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A Helical Folded Dipole Antenna for Medical Implant Communication Applications

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***Abstract* — Currently, most of implanted medical devices are using inductive coupling for communication, which leads to difficulty in transmitting medical data records for several meters range. In order for the implanted device is able to be used in longer range transmission, the device is wirelessly transmitted in the form of electromagnetic signals. This initiates us to study on a patient home monitoring system, in which the external devices such as portable equipments will provide a benefit for healthcare provider in accessing the important patient medical information via a networked connection. Because of this reason, an electrically small antenna for implantable devices is very essential components in monitoring systems to provide wirelessly communication between a patient and an access point. In this paper, a helical folded dipole antenna for an implantable device is proposed for wireless patient monitoring system. The implanted device is assumed to be applied by a syringe injection allowing to the device is simply injected into the human body. The proposed antenna is operated in UHF band 924 MHz, as a band of Indonesian RFID applications. The antenna is quite small in comparison to the band operation (*ka*≈0.08). Sufficient electrical performances are obtained such as reflection coefficient, impedance bandwidth, radiation pattern and gain. According to the link budget analysis, the proposed antenna has adequate gain within 10m transmission range by 225 MHz bandwidth (VSWR ≤ 2).**

***Index Terms* — Implanted antenna, helical dipole, medical devices, patient monitoring system, UHF band.**

I. Introduction

The development of wireless technology for health sector currently has greatly attracted both of academics and industrial researchers as the needs of the world and associated with rising healthcare costs and the demand for hospital resources [1]. One of the wireless medical technologies that is presently being developed is a medical implant communication. At the beginning stage, an implanted medical device uses an inductive coupling for such a communication, which it could only transmit their data within a few centimeters range only [2]–[4]. Nowadays, telecommunication technology has brought medical implant communications to be used for longer transmission range between the implanted device and an external device [2],[4]. The external devices such as home monitoring devices or portable equipments will provide the healthcare provider (e.g., the physician) could take benefit in accessing to essential patient medical information via a networked connection [2]. Since it relies on wireless technology, realization of the system is definitely required a small antenna inside the implanted devices as a front-end part of the patient monitoring to connect with an external access point. Hence, in this paper, a simple configuration of a helical folded dipole antenna is proposed for an implanted device aiming at wireless patient monitoring system. The device is assumed to be applied by a syringe injection, allowing to the device is simply injected into the human body. The antenna is operated in UHF band (924 MHz), as a band of Indonesian RFID applications [5]. The proposed antenna configuration and its electrical performances are described in the following sections.

II. System Consideration

Some important parameters for establishing a communication link in particular application, such as power consumption, communication range, data transfer rate, environment, size and cost, and security are required to be considered [3]. In the case of patient monitoring system, power consumption and data rate are dependent to signal bandwidth of the specified information, such as body temperature, respiration rate, blood pressure, blood glucose level, ECG, EEG, and others [2]. Communication link between the implanted devices and an access point via free space medium has been calculated in [6] for this study. It is assumed that the limit of the bit rate is up to 500 kbps and communication range is within indoor's room for several meters without any obstacles is present. The minimum gain of the implanted antenna is approximately −30 dBi for establishing communication within 10m of distance. In addition, the link margin is still within 8 dB for unexpected deterioration purpose due to material attachment in-/on- the human body such as antenna's capsulation, clothes materials, water absorption, interferences, etc [7].

III. Antenna Configuration

The proposed antenna configuration is depicted in Fig. 1. The antenna is a helical wire dipole type, at which both ends of the wire are folded to obtain a miniaturized structure, allowing for putting it into a syringe injection. It is also possible to be integrated with chip, battery, or specific

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circuits within an insulator. The dimension of the antenna with insulator is 38.2 mm in length and 4.5 mm in diameter for easiness in fabrication process. However, the antenna itself is quite small by 36mm × 1.6mm (*length*×*diameter*). In order for the antenna is able to be fabricated with insulator, it is insulated by a 1 mm ABS hollow-insulator to avoid a direct contact with the tissue phantom. The antenna is placed in an arm tissue model. The size of the model is 310mm × 60mm × 60mm. The numerical phantom consists of three different tissues, namely skin, fat, and muscle, referring to some studies [8], [9]. The thickness of the tissues is 2 mm, 4 mm, and 54 mm for skin, fat and muscle, respectively. The permittivities and conductivities of the tissues are calculated based on the Federal Communications Commission (FCC) [10] at 924 MHz. The values are listed in TABLE I. The antenna is put into the fat, close to the inner part of the skin by 2 mm from the surface. The antenna construction inside the numerical model is described in Fig. 2.

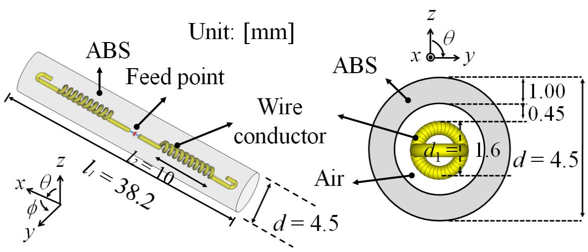


Fig. 1. A proposed antenna structure.

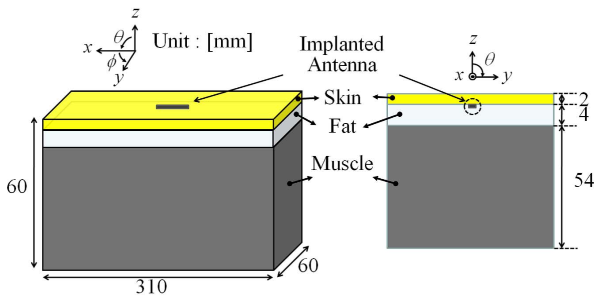


Fig. 2. The antenna is placed inside an arm tissue model.

TABLE I
ELECTRICAL PROPERTIES OF TISSUES AT 924 MHZ

Tissue	Electrical Properties	
	Relative permittivity	Conductivity [S/m]
Skin (dry)	41.284523	0.874705
Fat	5.458249	0.051615
Muscle	56.824448	1.004436

IV. CALCULATED AND MEASURED RESULTS

The antenna is numerically calculated by using the finite integration technique (FIT) for several performance parameters such as reflection coefficient, radiation pattern, gain, specific absorption rate (SAR) and temperature rise characteristics as well. However, only the three main basic parameters of the antenna are presented in this paper.

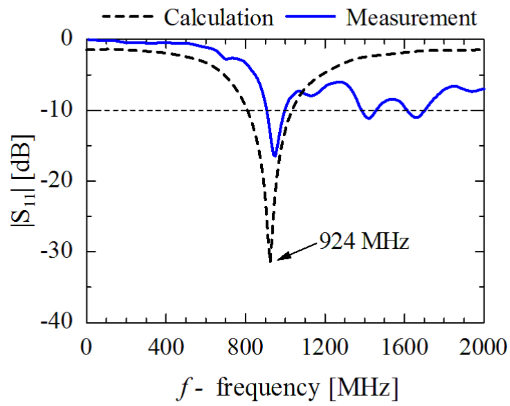


Fig. 3. The magnitude of reflection coefficient of the proposed antenna inside the phantom.

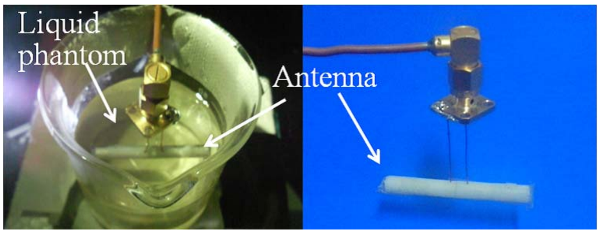


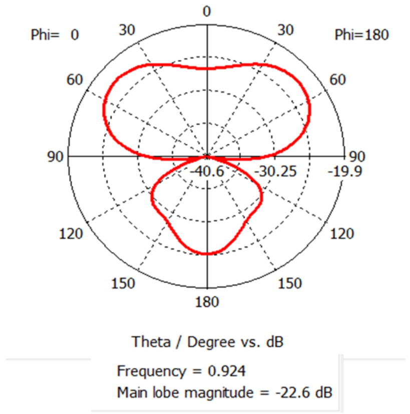
Fig. 4. View of the fabricated antenna and its measurement in a liquid phantom.

A. Reflection Coefficient

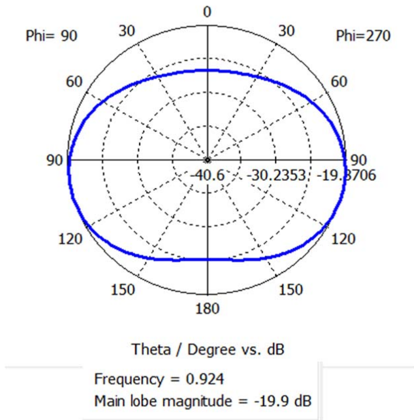
The magnitude of antenna reflection coefficient is depicted in Fig. 3. The simulation shows that the antenna resonates at 924 MHz by -31.35 dB with 225 MHz of the bandwidth (VSWR≤2). The antenna is measured inside a liquid phantom at 924 MHz, where the relative permittivity is 56.10 and the conductivity is 1.04 S/m. Based on the simulation, the input impedance of the antenna at the feeding point is (52.77 − j0.05)Ω, however, the measured result shows by (31.27 + j5.10)Ω at frequency 924 MHz. This shows us that besides the effect of the fabricated antenna itself, the phantom also significantly affects the antenna impedance. The fabricated antenna and its measurement view is shown in Fig. 4.

B. Radiation Pattern and Gain

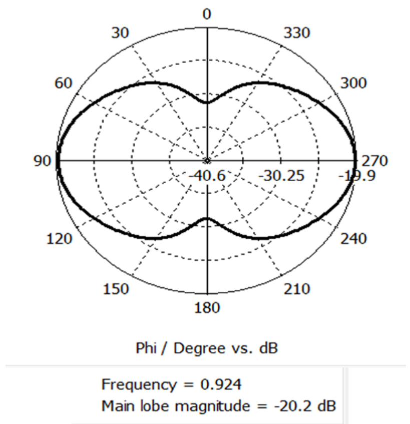
The simulated radiation pattern in two-dimensional plot is shown in Fig. 5. The view is divided into three main planes, namely coronal (*xz*-), axial (*yz*-) and sagittal (*xy*-) plane. The radiation pattern in coronal and axial planes of the upper-part of the model in Fig. 2, is slightly reduced due to the presence of the tissue at the left and right side of the antenna. The gain is deeply reduced around −20 dBi due to the lossy medium. However, the gain is still above −30 dBi, as a required gain for communication. Within −30dBi-beam coverage, the antenna beam covers more than 180° of the upper part of the arm model in coronal plane. As for the axial and sagittal planes, the −30 dBi-beam coverage is more than 360°, except at 0° and 180° of the sagittal plane. This because the wave experiences slower propagation velocity due to the longer tissue depth, allowing the gain reduces at around 0° and 180°. However, in general speaking, the gain is more than • 30 dBi, which is more than 10m of the coverage.



(a) *xz*-plane



(b) *yz*-plane



(c) *xy*-plane

Fig. 5. The simulated gain performance in (a) coronal (*xz*-) plane; (b) axial (*yz*-) plane; (c) sagittal (*xy*-) plane.

V. CONCLUSION

A helical folded dipole antenna has been proposed aiming at medical implant communication applications, specifically for patient monitoring system. The antenna is quite small in UHF band with good characteristics including the reflection coefficient, input impedance, bandwidth, radiation pattern and gain. According to the simulation results, the gain more than -30 dBi (10m communication distance) in the 180-degrees upper-part of the arm tissue is confirmed. The sufficient bandwidth also can be obtained. In addition, the antenna is validated by using a liquid phantom. As a result, the reflection coefficient agrees with the simulation result, eventhough the input impedance is still affected by the phantom environment. In the near future, the radiation pattern and gain will be measured in a physical phantom model and antenna system measurement test will be also considered.

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