A Novel Rectangular Array Antenna Design Using Proximity Coupled for Gain Enhanced Characteristics

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Abstract – A novel rectangular microstrip patch is designed using proximity coupled feeding technique for wireless applications. In this paper, the proposed structure is designed at 5.2GHz and compares the performances of single element, 2-element and 4-element at same operating frequency. This antenna array has been designed, simulated and analysed on FR4 epoxy with dielectric constant 4.4 by which return loss, VSWR, gain, directivity and radiation pattern are computed. The main aspect of this paper is to design a high directivity antenna with high gain which covers broadband to cover C-band applications such as WiMAX, long distance radio telecommunications and satellite communications.

Keywords –**Microstrip array, Proximity coupled fed, series fed, Corporate fed, Gain, Efficiency.**

1. INTRODUCTION

In day- to-day life, the priority of wireless communication technology grows proportionally with our future generations. The heart of wireless communication systems is Antenna. Without the device antenna, there is no transfer or reception of data. Micro strip antennas place an essential role in today's research because of its crucial characteristic like narrowband as well as broadband. Micro strip patch antennas are widely used for antenna design due to its low cost, light weight and ease of fabrication [1-3]. The predictable bandwidth of micro strip antenna is in between 1% to 5%. Patch antennas are more required due to its low size in Bio-medical applications. There are many techniques for enhancing the gain such as defected ground structures [4-6], resonance gain methods [7], layers of dielectric are stacked above the patch [8-9] etc.,. To emphasize the gain of an antenna, it is very essential to control or suppress an undesirable wave. The analytical solutions for a metallic bar on a ground plane are explained in [10].

In this article, rectangular microstrip array designed using proximity coupled technique on FR4-epoxy glassy substrate material with their dielectric constant (ε_r) = 4.4 and height (h) = 0.159cm. This paper organized into five sections. Section 1 describes about the introduction. Section 2 explains the proposed design methodology and its parameters. Section 3 discusses about the simulation results and its performance comparison table. Section 4 concludes with conclusion. Section 5 describes about the acknowledgement and Section 6 mentions references.

II. ANTENNA DESIGN METHODOLOGY

Substrate selection is the main aspect in the design of microstrip patch antennas. Dielectric constant and thickness of substrate plays a vital role in the cross-polarization characteristics. Symmetrical radiation pattern obtained with small cross polarization the dielectric constant is smaller. If it increases then the radiation pattern deteriorates. The impedance bandwidth of the microstrip patch antenna is proportional with the substrate thickness [11].

Compared to all the feeding techniques, Proximity coupled fed has more advantages such as to reduce the harmonic radiation and it eliminates spurious radiation and provides very high bandwidth because of its design thickness. Proximity coupled fed techniques is also called as Electromagnetic coupling technique. The feed line is sand witched between the two dielectric substrates. The ground plane placed at the bottom of the down substrate and radiating patch is placed on the top of the upper substrate. The dielectric constant of top substrate is lower compared to bottom substrate. In this design both the substrate materials are FR4-epoxy but their dielectric constants are $\varepsilon_{r1} = 3.4$ for top and $\varepsilon_{r2} = 4.4$ for bottom substrates respectively. The major problem with this feeding technique is difficult to fabricate because of its structure alignment.

Figure 1 shows the 3D structure of basic proximity coupled rectangular patch antenna design. Figure 2 shows the top view of figure 1 and parameters are mentioned in it. Table 1 shows the list of parameters. The dimensions are computed at 5.2GHz using transmission line model [12].The ground plane dimensions are equal with substrate dimensions. This antenna is designed and simulated using High frequency Structure Simulator (HFSS).

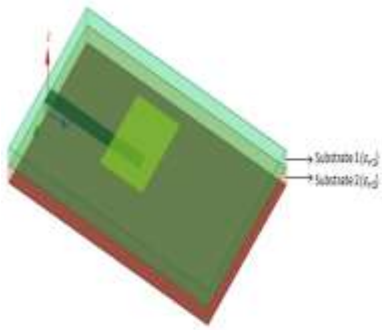


Figure 1: 3D view of proximity coupled patch antenna

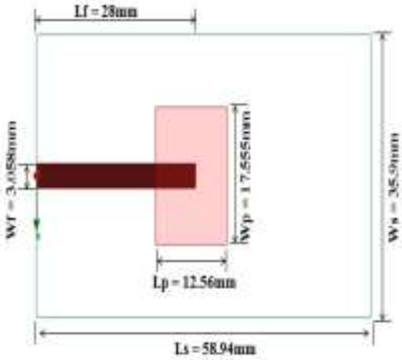


Figure 2: Top view of figure 1.

Table 1: List of parameters denoted in figures 1,2,3 (All units are in mm)

L_s	W_s	h	L_f	W_f	L_p
58.94	35.9	1.6	28	3.058	12.56
W_p	L_{s1}	W_{s1}	L_{s2}	W_{s2}	L_{f1}
17.55	65	35.9	65	64.74	11.36
L_{f2}	W				
11.80	31.89				

In Military and defence system applications, single antennas are not sufficient for its efficient operation because of its characteristics like gain, beam scanning and bandwidth. The simple solution for all these problems is array design. There are three types of feds series, corporate and series- corporate fed. The elements spacing in array design is equal to half of its wavelength. There is an interaction between the elements due to its closer proximity between elements. Figure 3 shows the series fed 1x2 rectangular microstrip patch array design and parameters are listed in table 1.

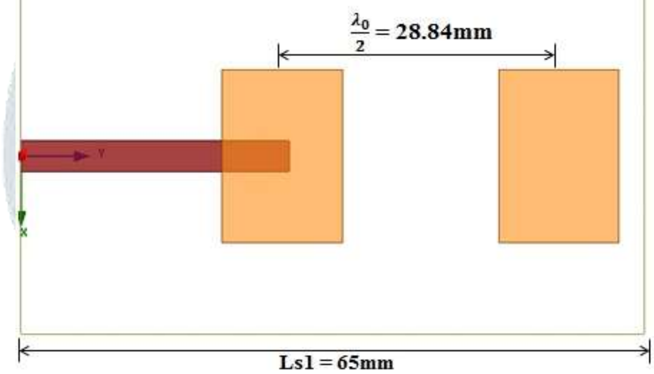


Figure 3: Series fed 1x2 rectangular microstrip patch array

Figure 3 presents the design as uniform linear array with half wave length distance between elements. Radiation pattern will be observe only on broadside (i.e., ϕ=90°) not in end-fire because all the elements are series fed with inphase currents. The array factor for 'n' element array is given by [12]:

$$AF = \sum_{k=0}^{n-1} \frac{\sin(\frac{k\Psi}{2})}{\sin(\frac{\Psi}{2})} \quad (1)$$

Where Ψ = Progressive phase constant = βdcosθ+δ

Figure 4 shows the proposed design i.e., corporate fed 2 x 2 rectangular microstrip arrays with equal element spacing. The parameters are listed in table 1.

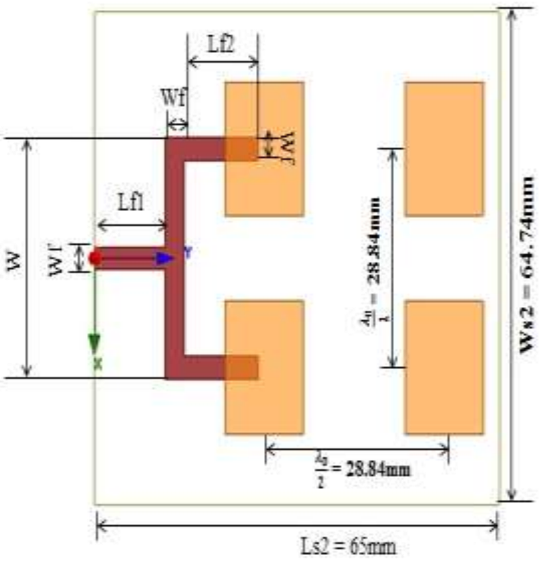


Figure 4: Proposed antenna design (Corporate fed 2x2 rectangular patch array)

III. Simulation results and Discussion

HFSS software is used for the simulation and is the industrial simulation tool for electromagnetic solutions [13].

A) Single element proximity coupled design

S-parameters describe the relationship between input-output terminals of an electrical system. S11 means how much power is reflected from antenna. The parameter is known as “reflection coefficient”. Figure 5 shows the return loss characteristics of the initial design as shown in figure 2.

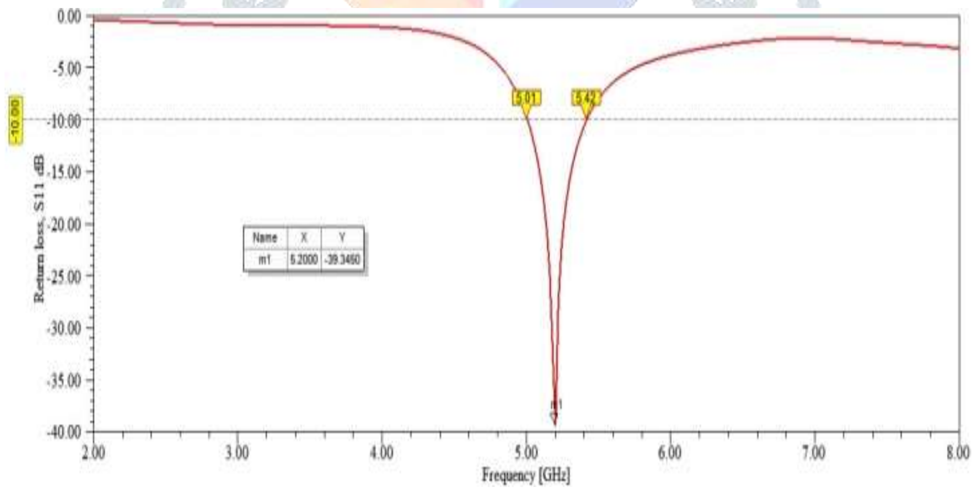


Figure 5: Return loss characteristics of single element proximity coupled fed antenna

From graph, observe that this antenna resonates at 5.2GHz with good impedance matching (return loss = -39.34dB). This antenna can operated in the range of 5.01-5.42GHz with impedance bandwidth of 410MHz. Figure 6 shows the VSWR characteristics. Figure 7 shows smith chart curve.

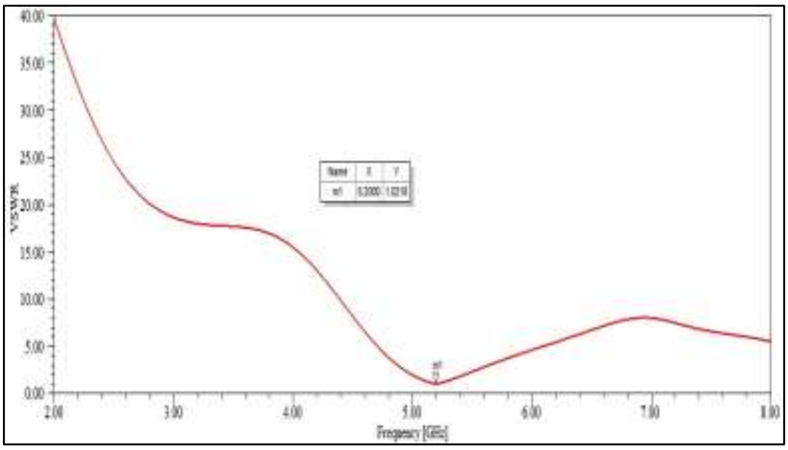


Figure 6: VSWR characteristics

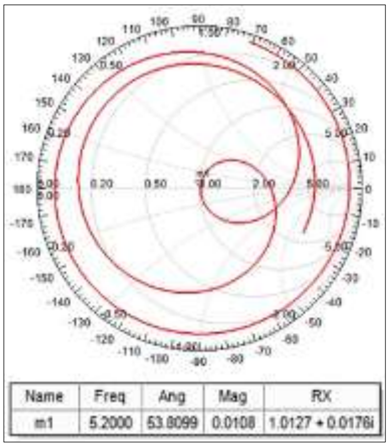
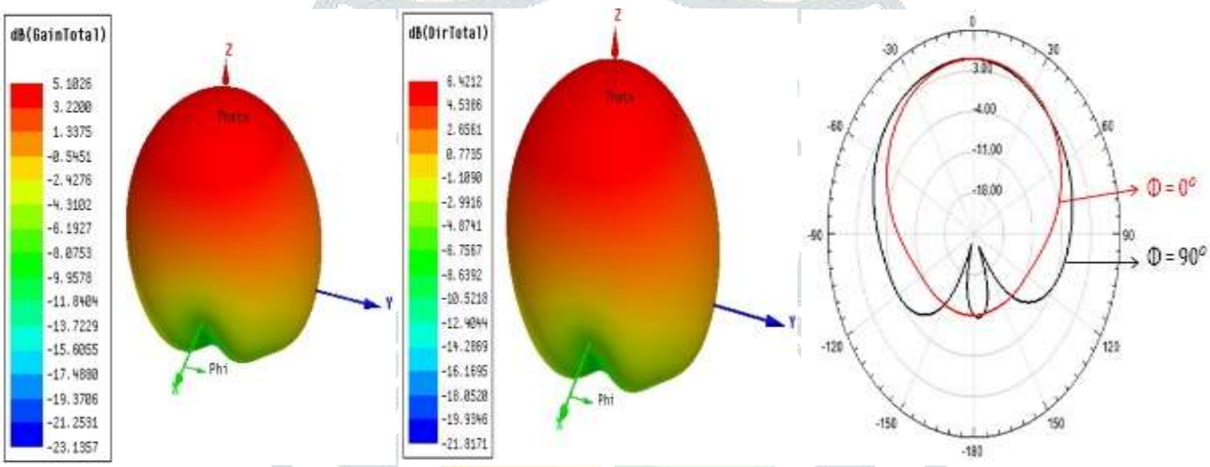


Figure 7: Smith chart

From graph, notice that its value is 1.02. So designed antenna is perfectly matched without information loss. Figure 8 shows far field reports for single element design. Its gain value is 5.102dB, directivity is 6.421dB and efficiency is 74.5%.

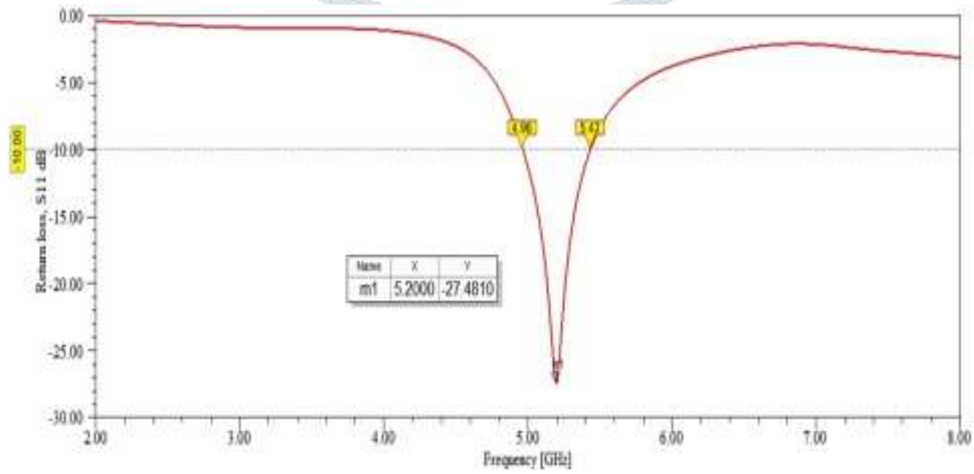


(a) Gain plot (b) Directivity plot (c) Radiation pattern

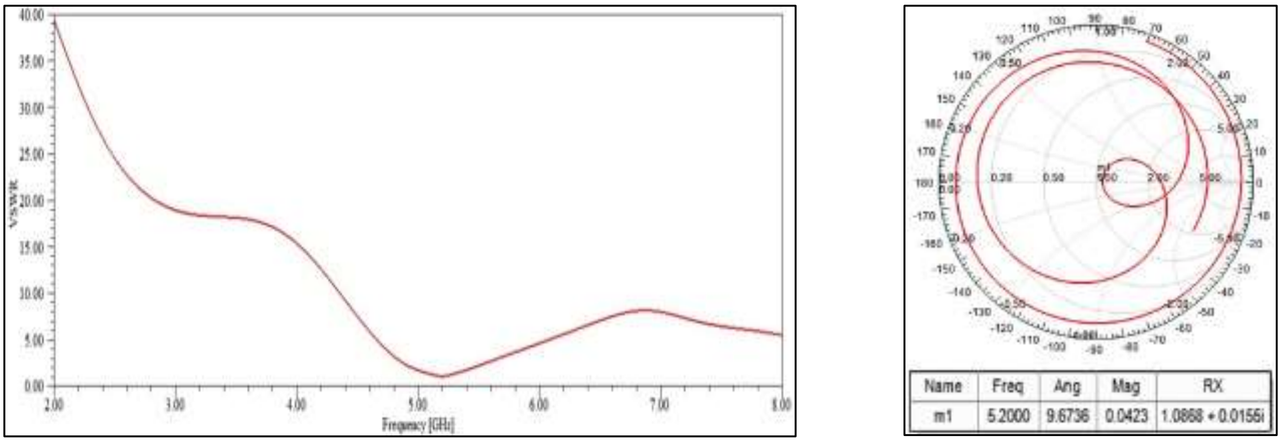
Figure 8: Far field reports for single element proximity coupled fed design

B) Series fed 1 x 2 Array proximity coupled design

The usage of antenna array has grown in communication without the need of relay stations to transmit signals over long distances [14]. Terminal solution reports of series fed 1 x 2 array design are shown in figure 9.



(a) Return loss characteristics

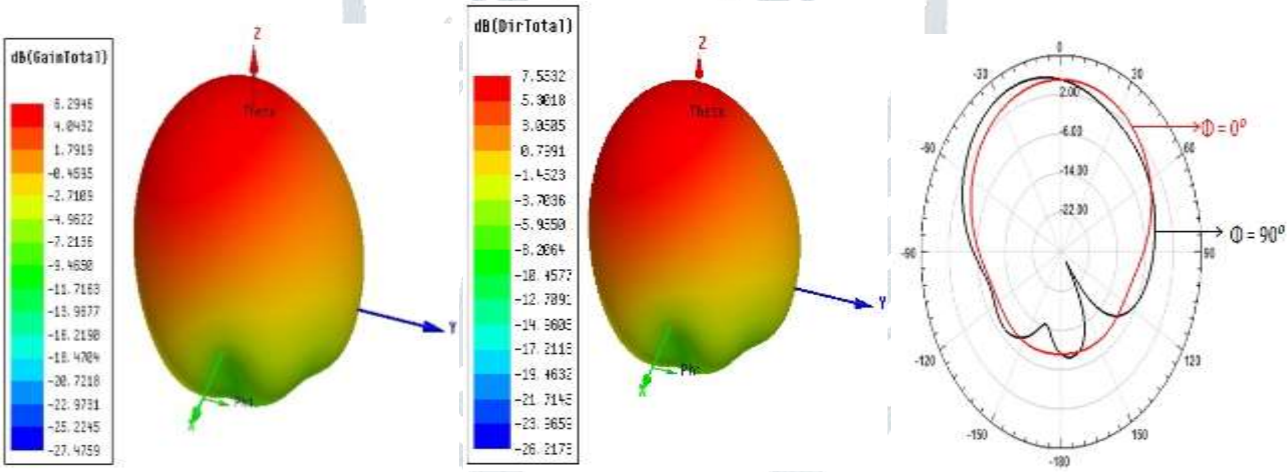


(b) VWR characteristics (c) Smith chart

Figure 9: Terminal solutions reports for series fed 1 x 2 array proximity coupled design

The impedance bandwidth of this design is 470MHz in the range of 4.96-5.43GHz resonating at 5.2GHz with reflection coefficient -27.48dB to cover the wireless LAN applications. Its VSWR value is almost nearer to 1.0812. From smith chart, designed is antenna is perfectly matched at given resonant frequency.

Figure 10 shows the far field report characteristics. Figure 10(a) shows the maximum gain of designed antenna, which value is 6.294dB. Figure 10(b) shows the maximum directivity of designed antenna is 7.553dB. Figure 10(c) shows the radiation pattern representation of 1 x 2 array design. Red indicates E-plane and black indicates the H-plane.



(a) 3D Gain plot (b) 3D directivity plot (c) Radiation pattern

Figure 10: Far field reports for series fed 1x2 array proximity coupled fed design

C) Corporate fed 2 x 2 Array proximity coupled design

The main advantage of this type of feeding in this design is power splits equally at every junction for uniform aperture distribution. This is commonly accomplished by using quarter wave lines. Compared to series fed array, it provides better directivity as well as good efficiency and reduces beam fluctuations over wide band of frequencies [15]. Figure 11 shows the comparative analysis of impedance bandwidth characteristics for single element, series fed and corporate fed design (proposed design).

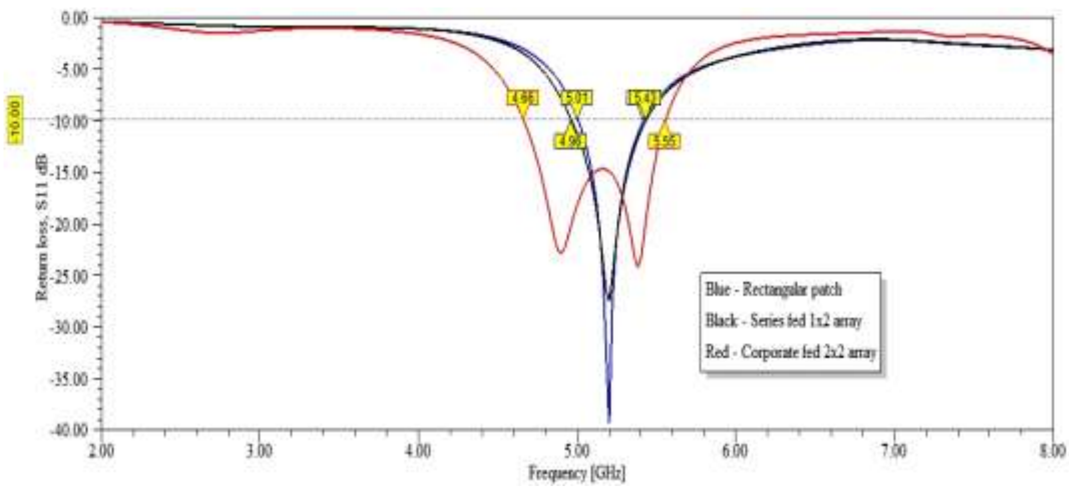


Figure 11: Comparative analysis of impedance bandwidth characteristics.

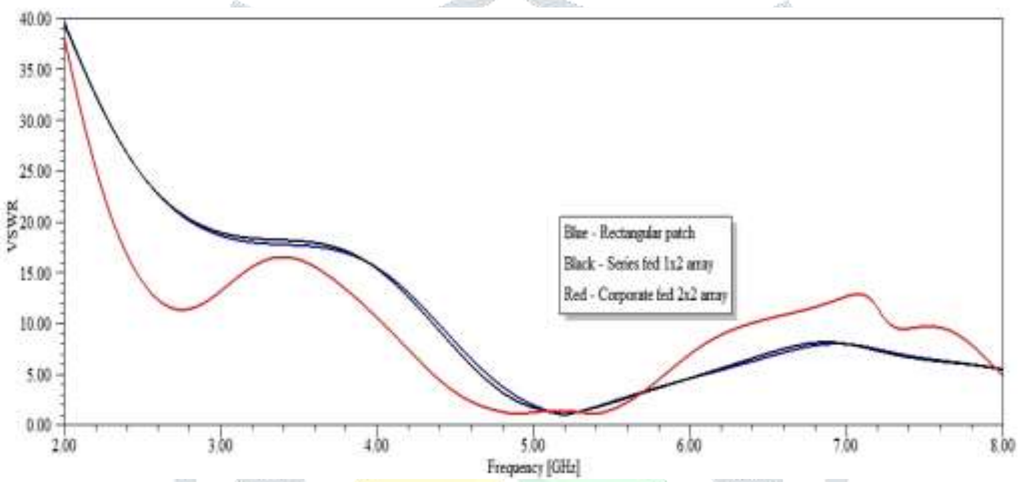
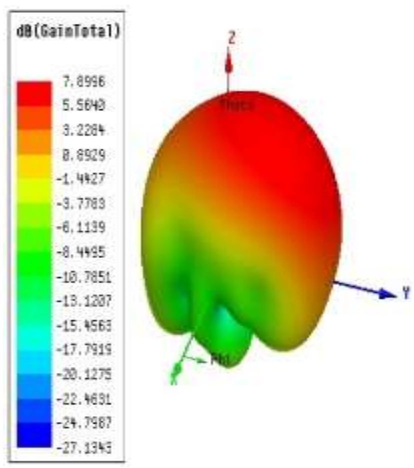
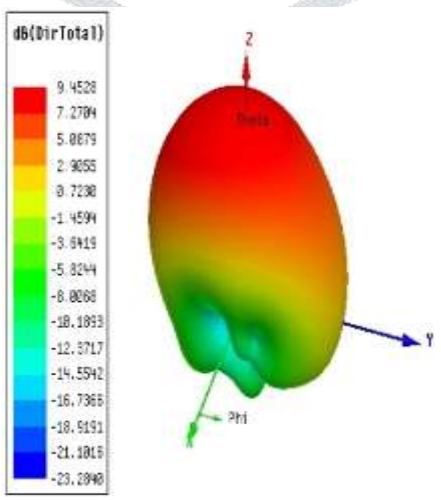


Figure 12: Comparative analysis of VSWR characteristics

From figure 11, proposed antenna operates to cover the bandwidth of 890MHz in the range of 4.66-5.55GHz with good reflection coefficient. From figure 12, compared to remaining structures proposed design has good superior characteristics. Figure 13 shows 3D gain plots of proposed design at resonant frequencies. Compared to single element and series fed 1 x 2 array design, proposed structure results good radiation characteristics with gain improvisation. Figure 14 results the characteristics of directivity plot of proposed design.





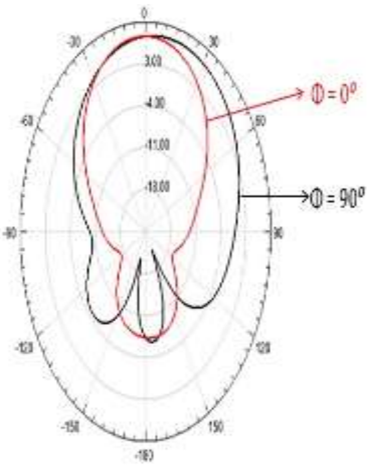


Figure 13: 3D gain plot Figure 14: 3D Directivity plot Figure 15: Radiation pattern

From these two graphs, proposed structure is high efficient design with 85%. From the observation of results, designed structure results the broad side radiation characteristics. Figure 15 shows the radiation characteristics of antennas.

d) Summary of these designs

S. No	Design	Resonant frequency, f_r(GHz)	Impedance Bandwidth, (MHz)	Reflection coefficient, S_{11} dB	VSWR	Gain in dB	Directivity in dB	Radiation efficiency, η%
1	Single element	5.2	5.01-5.42= 410MHz	-39.34	1.02	5.102	6.421	79.5%
2	2-element series fed	5.2	4.96-5.43= 470MHz	-27.48	1.08	6.294	7.553	83.33%
3	4-element corporate fed	5.2	4.66-5.55= 890MHz	-24.26	1.13	7.899	9.452	83.56%

IV.CONCLUSION

In this paper, proximity coupled antenna is designed for improving the bandwidth using HFSS tool. The proposed structure is designed at 5.2GHz to cover WLAN applications. Gain enhancement is also one of the essential parameter in the antenna specifications. 1 x 2 series fed and 2 x 2 corporate fed array structures are implemented for enhancing the gain, which results 6.24dB and 7.093dB respectively. Compared to series fed structure, corporate fed structure is highly efficient and suitable for wireless applications to cover bandwidth in the range of 4.66GHz to 5.55GHz. Various parameters of each antenna are plotted.

V.ACKNOWLEDGEMENT

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