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Implantable Compact Patch Antenna for Wireless Body Area Network Applications

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Abstract— **The Ultra wide-band Wireless Body Area Networks have rapidly progressed in recent years, due to its high data rate transmission capabilities with low power spectral densities. Here an implantable compact, low profile microstrip patch antenna for Wireless Body Area Network (WBAN) is presented, which is operated at Ultra wide-band (UWB) frequency from 4.4 GHz to 6.8 GHz with the bandwidth of 2.4 GHz. The proposed antenna is characterized in free space (air) and lossy environment by submerged in to soybean oil as human fat tissues. The proposed antenna is implantable in human body for monitoring the patient's health. The proposed antenna is fabricated on FR4-eproxy substrate with a dielectric constant of 4.4 and 1.6 mm thickness. The overall size of antenna is 13 mm × 13 mm × 1.6 mm. The parameter of proposed antenna was simulated using HFSS 13.0 software in term of return loss, gain, VSWR, and radiation pattern. Radiation loss and operating bandwidth of the antenna were measured using vector network analyzer (VNA). The antenna is suitable for WBAN applications such as malignant tumor detection, heart attack and high blood pressure measurement etc.**

Keywords- WBAN; implantable; Ultra wideband; medical application; patch antenna.

I. Introduction

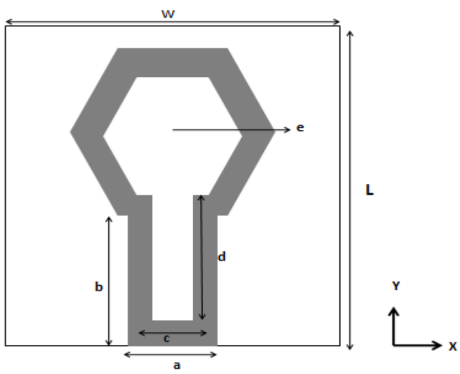
The networking and communications with the use of wearable and implantable wireless sensors to human-to-human and human self is referred to body-centric wireless communications. Its area is combination of Wireless Body-Area Networks (WBANs), Wireless Sensor Networks (WSNs) and Wireless Personal Area Networks (WPANs) [1]. A Wireless Body Area Network (WBAN) system is a set of various miniaturized and low power independent node and sensors. In order to provide smart health care these nodes are attached to human body as wearable or implantable devices. Moreover, a wireless body area network (WBAN) systems use for multiple applications such as home and health care, medicine, sports, multimedia, biomedical, commercial, and military services. These devices are attached on or implanted in the body which is capable of establishing a wireless communication link [3]. Implantable devices provide continuous health monitoring and real-time feedback to the user or medical personnel. It can be able to reside for long period of time in patient body for monitoring the health. In order to monitor a patient's health status, implanted devices are used to collect various physiological parameters in medical diagnosis and wirelessly transmit that information to external medical devices [4]. During the previous research topics, the number of papers covered upper band, lower bands or full band of UWB [5-7]. Ultra wide-band (UWB) has various applications to be research; one of them is in Wireless Body Area Network (WBAN) application [13,14]. According to Federal Communication Commission (FCC) 2002, Ultra Wide-band covers a full bandwidth from 3.1 to 10.6 GHz. The bandwidth is more than 20% of the center frequency or more than 500MHz and the average power spectral density should not be over -41.3dBm/MHz [2]. In general, UWB have two main characteristics that increase the demand on its medical applications, firstly, the nature of UWB as an electromagnetic wave with good penetration, secondly low hazard due to its low power.

Specially, for health monitoring systems, biotelemetry, hyperthermia, and breast cancer detection implanted devices are widely used. The implantable antenna should be small in size for easily implantation in human body in order to operate and provide better performances [8, 9].

In this paper, a compact microstrip antenna is used to fulfill the requirements of medical applications. The performance of proposed antenna is measured in free space environment (air) and lossy medium. In order to evaluate antenna performances in lossy medium the proposed antenna is submerge in to soybean oil. Soybean oil is chosen as the human fat tissues due to their similar dielectric properties to the human tissues. Proposed antenna is applicable for health monitoring, blood pressure measurement, breast cancer detection and etc. This proposed antenna is very compact in compared to others antenna found in early research literature [9-11] is very compact in size, simple structure and easy to fabricate. The antenna is designed by using HFSS software and VNA (Rohde and schwarz) [12] is used to measure return loss of proposed antenna.

II. ANTENNA DESCRIPTION

Figure 1(a) and (b) shows the specific schematic configuration of the proposed microstrip antenna for WBAN applications. Antenna has hexagonal shaped radiator with slot in radiating element and feed line.



(a)

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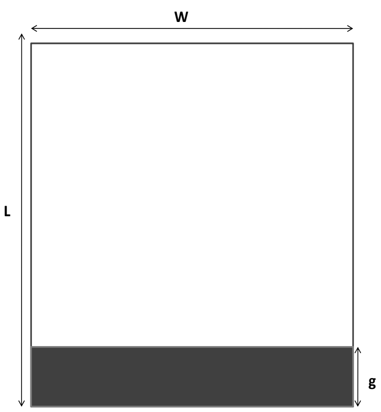


(b)

Fig.1. Schematic configuration of the proposed patch antenna.
(a) Top view (b) Bottom view

The antenna consists of a single hexagonal shaped radiating element with the thickness of 0.035 mm and it is printed on both sides of the surface of the FR-4 substrate. The FR4 substrate has a dielectric constant is 4.4, with 0.02 loss tangent and 1.6 mm thickness. Length and width of the substrate are denoted by L and W respectively. The overall dimensions of the proposed antenna are 13mm x 13mm x 1.6 mm. This small printed antenna is fabricated on both sides of the substrate. At the top, the radiating element of antenna is composed of hexagonal shaped with hexagon slot and rectangular slot and microstrip freed line. The ground is in form of rectangular strip with dimensions of 13 mm x 1 mm. The optimized dimensions of the proposed antenna are shown in Table I.

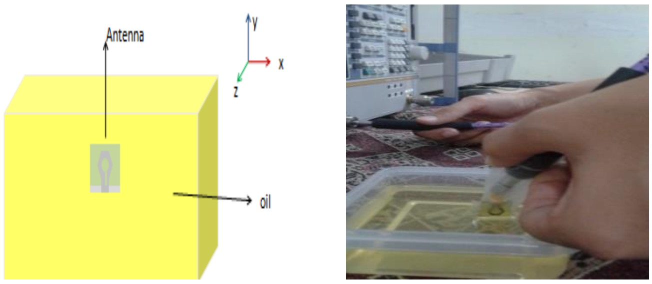
TABLE I DIMENSIONS OF PROPOSED ANTENNA.

Parameters	W	L	a	b	c	D	E	F	g
Measurement (mm)	13	13	3	5	1	4.4	2.4	13	1

III. EXPERIMENTAL SETUP

The experimental setup of the proposed antenna is characterized in two approaches: (i) designing and simulation of an antenna in free space environment and (ii) directly designing and simulation of an antenna in lossy environment. Figure 2 shows the designing of simulation and measurement setup of proposed antenna in lossy environment. Initially, antenna is designed in free space and then it is implanted inside the human fat tissues. According to literature survey,here soybean oil considered as a human fat tissues because of its similar dielectric properties to the human fat tissues [6].

When a proposed antenna was submerged in to oil it was be coated with a thin plastic insulating layer to protect the voltage network analyzer cable connector and antenna connector. A plastic bowl with dimensions of 80mm x 80mm x 25mm was used as a container for soybean oil, during the measurement of proposed antenna. The antenna was placed at 5mm to 8mm from the top of the oil container.



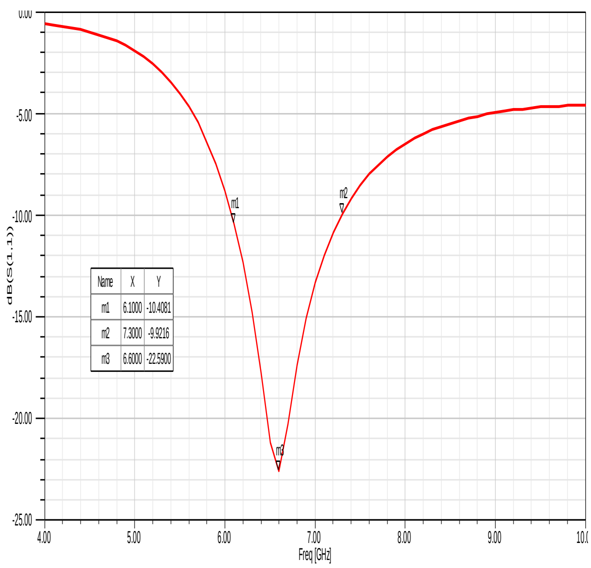
(a) (b)

Fig. 2. Setup of designed antenna (a) Simulation in oil and (b) Measurement in soybean oil.

IV. RESULTS DISCUSSIONS

The simulated and measured return losses of the proposed antenna in free space environment and soybean oil are shown in Figure 3 and 4. The simulated bandwidth of proposed antenna lies 6.1 GHz to 7.3 GHz and measured lies is 6.5 GHz to 8.9 GHz in free space environment. The simulated bandwidth of proposed antenna lies in 4.3 GHz to 5.5 GHz and measured bandwidth lies is 4.4 to 6.8 GHz in lossy environment and they have good agreement. The simulated gain of the antenna is 1.6 dBi in free space and 3.8 dBi in soybean oil, which indicates that the designed antenna can perfectly operate in free space and lossy environment for WBAN applications. The VSWR of the proposed antenna is less than 2 in free space and soybean oil for good performance.

Fig. 3(a) Simulated reflection coefficient S_{11} of proposed antenna in free space environment.



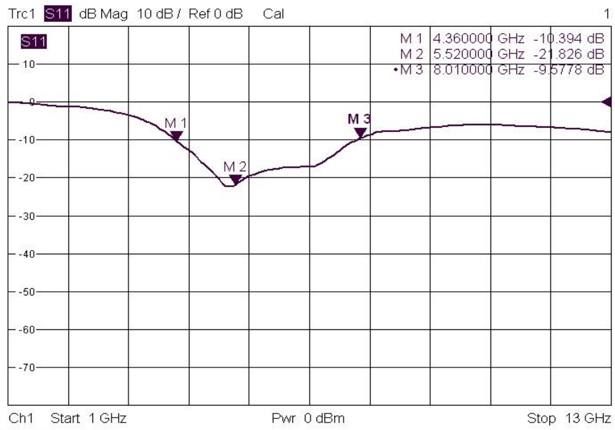


Fig. 3(b) Measured S_{11} in free space environment.

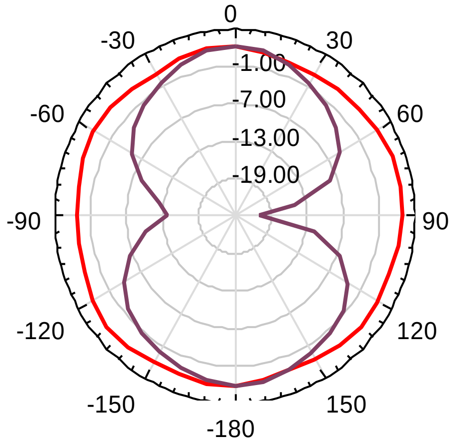


Fig. 5(a). Radiation pattern of proposed antenna at 6.6 GHz in E-plane at $\phi = 0^0$ and 90^0.

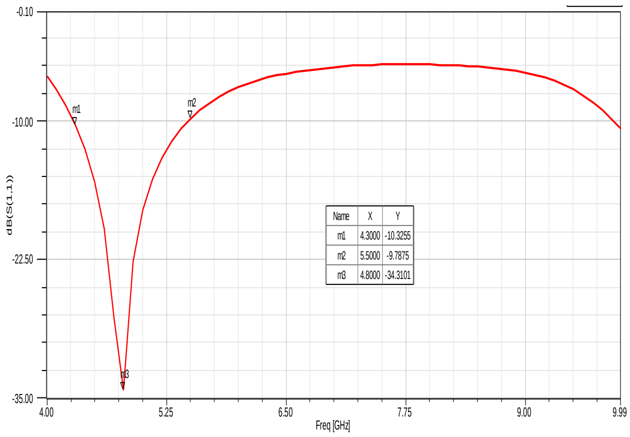


Fig. 4(a). Simulated S_{11} of the proposed antenna in soybean oil.

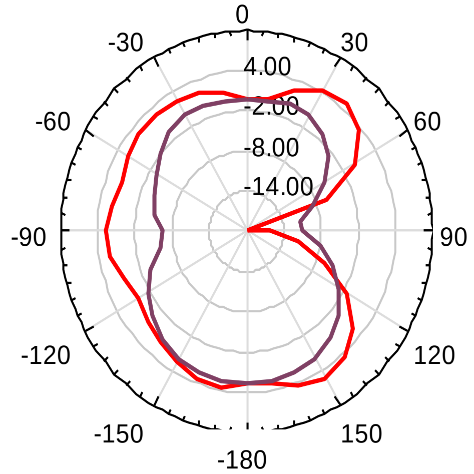


Fig. 5(b) Radiation pattern at 4.8 GHz frequency in E-plane at $\phi = 0^0$ and 90^0.

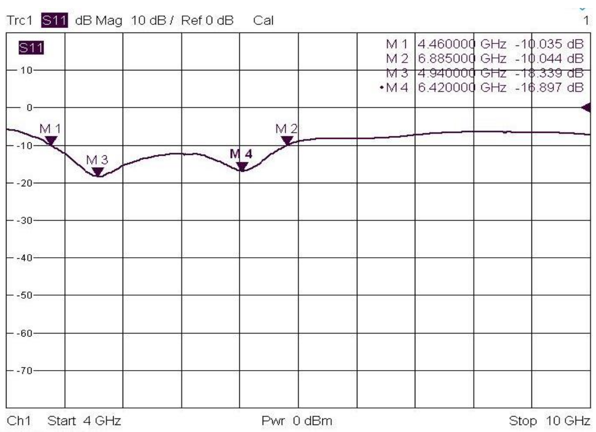


Fig. 4(b) Measured S_{11} of proposed antenna in soybean oil.

From the above figures it is found that the resonant frequency is reduced when the antenna submerged in to oil as compared to free space environment. The radiation pattern of the proposed antenna is also shown in Figure 5 (a) at 6.6 GHz and Figure 5(b) at 4.8 GHz frequency. The radiation pattern of proposed antenna is omni-directional, which receives and transmits physiological parameter's information from human body.

Figure 6 (a) and (b) shows the simulated gain of the proposed implantable antenna in free space environment and soybean oil. The gain of the antenna is 1.6 dBi and 3.8 dBi achieved at 6.6 GHz and 4.8 GHz which is acceptable to perform antenna.

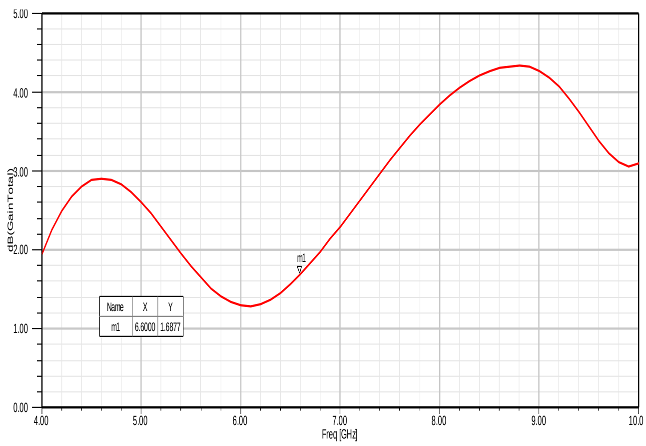


Fig. 6 (a) Simulated gain of proposed antenna in free space.

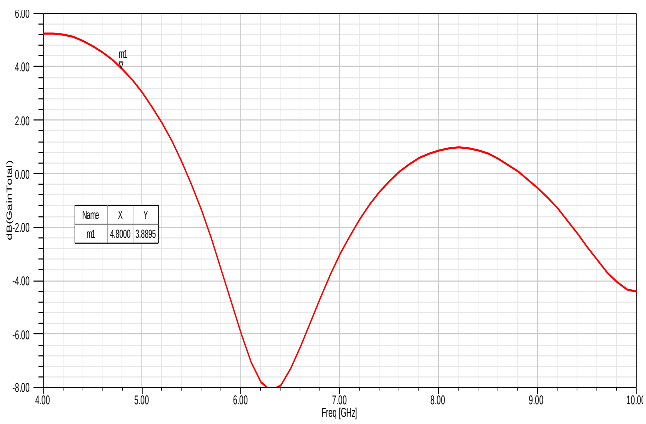


Fig 6 (b) Simulated gain of proposed antenna in soybean oil.

From the above results it is clear that the proposed compact WBAN antenna is able to operate in wireless medical applications as an implantable device to receive and transmit the signals from human body due to its wide bandwidth, compact size, low gain, good VSWR (less than 2) and omni-directional radiation pattern.

V. CONCLUSIONS

A compact printed antenna has been presented for Wireless Body Area Network (WBAN) system as implantable applications. The proposed antenna was successfully operated at Ultra wideband frequency from 4.3 GHz to 6.8 GHz range. The overall dimensions of the proposed antenna were 13 mm x 13 mm x 1.6 mm, which is suitable for implanted in-body for measurement the human physiological parameters. Measurements were successfully done and were found in good agreement, in free space and lossy environment. The simulated gain of presented antenna is positive and radiation loss is >-10 dB is obtained. The operating bandwidth of designed antenna is 2.4 GHz and VSWR < 2 is obtained in operating frequency range for well performances for implantable device.

The radiation pattern is omni-directional, which can receive and transmit information from various directions to the body The small physical size and good quality performance of the proposed antenna is suitable for applications in wireless implantable communication system.

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