

# Designing of a 2x2 E-shaped Microstrip Patch Grid Antenna

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**Abstract**— In this work, a 2×2 grid of E-shaped patch antennas is proposed. The design of the grid is achieved through the design of a single element, the design of a 1×2 array and finally the design of the 2×2 grid on an FR4 epoxy substrate of thickness 1.5 mm. A corporate feed network of microstrip lines is used to excite the array. The performance of each stage is studied in terms of the return loss parameter, the far field gain, and the beam-widths are observed in each case from simulation results. The resonant frequency in each case is 3.8 GHz. It is observed that as the number of elements is increased, the beam-width reduces. In other words, the directivity is increased. Further, it is also observed that the gain and bandwidth is the minimum for the single patch, followed by that of the 1×2 array and the maximum for the 2×2 grid. Thus, the construction of the grid leads to increase in gain, bandwidth and directivity of the antenna.

**Keywords**— Microstrip patch antenna, 3.8GHz, stub matching, 2x2 grid pattern, Antenna gain

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## 1. Introduction

Microstrip patch antennas have received significant attention worldwide in the past few decades because of its small size, low profile, light weight, low production cost and other aspects of the advantage [1][2]. Today it is widely being used in mobile communications, satellite communications, radar, and other various fields [3]. The performance of an antenna can be enhanced in terms of different parameters by constructing an array of microstrip antennas. Till now various array forms of microstrip patch antennas have been designed [4]-[7] for various applications such as GSM, radar etc. An array can be designed as a one dimensional array consisting of antenna elements along a line or it can be designed in a grid pattern by placing equal numbers of patch in row and column wise as in [3][4]. In addition to the basic advantages of the microstrip patch antenna, the grid pattern antenna has the advantages of high gain, high bandwidth, narrow focused beam, low sidelobe and radiation characteristics [9].

In this paper a 2×2 microstrip patch grid antenna is designed at 3.8 GHz frequency. The antenna is having an E-shaped patch, as it has a larger bandwidth as compared to a rectangular patch [10]. The antenna is designed with a single patch first and then it is transformed to a 1×2 array. Finally a 2×2 grid of microstrip patch antennas is derived out by combining two 1×2 arrays. Initially, a quarter wavelength transformer is used for impedance matching in the 1×2 array. A stub matching technique is used in case of the 2×2 grid to ensure that return loss is below -15 dB.

The design procedure of all the three configurations: the single patch, the 1×2 array, and the 2×2 grid is discussed in section II. Section III includes the simulation and measurement results and discussions of the work. Finally, the conclusions are made in section IV.

## 2. Design Procedure

The design procedure involves the design of the single patch antenna element followed by the design of a 1×2 array and finally a 2×2 grid of microstrip antennas. FR4 epoxy substrate with a dielectric constant,  $\epsilon_r$  of 4.4 and a thickness of 1.5 mm is used for the designs. The details of these design steps are discussed as follows.

### 2.1 Design of a Single Patch E-shaped Antenna

The topology of the E-shaped patch antenna element and its various geometrical parameters are shown in Figure 1. The dimensions are experimentally tuned with Ansys HFSS to obtain resonance at 3.8 GHz with a return loss of -16 dB. The final dimensions of the patch are shown in Table 1.

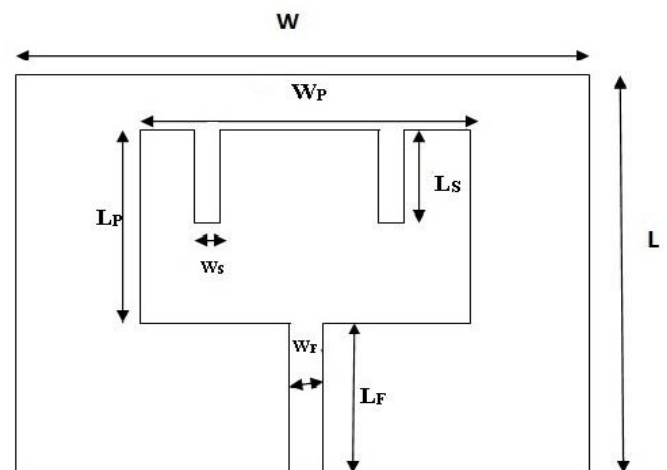


Fig.1 Micro strip single patch E- shaped antenna

TABLE I. DIMENSIONS OF SINGLE PATCH ANTENNA

Specifications	Dimensions (in mm)
Length of the substrate, L	60
Width of the substrate, W	60
Length of patch, $L_P$	18.4
Width of patch, $W_P$	25
Feed width, $W_F$	2.868
Slot length, $L_S$	0.8
Slot width, $W_S$	0.5

**B. 1x2 Patch Antenna design**

The 1x2 array is designed using the E-shaped patch antenna as elements. The dimensions of the patch are kept the same so that the array also resonates at 3.8 GHz. In this design a corporate feeding network is used. The patch elements are fed in parallel using microstrip transmission lines. These lines are divided into two branches in order to match the impedance of patch elements. The power divider accomplished by using quarter wavelength transformer [11] with 70.71 ohm to match 100 ohm to 50 ohm as in [6]. The patch spacing kept is  $\lambda/4$  that is 19.723 mm. Fig. 2 shows the design view of the specified.

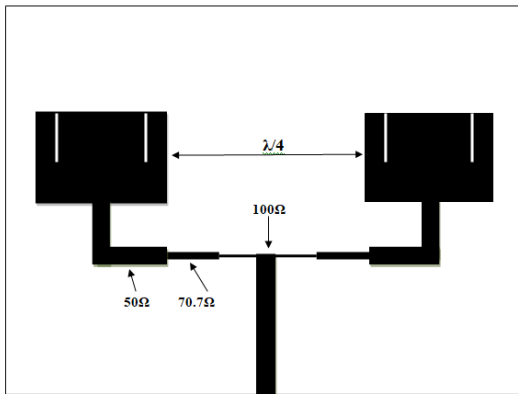


Fig.2. Layout of 1x 2 patch antenna

**C. 2x2 Grid micro strip patch design**

In the design of 2x2 micro strip patch grid antenna, four patch elements are used in a grid shape as shown in Figure 3. The feed line splits into two branches as in case of the 1x2 array. Each branch further splits into two sub-branches each of which excites one E-shaped patch antenna as in [7]. Quarter wavelength transformer technique is used in each split to ensure proper impedance matching. Each element has the same dimensions as discussed in Section II (a) above.

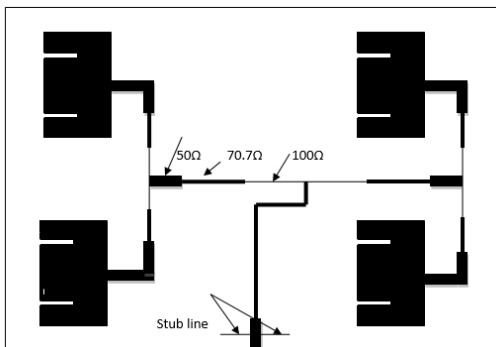


Fig.3. Layout of 2x 2 Micro strip patch Grid antenna

Although quarter wavelength transformers are used at each split of the corporate feeding network, experimentally it was observed that the impedance was not perfectly matched and the return loss was above -10 dB. To further improve the impedance matching, stub lines are used just near the feed position of the corporate network as shown in Figure 3. Each of the two stub lines has a width of 0.5 mm and length of 5 mm. A similar approach for impedance matching was reported in [5].

**3. Results and Discussion**

The single patch antenna, the 1x2 array and the 2x2 grid are designed and simulated to analyze the results. The final 2x2 element is fabricated on a copper-FR4 epoxy PCB and the performance is measured using a vector network analyzer (VNA) and a radiation pattern measurement setup. The simulation and measurement results are discussed in this section.

**3.1 Analysis of Resonant Frequency and Return Loss**

The frequency response of the return loss parameter (S11), obtained for the single patch antenna from simulation results, is shown in Fig. 4. It is observed that the antenna has a resonant frequency of 3.8 GHz and a bandwidth of 140 MHz. The return loss obtained at 3.8 GHz is -15 dB.

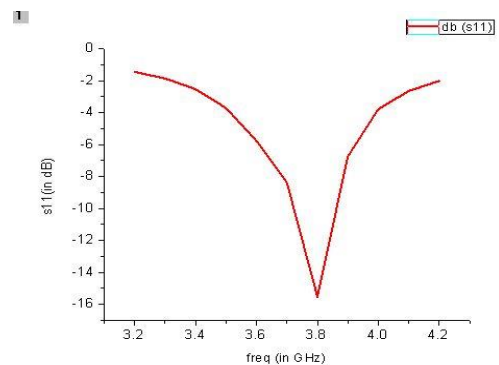


Fig.4. Return loss plot for E-shaped single patch antenna

In case of 1x2 array, the S11 vs. frequency plot is shown in Fig. 5. The resonating at desired frequency of this structure is also obtained at 3.8 GHz with a bandwidth of 145 MHz. The return loss obtained at the resonating frequency is -25 dB.

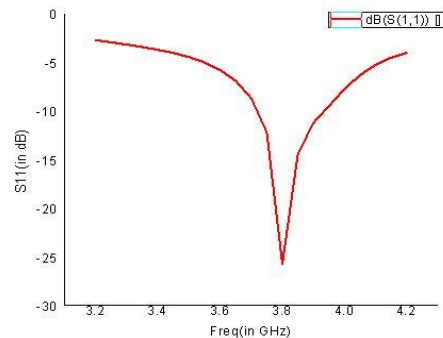


Fig.5. Comparison plot of s11 for single patch and 1x2 antenna

Figure 6 shows the return loss for our desired 2x2 grid antenna. From the plot it can be seen that the antenna is delivering the minimum return loss of -16.5 dB, with a bandwidth of 160 MHz.

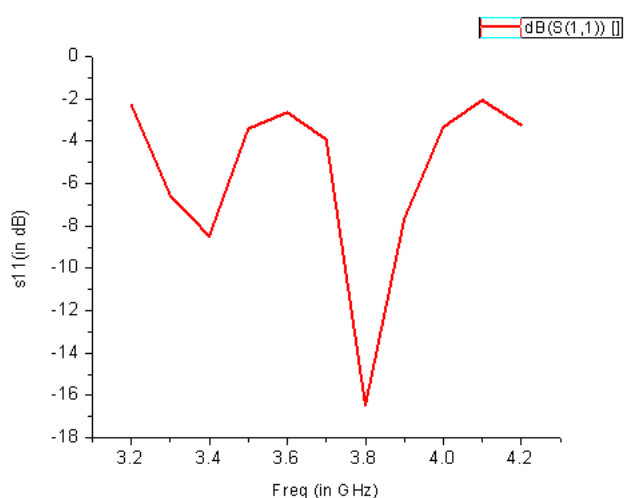


Fig.6 Return loss plot for E-shaped 2x 2 grid pattern antenna

### 3.2 Antenna Gain and Radiation Pattern

Obtaining enhanced gain and narrow beamwidth is the key advantage of constructing arrays from individual antenna elements. The radiation patterns of the far field gain of each of the three stages of the design are obtained from simulation results and compared.

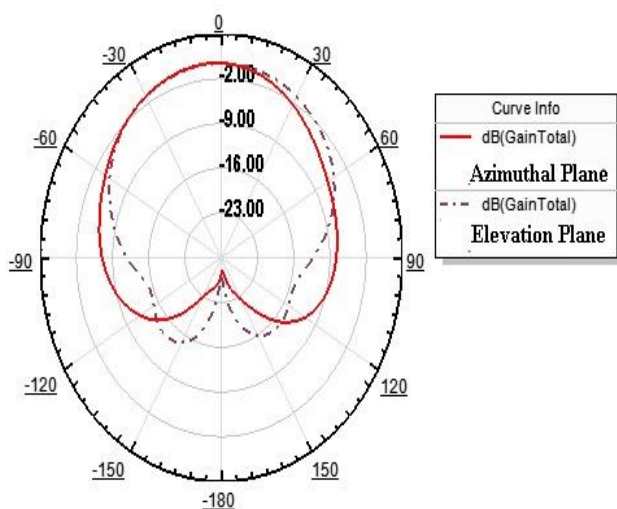


Fig.7. Radiation pattern of single patch antenna

Fig. 7, 8 and 9 show the far field radiation pattern in the azimuthal plane and elevation plane of the single patch antenna, the 1x2 array and the 2x2 grid structure respectively. It is observed that the single patch has a peak gain of 2.3 dBi along the direction of the major lobe. The 1x2 array has a peak gain of 3.4 dBi and the 2x2 grid has a peak gain of 6.5 dBi. Thus, the gain is enhanced as the number of elements in an array is more.

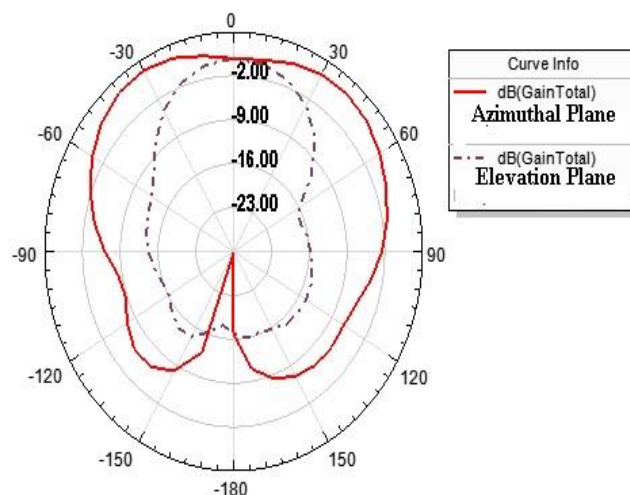


Fig.8. Radiation pattern of 1 x 2 patch antenna

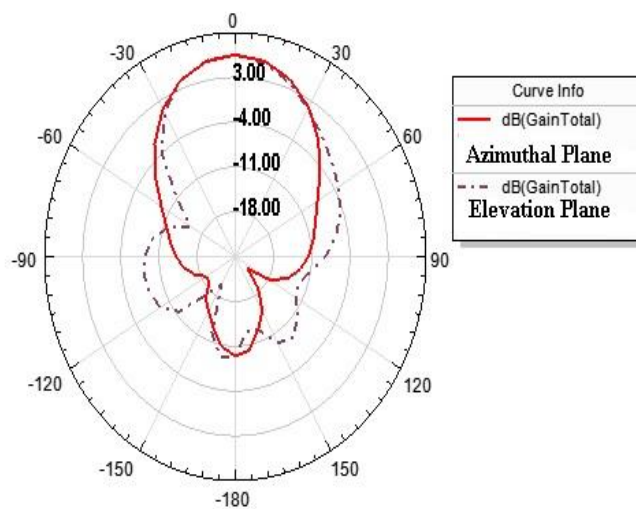


Fig.9. Radiation pattern of 2 x 2 Grid micro strip antenna

Comparing Fig. 7 and 8, it is observed that the 1x2 array has a narrower beamwidth in the elevation plane compared to the single patch. However, in the azimuthal plane, the presence of a single broadside lobe is not observed. When Fig. 9 is compared with Fig. 7 it is observed that the major lobe of the 2x2 grid is significantly narrow as compared to the single antenna element and the 1x2 array in both the azimuthal plane and the elevation plane.

### 3.3 Fabrication and Measurement Results

The final 2x2 grid antenna is fabricated on a copper-FR4 epoxy substrate as shown in Fig. 10. The frequency vs. S11 parameter plot obtained from VNA for the fabricated antenna is compared with the simulation result in Fig. 11. The measured far field radiation pattern of the antenna in the azimuthal plane and the elevation plane is shown in Fig. 12.

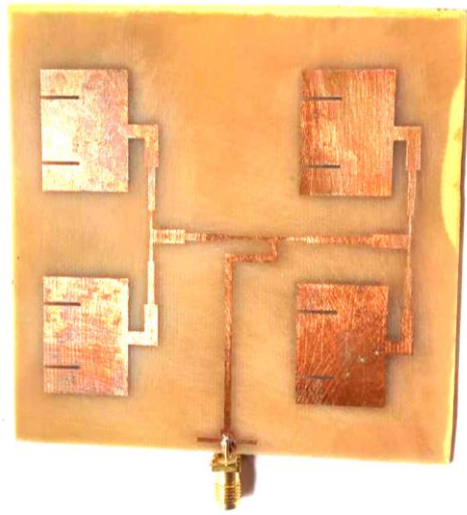


Fig. 10: The fabricated 2x2 grid array with E-shaped patch antenna elements

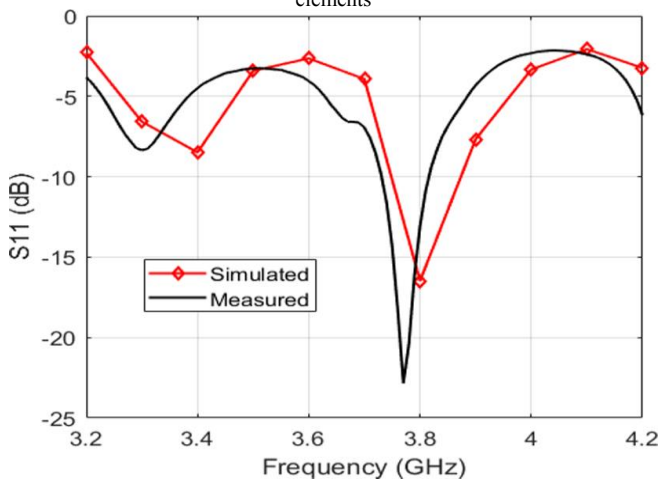


Fig. 11 Comparison of the simulated and measured S11 parameter plot for the 2x2 grid antenna

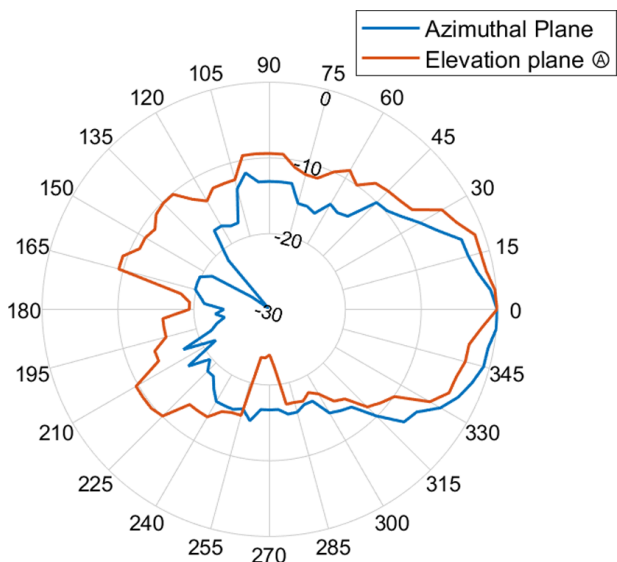


Fig. 12 Measured normalized radiation pattern of the 2x2 grid antenna in the azimuthal plane and the elevation plane

It is observed from the measurement results that the antenna resonates at 3.77 GHz which is very close to 3.8 GHz. The

radiation pattern of the fabricated grid antenna is almost similar to the simulation result.

### 3.4 Discussion

From the analysis of the resonant frequency and return loss presented in Section III (A), it is observed that the bandwidth of the antenna for the 1x2 array is more than that of the single patch antenna by around 5 MHz. The bandwidth further increases by about 15 MHz when the 2x2 grid is constructed as compared to the 1x2 array. The 2x2 grid has a bandwidth of 160 MHz which is significantly large in comparison with a single patch antenna.

In each case, a directional radiation pattern is obtained. The far field peak gain increases as the number of elements is more as discussed in Section III (B).

The comparison of these parameters are presented in Table II.

TABLE II. COMPARISON TABLE OF RESULTS

Antenna specifications	Antenna configuration type		
	Single patch	1x2 array	2x2 grid
Bandwidth (in MHz)	140	145	160
Gain (in dBi)	2.3	3.4	6.5
Radiation pattern	Directional	Directional	Directional

### 4. Conclusions

The proposed design and the experimental results show that by constructing a 2x2 grid of E-shaped patch antenna elements, the gain, the bandwidth and the directivity can be enhanced. The 2x2 grid yields a larger gain and bandwidth compared to a single patch antenna and a one-dimensional 1x2 array. From the comparative analysis of the radiation patterns as presented in Section II(B), it may be concluded that a one dimensional array of microstrip antennas enhance the directivity of the antenna only in the azimuthal plane. The proposed 2x2 grid of the antenna increases the directivity in both the azimuthal plane and the elevation plane. This is an additional advantage of a 2-dimensional grid of microstrip antennas.

### 5. Acknowledgment

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