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Removal of Mutual Coupling Between MIMO Antennas Using U Section and Concave Microstrip Structures

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Abstract

In this paper, a method is proposed to reduce mutual coupling between Microstrip antenna arrays used for MIMO applications. For this, a U section and Microstrip antennas with concave shape is used. The mutual coupling is observed to be equal to -6 dB when the antennas are placed at a distance $\lambda/10$ and is decreased to -37 dB by using the method proposed in this paper. It is also observed that there is an improvement in the return loss by -16dB as mutual coupling is reduced. Further, a corporate feed network is designed and observed that the power is divided equally well among all the ports. A 2x2 array is designed for MIMO applications using corporate feed network and as the distance between the two 2x1 array is far greater than $\lambda/2$, there will be no mutual coupling between them. It is shown in this paper that the overall gain and directivity is improved. All the simulations were carried out in Advanced Design System (ADS) Tool.

Index Terms: Corporate feed network, MIMO, mutual coupling, and power divider.

Introduction

PATCH antennas are widely used because of their small size, light weight, low cost, low profile, easy to feed, mechanically robust , easy to fabricate and work on frequencies greater than 1MHz. Patch antennas contain a metallic patch on dielectric substrate that is grounded. Patch can be rectangular, circular, and square or of any shape but rectangular shaped patch antennas are widely used [1].

Multiple Input Multiple Output (MIMO) communication techniques employ multiple antennas at both transmitter and receiver sites to improve throughput in multipath fading. In the recent advancements Microstrip antennas are mostly used because of its inherent advantages in implementation. The problem arises when these multiple antennas are closely spaced is mutual coupling.

Mutual Coupling is the electromagnetic interaction between antennas in antenna arrays. Mutual coupling effects the array radiation characteristics, if antennas elements are closely spaced. Mutual coupling is the very important issue since the early days of antenna array design. Several methods have been proposed in the literature to reduce mutual coupling while keeping the antenna elements close to each other. Some of the techniques for reducing mutual coupling in the Microstrip circuits are using defected ground structures (DGS), electromagnetic band gap (EBG) structures and parasitic elements in between the elements in array. Mutual coupling can be reduced by using these techniques but the complexity increases along the with significant change in the radiation pattern. The purpose of this work is to reduce both spacing between the elements along with the reduction of mutual coupling effect. [2].

In this technique concavity shaped patch antennas with U section are used to reduce mutual coupling. First two patch antennas with distance much far less than $\frac{\lambda}{2}$ are simulated to see the effect of mutual coupling then patch antennas with length concavity are simulated with a U section between them and significant decrease in mutual coupling is noticed with good return loss parameter[3].

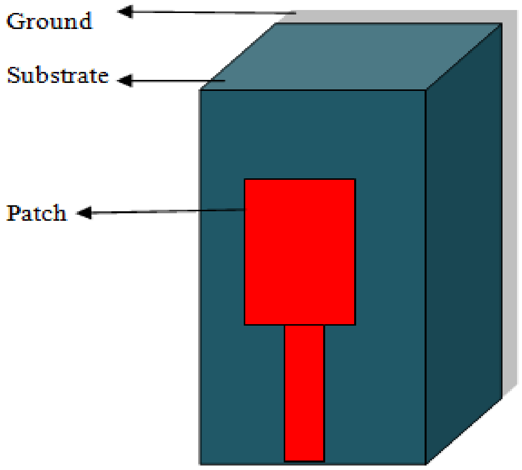

Figure 1: Microstrip Patch Antenna

Corporate feed network (multiple feed lines) is designed and simulated and ensured that equal power division among all the ports. It is a power divider network divide power in all ports equally with input impedance of 50Ω [4]. This corporate feed network is used in designing a 2x2 antenna array for MIMO application. Directivity and gain increases for antenna array with corporate feed network, with good amount of radiated power. ADS tool is used to simulate the antenna array.

Several technique have been used to reduce the mutual coupling so that antenna efficiency, radiation pattern, gain and directivity can also be improved. Patch antenna with a simple microstrip U section discussed in [5] to conserve the radiation pattern with removal of mutual coupling. Mutual coupling is reduced using EBG structure suppress the surface wave for 2.4 GHz discussed in [2] . DGS structure with U shaped resonator remove the mutual coupling that does not degrade the RL characteristics for 2.45 GHz and 4.5 GHz discussed in [9].Spiral resonator with metamaterial that have negative permeability or permitivity reduce the effect of mutual coupling at resonant frequency 4.5GHz[10]. Concave patches with optimize dimension designed in[3].

In this paper, concave patches with U section with a corporate feed network for 5.1GHz is used to reduce the coupling with that good amount of gain and directivity which is useful for MIMO applications.

Approaches used in this paper, first step is to design two patch antennas as discussed in section II to see the effect of mutual coupling.

Second step is to mitigate the effect of mutual coupling, patches used in section II are cut in concave shape and a U section is placed between the concave patches.

As our main aim is to design an antenna array for MIMO applications so a corporate feed network is designed with microstrip lines and patches used in section III is combined with corporate feed network to obtain a high gain and directivity.

Structure of Antenna Array

The antenna array is designed with a dielectric substrate of 4.4 permitivity and with thickness 1.6 mm. In the proposed structure Microstrip line feeding is used with an input impedance of 50Ω. The dimension for the patch are calculated according to the formulas given [7-8] below.

Width of patch antenna given as:

$$W = \frac{1}{2 f_r \sqrt{\mu_o \varepsilon_o}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{c}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \quad \ldots\ldots \quad (1)$$

Length of patch antenna:

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_r} \sqrt{\varepsilon_o \mu_o}} - 2\Delta L \quad \ldots\ldots \quad (2)$$

Extension length of patch antenna:

$$\Delta L = h(0.412) \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad \ldots\ldots \quad (3)$$

Effective dielectric constant:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \qquad \ldots\ldots \qquad (4)$$

Inset length for patch antenna to insert feed line can be calculated as:

$$G_1 = \frac{1}{90}\left(\frac{w}{\lambda_o}\right)^2 \qquad \ldots\ldots \qquad (5)$$

$$R_{in} = \frac{1}{2G_1} \qquad \ldots\ldots \qquad (6)$$

$$R_c = R_{in}\cos^2\left(\frac{\pi}{L}H\right) \qquad \ldots\ldots \qquad (7)$$

for X and Z

$$X = Z = \frac{2W}{5} \qquad \ldots\ldots \qquad (8)$$

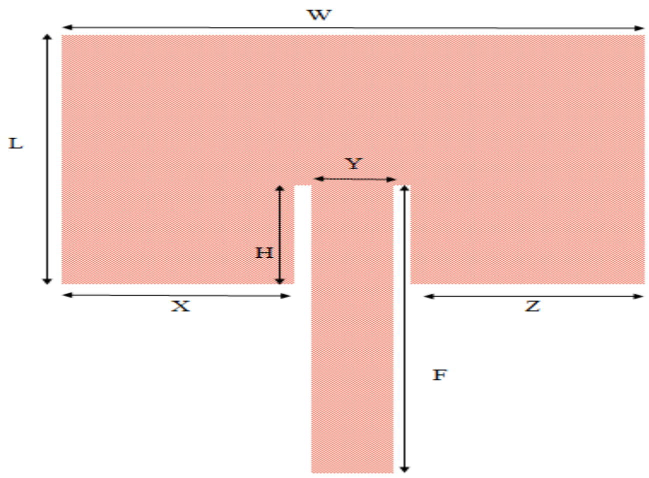

Figure 2: Dimension of Patch Antenna

Patch antennas dimension are calculated at the resonance frequency of 5.3 GHz .According to frequency, length of patches is L=12.95mm and width of patches is W =17.22mm. Patches are inset feed with feed length given by F=15mm, H=5.127mm, X=Z= 6.888mm and Y = 2.444mm.

The two patch antenna array is simulated on ADS as given in fig. 3 and the distance between two patches is 18.33mm that is less than $\frac{\lambda}{2}$. The simulated antenna can be used for application IEEE802.11a Wireless LAN (WLAN) and Wi-Fi.

Distance far less than $\frac{\lambda}{2}$ is considered to see the effect of mutual coupling. If distance equal to or greater than $\frac{\lambda}{2}$ then there will be no mutual coupling between antennas. Input is provided through a port of impedance 50 Ω and then S12, S21 which is mutual coupling and S11, S22 that is return loss is calculated using ADS Tool. It is observed thatS11andS22 = -10.51dB and S12andS21= -6.48dB at frequency 5.3GHz and Gain = 6.16dB and directivity =6.85dB.

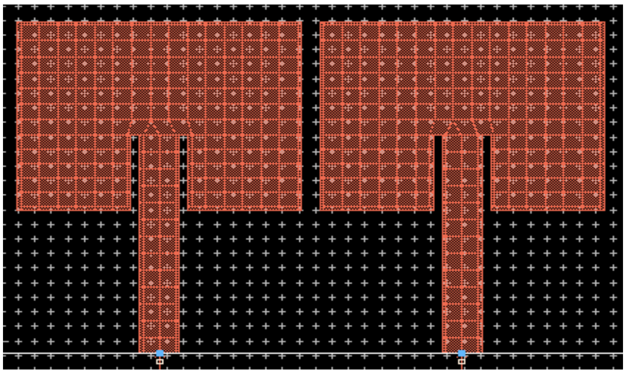

Figure 3: Structure of Patch Antenna Array

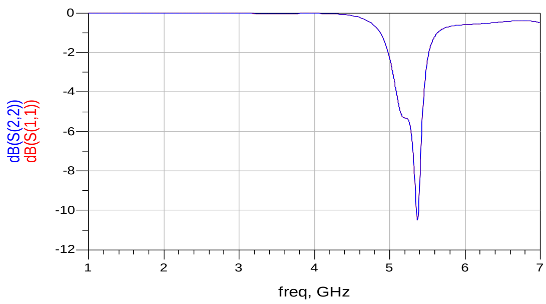

Figure 4: Plot of Return Loss For Closely Spaced Patch Antenna Array

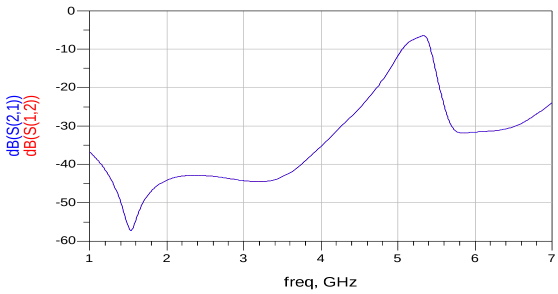

Figure 5: Plot of mutual coupling for closely spaced patch antenna array

Return loss is the parameter which is used to analyze the radiation characteristics of the antenna. It is the ratio of radiated power to the incident power in dB. If the radiation resistance of the antenna is not matched with the free space impedance then the antenna will not radiate at the resonant frequency. Its value should be highly negative in dB so that antenna radiates large amount of power provide to them and very less amount power reflected back at the input of the antenna.

Patches With Length Concavity A U Section

Patches with concavity shaped and with a U section between them decrease the mutual coupling and increase the return loss parameter. Length of the concavity is chosen to be h=0.9mm. By doing this, the distance between patches increases with no change in the radiation characteristics. Width of the patch is proportional to the frequency of operation, as the length of array is increased by this technique it is observed that there is a shift in the frequency of operation. Main work was to cut the patches properly .Same patch used in section II are used to create a concave shaped patch antennas.

The length of the U section with concavity is chosen in such a way that it has an opposite effect to the coupling between the antennas and also U section will add an extra coupling path to diminish the mutual coupling [5].

This technique efficiently decrease the mutual coupling and help to create the antenna arrays that can be use in MIMO applications and many other application that is beam forming and smart antennas.

Dimensions of U section are given as length of U section’s bigger arm is 9.14mm and width of arm is 0.24mm and length and width of small arm between bigger arms is 0.48mm and 0.34mm respectively. U section is also a microstrip resonator that resist signal travelling from one antenna to other in an array.

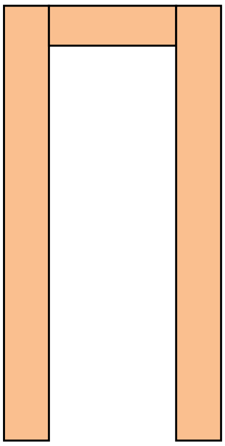

Figure 6: Dimension of U section

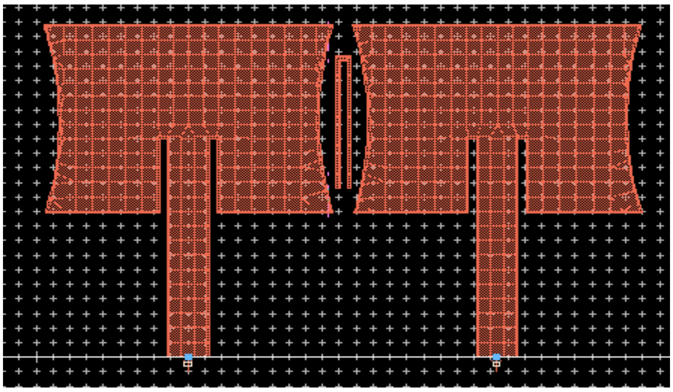

Figure 7: Structure of Length Concavity Patches With U Section

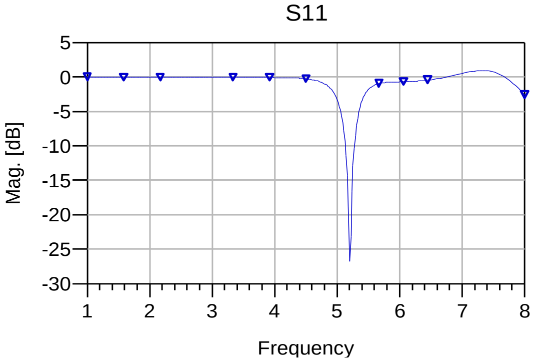

Figure 8: Plot of return loss(S11) for length concavity patches with U section

Now resonance frequency is 5.2 GHz with S11 = - 26.75dB and S22 = -29.5dB and S12 and S21 = -37.33 dB. So there is difference of about 30dB which shows that patch antenna have good matching characteristics and mutual coupling decreases. As Frequency is 5.2 GHz because of concavity width is slightly changed that cause frequency shift. We can use best use these patches for WLAN applications, directivity = 7.55dB and gain = 6.51dB, gain has been decreased but directivity increase and above all mutual coupling decrease.

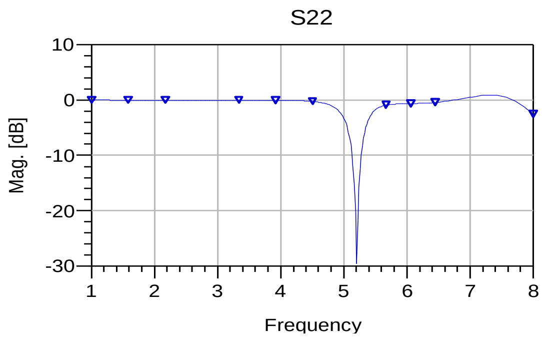

Figure 9: Plot of Return Loss (22) For Length Concavity Patches With U Section

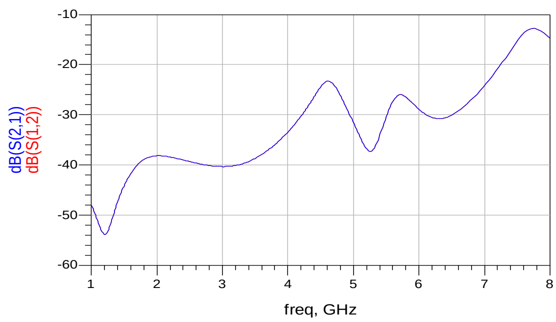

Figure 10: Plot of Return Loss For Length Concavity Patches With U Section

Table 1: S Parameters of Patch Antenna Array

Antenna structure	S11	S22	S21	S12
Antenna array without U section and concavity	-10.51dB	-10.51dB	-6.48 dB	-6.48 dB
Antenna array with U section and concavity	-26.75 dB	-29.5 dB	-37.33 dB	-37.33dB

Patch Antenna Structure With Corporate Feed Network

Corporate feed network is used to provide power to microstrip patch antennas and it work as a power splitter and provide a power split of 2n (n=2, 4, 8, etc.). Quarter wavelength transformer are used to maintain input impedance at 50 Ω [6].

Corporate feed network is made of microstrip lines so calculation for lines are according to the impedance and according to the frequency 5.3Ghz [11]as given below . This feed network then simulated on ADS.

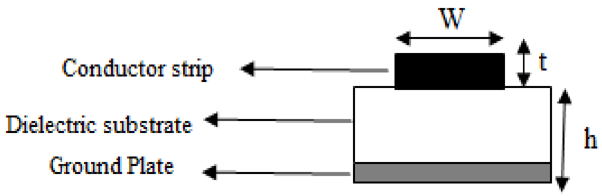

Figure 11: Microstrip Line

Characteristic impedance can be written as:

$$Z_o = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left[\frac{5.98h}{0.8w + t}\right] \text{ for h<0.8w} \qquad \ldots\ldots \qquad (9)$$

for wide microstrip line

$$Z_o = \frac{377}{\sqrt{\varepsilon_r}} \cdot \frac{h}{w} \qquad \ldots\ldots \qquad (10)$$

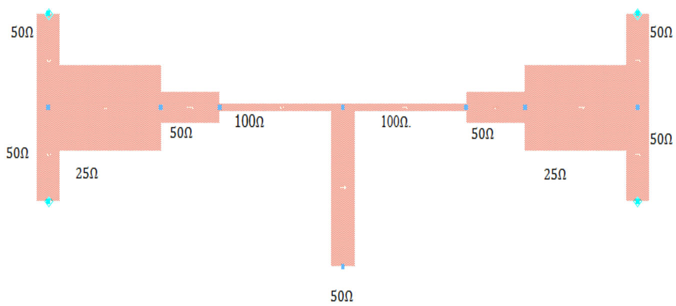

Figure 12: Structure of Corporate Feed

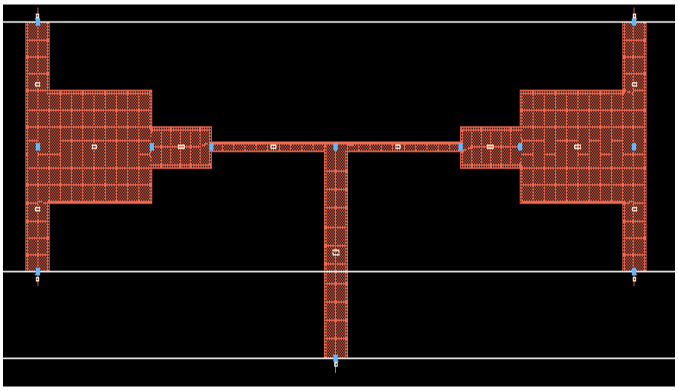

Figure 13: Structure of Corporate Feed on Software

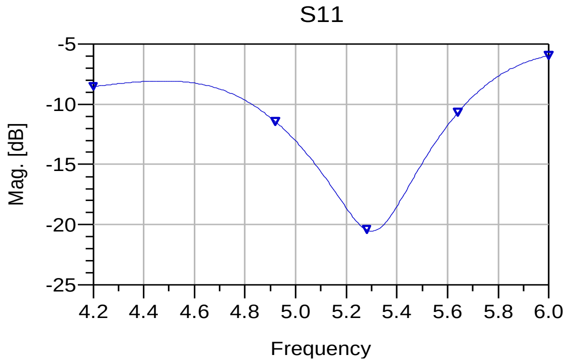

Figure 14: Plot S11 For Corporate Feed Network

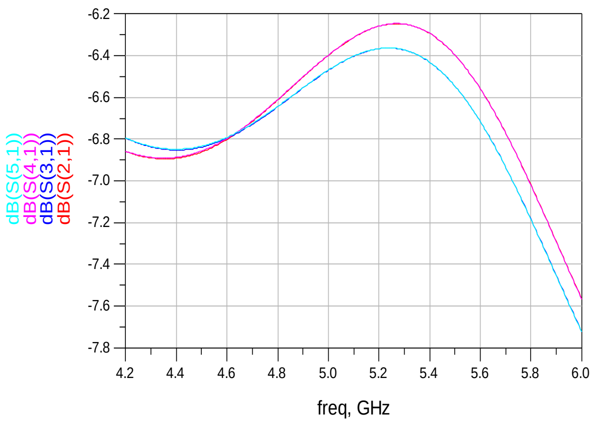

Figure 15: Plot of S21,S31,S41 and S51

Table 2: S Parameters For Corporate Feed Network

S Parameter	Value
S11	-20.52dB
S21	-6.24 dB
S31	-6.36 dB
S41	-6.24 dB
S51	-6.36 dB

Antenna array is design according this feeding network and results are observed that are useful for MIMO applications.

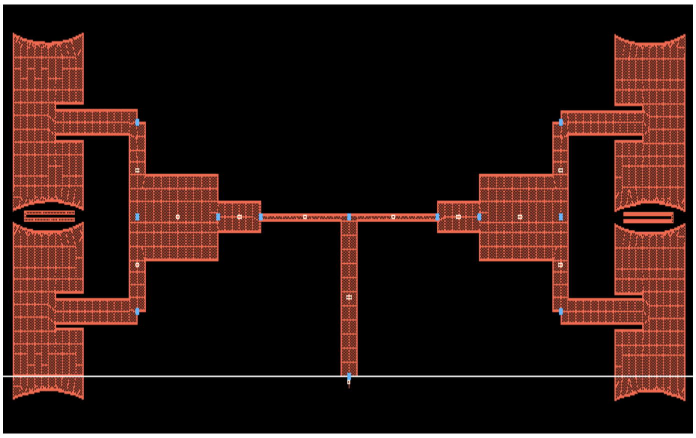

Figure 16: Structure of Corporate Feed Antenna Array With Concave Patches And A U Section

S11= -15.61dB at frequency 5.1 GHz ,there is shift in frequency due to fringing field of patch antennas. ,this result shows that power divided properly in antenna arrays and a good amount of power is radiated. Directivity = 9.45dB and gain = 8.65 dB and this values are much better than previous design of antenna in this paper.

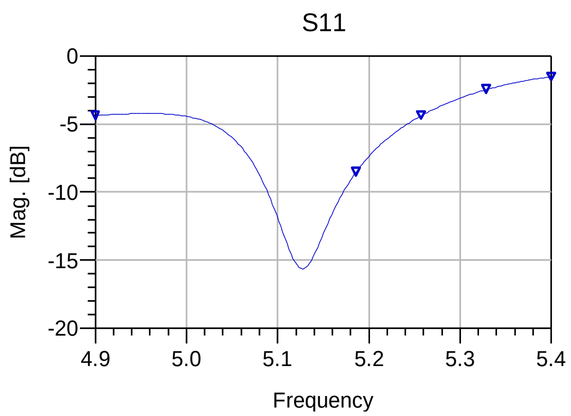

Figure 17: Plot For S11 Parameter For Corporate Feed Antenna Array With Concave Patches And A U Section

Table 3: Comparison of S11 Parameter

Corporate feed network	-20.52dB
Corporate feed network with patch antenna array	-15.61dB

Table 4: Gain and Directivity For Antenna Array

Antenna structure	Gain	Directivity
Antenna array with U section and concavity	6.51 dB	7.55 dB
Antenna array with U section and Concavity and with corporate feed network	8.65dB	9.45dB

Conclusion

This paper presents a simple technique which is very easy to implement to reduce mutual coupling with the use of concavity shaped patch and U section between them. It is also shown that, this technique not only cancels mutual coupling but also increases the return loss with very less spacing between the antennas. The gain and directivity is also increased with 2x2 array which is designed using corporate feed network. This array cab be used to implement spatial diversity for WiMAX applications.

References

[1] Rachmansyah, Antonius Irianto,and A. Benny Mutiara, "Designing and Manufacturing Microstrip Antenna for Wireless Communication at 2.4Ghz,"International Journal of Computer and Electrical Engineering, International, Vol. 3, No. 5,October 2011.

[2] G.N Gaikward et al: "Mutual Coupling Reduction Between Microstrip Antenna using Electromagnetic Band Gap Structure".

[3] Shahram Mohanna ,Ali Farahbaksh,Saeed Tavakoli, and Nadder Ghassemi,"Reduction of Mutual Coupling and Return Loss in Microstrip Array Antenna using Concave Rectangular Patches", Hindawi Publishing

Corporation International Journal of Microwave Science and Technology Vol. 2010.

[4] M.T. Ali, T. A. Rahman, M.R. Kamarudin, and M. N. Md Tan,"A Planar Antenna Array with Separated Feed Line for Higher Gain and Side lobe Reduction", Progress In Electromagnetic Research C, Vol.8,69-82,2009.

[5] Saeed Farsi, Hadi Aliakbarian, Dominique Schreurs, Bart Nauwelaers, and Guy A. Vandenbosch," Mutual Coupling Reduction Between Planar Antennas By Using a Simple Microstrip U-Section", IEEE Antenna And Wireless Propagation Letter, Vol.11,2012.

[6] Md. Tanvir Ishtaique-ul, Md. Al-Amin Chowdhury, Md. Kamal Hosain, and Md. Shah Alam," Performance Analysis of Corporate Feed Rectangular Patch Element and Circular Patch Element 4x2 Microstrip Array Antennas", International Journal of Advanced Computer Science and Applications, Vol. 2,No 8,2011.

[7] Balanis," Antenna Theory analysis and design", John Wiley and Sons, second edition ,1997.

[8] Kuldeep Kumar Singh and Dr. S.C. Gupta, "Design and simulation of Microstrip Patch Array Antenna for C Band Application at IMT(4400-4900MHz) Advanced Spectrum with Series Feed and Parallel Feed ", International Journal of Scientific & Engineering Research, Vol. 4,Issue 12,Ddecember-2013.

[9] Chandan K. Ghosh, Bappaditya Mandal, and Susanta K. Ghosh, "Mutual Coupling Reduction of a Dual-Frequency Microstrip Antenna Array by Using U-Shaped DGS and Inverted U-Shaped Microstrip Resonator", Progress In Electromagnetic Research C,Vol.48,61-68,2014.

[10] Amideh Kondoril, Mahommad Ali Mansouri-Birjandi, and Saeed Tavakoli,"Reducing Mutual Coupling in Microstrip Array Antenna Using Metamaterial Spiral Resonator", International Journal of Computer Science Issues,Vol.9,Issue 3,No1, May 2014.

[11] M. Kulkarni,"Microwave and Radar Engineering", fourth Edition,2010.