Design and Simulation of Inset Feed Microstrip Patch Array for Ka-Band Applications

[1]Shailendra Goswami, [2]Deepak Bhatia
[1,2]Dept.of ECE, UCE, Rajasthan Technical University, Kota, Rajasthan, India

Abstract
A compact microstrip patch array has been designed to provide better gain, return loss and bandwidth performance for Ka-band applications the feeding technique used in this array is inset feed method. The each element of array is designed by microstrip patch antenna with a single slot at different positions in rectangular structure. The Electromagnetic Simulation Software used to verify the results before fabrication is CST Microwave studio. The dielectric substrate used is RT/duroid with permittivity $\varepsilon_r = 2.2$ and height (h) = 0.25 mm. To get the better gain and return loss in the frequency range 28.64 - 28.8 GHz a 2×1 array is simulated. The simulated array is useful for the Ka band applications and shows the superior performance than earlier reported arrays.

Keywords
Microstrip Patch Antenna, Single Patch Element, Inset Feed Technique, Ka-Band Application.

I. Introduction

The main purpose of micro strip patch antenna for satellite communication systems and other applications due to its low profile and light weight resulting in improved antenna performances. It is easy to fabricate and low cost of mass production of microstrip patch antenna. These antennas are also designed for the Ka-band satellite applications due to the simplicity in structure, ease of fabrication, high gain and high efficiency. The substrate thickness and bandwidth specifications are quite stringent and difficult to achieve for conventional rectangular micro strip patch [1].

The Microstrip Patch Antenna is a single-layer design which consists generally of four parts (patch, ground plane, substrate, and the feeding part). The patch is a very thin ($t \ll \lambda_0$, where λ_0 is the free space wavelength) radiating metal strip located on one side of a thin no conducting substrate, the ground plane is the same metal located on the other side of the substrate. The metallic patch is normally made of thin copper foil plated with a corrosion resistive metal, such as gold, tin, or nickel. Many shapes of patches are designed for many applications and the most popular shape is the rectangular and circular patch [5]. It is used primarily to provide proper spacing and mechanical support between the patch and its ground plane. It is also often used with high dielectric-constant material to load the patch and reduce its size.

Generally, substrate materials can be separated into three categories according to the dielectric constant [2].

1. Having a relative dielectric constant in the range of 1.0–2.0. This type of material can be air, polystyrene foam, or dielectric honeycomb.
2. Having εr in the range of 2.0–4.0 with material consisting mostly of fiberglass reinforced Teflon.
3. With an ε_r between 4 and 10. The material can consist of ceramic, quartz, or alumina.

Microstrip patch antennas have many advantages. However, patch antennas also 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).

There are many way to choose the effective feeding technique between the transmission lines and Micro strip patch antenna but inset feeding is one of the mostly used technique By comparing the other antenna parameters the best feeding technique will be selected for the design of proposed micro strip patch array antenna is inset feed technique [6].

Microstrip antennas are used in single elements as well as in arrays. In communication systems array design is used to 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. Various parameters of the Micro strip patch antenna such as design considerations and feeding networks, as the feeding network and radiation array are printed on single layer by the ground plane. Micro strip patch antenna array which may be used for mobile satellite digital communication terminals.

II. Feed Techniques

The four most popular feed techniques which are used for the Micro strip patch are as follows [5]:

- Inset feed
- Coax feed
- Aperture coupling
- Proximity coupling.

As already described, in the proposed antenna is fed using an inset feed. Because the Inset feed antenna provide a method to control impedance with a planar feeding configuration. The feeding technique also affects the antenna parameters like VSWR, Return loss, bandwidth. So appropriate feeding is required between the transmission line and patch. For impedance matching the input impedance Z_{in} can be altered by selection of the Z_1, So that $Z_{in}=Z_o$ and the antenna impedance matched. The quarter wave length line is as follows [8].

$$Z_{in} = Z_o = Z^2_1/Z_A \quad (1)$$

The parameter Z1 can be altered by changing the width of the quarter-wave length strip, it is wider strip line is used to increased the band width and decreased the characteristic impedance (Z_o) which is a section of line.

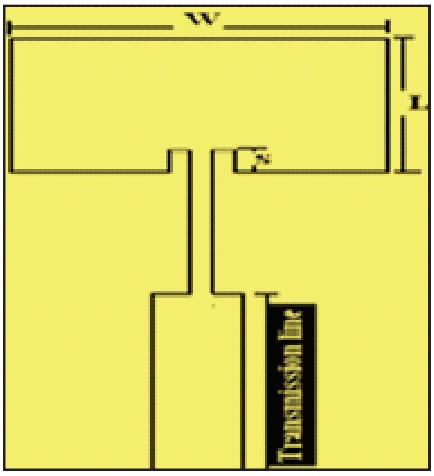
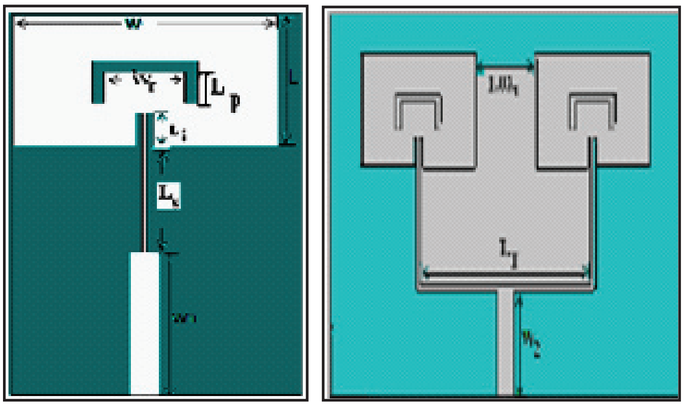


Fig. 1: Rectangular Micro Strip Patch Inset Feed

 ISSN : 2230-7109 (Online) | ISSN : 2230-9543 (Print)

III. Design of a Patch Antenna

Antenna element consists of a rectangular patch, substrates, a slotted ground plate, and a feeding circuit, as shown in fig. 1. The microstrip patch elements are arranged with equal spacing of $1.0\lambda_o$ to design antenna array of 2×1. Corporate networks are developed for feeding the each micro strip patch elements of the array [5]. In this work, a 2x1 rectangular patch array antenna with RT/duroid5880 substrate has been designed and simulated at 28.64-28.8 GHz frequency on CST Microwave studio. The RT/duroid5880 used to design this antenna as well as antenna array of 2×1 have the dielectric constant (ε_r) equals to 2.2 and height of this dielectric substrate is (h) = 0.25 mm. As 50 Ω quarter wave length transmission line is used normally, feed point is taken $Z_1 = Z_2 = 50\Omega$ resistance. An inverted U slot is also designed in the patch of each element to enhance the characteristics of the antenna. The single element microstrip patch antenna and the 2×1 array with the slot are shown in the fig. 2 (a) and fig. 2 (b), respectively. The dimensions of the antenna and array are given in the Table 1. All the dimensions are in millimeters.



(a) (b)

Fig. 2: Inset Feed Patch Antenna (a) Single (b) 2x1 Array Slot

Table 1: Physical Dimensions

Parameter's		Dimensions(mm)
Patch Antenna	W	6.6
	L	3.87
	W_r	2.6
	L_p	0.3
	L_i	0.95
	L_s	4.13
	W_1	4.63
	L_T	10.15
	W_2	3.60

IV. Simulation Results & Analysis

The designed patch antenna is simulated using CST simulation software. The various results of single element and antenna array have been obtained and some from them as described below.

A. Return Loss Curve

Return loss (S_{11}) is a measure of the effectiveness of power delivery from a transmission line to load i.e. patch antenna. Return and insertion loss can be used to characterize the antenna and provide an immediate estimate for performance of the antenna. A return loss of single element patch antenna is -16.00 dB which is obtained at 28.64 GHz. for 2x1 arrays, obtained return loss is -20.17dB at 28.8GHz frequency. Above result shows that array design enhance the return loss. The enhanced return loss means it increase the impedance matching. The return loss of an antenna is given as

$$Return\ loss = 10\log_{10}(P_{in} \backslash P_{ref}) \quad (2)$$

Frequency versus S-parameter graph of single element is shown in fig. 3 and same graph for the 2×1 antenna array is shown in fig. 4.

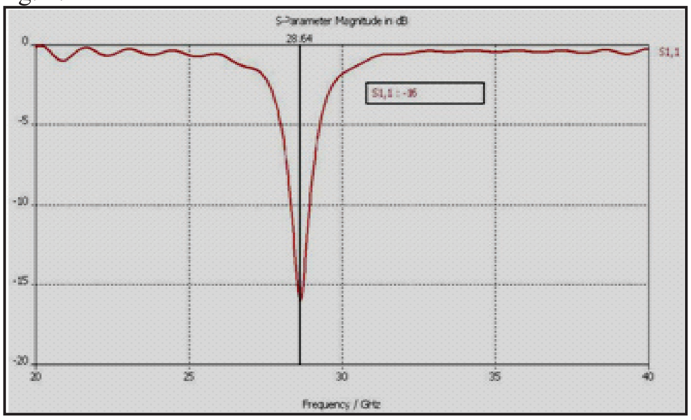


Fig. 3: Single Patch Return Loss (-16) at f=28.6GHz

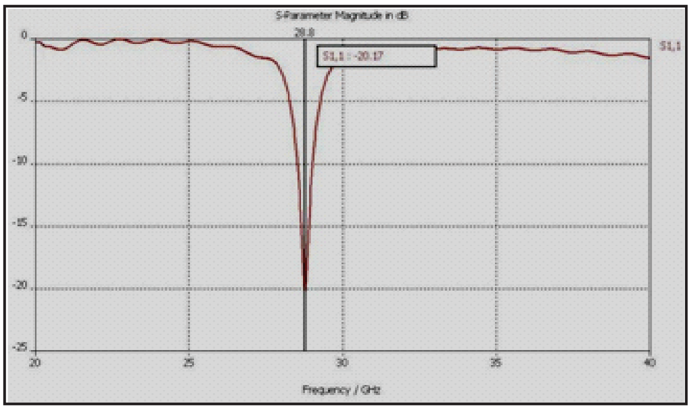


Fig. 4: 2x1 Array patch return loss (-20.17) at f=28.8GHz

B. Gain

The next important parameter is gain of antenna. So gain is also calculated using the simulator for the both single element as well as for the 2×1 antenna array. For the single patch antenna model a 3D Gain is 5.95dB and for the 2×1 antenna array Gain is 6.30 dB is obtained. The result shows that gain of single antenna is also improved using 2×1 antenna array. The Gain of single element and 2x1 array are shown in fig. 5 and fig. 6.

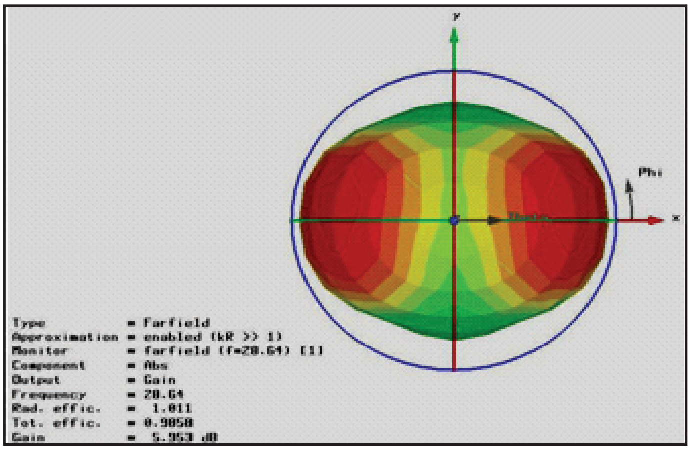


Fig. 5: Single patch antenna with Gain = 5.95dB

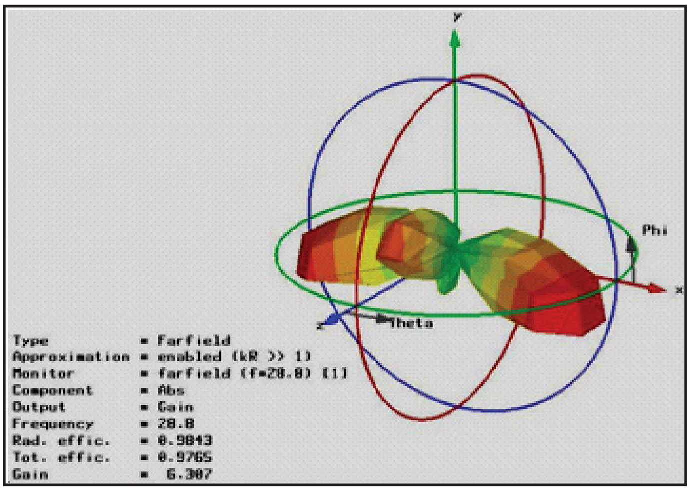


Fig. 6: 2x1Array with Gain = 6.30 dB

C. Radiation Pattern

The radiation field of the microstrip antenna maybe determined using either an “electric current model” or a “magnetic current model”. Radiation properties of the antenna can be represented by radiation pattern. The E-field and H-field patterns of single element and array are shown in fig. 7 to fig. 10.

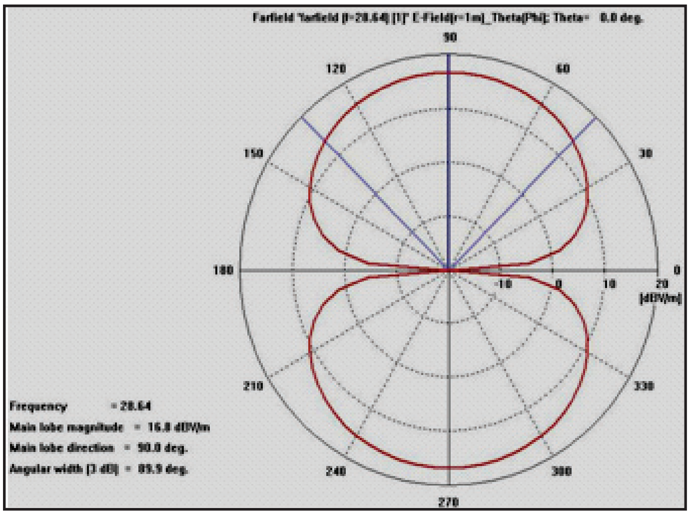


Fig. 7: Single patch antenna with E-Field

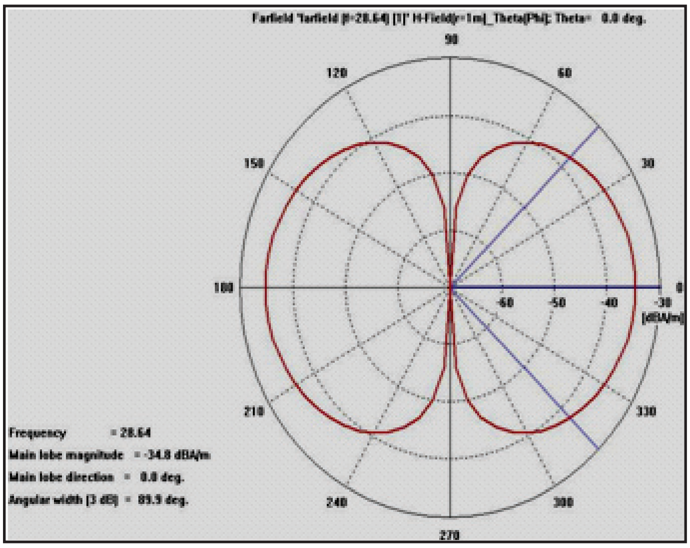


Fig. 8: Single patch antenna with H-Field

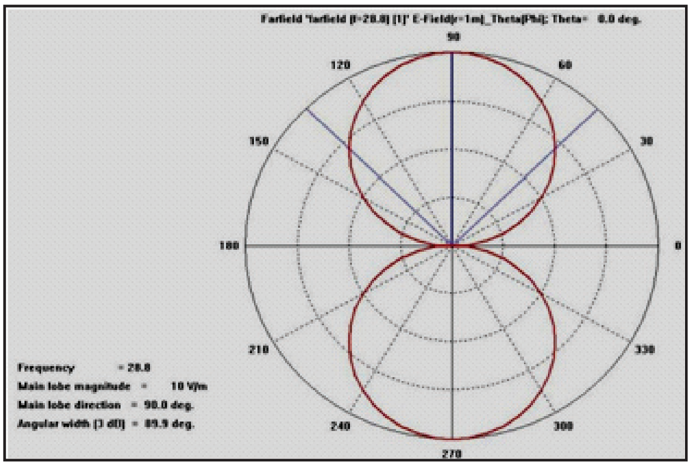


Fig. 9: 2x1Array antennas with E-Field

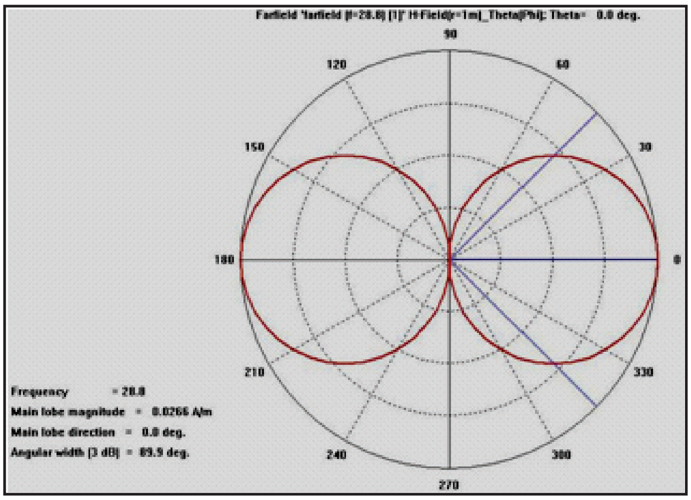


Fig. 10: 2x1Array antenna with H-Field

Table 2 shows the comparisons of different characteristics between single element and antenna array of 2×1 elements.

Table 2: Comparisons of Simulated Results

Quantity	Single patch	2x 1 Array
Patch Dimensions	12 x 10 mm	20 x 13 mm
Gain(dB)	5.95dB	6.30dB
Bandwidth	11.02 dB	15.29dB
Return loss (dB)	-16.00	-20.17
Directivity	5.90dBi	6.40dBi

V. Conclusion

The rectangular micro strip antenna array is designed using RT/ duroid5880 substrate which has the permittivity of value 2.2. Both models are designed using inset feed and works at frequency (f) =28.64 GHz for single patch antenna and -28.8 GHz for 2x1 patch antenna array The simulated 2x1 array models have better performance than single patch antenna which has been compared. The simulation shows a slight improvement in the return loss and gain in designed 2x1 arrays.

References

[1] Microstrip Antennas,“The Analysis and Design of Microstrip Antennas and Arrays”, David M. Pozar and Daniel H. Schaubert, Editors, Wiley/IEEE Press, 1995.

[2] Antenna Theory: Analysis and design/Constantine A. Balanis, third edition,Hoboken, NJ: Wiley, 2005.

[3] Yun Sun, Minghui Yang, Yang Hou, Kewu Han, Xiaowei Sun,"Designof a Ka-band Active Phase Array Antenna", ICMMT 2010 Proceedings

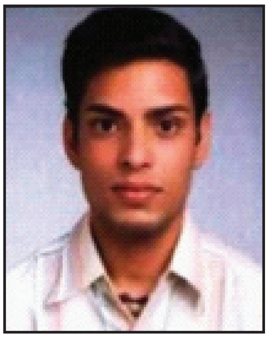
[4] M A Matin, M.P Saha, H. M. Hasan,"Design of Broadband Patch Antenna for WiMAX and WLAN", ICMMT 2010 Proceedings, pp. 1-3

[5] C.A. Balanis,"Antenna Theory Analysis and Design", 3rd edition, 2005.

[6] M. Ramesh, YIP KB,"Design Formula for Inset Fed Microstrip Antenna", Journal of Microwave and Optoelectronics, Vol. , No. 3, December 2003.

[7] K. Araki, A. Tanaka, E. Matsumura,"Wide Scanning Phased Array Antenna Design in Ka Band", IEEE Proc Microwave Antenna propagation, Vol. 150, No. 5 October 2003.

[8] S.Pinhas, S.Shtrikman,"Comparison between computed and measured bandwidth of quarter-wave microstrip radiators", IEEE Trans.Antennas Propag., Vol. 36, No. 11, pp. 1615–1616, 1988.



Shailendra Goswami received his B. Tech. degree in Electronics and Communication Engineering from Modi Institute of Technology, Kota, Rajasthan, in 2011. He pursuing his M.Tech. from University College of Engineering, Rajasthan Technical University, Kota, Rajasthan. He was Assistant professor in the department Of Electronics and Communication Engineering at MIT, Kota from Aug. 2013 to Sept. 2014.