

# The Analysis and Simulation of microstrip Spiral Antenna for Microwave Hyperthermia

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**Abstract**—The finite element method was used to simulate the distributions of the electromagnetic fields and the specific absorption rate (SAR) of the microstrip spiral antenna in phantom muscle tissues. The factors that affect the antenna performance are compared. These factors include spiral wire's width, space of adjacent spiral circle and circle numbers. A new microwave hyperthermia antenna which is not sensitive to its parameters and the inputting frequency's fluctuation is presented in this paper. the simulation results coincide well with experimental.

**Keywords**- microwave hyperthermia; microstrip; the finite element method; the specific absorption rate component

## I. INTRODUCTION

The approach of microwave hyperthermia has numerous applications in many fields, for instance, tumour therapy, stanching by heat coagulating and curdling of the abnormal hyperplasia tissue. It has been proved that microwave hyperthermia has more advantages than other methods in many cases [1], and it's side-effect is less than counterparts.

The clinic equipments of microwave hyperthermia have a simple structure and, are convenient to operate. microwave hyperthermia has less complications and little side effect. So it has extensive application prospects.

There are many sorts of radiators that are suitable for therapy on subsurface tumor [2]. The microstrip Archimedes spiral antenna has a compact structure, flexible application and wide heating area. So it is widely studied and applied [3-5].

the impact of the circle numbers, space of adjacent spiral circle and width of spiral wire to the reflection coefficient are analyzed. An microstrip Archimedes spiral antenna is designed, which is not sensitive to the spiral's structural parameters and working frequency influence.

## II. ANTENNA DESIGNING

### A. Antenna model

Fig. 1 shows the design of the microstrip Archimedes spiral antenna. The antenna is based on a 50  $\Omega$  semirigid copper-

Teflon coaxial cable with inner and outer diameter 0.9 mm and 3 mm, respectively, and relative dielectric constant  $\epsilon_r=2.1$  (dielectric constant of coaxial cable). The inner conduct was connected to the microstrip Archimedes spiral antenna. The outer conduct was connected to ground of microstrip substrate. Relative dielectric constant of substrate material is 2. Thickness, length and width are 1 mm, 30 mm and 30 mm respectively. The spiral antenna is clockwise rotation.

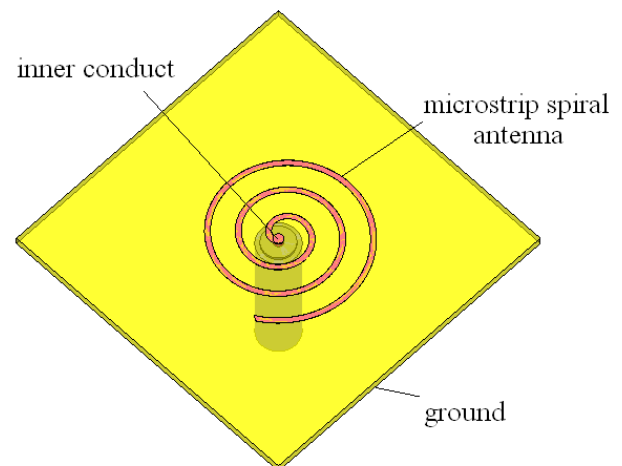


Figure 1. A schematic representation of the antenna

### B. The computational electromagnetic model

We employed a square model as the cross section of the antenna. The relative permittivity, density and conductivity of tissue at 37 °C are  $\epsilon_r = 47$ ,  $\rho = 1.05\text{g/cm}^3$  and  $\sigma = 2.17\text{ S/m}$ , respectively, at 2.45 GHz [1].

## III. COMPUTER SIMULATION

### A. Computation of the electromagnetic field distribution

The Ansoft's High Frequency Structure Simulation (HFSS) is applied in the computation process. The working frequency is set to 2.45GHz; excitation port is placed in the coaxial cable import end. In this model, the entire metal conductor is

supposed to a perfect conductor, and the tissue is considered to be infinity. An adaptive solution is applied. The maximum number of passes is set to 6 and maximum delta E per pass and refinement per pass is set to 0.2 and 20% [6].

#### B. Calculation of the SAR distribution

First, we calculate the electric field around the antenna and  $S_{11}$  parameter (the reflection coefficient). Next, we calculate the SAR distribution around the antenna from

$$SAR(W / Kg) = \frac{\sigma}{2\rho} |E|^2. \quad (1)$$

where  $\sigma$  is the conductivity of the tissue (S/m),  $\rho$  is the density of the tissue ( $Kg/m^3$ ), and  $E$  is the electric field (V/m) [1]. The SAR takes a value proportional to the square of the electric field around the antenna and is equivalent to the heating source generated by the electric field in the tissue.

### IV. CALCULATION RESULT AND EXPERIMENTS

#### A. Calculation Result

The reflection coefficient ( $S_{11}$  parameter) as a function of frequency for the different antenna's parameter is calculated in Fig.2 (parameters of the antenna are  $L=5$  mm,  $N=3$ ,  $W=1$  mm, 2.5 mm, 3.5 mm). Here,  $L$  is space of adjacent spiral circle,  $W$  is spiral wire's width,  $N$  is circle numbers of the spiral antenna.  $S_{11}$  decreases when the width of spiral wire decreases at 2.45 GHz. When width of microstrip wire is 3.5 mm, 2.5 mm and 1 mm,  $S_{11}$  is 0.53, 0.34 and 0.20 respectively.

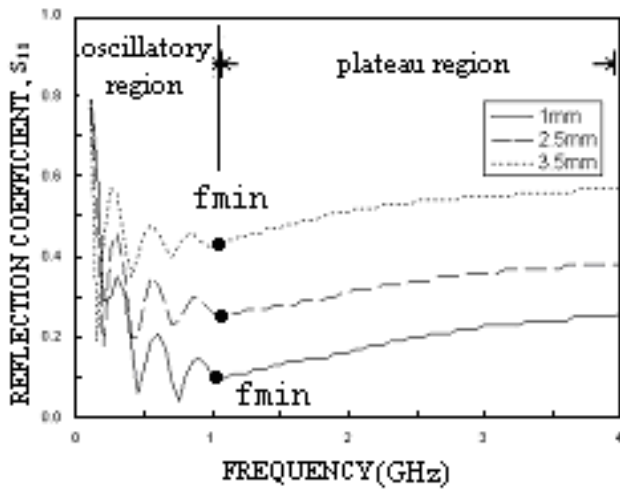


Figure 2. The reflection coefficient as a function of frequency for the different antenna's parameters ( $N=3$ ,  $L=5$  mm,  $W=1$  mm, 2.5 mm, 3.5 mm)

Fig.2 shows that  $S_{11}$  can divide into two areas: oscillatory region and plateau region. The lowest frequency of the plateau region is named as  $f_{min}$  in this paper. When the antenna's working frequency fall into the plateau region, the antenna is not sensitive to the fluctuation of the working frequency and changes of the antenna's structure parameters.

The reflection coefficient is not continuous decrease when width of the microstrip wire decrease. The reflection coefficient as a function of frequency for the different antenna's parameter is calculated in Fig.3 (parameters of the antenna are  $L=4$  mm,  $N=2$ ,  $W=0.2$  mm, 0.3 mm, 0.4 mm, 0.5 mm). From Fig.3 we can see that the reflection coefficient do not continue decrease when the width of the microstrip wire is less than 0.5 mm.

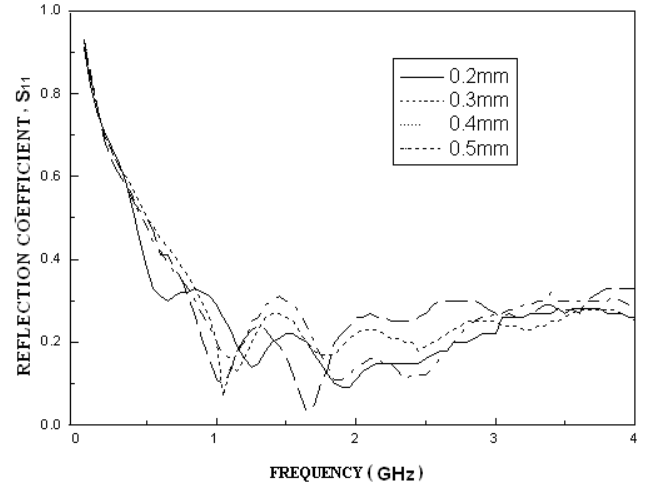


Figure 3. The reflection coefficient as a function of frequency for the different antenna's parameters ( $N=2$ ,  $L=4$  mm,  $W=0.2$  mm, 0.3 mm, 0.4 mm, 0.5 mm)

Fig. 4 shows the reflection coefficient as a function of frequency for the different antenna's structural parameters ( $N=3$ ,  $W=0.5$  mm,  $L=1$  mm, 2 mm, 5 mm). From Fig.4 we can see that  $f_{min}$  decreases gradually as the space of adjacent spiral circle increasing.  $S_{11}$  is 0.64, 0.23 and 0.16 respectively, when the antenna work at 2.45GHz.

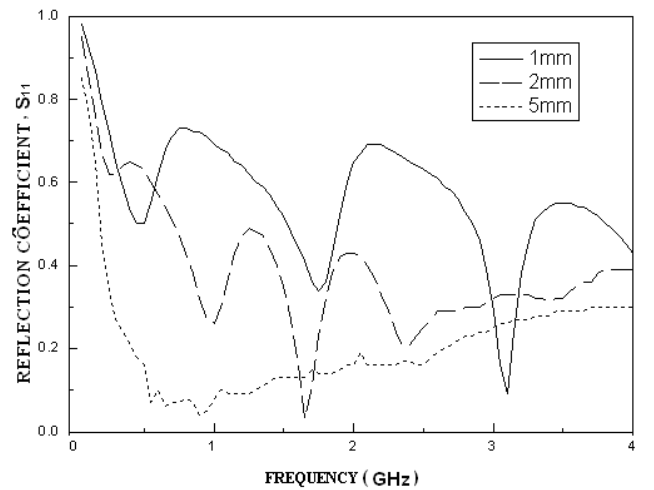


Figure 4. The reflection coefficient as a function of frequency for the different antenna's parameters ( $N=3$ ,  $W=0.5$  mm,  $L=1$  mm, 2 mm, 5 mm)

Fig. 5 shows the reflection coefficient as a function of frequency for the different antenna's structural parameters ( $L=5, W=0.5$  mm,  $N=1$  mm, 2 mm, 3 mm). From Fig.5 we can see that  $f_{min}$  decreases gradually as the antenna's circle increasing. Tab.I shows  $S_{11}$  of the microstrip antenna with the different structural parameters at 2.45GHz.

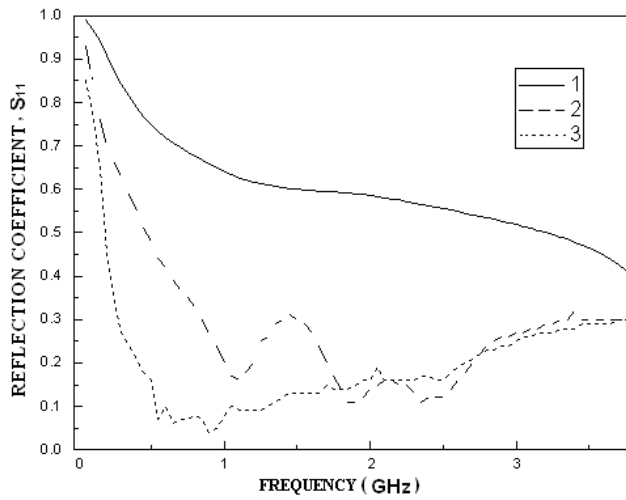


Figure 5. The reflection coefficient as a function of frequency for the different antenna's parameters ( $L=5, W=0.5$  mm,  $N=1$  mm, 2 mm, 3 mm)

TABLE.I THE REFLECTION COEFFICIENT OF ANTENNA WITH DIFFERENT PARAMETER AT 2.45GHz

N	L(mm)	W(mm)	$S_{11}$
3	5	1	0.20
		2.5	0.34
		3.5	0.53
2	4	0.2	0.15
		0.3	0.26
		0.4	0.18
		0.5	0.12
3	1	0.5	0.64
	2		0.23
	5		0.16
1	5	0.5	0.62
2			0.12
3			0.16

According to the above analyses, we designed optimized microstrip Archimedes spiral antenna, its parameters is listed as follows  $N=3, W=1$  mm,  $L=5$  mm. Fig. 6 and Fig. 7 show the antenna's SAR distribution.

### B. Experiments

The temperature distribution pattern was characterized, using a temperature sensing system, in a solid muscle equivalent phantom. The muscle phantom consisted of a glass cylinder filled with a mixture of 8.45%Tx-151, 15.2% polyethylene power, 75.45% water, and 0.9 NaCl [7]. A photograph of this prototype of antenna can be seen in Fig.8.

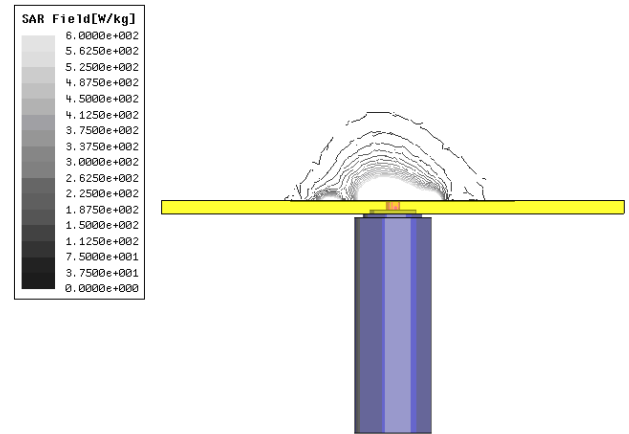


Figure 6. SAR distribution of the optimized antenna

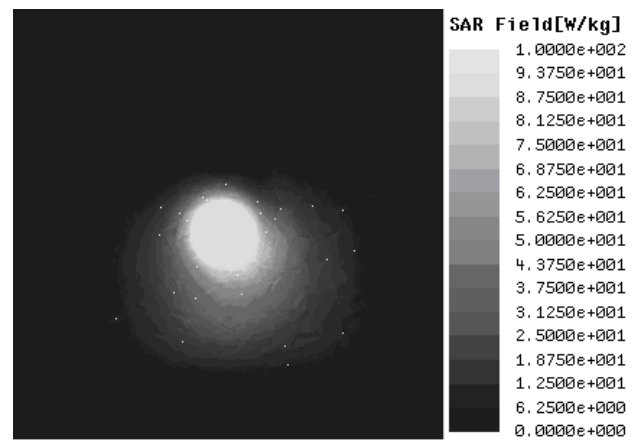


Figure 7. SAR distribution of the optimized antenna at apart from tissue 5 mm



Figure 8. The microstrip spiral antenna

The reflection coefficient of the microstrip Archimedes spiral antenna is measured by AV3618A RF Integrative Vector Network Analyzer. As an illustration, the reflection coefficient as a function of frequency is shown in Fig.9, where the results are compared to computer simulation.  $S_{11}$  of experiment is -12.6dB and  $S_{11}$  of computer simulation is -14.2dB at 2.45GHz. Similar comparisons were obtained. Fig.9 shows the antenna work at broadband.

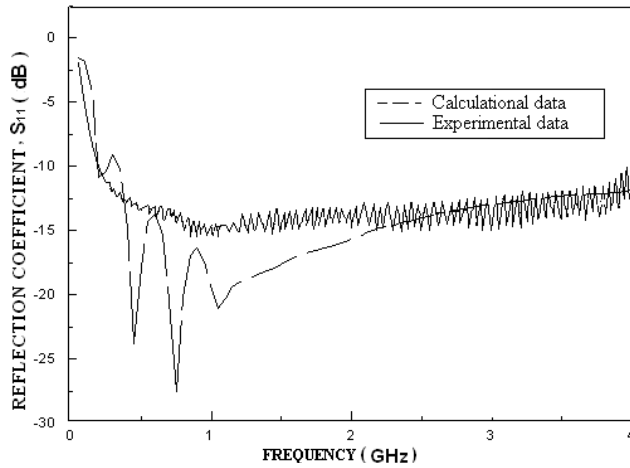


Figure 9. Simulated and measured the reflection coefficient

The heated results are shown in Fig.10 and Fig.11 when microwave power is 40 W, the initial temperature is 20 °C, and heating time is 60 s. Tab.II shows heating depth and diameter of the different microwave power at 2.45GHz. From these two figures we can see that the figure of the muscle equivalent phantom heated is circular. The temperature distribution reaches its highest value near the circle center. Compare with Fig.6, similar heated shape is obtained.

TABLE. II THE EXPERIMENTAL RESULT OF THE MICROSTRIP ANTENNA

Microwave power (W)	Heating time (s)	Heating depth (T>37°C) (mm)	Heating diameter (T>37°C) (mm)
10	60	3	8
20	60	6	19
30	60	10	26
40	60	14	34



Figure 10. Heated result of the plane spiral antenna

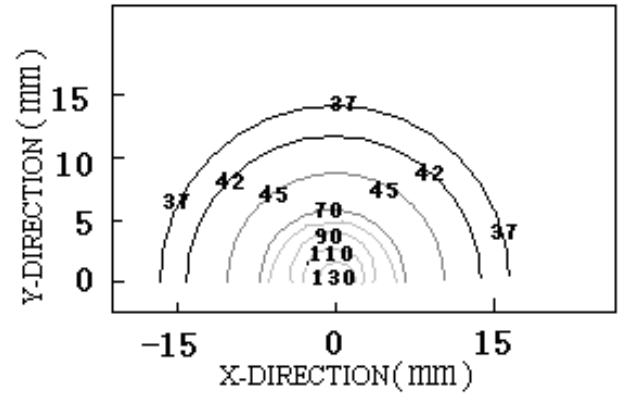


Figure 11. Temperature distribution of muscle equivalent phantom which is heated by microstrip antenna.

## V. CONCLUSIONS

The microstrip Archimedes spiral hyperthermia antenna is studied in this paper.  $S_{11}$  of antenna with different structural parameters are analyzed. The relation between  $S_{11}$  and antenna's structural parameters is obtained. The results show that increasing the space of adjacent spiral circle or the spiral circle numbers of the antenna can decrease the  $f_{min}$ . And suitable decreasing the width of spiral wire of the antenna can decrease the  $S_{11}$  parameter.

## REFERENCES

- [1] LI Ding-jiu, HU Zhi-sheng, and ZHONG Yu-bin. "Tumor thermatology". Zhengzhou:Zhengzhou University Press,2003
- [2] ZHANG Da. "Tumor microwave hyperthermia". Chinese Journal of Clinical Oncology and Rehabilitation 2001, 8(5),pp.128-129
- [3] E.R Lee, T.R Wilsey, P Tarczy-Hornoch, D.S.Kapp, P.Fessenden, A.Lohrbach, and S.D.Prionas. "Body Conformable 915MHz Microstrip Array Applicators for Large Surface Area Hyperthermia". IEEE Transactions on Biomedical Engineering. 2002, 39( 5),pp.470-484
- [4] S Jacobsen, H O Rolfsnes, and P R. Stauffer. "Characteristics of Microstrip Muscle-Loaded Single-Arm Archimedean Spiral Antennas as Investigated by FDTD Numerical Computations". IEEE Transactions on Biomedical Engineering. 2005, 52(2),pp.321-331
- [5] Zeji G, Carey M R, Paul J W, and Brian A V . "A 2 1/4-Turn Spiral Antenna for Catheter Cardiac Ablation". IEEE Transactions on Biomedical Engineering. 1999, 46(12),pp. 1480-1482
- [6] XIE Yong-jun, WANG Peng, LI Lei, ZHOU Jian-hua, and LEI Zhen-ya. "Ansoft HFSS foundation and application". Xi'an:XiDian University Press,2007.
- [7] Guy AW. "Analysis of electromagnetic fields induced in biological tissue by thermographic studies on equivalent phantom models". IEEE Trans on MTT ,1971 ,19,pp.205-215.