A new interstitial antenna for microwave ablation

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Abstract: We propose an interstitial coaxial antenna that can insert without a catheter for microwave ablation therapy, operating at 2.45 GHz. The cap of the antenna is an arrowhead that bonds copper plate and ceramic plate to suppress heat conduction in the tip direction. The temperature distribution in the improved liver phantom is measured by using the infrared thermography device. As a result, it is clarified that we nearly get the spherical distribution of an assumed tumor in shape.

Keywords: ablation, interstitial coaxial antenna, non-catheter type, microwave heating

Classification: Antennas and Propagation

References


1 Introduction

Microwave ablation (MWA) is a promising technology for thermal therapy of tumors [1]. The basic principle of MWA is to apply microwave power to the tumor through antenna operating typically at 2.45 GHz. Interstitial antenna is inserted into the tumor, guided by ultrasound or other medical imaging device. The microwave power radiated by the antenna heats the tumor above 60°C and thus cell death occurs almost instantaneously. The extension of ablated tissue along the antenna axis is strictly linked to antenna design. The region of ablated tissue, namely assumes a non-spherical shape which is undesirable since it could damage healthy tissues.

To overcome this issue, several types of coaxial-based antenna, including the monopole antenna, the dipole antenna, the slot antenna, and others have been developed for MWA [2]. Since these are a catheter type, further insertion devices are necessary [3].

In this letter, we propose an interstitial coaxial antenna of the non-catheter type with the cap of new structure to get nearly spherical heating.

2 Experiment

Fig. 1 provides the longitudinal cross-sectional view of a proposed coaxial antenna where $W$ represents the slot size. The cap, having an arrow shape, makes the antenna insertion into the tissues easier. Also, the arrowhead that bonds the copper plate and the ceramic (relative permittivity: 9.8) plate suppresses heating to the tip direction.

The target of therapy is assumed to liver tumor of an early stage. The liver phantom at $f = 2.45$ GHz has been already developed [4]. It is the mixture of six kinds of materials as shown in Table I when the weight is 500 g. The relative permittivity $\varepsilon$ and conductivity $\sigma$ in the interior and the surface of the made phantom were measured 18 hours later by using our coaxial reflection method [5]. The differences with $\varepsilon = 43.0$ and $\sigma = 1.69$ S/m of the liver are 0.80% in relative permittivity and 30% in conductivity. These values are the average of the 20 locations of random. We have adjusted the weight of Polyethylene Powder and Sodium Chloride to reduce the difference with the conductivity. The mixed weights of the improved phantom after the search were shown in Table I. In this case, the differences with the liver value are 1.3% in relative permittivity and 6.3% in conductivity. Since the electrical constant of tumor tissue is about equal to that of the liver, we treat both the same. As reviewed in Ref. [2], we also remark that a

![Fig. 1. Cross section of a proposed antenna and its photo.](image_url)
catheter type antenna with 2 slots in Ref. [4] is one structural idea of obtaining a heating distribution close to a spherical shape as compared to the antenna with 1 slot. The infrared thermography device was used to measure the temperature distribution. The made phantom is a rectangular block which has a length of 60 mm, a width of 60 mm, and a height of 90 mm. The central longitudinal cross-section of the block to insert antenna is cut before heating and the temperature of the cut plane is quickly measured by using the infrared camera after heating.

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight [g]</th>
<th>Improved</th>
<th>Ref. [4]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deionized Water</td>
<td>400</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Polyethylene Powder</td>
<td>60.1</td>
<td>79.0</td>
<td></td>
</tr>
<tr>
<td>Agar</td>
<td>12.4</td>
<td>12.4</td>
<td></td>
</tr>
<tr>
<td>TX-151</td>
<td>5.45</td>
<td>5.45</td>
<td></td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>2.70</td>
<td>3.35</td>
<td></td>
</tr>
<tr>
<td>Sodium Dehydroacetate</td>
<td>0.250</td>
<td>0.250</td>
<td></td>
</tr>
</tbody>
</table>

Figs. 2(a), (b), and (c) illustrate the rising temperature distribution inside the liver phantom of the proposed antenna when $W = 2$ mm, 4 mm, and 6 mm where the dotted circle indicates the assumed spherical tumor with a diameter of 14 mm and the heating time $t = 60$ s. Also, pink part is the heating range above 60 °C which is the sum of a rising temperature of 23 °C and a body temperature of 37°C. The temperature distribution of Fig. 2(d) in the conventional antenna corresponds to that of Fig. 2(a). This antenna for comparison is the same structure and size of the proposed one except the arrowhead of the cap being all coppers. In the proposed antenna, $W = 2$ mm is appropriate since the heating along the axis direction of the antenna increases with $W$. The conventional antenna also has the same characteristics. Note that the $|S_{11}|$ varies with $W$. The $|S_{11}|$ of the proposed and conventional antennas with $W = 2$ mm inserted into the phantom were $-6.2$ dB and $-7.2$ dB. The input power $P$ to the antenna set to 20 W since both difference is small. The heating of the tip direction of the proposed antenna is suppressed more by 30% than that of the conventional antenna, as can be seen from a comparison of Figs. 2(a) and (d). In actual therapy, this fact suggests that we can control overheat of healthy tissues and heat only tumor tissue of an early stage. The healthy tissue around the antenna tip and tumor are still around 50 °C. Although healthy cells do not die even if kept at this temperature for a few minutes [1], it is thought that a slight increase in body temperature occurs as one side effect of biological reactions.
3 Conclusion

We proposed an interstitial coaxial-slot antenna of a needle-like cap that does not require an insertion device for microwave ablation therapy. The tip direction of the antenna is hard to be heated because of the cap consisting of an insulator as well as conductor. In the first place, we improved the conventional liver phantom. Secondly, we conducted the heating experiment of the antenna inserted to the phantom. As a result, the temperature distribution was close to an assumed spherical tumor.

However, the heating to the power supply side is not almost suppressed and the impedance between the antenna and the feedline is not matched. In the near future, we will challenge these issues solved by implementing the choke [2].

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