Effect of Kidney Malignant Tissues on Antenna Resonance

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Abstract A logarithmic spiral microstrip antenna (LSMA) is designed, simulated and measured in rabbit’s kidney. The antenna operates in the Medical Implant Communications Service (MICS) band at 403 MHz. It is fabricated on Rogers RT6010 (lossy) with relative dielectric constant of 10.2 and thickness 1.9 mm. There is a good agreement between the measured and simulated results for LSMA in rabbit’s kidney. A study is made to observe the effect of malignant tissues on the performance of the antenna. Results are considered as brain stone for early detection diagnosis for cancer.

Keywords Implanted Antenna, Spiral Microstrip Antenna, Logarithmic Spiral Microstrip Antenna (LSMA), Medical Implant Communications Service (MICS), Malignant Tissues, Wireless Technology

This paper presents an LSMA for early detection diagnosis for cancer. It studies the effect of tumor cells on the antenna performance [8].

2. Antenna Design

An LSMA embedded in a substrate is shown in Fig.1. The antenna width starts with width; \( W \) which keeps decreasing by a factor of 1.44 until it reaches to a minimum width of 0.2 mm. The antenna has the phenomena of both the spiral behavior and the log periodic behavior. It should be pointed out that this width is manufactured constraint. It occupies an area of \( L_4 \times L_5 \). The antenna is made of lossy copper and of thickness; \( t_2 \). The antenna is covered with superstrate of equal length of that of the substrate; \( L_2 \), width; \( L_7 \) and height; \( t_1 \). The substrate and superstrate are made of Rogers RT6010 and of thickness; \( t_1 \). A coaxial probe and shorting pin of radius; \( r_1 \) are located as shown in Fig.1 (b). Table I, lists the design dimensions for LSMA.

1. Introduction

Wireless technology is one of the fastest growing industries throughout the world. In implanted systems, the implanted systems is connected either to the patient’s cell phone or computer system, which sends and receives medical reports using the wireless technology. This system is similar to a home care unit which eases the patients by cutting off the long, regular hospital visits [1]-[6].

Implanted antennas are used as biomedical applications to cure or detect certain diseases inside the body. It can be implanted inside the body or embedded under the skin. This depends whether it elevates the temperature of the patient’s body or not. Different shapes and types of antennas can be used depending on where it would be implanted inside the body. These types include; dipole, loop, microstrip and PIFA antennas [7].

Cancer is becoming one of the most common diseases in the world, which invades the body. For this reason, cancer detection is becoming one of the most serious topics in the medical industry. The main problem for cancer detection is that a sample should be taken from the patient and in this case it is considered destructive. In this paper, a brain stone for detecting cancer in the human body is presented.
Table 1. Design Dimensions of LSMA

| Parameters | LSMA(mm) | Parameters | LSMA(mm) |
|------------|----------|------------|----------|
| L₁         | 6        | L₁₀        | 7.22     |
| L₂         | 11       | L₁₁        | 3.05     |
| L₃         | 0.85     | L₁₂        | 6.82     |
| L₄         | 10.5     | L₁₃        | 1.1      |
| L₅         | 5.5      | L₁₄        | 2.39     |
| L₆         | 8.72 W   | t₁         | 1.9      |
| L₇         | 4.21     | t₂         | 0.015    |
| L₈         | 7.78     | r₁         | 0.25     |
| L₉         | 3.49     |            |          |

The antenna structure is placed in a kidney phantom block of permittivity of 66.4 and electrical conductivity of 1.1 as shown in Fig.2.

3. Simulation and Results

The antenna is designed using computer simulation technology microwave studio (CST MWS). Fig.3, illustrates the return loss of LSMA. The antenna resonates at 403 MHz with bandwidth of 18.11 MHz.

4. Antenna Fabrication

The designed antenna is fabricated using Rogers material Duroid 6010 (εᵣ=10.2, δ=0.0023, thickness=1.9 mm) as shown in Fig.4 (a), (b), (c).

A rabbit’s kidney is used to resemble the human kidney while the antenna is immersed as shown in Fig.4(d). Fig. 5 depicts both the measured and simulated return loss.

5. Effect of Malignant Tissues on Antenna Resonance

A study is made to observe the effect of malignant tissues on the performance of the antenna. According to Joines, W. T. et al.[9]; both the relative permittivity and conductivity of these tissues are greater than in normal tissues. The differences in electrical properties of kidney tissues from normal to malignant are about 6%. Hence the permittivity and conductivity of the kidney are 70.34 and 1.16 relative to 66.4 and 1.1 respectively. The study comprises 6 steps.

1. One malignant tissue is designed to cover one side of the antenna and of volume 196 mm³. It occupies 2.27% of the phantom and is located as shown in Fig.6.
2. The malignant tissue is designed to cover two sides of the antenna having a volume of 265 mm$^3$. It occupies 3% of the phantom and is located as shown in Fig.7.

3. The malignant tissue is designed to cover the four sides of the antenna having a volume of 530 mm$^3$. It covers 6.14% of the phantom and is situated as demonstrated in Fig.8.

4. The malignant tissue is designed to cover the antenna throughout the whole surface of the phantom. It has a volume of 2422 mm$^3$ and fills 28% of the phantom as shown in Fig.9.

5. The malignant tissue throughout the surface of the phantom aligned with the antenna gets covered to fill the top surface of the antenna. It has a volume of 5258 mm$^3$ and covers 60.9% of the phantom as depicted in Fig.10.

6. Finally, the malignant tissue is designed to cover the antenna entirely from top, bottom and surface having a volume of 8076 mm$^3$. It covers 93.5% of the phantom as represented in Fig.11.

Fig.12 illustrates the antenna response to each volume of malignant tissue mentioned previously. It is clear that as the
volume of malignant tissues increase; the antenna resonates at a smaller frequency outside the MICS band.

Figure 12. Simulated return loss for different volume of malignant tissues

Table II depicts each volume and its correspondent resonant frequency shift from 403 MHz. Fig.13 demonstrates the relation between the volume of malignant tissues and the resonant frequency.

| Volume (mm³) | Frequency (MHz) | Return loss (dB) |
|-------------|----------------|-----------------|
| 196         | 402.3          | -19.65          |
| 265         | 401.6          | -20             |
| 530         | 399.3          | -20.59          |
| 2422        | 399            | -20.55          |
| 5258        | 397.8          | -21.11          |
| 8076        | 396.7          | -21.84          |

Figure 13. Volume of malignant tissues vs. resonance frequency

One concludes that increasing the dimensions of malignant tissues in the kidney results in; negative shift of the resonant frequency with non significant change in the bandwidth. These results are considered as brain stone for early detection diagnosis of cancer. The tumor tissues of volume percentage of 2.27, 3, 6.14, 28, 60.9 and 93.5 conduct a shift of 0.7, 1.4, 3.7, 4, 5.2 and 6.3 MHz respectively.

A logarithmic spiral microstrip antenna (LSMA) is designed, simulated and measured in a rabbit’s kidney. The antenna achieves resonance at 403 MHz. Fabricated and simulated LSMA show a good agreement. The study which is made on the presence of malignant tissues shows that the antenna can be used as a tool for early detection diagnosis for cancer. Moreover; it can indicate in which cancerous stage is the tumor; depending on the frequency shift.

6. Conclusion

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