Compact Dipole Antenna for Implantable Devices

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Abstract - A miniaturized implantable dipole antenna is presented for industrial, scientific, and medical (ISM) (2.4 – 2.48 GHz) applications. The proposed antenna consists of one pair of folded arms and a T-shaped tuning stub. Whole structure is printed on an FR4 substrate with dimensions of 11×6×0.8 mm^3 and suitable for medical applications. The antenna is also theoretically test in human skin tissue. Low Specific absorption rate and acceptable radiation performances are obtained.

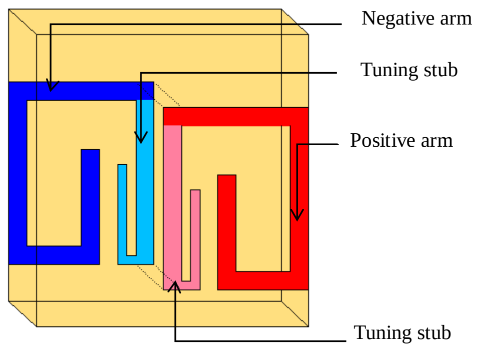
***Index Terms* —Implantable antenna, Industrial, Scientific, and Medical (ISM) band, Small Antenna**

I. Introduction

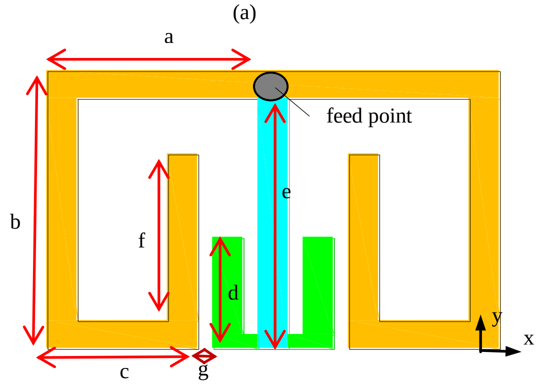
Wireless medical implantable devices are receiving great attention for obtaining both real-time and stored physiological data [1]. Among the device, the implantable antenna is an important element for wireless medical applications. There are many challenges in implantable antenna design such as bandwidth, radiation efficiency, and specific absorption rate (SAR) need be considered. Firstly, the dimension of an implantable antenna should be reduced for physiological acceptability. To reduce antenna size, techniques of short circuit, reactive loading [2-3], and multilayer structure [4-5] are used to lengthen the effective current path in a limited space. However, the fabrications are not easy for implementation. In this study, we design a compact implantable dipole antenna for medical applications. The tissue model used in this work is based on the corresponding one in [1], where the skin tissue thickness is 3.0 mm. A folded structure and a T-shaped tuning stub were used to miniaturize the antenna dimension. In addition, lower interaction between human tissue and radiator is also obtained.

II. Antenna Design

Fig. 1 (a) shows the structure of folded dipole antenna. It is a two layer structure. One set, which consists of a folded dipole arm and an L-shaped microstrip line, is spread on the upper layer of an FR4 substrate (thickness 0.8 mm, permittivity 4.4). Another set has similar structure is spread toward opposite direction on the lower layer. The front view shown in Fig. 1(b) presents the design is a folded antenna with T-shaped tuning which connects to the feed point. All parameters, which initial value will be generated by Ansoft's High Frequency Structure Simulator (HFSS), are shown in the figure. Here, the gap between dipole arm and tuning stub denoted as g. This gap largely affects the antenna features.



(a)



(b)

Fig. 1 (a) 3D structural drawing of the proposed antenna. (b) Front view and parameters of the proposed antnena.

III. Experimental Results and Discussions

Table I shows the antenna parameters for ISM 2.4 GHz operation. The path length $L = 2\times(a+b+c+f) = 56$ mm is about half wavelength at 2.4 GHz. Also, the parameters for the same operation band in human tissue are also presented. There is about 56% antenna size reduction (15×10 mm^2 vs. 11×6 mm^2). The antenna operated in free space is studied in Fig. 2. Firstly, the simulated very agree with the measured. The 10dB impedance bandwidth is over 2.38 ~ 2.43 GHz.

Table I. Antenna parameters in free space and in human tissue [1], unit: mm

parameter	a	b	c	d	e	f	g
Free space	7.5	10	5	5.5	9	5.5	1
Human tissue	5.5	6	2.5	3.5	7	3.5	0.5

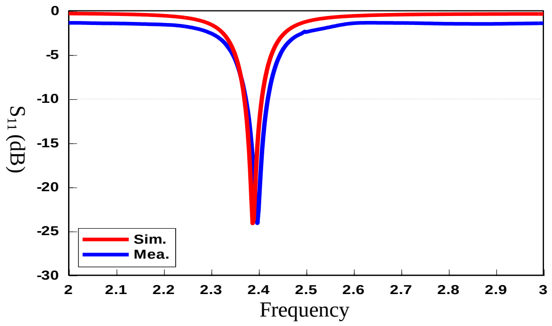


Fig. 2 Simulated and measured S_{11} of the proposed dipole antenna.

Fig. 3 shows the effects of structure parameters on S_{11}. Figure (a) indicates that resonate mode shifts toward lower frequency with lengthened dipole path length. (b) shows that the gap *g* largely affects not only the resonant frequency but also the impedance matching between the input port and antenna.

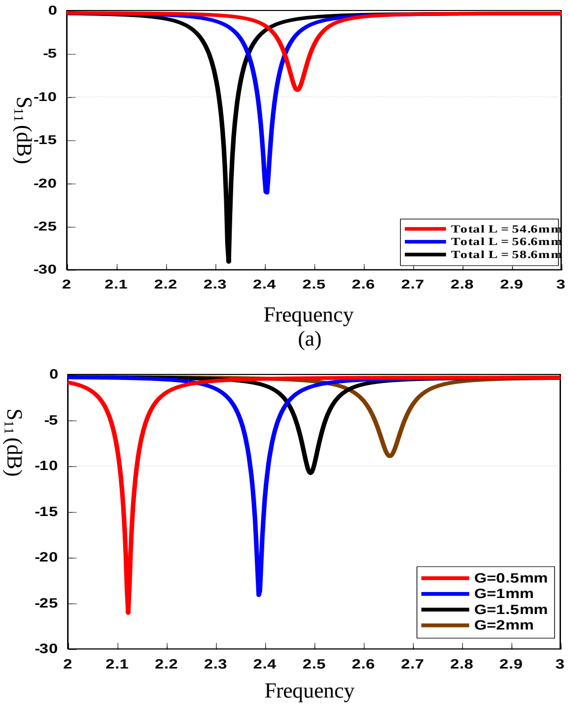


Fig. 3 S_{11} of the proposed dipole antenna against (a) path length L, and (b) gap g.

As the proposed antenna is implanted in chest and under skin 1 mm, the radiation performances are obviously degraded. In addition to lower resonant frequency f_r, the human tissue decreases the radiation efficiency from 42% to 3.4% and about 6.5 dB antenna gain.

Table II. Antenna radiation features against location. The structure parameters are the same for both cases .

Location	f_r GHz	Radiation efficiency(%)	Peak Gain dBi
Free space	2.4	42	-2.12
Chest	1.6	3.4	-8.82

Moreover, the capacitive coupling effect between the dipole arm and tuning stub degraded the near electric field. From the experimental results shown in Table III, the radiation efficiency and SAR decreased as the tuning stub close to the dipole arm (decreasing *g*).

Table III. The effects of gap *g* on antenna radiation features.

g mm	Peak Gain dBi	Radiation efficiency(%)	1W-SAR W/kg
0.5	-8.82	3.4	156
1	-9.15	2.7	189
1.5	-8.13	3.2	191
2	-6.63	4.5	202

CONCLUSIONS

This paper presents a small dipole antenna with a T-shaped tuning stub to reduce antenna size and SAR. The stub is proposed to introduce capacitive coupling with the dipole arms. Such effect is promising to achieve expected features. Although the limitations of the near-field coupling degrade the far field radiation, the proposed antenna still with performances suitable for implanted medical applications.

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