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Hyperthermia Applicator for Electromagnetic interaction with Human tissue at 434 MHz

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Abstract: *Hyperthermia is the most recent therapy in investigating the biological effects and applications of microwaves for treatment of cancer and tumour. It refers to an artificial heating above 45°C in order to cure cancer. Various antennas like slot antenna, loop antenna, dipole antenna and patch antenna etc. are used as Hyperthermia applicators for damaging and killing cancerous cells from the body. In this paper, an annular patch antenna operating at 434 MHz has been use as applicator. A simple planar three layer phantom model has been used to examine the effect of applicator at varying distances from the body. The Specific Absorption Rate and return loss are computed and compared at different distance of antenna from body. Finite Element Method is used to generate the model and predict the absorbed energy.*
Keywords: *Applicators, Hyperthermia, Finite Element Method (FEM), Specific Absorption Rate (SAR), Radiotherapy.*

I. Introduction

Cancer has become one of the most distressing diseases in the developed country these days. The most common therapies in use for treatment of cancer diseases are Radiotherapy and Chemotherapy. However these treatments have a lot of negative side effects, so it becomes essential to find out alternatives which permit the patient to fight the illness without any other consequences or symptoms of Radiotherapy and Chemotherapy. A number of clinical trials of Hyperthermia in combination with radiation therapy or chemotherapy have been reported [1]. The most efficient means in treatment of superficial tumours and Cancer is Hyperthermia [2]. Electromagnetic (EM) applicators operating in the range of 434–2450 MHz are generally used for Hyperthermia [3] .Hyperthermia has been one of the interesting area investigating biological effects and applications of microwave for treatment of cancer and tumour. Recently, methods for hyperthermia treatment using ultrasound or electromagnetic energy have been introduced into cancer treatment, fat reduction and muscle treatment [4]. External radio-frequency/microwave hyperthermia antenna applicators are designed to non-invasively combine electromagnetic (EM) energy through human skin as an extra anti-cancer treatment with an Ionizing or Chemo-Therapy [5]. These studies have paid attention on dealing of a number of types of cancer, including cancers of the head and neck. Numerous studies have exposed a major decline in tumour size when hyperthermia is combined with other treatments. High temperature hyperthermia, plus lasers and the use of radiofrequency, microwaves, and high-intensity focused ultrasound, are in advance consideration to be used as an substitute to standard surgical therapies [6]. The energy is deployed in regions with cancerous tumour masses to elevate the temperature to approximately 42–45°C. Since tumours have reduced rates of temperature cooling due to naturally impeded blood flow, the non-ionizing application aims to selectively impart the additional energy without damaging the enclosing healthy tissues. The advantage of using Hyperthermia include the direct killing of raised temperature tumourous cells, increased cell oxygenation, stimulation of the immune system, increased metabolic activity and an improved drug uptake in cells [7].Hyperthermia applicators are operated in a variety of Industrial Scientific Bands at 27, 434, 915 and 2450 MHz. An even Specific Absorption Rate (SAR) distribution has shown at 434 Mhz and a greater penetration depth than 915 MHz [8] and 2450 MHz [9].

II. Antenna Geometry

This paper include use of dielectric Taconic RF substrate of 130mm×130mm×2.7mm with circular Patch of diameter, R1=42mm, R2=51mm, R3=62mm. A ground with two rectangular slots of length L1=106 mm and L2 =108mm, w=4mm that intersect with a circle R4 =10mm. 50 ohm coaxial feed is applied at the annular ring at x=y=40mm. Fig. 1 shows the front and rare view of antenna and Fig. 2 shows the simulation model.

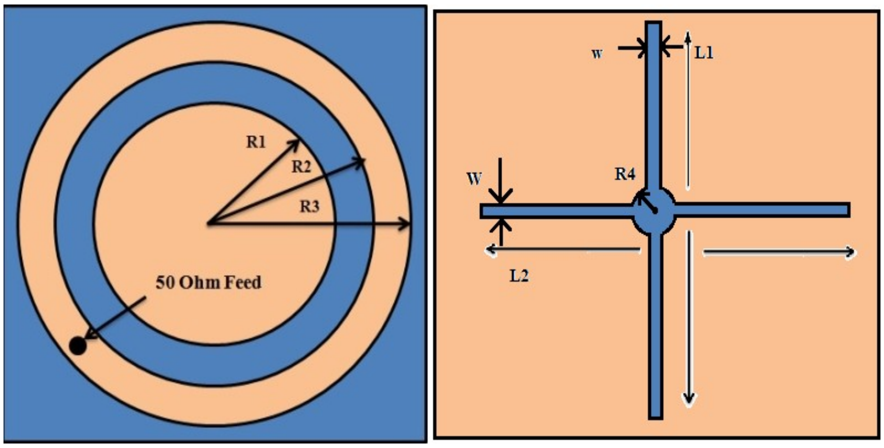

Figure 1: Compact patch antenna: (left) the front annular-ring/patch surface, (right) the rear ground plane/slots surface.

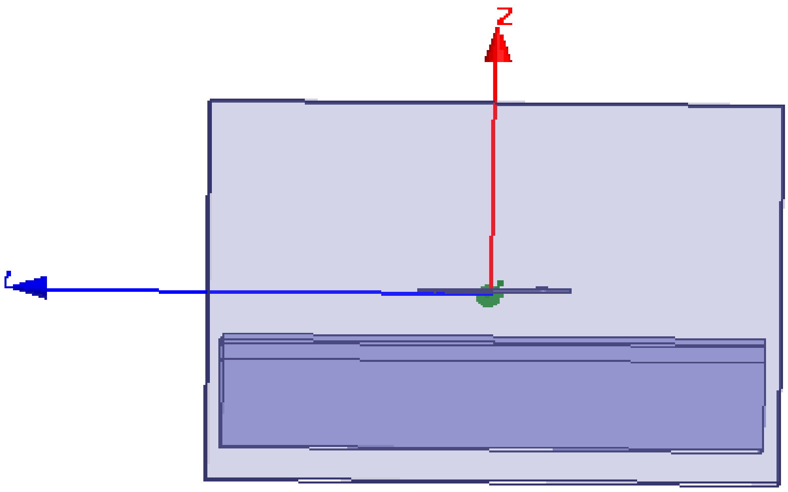

Figure 2. The Simulation model

III. Phantom Model And Water Bolus

A three layer tissue model is used along with a layer of water bolus containing deionised water to diminish computational resources. Water bolus is added to skin surface for tissue cooling and for the prevention of hotspots. It helps in maintaining skin temperature and serves the purposes of keeping get in touch with between the applicator and the patient. In addition improved controlled temperature allocation and heating pattern can play a significant role in the effectiveness of active drugs as well as the activation of new temperature-dependent ones [10] . A tri-layered tissue model consists of skin, fat and muscle. Table 1 details the dielectric parameters of permittivity (ε_r), conductivity (σ) and density (ρ) [11] at 434 MHz. The Skin width ranges from minima at the thorax, abdomen and spine to maxima at the adult thorax [12].In this we have taken skin thickness of 0.4 mm and 2.6 mm. Fat thickness ranges from 0 mm to 30 mm.

Table 1. Conductivity,Permittivity, Density and Thickness of Tissue Material at 434 MHz

Material	Conductivity (σ, S/m)	Permittivity (ε_r)	Mass Density (ρ, Kg/m^3)	Phantom tissue(mm)					
De-ionized Water	0.001	76.0	1000	5.0 mm					
Skin	0.702	46.05	1100	0.4			2.6		
Fat	0.041	5.560	916	0	15	30	0	15	30
Muscle	0.805	56.86	1041	99.6	84.6	69.6	97.4	82.4	67.4

IV. Absorption in human body

Biological effects depend upon the EM field in the tissues, i.e., on the Specific Absorption Rate (SAR), which is defined as the power deposited in a unit mass of tissue. Human tissues differ in their permittivity [13], varying with frequency. Relaxation phenomena occur at RF and microwaves. Specific absorption rate is the key parameter to calculate the absorption of EM waves in human body. SAR is typically averaged either over the whole body, or over a minute model volume [14] as shown in equation 1and expressed as Watts per kilogram. It is approximated that an increase of 1 degree is produced by SAR of 1 W/Kg in human body temperature, taking thermoregulation into account.

$$SAR = \sigma E^2 / \rho \ [W/Kg] \qquad (1)$$

Where σ is the conductivity of the tissue (S/m), ρ is the density of the tissue (Kg/m3), and E is the electric field (V/m) [15].

V. Methodology

Antenna is positioned in front of phantom model and the main purpose of antenna is to convey energy to the phantom. The antenna is placed at different distance from the phantom model to calculate the efficiency of antenna. In this we place antenna at 43.2mm (λ/16), 10.8mm (λ/64), 8.1mm (3λ/256), 5.4mm (2λ/256) and 2.7mm (λ/256) from the phantom. The parameters of antenna are developed for better SAR when we use water bolus. Ansoft HFSS software has been used for predicting the effect of the absorbed energy. FEM modeling is used for the analysis purpose.

VI. Results And Discussions

The illustrated results are the comparison of various antenna parameters at different distances from body. Comparison is being made on basis of some evaluated parameters. The parameters are Return loss and Specific Absorption Rate. The return loss and SAR as a function of frequency of designed antenna is depicted at different values of distances .Fig 2-6 show the value of return loss at various distances with dimensions of phantom with 0.4mm skin, 15 mm Fat and 84.6mm muscle. After analysis, SAR of 6.797 at 2.7 mm , 5.4103 at 5.4 mm, 0.0077 at 10.8mm, 0.011 at 10.8mm and 0.0054 SAR at 43.2mm is obtained. Table 2 illustrates SAR at 2.7mm, 5.4 mm, 8.1mm, 10.8 mm and 43.2 mm antenna and Phantom distance for various combination of skin ,fat and muscle thickness.

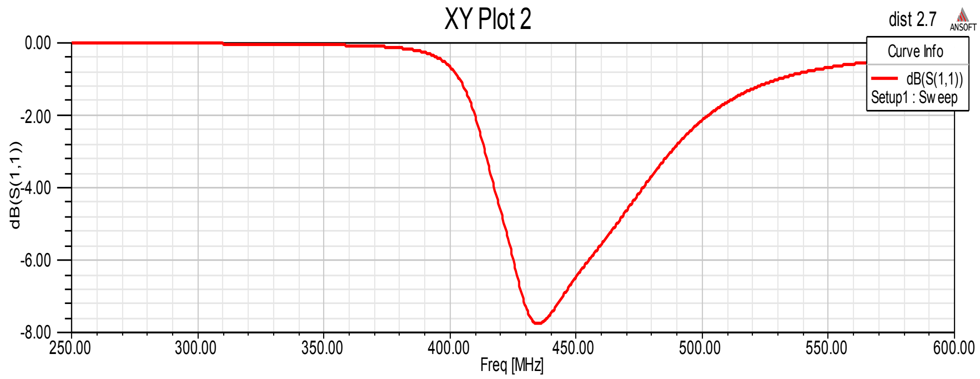

Figure 2. S11 for 2.7mm Antenna Waterbolus Distance

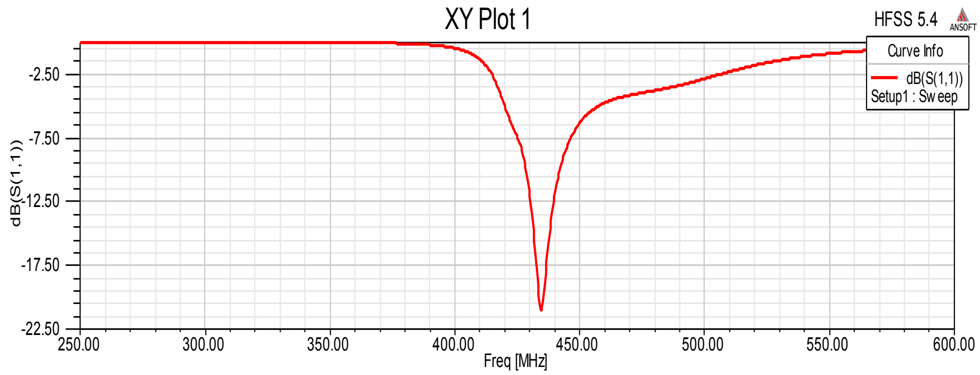

Figure 3. S11 for 5.4mm Antenna waterbolus Distance

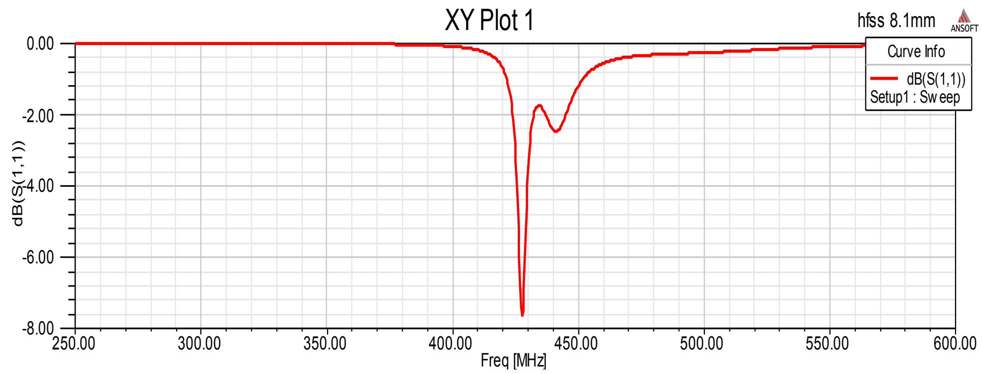

Figure 4. S11 for 8.1mm Antenna Waterbolus Distance

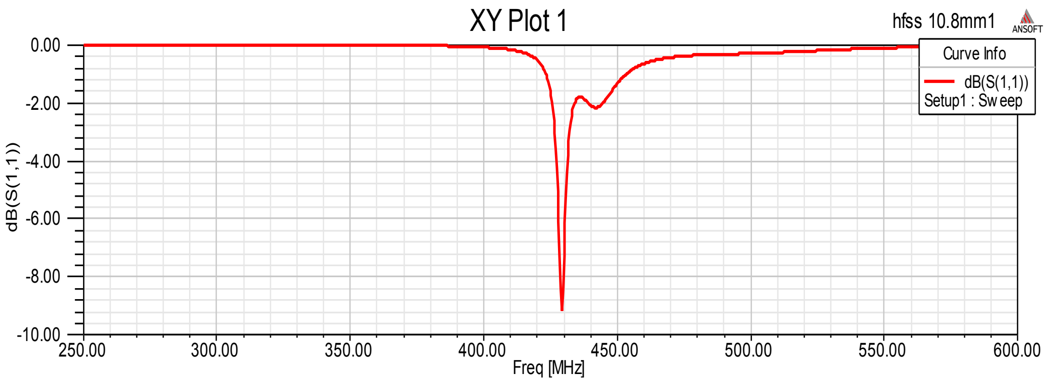

Figure 5. S11 For 10.8mm Antenna Waterbolus Distance

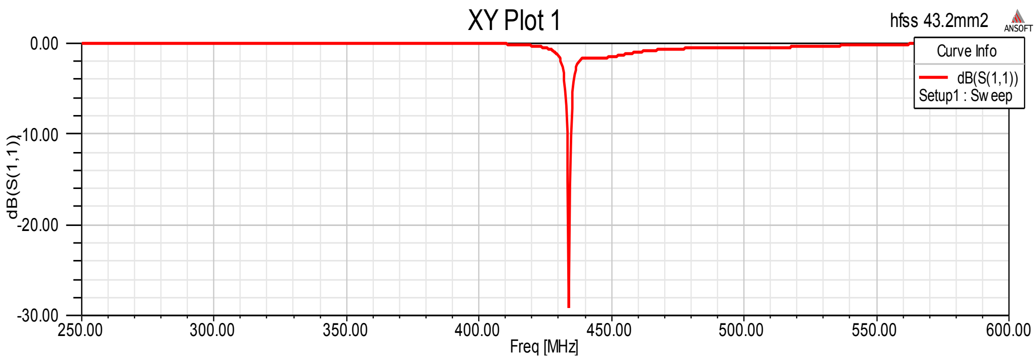

Figure 6. S11 for 43.2mm Antenna Waterbolus Distance

Table 2. SAR at different antenna waterbolus distance for various combination of skin, fat and muscle thickness.

Skin (mm)	Fat (mm)	Muscle (mm)	SAR(W/Kg) at				
			2.7mm	**5.4mm**	**8.1mm**	**10.8mm**	**43.2mm**
2.6	0	97.4	2.313	2.63	0.012	0.0090	0.0060
2.6	15	82.4	6.7978	5.419	0.011	0.0077	0.0050
2.6	30	67.4	7.69	8.963	0.0014	0.0093	0.0082
0.4	30	69.6	2.14	9.570	0.020	0.0027	0.014
0.4	15	84.6	5.85	4.653	0.0092	0.0053	0.0038
0.4	0	99.6	10.09	1.90	0.0073	0.0071	0.0057

VII. Conclusion

The performance of annular patch antenna for the treatment of cancer cells has been presented in this paper. The antenna performance is compared at different distances from the phantom model using FEM modeling. SAR and return loss has been evaluated at varying distances of 43.2mm (λ/16), 10.8mm (λ/64), 8.1mm (3λ/256), 5.4mm (2λ/256) and 2.7mm (λ/256) of antenna from the phantom. It has been observed that the value of SAR decreases as the distance increases. The value of SAR at distance 43.2mm, 10.8m, 8.1mm, 5.4mm and 2.7mm ranges from 0.0014(W/Kg) to 10.0(W/Kg) which lies in the permissible limits of exposed body as stated by IEC is 2-10(W/Kg). So this antenna can be used as an applicator in the treatment of Hyperthermia.

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