A Simple Folded Dipole Antenna for Medical Implant Communications at 900 MHz Band

Basari#, Dony Canisius Sirait#, Fitri Yuli Zulkifli# and Eko Tjipto Rahardjo#

#Antenna Propagation and Microwave Research Group (AMRG),
Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia,
Kampus Baru UI Depok, 16424 Indonesia

***Abstract* — Nowadays, implanted medical devices that are using inductive coupling for communication, cannot be used for transmitting medical data in several meters range. This triggers us to study about implantable device systems in order for communications is enabled to be longer range by transmitting wirelessly electromagnetic signal. In this system, the external devices such as home monitoring device or portable equipment will provide the patient more mobility, and the patient or the health care provider could benefit from timely and ease of access to important patient medical information via a networked connection. Due to such advantages, small antennas for implantable devices are very important components in monitoring systems to provide wirelessly communication between a patient and an access point. This paper proposes a simple structure of a folded dipole antenna for an implantable device aimed at wireless patient monitoring applications. The implantable device is assumed to be used with a syringe injection, so the device can be simply embedded into the human body. The antenna is operated in UHF band 924 MHz, which is band of Indonesian frequency allocation for RFID applications. The antenna is small enough in this band with good performances such as *S* parameter, impedance bandwidth, radiation pattern and gain. The antenna has enough gain for more than 10m range communication with 250 MHz bandwidth (VSWR ≤ 1.5).**

***Index Terms* — Implanted antenna, medical devices, patient monitoring system, RFID, short-range communication, UHF band.**

I. Introduction

In the beginning stage of development, implanted medical devices, which use inductive coupling for communication, could only transmit their data within a few centimeters range only [1],[2]. In the recent years, telecommunications has brought implantable device systems are required to enable longer communication between the implanted device and an external device [1],[3]. The external devices could be a home monitoring device or portable equipment, which provides the patient more in mobility. Through this 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]. In order to realize this approach, small antennas for implantable devices are essential components to the monitoring systems to provide wirelessly communication between a patient and an access point. This paper proposes a simple configuration of a folded dipole antenna for an implantable 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, which is band of Indonesian frequency allocation for RFID applications [4]. The system design, antenna configuration and its calculation results are provided in this paper in the following sections.

TABLE I
LINK BUDGET FOR COMMUNICATION AT 924 MHZ

Transmitter		
Frequency (MHz)	Implanted antenna	924
T_x power (μWatt)		25
Feed loss (dB)		0
Antenna gain (dBi)		- 30
T_x EIRP (dBW)		- 76.02
Medium Transmission		
Distance (m)	Air medium	10
Free space loss (dB)		51.75
Atmospheric loss (dB)		0
Propagation loss (dB)		51.75
Receiver		
Antenna gain (dBi)	Dipole antenna	2.15
Feed loss (dB)		0
Ambient temperature (K)		290
Noise figure (dB)		3.5
Noise spectral density N_0 (dB/Hz)		-200.00
Signal Quality Performance		
Bit rate (kbps)		500
Bit error rate		1×10^{-5}
E_b/N_0 (dB)		9.6
Deterioration in system (dB)		2.5
Total link C/N_0 (dBHz)		74.37
Required C/N_0 (dBHz)		66.08
Margin (dB)		8.29

II. System Design

In the system design, some parameters are very essential to establish a communication link in particular application, 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 500 kbps and communication range within indoor's room in several meters without any obstacles present. The link budget for patient monitoring system is described in TABLE I. As a result of the calculation, the minimum gain of the implanted antenna is approximately −30 dBi in order for medical device can communicate with an access point, which is separated at least by 10 m. Moreover, the link margin is 8.29 dB, which is more than enough value for unexpected condition.

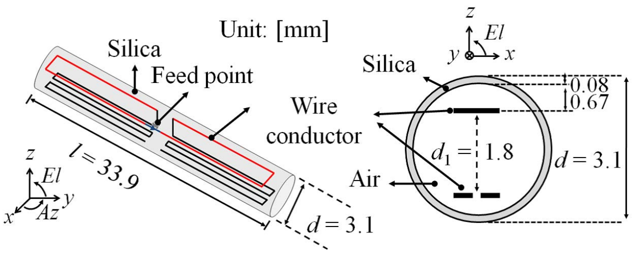


Fig. 1. A proposed antenna structure.

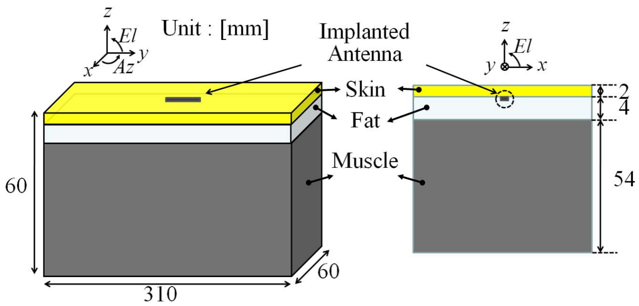


Fig. 2. Proposed antenna is put inside the tissue body layer.

III. ANTENNA STRUCTURE

The proposed antenna structure is depicted in Fig. 1. The antenna is folded wire 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 33.9 mm in length and 3.1 mm in diameter. The antenna is constructed by an upper-part one-folded solid wire and a lower-part two-folded wire, which is separated by 1.8 mm and insulated by a ±0.1 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 310mm × 60mm × 60mm. The human body-equivalent phantom is constructed by three different tissues, namely skin, fat, and muscle, referring to the study in [6]. The thickness of the tissues is 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 Federal Communications Commission (FCC) website [7] at the frequency 924 MHz. The electrical properties of the tissues are listed in TABLE II. 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 illustrated in Fig. 2.

TABLE II
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

IV. CALCULATION RESULTS

The antenna is numerically calculated by using the finite integration technique (FIT), which can have several performance parameters such as *S* parameter, radiation pattern, gain, specific absorption rate (SAR) and temperature rise characteristics as well. The first three basic antenna parameters will be presented in this paper.

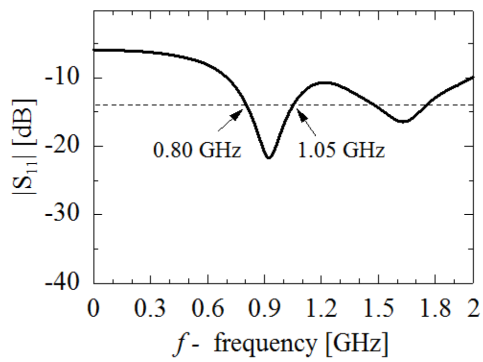
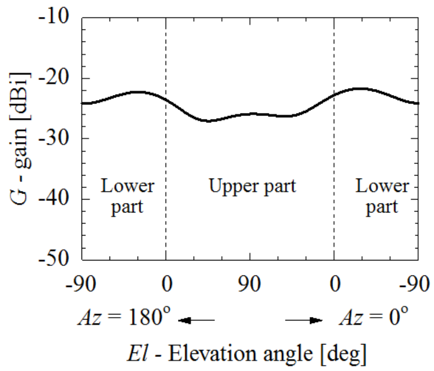


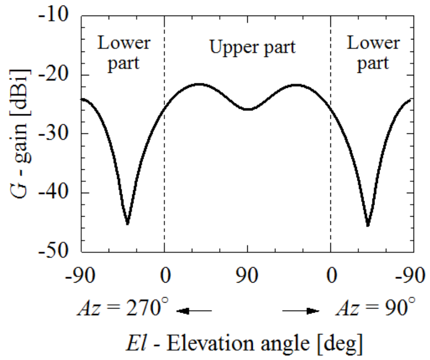
Fig. 3. S_{11} performance.

A. *S* parameter

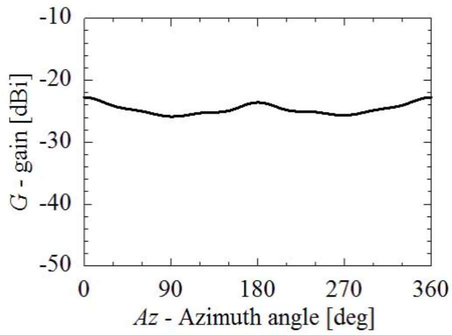
The *S* parameter of the antenna is depicted in Fig. 3. The antenna resonates at 924 MHz by -21.70 dB and has wide impedance bandwidth by 250 MHz (VSWR • 1.5), which is more than sufficient in Indonesian RFID band. From the simulation result, the input impedance of the antenna at the feeding point is 46.36 • and 7.05 • for the real and imaginary part, respectively, at the center frequency 924 MHz. Moreover, in the operation bandwidth, the resistance value is almost flat characteristics close to 50•-characteristics impedance, which is easier to be adjusted to the desired value when some other circuits are integrated to the antenna, such as chip and battery.



(a) *xz*-plane



(b) *yz*-plane



(c) *xy*-plane

Fig. 4. Gain performance in (a) axial (*xz*) (b) coronal (*yz*) plane (c) sagittal (*xy*) plane.

B. Radiation Pattern and Gain

The radiation pattern in two-dimensional plot is depicted in Fig. 4. The view is divided into three main plane, namely axial (*xz*), coronal (*yz*) and sagittal (*xy*) plane. The radiation pattern in axial and coronal plane of the upper-part of the model in Fig. 2, is slightly reduced due to the presence of the tissue effects at the left and right side of the antenna. Of course, the gain is definitely diminished due to such lossy medium. However, the gain is still above −30 dBi, the requirement gain for communication. The tissue size effect to the antenna gain is clearly observed, when the size is longer as depicted in Fig. 4(b) when the size of the tissue is about 31-cm in coronal direction rather than by only 6-cm in axial direction (Fig. 4(a)), in particular the change of gain pattern in lower-part arm tissue. In the sagittal plane, the wave experiences slower propagation velocity due to the longer tissue depth, allowing the reduced gain in both of the upper-side and lower-side of the arm tissue, but the pattern is changed to omnidirectional (Fig. 4(c)) rather than the 8-number pattern. However, the gain pattern is still more than −30 dBi, which is more than 10 m of the coverage.

V. CONCLUSION

This paper proposes a simple folded dipole antenna for implanted bioinformatics 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 gain is mote than -30 dBi in the 180-degrees upper-side of the arm tissue for at least 10-m indoor communication. The wide bandwidth is obtained by 250 MHz, which is more than enough for medical communication applications. In the near future works, the measurement will be conducted to validate the calculation results.

ACKNOWLEDGEMENT

This work was supported in part by Program Hibah Kompetisi Institusi (PHKI) 2012, Faculty of Engineering, Universitas Indonesia.

REFERENCES

[1] W. Huang and A.A. Kishk, "Embedded spiral microstrip implantable antenna," *Intl. Journal of Antennas & Propag.*, vol. 2011, Article ID 919821, 6 pages, 2011.

[2] P.S. Hall and Y. Hao, "Antennas and Propagation for Body-Centric Wireless Communications," ISBN 978-1-58053-493-2, 2006, *Artech House*, Norwood, MA, USA.

[3] D. Panescu, "Emerging Technologies [wireless communication systems for implantable medical devices]," *IEEE Engineering in Med. & Bio. Mag.*, vol. 27, no. 2, pp. 96• 101, 2008.

[4] Peraturan Direktur Jenderal Pos dan Telekomunikasi Nomor 221/ DIRJEN/ 2007, *Indonesian RFID frequency allocation*, 2007.

[5] Basari, K. Saito, M. Takahashi and K. Ito, "Satellite Communications," Chapter 2: Antenna System for Land Mobile Satellite Communications, Ed. N. Diodato, pp. 33–58, Sep. 2010, *Intech*, Rijeka, Croatia.

[6] A. Sani, M. Rajab, R. Foster and Y. Hao, "Antennas and propagation of implanted RFIDs for pervasive healthcare applications," *Proceedings of the IEEE*, vol. 98, no. 9, pp. 1648–1655, Sep. 2010.

[7] Body Tissue Dielectric Parameter. *Federal Communications Commission (FCC)*, USA. Available at http://transition.fcc.gov/oet/rfsafety/dielectric.html.