DESIGN OF A UWB ANTENNA ARRAY FOR KA BAND OPERATION

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Abstract: An ultra wide band circular ring patch antenna array is investigated in this paper. The initial design was a single element annular ring patch antenna fed with microstrip line on FR4 dielectric substrate with $\varepsilon_r = 4.4$ and thickness h=1.6 mm. Eigen value solution for 28 GHz yields inner radius a=3.0 mm and outer radius b= 4.05 mm for the patch. The single element shows a bandwidth of 37.2 % at 28.5 GHz with -21dB return loss. The antenna with four connected annular rings array, fed with microstrip line, shows enhanced bandwidth of 57.57 % at 28 GHz with return loss of -23.5 dB. The array also shows multi frequency response. The designed antennae can be used in wireless communication(Abstract).

Index Terms: Annular ring antenna, array antenna, ultra wide bandwidth antenna, wireless communication

I. Introduction

Printed antennas are small size, light weight, easy to install and conformal in shape. They are effectively used in wireless communications. One of the main drawbacks in microstrip antenna is narrow bandwidth. Therefore several techniques are used to increase the bandwidth. Waqas Farooq , et all [1] has reported a novel wearable antenna operating at 5 GHz where a microstrip patch is mounted on a gold base and wearable as a finger ring. By simulating it with CST Microwave studio it showed a good bandwidth of 90.3 MHz. Syed S. Jehangir and M. S. Sharawi [2] presented a semi ring slot yagi like antenna operating at 3.6 GHz. The measured bandwidth of the antenna is reported to be 374 MHz and directivity of 4.2 dB. In order to achieve higher gain, directivity and high front to back ratio (FBR), they have used a simple reflector element and achieved higher FBR. Salai Thillai Thilagam.J, et all [3], have reported an Octagonal shaped planar antenna which gave a bandwidth from 2 GHz to 10 GHz over wide multi resonant frequencies when simulated with Ansoft HFSS. A reconfigurable single slot-ring antenna using 32 PIN diode switches is proposed by Mahmoud Shirazi, et all [4] which is able to switch between S and C bands. Here the first design of a single slot ring gave a fractional bandwidth of 11.4% which was increased significantly and enhanced to 28.2% . Djelloul Aissaoui et all [5] reported a novel design of a fractal antenna for achievement of ultra Wide band response. In this paper five iterations are applied on hexagonal-cut circular antenna which is fed with a coplanar waveguide (CPW) feed. The simulation result showed a 8.6 GHz impedance bandwidth for operation ranging from 5.8 GHz to 14.4 GHz. Mohammad Shakawat Hossain,et all [6]presented a method of generation of wideband circular polarization (CP) using a stacked patch-ring microstrip antenna with a single probe feed. The proposed antenna displayed an enhanced 3dB axial ratio bandwidth of 8% and a simulated impedance bandwidth of 16%. Zhi Shen, et all [7] proposed a novel design of broadband radiation of the SIW cavity backed ring slot antenna. Experimental analysis confirmed an achievement of 12% bandwidth. Saurabh Dwivedi et all [8] reported a design technique where resonating frequency is reduced by lengthening the excited surface current path without increasing antenna length. After this an annular ring is introduced in between the symmetrical L-slotted patch and the resonance frequency is reduced by 29.91% when edge-fed or microstrip-line feed technique is used. The reported bandwidth of the final antenna is 100 MHz at 2.46 GHz. Yuanyuan Zhang [9] has investigated a centre-fed circular patch antenna with two coupled annular rings. They reported that due to the proper coupling of the two annular rings a wide band from 5.45 GHz to 7.16 GHz is achieved .In their measured result the reported bandwidth is 27.1%. A compact ring shaped monopole antenna is proposed by Rahul Singha, D. Vakula and N V S N Sarma [10] resulting in a impedance bandwidth from 6.5 GHz to 25 GHz which covers the entire UWB. Ashish Singh, et all [11] carried out a theoretical analysis of a slots and notches loaded microstrip patch antenna to achieve dual band operations. The bandwidth of the proposed antenna at TM_{01} mode is 3.42 % , at TM_{02} mode it is 3.81 % and for TM_{03} mode it is 4.80 % .

In this paper a microstrip annular ring and its array are designed as shown in Fig.1. The annular ring is designed at 28 GHz for the radiation mode of excitation TM_{120} .The antenna is fed with a 50 ohm microstrip line. Then the number of elements is increased to four and placed at suitable locations to form an array. Power is divided into the four elements through 50 ohm lines of different lengths. The design is characterised using Ansoft HFSS software tools for amplitude and phase distribution of power for enhanced bandwidth and desired radiation pattern. It is seen that the second configuration with four ring arrays gave increased bandwidth and also multi frequency response.

II. Simulation and Design of the Antenna Structure

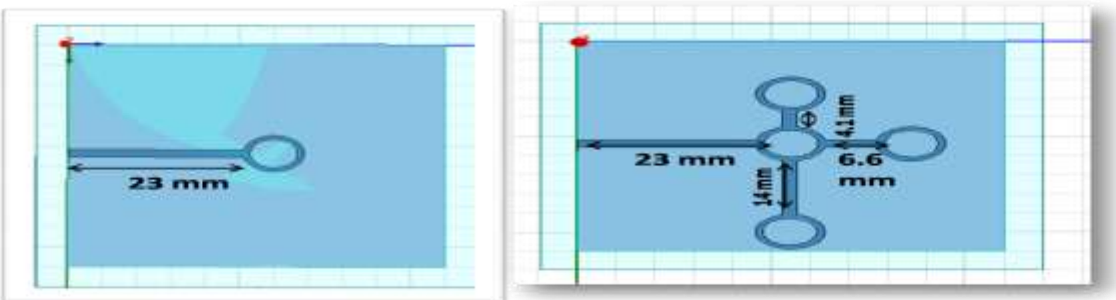


Fig 1. (a) A single element annular rings array (b) A four element annular rings array

As shown in Fig.1 (a) a single element annular ring patch antenna is designed on FR4 dielectric substrate having $\varepsilon_r = 4.4$ and thickness h=1.6 mm over a ground plane. The ring is fed with a 50 ohm microstrip line. The dimensions of the patch at 28 GHz are obtained from Eigen value equation [13, 14] for TM_{120} mode.

$$\frac{J_2'(ak)}{Y_2'(ak)} = \frac{J_2'(bk)}{Y_2'(bk)} \quad (1)$$

Here a is the inner radius and b is the outer radius of the ring, and $k = \frac{2\pi f_r}{c}\sqrt{\varepsilon_r}$, c = speed of light in free space = 3 X 10^8 m /sec. After computation with MATLAB for resonance at 28 GHz, the value of inner radius is 3.0 mm and outer radius is 4.06 mm. MATLAB simulation result is shown in Fig.2. The length and width of the 50 Ω microstrip feed line is L_f= 23 mm and W_f = 3 mm, respectively.

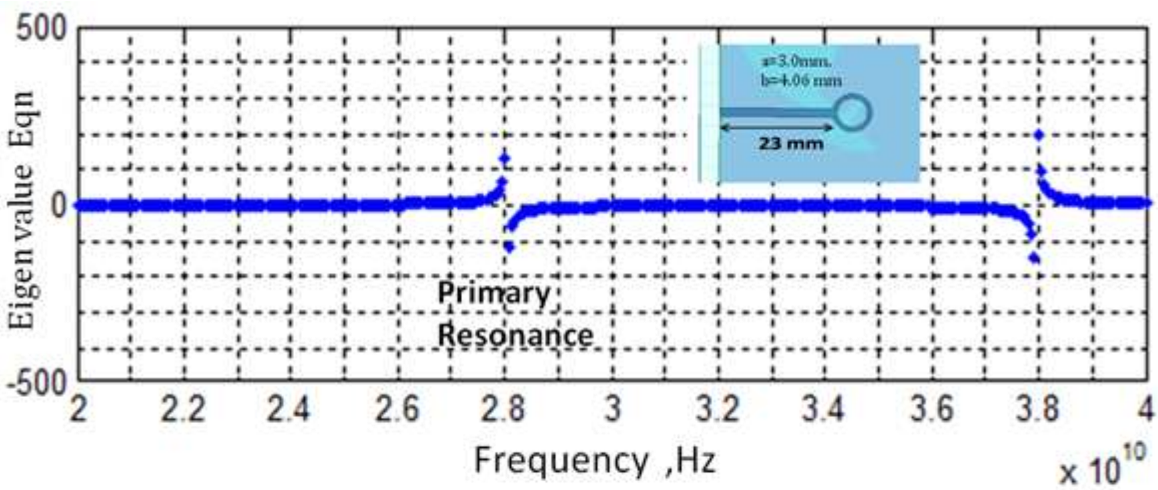


Fig 2. MATLAB simulation result for calculation of outer and inner radius of the ring patch antenna for frequency response at 28 GHz

The performances of this element are analyzed using Ansoft HFSS software tools. The S parameter vs. Frequency response of the single element is shown in Fig.3. It is seen that 37.2% band width is obtained for -10 dB return loss. The antenna also shows multi-frequency response at 13 GHz, 15.5 GHz, 20 GHz, 26.2 GHz, 28 GHz, 33.5GHz, 40 GHz and 49GHz.

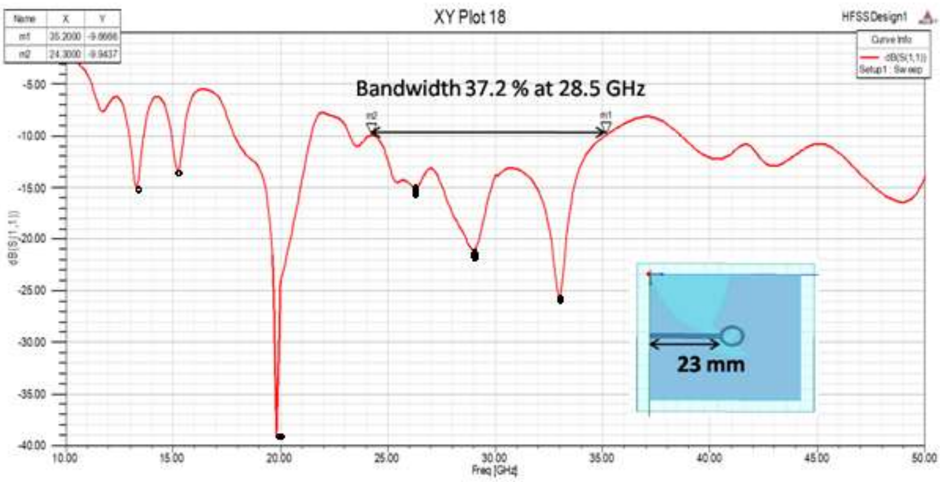


Fig 3 : The S parameter vs. Frequency response of Antenna 1 with one single resonating element

Using the same element size, the enhancement of band width is obtained for an asymmetric array of four elements as shown in Fig.1 (b). The amplitudes and phase of excitations of all the elements are adjusted using HFSS simulation and modelling to yield wide band width under return loss <-10 dB as shown in Fig.4. The different feed lengths are L_1=4.1 mm, L_2=6.6 mm and L_3=14mm, respectively and the main feed line is of length 23mm. It is seen that the antenna shows multi-frequency response at 13, 15, 16.5, 18.5, 20, 22.8, 25,28,32, 35, 38, and 41.5 GHz. With good impedance matching of S_{11}<= -10 dB, simulated bandwidth of > 57 % is achieved.

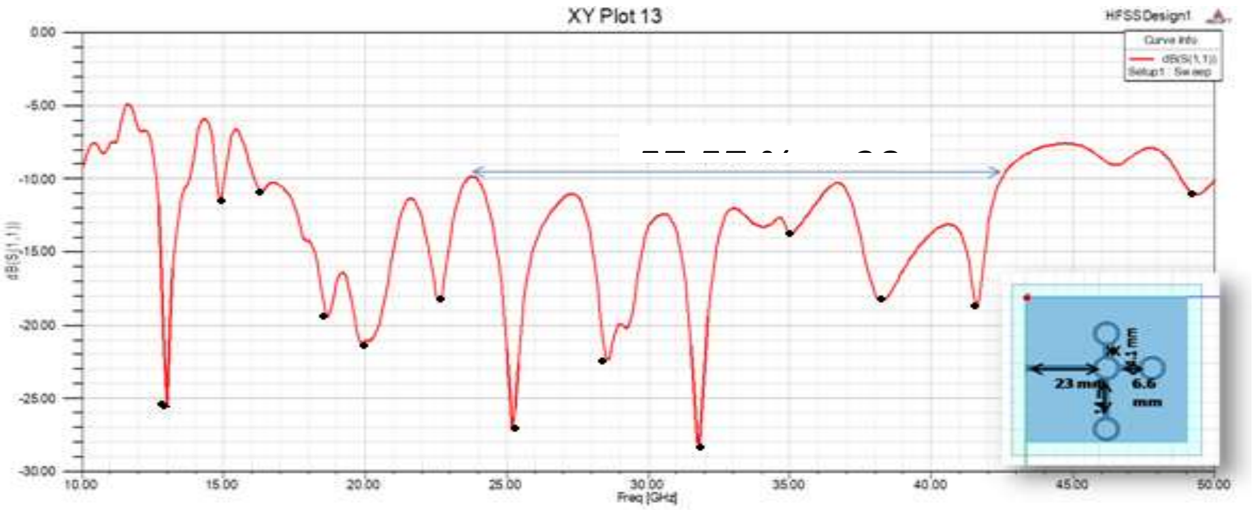


Fig 4 : Simulated Return Loss of the array antenna with four ring patches

Radiation Characteristics

The radiation characteristics of these antennas are shown in Figs.5 and 6. All the structures show broad side radiation. Other parameters of these antennas are given in Table 1. A comparison of resonance frequencies obtained from MATLAB computation and from HFSS simulation is given in Table 2.

Table I : Antenna performance parameters

Element number	Operating Frequency (GHz)	S_{11} (dB)	Bandwidth%	Gain (dB)	Directivity (dB)	Efficiency
1	28 GHz	-21	37.2 %	15	13	48 %
4	28 GHz	-23.5	57.57 %	15.1	13.01	59.9 %

Table 2 **:** Comparison between MATLAB and HFSS simulation results

Primary resonance frequencies through MATLAB computation	**Resonance peaks obtained through HFSS simulation**
28 GHz	13 GHz
38 GHz	15.5GHz
	20 GHz
	26.2 GHz
	28 GHz
	33.5 GHz
	40 GHz
	49 GHz

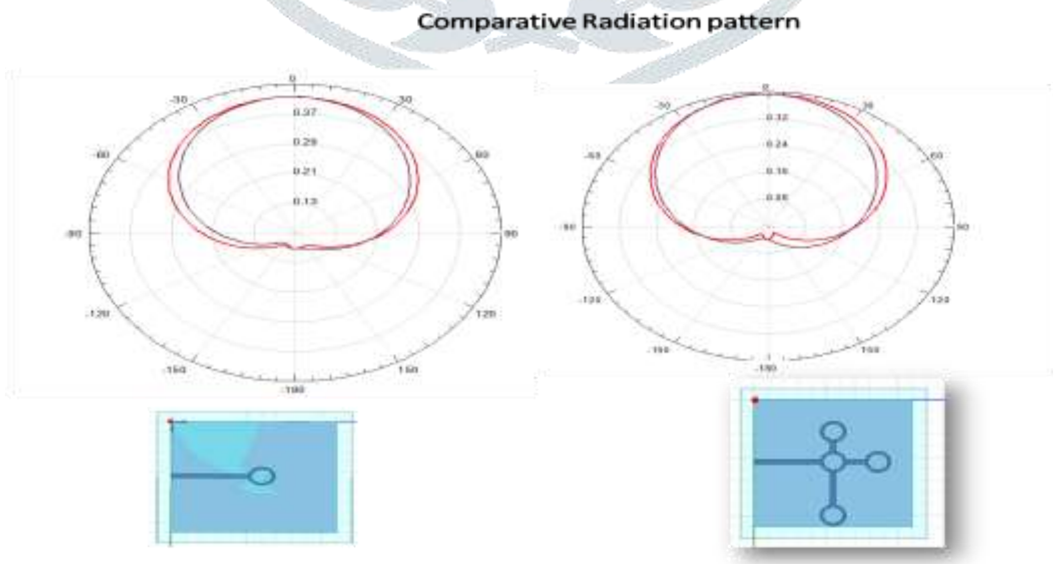
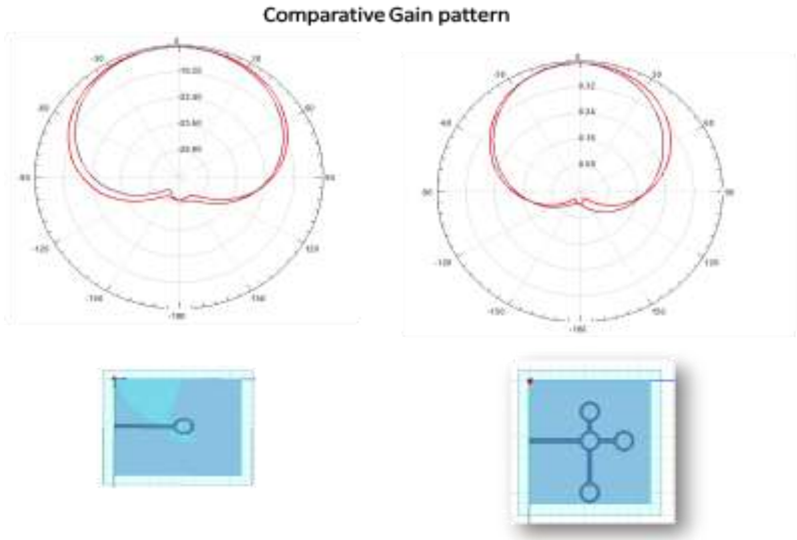


Fig 5 The simulated Radiation Pattern of the a) Antenna with single radiating element (b) Antenna with array of 4 radiating element



(a) (b)

Fig 6 The simulated Gain Pattern of (a) Antenna with single radiating element
b) Antenna with array of 4 radiating elements

Conclusion

This paper described design of an ultra wide band circular ring patch antenna array using Ansoft HFSS simulation and modelling. A single element annular ring patch antenna is designed with microstrip line feed on FR4 dielectric substrate having $\varepsilon_r = 4.4$ and thickness h=1.6 mm for radiating mode of operation TM_{120}. Eigen value solution for 28 GHz yields inner radius a=3.0 mm and outer radius b= 4.05 mm for the patch. The single element shows a bandwidth of 37.2 % with -21dB return loss at 28.5 GHz. In order to enhance the bandwidth further an array of four connected annular rings is designed for microstrip line feed. An enhanced bandwidth of 57.57 % with return loss of -23.5 dB at 28 GHz is obtained for this array. The array also shows multi frequency response.

The radiation pattern is found similar for the whole frequency range from 10 GHz to 40 GHz. It is observed that the antenna with four radiating annular ring elements gives better performance in terms of bandwidth and efficiency. The bandwidth is increased by 20 % and efficiency is increased by 11 % .Due to the limited and restricted accessibility to the measurement devices in this high frequency range the authors could not verify the results by measurements. According to the IEEE and FCC definition the antenna is suitable for Ultra Wideband Applications [19]. The designed antenna can be used in wireless communication.

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Reference

[1] Waqas Farooq , Masood Ur-Rehman , Qammer Hussain Abbassi , Xiaodong Yang and Khalid Qaraqe "Design of a Finger Ring Antenna for Wireless Sensor Networks"Antennas and Propagation (EuCAP),2016 10th European Conference 10-15 April 2016.DOI:10.1109/EuCAP.2016.7481827

[2] Syed S. Jehangir and Mohammad S. Sharawi "A Novel Compact Single Layer Semi-Ring Slot Yagi-Like Antenna with High Front-to-Back Ratio" 2016 IEEE 5th Asia-Pacific Conference on Antennas and Propagation (APCAP)

[3] Salai Thillai Thilagam.J,Manikandan.R, Dr.P .K.Jawahar "Optimized Octagonal Shaped Antenna using Split Ring Design and Analysis for Wireless Communication Applications" 2015 3rd International Conference on Signal Processing, Communication and Networking (lCSCN)

[4] Mahmoud Shirazi, Tianjiao Li, and Xun Gong "Reconfigurable Double Slot-Ring Antenna for Bandwidth Enhancement " 978-1-5090-0267-2/16/$31.00 ©2016 IEEE

[5] Djelloul Aissaoui and Noureddine B. Hacen, A. Tayeb Denidni "Design of a New Fractal Antenna With CPW-Fed For UWB Application " 978-1-4799-7815-1/15/$31.00 ©2015 IEEE

[6] Mohammad Shakawat Hossain, Saeed I. Latif, and Mohammad S. Alam "A Wideband Stacked Patch-Ring Antenna with Corner Perturbations for Circular Polarization"18th International Conference on Computer and Information Technology, 21-23 December, 2015

[7] Zhi Shen, Kirti Dhwaj, Hanseung Lee,Tatsuo Itoh, Li Jun Jiang "Broadband High Gain SIW Ring Slot Antenna" Proceedings of the 45th European Microwave Conference , 978-2-87487-039-2 © 2015 EuMA

[8] Saurabh Dwivedi, Shiv Gopal Yadav, Ashutosh Kumar Singh "Annular Ring Embedded L-Slot Rectangular Microstrip Patch Antenna" Proceeding of the 2014 IEEE Students' Technology Symposium , 978-1-4799-2608-4/14/$31.00 ©2014 IEEE

[9] Yuanyuan Zhang,Juhua Liu, Zhixi Liang, and Yunliang Long "A Wide-Bandwidth Monopolar Patch Antenna with Dual-Ring Couplers" International Journal of Antennas and Propagation Volume 2014 (2014), Article ID 980120, 6 pages

[10] Rahul Singha, D. Vakula and N V S N Sarma "Compact concentric ring shaped antenna for ultra wide band applications"2nd Radio and Antenna Days of the Indian Ocean (RADIO 2014) doi:10.1088/1757-899X/67/1/012004

[11] Ashish Singh, J.A. Ansari, Kamakshi, Mohd. Aneesh, Saiyed Salim Sayeed, A. Mishra" Analysis of slots and notches loaded patch antenna for dualband operation" 978-1-4799-1205-6/13/$31.00 ©2013 IEEE

[12] Sisir K Das and Annapurna Das, Antenna and Wave Propagation , TMH education pvt. Ltd. 1st edition 2013

[13] R Garg, P. Bhartia, 1. Bahl, and A. Ittipiboon, Microstrip Antenna Design Handbook.Norwood, MA: Artech House, 2001

[14] K.L Wong ; "compact and broadband microstrip antennas " New York: J.Wiley and sons,2002

[15] Anurima Majumdar ,Antara Ghosal, Sisir K Das, Annapurna Das "Analysis of a dual Frequency Slotted Circular microstrip Antenna" International Journal of Electronics and Computer Science Engineering –V2N4-1257- 1264.

[16] Antara Ghosal, Anurima Majumdar , Sisir K Das, Annapurna Das " Analysis of a Class of multi frequency Microstrip antenna for mobile handset" International Journal of Electronics and Computer Science Engineering –V3N2-108- 115

[17] Anurima Majumdar , Antara Ghosal ,Sisir k Das,Annapurna Das "The Effect of Defective Ground Plane on A Wide Band Dual Frequency Circular Patch Antenna" International Journal of Advanced Research in Computer and Communication Engineering Vol. 4, 2015

[18] Anurima Majumdar , Swatilekha Sarkar ,Gargi Majumdar , Shubham kumar Maurya , Sangeeta Hazra "Design and Analysis of a Wideband CPW fed Circular Patch Antenna for Wireless Communication Applications" International Journal of Innovative Research in Computer and Communication Engineering Vol. 4, Issue 5, May 2016

[19] www.wikipedia.org