ISSN 2347 - 3983
Volume 8. No. 7, July 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter78872020.pdf
https://doi.org/10.30534/ijeter/2020/78872020

RF Powered ECG Monitoring System for Silent Ischemia Patient

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ABSTRACT

Silent ischemia is a common manifestation of coronary artery disease (CAD). It can occur when blood flow is reduced to a human's heart, preventing the heart muscle from receiving enough oxygen. A partial or complete blockage of heart's arteries can lead to a heart attack. Hence, Holter monitor is a method used to measures and records the electrocardiogram (ECG) continuously for 24-48 hours. However, the present Holter monitor device is powered from battery have limited operational lifetime. Hence, an RF powered ECG monitoring system is proposed in order to improve power efficiency and operational lifetime. RF energy harvesting is a process of harvesting the ambient RF energy and performs RF to DC conversion for a subsystem from an integrated circuit. The ECG monitoring system is a part of wireless sensor node (WSN) proposed for measuring and recording the reading of ECG. The WSN is developed by using an ESP8266-12E WiFi Module interfacing with an AD8232 ECG Module. Data logging is implemented by interfacing the ECG monitoring system with the webserver through the ESP8266-12E so that the data collected by AD8232 ECG module can be visualized and stored in the webserver. The web server is developed by using HTML, Ajax and JavaScript for layout design, chart drawing and enable web page interactive

Key words: ECG, RF energy harvesting, Silent Ischemia, Wireless sensor Node (WSN), Wi-Fi.

1. INTRODUCTION

Normally, Heart attack occurs when the blood supply to part of the heart muscle itself is severely reduced or stopped. This is due to one of the coronary arteries is blocked by an obstruction, such as blood clot which has formed on the plaque due to atherosclerosis[1]. When the heart arteries are narrowed, less blood and oxygen reach the heart muscle for a short time will cause cardia ischemia happened [2]. When the ischemia is severe lasts too long, it can cause a heart attack and lead to heart tissue death [3][4]. In most case, the temporary blood shortage to heart cause the pain of angina pectoris [5] which results in spreading the pain to shoulders, arms and necks. However, there is a case without pain called silent ischemia, also known as myocardial ischemia. In fact, 70% to 80% of transient ischemic episodes are not associated with anginal chest pain or any other symptoms [6]. It occurs when the reduced blood flow to human's heart, preventing the heart muscle from receiving enough oxygen [7]. Hence, it causes partial or complete blockage of heart's arteries which leads to a heart attack. Myocardial ischemia might also cause serious abnormal heart rhythms. Abnormal rhythms such as ventricular tachycardia or ventricular fibrillation can interfere with the heart's pumping ability and can cause fainting or even sudden cardiac death [8]. Researchers have found that if a person has episodes of noticeable chest pain, he/she may also have episodes of silent ischemia. silent (asymptomatic) myocardial ischemia is the most common manifestation of coronary heart disease (CHD), accounting for more than 75 percent of ischemic episodes during daily life as assessed by electrocardiographic (ECG) monitoring [9][17]. Hence, there are two ways to diagnose silent ischemia, exercise stress test or Holter monitoring.

Holter monitor is a battery-operated portable tape recording which measures and records the electrocardiogram (ECG) continuously for 24-48 hours [10][18]. However, the operational lifetime of a battery is short and limited and it may cause any interruption of the ECG measurement during the replacement of battery. Hence, energy harvesting from ambient source is an alternative solution to alleviate this problem. In this paper, the work primarily focuses on developing an RF powered ECG monitoring system which can be used for continuous ECG monitoring. The measurement of the ECG can be visualized on a web server through wireless sensor node

2. LITERATURE SURVEY

Ambient RF energy is produced due to several sources such as cellular mobile transmitter, radio stations and Wi-Fi networks etc. RF energy harvesting is a process of harvesting the ambient RF energy and performs RF-to-DC conversion for a subsystem from an integrated circuit. The present wireless sensor node (WSN) is powered with battery which has limited operational lifetime. Hence, the harvested RF energy can be converted into DC supply for wireless sensor node has been proposed to improve the power efficiency and the operational lifetime [11]. The authors [12] developed a compact implantable ECG monitoring system by integrating an antenna and wireless charging coil. The device has been implemented in animal and it can communicate with the external base station at up to a distance of 1.8m. In this paper [13], a 13.56 MHz autonomous wireless sensor node with asynchronous ECG monitoring for near field communication is presented. The RF energy harvester supplies the system with 1.25 V and offers a power conversion efficiency of 19% from a -13 dBm RF source at 13.56 MHz. A battery-less, multi-node wireless body area network (WBAN) system-on-a-chip (SoC) are developed and discussed [14]. The experimental results shows a 4 node sensor network and ECG monitoring were successfully demonstrated by harvesting the RF signal at 433 MHz with a sensitivity of -8 dBm. The authors [15] proposed an ECG remote monitoring system that is dedicated to non-technical users in need of long-term health monitoring in residential environments and is integrated in a broader Internet-of-Things (IoT) infrastructure. However, there is a demand of high sensitivity RF harvester with good efficiency for battery less WSN operation is still under research. There are several limitations to implement a wireless module, power source and power management circuits in order to achieve maximum efficiency [11] [16]. Based on the literature review, the method of using RF powered WSN should be improved in performance especially in biomedical applications. So, an RF powered ECG monitoring system is proposed in this work, suitable for silent ischemia patient whose requires continuous ECG monitoring.

3. METHODOLOGY

The proposed method to improve the performance to measure the ECG monitoring for silent ischemia patient is shown as a block diagram in Figure 1. To implement the proposed method the Power Cast RF development harvester kit, AD8232 ECG sensor module, handheld AIM-TTI PSA II series 1MHz to 1.3 GHZ RF spectrum analyser and ESP8266-12E WiFi Module are used.

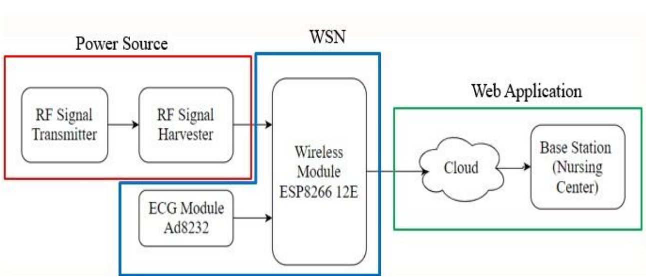


Figure 1: Block diagram of proposed method

The analysis of the RF signal is carried out by using a standalone RF energy transmitter. In this work, Power Cast standalone RF transmitter with harvesting development kit is used. The process of measuring the RF signal is started by receiving the RF signal transmitted from the transmitter by an antenna. The antenna is capturing the signal propagated from the transmitter. The RF energy harvested through the antenna is converted into DC source by the Power Cast RF harvester receiver. The converted DC source is regulated to certain level of voltage and is stored into the supercapacitor. The DC energy stored can be used to power up a wireless sensor or device. To analyze the minimum power required to power up the device, a handheld AIM-TTI PSA II series 1MHz to 1.3 GHZ RF spectrum analyser and digital multimeter are used to measure the voltage and the signal strength. The measurement varies due to the distance between the transmitter and receiver is affecting the signal strength transferred from the source. The results are recorded and analyzed. The Figure 2 shows the operation of Power Cast RF to DC harvester by varying the distance between transmitter and receiver harvester board.

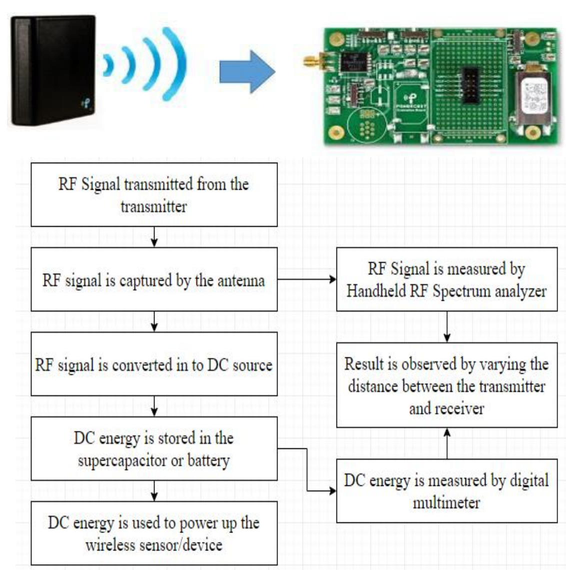


Figure 2: Power Cast RF to DC harvester operation

4. DEVELOPMENT OF RF POWERED WIRELESS ECG SENSOR MODULE

The ECG module is developed by an AD8232 integrated circuit. It is an integrated signal conditioning block for ECG which is designed to extract, amplify and filter small bio potential signals. The sensor is a cost-effective board used to measure the electrical activity of the heart. The electrical activity can be charted as an ECG signal and output as an analogue reading. The AD8232 acts as an op-amp help to remove the noise to obtain a clear signal from the PR and QT intervals. The board provides three electrodes, red (RA), yellow (LA) and green (RL).

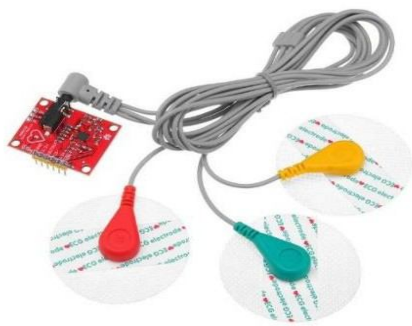


Figure 3: Electrodes connection to AD8232 ECG module

The electrodes can be attached on the body and there is a LED indicator light to show the rhythm of heart beat. The connections of ECG module with the electrodes are shown in Figure 3. The wireless sensor node (WSN) is developed by using a WiFi module, ESP8266-12E interfacing an AD8232 ECG Module. The amount of DC power required for WSN is obtained from the Power Cast RF-DC harvester. The source of RF energy is harvested from the transmitter. The Figure 4 shows the development of RF powered wireless ECG sensor node flow is mentioned.

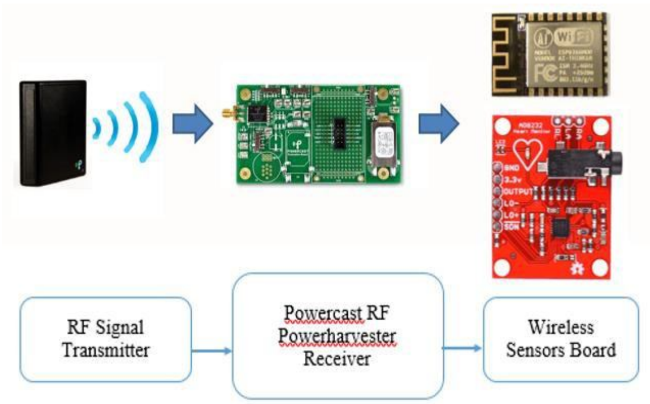
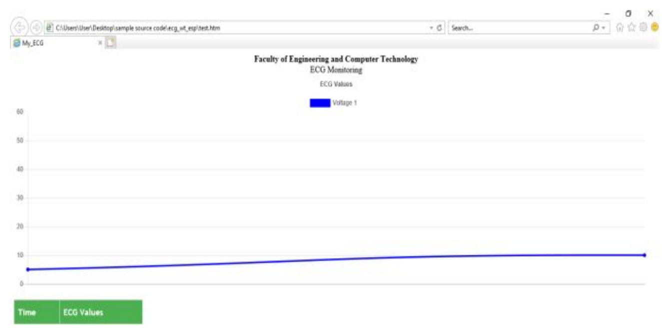


Figure 4: Development of RF powered wireless ECG sensor node

When the RF signal is converted into DC energy, the boost converter is then boosted up the energy to 3.3V as a DC power supply to the WSN. Once the WSN is powered up by 3.3V DC supply, the WiFi module is turned on and the ECG module will start transmitting the ECG signal to the webpage set up at the base station via WiFi module. The ECG signal is transferred and visualized in real-time. Hence, the clinicians can monitor the patient's condition in real-time.

In this work, a data logger web server with real-time graphs and tables is developed. Graph plotting in the webserver is built by using chartjs.org, which is one of the open-source chart drawing library and knowledge of Asynchronous JavaScript and XML (Ajax), Hypertext Markup Language (HTML) and JavaScript. Ajax is a set of web development techniques and client- side programming to allow for data to be sent and received to and from a database or server. HTML is a standard markup language for webpages. It allows web page to be updated asynchronously by exchanging small amount of data with the server behind without reloading the whole page. HTML can be assisted by Cascading Style Sheets (CSS) and scripting language such as JavaScript. The web browser receives HTML documents from a local web server and renders the documents into multimedia webpage. JavaScript is a high level, interpreted scripting language which enables interactive web pages and works as an essential part of web applications. In this work, the program can be developed by using HTML and Javascripts for creating the configuration on WiFi module.

Figure 5: Creation of webpage layout for plotting ECG data



The web page layout created is shown in Figure 5, the ECG data can be updated in the table and the graph can be plotted in real-time. The blue colour box is labelled as Voltage 1 which indicates the ECG value. There are 2 columns in the table which is the time in x axis and ECG data value in y axis. The data will start logging into the table when the data is received from the WSN through the ESP module. The Figure 6 displays the flow chart of operation of wireless ECG sensor node and it value can be plotted real time and stored in web cloud.

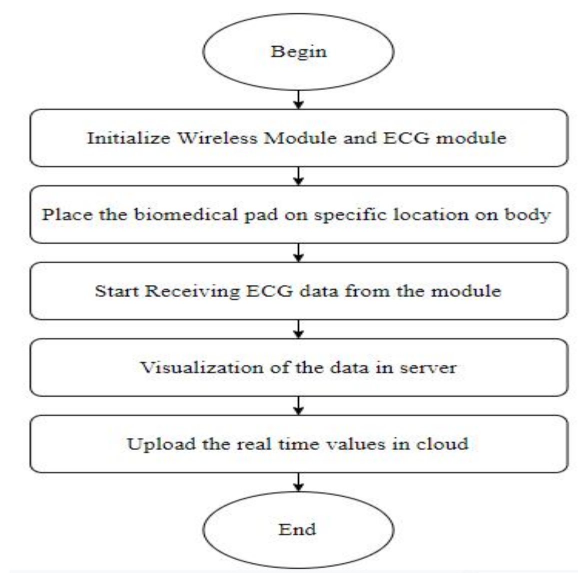
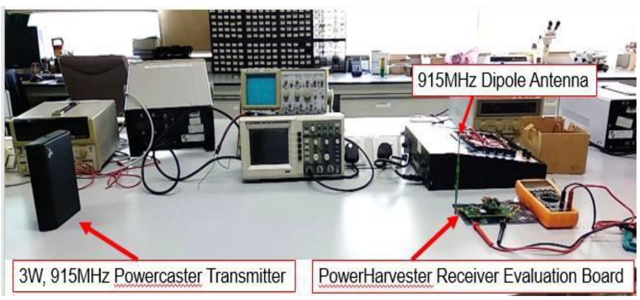


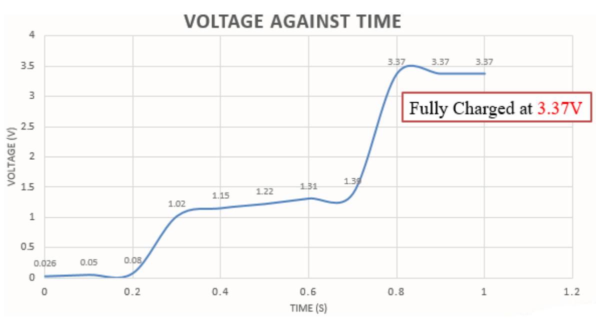
Figure 6: Flow chart of operation of wireless ECG sensor Node

5. RESULTS AND DISCUSSION

To analyze the RF signal strength and its effect with distance from transmitter to receiver in RF energy harvester, a few experimental studies are carried out to find out the rate of charging for battery and capacitor. The effect of distance is studied by conducting an experiment on varying the distance between the standalone transmitter and receiver. The Figure 7 depicts a graph in which the rate of charging of a capacitor by using Power Cast RF harvester. From the result, it is observed that the time taken for the battery to be charged fully within 1 second. The maximum voltage charging rate of a capacitor found to be 3.37V by keeping the distance between the transmitter and receiver at less than 0.5m.



(a)



(b)

Figure 7: (a) Experimental setup for measuring RF signal strength (b) Rate of charging of a capacitor by RF harvester

The distance between the standalone transmitter and the receiver is varied from 0.5m to 2.0m and the power harvester results are analyzed. The Figure 8 shows the results on rate of charging of capacitor with variable distances of 0.5m and 2m. From the results, it is noticed that the rate of charging at a distance of 0.5m is the highest, whereas when the distance is longer between the transmitter and receiver, the weaker the RF energy is harvested. Hence, the time taken to charge the capacitor becomes longer. The maximum distance between the transmitter and the receiver is 2.0m, hence there is very low RF energy can be harvested. If we increase the distance more than 2m, the harvested energy stored in the capacitor is not sufficient to activate the ECG sensor. In the same experiment, there are two types of antenna are used such as dipole antenna and patch antenna. The distance between the transmitter and the receiver is varied from 0.5m to 2.0m as did previously. The average time delay is compared between the two types of antenna. From the result shown above, the patch antenna has a minimum average time delay compared to dipole antenna. This is because the patch antenna has a wider range and higher gain compared to dipole antenna and it is very compact to design and fabricate.

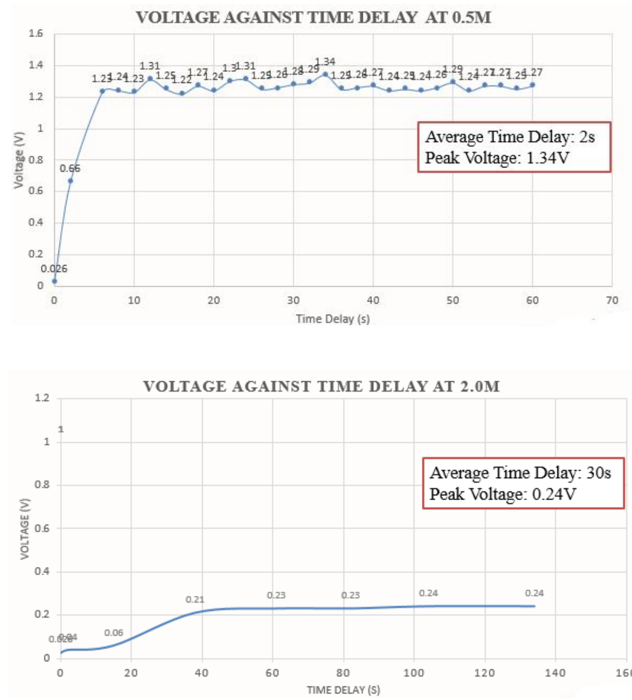


Figure 8: Capacitor charging at a distance of 0.5 m and 2.0 m

A few survey and experimental study were conducted at indoor with two types of antenna. The results of measurement to make full charge of a capacitor are shown in the Table 1.

Table 1: Measurement of time delay to full charge of capacitor

Types of Antenna	Distance between transmitter and receiver	Avg. Time Delay
915MHz Dipole	0.5 m	1s
	1 m	5 s
	2 m	240 s
915MHz Patch	0.5 m	0.5s
	1 m	1 s
	2 m	35 s

In the experimental analysis, the power transferred from the transmitter to the receiver is measured at different distance by using the RF spectrum analyzer. The result can be captured from the RF spectrum analyzer. From the analysis, it is observed the distance between the transmitter and receiver can be maintained up to 2.0m to make charging the capacitor. The minimum power required to power up the wireless sensor is 0.015mW. The longer the distance between the transmitter and receiver, the lower the power is transferred. Hence, the lower power is received by the RF harvester and the wireless sensor cannot be powered up. The spectrum analyzer results in Figure 9 shows the measurement of RF signal power at -25.6 dBm at a distance between transmitter and receiver is 3m. In this case, the capacitor cannot able to charge because of poor RF signals is transferred.

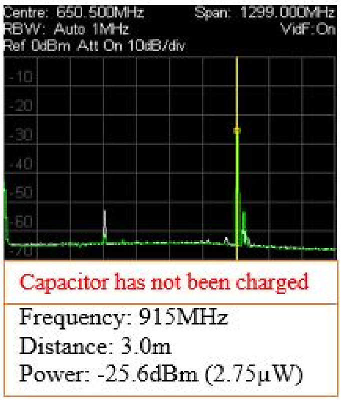
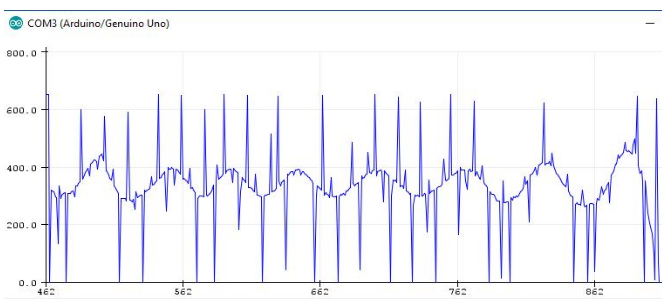
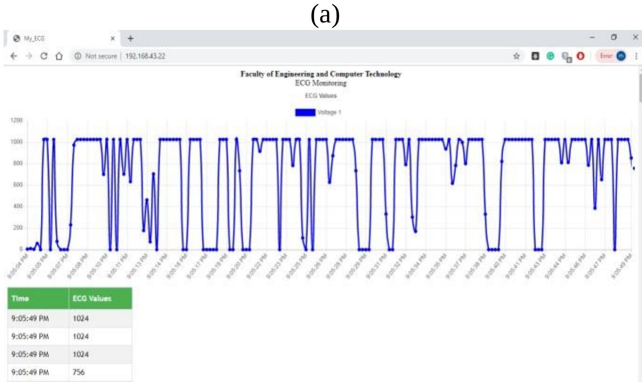


Figure 8: Spectrum analyzer display of signal at distance of 3 m



(a)



(b)

Figure 9: (a) ECG signal measured directly from ECG module (b) ECG signal as data captured in webserver

The patient ECG signal captured directly from ECG module is shown in Figure 9(a). It is noticed that the ECG signal is shown on the console without any delays. However, the same signal of data is transferred to webserver for storage which shows some delays as shown in the Figure 9(b). From the figure above, ECG reading can be observed through the waveform of the signal. The signal is updated in real-time on the console. The waveform captured in the green box indicates the 1 cycle of the waveform. When the data is visualized on the webserver, the waveform is different compared to the console. This is because there is a time delay when transferring the data from WSN to the webserver but the reading of ECG data is readable from the webserver.

6. CONCLUSION

In this paper, Power cast RF development kit is used for implementing a non-conventional method of harnessing energy to power up a medical-based device and to maintain the sustainability of the device. The wireless sensor node is developed by using an ESP8266-12E Wi-Fi Module interfacing with an AD8232 ECG Module. The proposed idea of RF powered wireless ECG data transmission solves the issue related to battery lifetime during Holter monitor. It is a method to diagnose silent ischemia patient through continuous ECG monitoring for 24-48 hours. A web server has been developed for ECG data visualization so that clinicians can monitor the patient's condition anywhere in the hospital. The web server is developed by using HTML, Ajax and JavaScript for layout design, chart drawing and enable web page interactive. The developed RF harvested powers can be sufficient to supply to the WSN. After a thorough investigation, the results and analysis recorded based on the data collected, the minimum RF signal strength required to power up the ECG sensor is -18.1 dBm which is equivalent to 0.015 mW at 915 MHz and the maximum distance between the transmitter and receiver for RF energy harvesting is 2m. The output voltage obtained from the RF harvester board varies from 1.5 V to 3.3 V which depends on the distance between transmitter and receiver.

ACKNOWLEDGEMENT

Authors wish to acknowledge the support for this research work through internal grants (AURRB/1/2017/TK04/AIMST/02/21) from research management center (RMC), AIMST University.

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