Compact Dual-Band Implantable Antenna for E-Health Monitoring

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***Abstract*— This work presents a compact dual-band Planar Inverted F-antenna (PIFA) antenna useful for E-health monitoring and wireless sensors systems. The antenna operates in the Industrial Standard and Medical (ISM) and Wireless Medical Telemetry Service (WMTS) bands. It offers a compact size with dimensions 12.6 × 8.5 × 2.4 mm^3. Two different simulators have been used to verify the results. The proposed antenna performs well in the presence of a bio-compatible insulator (BCI) material.**

Keywords—E-Health; ISM Band and WMTS Band; Implantable Antenna; Bio-Compatiable Insulator

I. Introduction

An active medical implant is an electronic device surgically implanted inside a human body or an animal. Implants have been developed to treat a diverse range of medical conditions, including pacemakers for cardiovascular disorders, cochlear implants for the hearing impaired and automated implantable medicine pumps to assist with conditions requiring frequent delivery of intravenous drugs.

Most implants require a communication link with the outside world in order to monitor the patient's condition and to facilitate periodic device reprogramming. Ongoing maintenance is also required, such as monitoring the condition of the device's internal battery. Once it has been implanted, the device is not removed again for maintenance or battery replacement unless absolutely necessary, as to do so requires the patient to undergo further surgery [1].

Once the implant is operated in to the body, its job starts, which is to communicate with the outside world. Due to health reasons and feasibility of the system the in vivo implant needs to communicate wirelessly with the transmitter and receiver outside. In the early days this communication was carried out by low frequency inductive communication between the transmitter and the receiver. However, this method had its limitations. For example, the data rate was low and the measurement probe had to be placed directly on the patient's skin in order to create an effective communication link. This required the presence of a well-trained medical professional.

An alternative to this method is the electromagnetic radio signal. This method is much more feasible and comes with many benefits, unlike the inductive coupling. The range of communication increases. The patient can be monitored over long distances, which saves time by avoiding unnecessary visits to the clinic. In order to establish these links frequency spectrums are defined. The Industrial, Scientific and Medical (ISM), as the name suggests, is a frequency band reserved for industrial, scientific, and medical purposes. There are other communication devices working in the same range which can cause interferences due to powerful emissions and disrupt radio communication. Therefore, these devices are limited to certain band of frequencies. Wireless Medical Telemetry Service (WMTS) band has been introduced as another band specifically for medical applications. It works in 608-614 MHz, 1395-1400 MHz and 1427-1432 MHz bands. However, these band are not internationally agreed upon, so the devices produced in one country cannot be freely used in another country.

With the development of technologies different techniques are introduced to design an antenna for that can give different frequency response. Either the antenna will follow a wide band [2] or it will work in a multiband scenario. [3]. Multiband seems to be a good option that can cover the two medical bands. Using multiband antennas, the chances of interference with other commercial bands can also be avoided [4].

One technology that is mostly used [5] describes the design of an implantable Planar Inverted-F Antenna (PIFA) for the use with a Transcutaneous Energy Transfer (TET) system, which operates in the MedRadio band at 403.5MHz. It is suitable for implantation depths of more than 20 mm. Different optimization techniques such as particle swarm optimization and genetic algorithm are used in [7] to design defected ground plane structures in order to improve the bandwidth and achieve a dual band resonance for medical applications.

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The most important part of any wireless system is the antenna design. Since, the wireless systems need to be implanted into a human body. The devices are mostly small in size, which obviously means a small antenna. For this purpose, a lot of research is being carried out in the field of antenna design to minimize the antenna size as much as possible. A similar kind of work is presented in this report. A planer Inverted-F antenna (PIFA) is presented that is optimized to work in the ISM and WMTS bands.

II. ANTENNA DESIGN GEOMETRY

The main objective in designing an implantable antenna is that it should offer small size with good resonance and omni-directional radiation characteristics. From the literature review of various designs [6-8] and as per our working frequency requirements, we agreed upon using the Planar Inverted F-Antenna (PIFA). The general working principle of PIFA is shown in Fig.1 [9]. It consists of a large ground plane, which can be beneficial to the electronic components placed below the antenna from the fields generated by the antenna. The planar patch or resonating plate is above the ground plane at a certain height h. The resonance of the planar plate is about quarter wavelength *($\lambda/4$)* due to the shorting pin W. The position of the feed controls the input impedance of the patch which is placed between the open and the shorted end. Distance between the feeding point and shorting pin (D) is used to control the impedance of the PIFA. To increase impedance of the antenna the feed is placed away from the shorting pin and moved closer if a low impedance is desired. The resonant frequency of the PIFA depends on W. If $W=L2$, then the shorting pin runs the entire width of the patch. The resonating plate is placed on a certain substrate with certain permitivity ε_r and loss tangent $\tan\delta$.

Fig.2a shows the configuration of the proposed PIFA implantable antenna. It consists of a substrate made of FR4 material having ε_r = 4.4 and $\tan\delta$ = 0.002 with height H_{sub} = 2.4 mm. Bottom side of the substrate consists of finite ground plane while the top side contains the resonator PIFA element. The size of the substrate and ground plane, made with copper, is L_{sub} x W_{sub} = 12.6 x 8.5 mm^2. The top side of the substrate has a slot introduced in the copper resonator. The shape of the slot is that of an inverted F. The dimensions of the slot are W_{slot} = 1 mm and $L_1+L_2+L_3$ = 11.5 + 6 + 4 = 21.5 mm. The antenna is excited via a discrete coaxial port placed next to the shorting strip. The shorting strip has dimensions L_{strip} x W_{strip} = 2.4 x 0.5 mm^2 and is on the edge of the PIFA resonator. The width of the shorting pin controls the impedance of the PIFA antenna which in our case is matched to 50 Ω.

Fig.2b shows the proposed implantable antenna enclosed in bio-compatible insulator (BCI) and then inside a replica of human skin. These BCI assist the implantable antennas to work properly by avoiding metallic oxidation and short circuits form the tissues inside the human body. BCI acts an electromagnetic interference shield [10]. The dimensions of the BCI material is L_{bio} x W_{bio} = 17 x 12 mm^2 and height of 4.4 mm. The permitivity of the BCI material at the 1.4 and 2.45 GHz is 2.1 with electrical conductivity of 1.6 S/m [11-12]. The antenna with the BCI material is then placed inside the human skin phantom to emulate the simulations accurately. The phantom is subdivided into many layers of skin, fat and bone with total height of 11 mm. The dimensions of the phantom are $L_{phantom}$ x $W_{phantom}$ = 30 x 15 mm^2. The dielectric constant of the phantom material used is 52.7, permeability 1, and electrical conductivity of 1.7 S/m [13].

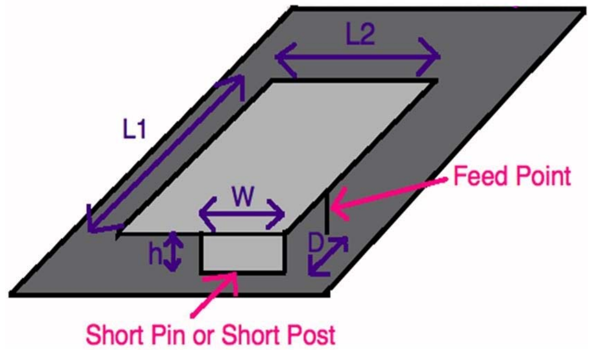
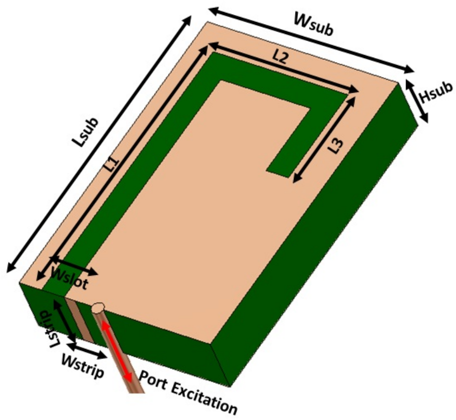
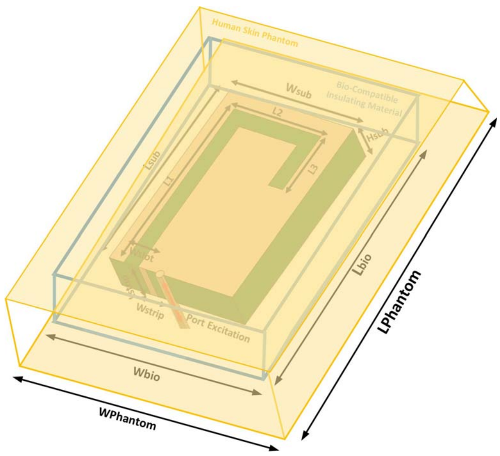


Fig.1 General PIFA design [9]



(a)



(b)

Fig.2 (a) Dimensions of proposed PIFA antenna (b) PIFA design enclosed in bio-compatible insulator and human skin phantom with relevant dimensions.

III. RESULTS AND DISCUSSION

The proposed implantable antenna was simulated in a commercially known electromagnetic simulator, Computer Simulation Tool (CST). The antenna produced return loss parameters as shown in Fig.3. Dual band resonance was seen at 1.4 GHz and 2.45 GHz in the WMTS and ISM band. To confirm the results another simulator HFSS was used. Both results agreed on the simulated design. Another design parameter of antenna is the directivity.

The directivity of the antenna can be analyzed in two principle planes. A PIFA in general has an omni-directional radiation pattern. The 3D radiation pattern of the antenna is shown in Fig. 4a and Fig.4b at 1.4 GHz and 2.45 GHz, which confirms omni-directionality. The antenna achieves directivity of 2.78 dBi and 3.29 dBi respectively. Table. I shows the results achieved through the antenna design.

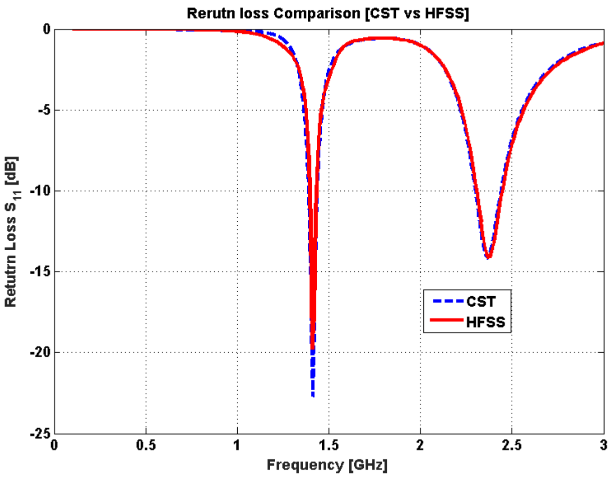


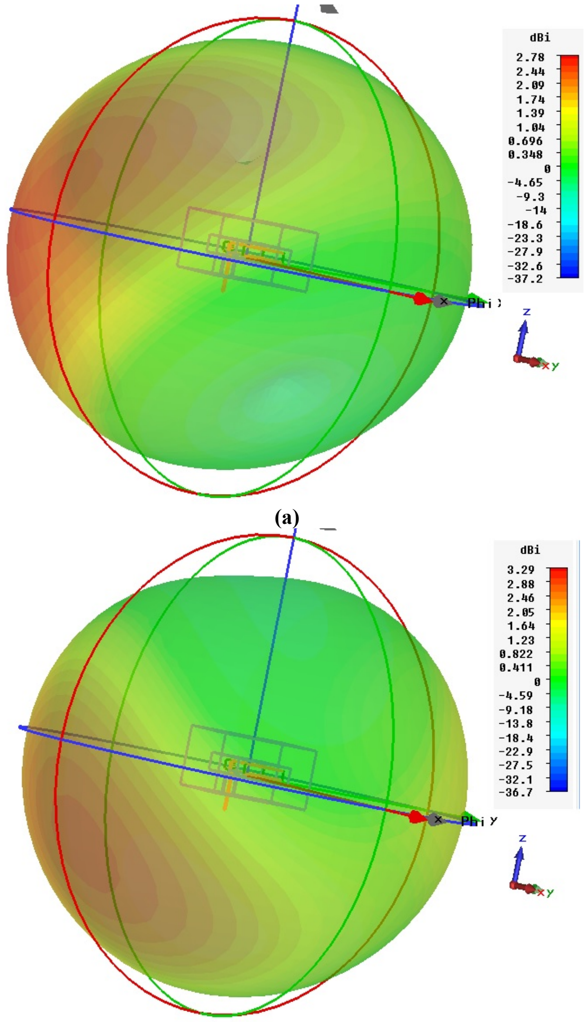
Fig.3 Dual-band return loss S_{11} of proposed PIFA antenna with comparison done between CST and HFSS

TABLE I. ANTENNA DESIGN SIMULATION RESULTS

Resonance frequency (GHz)	1.4	2.45
Directivity (dBi)	2.78	3.29
Impedance bandwidth (%)	3.5 %	8.6 %
Return Loss (dB)	-24.5	-14.5

IV. CONCLUSION

A compact dual-band antenna is presented for E-health monitoring systems. The radiation pattern is omni-directional as is required for most of the monitoring and wireless sensors in the E-health system for transmit and receive purposes. The antenna is simulated with a BCI to take into account its effect and protect it from the surrounding environment. The results achieved by the antenna makes it a viable candidate for implantable and bio medical applications.



(b)

Fig.4 3D radiation plot (a) Directivity at 1.4 GHz (b) Directivity at 2.45 GHz

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