep state [2] makes SimpliciTI very well suited for battery powered applications.

ZigBee is wireless communication standard managed by the ZigBee Alliance and is based on the standard IEEE 802.15.4 physical and Media Access Control (MAC) layers [4].
Main properties of ZigBee are [5]:
Flexible network topology. Simple star topology as well as more complicated mesh topology are possible. This makes ZigBee *easy to install* because when using mesh topology network range is not limited to maximum range of the single device.
ZigBee *scalability* is also achieved by static and dynamic star and mesh topology allowing mode than 65000 nodes with low latency to be connected to the same network [5].
Low power is achieved by allowing long periods of non-communication without the need for re-synchronisation [5].
Because ZigBee Alliance is not limited to one company many manufacturers produce ZigBee modules and equipment such antennas. This makes competition on the market which means *low prices*.

The cause of choosing these two transmission standards is that they were designed for monitoring and control applications [5], [2]. Such applications are closely related to measurement systems field.

This paper is a presentation of characteristics of both standards in the area of measurement systems.

The following sections describe the measured parameters, the methodology of making presented measurements, used wireless modules and environmental conditions under which all presented measurements were made.

At the end the conclusion is made on the basis of experimental results.

2. RESEARCH OVERVIEW

Characteristics of tested modules is based on Quality of Service (QoS) parameters. These parameters derived from [6] are listed in Table 1.

Table 1. QoS parameters.

Category	Parameters
Timeliness	Delay Response time Jitter
Bandwidth	System-level data rate Application-level data rate Transaction time
Reliability	Mean time to failure (MTTF) Mean time to repair (MTTR) Mean time between failures (MTBF) Percentage of time available Packet loss rate Bit error rate

In this research only three parameters have been selected namely *packet loss rate, delay,* and *jitter*. This is because the goal of this research is to evaluate the basic characteristics of two wireless data transmission modules of two different standards. The QoS parameters does not include power consumption of the module and signal strength measured as the power of signal received by the receiver. Both tested modules are designed to by battery powered so the power consumption is very important parameter.

3. MEASURED PARAMETERS

As concerning the quantization of the *packet loss rate*, the following parameter is defined: *PER (Packet Error Rate) or Packet Loss Rate*. It describes what fraction of all sent packets were corrupted or lost and can be calculated as:

$$PER = \frac{P_{corr}}{P_{total}} \cdot 100\% \qquad (1)$$

where P_{corr} is number of corrupted or lost packets and P_{total} is number of all packet sent.

By measuring this parameter it is easy to determine the characteristics of examined wireless module in different environmental conditions such as distance between devices or interference with other devices of the same or different standard. The increase of PER according to [6] may be caused by collision or weak signal. In this research collision is not the case because only receiver and transmitter are in range. This means that only weak signal is the cause of PER increase. However the increase of PER because of collision will be investigated in further research. As an addition to PER, power of signal received by the receiver is measured. By correlating increase of PER with signal strength it is easier to determine the cause of PER increase as the result of weak signal or interference from other devices.

As concerning the quantization of the *delay*, the following parameter is defined: *DOF (Delay of Frame)*. It describes the delay between writing data frame to the transmitter output buffer and reading it from receiver input buffer. This parameter is especially important in high speed systems where the low response time is needed [6].

As concerning the quantization of the Jitter, it is defined in [6] as delay variability. Therefore, it can be evaluated by measuring differences between each measurement of DOF.

Another parameter that must be added to the previous ones is the value of current taken from the power source in different states of the wireless module (Sleep/Idle, Receive, transmission).

4. MODULES USED

4.1. SimpliciTI

The SimpliciTI module used in this research is EZ430-RF2500 from Texas Instruments [7]. This module was chosen because of its simplicity, small dimensions and low price. It consists of the following devices:

- 2 boards with MSP430F2274 microcontroller and CC2500 transceiver with chip antenna, two leds and pushbutton,
- USB interface for programming and communication with PC,
- Battery holder with connector to transceiver board

This module is thought as a development tool for wireless sensor networks and can be used as a standalone device or incorporated into an existing project [7].

There is demonstration application available for this module but for this research it was needed to create custom application to be able to measure all given parameters.

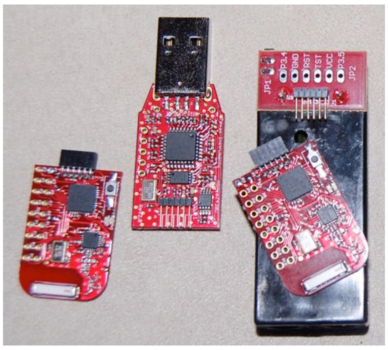

Fig. 1. EZ430-RF2500 – SimpliciTI evaluation module.

4.2. ZigBee

The ZigBee module used in this research is RZ RAVEN from Atmel [8]. This module was chosen because it contains all hardware and software needed to complete this research without the need to create custom software. The low price was advantage as well. There are following devices in the kit:

- LCD module (AVRRAVEN)
- USB module (RZUSBSTICK)

This development kit is aimed for various applications – simple point-to-point communication, sensor networks and human interface devices [8].

Application named Radio Evaluation Software (RES) provided by Atmel lets user to perform certain tests [6]:

- PER/Range Characterization Test
- RF Characterization Test
- DC Characterization Test

PER/Range Characterization Test provides possibility to test how the distance between transmitter and receiver and environmental conditions (such as presence of another radio device nearby) affects data transmission. This test also provides information about the signal strength.

RF Characterization Test is convenient to test characteristics of radio transmitter/receiver in terms of different radio frequency related tests [9].

DC Characterization Test provides important information about current consumption of the device in different working states such as transmission, reception or idle state.

For this research, only PER/Range test and DC characteristics are important because RF performance is not subject of this research. RF performance test is used to test transmitter output (modulation and carrier frequency) compliance with regulatory agency requirements [9].

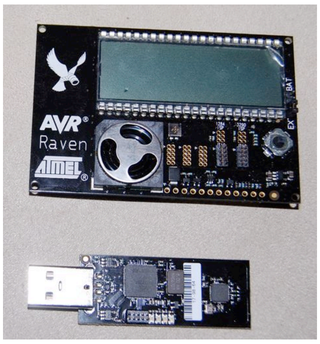

Fig. 2. RZ RAVEN ZigBee evaluation kit.

5. TESTING EQUIPMENT AND PROCEDURES

5.1. Testing equipment

Testing equipment consists of :

- PC,
- USB module with SimpliciTI or ZigBee interface,
- Remote wireless device of respective standard, SimpliciTI or ZigBee,
- Digital Oscilloscope – HP 1652b.

The PC with terminal emulation software is used for communication with USB module of different modules. Both SimpliciTI and ZigBee modules use simple commands for configuration and performing tests as well as to display results of the test.

Remote module was fixed to the portable tripod to ensure its unchanged orientation and reduce human body interference. This also makes it easier to position module exactly at the needed distance from PC. The concept of test setup for PER measurement is shown on Fig. 3.

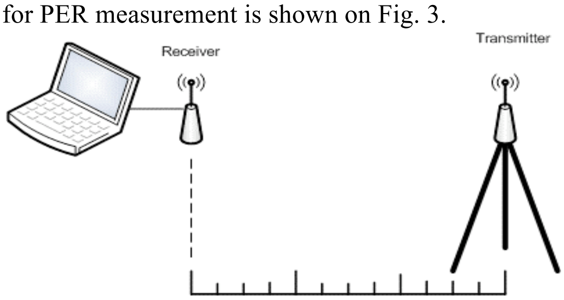

Fig. 3. PER test setup.

Digital oscilloscope and series resistor was used to monitor current consumed by the battery operated remote module in different operation states (Idle/Sleep, Reception, Transmission). DC characteristics measurement circuit is shown in Fig. 4. This circuit is used to test current consumption of the device.

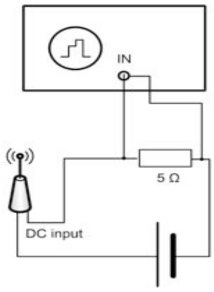

Fig. 4. DC characteristics measurement circuit.

Digital Sampling Oscilloscope was used to measure DOF parameter described in section 3. DOF measurement circuit is shown in Fig. 5. DOF is measured with oscilloscope as a time between start of frame transmission in the transmitter and reception of the complete frame in the receiver.

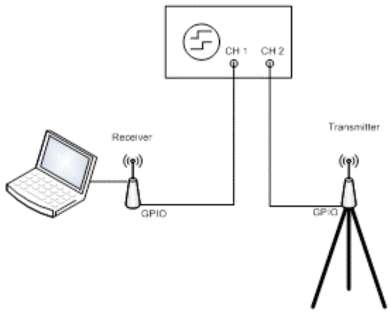

Fig. 5. DOF measurement circuit

5.2. Test Procedure

Following tests were performed:

- PER/signal strength
- maximum range (maximum distance between transmitter and receiver where no transmission errors occur)
- DC characteristics
- DOF

In PER test the battery operated remote module was used as a transmitter to easily move it in the testing ground and PC with wireless USB module was used as a receiver as in Fig. 3. The parameter itself was measured in terms of distance between remote device and USB module. There were three measurements made at each spatial position and average value of PER was calculated.

DC characteristics was measured in different setup. The main difference was that remote device was powered from internal battery with series resistor connected. Digital oscilloscope was used to measure the voltage drop on series resistor which was proportional to current consumed by the device. The circuit is shown in Fig. 4.

DOF was measured by using general Input/Output ports of the microcontrollers used in the remote and USB devices. Two probes of the digital sampling oscilloscope were connected to respective modules to measure time between writing packet to output buffer in the transmitter (this was indicated by the change of microcontroller pin state) and reading transmitted packet in receiver (this was also indicated by the change of general Input/Output port pin state). The DOF circuit is shown in Fig. 5.

6. EXPERIMENTAL RESULTS

6.1. SimpliciTI

Results of transmission power loss due to distance increasing between transmitter and receiver are shown in Fig. 6.

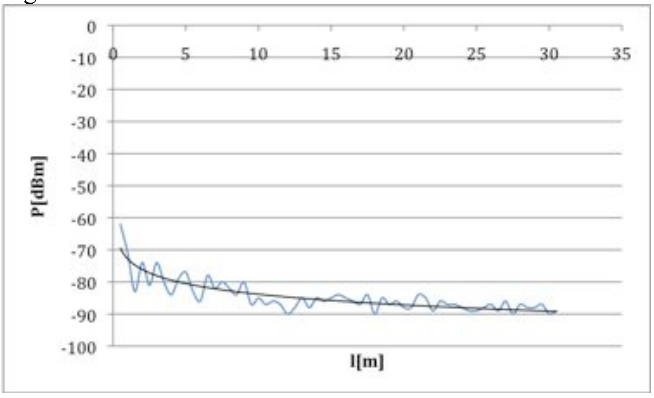

Fig 6. SimpliciTI transmission power loss due to distance increasing between transmitter and receiver.

The maximum distance at which most data packets were transmitted is about 30 m which is lower than 50m mentioned in [7]. Also [7] explains that the maximum transmission distance can be affected by the orientation of antennas of both transmitter and receiver. In this research the parallel orientation of on-board chip antennas was chosen basing on experiments with different antenna orientations.

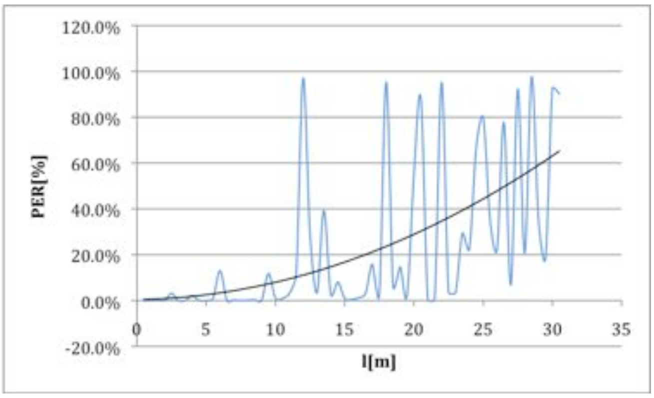

Fig. 7. SimpliciTI Packet Error Rate increase due to distance increase between transmitter and receiver

Packet Error Rate was fluctuating up to about 24 m and rapidly risen at the distance over 24 m. The maximum distance where all packets were lost was about 30 m.

Table 2. SimpliciTI current consumption in different states.

Idle	19 mA
Receive	19.4 mA
Transmit	23 mA

The current consumption, shown in Tab.2 is about the same as in [10] in reception mode and transmission mode. It is different in idle mode (1.5 mA [10]) because in [10] device is in sleep state during idle and in this research device it is in active state to avoid any delay caused by the need to wake up device from sleep state before receiving frame.

The measured Delay of Frame was 4.5 ms and it was stable in all measurements meaning that there was no *jitter* [6].

6.2. ZigBee

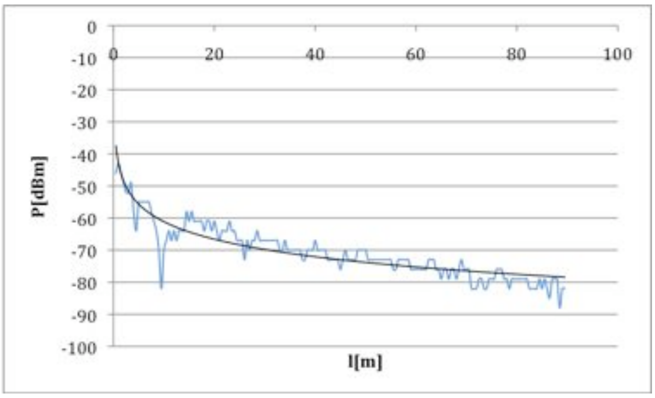

Fig. 9. ZigBee transmission power loss due to distance increase between transmitter and receiver

The measured maximum distance between transmitter and receiver with almost no data loss was 100 m which fully comply with [5].

Table 3. ZigBee current consumption in different states.

Idle	4 mA
Receive	5.3 mA
Transmit	18.5 mA

The current consumption of RZ-RAVEN, shown in Table.3, is lower than eZ430-RF2500 in reception and transmission modes, Especially in reception mode where eZ430-RF2500 (SimpliciTI) consumes four times as much current as RZ-RAVEN (ZigBee).

The measurement of Delay of Frame varied from 1 ms to about 100 ms. This may be due to the very complex ZigBee stack. This variation of Delay of Frame or jitter [6] limits the use of tested ZigBee modules in DMS because of potential problems with time synchronisation between devices.

7. CONCLUSIONS

This research is the part of wider work aimed to extend the use of different wireless transmission standards in measurement systems. The approach is based on the use of set of QoS parameters (usually used to characterize telecommunication applications), in the field of measurement systems.

Both SimpliciTI and ZigBee modules have slightly different characteristics. RZ RAVEN (ZigBee) has greater range but power consumption in sleep state is higher than SimpliciTI module (EZ430-RF2500). Both modules can be battery powered and both are small in size. EZ430-RF2500 has the advantage of 16 bit microcontroller and SimpliciTI API is smaller. However RZ RAVEN has more peripherals.

The results of this research shown that some parameters especially the maximal range of SimpliciTI module is lower than declared by the manufacturer.

The complete research over these wireless modules will give information of how and where and in what application can these wireless transmission standards can be used in the field of measurement systems.

REFERENCES

[1] A. Aiello, D.L. Carni, D. Grimaldi, G. Guglielmelli, *Wireless Distributed Measurement System by Using Mobile Devices*, IEEE-IDAACS, 2005

[2] *SimpliciTI Overview (Rev. B)*, Texas Instruments, 2008

[3] *Low-Power RF Selection Guide*, Texas Instruments, 2008

[4] *Maximizing Throughput in ZigBee Wireless Networks through Analysis, Simulation and Implementations*, T. Ryan Burchfield, S. Venkatesan, D. Weiner

[5] *ZigBee Overview*, ZigBee Alliance, 2007

[6] *VOIP Performance Measurement using QoS Parameters*, A.H. Muhamad Amin, IIT 2005

[7] *eZ430-RF2500 Development Tool User's Guide (Rev. C)*, Texas Instruments, 2008

[8] *AVR2016: RZRAVEN Hardware User's Guide (rev. A)*, Atmel, 2008

[9] *AVR2002: Raven Radio Evaluation Software (rev. A)*, Atmel, 2008

[10] M.Morales *Wireless Sensor Monitoring Using the eZ430-RF2500*, Texas Instruments 2008