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Design and Implementation of Dual Band Array Antenna for Wireless Applications

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ABSTRACT— This paper presents the development and characterization of 1×4 dual band antenna array on a flexible polyimide substrate. In this paper we have presented the design of a dual band microstrip antenna which will be operating in the wireless LAN band and IEEE 802.11a/b/g. In this paper a dual band microstrip antenna is designed and its measurement results in terms of return loss, VSWR and radiation patterns are studied. Microstrip design equations are introduced and validated by simulated results. This antenna is implemented on polymide substrate with ϵ_r=4.3, h=1.6mm and operating frequency of 5.25 GHz. By this design it is also shown that dual band operation is possible with proper position of the feed line and proper determination of inset size. Designed antennas are simulated by Ansoft High Frequency Structural Simulator (HFSS) by using the FEM (Finite element method).

Keywords— Dual band array antenna, IEEE802.11a/b/g, Polymide subsrate,VSWR, WLAN.

I . INTRODUCTION

Microstrip antenna arrays are widely used in various applications like wireless communication system, satellite communication, Radar systems, Global positioning systems, Radio Frequency Identification (RFID), Worldwide interoperability for microwave access (WiMax),and Medicinal applications of patch [1].

Now a days communication plays an important role in the worldwide society. The communication systems are rapidly switching from “wired to wireless”. Wireless technology which provides alternative less expensive and a flexible way for communication. Antenna is one of the important elements of the wireless communications systems. Thus, antenna design has become one of the most active fields in the communication studies. Antenna is a radiating element which radiates electromagnetic energy uniformly in Omni direction. For point to point communication applications antenna should have increased gain and reduced wave interference. Antenna is a transducer which is designed to transmit or receive electromagnetic waves. Microstrip antennas have several advantages over conventional microwave antenna and therefore are widely used in many practical applications. Microstrip patch antennas are one of the most versatile, conformal and easy to fabricate. The recent growth in the ambit of modern wireless communication has increased demand of multiband antennas that can satisfy the requirements pertaining to Wireless Local Area Network(WLAN).The development of dual band antenna that can cover the 5.25 GHz (5.15-5.85GHz) band and 9.25 GHz (9-9.5 GHz) band for IEEE802.11a and IEEE802.11g standards respectively, are thus highly desirable [2].

Harish et.al [3] proposed the development and characterization of an ink-jet printed 2-bit, 1×4 phased-array antenna (PAA) system on a flexible Kapton polyimide substrate utilizing carbon nanotube thin-film transistors (CNT-TFTs) as switching elements in the phase-shifting network. A multilayer metal interconnection strategy is used to fabricate a complete PAA system with control lines which is costly. Due to the low profile of the antenna, the local networks for flexible antennas are expected to provide coverage for short- (10 m) to medium-range (5 to 10 km) wireless operation [3]. Phased arrays require large antenna separations and supporting circuit real estate to allow reduced mutual coupling between antenna elements. Moreover, the need for phase shifters makes them costly and complicated to implement in a wearable applications [4].

The advantages of the microstrip antennas are small size, low profile, and lightweight, conformable to planar and non planar surfaces. However, patch antennas have disadvantages. The main disadvantages of the microstrip antennas are: low efficiency, narrow bandwidth of less than 5%, low RF power due to the small separation between

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the radiation patch and the ground plane(not suitable for high-power applications) [5].

In this paper, we focus on the design and characterization of a dual band and dual band array antenna by introducing a slot and compare the results with single band and single band array antenna.

II. DESIGN PROCEDURE AND EQUATIONS

The early work on microstrip antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems. Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration. A microstrip antenna is characterized by its length, width, input impedance, gain and radiation patterns. Various parameters, related calculation and feeding technique will be discussed further through this section. The length of the antenna is about half wavelength of its operational frequency.

A. Microstrip Line Feed Technique

This method of feeding is very widely used because it is very simple to design and analyze, and very easy to manufacture.

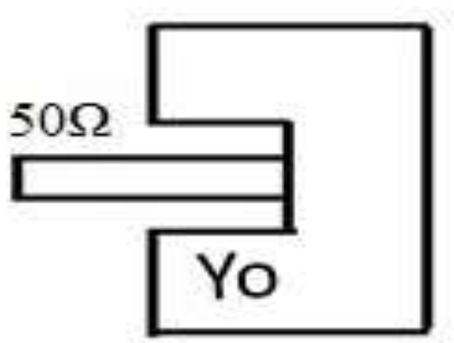

Figure 1. Microstrip patch antenna with feed

The procedure to find the position of the feed point (Yo) of the patch in figure 1 has been discussed below.

The impedance of the patch is given by [6]

$$Za = 90\,\frac{\epsilon_r^2}{\epsilon_r - 1}\left(\frac{L_T}{W_T}\right)^2$$

where ϵ_r=dielectric constant, L_T=length of transmission line

W_T =width of transmission line

The characteristic impedance of the transition section should be $Z_T = \sqrt{50 + Za}$ (2)

The width of transmission line is calculated by [6]

$$Z_T = \frac{60}{\sqrt{\epsilon_r}}\ln\left(\frac{8h}{W_T} + \frac{W_T}{4h}\right) \quad \text{for} \quad \frac{W_T}{h} > 1$$

(3)

where h = height of substrate

The width of the 50Ω microstrip feed can be found using the equation given below [5]

$$Z_O = \frac{120\pi}{\sqrt{\epsilon reff}\,(1.393 + \frac{W}{h} + \frac{2}{3}\ln(\frac{W}{h} + 1.444))} \quad \text{for} \quad \frac{W_T}{h} < 1$$

(4)

where Z_O=50 Ω

The length of the strip can be found by [5]

$Rin(x = 0) = cos^2(\frac{\pi}{2} x_o)$

The length of the transition line is quarter the wavelength is defined by $l = \frac{\lambda o}{4\sqrt{\epsilon reff}}$

where ϵ_{reff}= effective dielectric constant

B. Design Equations of Proposed Dual Band Antenna

Thickness of the substrate, h ranges between [9]

$0.003\lambda o \le h \le 0.05\lambda o$

where

λo = free space wave length

Guide wave length is given by [9]

$\lambda g = \lambda o/\sqrt{\epsilon_r}$

where ϵ_r= permittivity of substrate

By using the microstrip design equations, [6] the width and length of the patch are calculated and the values are L_p=13.33 mm and W_p =17.6 mm. The Performance of the microstrip antenna depends on its dimension. Depending on the dimension the operating frequency, radiation efficiency, directivity, return loss and other related parameters are also influenced.

Length of substrate is given by[6], $L_S = L_P + 6h$

Width of substrate is given by[6], $W_S = W_P + 6h$

Where h = Thickness of substrate.

Length of notch H=0.822$\times \frac{L_P}{2}$

where L_P =Length of patch

Width of notch $Y = \frac{W_P}{5}$

where W_P=width of patch

Based on above equations the design dimensions of the antenna are calculated and are shown in Table I.

(1)

Table I. Design dimensions for dual band antenna

Dimensions	Length(mm)	Width(mm)
Substrate & ground	22.9	27.2
Patch	13.33	17.6
Notch	5.478	3.52
Feed line	7.904	1.85
Wave port	1.85	1.6

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Slot	1.25	3.52

Figure 2 shows an single element dual band antenna that has been designed to cover operating frequency of 5.25 GHz and 9.25 GHz by introducing the inset feed method. Micro strip antenna mainly contains three types of elements they are patch, substrate and ground plane. Perfect electric conductor is used as a patch material and polymide substrate material. The dual band microstrip antenna (MSA) is realized by cutting the slots of different shapes. The geometry of dual band rectangular microstrip antenna is shown in figure 2.

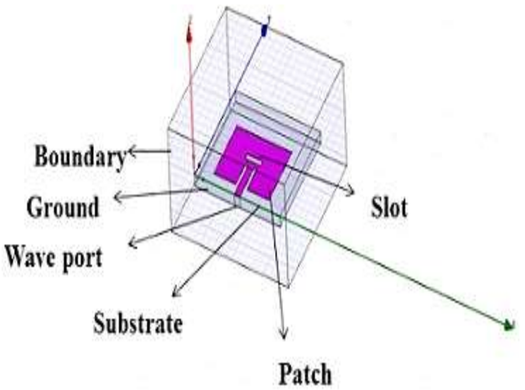

Figure 2. Simulated geometry of dual band antenna design in HFSS tool

It is constructed on the substrate having dielectric constant $\epsilon_r = 4.3$ and thickness h=1.6 mm. For microstrip antennas, the dielectric constants are usually in the range of $2.2 \leq \epsilon_r \leq 12$ [5].Dielectric constants in the lower end of the range can give us better efficiency, large bandwidth, loosely bound electric field for radiation into space, but at the expense of large element size. In microwave circuit that requires tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element size. In some applications we need small size antennas, substrate with high dielectric constant is a better choice in such applications. High dielectric constants have greater losses so they are less efficient and have relatively small bandwidth. The proposed structure is simulated using HFSS simulation software. The designed antenna operates at a resonant frequency of around 5.25 GHz [5]. The next stage is to simultaneously bring the input impedance of all modes to 50Ω at resonances through the use of an inset feed position control.

C. Proposed Dualband Array Antenna Design in HFSS

Microstrip antennas are used in communication systems to enhance the performance of the antenna like gain, directivity, scanning the beam of an antenna system, and other functions which are difficult to do with the single element. An antenna array consists of identical antenna elements with identical orientation distributed in space. The individual antennas radiate and their radiation is coherently added in space to form the antenna beam. For a linear array, the antennas are placed along a line called the axis of the array [8].

The corporate-feed network is used to provide power splits of 2^n (i.e., n = 2; 4; 8; 16; 32, etc.). This is accomplished by using either tapered lines or using quarter wavelength impedance transformers [7]. In a uniform array the antennas are equi-spaced and are excited with uniform current with constant progressive phase shift. Spacing between any two adjacent elements of the array is (d) which is in the range of $\lambda/2 \leq d \leq \lambda$ where λ= Wavelength and d= spacing between two antennas.

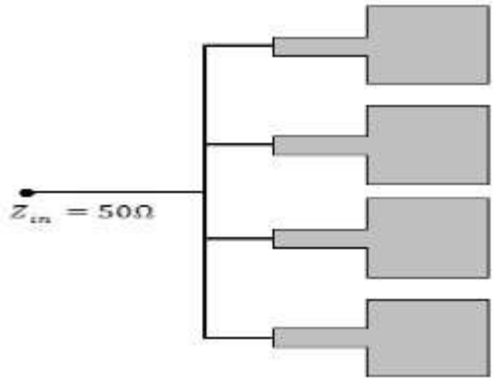

Figure 3. Four element micro strip array

A 4-element antenna array is as shown in figure 3. By using equations (1), (2) and (3) we calculate the dimensions of 200Ω transmission line .Length and width of feed line for different impedances are shown in Table II.

Table II. Impedance matching table

Impedance(Ω)	Length(mm)	Width(mm)
50	7.904	3.11
100	8.295	0.72
200	8.642	0.48

Figure 4 shows the schematic of 4 element dual band array antenna in HFSS tool.

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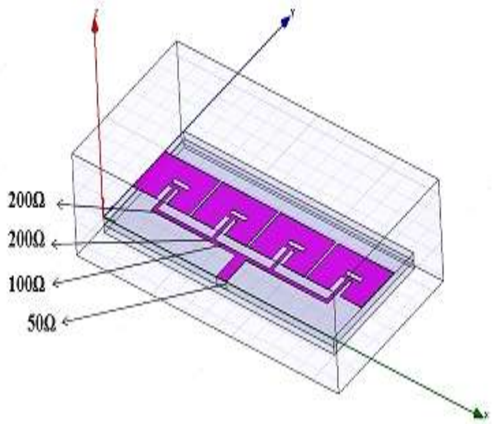

Figure 4. Simulated dual band array antenna design

III.SIMULATION RESULT FOR DUAL BAND ANTENNA

The characteristics of proposed antenna are investigated through a parametric study. Frequency domain results were measured and are presented in terms of VSWR and radiation pattern. The antenna was excited using a rectangular edge-fed micro strip line. A partial conducting ground plane was used to enhance the bandwidth of the antenna. The simulated results of the return loss |S11| and the standing wave ratio (VSWR) of the antenna for frequency 5.25 GHz and 9.25 GHz are discussed.

A. Return loss

Figure 5a shows the return loss plot for the frequency of 5.25 GHz for single patch without slot and Figure 5b shows the return loss graph for frequency of 5.25 GHz and 9.25 GHz with introducing the slot. Return loss at 5.25GHz is -13.01 dB and for 9.25GHz is -15.8 dB. By introducing slot, band width of antenna is increased as compared to without slot.The bandwidth of single band antenna is 196 MHz and for dual band antenna is 233MHz. The efficiency of single band antenna is 86% and by introducing slot the efficiency is 88%. The maximum efficiency achieved in literature is [1-4] 85%.

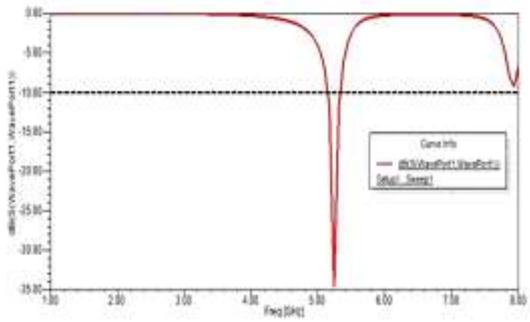

Figure 5a. Return loss graph for single band antenna

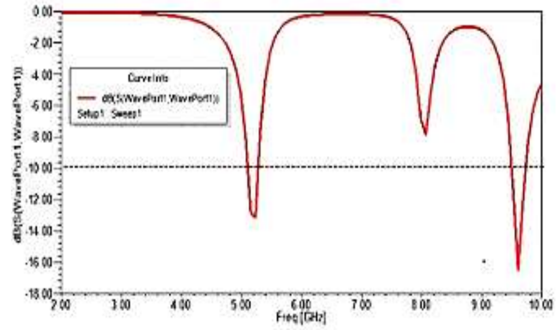

Figure 5b. Return loss graph for dual band antenna

B. Voltage Standing Wave Ratio

The simulation results for VSWR for the frequency of 5.25 GHz and 9.25GHz is shown in the figure 6. VSWR for the frequency of 5.25 GHz is 1.5 and for 9.25GHz is 1.40 for better performance of antenna VSWR value should be in range 1 to 2 [7].

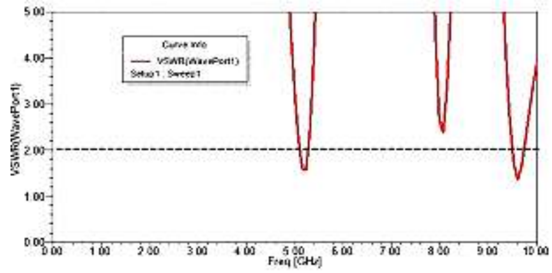

Figure 6. VSWR plot for the dual band antenna

D. Radiation characteristics of E and H-plane

The proposed microstrip dual band antenna shows an omni directional radiation pattern and antenna has a wide frequency over the operating band and it radiates electromagnetic energy equally in all directions .The obtained radiation patterns including the co polarization and cross polarization.

Figure 7 shows radiation characteristics of E-plane for all values of φ, and θ=90degree, where φ is magnetic field angle and θ is electric field angle. It is observed that E-plane is perfectly symmetric along both sides along φ.

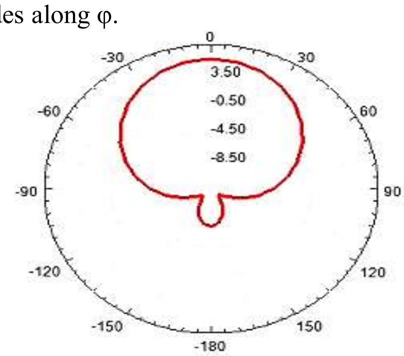

Figure7. Elevation pattern (E-Plane) gain plot (for θ=all values and $\varphi = 0$degree)

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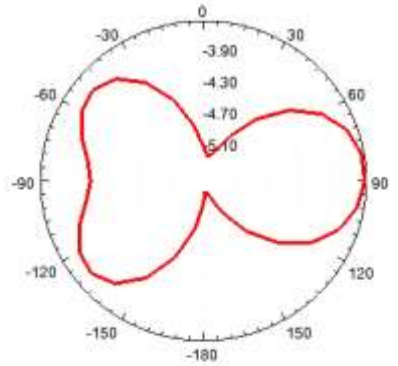

Figure 8. Azimuthal pattern (H-plane) gain plot (for φ = all values and θ = 90degree)

Figure 8 shows the radiation characteristics of H-plane for all values of θ and φ=0degree and the result shows that H-plane is almost symmetric on both sides. The gain of single band antenna is 3.3 dB and directivity is 3.5 and For dual band antenna gain is 3.58 dB and directivity is 3.9dB which is better gain and directivity as compared to[1-5].

IV.SIMULATION RESULTS FOR DUAL BAND ARRAY ANTENNA

The characteristics of proposed microstrip array antenna are investigated through a parametric study. Frequency domain results were measured and are presented in terms of VSWR and radiation pattern which is more efficient to single element dual band antenna. The designed dual band array antenna gives better improvement in return loss and gain when compared to dual band antenna.

A .Return loss

Figure 9a shows the return loss graph for the single band array antenna without slot and Figure 9b shows the return loss plot for dual band array antenna with slot. By introducing the slot in the single band array antenna its behave like dual band array antenna and band width of the antenna is increased as compared to without slot antenna. S parameter display at operating frequency 5.25 GHz is -13 dB and for 9.25GHz is -14.88dB which gives better bandwidth as compared to single element dual band antenna. The bandwidth of single band array antenna is 200MHz and for dual band array antenna is 327MHz.The efficiency of single band array is 84% and for dual band array is 82%.[1-3] the efficiency of array antenna is 80%.Dual band array antenna is more efficient as compare to single band array antenna.

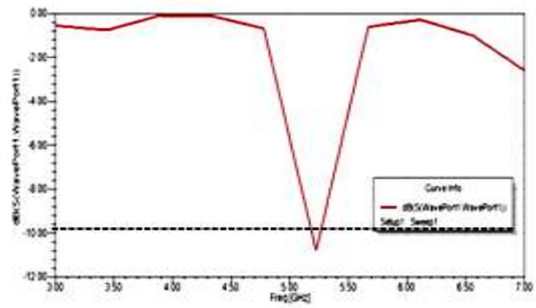

Figure 9a.Return loss graph for single band array antenna

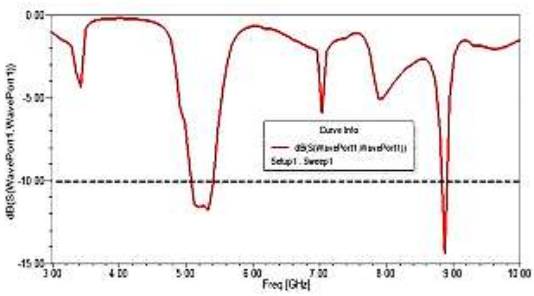

Figure 9b.Return loss graph for dual band array antenna

B. Voltage Standing Wave Ratio

Figure 10 shows the VSWR plot dual band array antenna. VSWR for 5.25 GHz frequency is 1.70 and for 9.25 GHz is 1.50.which shows the impedance matching between transmission line and patch antenna.

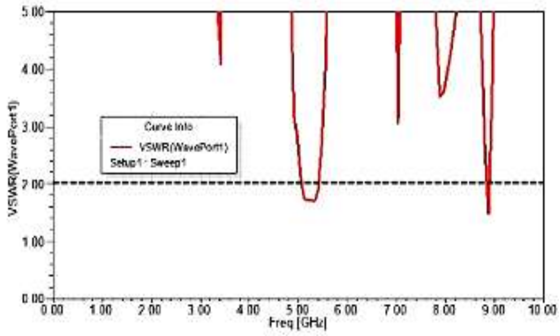

Figure 10.VSWR plot for the dual band array antenna

E. Radiation characteristics of E and H-plane

The proposed microstrip dual band array antenna shows an omni directional radiation pattern and antenna has a wide frequency over the operating band and it radiates electromagnetic energy equally in all directions with improvement in gain and directivity as compare to single element antenna.

Figure 11 shows radiation characteristics of E-plane for all values of φ, and θ=90degree, where φ is magnetic field angle and θ is electric field angle. It is observed that E-plane is perfectly symmetric along both sides along φ.

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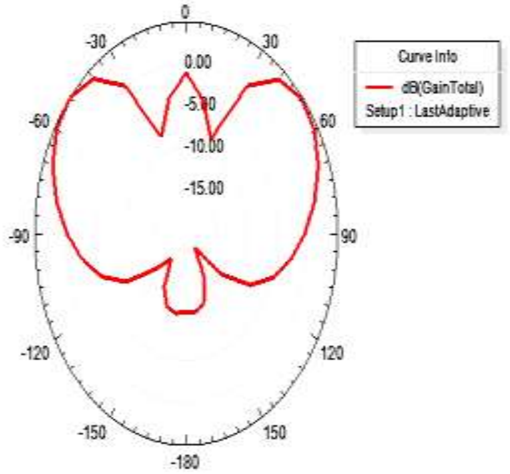

Figure 11. Elevation pattern (E-Plane) gain plot (for θ=all values and $\varphi = 0\text{degree}$)

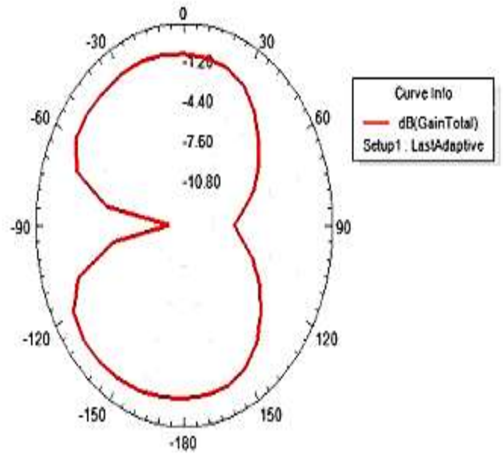

Figure 12. Azimuthal Pattern (H-plane) gain plot (for $\Phi = \text{all values and } \theta = 90\text{degree}$)

Figure 12 shows the radiation characteristics of H-plane for all values of θ and φ=0 degree and the result shows that H-plane is almost symmetric on both sides. The gain of single band array antenna is 4.2 dB and directivity is 4.3dB and gain of proposed dual band array antenna is 5.08 dB and directivity is 5.5 dB which is better gain and directivity as compare to [1-6] array antenna.

V. CONCLUSION

Dual band microstrip antenna is designed by using HFSS and its parameters are analyzed. To improve the performance in gain and bandwidth of antenna, a 1 x 4 dual band microstrip array antenna is designed and its parameters are studied. The performance of the designed antennas in terms of their parameters is compared with single band and single band array antenna. The gain of dual band array antenna is 5.08 dB whereas the gain of single band array antenna is 4.2 dB. Dual band and dual band array antenna is found to be more efficient when compared to single band and single band array antenna. In future by introducing active devices such as pin diode or varactor diode, a phased array antenna with beam steering can be achieved with improvement in gain and bandwidth.

REFERENCES

[1] Asst. Lect. Basim Khalaf Jarulla, Asst. Lect. Izz Kadhum Abboud and Asst. Lect. Wail Ibrahim Khali "Dual band microstrip antenna with slit load design for wireless local area network application" Al-Qadisiya Journal For Engineering Sciences, Vol. 5, No. 4, 347-353, Year 2012.

[2] Rachmansyah, Antonius Irianto, and A. Benny Mutiara, "design and implementation of series micro strip patch antenna array for wireless communication at 2.4GHZ " International Journal of Computer and Electrical Engineering, Vol. 3, No. 5, October 2011.

[3] Harish Subbaraman, Member, IEEE, Daniel T. Pham, Xiaochuan Xu, Maggie Yihiong, Senior Member , "Inkjet printed two dimensional phase array antenna On a flexible substrate," IEEE transaction on propagation vol.12,2013.

[4] Md. Rashidul Islam, Member, IEEE, and Mohammod Ali, Senior Member IEEE, "900 MHZ Beam steering parasitic antenna array for wearable wireless applications," IEEE transaction on antennas and propagation,vol.61, No.9,September 2013.

[5] P. N. Mishra "Planar Rectangular Microstrip Antenna for Dualband Operation" IJCST Vol. 2, Issue 3,September 2011.

[6] Muhammad Mahfuzul Alam, Md. Mustazur Rahman Sonchoy, and Md. Anamika Srivastava,Priya Upadhyay, Richa Sharma " Design and implementation of series micro strip patch antenna array for wireless communication" Int.J.Computer Technology & Applications,Vol 3 (5), 1769-1774.

[7] Osman Goni "Design and Performance Analysis of Microstrip Array Antenna" Progress In Electromagnetics Research Symposium Proceedings, Moscow, Russia, August 18{21, 2009 1837.

[8] Randy L. Haupt, "Antenna Array, A Computational Approach", John Wiley & Sons Ltd, Reprinted 2010.

[9] C. A. Balanis, "Antenna Theory, Analysis and Design,"John Wiley & Sons, New York, 1997.