Microwave Tumor Detection Using a Flexible UWB Elliptical Slot Antenna with a Tuning Uneven U-shape Stub on LCP

Negar Tavassolian *, Symeon Nikolaou, and Manos M. Tentzeris

GEDC, School of ECE, Georgia Institute of Technology, Atlanta, GA 30332-250, USA

E-mail: negar@ece.gatech.edu

Abstract

In this paper, we investigate tumor detection capabilities of the CPW-fed Elliptical Slot Antenna with a Tuning Uneven U-shape Stub on flexible liquid crystal polymer (LCP) in the UWB Microwave range of frequencies. The software "Microstripes" (based on FDTD) is used in our work to develop a realistic breast model and to analyze the tumor response of several tumors with different sizes and orientations.

I. Introduction

Currently, the most commonly used methods for detecting breast tumors are X-ray mammography and ultrasound imaging. However, both these methods exhibit several limitations in detecting breast tumors at an early stage [1]. Microwave detection of breast cancer is particularly motivated by the considerable contrast in the dielectric properties of normal and malignant breast tissues at microwave frequencies. Moreover, microwave attenuation in normal breast tissue is low enough to make signal propagation through even large breast volumes feasible [2]. In addition, microwave technology would be non-ionizing and non-invasive. For these reasons, microwave breast imaging has been suggested recently for early detection of breast tumors. For breast imaging, we are interested in the 1-11GHz regime because it appears to balance the conflicting demands of better spatial resolution (higher frequencies) and better penetration depth (lower frequencies).

The CPW-fed Elliptical slot antenna on LCP was designed in [3] and is used in our work as the radiator for microwave breast tumor detection. This uniplanar compact antenna has return loss below -10dB and consistent radiation pattern in the UWB range of frequencies (1-12GHz). We tested the detection performance of this antenna for different orientations close to a realistic hemispherical breast model. The commercial software "Microstripes" (based on the FDTD method) was used to develop the breast model and to calculate the tumor response of tumors with different diameters (up to 6 mm) located inside a gland. Different antenna locations and different electrical parameters of the tumor-containing gland are analyzed in this paper. The excitation pulse is a wideband pulse centered at 6GHz with a bandwidth of 10GHz. Details can be found in [4].

II. Geometry of the Problem

The hemispherical breast model is adapted from [5]-[7], and is shown in Fig.1. The model contains the important breast tissues such as skin, chest wall and randomly placed mammary glands. The shape and orientation of the random glands are based on [5], [6].

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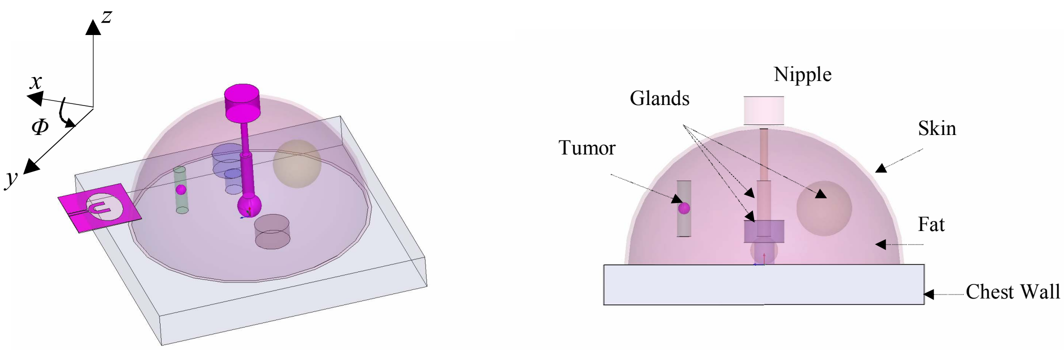
The glands are modeled as spheres (radius 8.5mm < r < 12.5mm) and cylinders (radius 2mm < r < 18mm, height 12mm < h < 27mm). The tumor is modeled as a sphere (diameter varies between 2-6mm), embedded inside a gland, as this is the case for tumors in real life. The electrical parameters of the tissues are listed as follows [5]-[7]:

- Skin (2mm thick): $\varepsilon_r = 36$, $\sigma = 4$ S/m
- Breast fat: $\varepsilon_r = 9$, $\sigma = 0.4$ S/m
- chest wall (16cm×16cm×2cm): $\varepsilon_r = 50$, $\sigma = 7$ S/m
- Tumor: $\varepsilon_r = 50$, $\sigma = 4$ S/m
- Different Glands: $11 < \varepsilon_r < 15$ and 0.4 S/m $< \sigma < 0.5$ S/m
- Immersion gel for antenna matching: $\varepsilon_r = 10.2$, $\sigma = 0$

The simulation consists of two parts: First we rotate the antenna around the breast to view the effect of different gland arrangements on tumor response. The simulation is repeated for different tumor diameters. Next, we place the antenna in a fixed position and change the electrical parameters of the tumor-containing gland to examine the sensitivity of the tumor response to gland parameters.



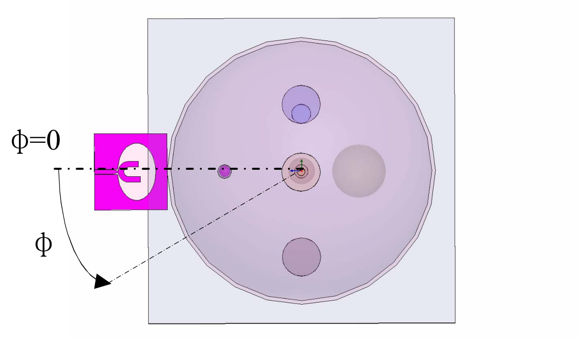
(a) (b)

Fig.1. Hemispherical breast model (a) general view showing the antenna near the model (b) side view. Adapted from [5]-[7].

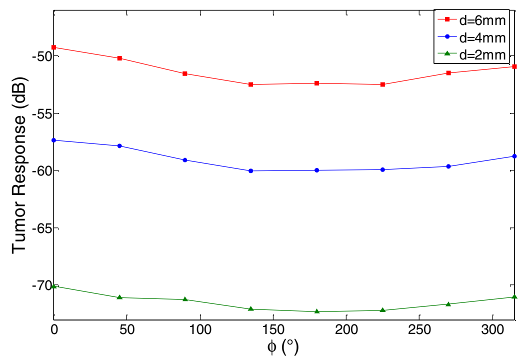
III. Sensitivity to different gland arrangements

Without loss of generality, we assume that the antenna is located at mid-breast plane, 5mm away from the skin and is rotated (azimuth) around the breast on this plane as shown in Fig.2.a. The tumor-containing gland is a cylinder with r=10mm and h=24mm and electrical parameters ε_r=12 and σ=0.4 S/m. Tumor responses for eight different antenna locations and for 3 different tumor sizes (diameters of 2mm, 4mm, and 6mm) are shown in Fig.2.b. The radiated power is less than 120 mW for all cases, which ensures safety and compliance with standards. Also, the amount of power absorbed in a volume of tissue (known as SAR) is expected to be one or two orders of magnitude below those of a cellular telephone [1]. Thus, microwave imaging will not create a health risk to the patient. The reflected electric field from the tumor at the antenna feedpoint is measured and normalized to the incident field to find the tumor response.

It is seen that the tumor response level for this antenna is much higher than for similar antennas [5], [6]. The tumor response is realistic even for a tumor with a 2mm diameter (higher than -75dB). The tumor response decreases as the antenna moves away from the tumor, although the return variation between the extreme cases of φ=0° (closest to the tumor) and φ=180° (furthest distance from the tumor) do not differ more than 4dB for all tumor sizes, showing that the antenna has the ability to detect tumors of the above sizes in all locations.



(a)



(b)

Fig.2. (a) Central cross-section plane of the breast model shown in Fig.1. The antenna is located in this plane and is rotated to eight locations, defined by increments of 45° of the angle φ. (b) Tumor response levels for each antenna location and for 3 different tumor sizes

IV. Sensitivity to gland parameters

To evaluate the sensitivity performance of the proposed antenna, the permittivity of the tumor-containing gland was modified according to the values at the horizontal axis of Fig.3. The gland conductivity was kept as σ=0.4S/m and the permittivity value varied within ±25% around its assumed value of ε_r=12. The tumor diameter is 6mm. As seen in the graph, the variation in the tumor response is as small as almost 3dB. As expected, tumor response decreases as the permittivity of the tumor containing gland approaches that of the tumor. Results showing the detection resolution that allows for the separation of neighboring and/or shadowing tumors will be presented at the conference.

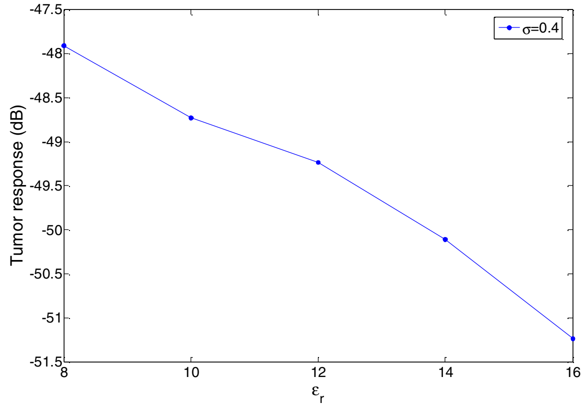


Fig.3. Tumor response variation with permittivity of the tumor-containing gland

V. Conclusions

This paper reports on tumor detection capabilities of the CPW-fed Elliptical Slot UWB Antenna with a Tuning Uneven U-shape Stub on flexible LCP. Results show that this antenna has a much higher tumor response compared to previously published work over the UWB microwave frequency range. Also, this antenna has low sensitivity to variations of the electrical parameters of the gland and to gland arrangements (antenna locations), while allowing for the detection of tumor sizes down to 2mm in diameter The antenna proves a suitable choice for microwave tumor detection.

References:

[1] E.C. Fear, P.M. Meaney and M.A. Stuchly, "Microwaves for Breast Cancer Detection?", *IEEE Potentials, vol. 22, Issue 1, Feb-Mar 2003, pp:12–18*

[2] C. Hagness, A. Taflove and J. E. Bridges, "Three-dimensional FDTD analysis of a pulsed microwave confocal system for breast cancer detection: Design of an antenna-array element", *IEEE Transactions on Antennas and Propagation, vol. 47, pp. 783–791, May 1999.*

[3] S. Nikolaou, G.E. Ponchak, J. Papapolymerou and M.M. Tentzeris, "CPW-fed Ellipti cal Slot UWB Antenna with a Tuning Uneven U-shape Stub on Liquid Crystal Polym er (LCP)", *Proc. Of the 2006 ACES Conference, Miami, FL, March 2006.*

[4] http://www.flomerics.com/microstripes/

[5] N. Tavassolian, H. Kanj and M. Popovic, "The Effect of Breast Glands on Microwave Tumor sensing with Dark Eyes Antenna", *IEEE AP-S International Symposium, Albuquerque, New Mexico, July 2006*

[6] N. Tavassolian, H. Kanj and M. Popovic, "Assessment of Dark Eyes Antenna Radiation in the Vicinity of the Realistic Breast Model", *12th International Symposium on Antenna Technology and Applied Electromagnetics (ANTEM) Montreal, Canada, July 2006*

[7] E.C. Fear and Michael Okoniewski, "Confocal Microwave Imaging for breast tumor detection: application to a hemispherical breast model", *Microwave Symposium digest, 2002 IEEE MTT-S International, vol. 3, 2-7 June 2002, pp. 1759-1762*

[8] E. C. Fear, S. C. Hagness, Paul M. Meaney, Michael Okoniewski and Maria Stuchly, "Enhancing Breast Tumor Detection with Near-Field Imaging", *Microwave Magazine, vol. 3, Issue 1, March 2002, pp: 48 – 56*