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# Ultra-wide band microstrip antenna for 4G applications

Mohamed Fathy Abo sree<sup>1,2</sup>, Muhammad Aly Ibrahim<sup>2</sup>, W. Swelam<sup>3</sup>, Mohamed H. Abd El-Azeem<sup>1</sup> and Hadia El Hennawy<sup>2</sup>

<sup>1</sup>Arab Academy For science and Technology Maritime Technology, Department of Electronics and Communication, Cairo Branch AASTMT, Egypt

<sup>2</sup>Ain Shams University, Faculty of Engineering, Cairo, Egypt.

<sup>3</sup>Egyptian Armed Forces

[eng\\_m\\_fathey@hotmail.com](mailto:eng_m_fathey@hotmail.com) , [mohamed.fathy@aast.edu](mailto:mohamed.fathy@aast.edu) ,  
[Muhammadalyibrahim@hotmail.com](mailto:Muhammadalyibrahim@hotmail.com) , [wswelam@gmail.com](mailto:wswelam@gmail.com) ,  
[mhabdazeem@hotmail.com](mailto:mhabdazeem@hotmail.com) , [helhennawy@ieee.org](mailto:helhennawy@ieee.org)

**Abstract.** Presently, there is an expanded activity for ultra-wideband (UWB) technology for use in a few present and future applications. UWB got an exceptional attention, particularly after the approval of utilizing the unlicensed band beginning from 3.1 to 10.6 GHz for commercial use. A compact ultra-wide band microstrip antenna is introduced in this paper. The antenna consists of dual elements each having a size of 24X24 mm<sup>2</sup>, while the total size is 58X24 mm<sup>2</sup>. A decoupling circuit is added to the design; afterwards the spacing between the elements is adjusted. The first element covers the range between 3.29 and 6.9 GHz using the digital ground and the second antenna covers the frequency range from 8.76 GHz to 13.27 GHz using defective ground..This type of antenna is designed to be used for 4G applications. The antenna's structure and the parametric study, including the reflection coefficients, gain, coupling and decoupling, will be discussed further in this work. In addition to that comparison of similar UWB antennas is done.

## 1. Introduction

According to the major demand of high data rate in the wireless communication technology such as 3G and 4G; communication systems were created to improve these rates, and enhance the wireless communication [1].

The 3G system can cover a data rate of 5.8 Mbps for the uplink and 14 Mbps for the downlink. Also, the 3G system is allocated in the frequency band between 1.8GHz and 2.5GHz; 3G system applications and services include mobile internet access, mobile TV services and video call services [2-3].

Besides that, the 4G system can cover high data rates that reach 100Mbps for the mobile or moving user and 1Gbps for the stationary user. In addition to that, the 4G communication system is allocated in the frequency band from 2GHz to 8GHz. Where 4G systems offer the user high performance and high capacity; examples for the 4G applications are tele-medicine applications, tele-geoprocessing applications and educational applications [4].

The 3G/4G antennas are smart antennas; microstrip antennas are considered as an example for smart antennas, which are characterized by their low profile. That can be applicable to planar and non-



planar arrays, due to their low cost, ease of fabrication, high performance; and according to the selected patch shape they are versatile from the point of view of resonance frequency, polarization and field pattern. According to these specifications microstrip antennas can be used in aircrafts, spacecraft, missiles and satellite applications and....etc. Microstrip antennas consist of conductor plates separated from each other by a dielectric with specific permittivity and specific height [5].

Our design is made up of multiple antennas that are put together to work simultaneously at different ranges. These antennas are placed for transmitting and receiving data. Adding more antennas increases quality, reliability, throughput between transmitter and receiver [6].

Increasing the diversity is one of the primary reasons of using multiple antennas. Diversity is done by placing two antennas at a certain distance from each other, and because of the difference in physical location, each receives a slightly different version of the signal sent by the transmitter. The receiver compares between the received signals and gives out the best form of signal [6-8].

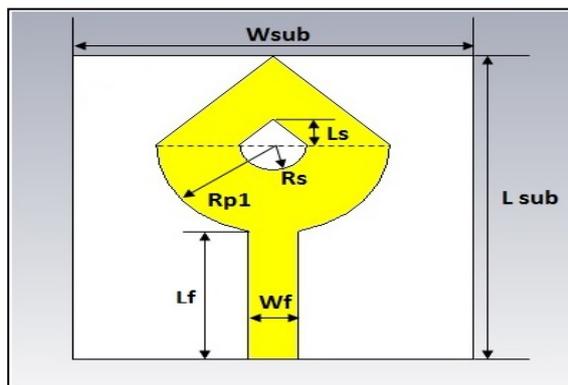
Difference created between the transmitter and receiver can increase reliability of the link between them; and this is good for noisy channels, it also can increase the used range between them [8-9].

For increasing the data rate we ask for spatial multiplexing, it can increase the capacity of the system. The source is divided into independent streams called spatial streams; in this case the throughput is doubled [9-12].

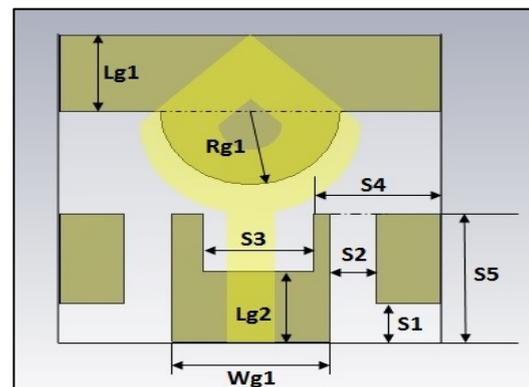
In this paper we introduce a microstrip antenna composed of two single elements as the first element covers the bandwidth from 3.29GHz to 6.9 GHz and the second element covers the bandwidth between 8.76GHz and 13.27 GHz. Also, there is a decoupling circuit implemented between the two elements' grounds to reduce the coupling effect between them..

## 2. Antenna Structure and Design

The antenna introduced in our work is composed of two single microstrip antennas of different frequency bands, implemented on FR-4 dielectric of permittivity  $\epsilon_r = 4.4$  and dielectric height 1.6 mm. The first antenna covers a band from 3.29 GHz to 6.9 GHz as the type of the ground which is designed to help in achieving this band is called a Digital Ground. The following diagrams show the geometric dimensions of the first antenna. Where figure 1 represents the top view and figure 2 shows the bottom view of the antenna and its ground's structure.

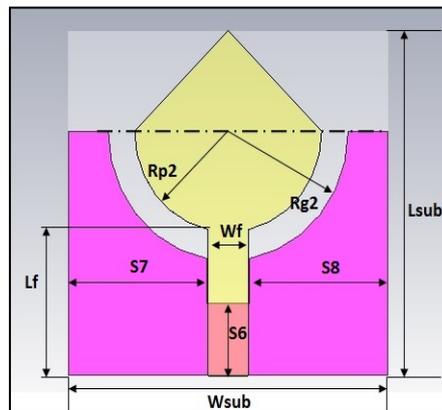


**Figure 1** The front view for the first antenna



**Figure 2** Ground of the first antenna

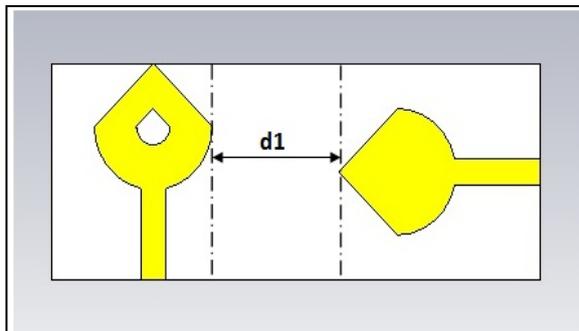
The second antenna covers a band between 8.76 GHz and 13.27 GHz, where the type of the ground designed to help in achieving this band is called a Defective Ground [13-14]. Figure2 shows the geometric dimensions of the second antenna.



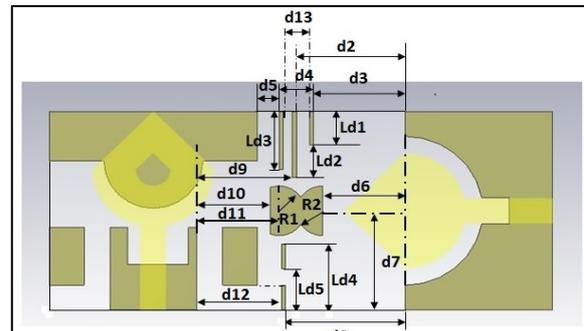
**Figure 3** The Total dimensions of the second antenna

Then the two antennas are placed together on one FR-4 substrate of 58x24 mm<sup>2</sup> to implement one microstrip antenna. Coupling effect occurs in the design of this antenna between the two single elements, and to reduce the coupling effect we used two techniques explained in the following paragraph.

Firstly, the spacing between the two single elements is increased as illustrated in figure 3. Secondly, a digital decoupling circuit is implemented between the two elements' grounds; figure 4 shows the total dimensions of the antenna.



**Figure 4** The front view of the Microstrip antenna



**Figure 5** dimensions of the decoupling

The following three tables demonstrate the different dimensions of the Microstrip antenna, expressed in millimetres:

**Table 1** Dimensions of 1st antenna

Layer	Variable and Dimension					
<b>Substrate</b>	Lsub	24	Wsub	24		
<b>Patch</b>	Wf	3.01	Lf	10	Rp1	7
	Rs	2	Ls	2		
<b>Ground</b>	S1	3	S2	3	S3	7
	S4	8	S5	10	Lg1	6
	Rg1	5.7	Wg1	10	Lg2	5.5

**Table 2** Dimensions of 2nd antenna

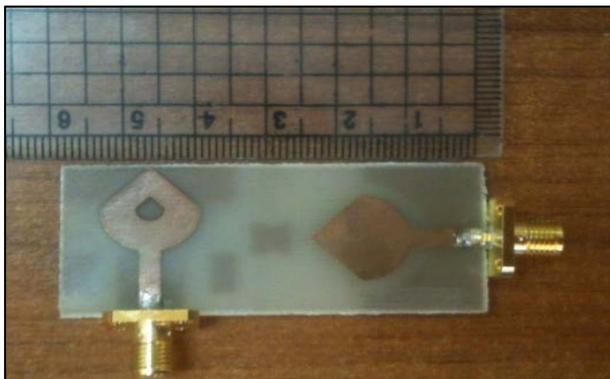
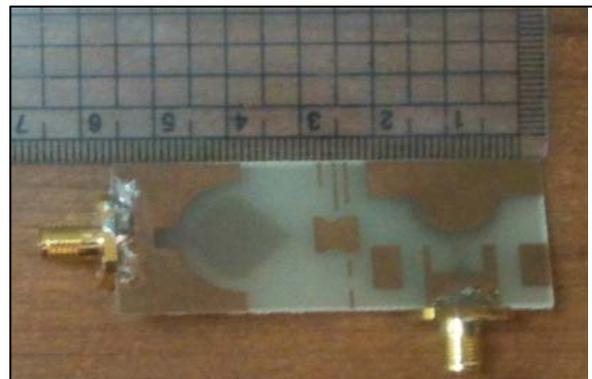
Layer	Variable and Dimension		
Substrate	Lsub=24 mm	Wsub=24mm	
Patch	Lf=10mm	Wf=3.01 mm	Rp2=7mm
Ground	Rg2=9mm	S6=5mm	S7=10.4mm
	S8=10.4 mm		

**Table 3** Decoupling Circuit Dimensions

Layer	Variable and Dimension					
Substrate	Lsub1	24	Wsub1	58		
Patch	d1	15				
Ground	R1	3	R2	3	Ld1	4
	Ld2	4	Ld3	7	Ld4	8
	Ld5	5	d2	9	d3	8.5
	d4	4	d5	2.5	d6	9.5
	d7	12	d8	13.25	d9	4.5
	d10	1.5	d11	2.5	d12	10.25
	d13	3				

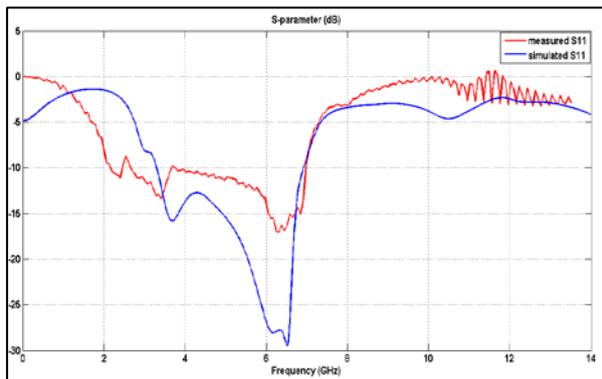
### 3. Antenna Results

This section will present the fabricated Microstrip antenna on a FR-4 substrate with dimensions 58X24 mm<sup>2</sup>; the following shows the real fabricated antenna. Where figure 6 shows the front view of the fabricated antenna. While the second figure 7, is a representation of the backside view of the fabricated antenna.

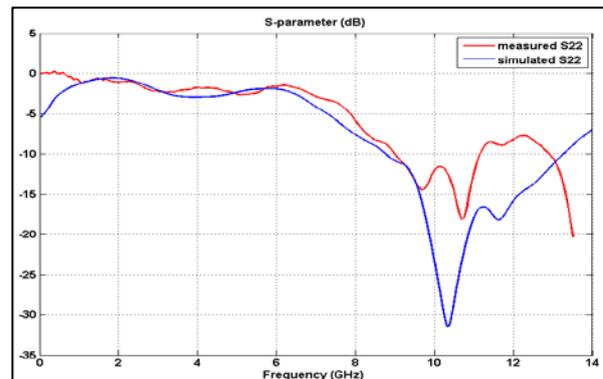
**Figure 6** The front view of the antenna**Figure 7** The back view of the antenna

#### 3.1. S-Parameter

At first, a comparison between the bandwidths of the two elements of the antenna is represented; simulation results and measurement results are illustrated. Where figure 8 shows the comparison between the measured and simulated results based on the S(1,1) factor, that reach a level below the (-15 dB) in the measured, compared to almost (-30 dB) in the simulated. While figure 9 shows the comparison based on the S(2,2), as it decays below the (-15 dB) for the measures.



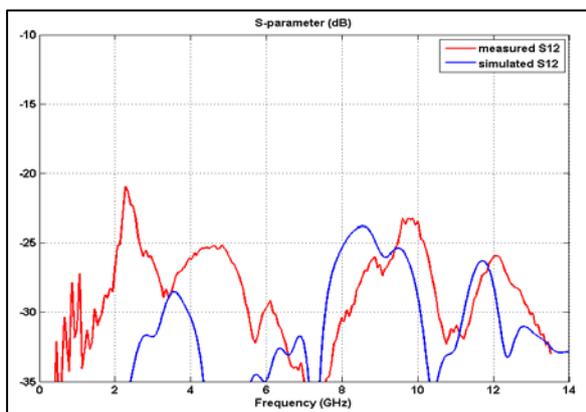
**Figure 8** simulated and measured bandwidth of the first element



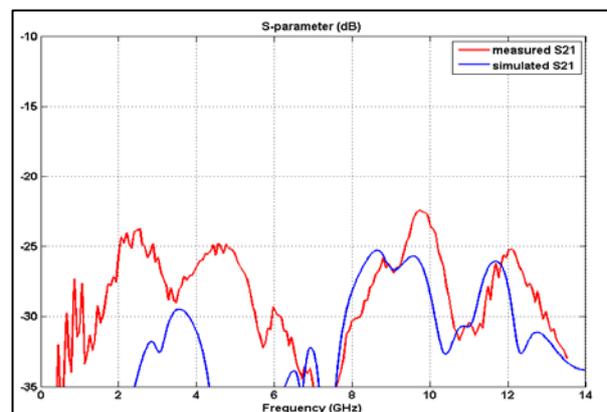
**Figure 9** simulated and measured bandwidth of the second element

The difference between the simulated and measured results is basically due to the theoretical results using waveguide port on the software tool simulation; while in the practical antenna an SMA connector was used to be able to measure the s-parameter of the antenna. The SMA connector had a large effect on the s-parameter because the antenna has a small size therefore the SMA connector was able to make an observed difference between the simulated and measured results.

Secondly, we compare the coupling effect between the two elements of the antenna which is simulated and measured, where figure 10 and figure 11 represent the comparison between the coupling effect which is simulated using the software and the practical coupling effect.

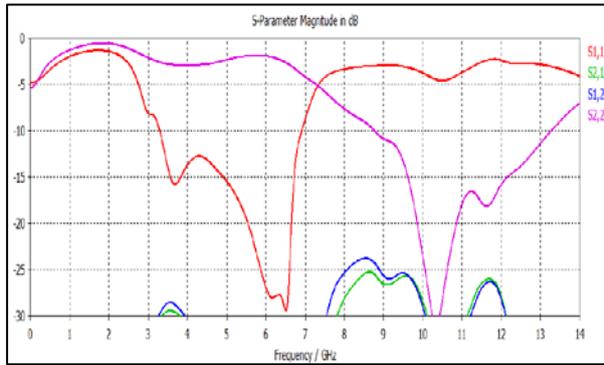


**Figure 10** Simulated and Measured coupling effect (S1,2)

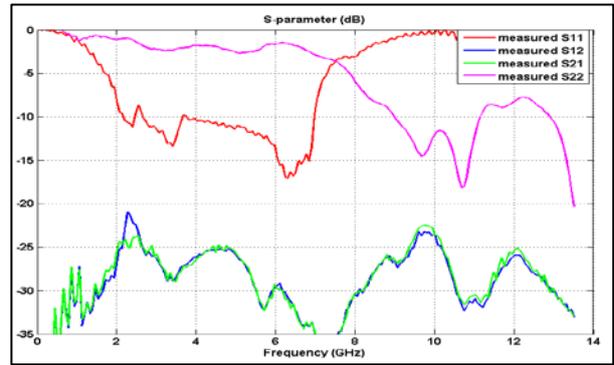


**Figure 11** Simulated and Measured coupling effect (S2,1)

Finally, the overall s-parameter is shown and to explain the purpose of this antenna design, and to prove that the antenna elements are separated in the frequency domain. Thus figures 12 and 13 represent the overall s-parameter. Where figure 12 shows the simulated results, and figure 13 shows the practically measured results.



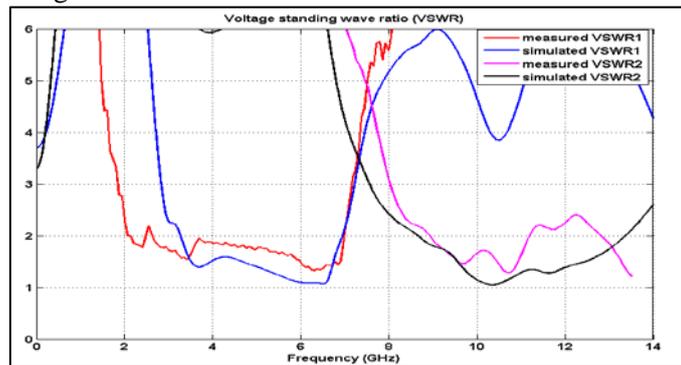
**Figure 12** Simulated overall S-parameter



**Figure 13** Measured overall S-parameter

### 3.2. VSWR

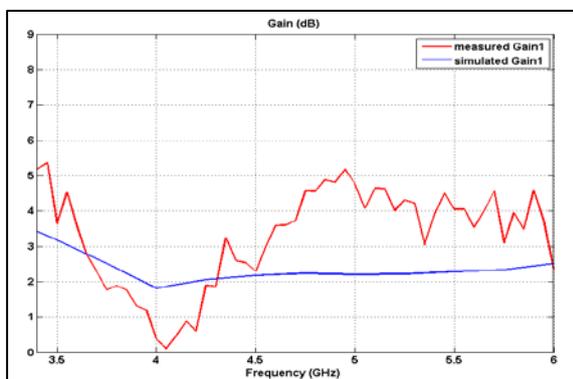
In this part, a comparison between the simulated and measured VSWR results will take place; figure 14 represents the difference between simulated and measured VSWR results. The result's graph demonstrates a curve tending to reach the value of 1 within the bandwidth interval.



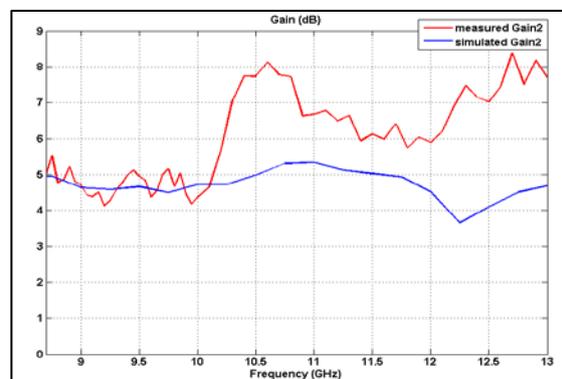
**Figure 14** Simulated and Measured overall VSWR

### 3.3. Gain

For the Gain, figures 15 and 16 represent the outcome between the simulated and the measured gain of the antenna. Where the measured results show a peak gain around the 6 dB at some intervals on port 1 shown in figure 15. While the maximum gain of the measured antenna at port 2, exceeds 8 dB as demonstrated in figure 16.



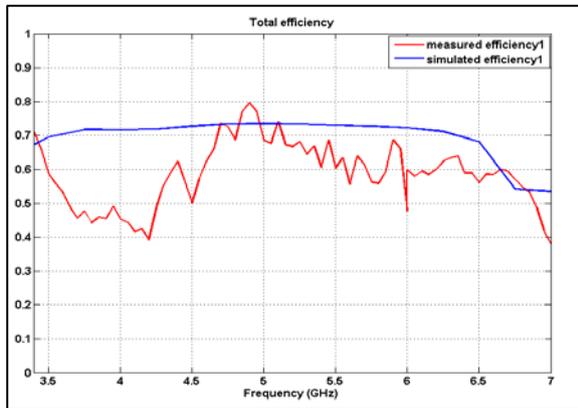
**Figure 15** Gain from port 1



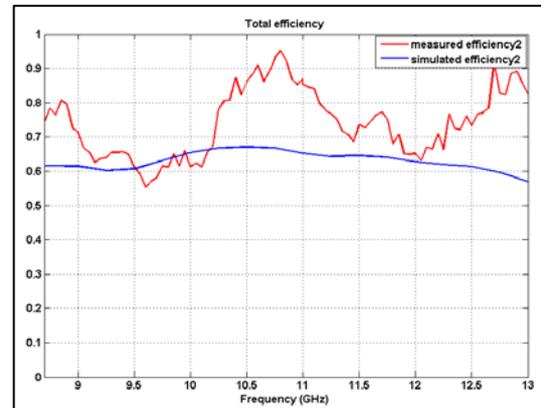
**Figure 16** Gain from port 2

### 3.4. Total Efficiency of Antenna

The Total Efficiency is represented in fig.10, it displays the simulated and measured. From the figure, it's noticed that the efficiency can reach levels above 60% and 70%.



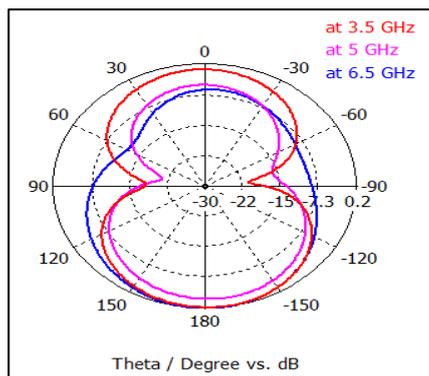
**Figure 17** Total efficiency simulated and measured at port1



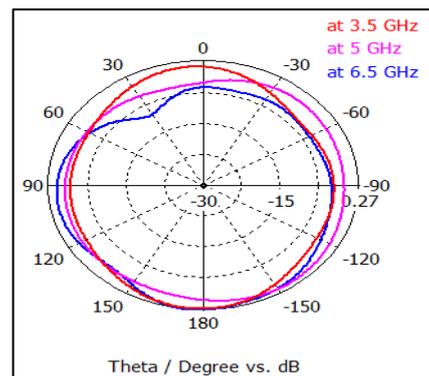
**Figure 18** Total efficiency simulated and measured at port2

### 3.5. Radiation Pattern

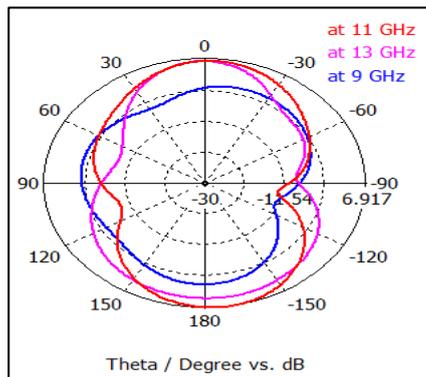
Also, the radiation patterns at both E-plane and H-plane are demonstrated in six different frequencies. The pattern is divided into three frequencies for the first element as they are located at the first band (S11). The other three frequencies are for the second element, that are located in the second band (S22). The following graphs including figure 19, 20, 21 and 22 illustrates the radiation patterns at these six different frequencies.



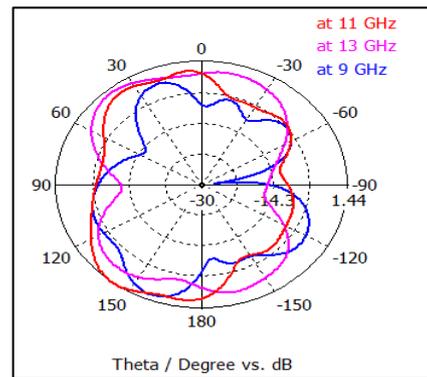
**Figure 19** E-Plane Radiation patterns from port1



**Figure 20** H-Plane Radiation patterns from port1



**Figure 21** E-Plane Radiation patterns at port2



**Figure 22** H-Plane Radiation patterns at port2

#### 4. Comparison

In this part we will be comparing our suggested design with other designs and other papers, that similarly are designed to operate within the UWB. The comparison will be based on the dimension, minimum value of return loss (S11) reached, the total bandwidth achieved in GHz and the gain in dB. This comparison is represented at the next table:

**Table 4** Comparison Table

Ref.	Dimensions	Return Loss (min. db)	Bandwidth (total)	Gain (dB)
<b>This Work</b>	58 x 24 mm <sup>2</sup>	-18	8.1 GHz	8
[15]	30 x 35 mm <sup>2</sup>	-30	8.2 GHz	6
[16]	30 x 17 mm <sup>2</sup>	-35	4.15 GHz	4
[17]	29.4 x 29.4 mm <sup>2</sup>	-30	9.2 GHz	5.5
[18]	32.42 x 27 mm <sup>2</sup>	-45	7.19 GHz	5.4

From the table above, the proposed antenna design was able to achieve the highest gain value compared to the other papers. While it was also among the highest reachable bandwidth with a range exceeding the 8 GHz.

#### 5. Conclusion

The Microstrip antenna designed in this paper is implemented on a 58x24mm<sup>2</sup> FR-4 substrate, and composed of two elements. Each element covers a specific bandwidth so the two elements of the antenna are separated in the frequency domain; also, a decoupling circuit was designed between the two elements to minimize the coupling effect as possible. The antenna was then fabricated and measured to compare the results with the simulation. A total bandwidth of approximately 8.2 GHz was achievable and the minimum value of the return loss measured was around the -18 dB.

The future work for this design will include further enhancements to reach better values concerning the return loss, while maintaining the large bandwidth offered, and also attain the high results of the gain.

## 6. References

- [1] Ishan Shah, Shiv Shukla, Rohan Shrotriya, Nupur Mehta, Nirja Mehta, Shivang Bakliwal, (Comparative Study of 4G Technology, Applications and Compatibility in Prevailing Networks), International Journal of Electronics Communication and Computer Technology (IJECCCT) Volume 2 Issue 6 (November 2012).
- [2] Amit Kumar, Dr. Yunfei Liu, Dr. Jyotsna Sengupta, Divya, (Evolution of Mobile Wireless Communication Networks: 1G to 4G) , IJECT Vol. 1, Issue 1, December 2010.
- [3] K. Kumaravel, (Comparative Study of 3G and 4G in Mobile Technology), IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 5, No 3, September 2011.
- [4] Constantine A. Balanis, (Antenna theory: Analysis and design).
- [5] David M. Pozar, Daniel H. Schaubert, (Microstrip Antennas: The Analysis and Design of Microstrip Antennas and Arrays).
- [6] Javier Rodriguez, Lluís Jofre, Sebastian Blanch, Stan Dossche, Jordi Romeu, ( CAPACITY OPTIMIZATION OF CLOSELY SPACED PATCH ANTENNAS).
- [7] Jagadeesh Babu. K, Sri Rama Krishna. K, Pratap Reddy. L, (A review on the design of antennas for upcoming 4G communications), INTERNATIONAL JOURNAL OF APPLIED ENGINEERING RESEARCH, DINDIGUL Volume 1, No 4, 2011.
- [8] Su Sandar Thwin, (Compact Band-Notched UWB Printed Planar Inverted Cone Antennas), International Journal of Computer Theory and Engineering, Vol. 3, No. 6, December 2011.
- [9] Mohamed M. Morsy, Mohamed A. Basha, Muhammad R. Khan, (Multi-Band Antenna for Wireless Devices), 978-1-4673 04627/12©2012 IEEE.
- [10] Wei LI, Yuan Yao, Junsheng Yu, (A Dual Broad-band Antenna for WLAN Application with High Isolation), 978-1-4673-0029-2/12/\$26.00 ©2011 IEEE.
- [11] Muhammad Saeed Khan, M. Farhan Shafique, A.D. Capobianco, E. Autizi, Imran Shoaib, (Compact UWB- Antenna Array with a Novel Decoupling Structure), Proceedings of 2013 10th International Bhurban Conference on Applied Sciences & Technology (IBCAST) Islamabad, Pakistan, 15th - 19th January, 2013.
- [12] L. Liu, S. W. Cheung, T. I. Yuk, (compact antenna for portable devices in UWB applications), Copyright (c) 2013 IEEE.
- [13] Breed, Gary. "An introduction to defected ground structures in microstrip circuits." High Frequency Electronics 7 (2008): 50-54.
- [14] Weng, Li Hong, et al. "An overview on defected ground structure." Progress In Electromagnetics Research 7 (2008): 173-189.
- [15] Awad, Noor M., and Mohamed K. Abdelazeez. "Multislot microstrip antenna for ultra-wide band applications." Journal of King Saud University-Engineering Sciences 30.1 (2018): 38-45.
- [16] Chen, Zubin, et al. "A Compact Printed Monopole Antenna for WiMAX/WLAN and UWB Applications." Future Internet 10.12 (2018): 122.
- [17] Pushjpalatha, K., et al. "Design of Combined UWB and MIMO UWB Antenna for Mobile Terminals." 2018 Fourth International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB). IEEE, 2018.
- [18] Kumar, Arun, and Manish Kumar Singh. "Band-notched planar UWB microstrip antenna with T-shaped slot." Radioelectronics and Communications Systems 61.8 (2018): 371-376.