WAVEGUIDE HORN APPLICATOR FOR MICROWAVE THERMOTHERAPY WITH DIELECTRIC LATERAL FACES

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Abstract: This paper describes the possibilities to use dielectric material as a lateral faces in waveguide-horn applicators. Two types of the applicator for local microwave thermotherapy are compared. At the parameters of the applicators (impedance matching, SAR distribution) are shown the advantages and disadvantages of the applicators with dielectric lateral faces.

Introduction

The microwave energy can be used for heating the biological tissue up to level 41 °C – 45 °C. That can be used for treatment of cancer. Healthy cells can survive higher temperature than tumour tissue (fig. 1).

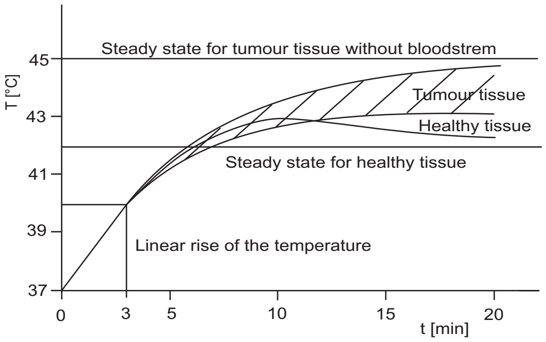

Figure 1: Temperature increase for healthy and tumour tissue.

The microwave applicator creates requested thermal distribution in the treatment area. One of possible types of the microwave applicator for hyperthermia is waveguide-horn applicator and various modifications. Waveguide type applicators can be used to transfer the power from the microwave generator to the biological tissue without high losses.

1 Feeding waveguide

Electromagnetic field is exited in feeding waveguide at the frequency 434 MHz. The parameters of the feeding waveguide are chosen that works in the middle of the dominant mode band. To decrease cut off frequency the feeding waveguide is filled by distilled water ($\varepsilon_r = 81$). The critical frequency of the dominant mode TE_{10} is then given by following formula:

$$f_{c,10} = \frac{c_0}{2a\sqrt{\mu_r \varepsilon_r}} = \frac{3.10^8}{2.0,058\sqrt{81}} = 287,4\,MHz \quad (1)$$

Critical frequences of the TE_{01} and TE_{20} mode are equal because we had chosen the height $b = 29\ mm$ one half of the windth $a = 58\ mm$.

$$f_{c,01} = f_{c,20} = \frac{c_0}{a\sqrt{\mu_r \varepsilon_r}} = \frac{3.10^8}{0,058\sqrt{81}} = 574,8\,MHz \quad (2)$$

N-type of connector has been used for connecting power generator to feeding waveguide. The distance between the feeding probe (N-connector) and short side of waveguide is usually chosen $\lambda/8$ so $l = 8\ mm$.

2 Horn of the applicator

The height of the horn is $B = 100\ mm$, the width is $A = 130\ mm$ and the length is $L = 76\ mm$.

2.1 Waveguide horn

The electric field strength in the aperture has assumed form

$$E_y(x,y) = E_0\, cos\left(\frac{nx}{A}\right) e^{-jk\Delta_a(x)} e^{-jk\Delta_b(y)} \quad (3)$$

where A is the width of the aperture, Δ_a and Δ_b are the deviation of the radial distance from the plane of the horn.

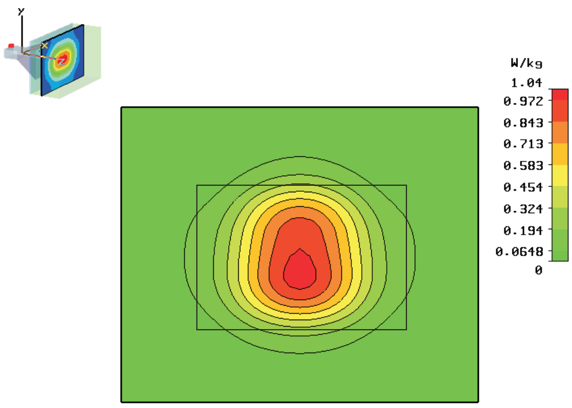

Figure 2: SAR distribution on the surface of the agar phantom.

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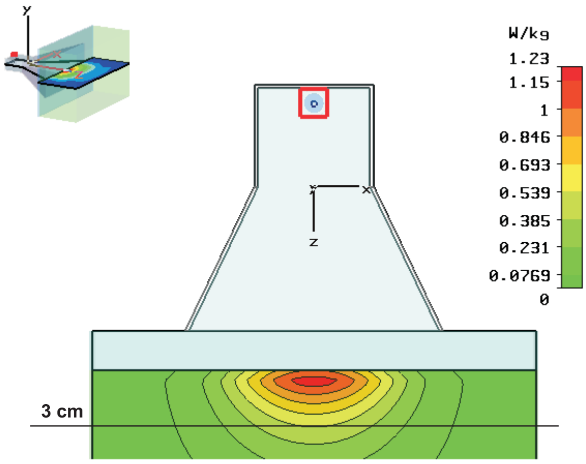

Figure 3: SAR distribution in the agar phantom.

Figure 2 and 3 describes SAR distribution in the agar phantom at the different cutting plane. There are also marked aperture of the applicator (fig 2) and effective depth of penetration (fig. 3).

Simulated impedance matching of the waveguide horn applicator at 434 MHz is $S_{11} = -34$ dB.

2.2 *Strip-line horn*

Let suppose, that inside the strip line the E field is quite uniform. When we made the lateral faces of the horn from the dielectric material we could assume larger area of thermal distribution in a biological tissue. We also inserted the dielectric cone into the aperture of the strip-line horn. The cone has radius $r = 15\ mm$ and its height is $v = 28\ mm$.

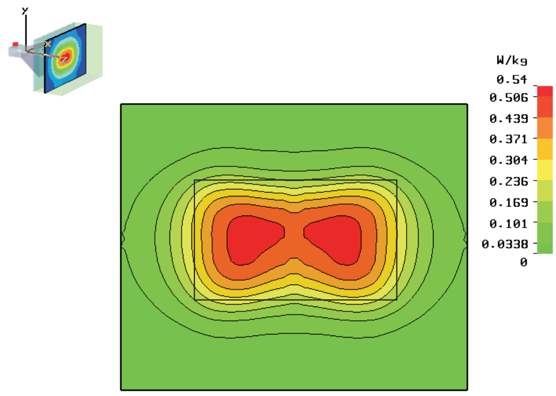

Figure 4: SAR distribution on the surface of the agar phantom.

On the figure 4 the influence of the dielectric cone to the SAR distribution on the surface of the agar phantom is shown (peaks lay around the perimeter of the cone).

Simulated impedance matching of the strip-line applicator at 434 MHz is $S_{11} = -29,15$ dB.

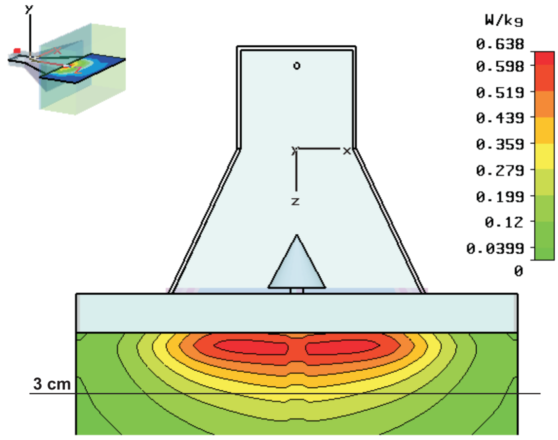

Figure 5: SAR distribution in the agar phantom.

3 Measurement

The strip-line horn applicator with the cone inside the aperture was made and measured.

Figure 6: Applicator with strip-line horn.

The SAR distribution was measured by aid of the thermal camera, see fig. 7 and we could calculate the SAR value in the middle of the applicator's aperture. Input power was 150 W during the 2 minutes.

$$SAR = c\frac{(T_1 - T_2)}{t} = 3000\frac{(29,5-23)}{120} = 162,5\,W/kg \tag{4}$$

where $c\left[J.kg^{-1}.K^{-1}\right]$ is material constant of the agar phantom, $T_1\,[^\circ C]$ and $T_2\,[^\circ C]$ is the temperature at the beginning and at the end of the time interval, $t\,[s]$ is duration of the time interval.

The impedance matching was measured by aid of the vector analyzer-sixport and at 434 MHz is $S_{11} = -43,31$ dB see fig 8.

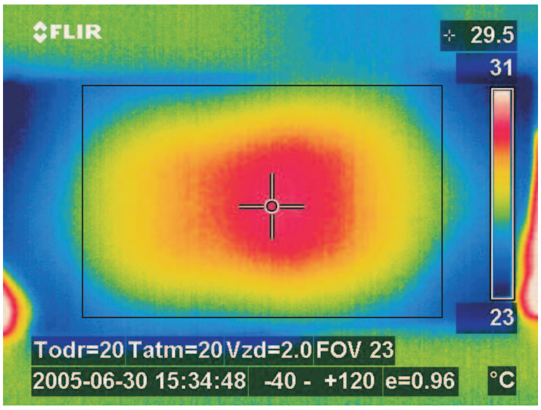

Figure 7: SAR distribution on the surface of the agar phantom.

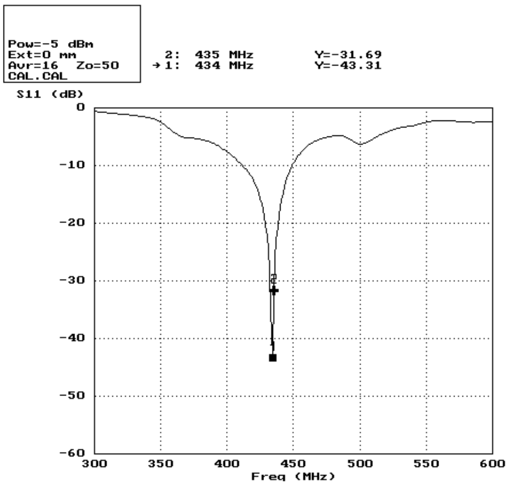

Figure 8: Impedance matching of the applicator.

4 Conclusion

The impedance matching of both types of the applicators at the working frequency are prefect. Simulationes shows that strip-line applicator achieve larger thermal distribution than the waveguide one. Simulated and measured SAR distributions of the strip-line horn applicator are in good agreement.

Acknowledgements

This research is supported by Czech Research Program: ”Transdisciplinary Research in the Area of Biomedical Engineering II” (MSM6840770012) and by Grant Agency of the Czech Republic project: Medical Applications of Microwaves: ”Therapy and Diagnostics” (102/05/0959).

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 ISSN: 1727-1983