Design of Miniaturized Antenna Array for Microwave Imaging Application

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Abstract. To detect the presence of tumor in the breast, a miniaturized Ultra-wideband (UWB) antenna is simulated with the use of CST microwave studio. In free space, its operating range is about 3.548GHz. The Flame Retardant (FR-4) material is used as a substrate in the design of the microstrip antenna. The antenna has the dimensions of 16 x 20 mm. The improved bandwidth is obtained by making some modifications in the patch and ground plane. To improve the gain and directivity, an array of 2 x 2 elements are created. The improvement in gain and directivity is analyzed for different spacing between the elements like λ/2 and λ. The spacing of λ/2 between the elements created gives the improved directivity and gain.

Keywords : Tumor, Ultrawide band, Flame retardant material, Antenna design.

1. Introduction

Nowadays, death rate and incidence of breast cancer is increasing for different age people which are shown in figure 1. The incidence rate decreases over the ages near 80 for women, is due to decrease in the screening rate, using mammography technique the cancer is detected before the age of 80 [1] and inadequate screening technique.

At present, X-ray mammography is the most primary technique to identify the breast cancer. The level of sensitivity of the mammography is reduced due to the higher density of the fibro glandular tissue which creates incorrect judgment of tumor in the breast. Along with these issue, X-ray mammography have high false positive and false negative rate which leads to operating on a patient. In addition to these imaging technique there are some other techniques, like magnetic resonance
imaging, ultrasound and Computer Tomography. Among these technique, X-ray mammography is the most popular technique for breast screening. But the above screening technique less specificity and hence they doesn’t provide any important information about the molecular structure changes.

A new technique called microwave imaging technique was developed so that the specificity and sensitivity are increased in order to detect an embedded object in the breast[11,12]. This new technique overcomes the disadvantages of the earlier methods. Normally Ultra – Wide Band (UWB) schemes are used for the microwave imaging technique[14,15]. Usually for imaging technique a sub-nanosecond range short pulse is used to reduce the noise below the acceptable level. Other vital characteristics of UWB signal is the capability to detecting the object whose dimension is greater than the Rayleigh’s limit [2].

UWB antennas which were used conventionally, such as resistively loaded bowtie [4], dipole antennas [3], and Vee dipoles [5].However, the above antennas has integral drawbacks in terms of their pulse distortion, bandwidth and size of the antenna configuration. The major weakness of the prevailing configurations is the large size of the antenna elements. The reason for undergoing large size antenna configurations is that, UWB antenna generates large bandwidth which is used for biomedical application, analysis of human organ, most predominantly for the cancer detection [15].

A single antenna element [6] is not enough for detecting the tumour deeper inside the tissue [7] in the case of microwave imaging technology. The resolution of the microwave image is improved by the increasing the number of antenna elements. The resolution of the image is found to be very important in screening of the breast in the human body. The boundary of human breast is covered by the antenna elements; there exist some small space in between the antenna elements. Therefore, to achieve improved image resolution, miniaturized antenna elements are arranged around the boundary of the breast with maximum number of elements. On the other hand, design of miniaturized antenna which is in direct interaction with biological tissues is a most challenging way to obtain return loss in free space [8,9&10].

Hence in this paper, a miniaturized directional antenna is designed using FR4 material. Also an array of antenna of size 2 x 2 elements is designed to increase the gain and directivity of the antenna.

2. Antenna Design

This section explains the miniaturized UWB antenna for microwave imaging application.

2.1 UWB antenna design

Ultra wideband antenna Structure is shown in the figure 2. Many efforts are made in the antenna design to improve the bandwidth of the antenna and return loss. The antenna is printed on the FR4 antenna substrate with a relative dielectric constant of 4.3. The size of the substrate is Ws x Ls, the thickness is 1.6 mm.

Initially, the bandwidth of the antenna is improved cutting a plane in the ground plane. Again the bandwidth of the antenna is improved by cutting a plane in the ground plane. Next the bandwidth is again improved by cutting different rectangular slots in the patch plane. The thickness of the patch and ground pane is 0.035mm.
3.1 Analysis of single miniaturized antenna

An UWB miniaturized antenna is simulated using CST software and reflection coefficient of the miniaturized antenna is exposed in the figure5. The proposed antenna has the bandwidth of 5.124GHz which is having the lower cut of frequency of 3.548GHz and upper cut of frequency of 8.672GHz which is having the maximum return loss of -35dB at 4.467GHz.
The far-field radiation pattern is shown in the figure. The 3-D radiation pattern is omni directional in shape. All the direction has almost uniform distribution. The maximum gain of the single miniaturized antenna at 6GHz is -0.1003dBi. The gain of the antenna is in negative value, it can be improved by the array of the antenna.
Figure 5. Reflection coefficient of miniaturized antenna

Figure 6. Radiation pattern of the miniaturized antenna

3.2 Analysis of array of miniaturized antennas

A 2 x 2 antenna array is designed in order to improve the gain. The following section shows the analysis of different spacing between the antenna.

3.2.1 Spacing between the antennas are λ

The spacing between the element is adjusted for λ which is 37.4mm. The reflection coefficient of the antenna is shown in figure 7. The high value of reflection coefficient occurs for the antenna 2.
The 3D radiation pattern of the array antenna at 6GHz is shown in figure 8. The gain of the antenna is improved to 2.58dBi so that the directivity is also improved to 3.99dBi.

3.2.2 Spacing between the antennas are $\lambda/2$

Initially the spacing between the element is adjusted for $\lambda/2$ which is 18.7mm. The reflection coefficient of the antenna is shown in figure 9.
Figure 9. Reflection coefficient of the array of antenna separated by λ.

The gain of the antenna is improved to 5.19dBi so that the directivity is also improved to 6.09dBi. The 3D radiation pattern is shown in figure 10.

4. Conclusion

Thus the paper explains about the design and simulation of UWB miniaturized antenna with little modifications in patch and ground in order to improve the bandwidth. The antenna is analyzed using FR4 substrate material. The important parameters like gain and directivity are improved by creating an array of 2x2 elements. The antenna array is analyzed for different spacing between the elements. It is observed that λ/2 spacing generate a better gain of 5.19dBi and improved directivity of 6.09dBi.
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