Numerical Evaluation of Clinical Applicator for Microwave Hyperthermia Treatment of Head & Neck Tumors

Numerical evaluation of clinical applicator for microwave hyperthermia treatment of Head & Neck tumors

Hana Dobšíček Trefná,*, Pegah Takook,*, Johanna Gellermann, *, Jian Yang *, Shirin Abtahi *, Mikael Persson *

*Dept. Signal and Systems, Chalmers University of Technology,
Hörsalsvägen 11, Gothenburg, Sweden
Email: hanatre@chalmers.se

***Abstract*—Design, analysis and evaluation of a novel antenna applicator for microwave hyperthermia. The self-grounded Bow-Tie antenna immersed in cylindrical water bolus serves as an array element. The applicator consists of 12 to 18 elements arranged in one to three ring set-ups and operates at frequency range between 400 and 1000 MHz.**

I. Introduction

Hyperthermia is presently used as an adjuvant to the radiation therapy in the treatment of certain types of cancers. Recently, randomised trials have shown a significant advantage of combining hyperthermia with radiotherapy and/or chemotherapy in the treatment of solid tumours [1]-[2]. The objective of hyperthermia treatment is to raise the temperature in the tumour to a therapeutic level 41°C-44°C for a sufficient period of time to achieve cell death or render the cells more sensitive to ionizing radiation and chemical toxins. The present challenge is adequately heating of deep seated tumours while preventing surrounding healthy tissue from undesired overheating and damage.

In order to improve the heat delivery to the tumor, we are developing a flexible applicator, which is tumor-volume-specific [3], [4]. In other words, an applicator that is capable of modifying the focus size depending of the tumour position and volume. The importance of the foci-spot size adjustments comes from the ability to restrain hot spots near the tumour, which are difficult to suppress. An adaptation of the heating pattern can be realised by varying the operating frequency of the antennas and potentially by the use of UWB pulse sequences instead of pure harmonic signals, as used in the present heating equipment.

In this contribution, we present a novel design of an antenna applicator for hyperthermia treatment in Head & Neck region. The applicator consists of 12 to 18 elements arranged in one to three ring set-ups. The self-grounded Bow-Tie immersed in cylindrical water bolus serves as an applicator element. The operating frequency range is from 400 to 1000 MHz.

II. Antenna array

A. Single antenna

The self-grounded Bow-Tie antenna [5] has been adapted for hyperthermia purposes. In particular the matching balun of [5] were re-design to Chebyshev taper [6] in order to achieve UWB behaviour of the antenna in the intended frequency band. The overall size of the antenna is 28x28x10 mm. While immersed in water bolus, the Reflection coefficient remains below -10 dB in frequency range of 400 to 1050 MHz.

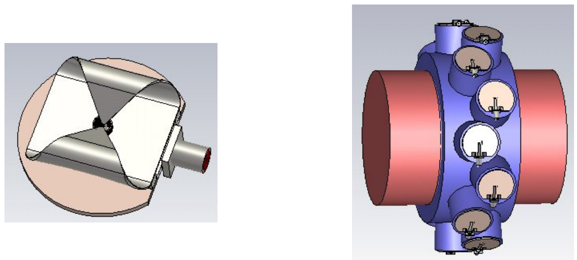

Fig. 1. (a) The Self-grounded bow-tie antenna. (b) The 8x2 ring arrangement.

B. Water bolus

During hyperthermia treatment, a water bolus filled with demineralised water is typically placed between the body and the applicator. The water bolus reduces hot spots and improves impedance matching between the biological tissue and the antennas. In our design, the antennas are immersed in the water bolus (Debye 1st order model, ϵ_{inf} = 5.5, ϵ_s = 78.36, τ = 8.28e^{-12} s), which considerably decreases the size of the antenna. The water bolus of cylindrical shape with radius 23 mm and height 30 mm is individual for each antenna.

Using of single water bolus is rather novel solution and it has several advantages above standard, common boli. At first, it allows more directive E-field propagation as shown in figure 2. The bolus of limited size (Fig. 2b) guides the wave towards the phantom and thus provides more focused energy dirstribution within it as well as naturaly prevent high coupling between adjacent antenna elements. At second, this solution offers predictable shape and profile of the bolus in clinical system and offers more comfortable solution for patients. In order to cool down the body surface, an additional water layer is placed between the body and water boli of the antennas. This layer has thickness of 1 - 2 cm and contain circulating cold water.

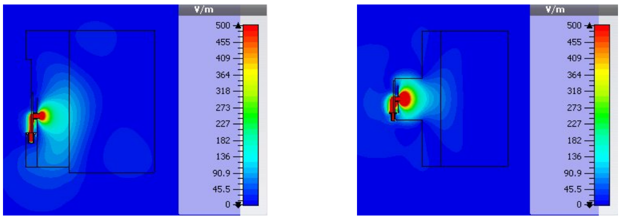

Fig. 2. E-field distribution along the antenna immersed in (a) standard water bolus. (b) novel two-layer water bolus.

C. Antenna applicator

The antenna applicator is based on a circular antenna array consisting of 12 to 18 elements. We consider three main array configurations: one configuration with 12 antennas placed in the single ring array and one configuration of two antenna rings with 8 antennas in each ring, and 18 antennas placed in three rings. The real applicator then consists of one main (inner) ring and the remaining two can be 'clicked on' if desired. The distance between the rings is 30 mm. In order to keep distance in terms of wavelength between radiating elemets body at different frequencies, the diameter of the applicator is adjustable and varies between 340 and 460 mm.

III. Results

The focusing abilities of the applicator are evaluated by using an anthropomorgical phantom of H&N region. The phantom, containing small laryngeal tumor of volume approx. 15 mm^3 consists of 6 tissues. The treatment plans were calcualted by using the time reversal algorithm [3].

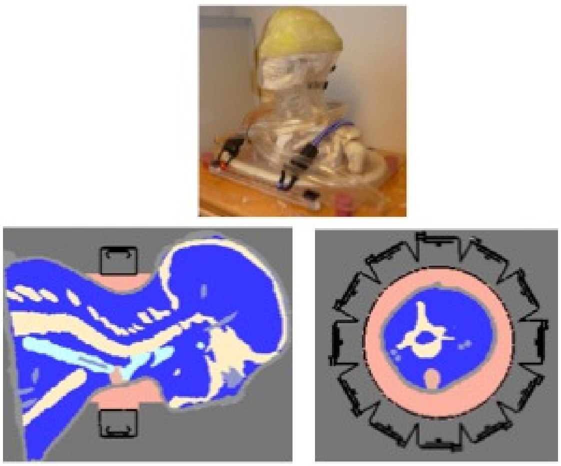

Fig. 3. (The anthropomorgical phantom and its dielectric model surrounded by water bolus (in pink). The laryngeal tumor is coloured in brown.

The PA distribution are presented for one ring setup with 12 antennas and for two different frequencies, 434 and 800 MHz. Simulation shows that focusing in the tumor is achieved in both cases. In the lower frequency case, the level of absorbed energy is higher with somewhat large focusing area. In both frequency cases various hot spots, points for which the maximal SAR exceeds a specific SAR selection level, can be delineated. Closer look however reveal the appearance of hot spots at different positions. Switching between two or more treatment plans during the treatment can be therefore expected to reduce significantly high energy levels in the treated area and subsequently lead to an improved treatment in means of higher tumor temperatures.

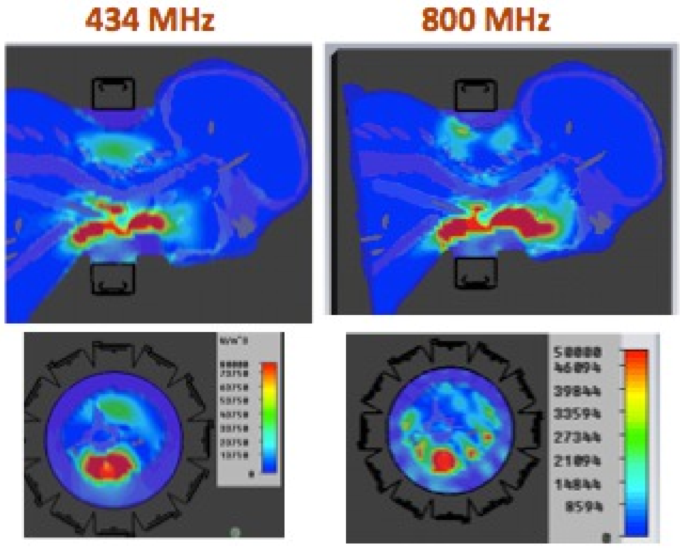

Fig. 4. (a) PA distribution in anthropomorgical phantom for frequency 434 and 800 MHz.

IV. Conclusion

The target of this work was to develop an UWB antenna applicator for microwave hyperthermia treatment of deep seated tumors. The applicator is based on a circular antenna array consisting of 12 to 18 selgrounded Bow-Tie antennas arranged in one to three rings. Antennas are immersed in single water boli attached to a thin common water layer. The simulation results on anthropological phantom suggests switching between two or more treatment plans during the treatment in order to reduce significantly high energy levels in the treated area.

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