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Design of Structural Antennas for Melanoma Treatment

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***Abstract* - One of the applications that use nanosecond and subnanosecond high voltage pulses is cancer therapy. In particular , non-thermal changes in the cells, especially the permeabilization of the membrane can be introduced using subnanosecond pulses. The motivation is to radiate intense subnanosecond pulses to the tumors non-invasively. Intense EM waves that is emitted at the first focal point is been focused at the second focal point where the target that is the tumor is present. Two antennas with PSR are designed to focus pulsed type field at the second focal point. The modified bicone antenna and elliptically tapered horn antenna as feeds for PSR is designed. Comparison of design parameters and radiation performance is done.**

Index Terms— bicone antenna, horn antenna, melanoma treatment, prolate spheroidal reflector

I.INTRODUCTION

The effects of pulsed type electric fields on biological cells and tissues have been the topic of research for many years. The demand of pulsed type electric fields has actually gushed the treatment of cancer with local, non-thermal and even drug-free therapy. In 1957 Stampfli and Willi established that the damage of the membrane is irrevocable if the pulses applied is longer but otherwise the membrane is recovered to its original characteristic. Experiments showed that that there was an increase in the permeability of the plasma membrane due to strong electric field pulses (Neumann and Rosenheck, 1972), this effect was named as electroporation. Current demand has been centered on the use of electrochemotherapy, the combination of reversible electroporation with the administration of otherwise low-permeant cytotoxic drugs.
When the permeable state is temporary, the permeabilization is referred as reversible (ref. electrochemotherapy) which is opposite to irreversible electroporation (IRE) (Silve et al., 2012). The first studies of IRE involved the investigation of cellular destruction through the application of electrical pulses. Davalos and coworkers investigated this concept by using a mathematical model and in vivo conditions (Davalos et al., 2005). Results showed that IRE could cause cell death without using thermal energy. In 2001 Schoenbach and coworkers described the cellular response (intracellular effects) due to sub-microsecond pulses with mega-volt per meter magnitudes (i.e.10 kV/cm) (Schoenbach et al., 2001). With the developments of electrical engineering, researchers could apply electric fields with even higher electric intensity and shorter (subnanoseconds) duration to cells. The probability of perforation into the interior of the cell for subnanosecond pulse is higher than the nanosecond pulses. For sub nanosecond pulses the pulse duration is in the range of 100–200 ps which makes it possible to accent the radiation on the target and produce small spot size in the tissue. This push towards further pulse shortening is drives the possibility of using wideband antennas, rather than direct contact electrodes, to deliver such pulses for noninvasive treatment of deep lesions (Joshi and Schoenbach, 2010) The use of antennas would allow one to apply such electric fields to tumors that are not easily accessible with needles and may be able to induce apoptosis in tissue (Joshi and Schoenbach, 2010; A possible configuration that would generate very high electric fields is using a focusing antenna (Baum, 2007; Schoenbach et al., 2008, Xiao et al., 2010). The antenna for emitting and focusing ultra-wide band and high power signals with low dispersion and high directivity can be a reflector-type antennas or arrays. Usually an ellipsoidal dish is used and it has two focal point. The radiation source is placed at the first focal point and the target (tumor) is placed at the second focal point.

II. REVIEW

In the proposed work, first we designed prolate spheroidal reflector (PSR) with Modified Bicone Antenna (MBA) as feed and its radiation characteristics are obtained.
Second, the elliptically tapered horn antenna (ETHA) feed for PSR is designed and its radiation

characteristics are obtained. Later, the radiation characteristics are been compared.

III. DESIGN OF PROLATE SPHEROIDAL REFLECTOR (PSR)

The IRA consists of three elements, a PSR; a miniature feed structure and feeding mechanism. The Centre and top radius of the sphere is 400mm.The reflector dimensions is same for both the antenna's.

III. Design of modified bicone antenna as feed for PSR – Antenna 1

The important design of prolate spheroidal impulse radiating antenna (PSIRA) is its feed antenna design. The MBA feed is suitable for UWB applications such as high power subnanosecond pulse radiation.. It has high directivity and high gain.

The design begins with bicone antenna. The two cones are slanted with a slant angle equal to 17 degree so that to concentrate the radiation in one direction. In order to improve the radiation characteristics the bicone antenna is reshaped or truncated at the bottom, top and side and rear end of the antenna The frequency spectrum is 0.5 GHz–1.5 GHz . The height of the antenna is 370.77mm. The length and width is designed as 240 mm and 163.68 mm, respectively. The feed gap between the cones is as 9 mm. The antenna with and without carving is shown in the fig1

The characteristic impedance of a bicone antenna is given by

$$Z_{in} = \eta/120\pi[\ln(\cot(\alpha/4))] \quad (1)$$

Where Zin is the input impedance of the antenna .η is the free space impedance and α is the cone angle .

The top radius of the cone is given by the equation

$$R = l * \sin(\alpha/2) \quad (2)$$

Where R is the top cone radius and l is the length of the cone

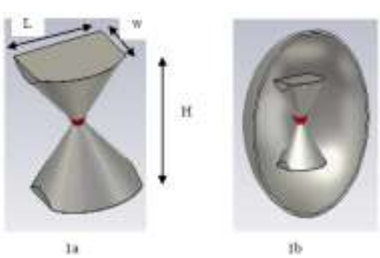

Figure 1: Bicone antenna a) without carving b)with carving

The emitted pulse from the feed antenna is focused in to the second focal point where the cancer tissue is present. The target (cancer tissue) is located at a distance of 700mm from the antenna. The length, width and height of the target is 400mm.The antenna with the target is shown in the fig2

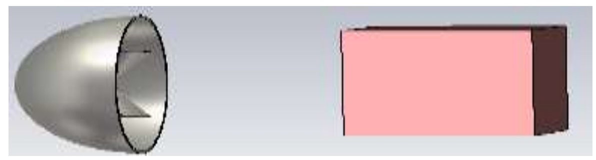

Figure 2 : Antenna with target

Table 1: Radiation characteristics of PSR with MBA feed

Sl. no	Radiation characteristics	Without target	With target
1	Directivity	9.892	9.672
2	Sidelobe level(dB)	-3.3	-1.1
3	3 dB beam width (degree)	28	23.7
4	Return loss	-28.3	-26.24

V.DESIGN OF HORN ANTENNA AS FEED FOR PSR – ANTENNA-II

In ETHA feed structure, the two metallic plates are separated by air dielectric. All the frequencies generated at the throat of the horn are arrived at the aperture together therefore a wide band pulse is radiated from the aperture. The total length of the horn is 149.466 mm. The height is 234.56mm. The width 70.46. The antenna covers the wideband spectrum of 0.5 Ghz to 1.5 Ghz.

Length and height of the Horn antenna is calculated using the following equations

$$\text{length}, a1 = \sqrt{3} * \lambda * ph \quad (3)$$
$$\text{height}, b1 = \sqrt{2} * \lambda * pe \quad (4)$$

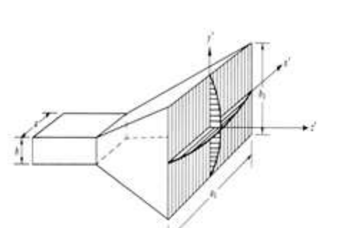

Figure3: Section of a horn antenna

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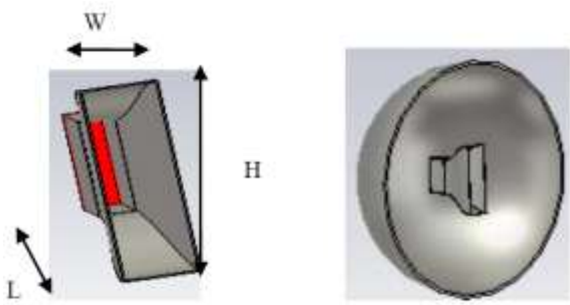

Figure 4: Horn antenna a) without carving b)with carving

The emitted pulse from the feed antenna is focused in to the second focal point where the cancer tissue is present. The target (cancer tissue) is located at a distance of mm from the antenna. The length, width and height of the target is 400mm.The antenna with the target is shown in the fig 5

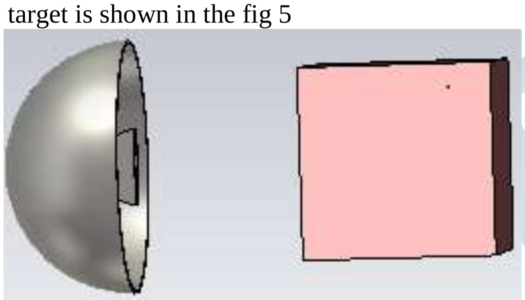

Figure 5: Antenna with the target

Table 2: Radiation characteristics of PSR with ETHA feed

Radiation characteristics	Without target	With target
Directivity	9.129	8.559
Sidelobe level(dB)	-10.1	-1.4
3 dB beam width (degree)	32.6	26.8
Return loss	-41.79	-42.481

VI. RADIATION CHARACTERISTICS COMPARISION OF ANTENNA-I AND ANTENNA-II CONFIGURATION

Electromagnetic simulation setup

The Antenna-I and Antenna-II are designed and simulated. In order to realize a model of the original antenna the simulation software CST Microwave Studio is used .It is based on the finite integration technique (FIT), a general approach, which describes Maxwell's equations on a grid space and can be used in both time domain and frequency domain. The time-domain solver is used to simulate the whole structure. The reflector and its feed are assumed to be perfect electric conductor (PEC).

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VII .COMPARISION

This section shows the comparison between the two configurations with target. Fig 6 shows the return loss of the two configurations with target. At 1GHz center frequency the return is comparatively less for Antenna-II (42.48dB) than the Antenna-I (-26.24dB) Fig 7 and 8 shows directivity. Antenna-I (9.634dB) shows higher directivity than that of Antenna-II (8.559dB) . II

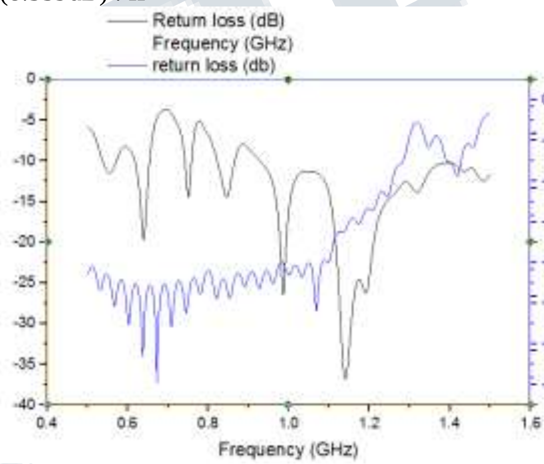

FIGURE 6 : RETURN LOSS OF THE TWO CONFIGURATIONS WITH TARGET.

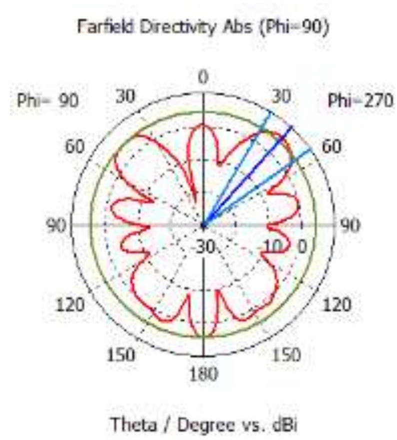

Figure 7 : Radiation pattern of Antenna-I with target

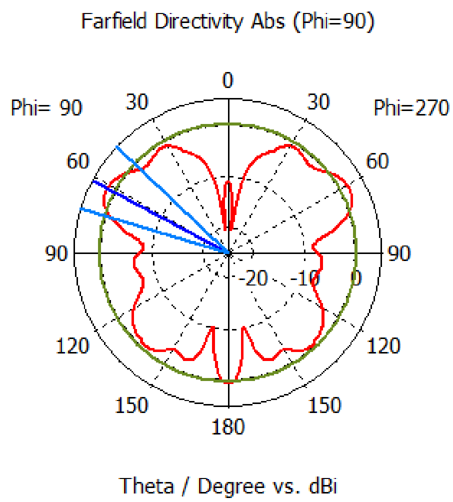

Figure 8 : Radiation pattern of Antenna-II with target

Fig 9 and 10 shows 4.1.3 Specific Absorption Rate (SAR) of two antenna configurations. SAR is defined as the power absorbed per unit mass of tissue and has units of Watts per Kilogram (W/kg). Melanoma treatment requires increased directivity which in turn yields higher SAR value, so that cancerous tissue will absorb more EM energy and gets destroyed. Antenna-I (Bicone) has reduced spot size as compared to antenna-II (Horn).

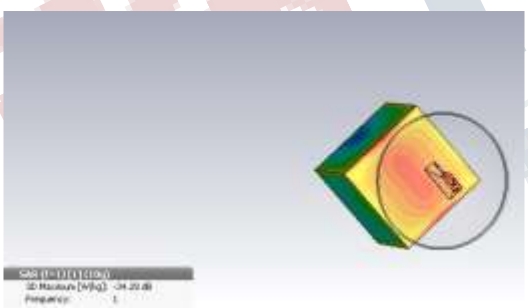

Figure 9 : SAR of Antenna-II

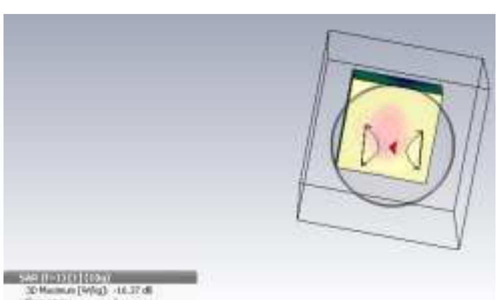

Figure 10 : SAR of Antenna-I

VIII. CONCLUSION

This paper describes a new type of subnanosecond launching systems for PSR. The PSIRA is used as a non-invasive pulse delivery system to treat melanoma in the near-field region. The two proposed antenna configuration is designed and simulated. The two antenna configurations are designed smaller in dimensions compared to the traditional IRA. The Antenna-I configuration has reduced spot size. Due to the miniature in size both the feeds can be utilized for array configuration. The array configuration is used to enhance the directivity as well as electric field intensity. The proposed feeds of PSR are wide band, less dispersive, more directive. The higher directivity make this antenna useful in medical imaging, detection of object buried in loss materials, detection of stealth targets. These two antenna configurations are suitable for high power applications such as electronic warfare.

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