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Implanted helical dipole antenna for UHF band applications

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1. Introduction

In the early stage of development, implanted medical devices, which use inductive coupling for communication, could only transmit their data within a few centimeters range [1],[2]. In the recent years, telecommunications has brought implantable device systems are required to enable longer bidirectional communication between the implanted device and an external device [1],[3]. The external devices could be a home monitoring device or portable equipment, that provides the patient more mobility. Through either approach, the patient or the health care provider (e.g., the physician) could benefit from timely and ease of access to important patient medical information via a networked connection [3]. Hence, small antennas for implantable devices are essensial components to the monitoring systems to provide wirelessly communication between a patient and an access point. This paper proposes an implanted helical dipole antenna for an impantable device in wireless patient monitoring applications. The design is considered that by only using a syringe the device can be embedded into the human body for simplicity purpose. The antenna is operated in UHF band 924 MHz as consideration Indonesian frequency allocation for RFID applications [4]. The design consideration, antenna structure and its calculation results are provided in this paper in the following sections.

2. System design consideration

The system design considerations have a key role for implementation in specified applications, such as power consumption, communication range, data transfer rates, environment, size and cost and security [3]. As for the patient remote monitoring, the power consumption and data rate are dependent to signal bandwidth of the specified information, such as body temperature, respiration rate, blood pressure, ECG, EEG, etc [2]. In order to enable a communication between the separated devices in free space medium, a link budget should be calculated [5]. In this paper, it is assumed to limit the bit rate up to 0.5 Mbps and communication range within indoor's room in few meters without any obstacles present. The link budget for patient monitoring system is described in Table 1. As a result of the calculation, the minimum gain of the implanted antenna is approximately -35 dBi in order to communicate with an access point, which is separated by 10 m.

3. Antenna structure

The proposed antenna structure is depicted in Fig. 1. The antenna is helical dipole type aiming at miniaturized construction, possibility use in syringe injection, and integration with chip, battery, or specific circuits within an insulator. The dimension of the antenna is 21.8 mm in length and 2.2 mm in diameter. The antenna is constructed by a 1.4 mm-diameter of 10-turns helical solid conductor each side, ended by a 2 mm conductor plate and insulated by a 0.2 mm silica hollow-insulator to avoid direct contact between the tissue and the conductor. The antenna is assumed as a model of the arm tissue (between the human shoulder and elbow). The size of the model is 310 mm × 60 mm × 60 mm. The human body-equivalent phantom is constructed by three different tissues, namely skin, fat, and muscle. The thickness of the tissues are 2 mm, 4 mm, and 54 mm for skin, fat and muscle, respectively. The permittivity and conductivity of the tissues are calculated by using an online calculator in [6] at 924 MHz. The electrical properties of the tissues is listed in Table 2. The antenna is inserted into the fat, close to the inner part of the skin by 2 mm from the surface. The detail of the construction in human model is depicted in Fig. 2.

4. Numerical calculation

The antenna is calculated by using the finite integration technique (FIT) in order to have several performance parameters such as *S* parameter, input impedance, radiation pattern, gain, and specific absorption rate (SAR) as well. Those parameters will be provided in the following section.

3.1 *S* parameter

The *S* parameter and input impedance of the antenna is depicted in Fig. 3. The antenna resonates at 924 MHz by -26.11 dB and has the bandwidth 13 MHz (VSWR < 2), which is sufficient in Indonesian RFID band. The input impedance at 924 MHz is 49.16 Ω and 4.97 Ω for the real and imaginary part, respectively. Moreover, in the operation bandwidth, the resistance value is almost flat characteristics close to 50 Ω, which is easier adjusted to the desired value when some other circuits are integrated to the antenna, such as chip and battery.

3.2 Radiation pattern and gain

The radiation pattern in two-dimensional plot is illustrated in Fig. 4. The view is divided into three main plane, namely sagittal (*xz*), axial (*yz*) and coronal (*xy*) plane. As for the sagittal and axial planes, the pattern is decreased at the border between the left and the right side of the model in Fig. 2, due to the presence of the tissue effects. However, the gain is above -30 dBi. In the coronal plane, the wave experiences slower propagation velocity due to the longer tissue depth, allowing the more reduced gain in both of the up-side and back-side of the arm tissue. However, in the up-side pattern, the gain is still more than -30 dBi, which is more than 10 m of the coverage.

3.3 Specific absorption rate (SAR)

The SAR calculation is based on the worst case, where the input power is set by 0.5 Watt rather than 25 µWatt, as consideration the leakage current from the circuit. When the calculation is based on 10g volume-averaged tissue of the partial body part, the peak SAR is 0.13 W/kg is obtained (Fig. 5), which is lower than the European standard limitation. In addition, the peak SAR is little bit higher by 0.32 W/kg when the 1g volume-averaged SAR is used for the calculation. Most of the high SAR value occur in the skin tissue, due to its high conductivity and broadside radiation pattern of the antenna. As for the 1g volume-averaged SAR, it is more localized around the antenna rather than the 10g volume-averaged SAR.

4. Conclusion

This paper proposes a simple helical dipole antenna for implanted bioinformatic applications in patient remote monitoring. The antenna is quite small enough in UHF band with good performances in terms of *S* parameter, input impedance, bandwidth, radiation pattern and gain. The antenna has a gain for 10m short range communication with 13MHz bandwidth and 50Ω impedance. The peak SAR is also less than the standard limitation for both of the 10g volume-averaged SAR and the 1g volume-averaged SAR. In the future works, the measurement will be conducted to validate the calculation results.

Acknowledgment

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Table 1: Link budget for communication at 924 MHz

Transmitter		
Frequency (MHz) T_x power (μWatt) Feed loss (dB) Antenna gain (dBi) T_x EIRP (dBW)	Implanted antenna	924 25 0 - 35 - 81.02
Medium Transmission		
Distance (m) Free space loss (dB) Atmospheric loss (dB) Propagation loss (dB)	Air medium	10 51.76 0 51.76

Receiver		
Antenna gain (dBi) Feed loss (dB) Ambient temperature (K) Noise figure (dB) Noise spectral density N_0 (dB/Hz)	Dipole antenna	2.15 0 298 3.5 -199.88
Calculation Results		
Bit rate (kbps) Bit error rate E_b/N_0 (dB) Deterioration in system (dB) Total link C/N_0 (dBHz) Required C/N_0 (dBHz) Margin (dB)		500 1×10^{-5} 9.6 2.5 69.25 69.09 0.16

Table 2: Electrical properties of tissues at 924 MHz

Tissue	Electrical properties	
	Permittivity	Conductivity
Skin (dry)	41.284523	0.874705
Fat	5.458249	0.051615
Muscle	56.824448	1.004436

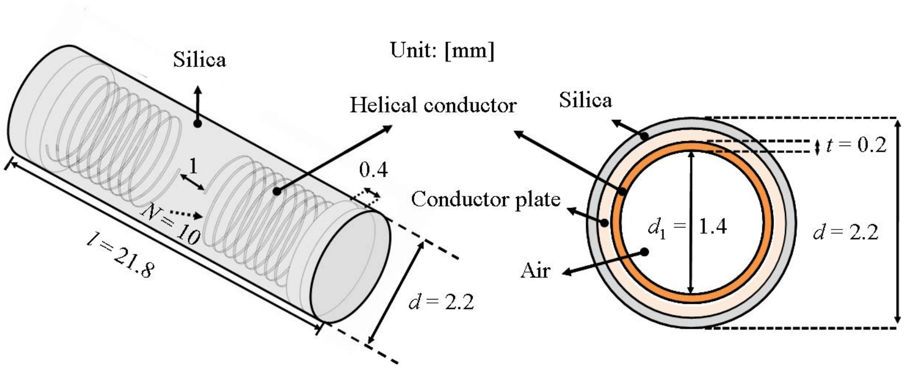


Figure 1: Antenna structure

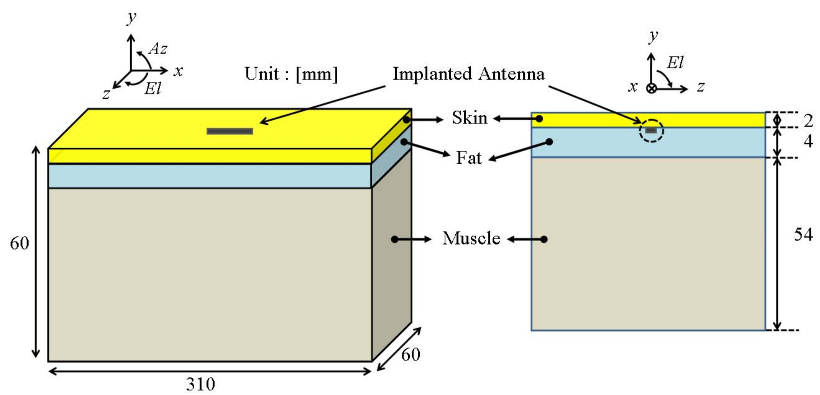
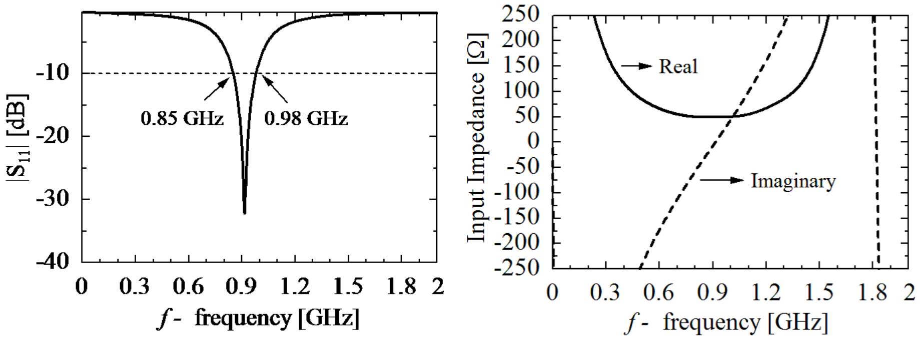
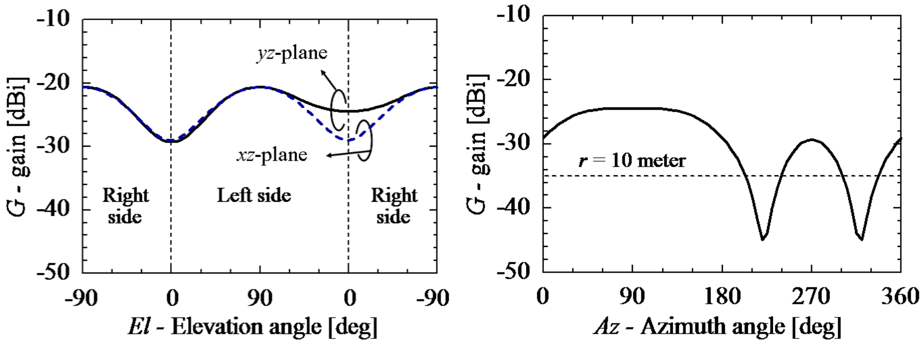


Figure 2: Antenna in tissue structure



(a) (b)

Figure 3: S-parameter (a) and input impedance characteristics (b)



(a) (b)

Figure 4: Gain performance in (a) sagittal (*xz*) and axial (*yz*) plane (b) coronal (*xy*) plane

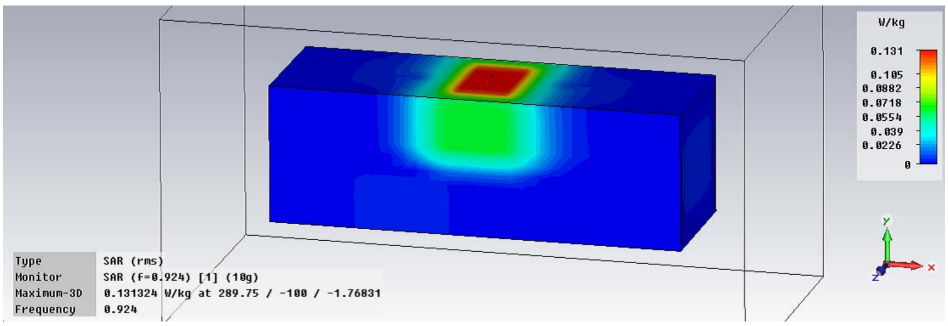


Figure 5: Result of 10g-averaged SAR calculation at 924 MHz

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