Diagnosis of Breast Tumors using a PIFA antenna

Engy Alaa El Din Hanafy
German University in Cairo
Faculty of Information Engineering and Technology
Cairo, Egypt
Email: engy.alaa1 {at} gmail.com

Abdelmegid Allam
German University in Cairo
Faculty of Information Engineering and Technology
Cairo, Egypt

Abstract— **Microwave detection techniques for breast cancer showed that there exist a contrast between the electrical properties between normal and malignant breast tissues that is worth observation. Taking advantage from such observation a spiral PIFA antenna is designed to help in the detection of breast cancer. The antenna is intended to operate in the Medical Implant Communication Service (MICS) frequency band from 402- 405 MHz. A heterogeneous breast model is designed with more resemblance to the realistic case. The antenna is designed to be used as a stethoscope. The whole structure is simulated on CST Microwave Studio and measurements are carried using Network Analyzer.**

Keywords- PIFA antennas, breast cancer, tumor detection

I. Introduction

Over the past decade the interest in using antennas in medical purposes has increased. Nowadays researches are focused to help increase the welfare of humans, reduce invasive surgeries, and offering better diagnosis and treatment for them. Modern communication technology is considered to be an attractive field for this kind of applications. Studies are conducted to the usage of antenna for medical detection, diagnosis and even treatment of some diseases. With the help of the evolution in wireless technology it became possible to integrate an antenna in an implanted device, and placing it inside the human body. Thus the term of antennas in biomedical applications is turning out to be more and more familiar [1]. One can now find growing number of biomedical devices such as cardio pacemakers, glucose level monitoring sensors, and capsule endoscope systems.

Cancer in general initiates when a cell starts to grow and behave in an abnormal way. In breast cancer specifically the malignant tumor starts in the cells of the breast [2]. Most probably it will start in the ducts or the lobules hence the name Ductal carcinoma in situ (DCIS) and Lobular carcinoma in situ respectively. Malignant tumors are first localized and invade the surrounding tissues then they evolve and spread (metastasize) to distant body places. A key role in the curing process is to detect breast cancer as early as possible.

It was found that a temperature difference between malignant and normal breast tissues exists. As well as the temperature variation, a difference in the dielectric properties between both types of tissues also occurs [3]. A study was done on normal, cancer and benign breast tissue samples obtained from cancer surgeries the electrical properties of the malignant tissues and the normal adipose dominated breast tissues, a large contrast was found between both tissues that can reach up to the ratio 10:1 [4].

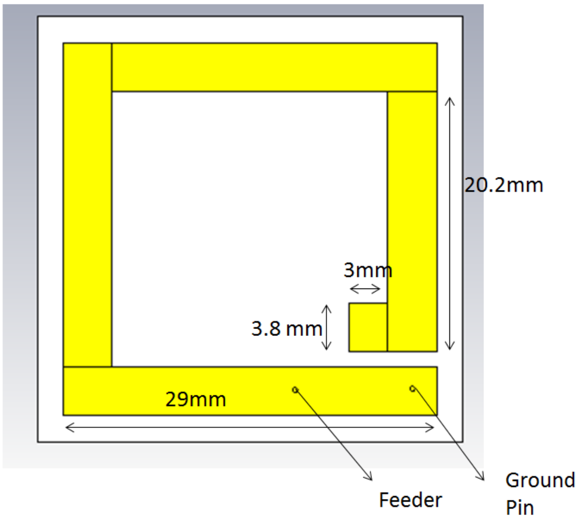
Breast density is an important factor in determining the risks of having breast cancer. A breast is said to be dense if it contains more fibro glandular tissues than fatty tissues. Breast density is determined using mammograms. Dense breast looks white on mammogram as well as tumors. Thus mammograms might not be effective in case of dense breast [2].

According to American Joint Committee on Cancer (AJCC) staging of breast cancer is related to the size of the tumor. In stage T-1 the size of the tumor is from 0 up to 2 cm, whereas stage T-2 has the tumor size is from 2cm up to 5cm. The third stages' tumor size by then is greater than 5cm. Finally stage T-4s any tumor whose size became with direct extension to the chest wall or skin.

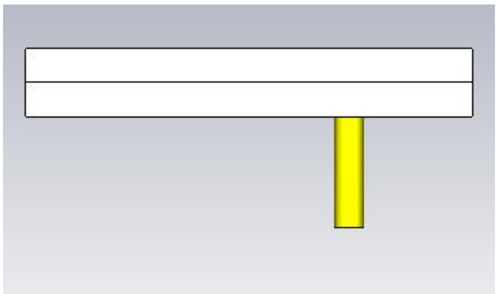
Many studies considered the breast as a homogenous medium with adipose tissues and covered by skin. This case is not very close to the real due to the existence of fibro-glandular tissues. This study considers the effect of the fibro-glandular tissues was also taken into consideration. It's worth mentioning that the electrical properties of the fibro-glandular tissues is very close to that of the malignant tissues making it harder to sense the presence of tumor [5]. The aim is to design an antenna to be used as a stethoscope. The return loss of the antenna will be monitored once it's surrounded by normal tissues and then when the tumor is introduced.

II. Antenna Design

Planner Inverted -F Antennas (PIFA) are known for their compact size and ease of fabrication. Therefore a spiral PIFA is used in the design. The antenna is mounted on a Rogers's 4350b substrate of relative permittivity 3.66 and loss tangent 0.04. A superstrate layer is also added to provide better antenna performance and more protection. The thickness of the substrate as well as the superstrate is 1.524 mm. The overall dimensions are 3.3×3.3 cm^2. The antenna is fed using a 50 Ω coaxial feeder. The position of the feeder is selected for good matching properties. The simulated antenna is shown in Fig. 1. The fabricated antenna is shown in Fig. 2.



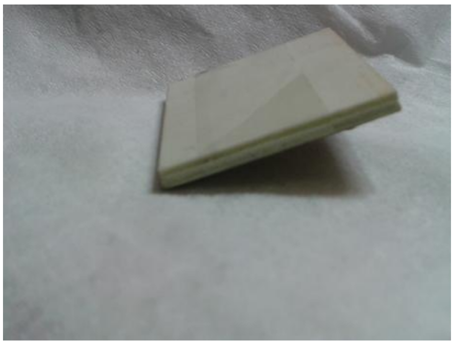
(a) Front View of the antenna



(b) Side View of the antenna

Figure 1. Simulated Antenna Structure

(a) Front View of the antenna



(b) Side View of the antenna with the superstrate layer

Figure 2. Fabricated Antenna Structure

III. Simulation And Measurements

CST Microwave studio is used as the simulation tool and Vector Network Analyzer for measurements. The model of the breast done on the CST in a hemispherical structure of the adipose tissues, a cylinder representing the glandular tissues is embedded inside the adipose tissues. The cylinder constitutes about 60% from the total area of the breast. This percentage was chosen to resemble the common breast density case for many women. The overall structure is surrounded by a skin layer. The dielectric properties of the adipose, glandular, and skin tissues were taken from the FCC database for the human body tissues electrical properties for the frequency range of the MICS band which is from 402 MHz up to 405 MHz. The antenna is placed in direct contact with the breast surface at the center. It's oriented vertically like a stethoscope. The antenna orientation is shown in Fig. 3.

A. Antenna Simulation and Measurement in Air

To guarantee the fabrication process of the antenna, it was simulated and measured in air in the absence of any breast tissues. Fig. 4 illustrated the return loss results of the measurement and simulation of the antenna. It's clear that both results come to a good agreement.

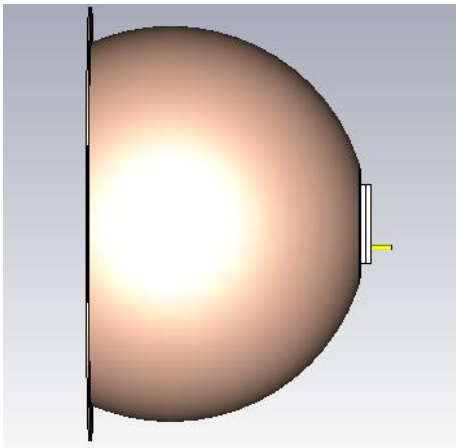


Figure 3. Antenna Orientation Used in Simulation

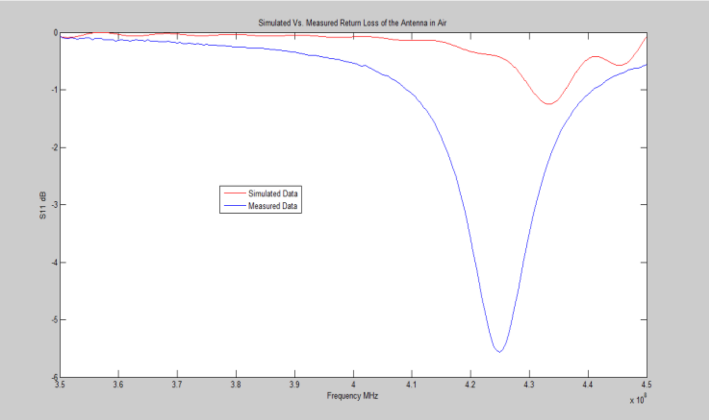


Figure 4. . Simulated vs. Measured Return Loss in Air with superstrate layer

B. *Simulation and Measurements with Normal Breast Tissues*

According to the American College of Radiology (ACR) there is a system called Breast Imaging Reporting and Data System (BI-RADS) used to describe the mammograms reports. According to this system the breast density can be divided to four categories, most women are in the second and third categories having fibro-glandular tissues with percentage ranging from 26-75% from the total breast area. As mentioned before the glandular tissues were simulated representing approximately 60 % of the total breast area.

The antenna was measured on some volunteers and the results between both the simulated and measured return loss where compared. Fig. 5 shows the comparison between both results.

C. *Simulation and Measurements in the Presence of Malignant Tumor*

As mention before as the size of the tumor changes the cancer stage changes. In this investigation simulation was carried on the first three stages of cancer. The tumor is simulated as a sphere with varying diameter according to the cancer stage. For the first stage of cancer a tumor of diameter 2 cm is used. Similarly for the second stage a tumor of size 3cm is used. And finally for the third stage a tumor of size 5 cm is used. It's worth mentioning that the five years survival rates according to the National Cancer Institute's SEER database can reach 100% for stage one and 93 % for stage two, and 72% for stage3.

Fig. 6 shows the comparison of the return loss between different tumor sizes and normal tissues. As observed when the tumor size increases the resonant frequency is up shifted. Table I summarizes the effect of tumor of different stages on the resonance frequency of the antenna, showing the exact resonant frequency for each malignant tumor stage as well as the resonant frequency of only normal tissues.

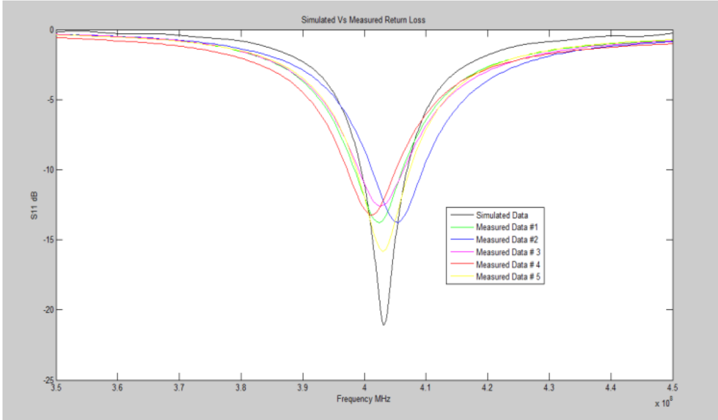


Figure 5. Simulated and Measured return loss in normal tissues

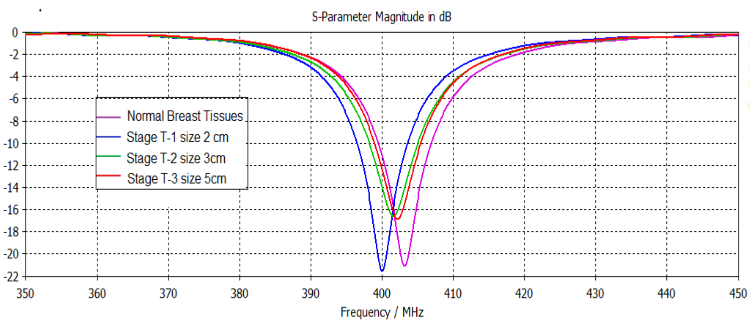


Figure 6. Simulation of different tumor sizes versus the normal tissues.

TABLE I. EFFECT OF THE TUMOR ON THE ANTENNAS' RESPONES

Tissue Type	Resonant Frequency
Normal Tissues	403 MHz
Normal Tissues & Tumor in stage 1	400 MHz
Normal Tissues & Tumor in stage 2	401 MHz
Normal Tissues & Tumor in stage 3	402 MHz

IV. CONCLUSION

A spiral PIFA antenna was designed and fabricated to help in the detection of breast cancer. The antenna was first simulated surrounded with normal tissues only. When it's surrounded by normal tissues a heterogeneous breast model was taken into consideration the fibro-glandular tissues existence not only the adipose tissues. Then simulation was done with the presence of malignant tumor. One can find that as the stage of the cancer elevated the resonant frequency of the antenna is up shifted. Good agreement was found between the measured and simulated results. The antenna could be used as a primary indicator for breast tumors.

REFERENCES

[1] Y.Rahmat-Samii and J.Kim," Implanted Antennas in Medical Wireless Communications," A Publication in the Morgan and Claypool Publishers' series, 1st edition, vol.01, 2006.Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955.

[2] American Cancer Society [Online]. Available: http://www.cancer.org/cancer/breastcancer/detailedguide/breast-cancer-what-is-breast-cancer.

[3] E.C. Fear, "Microwave Imaging of the Breast," Technology in Cancer

[4] Research J. M. Lazebnik, D. Popovic, L. McCartney et al., "A large-scale study of the ultrawideband microwave dielectric properties of normal, benign and malignant breast tissues obtained from cancer surgeries," Physics in Medicine and Biology, vol. 52, no.20, pp. 6093–6115, 2007.

[5] E. C. Fear, S. C. Hagness, P. M. Meaney, M. Okoniewski, and M. A. Stuchly,"Enhancing breast tumor detection with near-field imaging," IEEE Microw. Mag.,vol. 3, no. 1, pp. 48-56, Mar. 2002.