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Design of an implantable antenna for biomedical applications

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Abstract
This paper proposes the design and investigation of the implantable antennas for biomedical applications. The designed antenna is intended to operate under Industrial, Scientific and Medical (ISM) band that has a frequency band of 2.4-2.48 GHz. The proposed antenna is described by its compact size and higher accuracy in contrast to preceding implantable antennas. The proposed antenna has overall dimension of 13×16×1.035 mm^3. The antenna is embedded in Teflon substrate which is biocompatible with dielectric constant of 2.1 and a loss tangent of 0.00028. Computer Simulation Technology (CST Studio Suite) software is used to design and analyse the proposed antenna. The proposed antenna shows good performance parameters like lower return loss, better gain and perfect impedance matching.

Keywords: ISM band, implantable antenna, biomedical application, biotelemetry

1. Introduction
In today's world implantable biomedical antenna plays an important role. It is very essential for medical applications such as Radiometer, Intracranial pressure monitoring, Pacemaker, Endoscopy and Sugar level check. Implantable devices are capable of communicating with external devices using wireless technology. These implantable antennas own some features such as small size, wireless operation, better accuracy and efficiency. Biomedical antennas are developed to check patient's health and for tracking abnormalities in human body.

Implantable antenna provides a wireless system for detection. Due to wireless system doctor can easily diagnose the problem and it provides faster result than in physical mode. The antenna is critical for ensuring stability of wireless powering and connectivity with implantable devices [2]. It allows for constant surveillance of the patient's wellbeing. It provides patient's safety and it is more efficient. The implantable antenna should be designed under "Medical Implant Communications System" (MICS) and "Industrial, Scientific and Medical (ISM) bands" [1]. MICS is a short-range transmission network with low operating power, working at 401-406 MHz frequency range. This band is used to communicate data that aids in the diagnostic or therapeutic functions of medical implant devices. "The ISM band operates at a frequency of 2.4-2.48 GHz" [12].

In this paper, Rectangular microstrip antenna patch loaded with F shaped slot is proposed biomedical application is designed in the range of 2.4-2.48 GHz. The suggested antenna has an overall dimension of 13×16×1.035 mm^3. The main benefit of the proposed system is that it uses little space and improves antenna performance. The antenna is constructed first, and then it is tested with a single layer of muscle. The parameters of the antenna are measured such as return loss, Directivity, gain, radiation pattern and VSWR.

2. Related works
The medical field IoT has the ability to improve healthcare by tracking vital signs. Data from a patient's screening instruments can be sent directly to their medical records. This reduces the need for data entry, which will usually be performed by a medical practitioner, in addition to the chance of human error that it entails. Here are summarised key points about implantable antennas from few literatures.

"T. Karacolak, A.Z. Hood and E. Topsakal" [4] proposed an implantable antenna operates at dual frequency band for monitoring glucose level. For in vitro testing of implantable devices, they used a skin mimicking gel. The substrate used is Rogers RO3210. The proposed antenna possess a bandwidth of 35.3% in MICS and 7.1% in ISM bands.

"Soheil Hashemi and Jalil Rashed-Mohassel" [5] designed two types of size reduced dual operating band antenna. One of the antenna is a comb antenna and another one is a meander type antenna. They have used Rogers 3003 and 3210 substrates with the aim of achieve better gain. The antenna was first designed in a human phantom model and the gain achieved from two antennas are 16 dBi and -23 dBi.

"Wu Q-H, Xuan X-W, Wang W, Li K, and Zhao H-B" [8] A miniaturised implantable planar inverted-F antenna for biotelemetry applications was proposed. Because of its high biocompatibility and ability to mitigate radiation, alumina substrate is chosen for this design. At 2.45GHz, the planned antenna obtained -4.5dBi gain.

"N. Abbas *et al*.," [9] used a material with high dielectric constant called Rogers ULTRALAM substrate. They have designed a compact wide band implementable antenna and achieved a gain of -15dBi at ISM band. A circular wide band antenna is proposed here. The designed antenna is tuned to operate for biotelemetry applications and a simulated bandwidth is about 420 MHz.

"S. Bakogianni and S. Koulouridis", [7] designed a miniaturised Med Radio implantable antenna. Here the intention is to design antenna for use in the Medical Device radio communications (MedRadio) Services band at a frequency range of 401-406 MHz. Two dipoles of the same physical size but different geometry are formed. Rogers RT Duroid 6010 substrate is preferred here. Initially a straight dipole antenna is employed. The open folded dipole antenna (FDA) and the meander line configuration (MLA) have achieved gain of -28dBi and -27dBi respectively.

3. F slot loaded antenna design

The proposed antenna is first tested using human phantom models with sufficient electrical conductivity and relative dielectric permittivity, such as skin and muscle. A CPW-fed implantable antenna operating in Industrial, Scientific and Medical (ISM) band (2.4-2.48GHz) is being developed for biomedical applications. A Coplanar Waveguide (CPW) feed is known to reduce antenna's back radiation. It may also respond to high frequency ranges. The proposed antenna geometry occupies the area of 13mm×16mm×1.035 mm which is depicted in Fig. 1. The developed antenna is embedded in a Teflon substrate of thickness 1 mm with dielectric constant = 2.1 and tangent loss (tan δ) = 0.00028. F shaped slots and I slits are added inside the ordinary patch antenna to achieve low return loss and high gain. The space between Coplanar Waveguide feed and ground is 0.5mm.

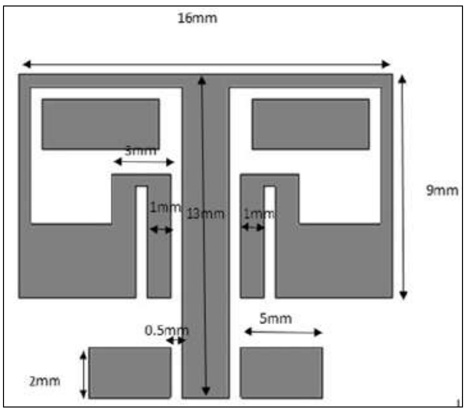

Fig 1: F slot loaded antenna geometry

The unidirectional radiation pattern of the antenna is obtained by planar structure that changes the current pathway and direct outside current. This initial design ensures the compactness of the medical antenna.

"The Monopole antenna etched with F shaped slots and slits can be equivalent to folded loop antenna" [7]. This method is carried out to cancel backward radiation and to achieve boresight radiation. A basic phantom model is chosen as seen in Figure 2, with 4 mm of skin, 4 mm of fat, and 8 mm of muscle since the antenna is intended for implantable use, it cannot be simulated in free space.

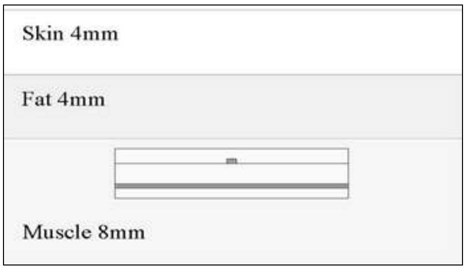

Fig 2: Human tissue model

4. Simulation of F slot loaded antenna

Table 1 shows the numerical values of permittivity and conductivity for all tissues used in our models. The tissue's permittivity (ε) and conductivity (σ) values change with frequency.

Table 1: Permittivity and conductivity of human tissue

Frequency (GHz)	Permittivity (ε_r)	Conductivity (σ)
2.0	53.29	1.45
2.4	52.79	1.70
2.45	52.72	1.73

F shaped slot is etched carefully on one side and flipped on other side to achieve resonance at operating frequency. Slits are generated at the bottom side in parallel with F slots to change current path. The antenna layout a designed in CST is software is depicted in Figure 3.

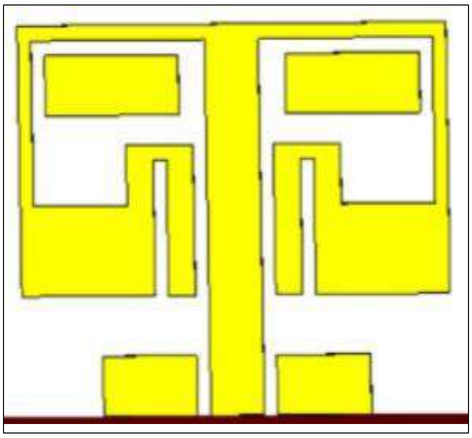

Fig 3: F slot loaded antenna geometry

S_{11} of the S-parameter provides the return loss value of the proposed system. "The return loss parameter represents the amount of power is reflected from antenna and referred to as reflection coefficient". Figure 3 depicts the return loss obtained from the F slot antenna as –30dB at the resonant frequency 2.4 GHz.

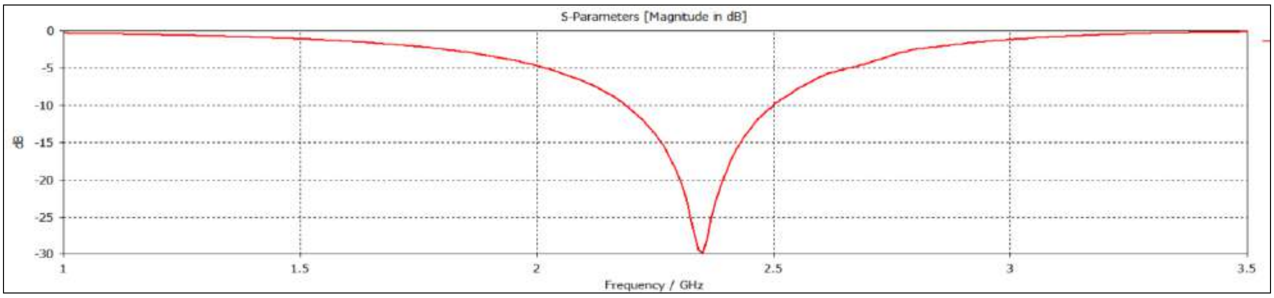

Fig 4: S11 response of the proposed antenna

The simulated radiation pattern of the antenna is displayed in Figure 4. The far field radiation intensity ensures the omnidirectional coverage of F slot antenna.

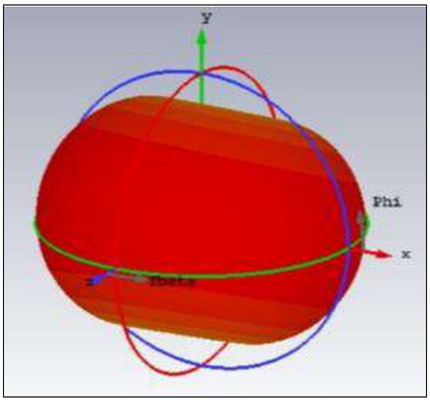

Fig 5: 3D view of the radiation

The main lobe magnitude states 1.4 dBi and an angular width of 90.1 degree which is pointed towards broadside direction in H Plane as stated in Figure 5. The antenna's directivity is approximately 16.07dBi. The antenna's gain is 12 dBi, with a top frequency of 2.45GHz.

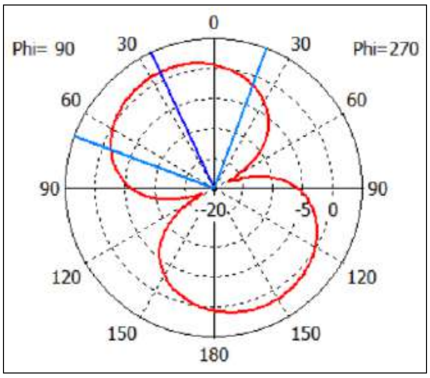

Fig 6: Far field pattern-H plane

Figure 6 portrays the principal plane pattern of the F slot antenna that confirms the radiation pattern is bidirectional.

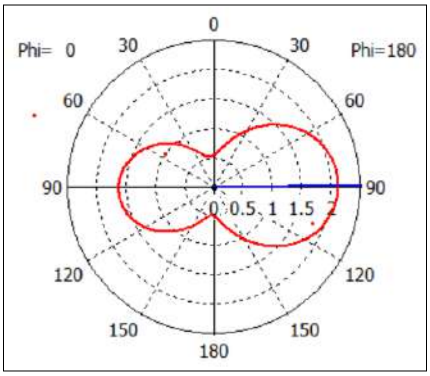

Fig 7: Far field pattern-E plane

The Voltage Standing wave ratio (VSWR) is also analysed using CST. To obtain perfect impedance matching to a transmission line the VSWR value should lie in the range of 1 to 2. Here the VSWR achieved is about 1.6 at 2.45 GHz shown in Fig. 7.

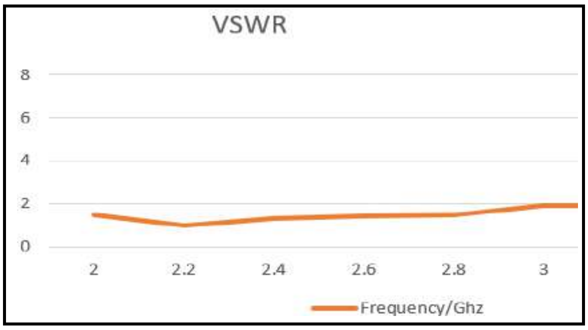

Fig 8: VSWR of F slot antenna

Due to body conductivity, the Gains of implantable antennas are usually in negative values. Our proposed antenna achieves around -10 dB at operating frequency.

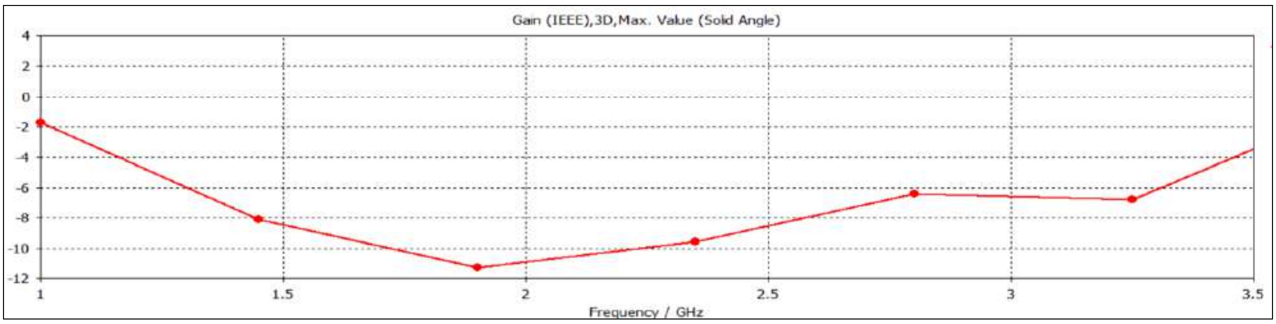

Fig 9: F slot antenna gain over frequency

5. Conclusion

The implanted monopole antenna suitable for biomedical applications was designed and simulated with CPW feed. The total dimension of the antenna is about 13 × 16 × 1.035 mm^3 and it is attained by utilising F shaped slot in patch structure. The antenna suggested in this paper meets out optimum performance parameters like return loss, Gain, VSWR and radiation pattern. By comparing with many previous implantable antennas this antenna provides better miniaturization and suitable performance. Gain is better as the Teflon substrate has superior dielectric constant that makes the antenna appropriate for medical and wireless biotelemetry applications at ISM Band.

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