Design of Ultra-Wideband Microwave Antenna Array for Detection Breast Cancer Tumours

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Abstract. Microwave imagery for identification of Breast cancer is based on the electrical contrast between fatty breast tissues. We implemented a simple fractal antenna in this paper (peano patch antenna) in the Ultra-Wideband frequency (6.744) GHZ as low as (-42.657 dB). For breast imaging on a microwave system, the option of antenna is made of an antenna array consisting of 18 antennas. For better detection of tumors, the antenna is positioned in a circular design so that it can be faced directly to the phantom of the breast. This choice is made by positioning the array antennas on the breast skin to test the magnetic, electrical fields and current density in healthy tissue of breast phantom built and simulated in the studio simulator CST Microwave.

Keywords: UWB, (peano patch antenna) fractal antenna, circular design, microwave system detection of tumors, CST.

1. Introduction
The most prevalent type of cancer in females in the world is breast cancer, usually a rapid growth of breast tissue cells, mainly in the lobules and the epithelium of the duct. If there are a metastatic cancer cells which spread to other parts of the body including the liver, lungs, bonces and brain. The cancer cells divide out of reach and grow large, forming a new tumor. While new tumors grow large in another part of the body, it's always a cancer of the breast. Since the last breast cancer medical examination in 2008, cases of cancer of this type have increased by over 20 percent, with a death rate of 14 percent. 1.7 million women worldwide were diagnosed with breast cancer in 2012 [1,2]. To reduce the risk of death from breast cancer, we must recognize the presence of malignant tissue in healthy tissues and treat this serious condition at its early stages. We will proceed with the study of microwave breast imaging (MBI) in order to quickly identify the presence of breast tumor. This technique has been widely used especially for biomedical diagnosis. The idea behind the MBI is to use a microwave transmitter signal emitting inward signals to the breast and to the receivers to detect those signals emitted after communicating with the breast. The amount of signal energy transmitted by the tumor while a tumor is present, typically with greater dielectrical properties than other breast tissues, is greater than that distributed by normal tumor-free breast tissues [2,3].

UWB that show in figure 1 is a very important technology for potential wireless short-range communications. This UWB contact has some benefits, it gives high data rate and immunity to interference from multipath. This system design is also very simple, low cost and low energy consumption. Patch antenna has recently been extensively used in ultra wide band (UWB) applications, and continues to meet the changing demands of new generation antenna technology. In march 2002, the Federal Communications Commission (FCC) approved UWB to allocate a spectrum of 3.1-10.6 GHz for unlicensed use of UWB devices [4,5,6,7,1].
The early detection of breast cancer can make the therapy processes is more efficient. There are many methods for detection of breast cancer such as x-ray, MRI and ultrasound. The X-ray method demand the press on breast which is a painful process as well as the X-ray is an ionizing radiation which affect on the human body. The ultra sound and MRI is more safe but it is too expensive, recently the reasrchers have studied an alternative method for breast cancer detection. The microwave has been approved as an effective way because of its lower cost and is has no ionizing effect on the human body. The UWB antenna is consider an important branch of the detection by using microwaves.

Many researchers discussed various structures of the UWB antenna. A Afyf et al have investigated a circular design of rectangular patch antenna composed 8 antenna and 1 antenna in the center of the circular with bandwidth (480MHz) and return loss (-23dB) [10]. Other researcher study a 20 element hemisphere-conform antenna array are positioned in three rows each of which has a certain gap in the same column covers the breast area. The bandwidth (3.8GHz) and return loss (-28dB) [11]. A liner array have been search by Mazhar et al consist 4×1 antenna with bandwidth (5.3GHz) and return loss (-39dB) [13]. M.T.Islam et al. have investigated a 1 × 9 antenna array (one for transmitter and eight for receiver) the shape of antenna is Vivaldi antenna with different bandwidth and return loss (-34dB) [12]. The researchers have mentioned above realized high return loss. to address these limitations a circular array of 18 antennas are designed by using CST Microwave studio simulator. UWB's antenna are concepted of a fractal antenna (Peano patch antenna) using a 6.744 GHz signal for microwave imaging and this array is simulated with a geometric form of a semi-sphere, a model of the breast the actual human breast should be modelled.

![Figure 1. Ultra Wide Band (UWB) Technique](image)

2. Methods

2.1. Design of the antenna
Antenna is an essential element of the microwave system for imaging. An optimized antenna is required to correctly diagnose a tumor. Our antenna designs the fractal antenna (Peano patch antenna) at 6.744 GHz with a total dimension of 12×12mm made of copper with a thickness 0.035mm on a substrate FR-4 with a relative permittivity of 4.3, a width of 24mm, a length of 28 mm with a thickness of 1.5mm and ground made of copper with a thickness 0.035mm as shown in figure 2 and the parameters of antenna shown in the table 1. This antenna is design by CST Microwave studio simulator.
Figure 2. Antenna design by CST (a) Front side (b) Back side

| Antenna parameters                  | Dimensions (mm) |
|-------------------------------------|-----------------|
| Width of substrate (W)              | 24              |
| Length of substrate (L)             | 28              |
| Thickness of substrate (h)          | 1.5             |
| Length of feed line (Lfl)           | 10              |
| Length of patch (Lp)                | 12              |
| Thickness of patch (t)              | 0.035           |
| Width of feed line (Wfl)            | 1.8             |
| Width of patch (Wp)                 | 12              |
| Length of square Peano slot at right, left up and down sides (Lss1) | 1          |
| Width of square Peano slot at right, left up and down sides (Wss1) | 1          |
| Length of square Peano slot at right, left up and down sides (Lss2) | 0.5        |
| Width of square Peano slot at right, left up and down sides (Wss2) | 0.5        |
| Length of Slot (Ls)                | 2               |
| Width of Slot (Ws)                  | 2               |
| Length of ground slot (Lgs)         | 13              |
| Width of ground slot (Wgs)          | 24              |

2.2. Design of the Breast phantom

Researchers have used various design of breast phantoms. All these phantoms have essential electrical properties that are the relative permittivity and conductivity [2,8]. Extensive breast has shown that the properties of healthy and abnormal breast tissue, especially in the frequency of microwaves, are significantly different. However, we adopted a hemispheric shape in this paper to model the breast phantom that show in the figure 3 consisting of a skin with an outer radius of 70mm and thickness of 2mm, a fatty tissue considered a normal tissue with a n outer radius of 68mm and the spherical tumor with a radius of 10mm in the center of the breast. The table 2 refer to the components of breast model that used design in the CST Microwave studio simulator.
Figure 3. Antenna on breast model

Table 2. Components of breast model

| Component     | Dimensions (mm) |
|---------------|-----------------|
| Skin          | 2               |
| Tumor         | 1               |
| Glands        | 1.2             |
| Fatty Tissues | 1.5             |

2.3. Design of the antenna array

The antenna array was set in a circular configuration around the breast, as shown in figure 4. The series is composed of n=18 antenna components that are evenly spaced and identical. It is believed that the breast radius is 70 mm and that the array unit is mounted further 10 mm from the breast, giving a total radius of 80 mm from the middle of the breast to the antenna and the angle between two antennas is equal to 20°. All the antennas are connecting in the same port by lumped port. It is therefore possible to circumference c of the circular array as follows [9,10]:

\[
c = 2\pi r = 2 \times \pi \times 80 = 502.56 \text{ mm} \quad (1)
\]

\[
d = \frac{c}{n} - \text{wp} = \frac{502.56}{18} - 24 = 3.92 \text{ mm} \quad (2)
\]

Where:
wp = patch width of an antenna
d = Distance between any adjacent antenna in the array
r = breast radius
n = number of antenna
c = surrounding of the circular array

For the analysis of the mutual coupling between adjacent antenna, this spacing between adjacent antenna is important.
2.4. Result:

The antenna array simulation results as shown in figure 5 reveal that successively conducts the resonance frequency radiation pattern (6.744 GHz) that operate at range from 6.1 to 12GHz with a minimum of -10 dB and the maximum gain (4.6 dB). This antenna array is therefore clearly adequate for use breast imaging on a microwave system. The antennas are all related by an impedance of 50 ohm. The feeding point is connected to a lumped port which acts as a waveguide port for all radiators. When two or more neighboring antennas come closer to each other we can define the situation of mutual coupling. Whereas one antenna transmits part of the energy, another receives it, and both exist in the transmission and receiving mode. Amongst the configuration of the annular array in mode of transmission is known as reciprocal coupling as the antenna used to radiate one portion of energy provided by the other.

The $S_{11}$ that show in the Figure 5 (a) refer to a fundamental parameter for characterizing an antenna's bandwidth. It shows how much power from the antenna is reflected. It also called reflection coefficient or return loss $\leq -10$ dB, (b) the ratio between maximum to minimum voltage called The voltage standing wave ratio (VSWR) $\leq 2$ dB for pattern of standing wave. this ratio is appearing as the load reflecting the delivered power and is consider the difference between the transmit and reflecting power and (c), (d) display the antenna's 3D radiation pattern. On noted antenna had an omnidirectional radiation pattern.
2.5. Mutual Coupling of the Antennas:

The basic requirement of an antenna's reflection coefficient for exceptional performance is typically less than (-10 dB). In the case of breast cancer detection, however, we need to put more than one antenna around the breast to improve the resolution of the image of the image. Through increasing the number of antennas, we can obtain more imagery from various breast locations. But as if the distance
between two consecutive antennas is decreasing, this could be costly, and mutual coupling between antennas is beginning to increase. The electromagnetic interaction is called reciprocal coupling between two consecutive of the antenna. Increase in mutual coupling has the following effects on the antenna array [10]:

- Changes the received antenna voltages.
- Changes the corresponding antenna characteristics.
- Changes the pattern of radiation.

3. Conclusion and future work

In the paper the UWB antenna studies are intended for use in an antenna array scanning system focused on the detection of microwave breast cancer. The system varies in several ways from the one suggested for the antenna. A fractal antenna (Peano patch antenna) is designed to select an appropriate antenna that can be used for breast imaging on a microwave system to distinguish malignant tissues which grow in the breast of the woman. This study shows that antenna ensures a decrease in the effects of current density, magnetic fields and electrical fields within healthy tissue relative to a tumor with malignant tumor present in the breast. We have developed a simplified antenna array compared to other works to enhance the imaging for identification of tumors. The results of the simulation of the of the antenna array show strong impedance that matches high radiation level and low mutual coupling. This array has proven effective and easy to make for breast imaging on a microwave system compared with other imaging techniques. The antenna showed strong pattern of omnidirectional radiation with appropriate gain. We also build antenna array consisting of 18 antenna elements which achieve a lower return loss at -42.657 dB with bandwidth (5.9GHz) that improve the transmit and receive of the signal that lead to a beater detection of cancer tumor at early stage in the breast tissue. In the future study we will try to minimize the number of antenna's array and improve the return loss (dB), as a result this will reduce the cost of printing the antennas also we will use other material in the design that affect the performance of antenna.

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