PLANAR ANTENNA DESIGNS FOR ISM BAND WIRELESS APPLICATIONS

Er.Gurpreet Kaur[1], Dr.Naveen Dhillon[2]

[1] P.G Student, Department of ECE, RIET, Phagwara, Panjab

[2] Professor, Department of ECE, RIET, Phagwara, Panjab (India)

ABSTRACT

Conventional microstrip antennas in general have the attractive features of low profile, light weight, easy fabrication and conformability to mounting host more popular ISM band wireless systems are used in many applications where maximum range is required. However, microstrip antennas inherently have a narrow bandwidth and low gain. Bandwidth enhancement is a demand for practical applications. In addition, applications in present day mobile communication system usually require smaller size in order to meet the miniaturization requirements of mobile units. My research work proposes design, simulation and comparative analysis of broadband, good gain microstrip antenna for modern communication units. Using modern technology for analysis and design of microstrip patch antenna to overcome their disadvantages is rewarding especially in the modern communication system industry .In this paper; three Planar Microstrip antenna designs using FR-4 substrate material are presented for ISM band wireless applications. First design reveals a single element antenna with micro-stripline inset feeding. Second design is a two-element antenna using Wilkinson power splitter for feeding the elements. Third design is a four element [2X2] array antenna in which the feeding is provided using Wilkinson power splitter. The modeling and simulations are performed on professionally used simulation software (IE3D). The results and performances of all three designs are analyzed & compared to choose the suitable design for implementation in the ISM band wireless applications such as WLAN/WiFi, Bluetooth, Zigbee & RFID.

Keywords***: Inset Feed, Wilkinson Power Splitters, Micro-Stripline, ISM Band, Impedance Bandwidth.***

I. INTRODUCTION

Microstrip antenna consists of a very thin metallic strip (patch) ($t << \lambda_o$) placed a small fraction of a wavelength above a ground plane ($h << \lambda_o$, usually $0.003\lambda_o \leq h \leq 0.05\lambda_o$). The microstrip patch is designed so its pattern maximum is normal to the patch (broadside radiator). End-fire radiation can also be accomplished by proper choosing mode of excitation. For rectangular patch, the length L of the element is usually $\lambda o/3 \leq L \leq \lambda o/2$. The strip and the ground plane are separated by a dielectric substrate as shown in Fig.1. The ones that are most desirable for antenna performance are thick substrates whose dielectric constant is low because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular or any other configuration. Square, rectangular, dipole, and circular are the most common because of ease of analysis and fabrication, and their attractive radiation characteristics. Arrays of microstrip elements, with single or multiple feeds may also be used to introduce scanning capabilities and achieve greater directivities. The microstrip feeding line is a conducting strip of much smaller width compared to the patch. It is easy to fabricate, simple to match by controlling the inset position and simple to model as shown in Fig. 2. However, as the substrate thickness increases, surface waves and spurious feed radiation increases, which for practical designs limits the bandwidth (typically 2-5%). Microstrip patch with inset feed in fact the quarter wave length makes some deformation in the radiation pattern so the use of inset feed is preferred, Fig.3. The slot (s) is taken between (0.2-0.5 mm) and the value of inset length y_o can be calculated as follows:

$$y_o = \frac{\lambda_o}{2\pi\sqrt{\varepsilon_{eff}}}\cos^{-1}\sqrt{\frac{2Z_o}{Z_{in}}}$$

Where Z_o is 50 ohm microstrip line corresponding to W_o.

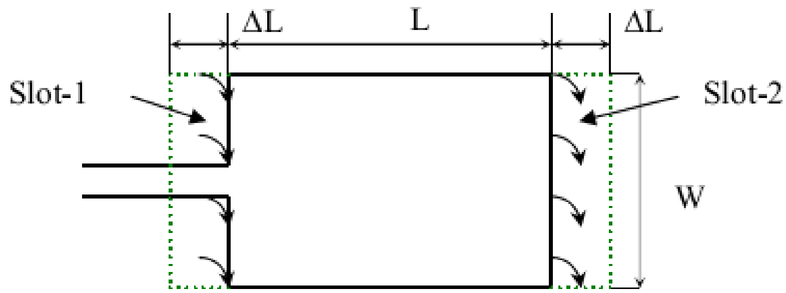


Fig.1 Physical and effective length of a rectangular patch antenna

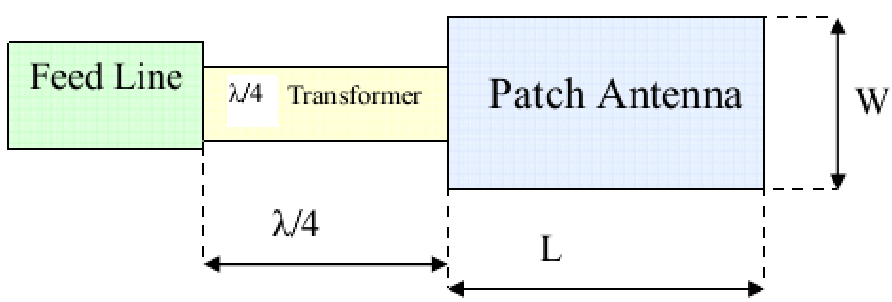


Fig.2 The Feed Matching With Quarter Wave Transformer

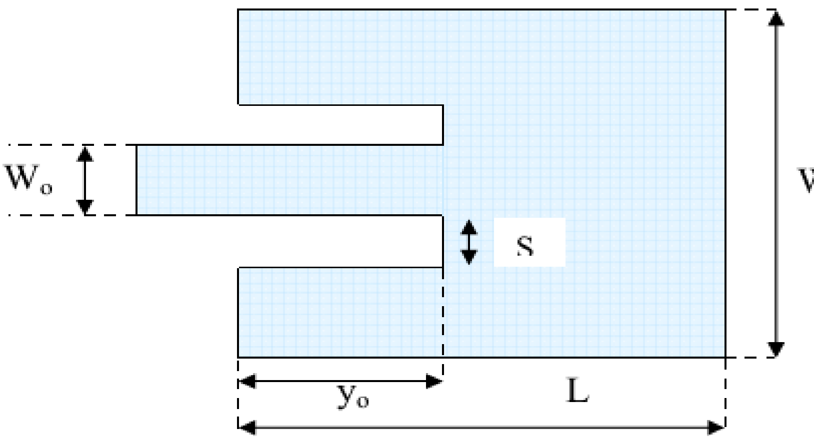


Fig.3 The Inset Feed Patch Antenna

Usually, the radiation pattern of a single element is relatively wide, and each element provides low values of directivity (gain). In many applications, it is necessary to design antennas with very directive characteristics (very high gains) to meet the demands of long distance communications. This can only be accomplished by increasing the electrical size of the antenna. Enlarging the dimensions of single elements often leads to more directive characteristics. Another way to enlarge the dimensions of the antenna, without necessarily increasing the size of the individual elements is to form an assembly of radiating elements in an electrical and geometrical configuration. This new antenna, formed by multi-elements is referred to as an array. Arrays are very versatile and are used to synthesize a required pattern that cannot be achieved with a single element. In addition, they are used to scan the beam of an antenna system, increase the directivity and perform various other functions which would be difficult with any one single element. In most cases, the elements of an array are identical. This is not necessary, but it is often convenient, simpler and more practical. The individual elements of an array may be of any form (wires, apertures, microstrip, etc). The total field of the array is determined by the vector addition of the fields radiated by the individual elements. This assures that the current in each element is the same as that of the isolated element. This is usually not the case and depends on the separation between the elements. To provide very directive patterns, it is necessary that the fields from the elements of the array interfere constructively (add) in desired directions and interfere destructively (cancel each other) in the remaining space. Ideally, this can be accomplished, but practically it is only approached. In an array of identical elements, there are five controls that can be used to shape the pattern of the antenna. These are:

1. The geometrical configuration of the overall array (linear, circular, rectangular, spherical, etc.).
2. The relative displacement between the elements.
3. The excitation amplitude of the individual elements.
4. The excitation phase of the individual elements.

5. The relative pattern of the individual elements.

1.1 The Array Factor

The total field of the array is equal to the field of a single element positioned at the origin multiplied by a factor which is widely referred to as array factor. This is referred to as pattern multiplication .The array factor is a function of the geometry of the array and the excitation phase. By varying the separation and/or the phase β between the elements, the characteristics of the array factor and of the total field of the array can be controlled. The array factor, in general, is a function of the number of elements 'N', their geometrical arrangement, their relative magnitudes, their relative phases 'β' and their spacing 'd'. The array factor will be of simpler form if the elements have identical amplitudes, phases and spacing. Since the array factor does not depend on the directional characteristics of the radiating elements themselves, it can be formulated by replacing the actual elements with isotropic point sources. Once the array factor has been derived using the point source array, the total field of the actual array is obtained by the use of equation:

E (total) = E (single *element at reference point*) * Array Factor

In this section, we will illustrate three different designs for single element and array antennas using the micro stripline inset feed. All the designs are done for the centre frequency 2.45 GHz on the FR-4 substrate material (6.4 = εr, h=1.49 mm).

II. GEOMETRY & ANTENNA MODELLING

2.1 Single Element Antenna with Inset Feed

Based on the design equations previously described in this paper, the geometrical dimensions for the single element microstrip patch antenna with inset feed is shown in Fig.4, (all dimensions in mm).This antenna is modeled and simulated using the professional software (IE3D).

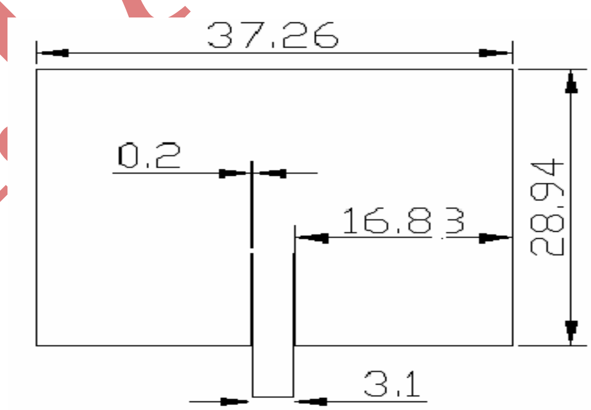


Fig.4 The Inset Feed Microstrip Antenna On FR-4 Material (All Sizes In mm)

2.2 Two Element Array with Inset Feed Antenna

The dimension of the two element microstrip array is shown in Fig.5 (all dimensions in mm). This antenna was also simulated using the professional software (IE3D). The feeding of both microstrip elements is done through Wilkinson power splitter for power distribution.

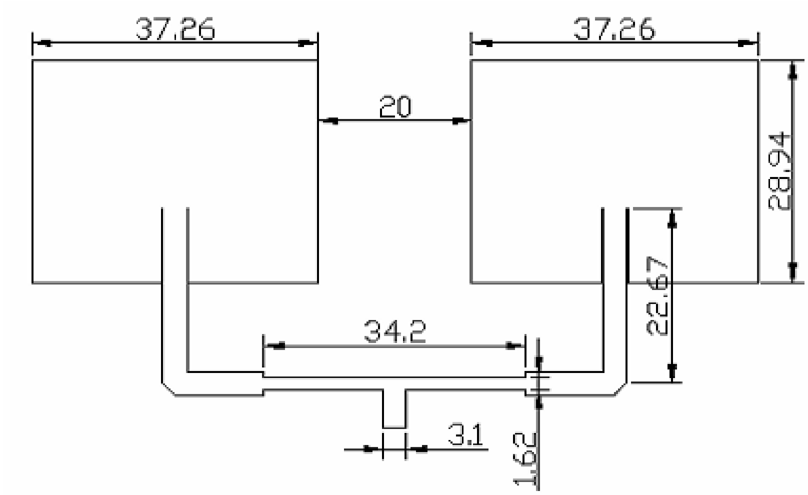


Fig.5 Two Element Array With Wilkinson Power Splitter For Power Distribution (All Sizes In mm)

2.3 Four Element Array (2X2) With Inset Feed Antenna

The dimension of the two by two arrays is shown in Fig.3.11 (all dimensions in mm). This antenna is also simulated using the IE3D.

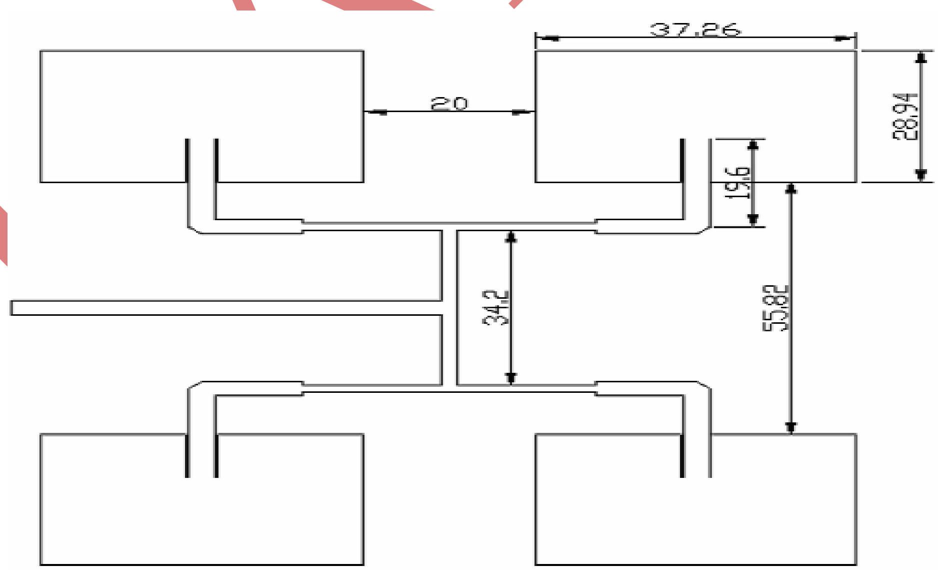


Fig.6 Four Element (2X2) Array Antenna (All Sizes in mm)

III. RESULTS AND DISCUSSION

3.1 Single Element Antenna with Inset Feed

The radiation pattern of single element microstrip antenna is shown in Fig.7. This radiation pattern has the following properties obtained using simulation software:

Total field properties:

Gain =5.05186 dB

Directivity = 6.38809 dBi

Maximum at = (0, 0) deg.

3dB Beam width = (80.8786, 160.872) deg.

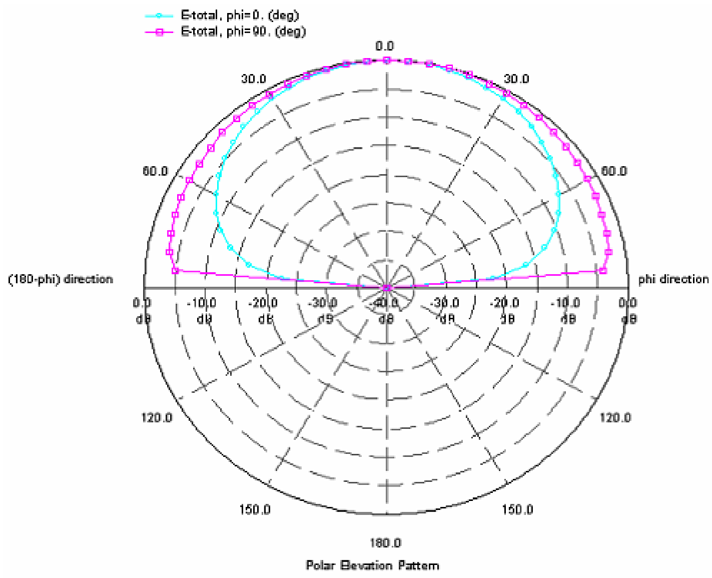


Fig.7 The 2-D Radiation Pattern For The Single Element Antenna With Inset Feed

The current distribution is illustrated in Fig.8.

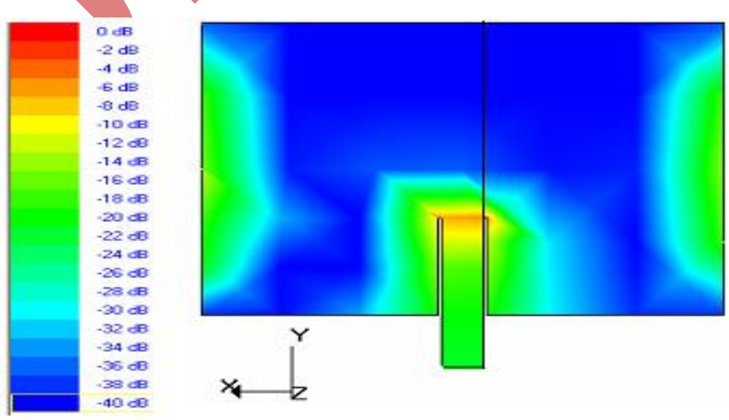
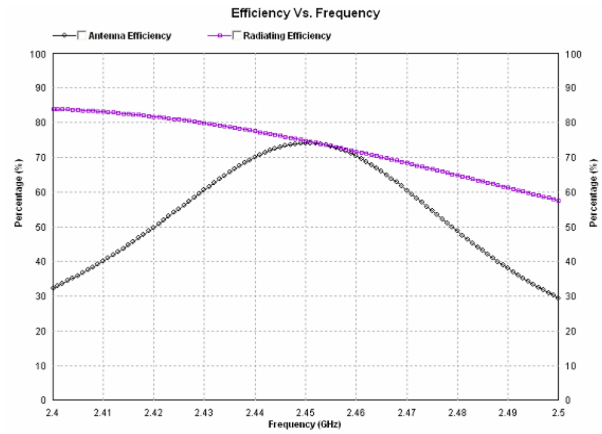


Fig.8 Current Distribution of the Single Element Inset Feed Antenna

It is clear that the current is distributed near the radiated edges and around the slot of the feed port only while the remaining of the antenna has negligible current distribution. The antenna and radiation efficiency against frequency are illustrated in Fig.9, and the good properties are achieved at resonance frequency with the following values:

Radiation Efficiency = 73.531%

Antenna Efficiency = 73.515%



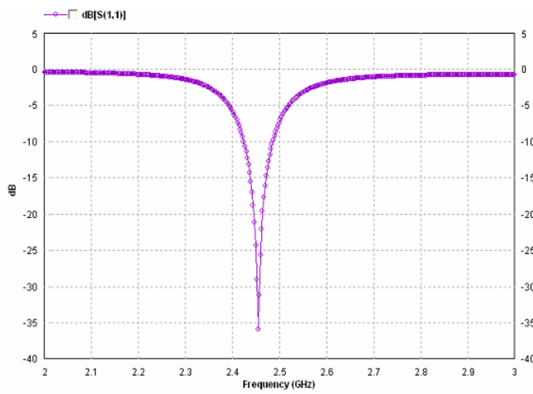


Fig.9 **Fig.10**

Fig.9 The Radiation Efficiency Against Frequency For The Single Element Antenna.

Fig.10 The Reflection Coefficient At Input Port For The Single Element Inset Feed Antenna

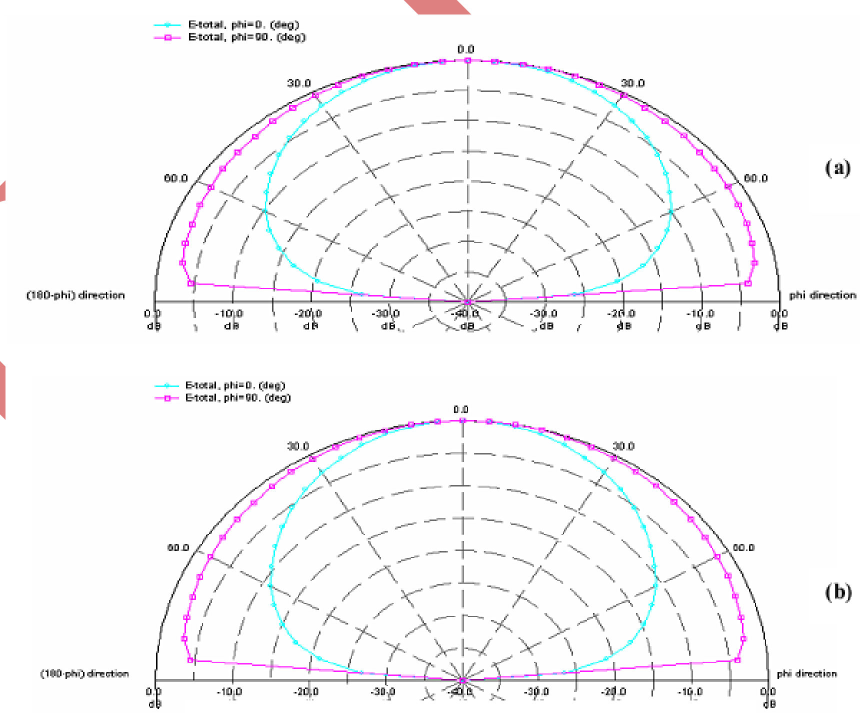


Fig.11 The Radiation Pattern When Take Array Factor (a) N=2 (b) N=4

The reflection coefficient for the antenna is shown in Fig.10, where it is nearly (-36dB) at the operating resonance frequency 2.454 GHz. This antenna achieves 10db bandwidth equal to 2.5%. When we take the array factor concept into consideration, the radiation pattern for N=2 and N=4 are shown in Fig.11. The field pattern for N=4 is more directed than that for N=2.

3.2 Two Element Array Antenna

The radiation pattern of two element array antenna is shown in Fig.12.

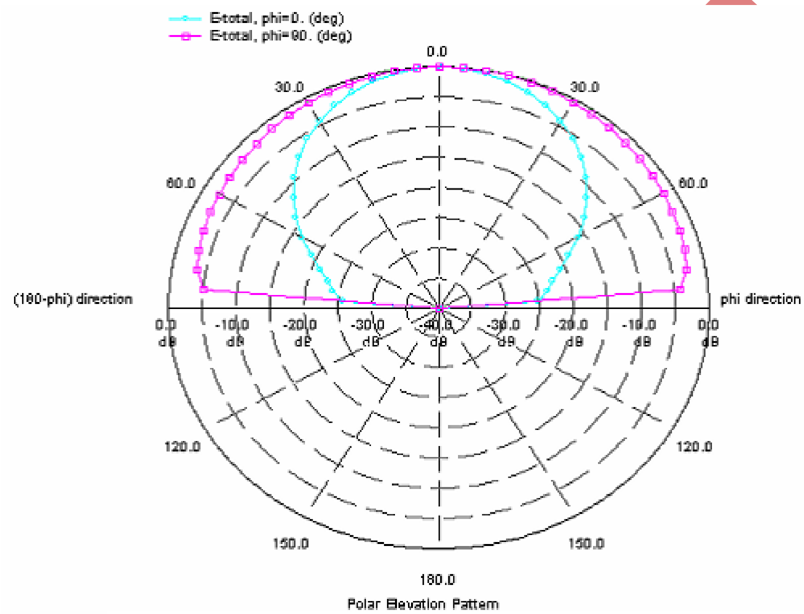


Fig.12 The 2-D Radiation Pattern For Two Element Array Antenna

This radiation pattern has the following obtained properties using the simulation software IE3D:

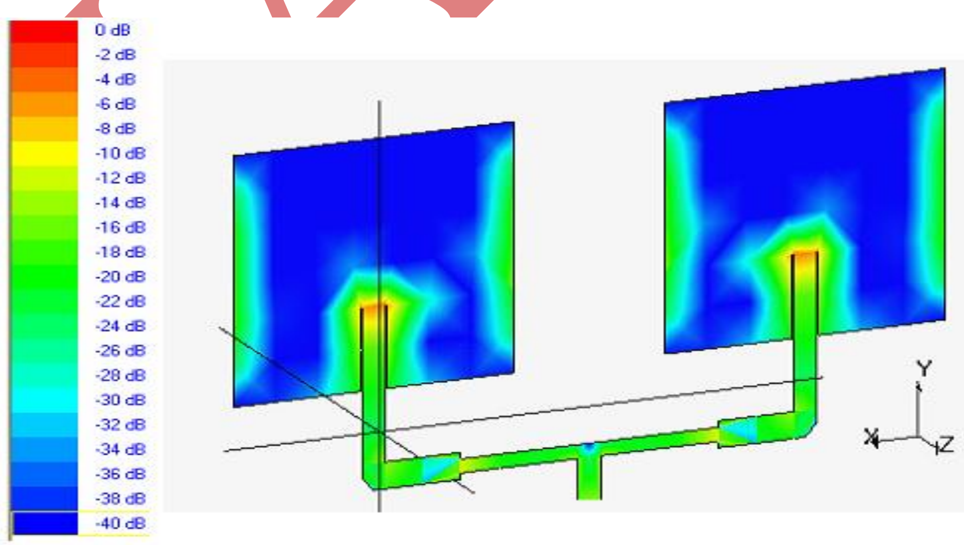


Fig. 13 The Current Distribution For The Two Element Array Antenna

Total field properties:

Gain = 6.18312 dBi

Directivity = 7.85289 dBi

Maximum at = (0, 30) deg.

3dB beam width = (50.28, 159.44) deg

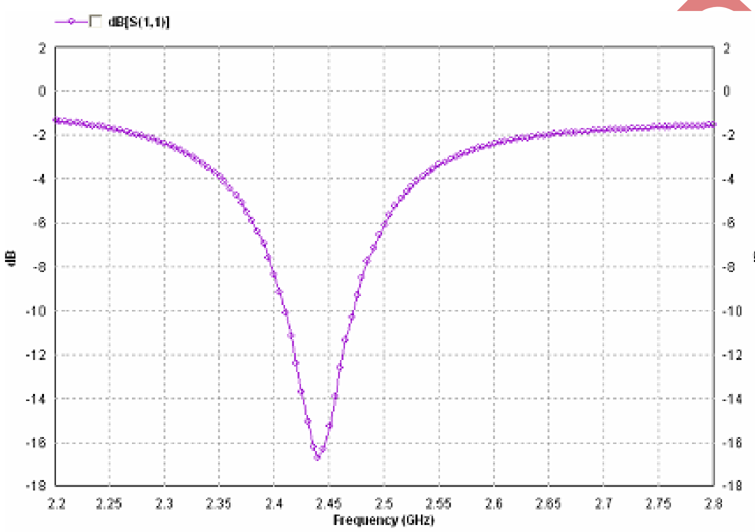


Fig.14 The Reflection Coefficient For Two Element Array Antenna

From these results, it is clear that the gain for the two element array is increased by 1 dBi and also the directivity is increased by 1.5 dBi. (This is the main benefit of the array). The current distribution is illustrated in Fig.13. It has a high current distribution around the radiating slot of the antenna and the current distribution is high for the adjacent radiating slot of the two elements due to the coupling of the two elements. Also the current is uniformly distributed through the power splitter except near the discontinuities between the 50 ohm and the 35.5 ohm branches. The antenna and radiation efficiency at resonance frequency achieve the following values:

Radiation Efficiency = 68.56%

Antenna Efficiency = 67.49%

The reflection coefficient for the antenna is shown in Fig.14, where it achieves around –16.7dB at the resonance frequency 2.44GHz, so the resonance frequency was shifted due to the coupling effect which is not taken into account during the design of that array. The 10 db bandwidth of this design is 2.39% at the resonance frequency.

3.3 Four Element (2X2) Array Antenna

The radiation pattern of the four element (2x2) array antenna is shown in Fig.15; this radiation pattern has the following properties (from simulation software):

Total field properties:

Gain = 7.09 dBi

Directivity = 8.96 dBi

Maximum at = (35, 270) deg.

3dB beam width = (49.85, 57.56) deg

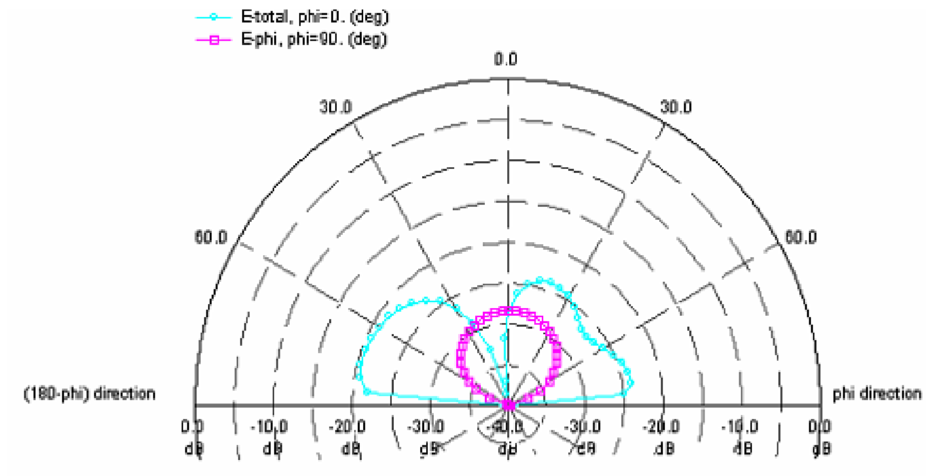


Fig.15 The 2-D Radiation Pattern For Four Element (2X2) Array Antenna

From these results, it is clear that the gain for the two by two elements array is increased by 2.04 dBi and also the directivity is increased by 2.572 dBi when compared with single element patch antenna. The antenna and radiation efficiency at resonance frequency achieve the following values:

Radiation Efficiency = 78.54%

Antenna Efficiency = 65.0 %

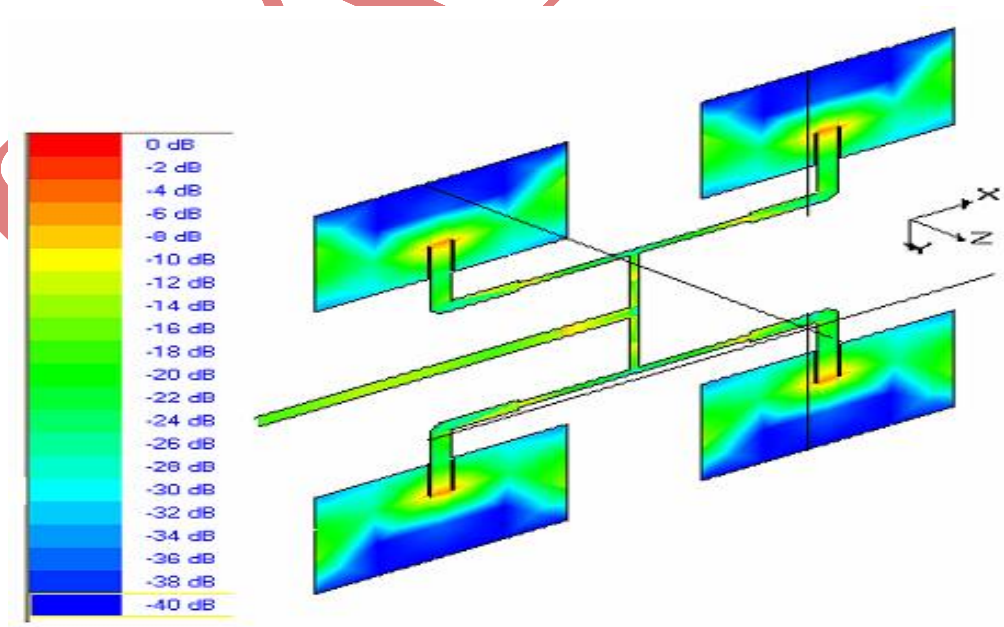


Fig.16 The Current Distribution For The Four Element (2X2) Array Antenna.

The current distribution is illustrated in Fig.16. In this array, the current is uniformly distributed around the radiating slots for each antenna except the outer slot. Also the current is uniformly distributed for the adjacent non-radiating slots which are due to the effect of the horizontal and vertical coupling. The reflection coefficient for the antenna is shown in Fig.17, where it achieves around –16.2 dB at the resonance frequency 2.46 GHz, so the resonance frequency was shifted due to the coupling effect between the four element arrays. The 10 db bandwidth of this design is 3.1%.

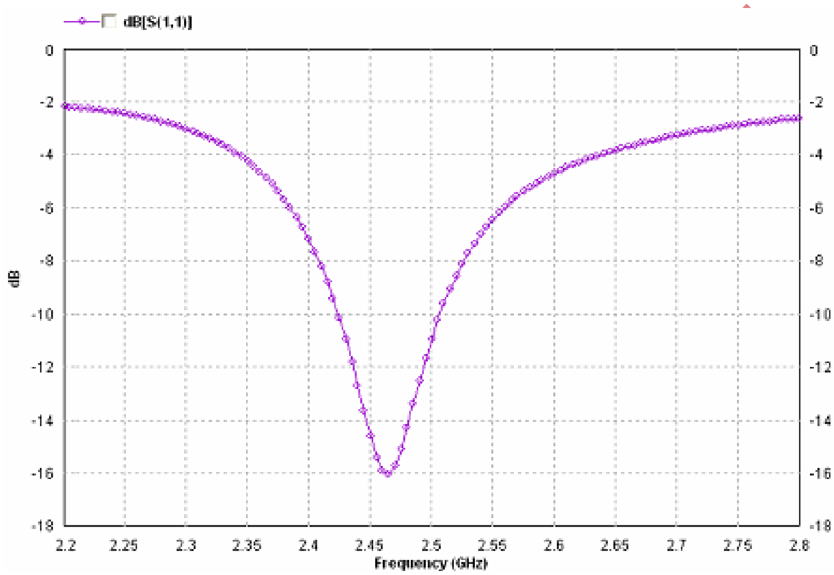


Fig.17 The Reflection Coefficient For Four Element (2X2) Array Antenna

IV. CONCLUSION

The objective of this project was to develop a planar single element microstrip antenna and antenna array that have a good performance in terms of bandwidth and gain for ISM band wireless applications. The developments of such antenna models were done using micro stripline inset feeding and simulation results were presented in this paper. The results analyze shows that they are well suitable for most of the ISM band wireless Communication systems such as WLAN, WiFi, Bluetooth, Zigbee etc.

V. ACKNOWLEDGEMENTS

It is my pleasure to thank Dr. Naveen Dhillon for stimulating discussions and Academic cum moral support, Infrastructure backup from the department of Electronics & Communication Engineering, Ramgarhia Institute of Engineering & Technology, Phagwara (A Pioneer in the area of engineering education), Panjab.

REFERENCES

[1] C. A. Balanis, *Antenna theory: analysis and design*, 2nd ed. John Wiley and Sons, New York, 1997.

[2] K. M. Luk, C. L. Mak, Y. L. Chow, and K. F. Lee, "*Broadband microstrip patch antenna*," Electron. Lett. vol. 34, pp. 1442–1443, 1998.

[3] Miguel a, Gonzalez deaza and Jun Zapata, "*Broad-Band Cavity-Backed and Capacitively Probe-Fed Microstrip Patch Arrays*", IEEE Trans. Antenna and Propagation, Vol.48, no.5, PP.784-789, May 2000.

[4] R. Garg, P. Bhartia, I. Bahk, A. Ittipiboor, *"Microstrip Antenna Design Handbook*", Artech House, 2001.

[5] Kin Lu Wong, "*Compact broadband microstrip antennas*", Wiley Interscience publication, John Wiley & Sons, Inc. ch.8, 2002.

[6] Waterhouse,B.R.,*MicrostripPatchAntennas*:ADesigner'sGuide,Kluwer AcademicPublishers,2003.

[7] Bancroft,R.,MicrostripandPrintedAntennaDesign,NoblePublishing Corporation,2004.

[8]Nakar,P.S.:'*Design of a compact Microstrip Patch Antenna for use in Wireless Cellular Devices.*'MastersThesisreport, 2004.

[9] Chen, J. S., "*Dual frequency annular ring slot antennas fed by CPW feed and microstrip line feed"* , IEEE Transactions on Antennas and Propagation, Vol. 53, No. 1, 569–571, 2005

[10] Suma,M.N., Raj.R.K, Joseph.M, Bybi.P.C, Mohanan.p, "*A Compact dual band planar branched monopole antenna for DCS/2.4 GHz WLAN applications*". Microwave and wire less components letters, IEEE,vol.16,issue.5,pp 275-277,2006.

[11] Wu, Y. J., B. H.Sun, J. F. Li, and Q. Z. Liu, "*Triple-band omni-directional antenna for WLAN application*", Progress in Electromagnetics Research, PIER B, Vol.6, 477–484, 2007.

[12] W. Ren,"*Compact Dualband Slot antenna for 2.4GHz WLAN Applications",* Progress in Electromagnetics Research, Vol.8, 319–327, 2008.

[13] M. T. Islam, M. N. Shakib, N. Misran and T. S. Sun, *"Broadband Microstrip Patch Antenna*," European Journal of Scientific Research, vol. 27, no. 2, pp. 174-180, 2009.

[14] J. R., "*Comparative Study of Microstrip Patch Antenna for Wireless Communication Application*," International Journal of Innovation, Management and Technology, vol. I, pp. 194-197, 2010.

[15] J. Li, "*An Omnidirectional Microstrip Antenna for WiMAX Applications*," IEEE Antennas and Wireless Propagation Letters, vol. 10, pp. 167-169, 2011.

[16] Sunita, Navjot Kaur, "*A Novel Quadfeed planar antenna for 5.6GHz wireless applications*," Proceedings of National Conference on Recent Trends in Information & Communication Technologies (RTICT-2013)

[17] Priyanka, N. Srivastava, ''*Bandwidth enhancement for Microstrip patch antenna using Suspended techniques for wireless applications''*, International Journal of Advancements in Research & Technology, Volume 2, Issue-5, May-2013.