In Body Antenna for Monitoring Pacemaker

Raja Rashidul Hasan
Department of EEE
American International University-Bangladesh (AIUB)
Dhaka, Bangladesh
hemalaiubeee@gmail.com

Md. Abdur Rahman
Department of EEE
American International University-Bangladesh (AIUB)
Dhaka, Bangladesh
arahman@aiub.edu

Sourav Sinha
Department of EEE
American International University-Bangladesh (AIUB)
Dhaka, Bangladesh
souravsinha272@gmail.com

Md.Nizam Uddin
Department of EEE
American International University-Bangladesh (AIUB)
Dhaka, Bangladesh
niyaznoble@gmail.com

Ta-Seen Reaz Niloy
Department of EEE
American International University-Bangladesh (AIUB)
Dhaka, Bangladesh
taseenreazniloy3@gmail.com

***Abstract*— Heart Attack is now a very common disease in our modern lifestyle. It occurs when heart is pumping too quickly or slowly or when body does not get enough blood. A pacemaker is an electrically charged medical device which is used to control irregular heartbeats called arrhythmias. It implants under the skin of our body. This paper represents an In-body patch antenna, which is designed on pacemaker with resonance frequency of 2.464 GHz. The antenna will be used to monitor the condition of the pacemaker wirelessly, weather it works properly or not. It can also be monitored heart function such as beat rate. The antenna is designed to operate at Industrial, Scientific, and Medical band (2.4 GHz-2.48 GHz) where the dimension of the antenna is $35 \times 22 \times 0.1\, mm^3$ and the dimension of the pacemaker is $40 \times 30 \times 10\, mm^3$. The pacemaker box is imitated in the box of a perfect electric conductor, which is used as a ground of the proposed antenna to maintain the compact size. The pacemaker embedded in the 2/3 muscle-equivalent phantom where the distance between the top of the phantom and the antenna is changed and analyzed. The substrate and superstrate is chosen Rogers R03010 for its flexibility. At operating frequency (2.464 GHz), Reflection coefficient, Voltage Standing Wave Ratio, total efficiency, and radiation efficiency are found -28.37 dB, 1.08, -35.50 dB, and -35.50 dB. Besides that, far-field radiation characteristics and biocompatibility of this antenna also discussed in this paper to ensure that a comfortable design for wireless monitoring of pacemaker. CST microwave studio is used to design this antenna as well as to calculate the findings.**

Keywords—Pacemaker, Perfect Electric Conductor (PEC), Wireless Monitoring, Voltage Standing wave ratio (VSWR), Federal Communications Commission (FCC).

I. INTRODUCTION

An artificial implantable pacemaker is a small medical device that delivers an electrical pulse by electrode contracting the heart muscles with the proper intensity to the desired location [1]. The main purpose of pacemaker is to stimulate the heart beating at normal rate. Many companies offer devices with wireless capabilities and monitoring system [2]. This wireless monitoring system is very useful as it reduces the number of face to face visits with doctors and also physical and mental burden of the patients. As it can communicate without a wire so there is no need piecing of the skin which can prevent the infection with a germ in a medical diagnosis but there is a need of antenna to transmit the data wirelessly [3].

In recent years, there were several researches on various telemetry antenna designs have been proposed. This antennas can directly communicate with other devices and flexible and offers more advantages [4], [5]. Compact size, wider bandwidth, radiation efficiency and most importantly the patient safety were the main requirements to design an antenna [6], [7]. Up to now, various types of antennas (such as loop antenna, monopole antenna and meander line antenna) have been developed for wireless monitoring [8], [9].

Certain bands have been recommended for designing a bio-suitable antenna such as medical implant communication service (MICS) (402-405MHz), ISM (2.4-2.48GHz), wireless medical telemetry service (WMITS) which is regulated by U.S. Federal Communications Commission (FCC) (MICS Federal Register, 1999) and the European Radio communications Committee (ERC) (ERC Recommendation, 1997) [10]. ISM band has small wave length because of its higher frequency range besides MICS band has larger wavelength with lower frequency. So that, ISM band is more suitable than MICS band [11].

In this paper, a design of miniaturized patch antenna is proposed for wireless pacemaker monitoring system, which operates at ISM band (2.464 GHz). The pacemaker embedded in 2/3 muscle-equivalent phantom ($\varepsilon_r = 38.1$, $\sigma = 0.53$ S/m) [12]. To analyze the characteristics, the distance between the top of the phantom and antenna is changed various times and observed the results. The pacemaker box is imitated in a box of a perfect electric conductor (PEC), which is used as ground of the designed antenna [12]. The antenna is designed with flexible material Rogers R03010 ($\varepsilon_r = 10.2$) as substrate and superstrate [13]. For its flexibility, it could be bent if required. All the important characteristics of the designed antenna those are needed to be investigated before implanting inside a human body such as S_{11}, VSWR, far-field radiation pattern, directivity, have been observed in CST microwave studio and discussed.

II. DESIGNING METHOD

There are few steps that have been followed to fulfill the goal of the research as described as follows

A. Antenna Designing

In this article, a microstrip patch antenna is designed with length of 35 mm and width of 22 mm. The designed antenna contains ground, substrate, patch and superstrate. The PEC material choose as ground and copper as patch with thickness of 0.1 mm. Flexible dielectric material Rogers R03010 is chosen for designing the substrate and superstrate with length and width of 40 mm and 30 mm. To design and analyze the antenna, CST microwave studio is used.

Fig. 1 displays the geometry of patch of the designed antenna whose dimension is $(35 \times 22 \times 3.2)\ mm^3$. The patch is located between the substrate and superstrate with Rogers R03010 (dielectric constant, ε_r = 10.2, tan δ = 0.0035) in order to decrease effects of a high conductive human tissue and to prevent the antenna being shorted [12], [13]. The antenna operates at 2.464GHz (ISM Band). The width of patch and the space between it is 2 mm and the feed line is 6.5 mm in height.

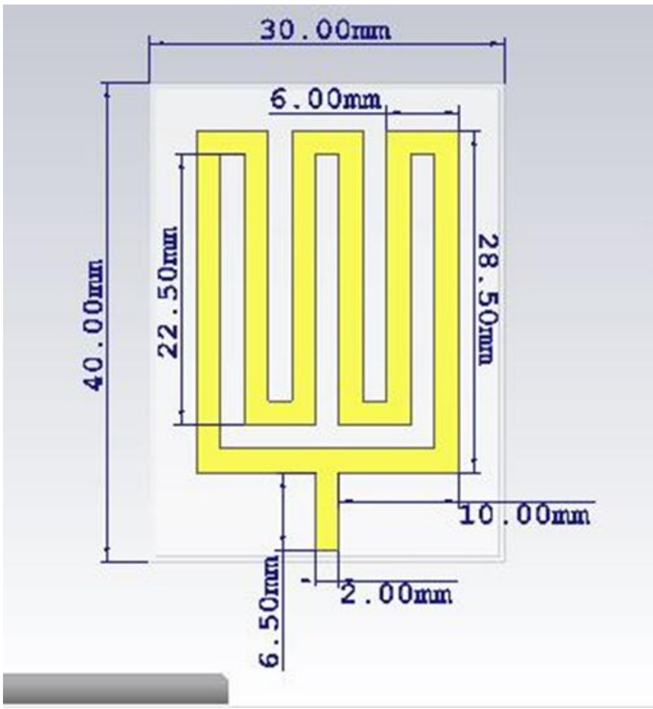

Fig. 1. Proposed microstrip patch antenna front view with dimension.

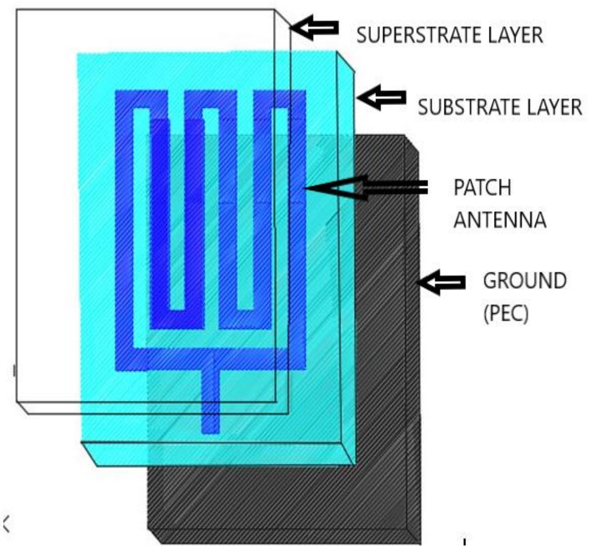

Fig. 2. Structure of the antenna.

In Fig. 2, the structure of the antenna is displayed which is located in between the substrate and superstrate on the surface of the pacemaker. The pacemaker box is designed with PEC which is served as the ground.

TABLE I. FEATURES OF ANTENNA LAYERS

Layer	Used materials	Total length(mm)	Total width(mm)	Total thickness (mm)
Superstrate	Roger R03010	40	30	1.55
Patch	Copper	35	22	0.1
Substrate	Roger R03010	40	30	1.55
Ground	Perfect Electric Conductor	40	30	0.1

Ddimensions of the proposed antenna can be seen from TABLE I.

B. Designing of Pacemaker Casing

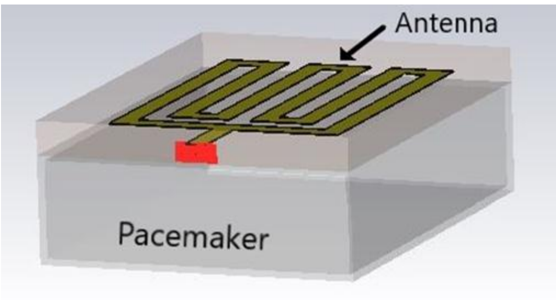

Fig. 3. Antenna with Pacemaker.

The placement of designed antenna with pacemaker casing is showed in Fig. 3. The red marks area indicates the waveguide port from where the antenna is feed. The dimensions of the pacemaker casing is given on TABLE II [12].

TABLE II. PACEMAKER SIZE PARAMETER

Name of Parameter	Size (mm)
Pacemaker height	30
Pacemaker thickness	10
Pacemaker width	40

C. Body Phantom

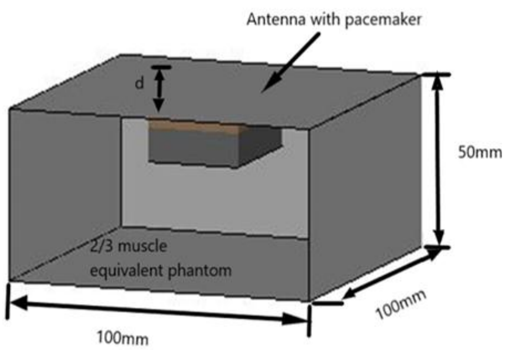

Fig. 4. 2/3 muscle-equivalent phantom with pacemaker inside.

Fig. 4, shows the 2/3 muscle-equivalent phantom with pacemaker. The antenna is located inside the surface of pacemaker which is used as antenna's ground. The pacemaker surface is made with perfect electric conductor (PEC) [12].

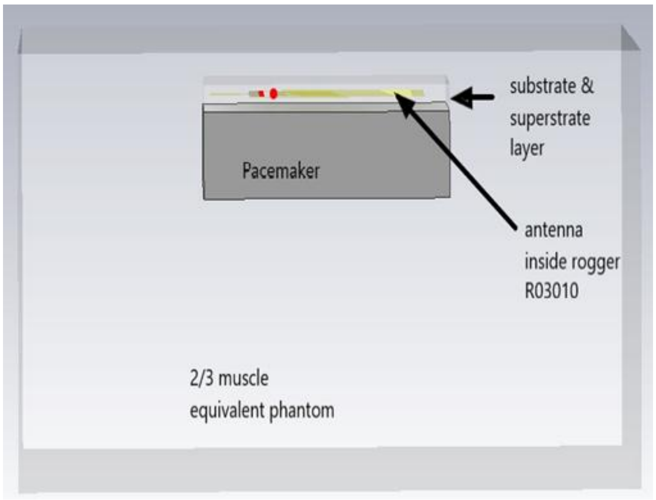

Fig. 5. Antenna with pacemaker inside 2/3 muscle-equivalent phantom.

Fig. 5 is the right view of the design, where the positioning pattern of pacemaker and antenna inside the 2/3 muscle-equivalent phantom is showed.

III. Characteristics Analysis of Designed Antenna

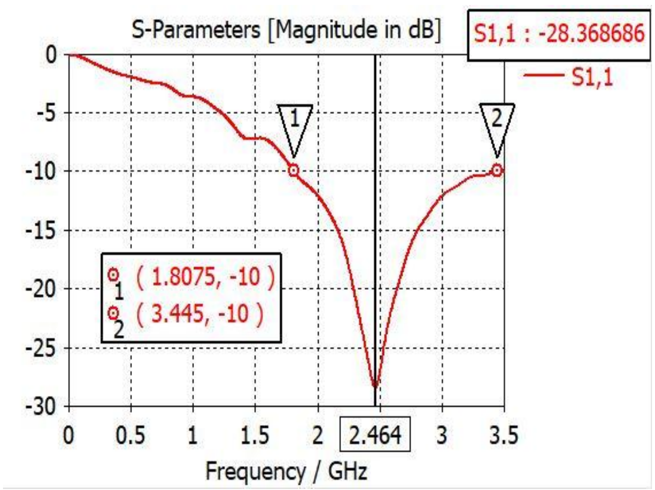

Fig. 6. S_{11} parameter of the antenna inside 2/3 muscle-equivalent phantom.

Reflection coefficient or S_{11} parameter is the amount of power radiated or reflected from an antenna [14]. At resonance frequency the return loss is observed after implanted the proposed antenna inside the 2/3 muscle-equivalent phantom. In Fig. 6, the X-axis represented the frequency in GHz & the Y-axis represented the return loss in dB. The resonant frequency or operating frequency of 2.464 GHz which is in ISM band with a return loss of -28.3687 dB. The return loss shows the maximum radiation with better performance of the antenna and the operating frequency makes the antenna biocompatible [13]. The bandwidth of this antenna is found 1.6375 GHz (1.8075 GHz to 3.445 GHz) by plotting a straight line in -10 dB which is compatible for implanting in human body [13].

The radiation characteristics of the designed antenna is explained in Fig. 7. It is noticed that the directivity of the antenna is 6.670 dBi and total efficiency is -35.50 dB and the radiation efficiency is observed -35.50 dB at resonance frequency 2.464 GHz.

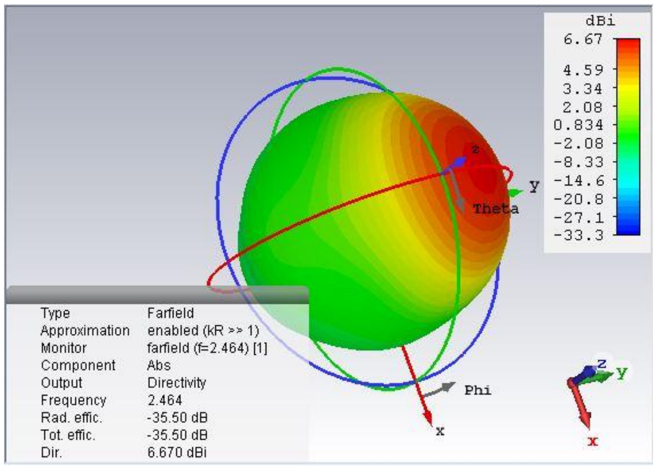

Fig. 7. Far-field radiation pattern view (3D) of the designed antenna inside 2/3 muscle-equivalent phantom.

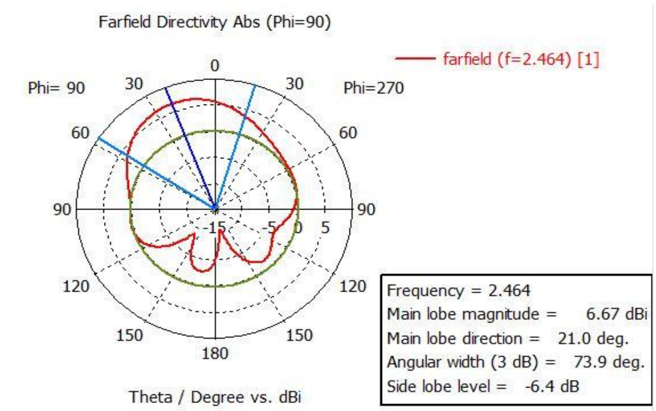

Fig. 8. Polar view of far-field radiation pattern of the designed antenna inside 2/3 muscle-equivalent phantom.

Far field radiation pattern in polar view is observed in Fig. 8, where main lobe magnitude is found in 6.67 dBi.

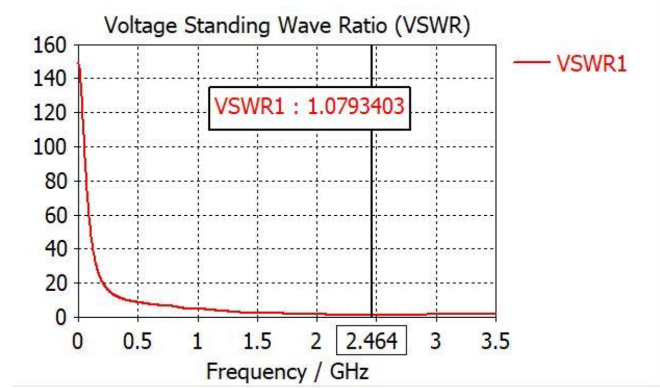

Fig. 9. VSWR of the designed antenna inside 2/3 muscle-equivalent phantom.

Voltage Standing Wave Ratio (VSWR) is the measurement of the power reflected from the antenna which is a function of reflection coefficient [14]. VSWR must be in between 1 to 2 for better performance [14]. In Fig. 9, the X-axis represented the frequency in GHz & the Y-axis represented VSWR which is 1.0793403 at resonant frequency of 2.464 GHz which is desired value.

IV. Comparison Analysis of Antenna for Different Position

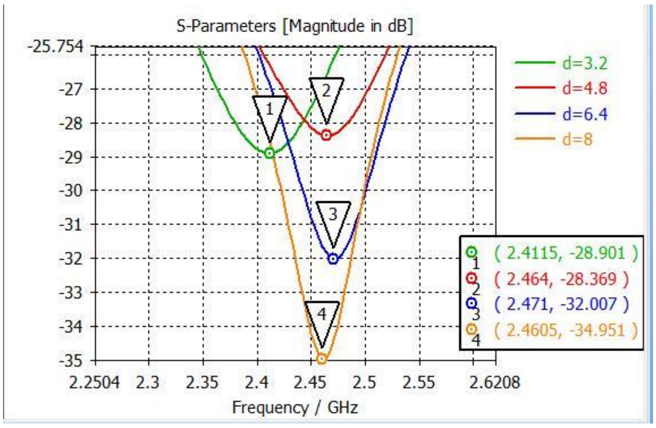

Fig. 10. Simulated S_{11} characteristics for various depth (d).

The distance of phantom surface to pacemaker is varied and analyzed for evaluating the effect of the thickness because of the pacemaker is placed in various depth of the muscle depending on different gender and age. In Fig. 10, reflection coefficient or S_{11} parameter of the proposed antenna for various depths (d) are showed with the resonance frequency. For the various depths d=3.2 mm, d=4.8 mm, d=6.4 mm, d=8 mm, the values of S_{11} are -28.90 dB, -28.37 dB, -32.01 dB, -34.95 dB with the resonance frequency of 2.41 GHz, 2.46 GHz, 2.47 GHz, 2.46 GHz. When the depth (d) from phantom surface to the proposed antenna is changed from 3.2 mm to 8 mm, the resonant frequencies of the proposed antenna are slightly shifted.

V. Conclusion

The proposed antenna has been designed and analyzed to make it biocompatible. The antenna and the pacemaker embedded in the 2/3 muscle-equivalent phantom. This antenna operates at 2.464 GHz (ISM band). At resonant frequency reflection coefficient or S_{11} is found -28.37 dB and VSWR is found 1.0793 which are satisfactory for in body wireless transmission. The far field directivity is observed 6.670 dBi. Total efficiency and radiation efficiency are found -35.50 dB and -35.50 dB respectively which are good for antenna performance. Lastly, for different position of the pacemaker along with the antenna varied and analyzed. Pacemaker plays an important role for arrhythmias patients. If it does not work properly then patient can face a severe problem or may die any time. So the monitoring of pacemaker is very much important for proper diagnosis. According to the antenna performance, it can be concluded that, the designed patch antenna is a body compatible antenna and it will be applicable properly for medical application such as pacemaker monitoring system.

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