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Design of Compact Microstrip Antennas Embedded in Water Bolus for Hyperthermia Applications

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***Abstract*—This paper presents the design of a circularly shaped spiral microstrip antenna and a conventional patch antenna both are embedded inside a distilled water bolus. The adequateness of the antennas is investigated for hyperthermia applications. The novelty of the spiral antenna is, it has a narrower radiation pattern and resonates at multiple frequencies to have a better control over the penetration depth and focusing considerations.**

I. Introduction

Electromagnetic hyperthermia is used to elevate the cancerous tissues temperature up to 45 °C. Many researches have shown that high temperatures damage the cancerous cells and their proteins build to shrink the tumors [1]-[2]. In general hyperthermia is used in conjunction with conventional therapies such as chemotherapy and radiation therapy [3]-[4]. An increase of temperature in cancerous cells causes a higher perfusion rate as a result the cancer drugs penetrates better into tumor or make cancer cells more sensitive for ionized radiation.

For a cancer specific hyperthermia application the design of a suitable applicator is needed. Since the electromagnetic penetration decreases rapidly through the lossy character of the tissues a multi-antenna applicator is needed to constructively interfere with the fields at the desired regions especially for deep regional hyperthermia applications. That is why the design of an effective single antenna element is the crucial step in designing the applicator. For the design of the single antenna element the penetration depth, resolution and the size are important parameters. There is a need for directive antennas operating at low frequencies (ISM band), having smaller lateral size and narrower beam width. However these conditions are constrained by inverse relationship about the electrical size of the antenna and its operating frequency.

Actually the design of a hyperthermia antenna is different from the antenna design in free space applications. In hyperthermia applications a distilled water bolus is used to cool the superficial heating and obtain a better matching between the antenna and the irradiated tissues. In this paper the microstrip antenna is chosen as a template since it has a high performance in many applications due to its lightweight, low profile with conformability and ease of integration in other systems [5]. In the design of a microstrip antenna if a solid substrate (typically $\varepsilon_r < 15$) is used then the size of the antenna is considerable huge. If a water bolus is used between the antenna and the body then most of the energy will be reflected at the interface and most of the radiation will be in lateral direction which is strictly an unwanted situation. However if the antenna is embedded inside the water bolus and if the distilled water bolus is considered as the merged substrate of the antenna then that will cause a considerably reduction in the antenna size with respect to its resonant frequency. In addition of the cooling of superficial tissues the antenna will also be cooled with this water bolus to sustain stable antenna characteristics during the treatment [6]-[7].

The aim of this paper is to design microstrip antennas for hyperthermia application having small size, narrow beam width and operates at desired frequencies. The results are presented for a conventional hyperthermia patch antenna and a circularly shaped microstrip antenna both are embedded in a water bolus. The simulations obtained by means of commercial electromagnetic software's CST Microwave Studio.

II. Antenna Design

In this work two antennas have been designed. The first one is the conventional rectangular patch antenna inspired from [6] and the second one is a circularly spiral shaped microstrip antenna both are embedded in a water bolus of 5cm thickness. The antenna sizes are optimized to reduce the size in order to have the opportunity to use more antennas for an applicator while holding the performance. The rectangular patch consist of a PEC ground plane with a patch length of 23.75mm, a

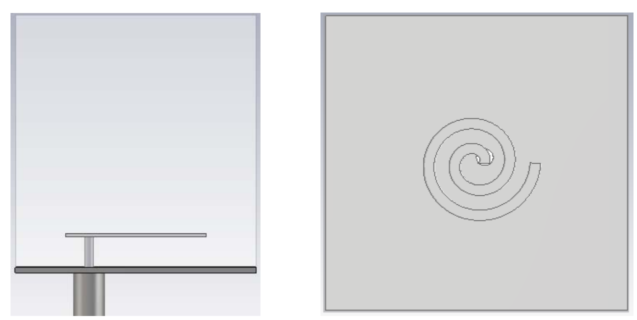

Figure 1. Side view of the rectangular patch antenna embedded in a water bolus (left) and the top view of the spiral antenna (right).

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width of 7.8mm, the height from the ground plane is 6mm, and it has feeding point 4.75mm from the patch's longitudinal direction shown in left side of Fig. 1. On the other hand the spiral antenna fed at the middle has 2 turns, the width of the microstrip is 3.2mm, the gap between the turns is 3.65mm and the height from the ground is 3.4 mm shown in right side of Fig. 1. Both antennas are fed by means of a coax having Teflon as a dielectric and the thickness of the microstrip antenna is chosen 0.65mm to have a rigid construction since the patch is not supported on a substrate but embedded in water.

III. SIMULATION RESULTS

During the design several parameter sweep has been performed in order to obtain an optimum design in terms of small size, having narrower beam width and desired resonant frequencies. The height of the water is chosen as 5cm assuming that will be the maximum thickness of a bolus. Although we performed simulations with different bolus thicknesses but there was not a noticeable difference in results as far as the antenna is embedded in water. The return loss values for both antennas are depicted in Fig. 2. Both antennas resonate at 434 MHz (ISM band) with a -10 dB band width of 8 MHz for spiral and 31 MHz for patch antenna. However the spiral antenna resonates also at 567 and 718 MHz.

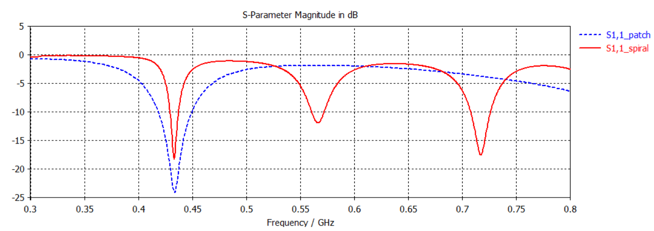

Figure 2. S_{11} values for patch (dashed line) and spiral (solid line) antennas.

The radiation patterns are depicted in Fig. 3 and in Fig. 4 at 434 MHz. The HPBW at $\phi = 0$ for the patch antenna is 81° and for the spiral antenna is 49° and at $\phi = 90^{\circ}$ for the patch antenna is 120° and for the spiral antenna is 63°. The main lobe magnitude for the patch antenna is 5.32 dB and 8.98 for the spiral antenna. At 434 MHz the spiral antenna is clearly superior to the conventional patch antenna in terms of directivity and beam width. The radiation pattern for spiral at 567 MHz is depicted in Figure 5.

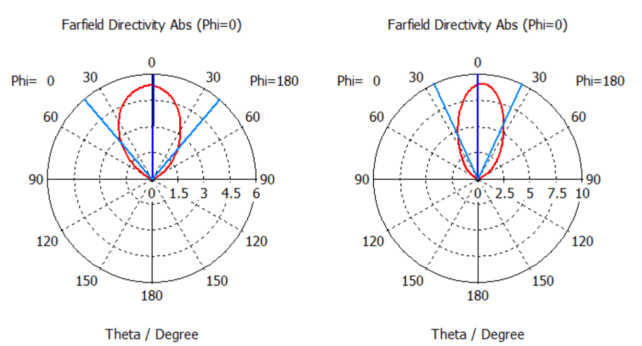

Figure 3. Radiation pattern for patch antenna (left) and spiral antenna (right) at 434 MHz at $\phi = 0$.

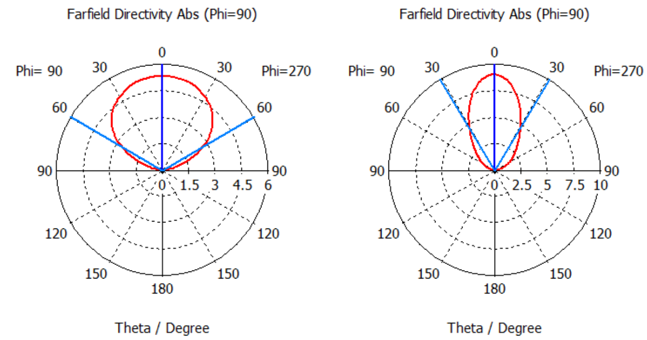

Figure 4. Radiation pattern for patch antenna (left) and spiral antenna (right) at 434 MHz at $\phi = 90^{\circ}$.

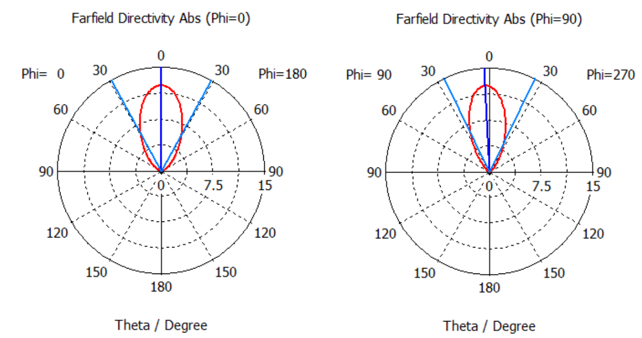

Figure 5. Radiation pattern for spiral antenna at $\phi = 0^{\circ}$ (left) and at $\phi = 90^{\circ}$ (right) for 567 MHz.

IV. CONCLUSION

Two microstrip antennas are presented for hyperthermia applications at ISM band. The spiral antenna has novel radiation pattern which makes it adequate for hyperthermia applications.

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