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ORIGINAL ARTICLE

Textile Ultra-Wide Band Antenna With X Band For Breast Cancer Detection

N Jebali[1]*, A Gharsallah[1], J M Ribero[2]

1 Faculty of Mathematical, Physical and Natural Sciences of Tunisia, Laboratory for Research on Microwave Electronics, El Manar University, 2092, Tunisia
2 Department of Electronics, University of Nice Sophia Antipolis, 06903, France

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***Corresponding author**.
N Jebali
Faculty of Mathematical, Physical and Natural Sciences of Tunisia, Laboratory for Research on Microwave Electronics, El Manar University, 2092, Tunisia
jebalinada1@gmail.com

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Abstract

Objectives: To detect breast cancer with the use of textile materials flexible antenna. **Methods:** The suggested textile antenna is fabricated with felt, as a substrate, and a conductive fabric: zelt, as a patch and ground plane. Multiple simulations were done in order to obtain an idea about the reflection coefficient, gain, directivity especially the specific absorption rate (SAR), which can valorize the antenna performance and guarantee human security in the presence of electromagnetic waves. The current density results are compared to each other in multiple cases in order to assure the detection process with several size of tumor (from 2 to 8 mm). The antenna works in the X band (from 8 to 12 GHz) which has been dedicated for satellite applications from past many years, radar and many other applications including the medical field where antenna has been used to help in patient monitoring, especially in the case of dangerous diseases like cancer. **Findings :** A novel proposed structure, with reduced size, flexible substrate and good efficiency percentage was obtained with the main purpose of detecting a very small tumor. The simulation's results as well as the measured ones are very similar and suitable for the intended purpose. **Application:** In comparison with previous research, this novel proposed structure is characterized by a minimized size, good flexibility as well as with acceptable results in the gain, directivity and SAR value. But, the most important benefit is the antenna being helpful in the identification and detection of breast cancer with a minimum difference between the unhealthy and healthy breast, according to the current density results.

Keywords: UWB; breast cancer detection; X band; Textile antenna; SAR

1 Introduction

Recently, textile antennas have been extensively used in many fields, like RFID's technology, medicine and wearability[1–3] According to many researches, wearable antennas are applicable in different fields related to the human monitoring domain[4–6] and should include good material in order to maintain the antenna performance[6].

There are many benefits that characterize the adoption of textile in the antenna fabrication, such as lightweight, and ease in the fabrication procedure, which can help in the production of this type of antenna and improve the commerce in this field[7].

Wearable antennas can also offer comfort of usage with the simplicity of moving in different directions. The selection of the antenna substrate is important to guarantee this comfort, it can be a nonconductive fabric, such as silk, leather, fleece or felt[7]. The textile antenna is also composed of a radiating element conductive fabric, necessary for the realization of patches and ground plane[7,8]. The choice of felt in this work is regarded for its low permittivity which is very important to ensure the efficacy of radiation performance[7–9]. According to the World Health Organization, breast cancer is considered as the most frequent cancer among women[10] and is the cause of 370000 deaths each year[11]. For example, in India, 70,218 out of 144,937 women died in 2012 due tobreast cancer[12].

The United States also witnessed this high frequency of this disease few years ago, but this crisis was controlled due to the reduction in mortality rate[13]. In Europe, 28.56% of women and men were affected by the disease in 2012 and 16.85% of them died[14]. There is an estimation which states that 10% of women will probably be affected by breast cancer up to the age of 75 years[15,16]. The situation in Africa is much more dangerous, where, breast cancer is the second risky disease after the diseases related to female cervix. Unfortunately, almost 70% of cancer cases are discovered at late stages (in stage III and even IV), where the survival rate in years is less than five years[17,18]. In recent years, many researchers have been trying to detect this disease with several methods. The follow-up of the current density results and the comparison between the case of a healthy breast and the breast tumor can help in early detection[15–19].

In this study, the detection of breast cancer was based on comparing the current density results of unhealthy and healthy tissues. Research studies related to the use of antennas in the medical field are faced with big problem of human exposition to the electromagnetic waves and the negative effects of electromagnetic waves on the patient's body. The only value about human exposure limitation is the Specific Absorption Rate (SAR) per mass of tissue[20]. The SAR results are presented in this study to confirm the safety of the use of antenna and valorize the work. In our case, the microstrip patch antenna is a good choice which can offer a small size, low cost and low weight[21]. Another deciding factor of this work was the ultra-wide band (UWB) which is defined as the -10 dB bandwidth signal that is superior to 20% or the bandwidth that is wider than 500 MHz[22,23]. This band has become a solution for applications with short range and high data wireless communication, radar and many other applications[24].

The proposed UWB antenna operates in the X band of 8 to 12 GHz, which is an interesting band for many researches, especially in the medical field[21,25,26]. The High frequency can guarantee a good range resolution and less penetration into the skin, compared to the low frequency, which valorizes the X band use. This latter limits the radiation in the skin level and blocks the penetration into the other layers of the human body[21–26].

2 Materials & Methods

2.1. Antenna Design

Figure 1 illustrates the proposed antenna with a textile substrate. This monopole antenna, powered by 50 Ohms, is composed of a flexible substrate namely the Felt (dielectric permittivity ε_r=1.22, tan δ= 0.016 and thickness h=1mm)[27], and the Zelt (conductivity 1×10^6 S/m and thickness of 0.06 mm) which is a conductive fabric used for patch and ground plane. Both Felt and Zelt have the same dimensions: L=44.33mm and W=37.5, both are flexible and comfortable for medical use. The antenna's dimensions are shown in Table 1.

Table 1. The dimensions of the UWB antenna

Parameter	Value (mm)
W	37.5
L	44.33
Wa	8.6
A	14.45
B	10
C	9.95
D	24

As mentioned in Figure 2, after simulating the antenna with the Computer Simulation Technology (CST) Microwave Studio at an X band from 8 to 12 GHz, the reflection coefficient (S11) presents a value of 10.15 GHz with a bandwidth of 947 MHz,

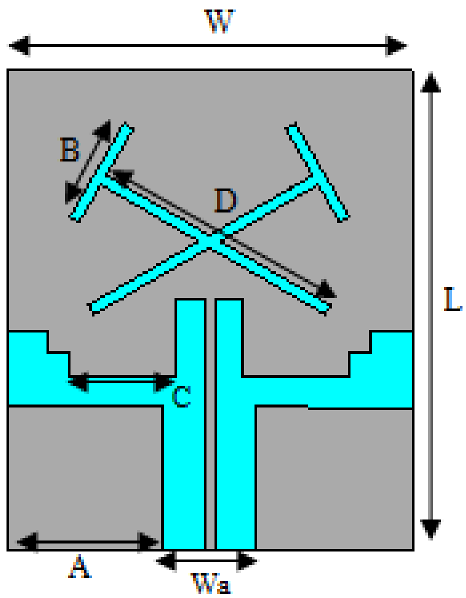

Fig 1. Design of the antenna's structure

which is a very interesting result valorizing the UWB.

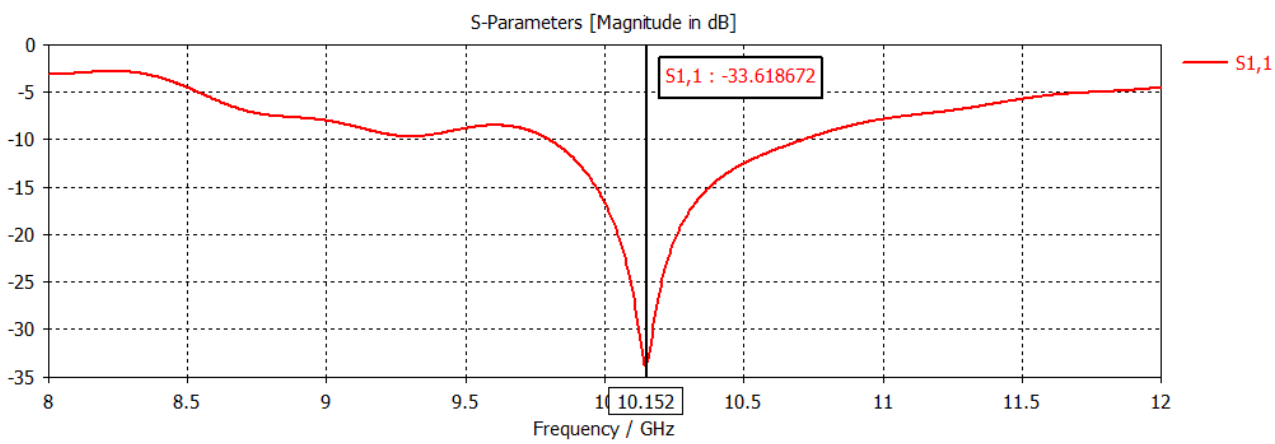

Fig 2. The reflection coefficient (S11) as a function of frequency

Figure 3 gives the result of the antenna's gain which is valued at 6.08 dB, while a value of 9.32 dBi is presented for the directivity result. The disruption of energy is located in the Z+ plan with an omnidirectional action.

The efficiency percentage of the antenna is calculated by the division of gain by the directivity multiplied by one hundred [28,29].

Efficiency = (gain/directivity) *100 [28,29]

= 65.23%

The antenna is said to be ideal when its efficiency equal to 100%. But in reality, an efficiency of 50%to 60% is sufficient to confirm that the antenna is good [30]. The Figure 4 displays the fabrication process of the Antenna. When measured, the reflection coefficient (S11) reached a value of 10.14 GHz, as shown in the Figure 5. This value is considered as a sign of good adaptation since it is close to the simulated results (10.15 GHz). A difference was observed between the simulated result and the measured values of both gain and directivity, due to the fabrication process. As mentioned in Figures 6 and 7 the gain reached

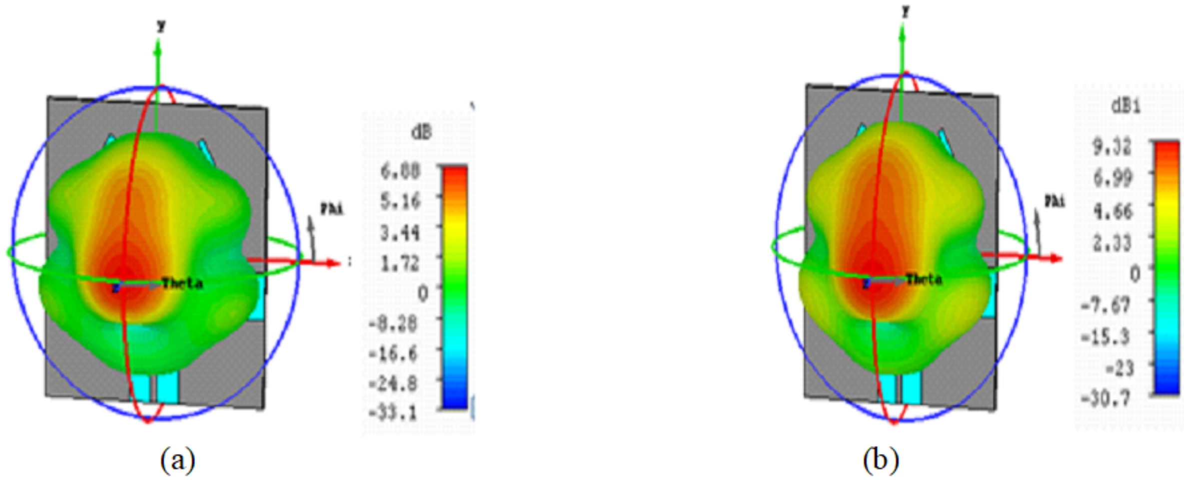

Fig 3. The electromagnetic simulation results of a) gain and (b) directivity

a peak of 5.6 dB while the value of the directivity was equal to 8 dBi.

Fig 4. The realized prototype of the antenna

3 Results

3.1. Results after the attachment of UWB Antenna on the breast phantom

3.1.1. ***Healthy breast***

The main aim of the antenna is the detection of tumor. The breast phantom has specific dielectric and thermal properties (ε_r=5.08, σ=0.13[S/m], Thermal conductivity=0.33W/(m*K), Specific heat=2550J/(kg*K), Density=1041[kg/m^3] [31–33]. The idea of this work was the comparison between healthy and unhealthy breast phantom based on the density current value. A simulation with CST was performed when the textile antenna was located on the healthy phantom as shown in Figure 8.

A coefficient reflection (S11) of 10.12 GHz with an attenuation of -28.7 dB and a bandwidth of 964 GHz is given in Figure 9. The bandwidth improved by 1.79% from the antenna gain in the absence of breast tissue.

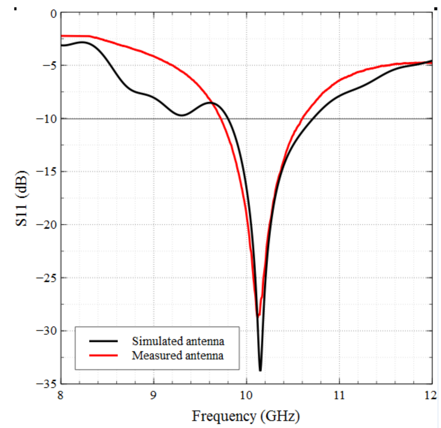

Fig 5. The result of the simulated and the measured reflection coefficient as a function of frequency

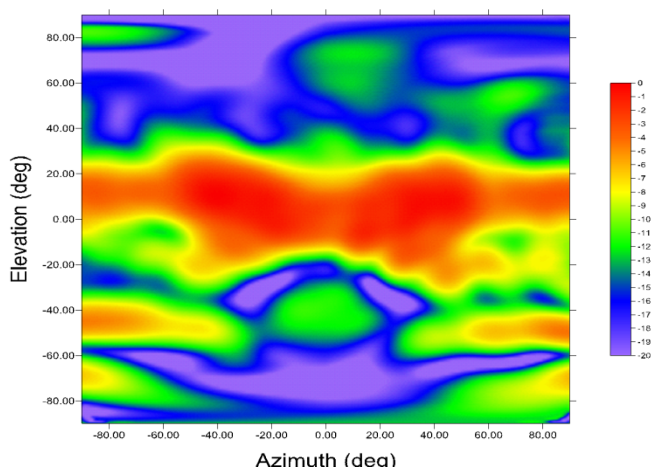

Fig 6. Far field amplitude

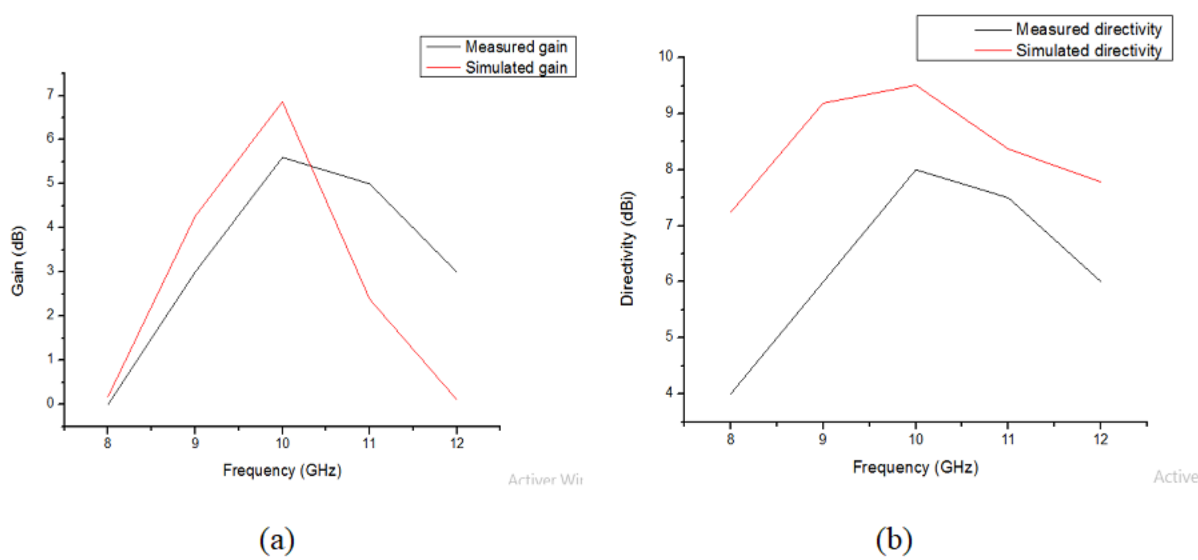

Fig 7. The simulated and the measured results depending on the frequencya) gain and b) directivity

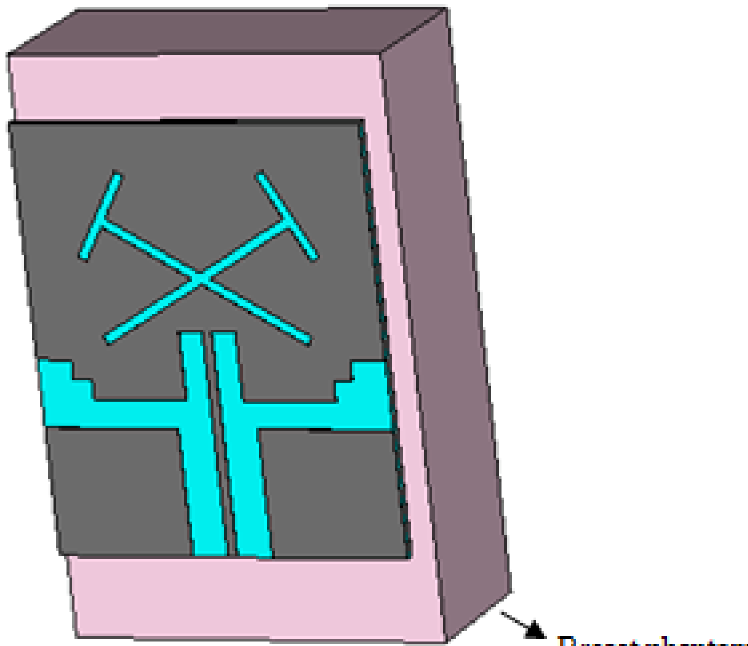

Fig 8. The position of the antenna on the breast phantom

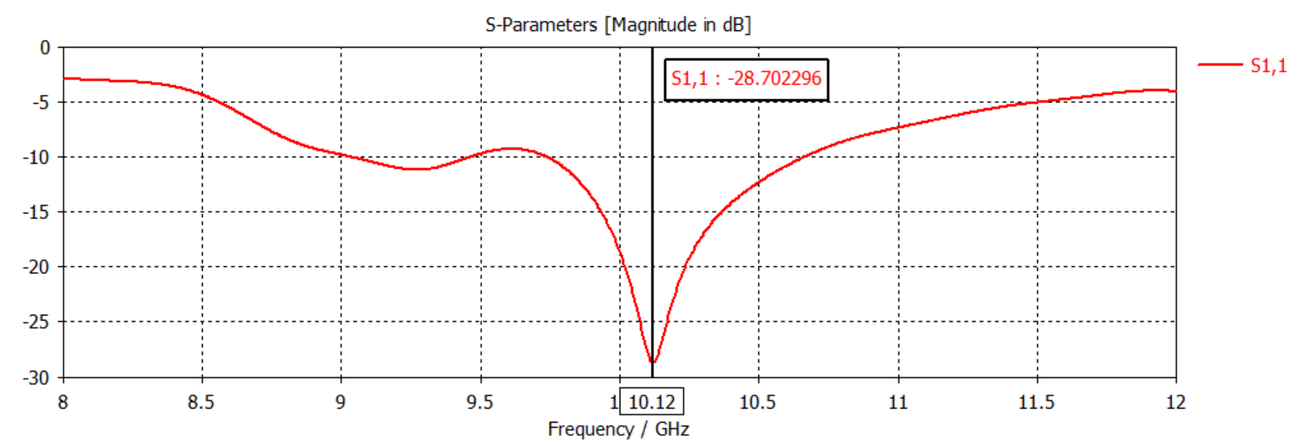

Fig 9. The reflection coefficient of the textile antenna when placed on breast phantom

As mentioned in Figure 10, there was an improvement in the antenna performance after meeting the breast tissue. More specifically, there is a gain of 9.15%, i.e. from 6.08 dB (before adding the phantom) to 7.51 dB; and a directivity increase of 9.44%, i.e. from 9.32 to 10.2 dBi. This slight improvement guarantees the proper functioning of the antenna despite the risk of absorption of the energy into the tissues.

The specific absorption rate expressed per mass unit of the body tissue, is the absorbed energy rate. The local SAR has a limit of 2 W/kg in 10g according to the European standards [34]. Figure 11 illustrates a SAR value of 0.72 w/kg, which is a very low amount compared to the maximum level required.

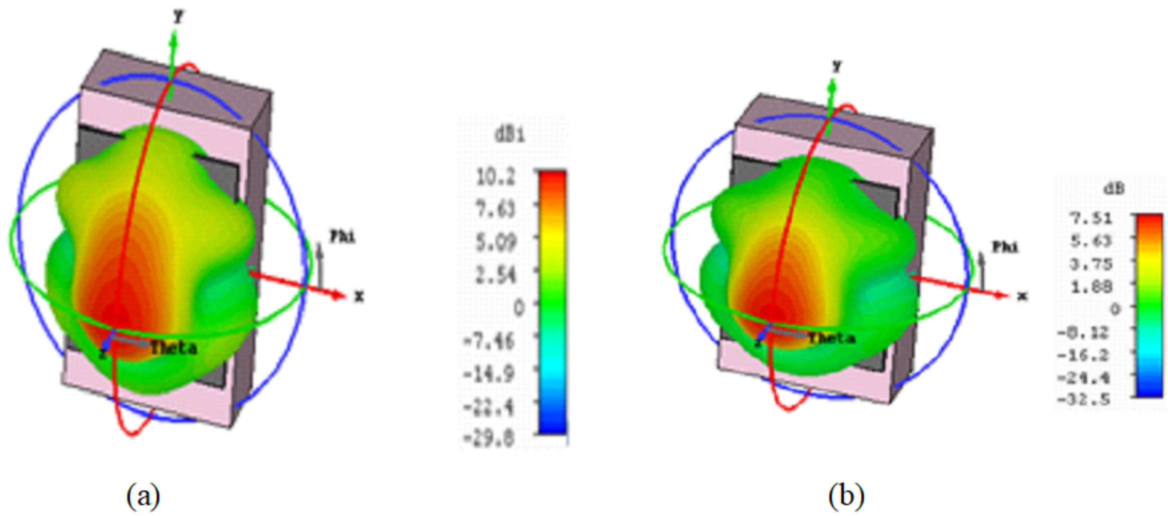

Fig 10. The CST simulation of gain and directivity after adding the breast tissue

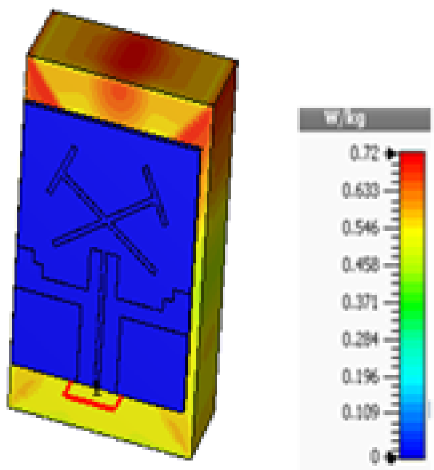

Fig 11. The SAR value when the antenna is in contact with the breast tissue

3.2. Breast phantom which contains tumor

Figure 12 highlights a phantom tumor (εr=59.06, σ=3[S/m], Thermal conductivity=0.5[W/(m*K)], Specific heat = 3610[J/(kg*K)], Density=1079[kg/m^3] 31-32-33 which is in the form of a cylinder with a 5 mm diameter. It is added to the breast phantom which constitutes an unhealthy tissue.

As shown in Figure 13, the reflection coefficient is measured at 10.12 GHz with an attenuation of -27.84 dBi. The gain and directivity are shown in Figure 14, with values of 7.55 dB and 10.3 dBi, respectively. These simulations are conducted to gauge the performance of the antenna in case of existence of tumor in the breast phantom. The results reveal a little increase in the values of both gain and directivity compared to the case of normal tissues.

An increase of 13.75% (from 0.72 to 0.819 w / kg) in the SAR value is observed compared to the healthy phantom, which marks the existence of a foreign body. The SAR value is acceptable as mentioned in Figure 15.

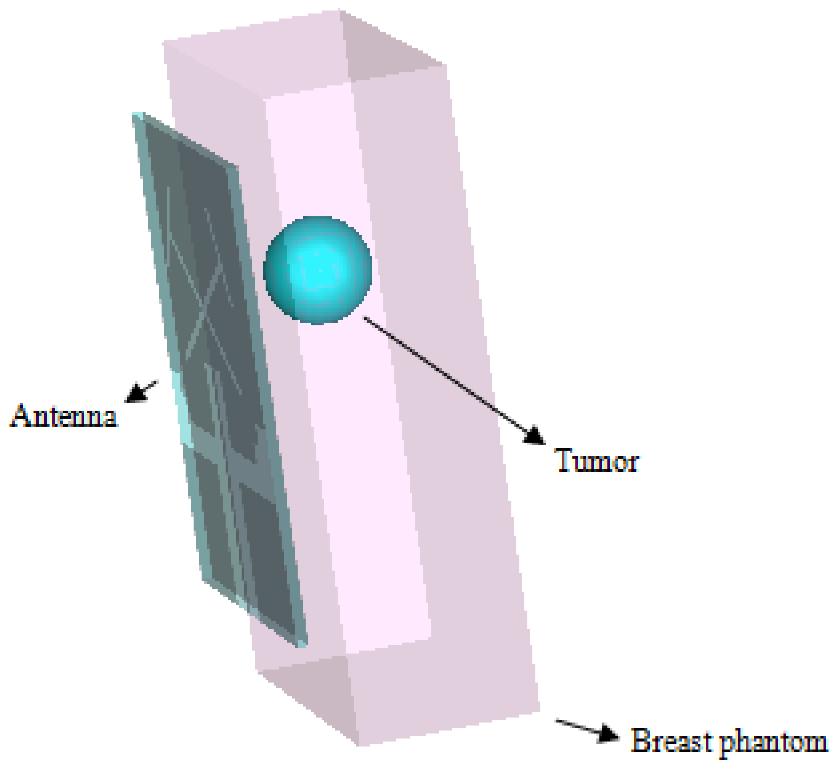

Fig 12. A cylindrical tumor inside the breast phantom

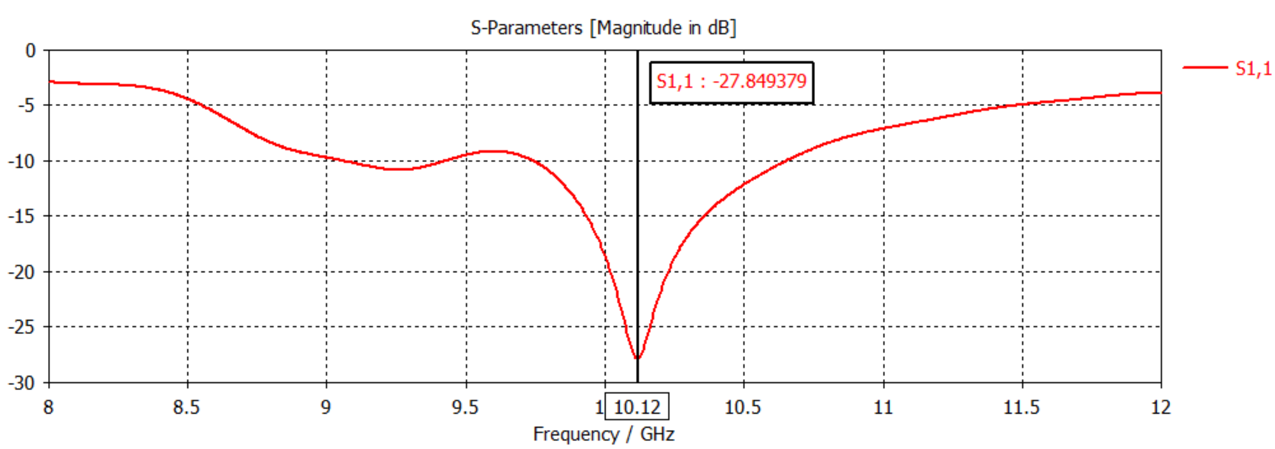

Fig 13. The reflection coefficient behavior in case of an unhealthy breast tissue

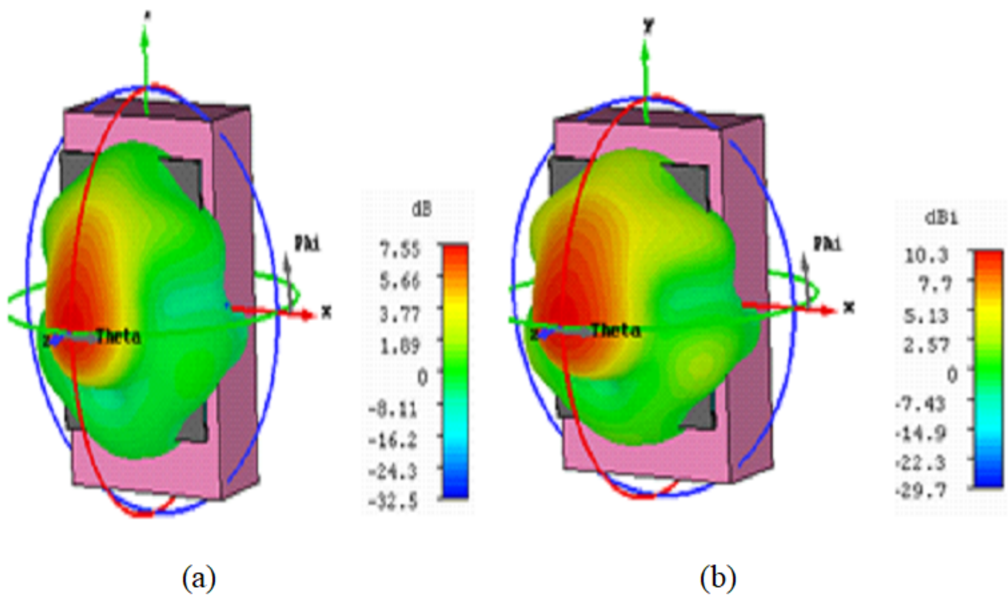

Fig 14. The gain and directivity values when the breast phantom contains a tumor

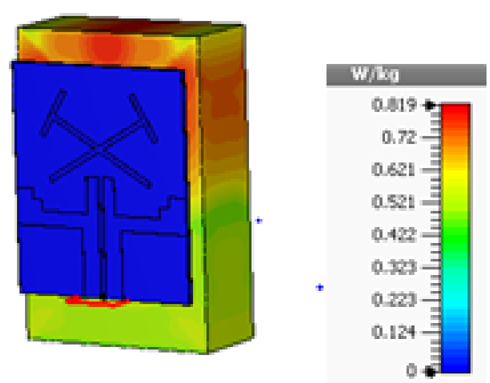

Fig 15. The specific absorpted rate after adding a tumor in the breast phantom

3.3. The Current Density S tudy

As shown in Figure 16, there is a significant transformation in the value of current density when compared to the normal and cancerous breast tissue. With the presence of tumor which takes a cylindrical form (diameter = 2 mm), the value is three times higher than that of the normal healthy case (from 152 to 465 A / m ^ 2). This detection technique confirms the sensitivity of the proposed antenna and its capacity to detect a very small tumor (2 mm) which in turn valorizes the current density study.

As shown in Table 2, other simulations are made by changing the size of tumors from 2 mm up to 8 mm. By increasing the tumor's dimensions, the current density value increases; and a value of 598 A / m ^ 2 is obtained when the tumor's diameter is around 8 mm, which is four times higher than healthy phantom.

In Table 3, a comparative study between our work and previous medical research [35–38] was conducted. This study concerns the following parameters of the antenna: maximum size, gain and directivity as well as impedance bandwidth and amplitude of the reflection coefficient. Regarding the gain and directivity, this work exceeds the values of research mentioned above, which confirms the success of the study and the manufacture of the antenna. In addition to its high performance and efficiency, the small size of the antenna makes it suitable for medical applications.

Table 2. The current density values depending on the tumor's diameter

Tumor diameter	Current density (A/m^2)
2mm	465
4mm	485
6mm	514
8mm	598

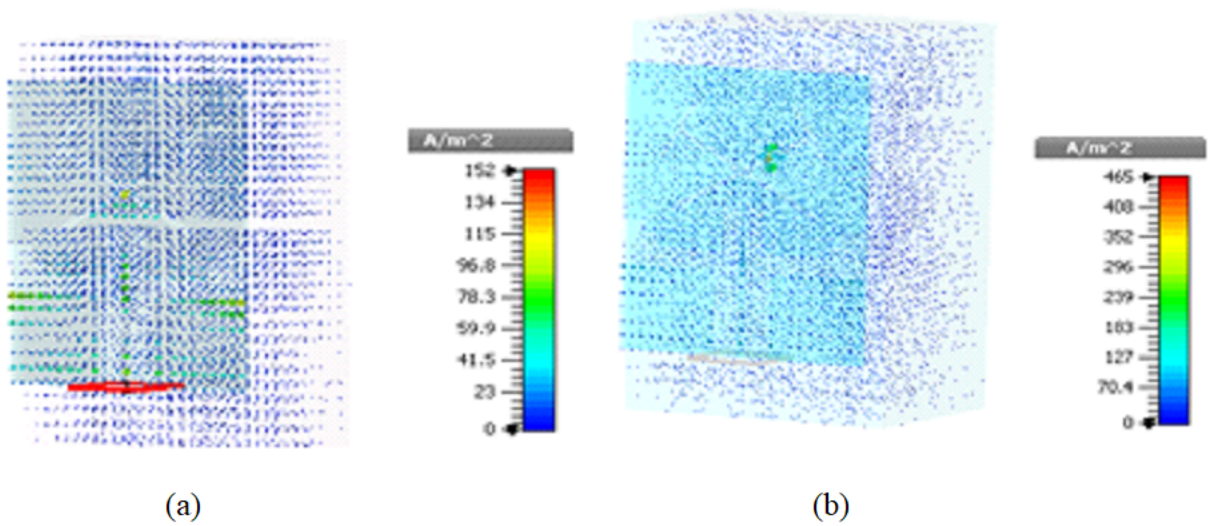

Fig 16. Current density in case of a (a) healthy breast tissue and (b) cancerous breast tissue

Table 3. The fabricated antenna's results in comparison with other research

Proposed antenna	**The antenna size (mm^2)**	**Impedance bandwidth (GHz)**	**Reflection coefficient magnitude (dB)**	The gain value (dB)	The directivity value (dBi)
Ref[35]	70*60	0-12	-23	_	6.17 dBi
Ref[36]	35*20	2.9-13	-32	_	5.8 dBi
Ref[37]	44*22	3.1-10.6	-25	_	5.5 dBi
Ref[38]	23*21	2-12	-28	4 dB	_
This work	37.5*44.33	8-12	-28.53	5.6 dB	8 dBi

4 Conclusion

In this study, a UWB antenna for the detection of breast cancer was presented using a small textile substrate that is comfortable for medical use. This structure operates in the X band of 8 to 12 GHz. Good simulation results using the CST in terms of gain, directivity and SAR were obtained after the study. Fundamental work in the study deals with interpreting the current density results in two cases: when the breast tissues are healthy and during the presence of cancerous tumors. An interesting increase in the value of current density is revealed in this study when the tumor exists, this opens up new perspectives for future research.

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