Printed Antenna Array for WLAN/WiMAX and X band Radar Applications

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Abstract - *This paper presents the development and characterization of dual band and 1×4 dual band antenna array on a flexible polymide 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 802.11 a/b/g. Dual-band antenna elements that support dual-polarization provide ideal performance for applications including space-based platforms, multifunction radar, wireless communications, and personal electronic devices. In many communications and radar applications, a dual-band, dual-polarization antenna array becomes a requirement in order to produce an electronically steerable, directional beam capable of supporting multiple functions. In this paper a dual band microstrip antenna is designed and its measurement results in terms of S(1,1) parameters 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=1.6 mm and operating frequency 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 is simulated by Ansoft High Frequency Structural Simulator (HFSS) by using the FEM (Finite element method).*

Key Words: Beem steering, Dual band array antenna, IEEE802.11a/b/g, WLAN etc.

1. INTRODUCTION

Micro Strip Antenna Array has been proposed with high efficiency for wireless communication. Micro strip 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), Medicinal applications of patch [1]. Communication plays an important role in the worldwide society now days and the communication systems are rapidly switching from "wired to wireless".Wireless technology provides less expensive alternative 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 radiate electromagnetic energy uniformly in Omni direction or finally in some systems for point to point communication purpose in which increased gain and reduced wave interference is required. Antenna is a transducer designed to transmit or receive electromagnetic waves. One of the type of antenna is the Micro strip patch antenna. Microstrip antennas have several advantages over conventional microwave antenna and therefore are widely used in many practical applications [1].Microstrip patches are one of the most versatile, conformal and easy to fabricate antennas.The recent growth in the ambit of modern wireless communication has the 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].

Wireless local area network (WLAN) has received much attention for the flexibility of network reconfiguration in office room, mobile internet connection and so on. A WLAN provides all the benefits of traditional LAN technologies without the limitations of being tethered to a cable. This provides greatly increased freedom and flexibility.Antennas capable of operating at multiple frequency bands are advantageous to many applications ranging from space-based radar to personal wireless communications. Synthetic aperture radar (SAR) typically operates in L and C-bands. For space-based SAR applications where minimizing the mass and weight of the radar system is essential to reducing the overall weight of the payload and cost of the mission, antennas capable of operating in multiple frequency bands with multiple polarizations are beneficial. Dual-band antenna elements are also desirable in radar applications because of their ability to improve data collection rates, while also allowing for true multifunction radar (MFR) operation. Wireless communications networks have shown an increased number of subscribers as well as an increased demand for multi-band equipment [3]. Wireless access points and laptops are both turning towards antennas capable of operating in multiple frequency bands in order to support multiple protocol.

2. DESIGN PROCEDURE AND EQUATIONS

A microstrip antenna consists of conducting patch and a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970. The early work of Munson on microstrip antennas for use as a low profile flush mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals for the last ten years. The microstrip antennas are the present day antenna designer's choice. 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. The length of the patch is very critical and important that result to the frequency radiated [2].

The advantages of the microstrip antennas are small size, low profile, and lightweight, conformable to planar and non planar surfaces. It demands a very little volume of the structure when mounting. They are simple and cheap to manufacture using modern printed circuit technology. 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 the radiation patch and the ground plane(not suitable for high-power applications) [4].

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 [2].

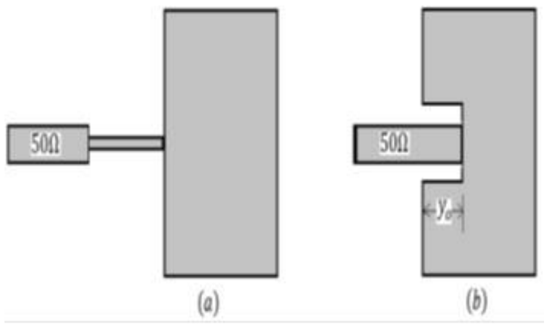

Figure 1 Microstrip patch antenna with feed from side

The position of the feed point (y_0) of the patch in figure (1b) has been discussed in detail in the section of Impedance Matching.

The impedance of the patch is given by [3]:

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

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:

$$Z_T = \sqrt{50 + Za} \quad (2)$$

The width of transmission line is calculated by [3]:

$$Z_T = \frac{60}{\sqrt{\epsilon_r}}\ln\left(\frac{8h}{W_T} + \frac{W_T}{4h}\right) \quad \text{for} \quad \frac{W_T}{h} > 1 \quad (3)$$

where, h = height of substrate

The width of the 50Ω microstrip feed can be found using the equation given below [4]:

$$Z_O = \frac{120\pi}{\sqrt{\epsilon reff}\left(1.393 + \frac{W}{h} + \frac{2}{3}\ln\left(\frac{W}{h} + 1.444\right)\right)} \quad \text{for} \quad \frac{W_T}{h} < 1 \quad (4)$$

where, Z_O=50 Ω

The length of the strip can be found by [4]:

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

The length of the transition line is quarter the wavelength:

$$l = \frac{\lambda o}{4\sqrt{\epsilon reff}}$$

where, λo = free space wave length

ϵ_{reff} = efective dielectric constant

Design Equations of Proposed Dual Band Antenna

- Thickness of the substrate, h ranges between [7] $0.003\lambda o \leq h \leq 0.05\lambda o$
  where,λo = free space wave length
- Guide wave length[7] $\lambda g = \lambda o/\sqrt{\epsilon_r}$
  where ϵ_r = permittivity of substrate
- Width of the patch[4] $W_P = \frac{c}{2f_r\sqrt{\frac{\epsilon_r+1}{2}}}$
  where, f_r =center frequency
- Length of the patch[4] $L_P = L_{eff}$ -2ΔL
  where, $\Delta L = 0.412\frac{(\epsilon_{reff}+0.3)(\frac{W_P}{h}+0.264)}{(\epsilon_{reff}-0.258)(\frac{W_P}{h}+0.8)}$

- Effective length of patch [3] $L_{eff} = \frac{c}{2f_r\sqrt{\epsilon_{reff}}}$
  c= Velocity of light=3$\times 10^{11}\,mm/sec$
- Effective dielectric constant
  $$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{W_P}}}\right)$$
  where, h= thickness of substrate and W_T = width of patch
- Length of substrate[4] $L_S = L_P + 6h$
- Width of substrate[4] $W_S = W_P + 6h$
  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.

Table I Design dimensions for dual band antenna

Dimensions	Length(mm)	Width(mm)
Substrate and 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
Slot	1.25	3.52

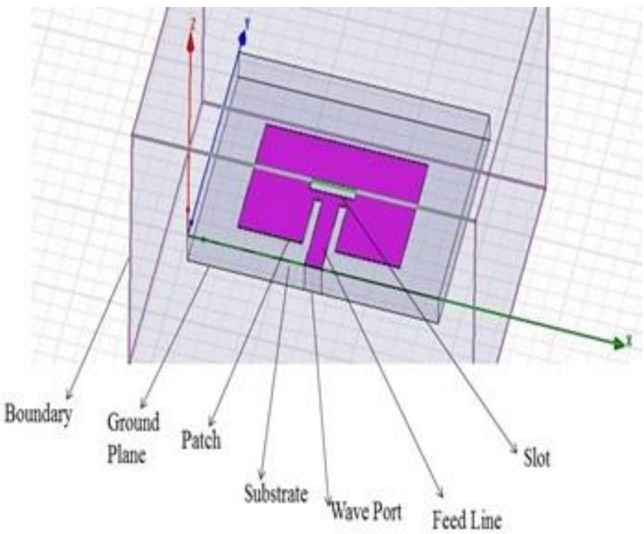

Fig 2 Simulated geometry of dual band antenna design

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. 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 application we need small size antennas, substrate with high dielectric constant is a better choice in this application. 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 design is for a resonant frequency of around 5.25 GHz.The first stage involves the creation of additional TMoδ resonant modes at a resonant frequency above that of the fundamental TM01 mode, with the same polarization sense [3]. 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.

Proposed Dualband Array Antenna Design in HFSS

Microstrip antennas are used in arrays as well as single elements. By using array in communication systems we enhance the performance of the antenna like increasing 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 [6].

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 [5]. 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) [6]: λ/2 ≤ d ≤ λ where, λ=Wavelength and d= spacing between two antennas

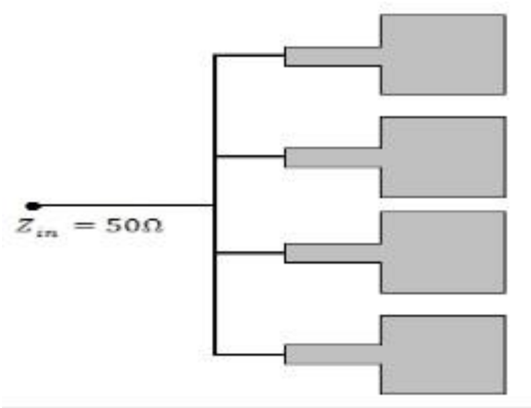

Figure 3 Four element micro strip array

combination of 4-elements array 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

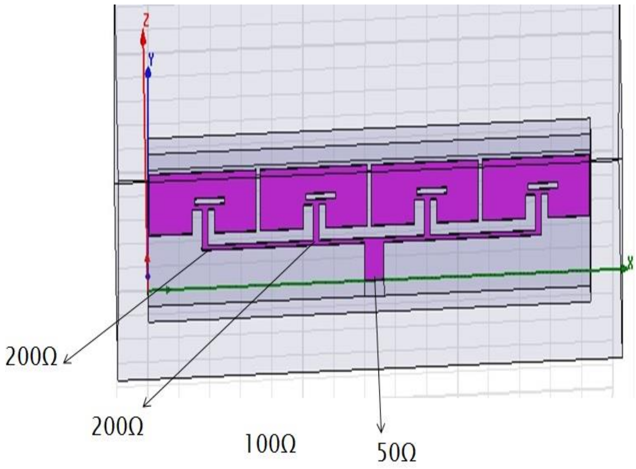

Fig 4 Simulated dual band array antenna design

3. SIMULATION RESULT FOR DUAL BAND ANTENNA

The microstrip single band antenna is designed using HFSS simulator. The performance of the antenna has been studied by comparing the Return loss, VSWR, S parameter, Gain, azimuthal and elevation patterns.

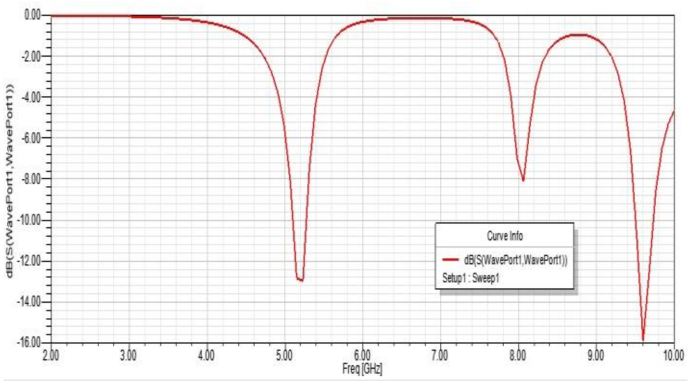

Fig 5 Return loss graph for dual band antenna

Fig 5 shows the return loss graph for frequency 5.25 GHZ and 9.5 GHZ. S parameter display at operating frequency 5.25GHZ ,S(1,1)=-13.01 dB and for 9.5GHZ, S(1,1)=-15.8dB.

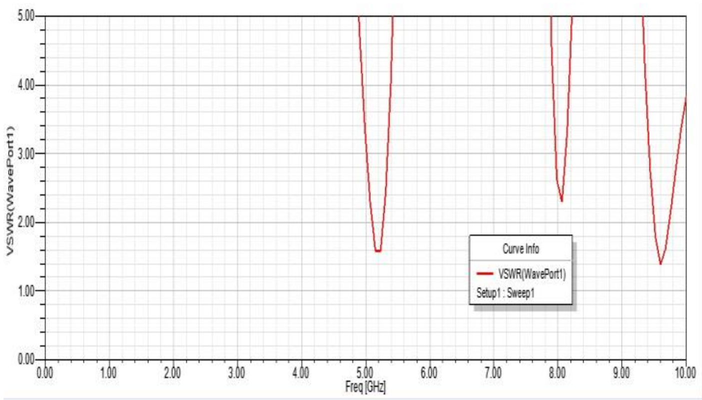

Fig 6 VSWR plot for the dual band antenna

The simulation results for VSWR for the frequency of 5.25 GHz and 9.25GHZ is shown in the figure 6. VSWR for 5.25 GHZ frequency is 1.5 and for 9.25GHZ is1.40 for better performance of antenna VSWR value should be in range 1 to 2 [7].

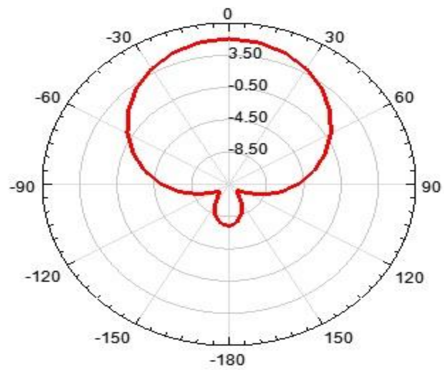

Figure 7 Elevation pattern (E-Plane) gain display (for θ=all values and φ = 0degree)

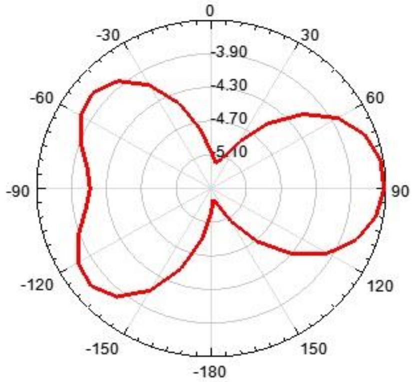

Figure 8 Azimuthal pattern (H-plane) gain display (for φ = all values and θ = 90degree)

The radiation pattern can be obtained from the Azimuthal and Elevation pattern gain displays in dB.The Elevation pattern (E-plane) gain display is shown in figure 7, for any value of θ, φ=0 degree and the Azimuthal pattern (H-plane) gain display is shown in figure 8, for any value of φ, θ=90 degree [7]. For dual band antenna gain is 3.58 db and directivity is 3.9dB

4. SIMULATION RESULTS FOR DUAL BAND ARRAY ANTENNA

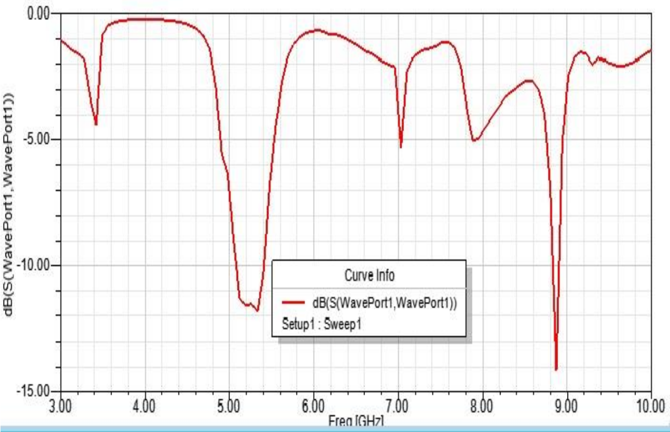

Fig 9 Return loss graph for dual band array antenna

Figb 9, shows the return loss graph for the dual band array antenna. S parameter display at operating frequency 5.25 GHZ, S(1,1) = -13 dB and for 9.25GHZ, S(1,1) = -14.88dB.

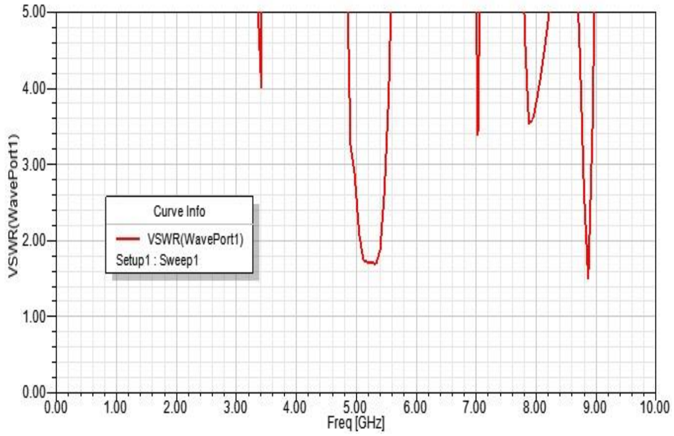

Fig 10 VSWR plot for the dual band array antenna

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. Fig 11 and Fig 12 shows the E-plane and H-plane respectively,

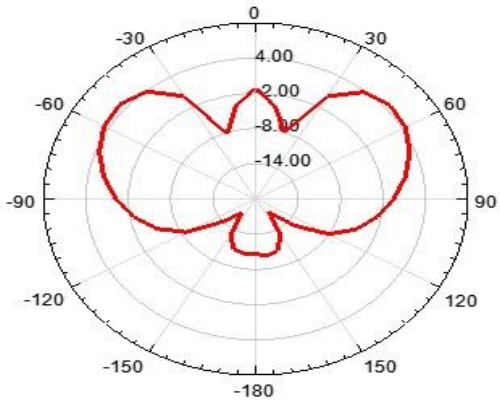

Fig 11 Elevation pattern (E-Plane) gain display (for θ=all values and φ = 0degree)

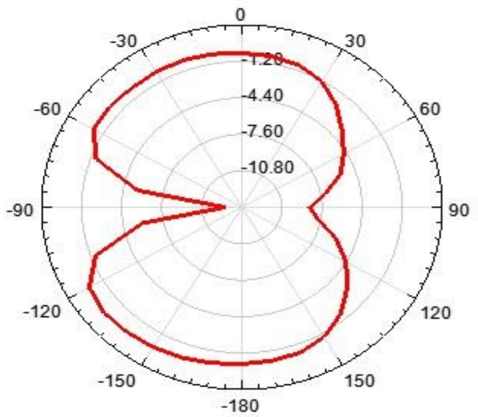

Fig 12 Elevation pattern (H-Plane) gain display (for θ=all values and φ = 0degree)

The gain of dual band array antenna is 5.08 dB and directivity is 5.5 dB.

5. CONCLUSION

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

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