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Relations of Input Resistance Increases and Current Distributions of a Normal-Mode Helical Antenna in a Human Body Condition

Norsiha Zainudin[1], Yoshihide Yamada[2], Tarik Abdul Latef[1], Kamilia Kamardin[2], and Nguyen Quoc Dinh[3]
[1]Faculty of Engineering, University of Malaya, Kuala Lumpur, Malaysia
[2]Malaysian-Japanese International Institute of Technology, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia
[3]Le Quy Don Technical University, Hanoi, Vietnam

***Abstract* - For capsule endoscopy applications, Normal-Mode Helical Antennas (NMHA) are trying to be used. However, when antenna was placed in a human body, it was reported that an antenna efficiency was decreased owing to increase of input resistance. To analyze the input resistance increase is important. In this paper, the relations of input resistance increases and current distributions on an antenna are examined. It is concluded that the input resistance increases have very close relation with decreases of current distributions.**

***Index Terms* — Normal-Mode Helical Antenna, input resistance, current distributions, human body.**

1. Introduction

Recently, radio-frequency (RF) sensors inside human bodies are developing for human healthcare applications [1]. A helical antenna had been used as a very small implantable antenna in capsule endoscopy system [2]. In applying a helical antenna, the self-resonant structure is important for effective antenna performance [3]. The self-resonant structures and antenna performances are changed when antenna is put in a human body that has large permittivity (ε_r) and conductivity (σ). As a particular change, input resistance (R_{in}) increases were reported [4]-[5]. In this paper, the reason of input resistance increase is investigated. Input resistance increases and antenna current distributions are obtained through electromagnetic simulations and comparisons are made.

2. Simulation Model

Normal-Mode Helical Antenna (NMHA) is placed in cylindrical human body phantom as illustrates in Figure 1. A capsule is used to cover the antenna so that the antenna not directly contact to the dielectric material. Simulation parameters are summarized in Table 1. The operating frequency of 402 MHz is selected based on Medical Implant Communication Service (MICS) [6]. The permittivity is changed depending on human body part.

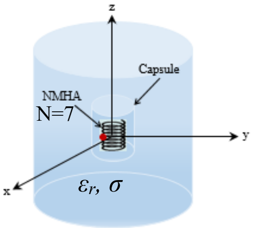


Fig. 1. NMHA simulation model.

TABLE I
Simulation parameters

Simulator	FEKO 7.0 MOM
Frequency	402 MHz
Dielectric material	ε_{r1} = 67.5, ε_{r2} = 46.7, ε_{r3} =11.6 σ = 0; 0.6; 1.1 (S/m)
Metallic wire material	Copper (σ=58 x 10^6 [1/Ωm])
Diameter of wire, *d*	1.2mm
Number of turns	N = 7
Mesh size (antenna wire)	λ_g /100
Mesh size (dielectric)	λ_g /30

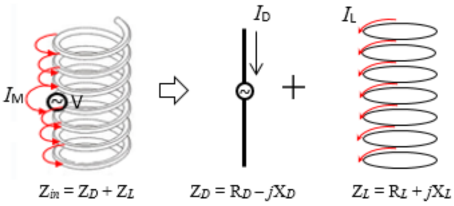


Fig. 2. Equivalent current model.

Figure 2 shows the equivalent current model. The coil current produced by the antenna can be divided into electric current source of the small dipole, and magnetic current source of the small loop. Current distributions become tapered and have maximum value (I_M) at the center point. The small dipole and small loop produces input impedance of $R_D - jX_D$ and $R_L + jX_L$, respectively. Antenna structures are designed to have zero reactance condition ($X_L = X_D$) which represents the self-resonant condition.

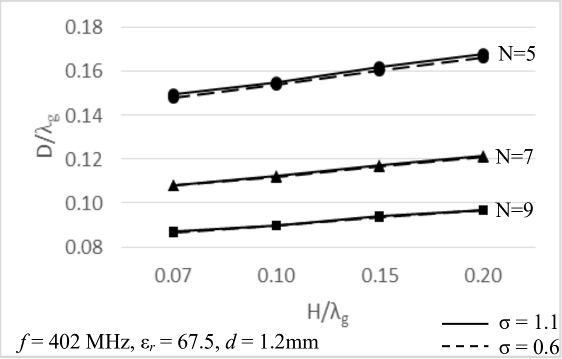


Fig. 3. Self-resonance structure.

Figure 3 shows the antenna self-resonant structure [5]. In here, λ_g is the wavelength in a dielectric material. Even though σ is changed to σ=0.6 and σ=1.1, self-resonant structure are not change.

3. Input Resistance

Input resistance increase by conductivity changes is shown in Figure 4. It is shown that the input resistance increases with the increase of conductivity.

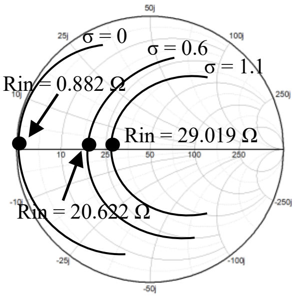


Fig. 4. Input resistance increase by conductivity.

Figure 5 shows the results of input resistance (R_{in}) dependence on conductivity.

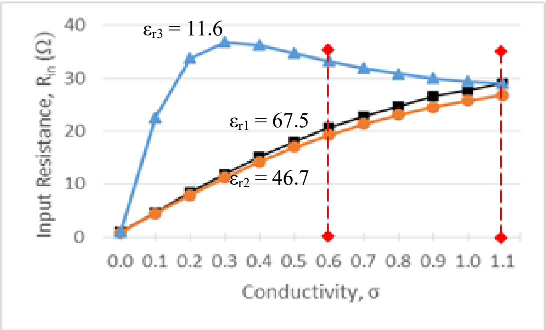
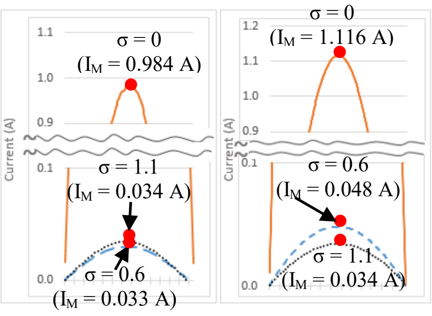


Fig. 5. Input resistance dependence on conductivity.

4. Current Distribution

The current distribution along the wire is shown in Figure 6. The input voltage is set to be 1V.



(a) εr = 11.6 (b) εr = 67.5

Fig. 6. Current distributions, I_M.

Currents on an antenna are drastically decreased by existences of σ. The input resistance (R_{in}) is calculated by the next equation.

$$R_{in}(I_M) = \frac{V}{I_M} \qquad (1)$$

The results of equation (1) are shown in Figure 7. R_{in} values agree well with the results of Figure 5.

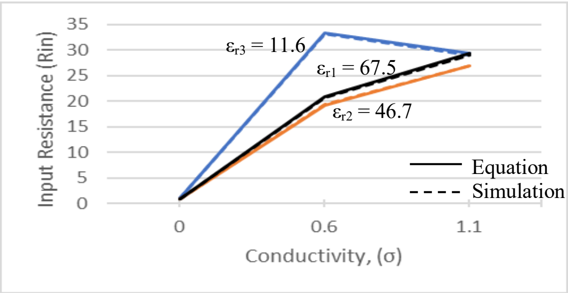


Fig. 7. Input resistance by I_M.

5. Conclusion

It is concluded that the input resistance increases have very close relation with decreases of current distributions.

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