Design and Implementation of Inset feed Square Patch Micro Strip Antenna Array for WLAN Application Using Dielectric Substrate

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Abstract -- **A Square patch Micro strip antenna array using inset feed for Wireless Local Area Network (WLAN) and worldwide interoperability S-band frequency is presented. The proposed antenna is fabricated on dielectric substrate with dielectric constant 4.2 and thickness of 1.5 mm. The key feature of this substrate is that it can withstand high temperature. The return loss is about -16dB at the operating frequency of 2.45 GHz with 50 Ω input impedance. The basic parameters of the proposed antenna such as Return Loss, VSWR, Radiation Pattern and 3D Polar Plots are simulated using An soft HFSS. Simulation results of antenna parameters of single patch antenna array are analyzed and presented.**

Keywords: *Radiation Pattern, VSWR, 3D Polar Plot, Inset feed.*

I. INTRODUCTION

ANTENNA is one of the important elements of a wireless communications system. Wireless technology provides less expensive alternative and a flexible way for communication. Communication plays a vital role in the worldwide society now-a-days and the communication systems are rapidly switching from "wired to wireless". Accordingly, antenna design has become one of the most active fields in the communication studies.

One common type of antenna is the Micro strip patch antenna [1]. A good antenna design can improve overall performance of the system. In the present paper, a 4 element high gain parallel micro strip antenna array using Inset feeding network at S-band is presented. The Inset-fed Micro strip antenna provides a method of impedance control with a planar feed configuration. This antenna features advantages of the printed circuit technology. These advantages make Micro strip antennas popular in wireless communication applications such as satellite communication, radar, medical applications, etc. Micro strip antenna in its simplest configuration is shown in Fig1. It consists of a radiating patch on one side of dielectric substrate ($^{a}_{r}$d"10) and a ground plane on other side.

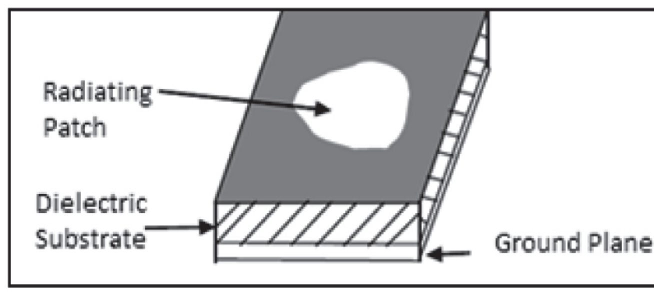

Figure 1. Microstrip antenna configuration.

Specifications for the design of the structure are as follows

- Number of elements : 4
- Input impedance : 50 Ω
- Resonance frequency : 2.4GHz
- VSWR: 1 – 1.4.

These specifications were chosen to design a lightweight and compact Micro strip Array Antenna at S-band for Man packs Wireless Communication. The design of the whole structure is performed in the following steps.

i) To design a single Micro strip patch antenna
ii) To design the power divider to feed the Antenna
iii) To design the complete array.

This paper provides a way to choose the effective feeding technique between the transmission lines and Micro strip patch antenna. By comparing the antenna parameters the best feeding technique will be selected for the design of Micro strip patch array antenna as Inset feed technique.

II. MICRO STRIP PATCH ANTENNA ARRAY

A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Micro strip patch is generally made of conducting material such as copper or gold and can take any possible shape. Common micro strip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. Some patch antennas do not use a dielectric substrate and instead use a metal patch mounted above a ground plane using dielectric spacers. The resulting structure is less rugged but has a wider bandwidth. Because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices [11].

The radiating patch and the feed lines are usually photo etched on the dielectric substrate. Micro strip antenna consists of very small conducting patch built on a ground plane separated by dielectric substrate. The conducting patch, theoretically, can be designed of any shape like square, triangular, circular, or rectangular. However rectangular and circular configurations are the most commonly used. Micro strip antenna has a drawback of small bandwidth and low gain. The bandwidth can be increased by cutting slots and stacking configuration and Gain can be increased by using different patch elements in an array to achieve optimum radiation characteristics.

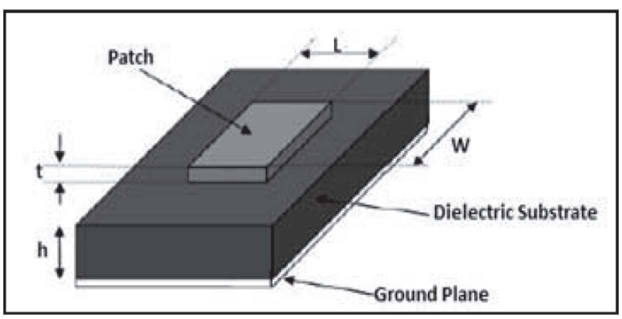

Figure 2. Structure of Microstrip patch antenna.

Consider a Micro strip patch antenna illustrated in figure 2. Micro strip patch antennae radiate primarily because of the fringing fields between the patch edge and the ground plane. For a rectangular patch, the length L of the patch usually satisfies

$$0.3333\lambda_0 < L < 0.5\,\lambda_0,$$

where λ_0 is the free-space wavelength ($\lambda_0 = 0.125$ mm). The patch is selected to be very thin such that $t << \lambda_0$ (where t is the thickness of patch).

The height h of the dielectric substrate is usually $0.003\lambda_0 \leq h \leq 0.05\lambda_0$. The dielectric constant of the substrate is typically in the range $1.2 \leq \varepsilon_r \leq 12$.

III. FEEDING OF ANTENNA ARRAY

Feed line is used to excite to radiate by direct or indirect contact.

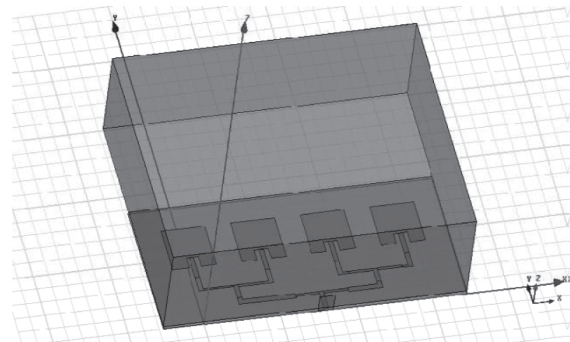

Figure 3. Proposed parallel micro- strip patch antenna array.

There are many different techniques of feeding. Four most common techniques are coaxial probe feed, micro strip line, aperture coupling and proximity coupling. The parallel or corporate feed has a single input port and multiple feed lines in parallel with the output port [11]. Each of these feed lines is terminated at an individual radiating element. Existing methods to feed Micro strip arrays can be categorized into parallel and series feed.

The series feed usually consists of a continuous transmission line from which small proportion of energy are progressively coupled into the individual element disposed along the line. The series feed constitutes a traveling wave array if the feed line is terminated in a matched load. For a uniform aperture distribution, the power is equally split at each junction.

However different power divider ratios can be chosen to generate a tapered distribution across the array. A corporate feed is most widely used parallel feed configuration. In this paper the corporate feed with inset feed is discussed for the antenna array design.

IV. DESIGN CONSIDERATION OF 4X1 MICROSTRIP PATCH ANTENNA ARRAY

In this paper a 4X1 array of individual Micro strip patch antenna is designed to achieve higher gain, better bandwidth, and input impedance of the antenna array. A single antenna has limited bandwidth. The square patch is chosen because it simplifies analysis and performance prediction. The antenna is designed to operate at 2.4 GHz with input impedance of 50 Ω, using FR4 ($\varepsilon_r = 4.2$) and height ($h = 1.6$mm).

The design starts with the simple rectangular Micro strip antenna with inset feed. Then, the Micro strip antenna is simulated using the An soft HFSS Software. After simulation, the M,icro strip antenna is fabricated using FR4, with dielectric constant ($\varepsilon_r = 4.2$) and height of 1.6 mm. Finally the Micro strip antenna performance is measured using the network analyzer and the measured values are compared with the simulated values.

A single element design is shown in figure 3. The dimension of the patch is 29 mm x 29 mm with inset feed at 8 mm. The width of the transmission line is 3mm as shown in figure 3.

V. DESIGN EQUATIONS

For an efficient radiation, the practical width of the patch can be calculated by using the following.

$$W = 1/(2\varepsilon r\sqrt{\mu o\ \varepsilon o})\times\sqrt{z}/(\varepsilon r+1)$$

$$W = 29mm$$

Length of the antenna (L)

$$L = 0.49X0.123/\sqrt{4.2}$$

$$L = 29mm$$

Free space wavelength (λ_0)

$$\lambda_0 = C/F$$

$$\lambda_0 = 0.125\ mm$$

Effective Dielectric Constant (ε_{re})

$$\varepsilon_{re} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\left(1+\frac{12}{w/h}\right)^{1/2} + 0.04\left(1-\frac{w}{h}\right)^2\right]$$

$$= 4.18\ mm$$

Guide wavelength (λ_g)

$$= \lambda_0 / \sqrt{\varepsilon_{eff}}$$

$$= 6.1\ mm$$

Micro strip Length of the Antenna (ML)

$$= \sqrt{Rr}\ x 50\Omega$$

$$= 157.5\ mm$$

For 50 Ω , L = 16.994 mm W = 3.063mm, For 70.7 Ω , L = 17.426mm, W = 1.623 mm

VI. SIMULATION RESULTS

The simulated results were obtained by considering an equivalent circuit of square micro strip patch antenna using HFSS for calculating various parameters. The designed parameters are utilized on HFSS software. The software used to model and simulate the Parallel Micro strip patch antennae is High Frequency Simulation Software HFSS version 11.1 [14].

Radiation Pattern radiates electromagnetic wave in one direction. Two types of radiation pattern are measured like E-Plane radiation pattern and H-Plane radiation pattern. E-Plane radiation pattern has circular and Omni directional radiation pattern that means it has a perfect circle. Gain is improved for the frequency range 2.4 GHz by using the inset feed patch antenna. Gain is increased when multiple of antennas are used in form of arrays. Here in this paper 4X1 elements are combined together in form of arrays to improve the Gain and Bandwidth of the antenna array [15].

The radiation patterns at the center frequency 2.4GHz, for S-band is plotted as shown in Fig 4.

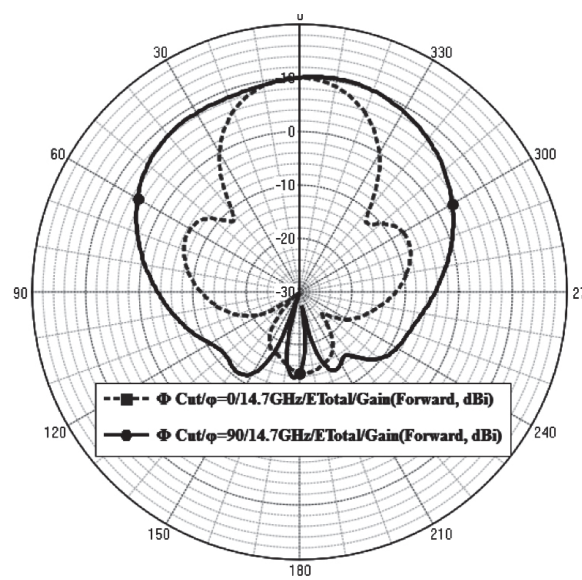

Figure 4. Radiation Pattern.

VSWR

The value of voltage standing wave ratio (VSWR) should be in the range between 1 and 2. The acceptable VSWR is 1.5. Figure 5 shows below that the value of VSWR is close to the ideal value of 1 and 2:1 VSWR Bandwidth = 0.89796 with the measurements that are provided as shown in figure 5.

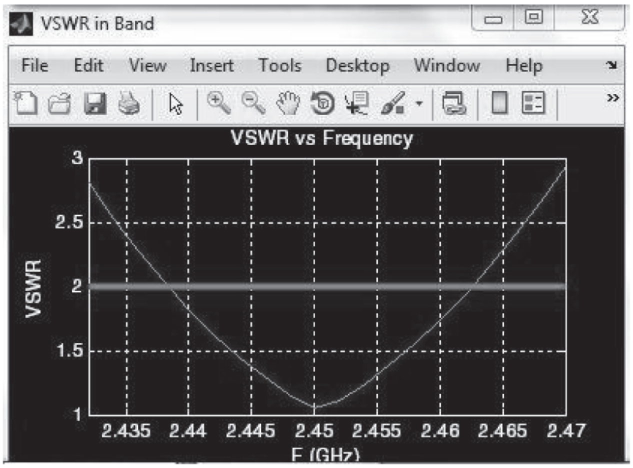

Figure 5. VSWR plot.

3D Polar Plots

The antenna should not have the side lobes and back lobes ideally. We cannot remove them completely but we can minimize them. Micro strip antennas can provide directivity in the range of 14 dB as shown in figure 6.

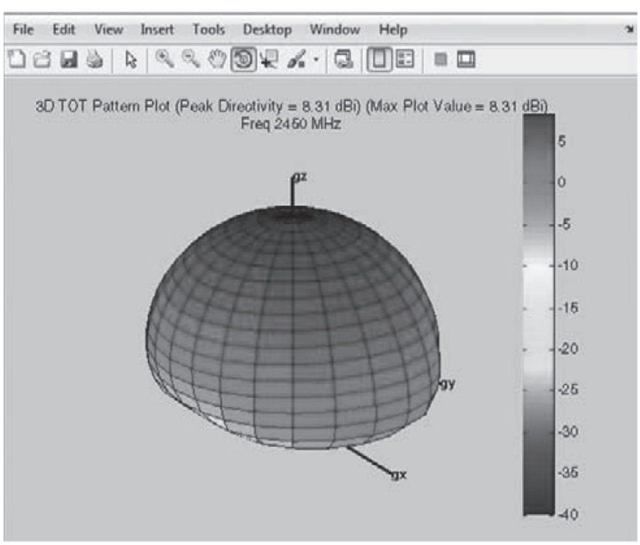

Figure 6. 3D polar plot.

Return Loss

The S11 parameter for the proposed antenna was calculated and the simulated return loss results are shown in Figure below. The value of return loss is -16 dB in this proposed antenna. The achieved return loss value is small enough and frequency is very closed enough to the specified frequency band for 2.45 GHz WLAN applications. Return loss as shown in Fig: 7.

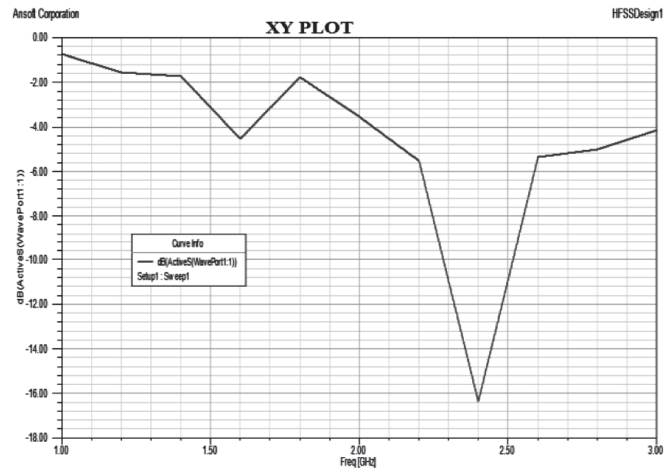

Figure 7. Return Loss.

VII. CONCLUSION

This paper presents the design and performance analysis of Micro strip Phased Array Antenna for WLAN Application. Physical patch dimensions were calculated in HFSS. Antenna simulator software was used to evaluate performance of the patch. The selected patches were arranged in planner array form for WLAN application. 4 patch elements were selected to achieve high gain and good efficiency. This proposed antenna model is found to be cost effective, features high efficiency for applications in 2.45GHz frequency range. The optimum design parameters were used to achieve the compact dimensions and high radiation efficiency. It provides a gain of 16.31 dBi, 95.6 percent efficiency and VSWR < 2 is achieved over the complete frequency band with linear polarization of antenna in the desired part of the beam.

VIII. ACKNOWLEDGMENT

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IV. REFERENCES

[1] James and P.S. Hall (Eds), *Handbook of Micro strip Antenna, Peter Peregrinus*, London, UK, 1989.

[2] J. C. Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[3] R. Garg, P. Bartia, I. Bahl, *et al*., *Micro strip Antenna Design Handbook*, 2001, pp 1 68, 253 316.

[4] M. Young, *The Technical Writer's Handbook*, Mill Valley, CA: University Science, 1989.

[5] Kashwan, R. Kumar, T. Gunasegaram *et al*., Design and Characterization of Pin Fed Micro strip Patch Antennae, *IEEE proceedings of FSKD*, 2011.

[6] N. Kanniyappan, Dr. R. Indra Gandhi, Design and Analysis of Micro strip Patch Antenna Feeding Techniques, *Proc. IEEE International Conference on Computational Intelligence and Computing Research*, 2011

[7] Mehmet ABBAK, *Micro strip Patch Antenna Array for Range Extension of RFID Applications*, Faculty of Engineering and Natural Science, Sabanci University 34956, Istanbul, Turkey.

[8] D. Orban and G.J.K. Moernaut, The Basics of Patch Antennas, *IEEE Antennas and Wireless Propagat.* Lett. Vol. 1, 2002, pp 56-59.

[9] M. T. I. Huque, *et al*., Design and Simulation of a Low-cost and High Gain Micro strip Patch Antenna Arrays for the X-band Applications, *Proc. International Conference on Network Communication and Computer ICNCC 2011,* New Delhi, India.

[10] A. Balanis, *Antenna Theory analysis and design*, Micro strip Antenna, Chapter 14, pp.720-784.

[11] C. A. Balanis, *Antenna Engineering,* 2nd ed., Willey, 1982.

[12] D. M. Pozar, Micro strip Antennas, *Proc. IEEE*, Vol.80, No.1, January 1992, pp. 79-81.

[13] http://www.antennatheory.com/arrays/main.php

[14] HFSS user manual version 11.1 and ANSYS Software License Agreement.

[15] http://www.antennatheory.com/definitions/vswr.php

[16]. M. A. Matin and A. I. Sayeed, A Design Rule for Inset-fed Rectangular Micro strip Patch Antenna, *Proc. International Conference on WSEAS transactions on communications,* ISSN: 1109-2742 Bangladesh, Volume 9, Issue 1, March 21-23, 2011.

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