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Frequency Reconfigurable Applicator for Superficial Hyperthermia System

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1. Introduction

Hyperthermia treatment system has a long history in medical. It has been regarded as an effective treatment for tumor cells as the efficacy and safety of it is proved. The effect of treatment can be enhanced when chemotherapy and radiation oncology are performed with heated tumor cell by hyperthermia treatment system [1]. The hyperthermia system using a microwave for the treatment of superficial tumor is in general adopt the frequencies at 433 MHz and 915 MHz to satisfy the temperature evenness occurred in targeted medium and the penetrating depth where superficial tumor existed [2]. The various heat distributions in targeted medium can be induced by varying the operating frequency. The hyperthermia system which has various frequencies for treatment is suitable and effective to patients who have tumor cells that has various shapes in various positions. In this paper, a frequency reconfigurable antenna operating at 433 MHz and 915 MHz as a radiator of superficial hyperthermia system is proposed. The system operating at both frequencies can improve the curative effect more than the system with a single frequency. Using the superficial hyperthermia system which makes different heat distributions can be a treatment for different symptoms of the patients by applies the proposed antenna using two different frequencies.

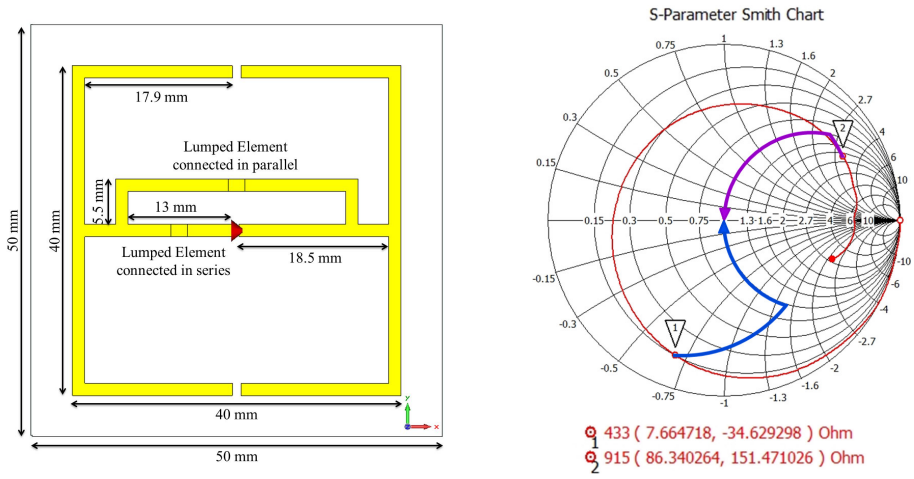
2. Frequency Selection and Environment Variables

The characteristics that SAR and temperature distributions depend on operating frequency have been reported by many clinical trials of the hyperthermia treatment of the microwave [1], [3]. The deeply existed tissue under the skin is not heated in general and heat pattern does not occur over a wide range by using the microwave applicator at 915 MHz for hyperthermia treatment system. The heat is induced right under the skin so that the treatment of the tumor cells near the skin is effective while the system operating at 433 MHz is advantageous for the treatment of wider or deeper distributed tumor cells. These operating frequencies can be selected flexibly by using the radiator which operates at both frequencies depending on the symptoms of the patient. The phantom is designed to analyse the increasing temperature characteristics as a human body model. The phantom operating at 433 MHz was designed with the dielectric constant of 57.73 and the conductivity of 0.82 [S/m] and the phantom operating at 915 MHz was designed with the dielectric constant of 55.92 and the conductivity of 0.97 [S/m] in accordance with Federal Communications Commission standard [4]. When the RF power signal radiates toward the phantom, a bolus which is composed of distilled water has to exist between the radiator and the phantom. The bolus operates to compensate the stability of reflection coefficient between the antenna and the phantom.

3. Design of Reconfigurable Dipole Antenna

3.1 Fundamental Antenna Design

The conventional dipole antenna is a resonant antenna of which the resonant frequency is determined by electrical length. The specific technique is used instead of adjusting the electrical length to operate at targeted frequency. The antenna design which resonant frequencies are obtained



(a) (b)

Figure 1: Design of (a) the fundamental dipole antenna and (b) the smith chart

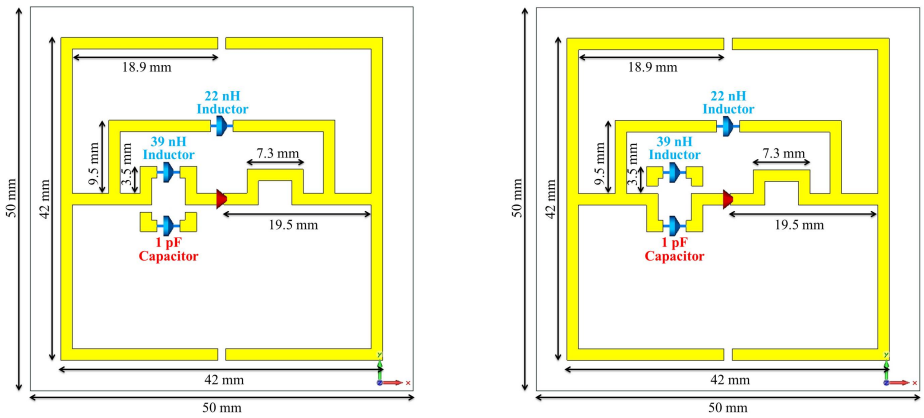
by using lumped elements is used in this structure. The fundamental design of a dipole antenna which does not have the resonance point is illustrated and the smith chart is illustrated in Fig. 1. The fundamental dipole antenna is designed based on microstrip with FR-4 substrate of dielectric constant ε_r=4.3. The uniformity of the thermal diffusion in the applicator can be improved by designing the shape of the rectangular antenna. The impedance matching for the antenna resonance can be realized in the targeted frequency by using the lumped elements. The impedance locus is shifted as the value of used lumped the elements varies. The point of marker No. 1 at 433 MHz which is represented in Fig. 1 (b) moves in the counter-clockwise direction on the chart of the admittance due to the connection of one inductor in parallel and then moves in the clockwise direction on the chart of the impedance by the connection in parallel of another inductor. The lumped elements used to operate at 433 MHz are the inductor connected in parallel of which the value is 22 nH and the inductor connected in series of which the value is 33 nH. Meanwhile, the point of marker No. 2 at 915 MHz which is represented in Fig. 1 (b) moves in the counter-clockwise direction on the chart of the admittance due to the connection of one inductor in parallel and then moves in the counter-clockwise direction on the chart of the impedance by the connection in series of one capacitor. The elements used to operate at 915 MHz are the inductor connected in parallel of which the value is 100 nH and the capacitor connected in series of which the value is 1 pF. Each value of lumped elements is determined by analysing smith chart [5] and trajectories are illustrated in Fig. 1.

3.2 Proposed Antenna Design

The geometry of the proposed dipole antenna is illustrated in Fig. 2 operating at 433 MHz which is in state 1 and 915 MHz which is in state 2 by converting the state with changes of the antenna shape and the reflection coefficient of each state in Fig. 3.The shape of the right side of the feeding is bent to modify the resonant length for a combination of both states of the previous design. The changes of lumped element are needed in the process of the compensation which is occurred the impedance characteristic by the modified design. The modifications of the shape and the values of lumped element make the antenna which operates at both frequencies with the same shape. The proposed antenna with two different states operates in each targeted frequency as the radiator for the hyperthermia system. The SAR patterns in 21.32 mm depth of the z-plane where the peak value of SAR occurred in each state are represented in Fig. 4. The temperature elevation and the temperature distribution are represented in Fig. 5 (a) in 18.89 mm depth in state 1 of the antenna and in Fig. 5 (b) in 16.49 mm depth in state 2 of the antenna where the temperature rise of peak value occurred in each state. The temperature distribution is simulated with 10 W-peak sources or 5 W-rms. The temperature in Fig. 5 is the celsius degree value increasing from room temperature of 15°C during a half hour heating. The simulation environment is set by the research which was studied previously [6].

3.3 Result and Discussion

The proposed antenna operates at frequencies that target and is shown to be suitable to apply the superficial hyperthermia application. As can be seen through the results of the simulation is presented the characteristics that the heat pattern formed by operation at 433 MHz is more deep penetration and more even than the operation at the other one. On the other hand, the heat pattern formed by operation at 915 MHz is represented by more focused heat-distributed pattern. When the antenna radiates for half hour at room temperature, the temperature change increases by around 10°C as antenna radiates at 433 MHz and the increases by around 25°C at 915 MHz.



(a) (b)

Figure 2: Designs of the proposed antenna of (a) the state 1 and (b) state 2

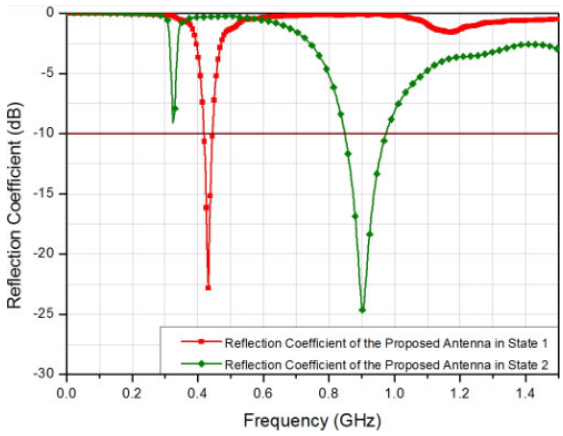
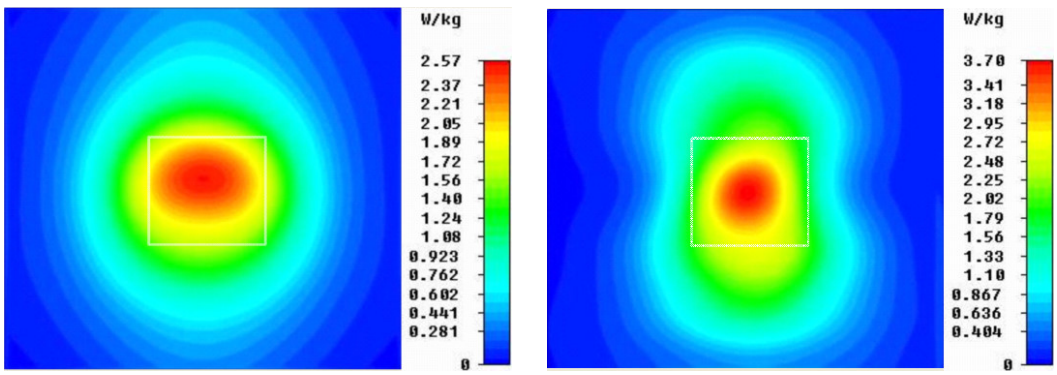
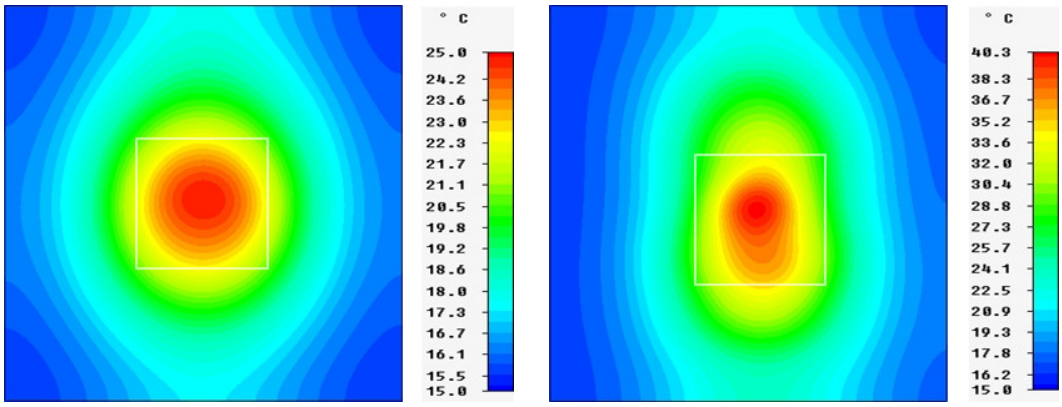


Figure 3: Reflection coefficients of the proposed antenna



(a) (b)

Figure 4: SAR distributions of the proposed antenna operating at (a) 433 MHz and (b) 915 MHz



(a) (b)

Figure 5: Temperature distributions at (a) 433 MHz and (b) 915 MHz

4. Conclusion

The reconfigurable antenna operating frequencies of 433 MHz and 915 MHz for effective use in the superficial hyperthermia system is proposed for the treatment of the tumor cells. The impedance matching with the lumped elements is also introduced. The temperature distributions are occurred different in targeted medium by the hyperthermia applicators which operate with different frequencies. Which the temperature distributions are formed differently can cause the various effect of the prescription compared with the applicator which induces the single distribution from the applicator with the single operating frequency. The effects of the proposed antenna are expected to apply the hyperthermia system at different frequencies selectively depending on the symptom of patients and improve the curative effect.

Acknowledgments

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