Transilvania University of Brasov, Romania

13th INTERNATIONAL CONFERENCE
"STANDARDIZATION, PROTYPES AND QUALITY:
A MEANS OF BALKAN COUNTRIES' COLLABORATION"

Brasov, Romania, November 3 - 4, 2016

Design and Implement of a Real Time Health Monitoring FHSSS Using NRF24L01 Transceiver

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Abstract
The objective of this work is to design and implement of real time health monitoring system. The system is based on frequency hopping spread spectrum technique. The designed wireless communication system can operate under complex environment, serious electromagnetic interference and also its supported higher data reliability. The system uses the NRF24L01 transceivers and E-health Sensor Platform V2.0 with three medical sensors. The sensors collects biological signals from patient's body, then these signals are processed by using arduino platform (UNO-R3 Module). The designed system transmitted the sensors data through 31 frequency-hopping channels with hopping rate of 100 hops/sec. At the receiver side, the received data is displayed in PC by using the serial monitoring of the IDE program. The spectrum of the channels can be seen by using the RF Explorer-3G combo spectrum analyzer with touchstone pro program. In this paper, the real time frequency hopping system is characterized with low power consumption, high data rate, better standby time performance, low cost, portable and designed with user friendly software tools.

Keywords
health monitoring system, wireless communication system, frequency hopping spread spectrum technique, NRF24L01 transceivers, e-health sensor platform

1. Introduction

The spread spectrum technique is based on Shannon Information Theory. This technique spreads the signal over a wide bandwidth in order to give safety against such attacks [1]. Spread spectrum technique offers several advantages and characteristics some are low probability of detection, low probability of intercept, low probability of exploitation, anti-jamming, resistance to fading, and multiple access [2, 3]. Frequency hopping spread spectrum (FHSS) is a branch of spread spectrum communication system. Because of its excellent performances, FHSS is widely used in military and civilian applications [1].

Frequency hopping spread spectrum is the periodic change of the carrier frequency of a transmitted signal. The communication systems can get a better interference resistance because of this time-varying feature. Frequency hopping system depends on the avoidance process in order to prevent interference. Even if the avoidance process fails, the frequency hopping stills suppress interference because this failure is temporary as the carrier frequency changes in periodic manner. By using the channel codes, the effect of the interference can be reduced [4].

The sequence of frequencies that determined by the frequency hopping system is called hopping pattern and hop set is the M available frequencies $\{f_1, f_2, \dots, f_M\}$. The rate of the change of carrier frequency is called hopping rate while the hopping band is the band that contain M channels where the hopping done over this band. The code sequence produced by the code generators determines the hopping patterns by controlling the frequency synthesizer. The frequency-hopping signal generated by combining the data signal after modulation with output of the frequency synthesizer [4, 5]. FH Spread spectrum systems can be divided into two different types they are Slow frequency hopping (SFH), and Fast frequency hopping (FFH) [6].

NRF24L01 is a 2.4GHz transceiver integrated with Enhanced Shock Burst (ESB) protocol. It's produced by Nordic Semiconductor company. This transceiver is designed for applications that needs ultra-low power consumption for wireless communication. The modulation type used by the NRF24L01 to modulate the data is the GFSK modulation. The NRF24L01 can operate with a power supply of 1.9 - 3.3 volts. The air data rate of the NRF24L01 can be 250 Kbps, 1 Mbps or 2 Mbps and the transmission distance is up to 1100 m. The Serial Peripheral Interface SPI is used to connect theNRF24L01 with the microcontroller [7, 8].

The NRF24L01 transceiver block diagram is shown in Figure 2. There are four main operation modes for the NRF24L01 they are the Power Down, Standby, RX, and TX modes. The NRF24L01 provides 126 RF channel with Operating frequencies ranging from 2.400 GHz to 2.525 GHz. The use of the ESB will provide several advantages such as ultralow power consumption and high communication performance. ESB features are 1 to 32 bytes static or dynamic payload length, Automatic packet handling, Auto Acknowledgement and Auto retransmit [8, 9].

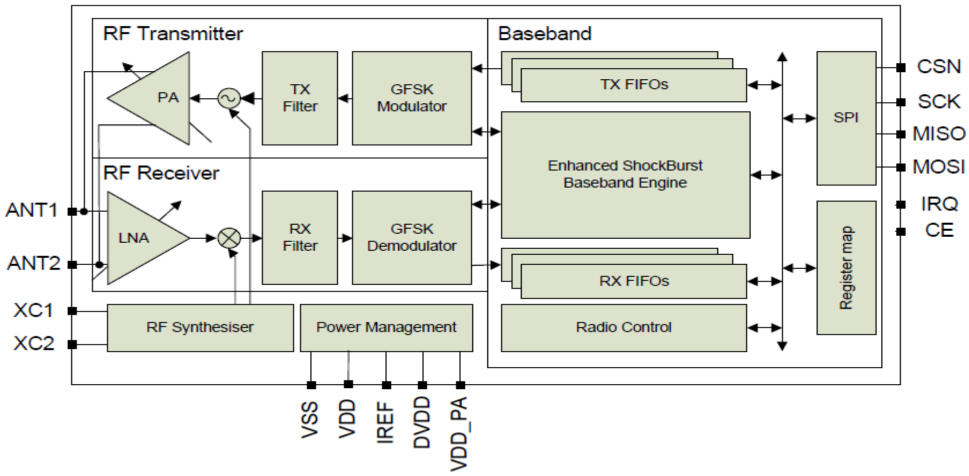

Fig. 2. Block diagram of NRF24L01 transceiver

2. Problem description

Wireless communication can improve data transmission and provide flexibility in many fields. Wireless communication is important in both civilian and military applications. There are many advantages related with using a wireless communication compared to a wired communication such as mobility, cost effectiveness and adaptability.

Taking into account the data transmission done in the medical environment. The biological signals are collected from the patient's body using medical devices and then transmits these signals to the host machine. If the transmission is done by using long lead wire or shielding wire then these wires will brought trouble to doctor and cause inconvenience and pain to patients. Therefore the use of wireless communication will save a lot of data wires and the movement of these devices become easier. Also it's gives convenient for doctors, patients and improve the quality of patient's life.

Medical devices requires high communication quality and very high reliability. When the wireless system operates on a fixed channels its ability to combat the interference and anti-jamming will be poor. And if a jamming signal is applied to this fixed channel, the loss on data will increase and the reliability becomes low. Therefore the fixed channel cannot be used with medical devices where needs very high reliability.

The frequency hopping spread spectrum is a transmission technique where the carrier hops from frequency to frequency (unfixed channel). And has several advantages such as strong anti-jamming, anti-interferenceability, and anti-multipath fading. So it's very suitable to use with medical instruments. The main purpose of frequency hopping technique is to increase the anti-interference ability of medical system and improve communication quality.

3. System design

This part of the paper descripts the design and implementation of the wireless medical system. This system operates under the rule of the frequency hopping spread spectrum technique. The sensing subsystem contains E-health Sensor Platform V2.0 and three medical sensors. The three sensors are Electrocardiogram (ECG), temperature, and airflow sensors. These sensors collect the data from the patient node and then this data is transmitted to the receiver side by using NRF24L01 transceiver. At the receiver side, the received data is displayed using the serial IDE. The block diagram of the proposed system is shown in Figure 3.

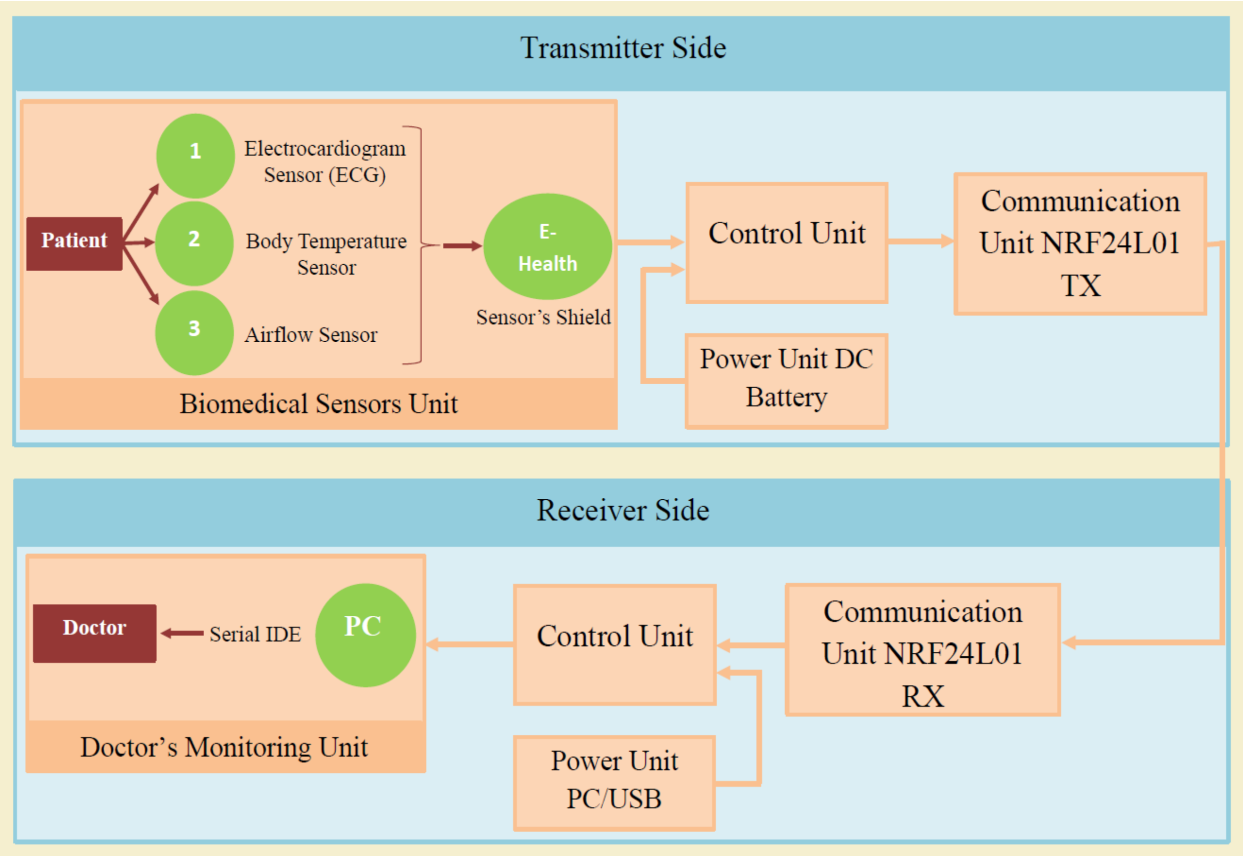

Fig. 3. Proposed system design

The main unit in the patient's sensor device is the control and computing unit, main tasks of control unit are controlling over all other subsystems and completing the processing and analysis of signals received from the sensors. Microcontrollers (MCU) with models (ATmega328) is used with the arduino platform (UNO-R3 Module). Arduino platform is open-source platform based on flexible, easy-to-use hardware and software. The MCU on the board is programmed by using the Arduino programming language that is Integrated Development Environment IDE. This language based on C/C++ language. The MCU does all tasks such as controlling, processing, and data analysis as they are shown in the flowchart of Figure 4.

When the transmitter is started its operates as a receiver. Its listens through united in option channel and waits to receive the request data from the receiver side. The united in option channel will be known for both transmitter and receiver. If the request data is not received then the transmitter will still listening through the united in option channel. When the request data is received the timer1 of the transmitter is initialized. The channels are stored in the MCU in the form of array. This array consists of channels numbers arranged in a random sequence (m-sequence) where the NRF24L01 converts this numbers to its equivalent frequencies. The channels counter (j) represents the location of the channels in the array and it is used to select between these channels. The sensors are read and stored in the form of array and then transmit this array. The transmission period is equal to 15 second and when this period is reached the transmission operation is stopped. After that the transmitter inter into waiting manner until it receives a request data.

The first step of the receiver side is to operate as a transmitter. The receiver transmits the request data to the transmitter side through united in option channel. The request data is entered by the user from the serial and it is represented by a character. If the receiver gets an ACK signal from the transmitter then the next step is to initialize the timer1. The receiver will return to the receive operation using channels sequence that is stored in the channels array. The receiver will read the received sensors data. When the transmitter side finished the transmission period there will be no data available to be received by the receiver. Then the receiver will be changed to a transmitter and waiting for a request to be entered from the serial in order to transmit it.

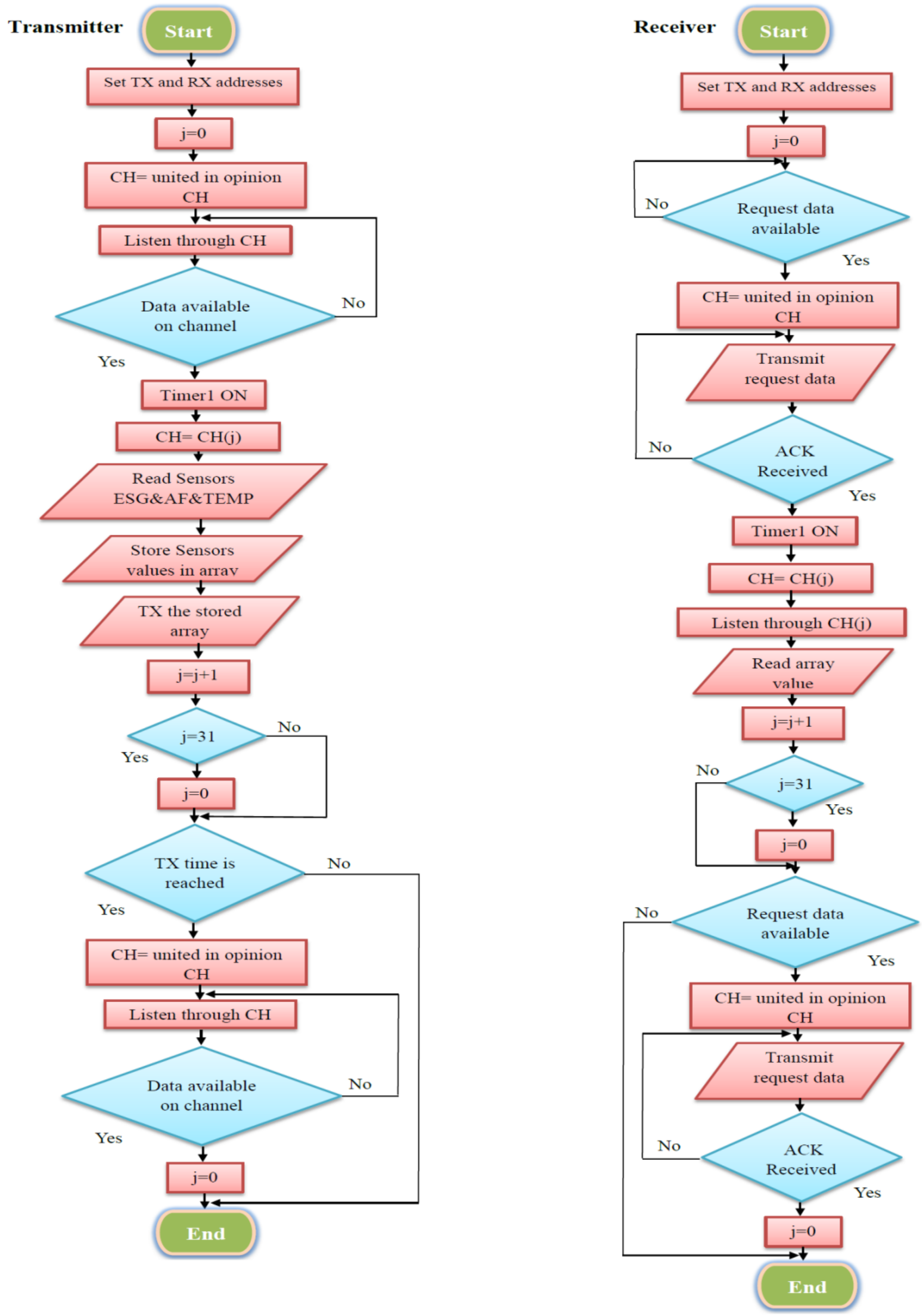

Fig. 4. Flowchart of control unit operation

4. Results

The transmitter side (patient's side) consists of three medical sensors and connected to the E-health, NRF24L01 transceiver, and Arduino UNO. While the receiver side consists of Arduino UNO and NRF24L01 transceiver as shown in Figure 5.

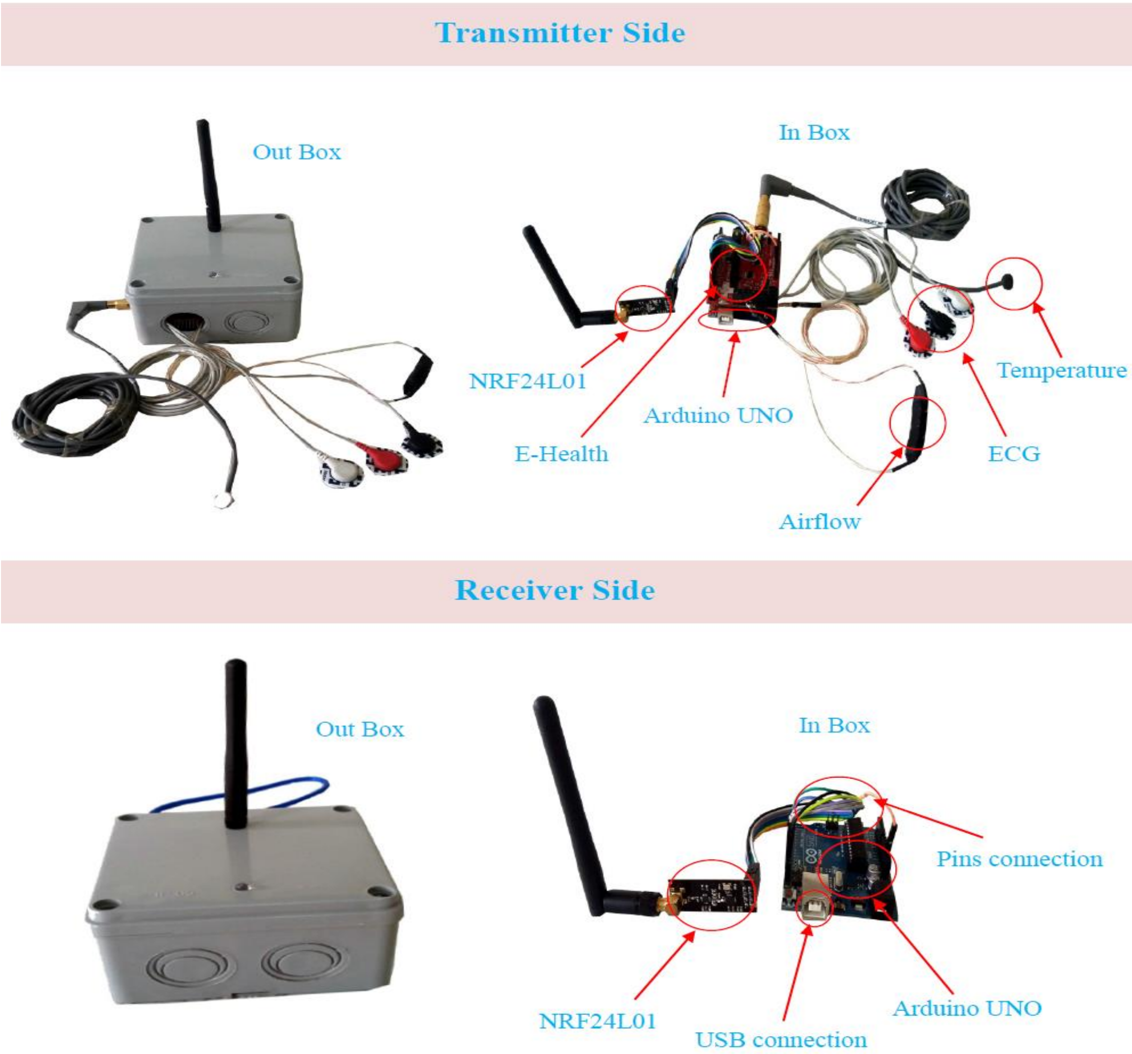

Fig. 5. Practical System design

After the transmitter and receiver's programs are uploaded to the MUC, the request data should be entered through the serial IDE of the receiver side in order to send the request to the transmitter side. When the transmitter is started, its operates as a receiver. Its listening through united in option channel and waits to receive the request data from the receiver side. After getting the order, transmitter will send the sensors reading through 31 frequency hopping channels. The transmitter stills in the sending case until the transmission period is finished. The transmission period is equal to 15 second and when this period is reached the transmission operation will be stopped. After that the transmitter is returns to the receiver case again (waiting to receive the request data). When a request data is received the transmitter will send the sensors reading again. The serial IDE results of the transmitter and receiver side is shown in Figure 6.

The spectrum of the obtained channels can be seen by using RF Explorer-3G combo handheld digital spectrum analyzer. RF Explorer depends on double balanced mixer and a highly integrated frequency synthesizer. It is very important device because its operate in all common frequency bands. The spectrum of the system's channels is shown in Figure 6 and they are obtained by using Touchstone Pro software.

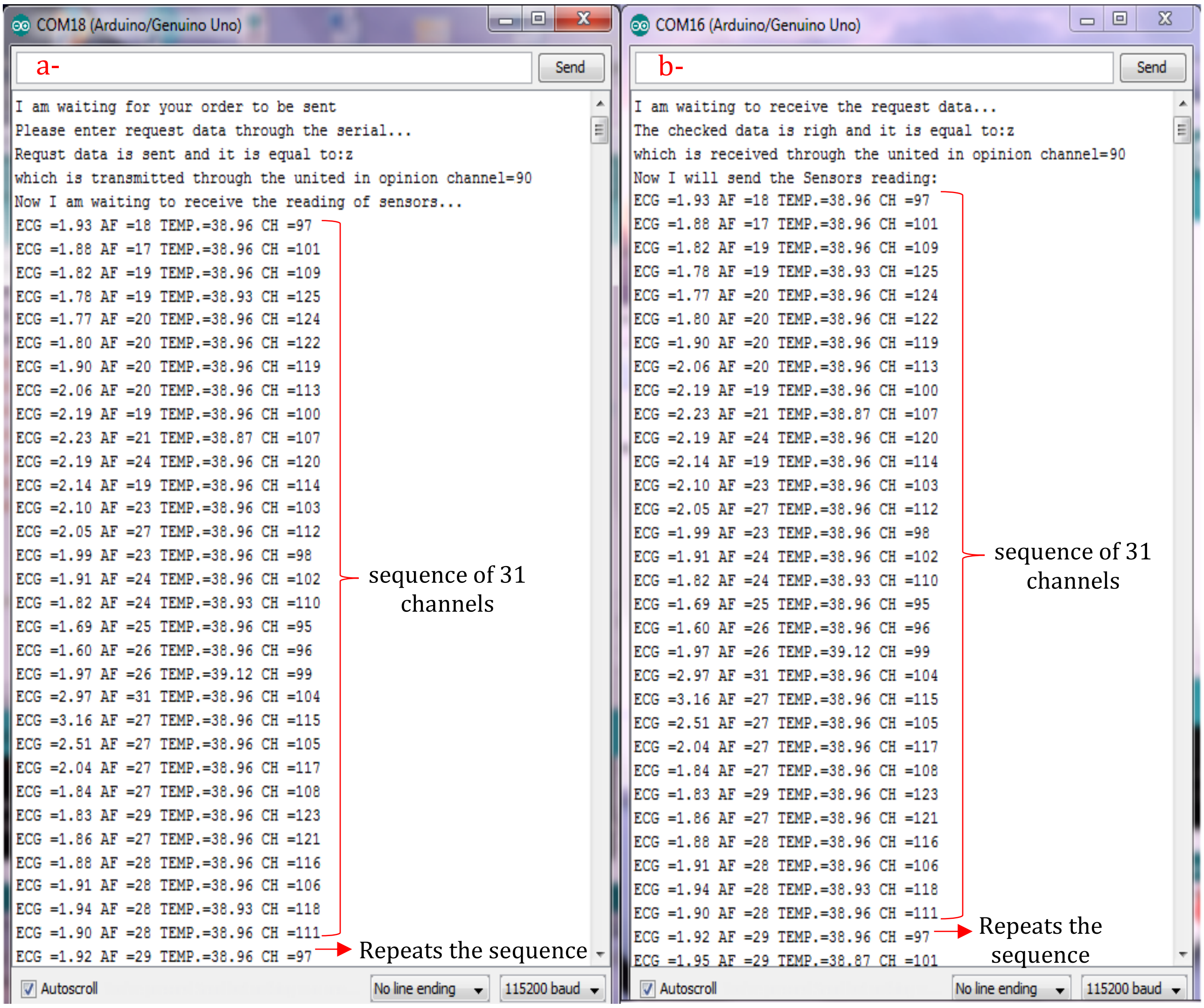

Fig. 5. The serial IDE results of (a) Transmitter and (b) Receiver

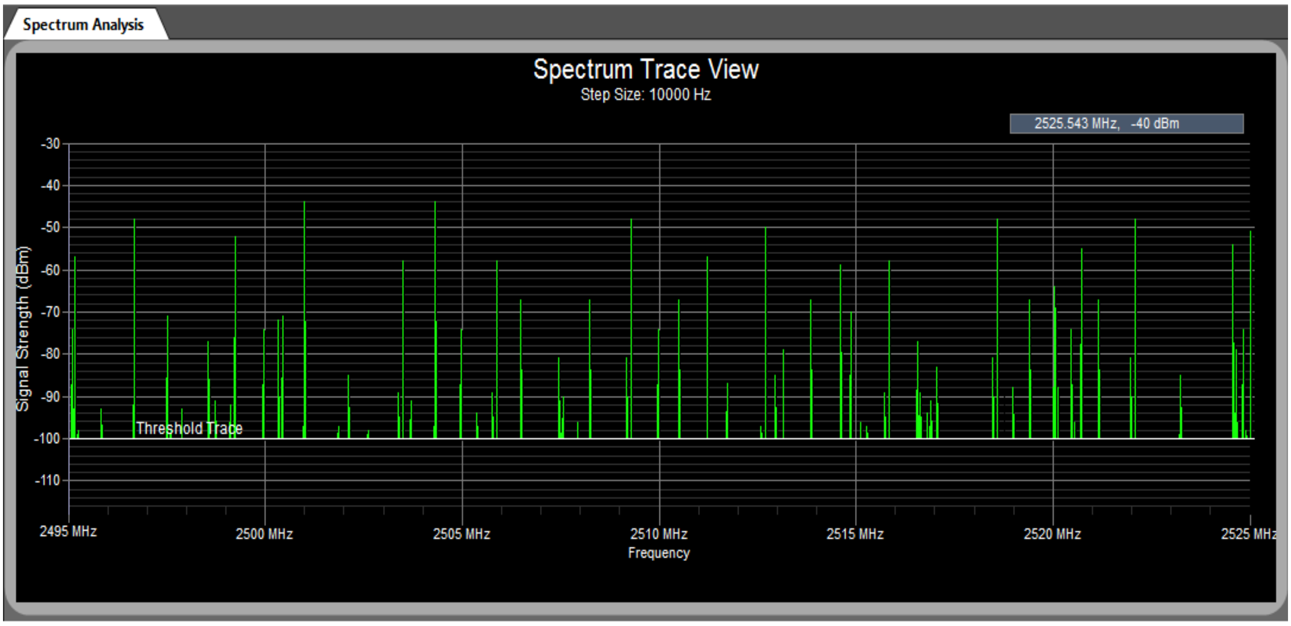

Fig. 6. Spectrum of transmitted channels

5. Conclusions

The proposed system uses three medical sensors (Electrocardiogram (ECG), temperature, and airflow sensors) with E-health Sensor Platform V2.0. The Microcontrollers (MCU) used in this system is (ATmega328) models that comes with the arduino platform (UNO-R3 Module). The other important component is the NRF24L01 transceiver that has many desirable features such as a low-cost, high reliability, low power consumption, small size, and fast frequency switching time. Also it has high on air data rate which make it suitable for high speed networking. With these good features the presented communication system has excellent anti-jamming performance, good confidentiality, strong anti-interference, good mobility, and high accessibility.The designed frequency hopping spread spectrum system has a 31 channels. These channels are arranged according to the m-sequence algorithm with 5 bits. The system hopping rate is 100 hop/sec and its obtained by using the timer of arduino. The system has a data rate up to 2 Mbps and a transmission distance up to 1100m. Its provide a real time monitoring and Can be used in serious environment with electromagnetic interference. The system is flexible and can be developed according to the new requirements.

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