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# Planar Rectangular Microstrip Patch Antenna Array with Corporate-Feed Network for Gain Enhancement

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***Abstract: The design and performance analysis of a inset-fed planar rectangular microstrip patch antenna array with corporate-feed network systems is presented in this paper. This design aims to increase the gain of the rectangular patch antenna through the use of a 16-element planar rectangular antenna array. Each element in this planar array is fed by T-junction power divider networks with quarter-wave transformer lines via the corporate-feed method. The antenna is designed over the operating frequency of 2.4 GHz using the substrate material FR-4, which has a dielectric constant of 4.4 and a loss tangent of 0.002. By the addition of radiating patches in the array design, the gain, directivity and bandwidth also has been improved significantly. The proposed antenna array provides a gain of 9.284 dB, a directivity of 16.2 dBi, and a bandwidth of 0.361 GHz. The designed antenna can be used for wireless applications.***
***Keywords: Corporate-feed, Inset-feed, Planar array, Power divider, Quarter-wave transformer***

## I. INTRODUCTION

Antennas are a vital component of modern wireless communication systems. Microstrip patch antennas have become very popular in recent years due to their light weight, low cost, low profile and ease of fabrication using printed circuit technology. Despite numerous advantages, the major limitations of microstrip antennas are their narrow bandwidth and low gain [1]. The microstrip antenna's gain and bandwidth can be enhanced in a variety of ways, such as by increasing its thickness, lowering the substrate's dielectric constant and implementing numerous feeding methods. Although they work as single elements, microstrip antennas are also regularly employed in arrays. An array antenna may provide better gain, directivity, and bandwidth than a single patch antenna. In a microstrip antenna array, individual elements are fed via corporate and series-feed techniques. The main limitation of series-feed arrays is their large variation in impedance. The corporate-feed network is used to provide power splits of $2^n$(i.e. $n$ = 2, 4, 8, 16, etc) [1]. This can be accomplished by using either tapered lines or quarter-wave transformer lines. The corporate-feed is ideal for scanning phased arrays, multibeam arrays or shaped-beam arrays. The main purpose of the study is to design microstrip antenna array for increasing the gain, improving directivity and enhancing bandwidth. In this research work, a single rectangular patch is designed to analyze the performance based on the inset-feeding technique. The single inset-fed rectangular patch is then arranged in a 4x4 planar array with the corporate feeding method to increase the gain, improve directivity and enhance bandwidth [2][3]. For better impedance matching and minimal return loss, the corporate-feed employs a T-junction power divider network with quarter-wave transformer lines [4].

## II. ANTENNA DESIGN

Inset-fed single rectangular patch antenna and 4x4 rectangular patch antenna arrays are designed for analysing the improvement of the above performance parameters. The proposed antennas are designed for 2.45 GHz and simulated using CST Microwave Studio Suite 2018 software.

### *A. Single Rectangular Patch Antenna*

The proposed antenna consists of a rectangular radiating patch and a ground plane on both the sides of FR-4 substrate. This radiating patch with a simple microstrip feeding technique will provide high impedance. To match the impedance with the 50 Ω feed line, an inset feed method is adopted in this design.

The microstrip-feed line width, inset gap and recessed distance are properly selected to match the impedance and minimize return loss. This antenna is designed for a resonant frequency of 2.45 GHz. The length and width of the rectangular patch antenna are calculated by the equations (1) and (2) respectively [1][5][7].

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

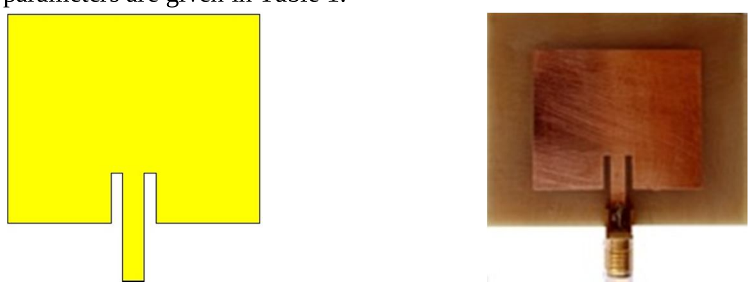
$$L = L_{eff} - 2\Delta L \quad (2)$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{r_{eff}}}} \quad (3)$$

$$\varepsilon_{r_{eff}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+12\frac{h}{W}}} \quad (4)$$

$$\Delta L = 0.412h\frac{\left[\varepsilon_{r_{eff}}+0.3\right]\left[\frac{W}{h}+0.264\right]}{\left[\varepsilon_{r_{eff}}-0.258\right]\left[\frac{W}{h}+0.8\right]} \quad (5)$$

Where, $W$ is the width of the substrate, $L$ is the length of the substrate, $f_r$ is the resonant frequency, $c$ is the speed of light in free space, $h$ is the thickness of the substrate, $\varepsilon_r$ is the dielectric constant of the substrate, $\varepsilon_{r_{eff}}$ is the effective dielectric constant, $L_{eff}$ is the effective length and $\Delta L$ is the extension length of the patch due to fringing field. The geometry of the proposed antenna is shown in the Fig. 1 and the optimized parameters are given in Table 1.



(a) (b)

Fig. 1 (a) Proposed inset-fed single patch structure, (b) Fabricated antenna

TABLE I

OPTIMIZED PARAMETERS OF INSET-FED SINGLE RECTANGULAR PATCH ANTENNA

| Parameters | Dimensions (mm) |
|---|---|
| Length of the patch | 29 |
| Width of the patch | 35 |
| Length of the ground plane | 45 |
| Width of the ground plane | 54 |
| Inset gap | 1.6 |
| Inset feed length | 7 |
| Feed line width | 3 |
| Feed line length | 8 |

### *B. Rectangular Patch Antenna Array*

The 4x4 rectangular patch antenna array is designed for 2.45 GHz resonant frequency with the same patch dimensions as the single element. The inter-element spacing is selected as 0.6λ to avoid coupling between patch and feed network, which will make the feed network to resonate [6]. As inter-element spacing increases, grating lobes appear in the radiation pattern. All the elements in the array are fed by corporate-feed technique with T-junction microstrip power divider network. In this power divider, quarter-wave impedance transformer lines are incorporated to match 50 Ω microstrip lines to 100 Ω lines. The quarter-wave transformer line characteristic impedance is calculated by using equation (6) [1][7].

$$Z_c = \sqrt{Z_{in} Z_0} \quad (6)$$

Where $Z_{in}$=100 Ω and $Z_0$=50 Ω. The characteristic impedance of this quarter-wave transformer line $Z_c$ is 70 Ω. The power divider network used in this study has been designed for a width of 0.8 mm for 100 Ω lines, 1.65 mm for 70 Ω lines, and 3 mm for 50 Ω lines. Fig. 2 shows the power divider used in the proposed rectangular antenna array.

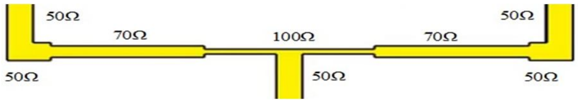
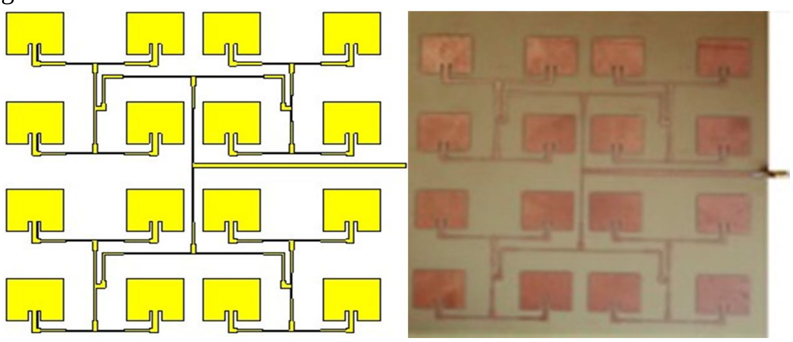



Fig. 2 Power divider with $\lambda/4$ transformer

Multiple-section of quarter-wave impedance transformers are employed in corporate-feed network to feed power to all the elements in the array. The design structure of the proposed 4x4 planar rectangular patch antenna array and the fabricated image of the proposed antenna array are shown in Fig. 3.

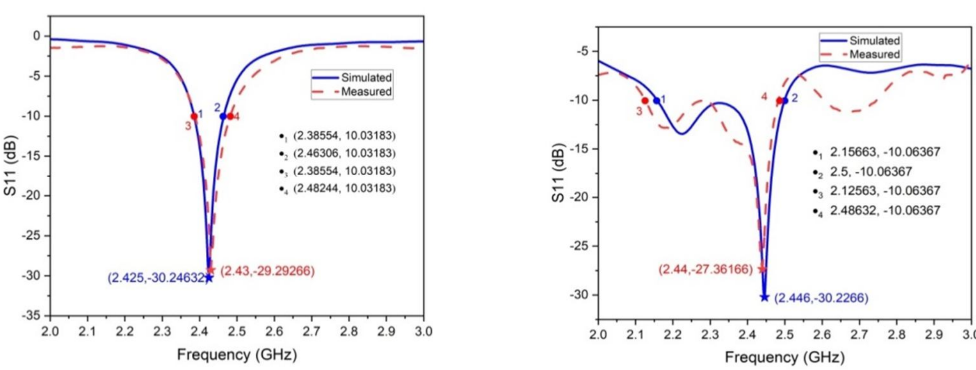


(a) (b)

Fig. 3 (a) Proposed array antenna structure, (b) Fabricated antenna

## III.RESULT AND DISCUSSION

Comparison between the simulated and measured results for the single rectangular patch antenna and the rectangular microstrip antenna array of 16-elements are discussed in this section. The simulated and measured return loss curves of the proposed inset-fed single rectangular patch antenna and rectangular microstrip antenna array are illustrated in Fig. 4. Good agreement exists between the simulated and measured return losses for both antennas. Single element antenna provides a return loss of -30.246 dB at a resonant frequency of 2.425 GHz by simulation and -29.293 dB at a resonant frequency of 2.43 GHz by practical measurement. It gives a bandwidth of 77.52 MHz and 96.9 MHz from the simulated and measured plot respectively. But the 4x4 array antenna provides a return loss of -30.22 dB at a resonant frequency of 2.446 GHz by simulation and by measurement the return loss obtained is -27.36 dB at a resonant frequency of 2.44 GHz. The simulation gives a bandwidth of 0.343 GHz and by measurement 0.361 GHz of bandwidth is achieved. There is a significant improvement in the bandwidth of the antenna by the addition of radiating patches in the array antenna.




(a) (b)

Fig. 4 Proposed antenna return loss (a) Single patch, (b) Array antenna

Fig. 5 describes the realized gain verses frequency plot of the proposed single rectangular patch antenna and rectangular antenna array. An improved gain of 9.284 dB has been achieved with a planar array of 16-element inset-fed rectangular patch antennas, while the maximum gain obtained by a single-element antenna is 2.205 dB.

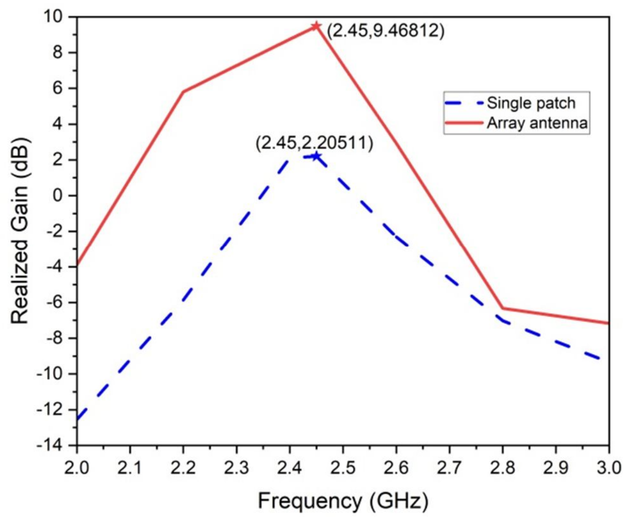
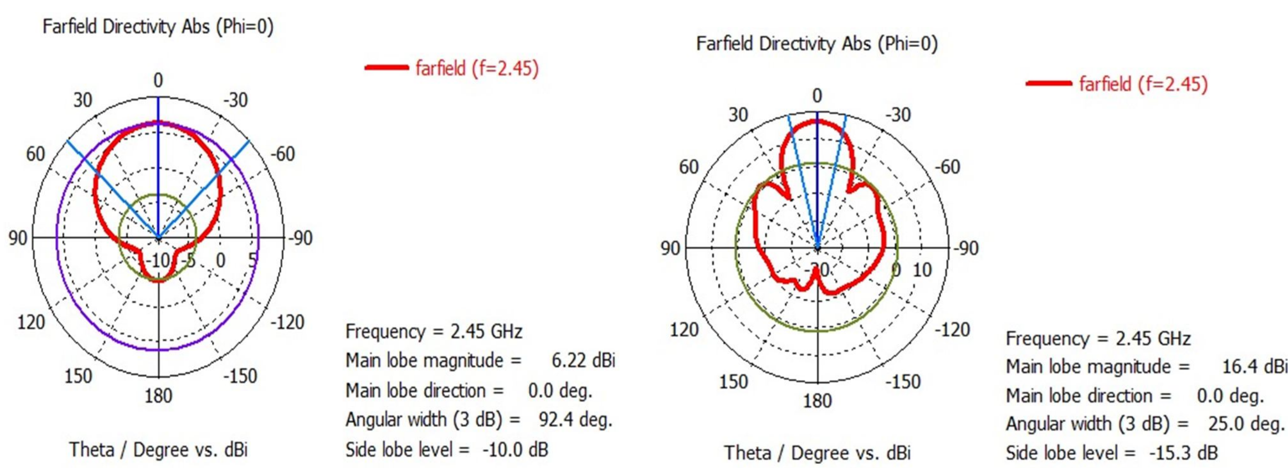



Fig. 5 Gain vs. frequency plot of proposed single patch antenna and array antenna

The radiation patterns of both the proposed antennas are shown in Fig. 6. The maximum directivity obtained by this antenna is 6.22 dBi and the half power beamwidth is 92.4$^o$. With the addition of radiating elements, the 4x4 array antenna's directivity improved and narrowed its beamwidth. The maximum directivity of 16.4 dBi obtained by 4x4 array antenna with a half power beamwidth of 25$^o$.




(a) (b)

Fig. 6 Proposed antenna radiation pattern (a) Single patch, (b) Array antenna

The proposed single rectangular patch and 4x4 patch antenna arrays' simulated and measured VSWR and impedance are illustrated in Fig. 7 and Fig. 8. For both the proposed antennas, there is a good matching between the measured and simulated values of these parameters. Simulated and measured results of inset-fed single element rectangular patch and 4x4 planar array antennas are listed in Table 2. This proposed work achieves comparatively high performance characteristics with an array of 16-elements of inset-fed rectangular microstrip patch antenna. Along with the increase in the antenna size due to the addition of radiating patches in the array design, the gain, directivity and bandwidth also has been improved significantly.

TABLE 2
RESULTS OF SINGLE PATCH ANTENNA AND ANTENNA ARRAY

| Parameters | Single patch antenna | | Antenna array | |
|---|---|---|---|---|
| | *Simulated* | *Measured* | *Simulated* | *Measured* |
| Resonant frequency | 2.425 GHz | 2.43 GHz | 2.446 GHz | 2.44 GHz |
| Return loss | -30.246 dB | -29.293 dB | -30.22 dB | -27.36 dB |
| Bandwidth | 77.52 MHz | 96.9 MHz | 0.343 GHz | 0.361 GHz |
| Gain | 2.205 dB | - | 9.284 dB | - |
| Directivity | 6.22 dBi | - | 16.2 dBi | - |
| Beamwidth | $92.5^0$ | - | $24.6^0$ | - |
| VSWR | 1.063 | 1.056 | 1.044 | 1.059 |
| Impedance | 49.58 Ω | 47.65 Ω | 50.53 Ω | 49.88 Ω |

## IV. CONCLUSIONS

Inset-fed planar rectangular microstrip patch array antenna using corporate feeding technique is presented in this paper. The gain, directivity and bandwidth of the proposed planar antenna have been improved by increasing the number of array elements and feeding these elements through the corporate feed method. The use of quarter wave transformers into the corporate feed power divider network has improved the impedance matching in the proposed planar array antenna. The planar array antenna provides good performance characteristics. The prototypes of all the simulated antennas are fabricated on FR-4 substrate and measured results are in good agreement with those obtained from simulations. These designed antennas are very simple, cost effective and high efficiency for the applications in S-band frequency ranges like WiFi, WLAN and Bluetooth services.

## V. ACKNOWLEDGMENT

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