Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
Article DOI: 10.21474/IJAR01/3066
DOI URL: http://dx.doi.org/10.21474/IJAR01/3066

RESEARCH ARTICLE

PARAMETRIC STUDY AND DESIGN OF ULTRA WIDE BAND PLANAR MICROSTRIP ANTENNA FOR BREAST TUMOR DETECTION

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Manuscript Info

Manuscript History

Received: 03 December 2016
Final Accepted: 30 December 2016
Published: January 2017

Key words:-
Patch Antenna , Ultra Wide Band UWB Communications, Microstrip line, Bandwidth, Stationary Wave Ratio SWR and antenna input impedance.

Abstract

In this work, we focus on the design of a rectangular patch antenna for use in Ultra Wide Band (UWB) in breast cancer detection. After modeling and validation of the base antenna, we perform the parametric study on the choice of the dielectric substrate, the height of the ground plane, the transition between the patch and the microstrip line. This is in order to optimize these parameters to meet the standards set by the Federal Communications Commission (FCC) for UWB communications in terms of bandwidth, standing wave ratio (SWR) and antenna input impedance.

Introduction:-

With the development of wireless communications, Ultra Wide Band (UWB) systems has recently attracted attention of scientists because of the benefits they offer. Thanks to a much wider bandwidth, this new technology is very robust in complex environments. Furthermore, the transmission power being of the same level as the noise, the technique can coexist with narrowband systems(1).

The Federal Communications Commission (FCC) has established in February 2002, Terms of use the frequency spectrum between 3.1 and 10.6 GHz and emission power limits allocated to the various UWB applications (2).Given its characteristics (low power, narrow pulses) even noticed, we begin to realize the benefits of UWB technology in many areas of research.These include medical microwave imagery that has generated considerable interest in recent years. This technique could be a very effective means for detection of malignant tumors including breast cancer (3).

We propose in this work to perform parametric study and design of a planar antenna patch for application on Ultra Wide Band UWB. After modeling and validation of the base antenna, there follows the parametric study consisting on the choice of dielectric substrate, height of the ground plane, form of transition between the patch and the microstrip line. This is in order to optimize these parameters to meet the standards set by the Federal Communications Commission FCC for UWB communications in terms of bandwidth and SWR standing wave ratio.

Theorecal study:-

The transmission-line model representing the microstrip antenna is defined by two slots, separated by a lowimpedance ZC transmission line of length L. Since the dimensions of the patch are finite along the length and width, field lines suffer the edge effects on both sides of the patch. These effects are a function of the patch dimensions and the height h of the substrate (4).

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The signal transmission is not dispersive if the mode of propagation is TEM (Transverse Electro- Magnetic). This is possible if the electromagnetic field that propagates through the line meets one type of material. For the microstrip line of Figure 1, which the field lines are shown in Figure 2. A portion of the electric field lines are reflected in the substrate and a part in the air (5). Many studies have shown that such a transmission line is the seat of a wave propagating in quasi-TEM mode. We must therefore consider not only the dielectric constant of the substrate but rather εreff workforce.

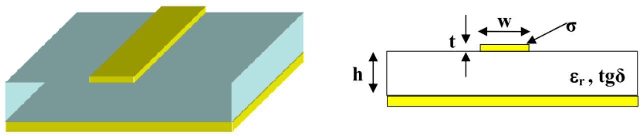

Fig 1:- Microstrip Line

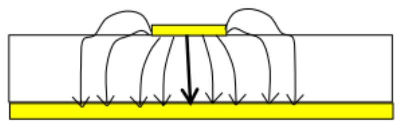

Fig 2:- Electric field lines

A good approximation was proposed by EO Hammerstad in (6) and (7) giving the values of the effective dielectric constant εreff and characteristic impedance Zc for a microstrip line that the width is W and the height of the substrate is h. For calculation, we adopt the approximation given in equations (1), (2), (3) and (4).

In the case of $W/h \leq 1$:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[(1 + 12\frac{h}{W})^{-\frac{1}{2}} + 0.04\,(1 - \frac{h}{W})^2\right] \quad (1)$$

$$Z_c = \frac{60}{\sqrt{\varepsilon_{reff}}}\ln\left[\frac{8.h}{W} + \frac{W}{4h}\right] \quad (2)$$

In the case of $W/h \geq 1$:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (3)$$

$$Z_c = \frac{120.\pi}{\sqrt{\varepsilon_{reff}}}\left[\frac{W}{h} + 1.393 + 0.667\ln\left(\frac{W}{h} + 1.444\right)\right]^{-1} \quad (4)$$

Modeling antenna base:-

The structure of the antenna considered as a first step will be DM sheen antenna's mentioned by P. Wang in (8). It is a rectangular planar antenna made up of a ground plane, a dielectric substrate of permittivity εr value of 2.2 and a rectangular patch showed. respectively, in Figures 3 and 4 and whose dimensions are showed in Table 1.

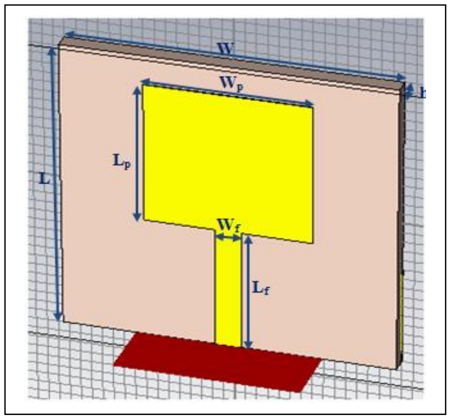

Fig 3:- Front face of the planar rectangular antenna base（Substrate and patch）

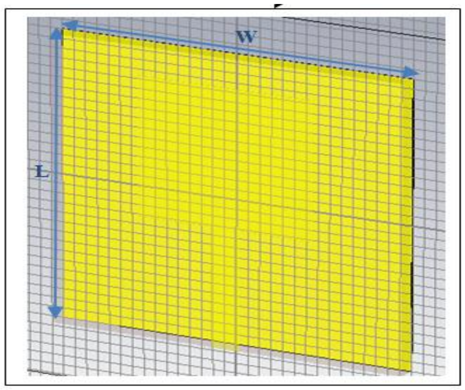

Fig 4:- Back face of the planar rectangular antenna base（ ground plane)

Table 1:- base antennadimensions

Greatness	Value in (mm)
L	30
W	30
L_p	16
W_p	12,45
L_f	4,00
W_f	2,46
h	0,795

The patch witch dimensions Wp x Lp is feding by a microstrip line whose dimensions are Lf and Wf selected in order to have a value of 50 Ohm for input impedance. We had choose CST MWS (Computer Simulation Technology - Microwave Studio), as a simulation tool based on the Finite Integration Method FIT. Other methods exist , we have used in a previous work [(9)], the Finite Difference Time Domain FDTD for modeling a planar antenna microstrip.

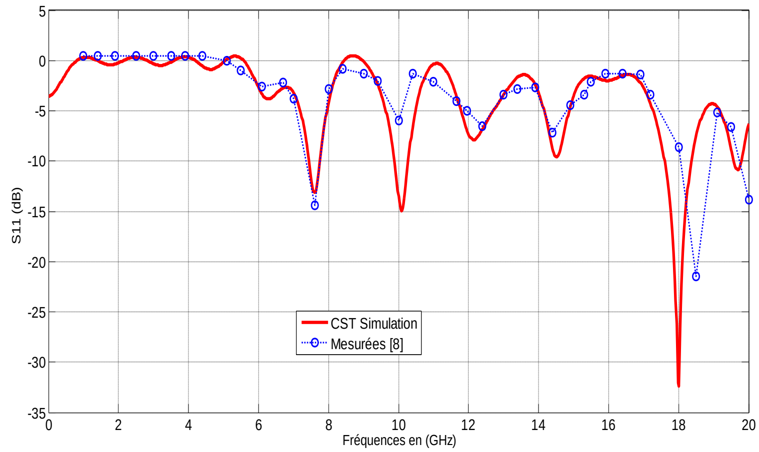

Fig 5:- Simulated and measured return loss S_{11} versus frequency for planar base antenna.

Figure 5 illustrates the return loss versus frequency of this antenna. Simulation results on red color are compared with measurements results referred to P. Wang [8] drawn on blue points. We find good agreement between the two results including first and second resonant frequencies of 7.6 Ghz and 10 Ghz. For height frequency beyond 18 GHz a slight difference was remarked but no effect since the frequency range of the ultra wide band UWB is between 3.1 and 10.6 GHz. We can confirm and validate the method used for this study. This antenna will be improved through a parametricstudy to satisfy the ULB requirements set by the Federal Communications Commission FCC.

Parametric study:-

A. Substrate choice:-

We use a substrate with relative permittivity value of 4.6. On the other hand in [5], for microstrip technology the characteristic impedance Zc of a microstrip line, with w for lying on a substrate with a height h, varies versus ratio value of w/h as illustrated in Figure 6. To have a characteristic impedance matched at 50 Ohms and a substrate relative permittivity of value 4.6, the w/h ratio must be taken equal to value 1.85. So for the most common and inexpensive substrate with value height of h = 1.5 mm, width microstrip line must have a value of w_f = 2.8 mm which we will use for the microstrip line to feed the patch of the microstrip antenna.

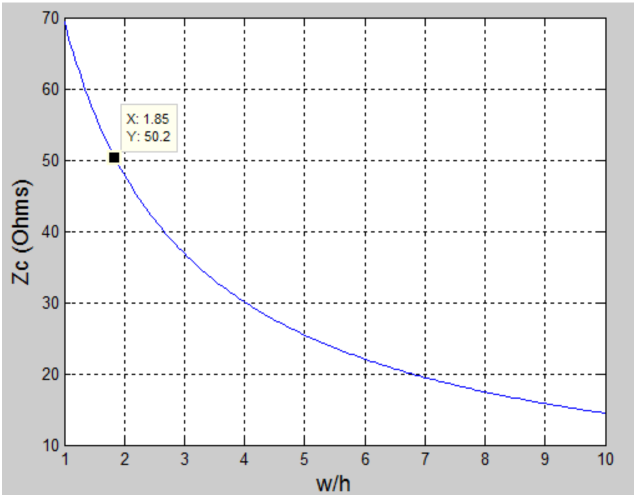

Fig 6:- Impedance caracteristic versus ratio w/h in microstrip technology for relative permittivity value 4.6

Effect of ground planesize:-

The choice has been set for an FR-4 substrate with relative permittivity 4.6 and 1.5 mm for substrate height.

The patch ofmicrostrip antenna has dimensions values of 14.5x15 mm^2 and the starting area ground plane is 30x30 mm^2 as mentioned in Table 2.

Table 2:- Starting planar microstrip antenna dimensions

Greatness	**Value in (mm)**
L	30
W	30
L_p	14,5
W_p	15
L_f	12,5
W_f	2,8
h	1,6

We simulate this first structure. After we change the ground plane size on reducing its lengthLpm, as shown in Figure 7.

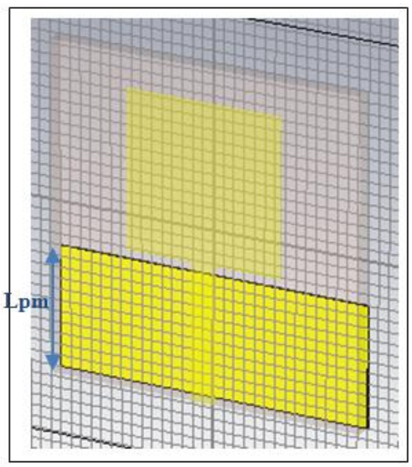

Fig 7:- Reducing the length Lpm of planar microstrip antenna ground plane

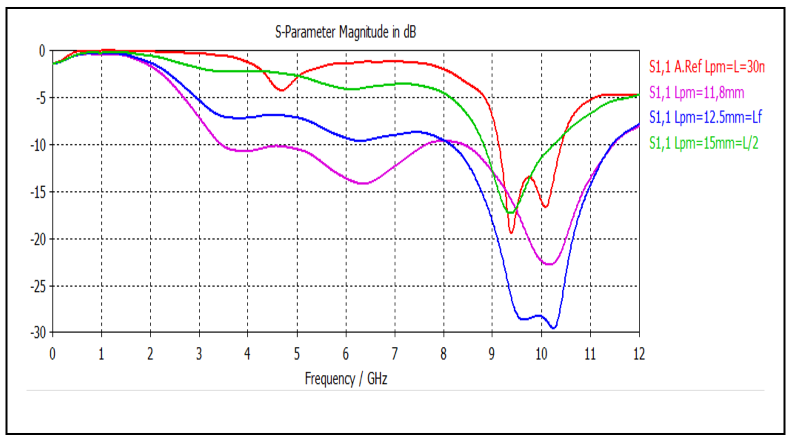

Fig 8:- Return loss S_{11} versus frequency After Reducing the length Lpm of planar microstrip antenna ground plane

Figure 8 shows the return loss versus frequency for four structures of planar microstrip antennas identical but whose height ground plane is different. The red curve represents return loss S_{11} versus frequency for the starting antenna with a full ground plane 30x30 mm^2. The bandwidth at -10 dB in this case is [9,1Ghz ; 10,4Ghz] with a width of 1.3 Ghz. The others curves show the effect of the reduction the length of the ground plane on the frequency bandwidth for planar microstrip antenna. The results are summarized in Table 3. We see that the reduction of the ground plane allows the increase of the width of bandwidth for planarmicrostrip antennas studied.

Table 3:- Bandwidths versus length ground plane of the planar microstrip anntenna

Ground plane width	Ground plane length Lpm	Bandwidth at -10 dB
30 mm	30 mm	1,30 Ghz
30 mm	15 mm	1,44 Ghz
30 mm	12,5 mm	3,30 Ghz
30 mm	11,8 mm	4,2Ghz and 3 Ghz
30 mm	10,8 mm	4,30 Ghz
30 mm	10,5 mm	4,25 Ghz
30 mm	10 mm	4,20 Ghz

Other hand, we see in case of ground plane length value Lpm = 11.8 mm, Figure 9, the antenna can operate on two frequency bands . The first [3,4 GHz ; 7.6 Ghz] with width 4.2 GHz band and the second [8.4 Ghz ; 11.4 GHz] with width 3 Ghz. In this case, this antenna can be regarded as ultra wide band UWB antenna operating in two bands of frequencies and that return loss reaches a maximum absolute value respectively 14.6 dB and 23 dB . Furthermore, this antenna has a rejection band [7.6 Ghz ; 8.4 GHz].

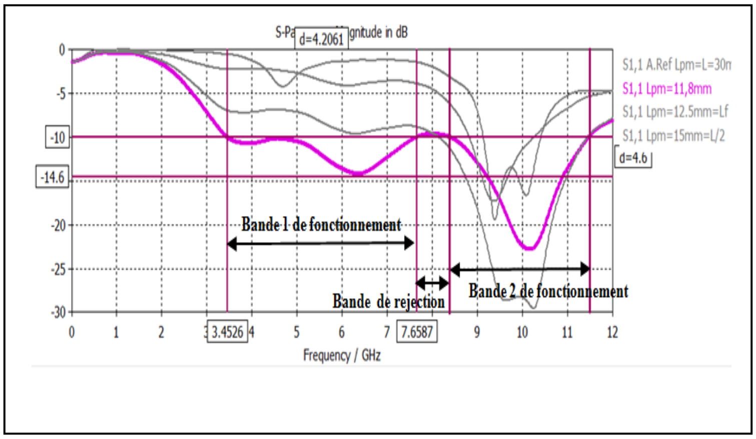

Fig. 9:- Return loss S_{11} versus frequency for the length Lpm of planar microstrip antenna ground plane.

So reducing the length of ground plane for rectangular planar microstrip antenna, has allows us to expand bandwidth from an initial value of 1.3 Ghz to 7.2 Ghz. This last value is divided into two width 4,2 GHz and 3 GHz corresponding ontwo operating bands .

Effect of the transition between the patch and themicrostrip feed line:-

In order to improve the frequency band and increase the absolute value of return loss, we modify the transition between the patch and the microstrip feed line. The passage of the rectangular shape of the patch to the linear shape of the microstrip feed line, instead of brute, will be done progressively as it is shown in figure 10.

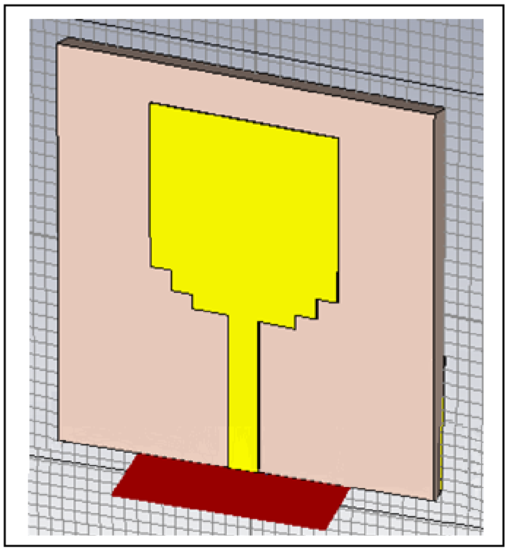

Fig 10:- Shape of the planar microstrip antenna according to modification of the transition between the rectangular patch and themicrostrip feed line.

Therefore, the rectangular planar microstrip antenna having two frequency bandwidths respectively width of 4.2 GHz and 3 GHz , and witch the transition between the patch and the microstrip feed line was brute, can be improved by adopting a gradual transition staircase from the patch to the microstrip feed line. In Figure 11, red curve shows the improvement in the bandwidth that becomes [3,1 GHz ; 18.7 GHz] , which gives a best width value of 15.6 GHz for bandwidth.

Results:-

Comparing the return loss S_{11}versus frequency of the three structures of planar microstrip antennas shown in Figure 11,we notice a large improvement ofbandwidth for final structure designed antenna on red curve.

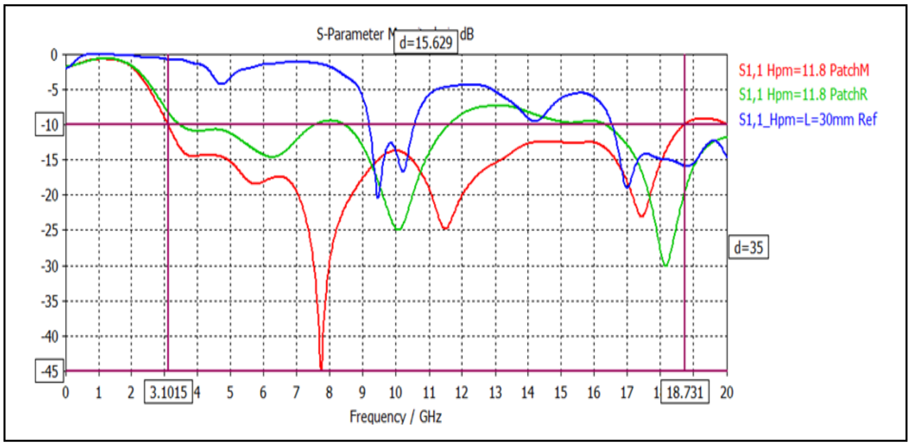

Fig. 11:- Return loss S11 versus frequency for three antennas : starting antenna, without and with gradual transition between planar patch and microstrip feed line.

Indeed the blue curve of base antenna with area ground plane of 30x30 mm^2 has a width bandwidth of 1.3 GHz which increases to 7.2 GHz divided into two bands of 4.2 GHz and 3 GHz on the green curve for reducing the ground plane to 30x11.8 mm^2. While the red curve shows a clear improvement in the bandwidth of the final structure of planar microstrip antenna modified by adopting a gradual transition between the microstrip line feed and the rectangular patch, which gave us a bandwidth [3,1Ghz ; 18.7 GHz] and a width of 15.6 GHz . On the other hand, return loss is also enhanced in maximum absolute value from 25 dB to 45 dB. This result meets the standards set by the Federal Communications CommissionFCC for Ultra Wide Band UWB communications witch the frequency band is [3.1 Ghz ; 10.6 GHz].

Other hand, Figure 12 allows comparison of antenna input impedance versus frequency for base antenna on red curve and final structure of microstrip antenna adopted on greencurve. The first varied between 12 Ω and 60 Ω and the second is between 27 Ω and 43 Ω over the entire bandwidth of the antenna [3.1 GHz ; 18.7 GHz]. This stable result is obtained after reducing area ground plan and adopting a gradual transition between the microstrip line feed and the rectangular patch of final antenna.

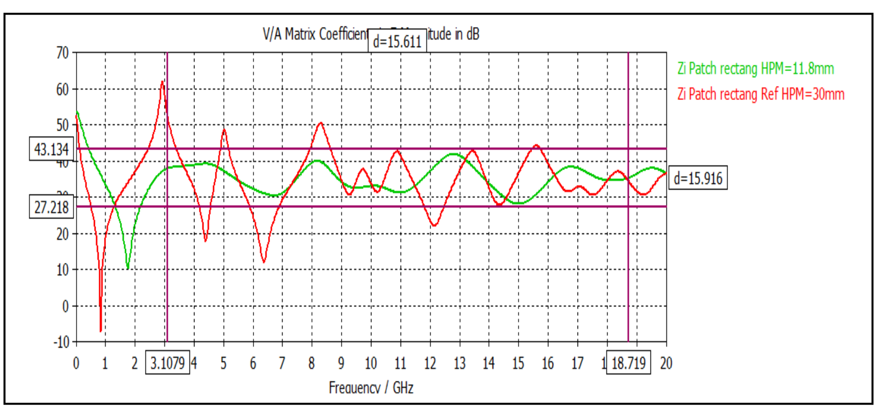

Fig 12:- Antenna input impedance versus frequency for two cases, with total ground plan and second with reducing height ground plan at 11,8mm and gradual transition.

Standing Wave Ratio SWRcan also allows to characterize the impedance mismatch . The ideal value of this ratio must be less than or equal to 2 over the entire antenna frequency band.
For the base antenna with area ground plane 30x30 mm2, the standing wave ratio, Figure 13, have very large values for the low frequencies and reaches a valueof 15 at frequency 6.8 GHz and a value of 4 at both frequency of 4.7 GHz and 12 GHz.

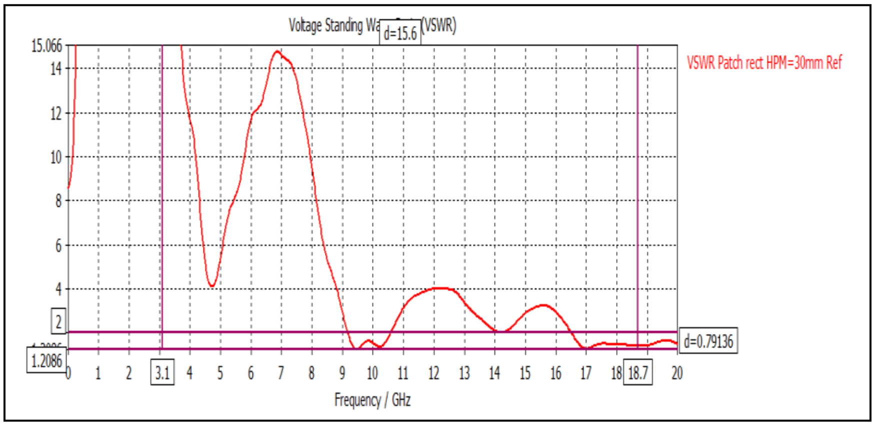

Fig. 13:- Standing Wave Ration SWR versus frequency for starting antenna with total ground plan dimensions 30x30 mm^2

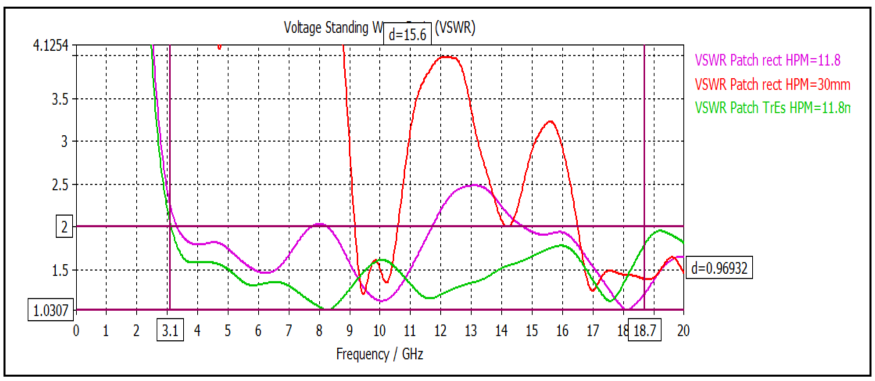

Fig. 14:- Standing Wave Ration SWR versus frequency for three antennas : starting antenna, without and with gradual transition between planar patch and microstrip feed line.

Figure 14, shows an improvement of the Standing Wave Ratio SWR for the final structure of the planar microstrip antenna. Indeed, the green curve shows that SWR factor remains below a value 2 over the entire frequency band [3,1Ghz ; 18.7 GHz].

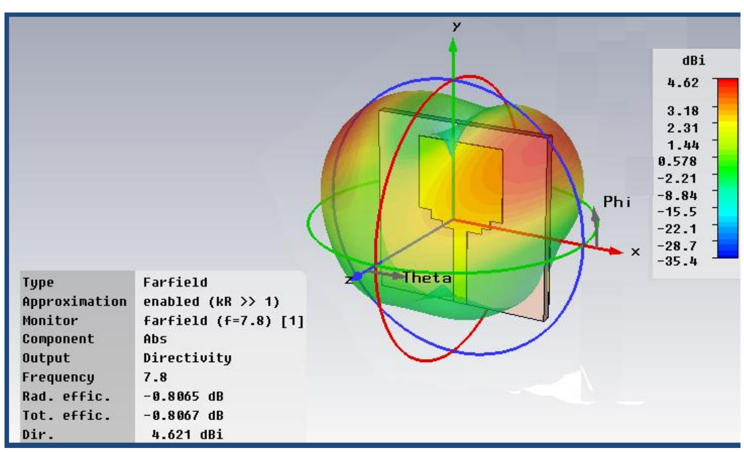

Fig. 15:- Three-dimensional radiation diagram at the 7.8 Ghz frequency of the ULB planar antenna designed

The chosen final structure of the planar antenna chosen for use in Ultra Large Band has a radiation pattern which is represented in FIG. 15 in three dimensions. At the frequency 7.8 GHz, a maximum gain of 4.6 dBi is obtained with respect to an isotropic antenna.

In FIG. 16, we represent the same two-dimensional radiation pattern in the plane E. The angle of opening of this half-power antenna (-3 dB of the maximum power) is equal to 107.2 deg.

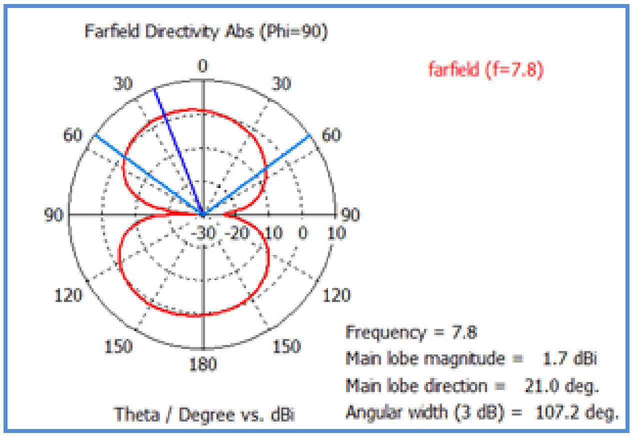

Fig. 16;- Two-dimensional radiation diagram of the ULB planar antenna at the 7.8 Ghz frequency in E plane (variable theta and constant phi).

Conclusion:-

The parametric study allows us to explore the effects of reducing ground plane area and the gradual transition between the microstrip line feed and rectangular patch. This enabled us to design a rectangular planar microstrip antenna meets the requirements of the Ultra Wide Band UWB set by The Federal Communications Commission FCC. This final structure antenna can be used for breast cancer detection. For future work, performance of this antenna can be improved in matters of gain by networking this structure.

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