

Gain Enhancement of Series Feed Square Patch Microstrip Antenna Array for S band & C Band Applications

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Abstract— Gain is the ability of an antenna to concentrate the radiated power in a desired direction. Only small gain can be achieved by single antenna that is why, antenna arrays are required to improve the gain by using different feed networks. This paper describes the design and performance of a series feed antenna array. The operating frequency of 2.4GHz is used. The aim of this paper is to improve the gain of a series feed antenna array. Line feed is used for designing single antenna, 2x1 & 4x1 microstrip antenna array. These series feed microstrip antenna arrays are useful for both S and C band. The proposed antenna is simulated by IE3D version 9.0 Zealand simulation software based on method of moments.

Keywords: patch antenna, enhance gain, Microstrip Patch antenna array, microstrip line feed

I. INTRODUCTION

A microstrip patch antenna consists of a radiating patch on one side and ground plane on the other with a dielectric substrate between them. Microstrip patch antenna possesses many advantages such as low profile, light weight, small volume and compatibility with microwave integrated circuit (MIC) and monolithic microwave integrated circuit (MMIC) but the major drawback of microstrip antenna is its narrow bandwidth and low gain. The use of Microstrip arrays is limited in a way that they tend to radiate efficiently only over a narrow band of frequencies and they cannot operate at the high power levels of waveguide, coaxial line or even stripline [1]. In various communication and radar systems microstrip antenna can be very useful. Microstrip antennas are very versatile and can be used amongst other things, to synthesize a desired pattern that cannot be achieved with a single element. In addition, they can also be used to scan the beam of an antenna system, increase the directivity and perform various other functions which would be difficult with a single element. The elements can be feed by a single line or by multiple lines in a feed network arrangement. The first is referred as the *series-feed network* while the second is referred as *corporate-feed network* [2]. Antenna arrays are used to enhance the gain. This paper presents the characteristic of microstrip antenna arrays, there performance comparisons are also given for better understanding. In the present work the gain of antenna is increased upto 11.50 db by using the series feed methods. The proposed antenna arrays are designed on glass epoxy substrate ($\epsilon_r=4.4$) [6]. The substrate material has large influence in determining the size and bandwidth of an antenna. Increasing the dielectric constant decreases the size but lowers the bandwidth and efficiency of antenna while decreasing the dielectric constant increases the bandwidth but with an increase in size. The design frequency of proposed antenna is 2.4 GHz.

II. MICROSTRIP SERIES FEED ANTENNA ARRAY DESIGN

Microstrip antennas are used not only as single elements but are very popular in arrays. The objective of the study of antenna array is to increase the gain and directivity of antenna. The greater the number of elements in an array, the more is its directivity and consequently will have a greater gain. The use of antenna arrays has been increased vastly in telecommunications. If we reduce the width of the patch, the radiation impedance is insufficient to match the input impedance. We can use the microstrip patch as a transmission line and connect a line opposite to the feed to lead the other patches. If we space the patches by half wavelength, the impedance of the patches will add in phase at the input. The Characteristic impedance of the connecting lines has no effect at center frequency. The junction of transmission-line feeder and the patch introduces extra phase shift. A major limitation in series-feed arrays is the large variation of the impedance and beam-pointing direction over a band of frequencies.

III. ANTENNA DESIGN

For designing a rectangular Microstrip patch antenna, the length and width are calculated as below [4]

$$W = \frac{c}{2fr} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

Where c is the velocity of light, ϵ_r is the dielectric constant of substrate, f_r is the antenna design frequency, W is the patch width, and the effective dielectric constant ϵ_{reff} is given as [4]

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}} \quad (2)$$

At $h=1.6\text{mm}$

The extension length ΔL is calculated as [4]

$$\frac{\Delta L}{h} = 0.412 \frac{(\epsilon_{\text{reff}} + 0.3) \left(\frac{W}{h} + 2.64\right)}{(\epsilon_{\text{reff}} - 2.58) \left(\frac{W}{h} + 0.8\right)} \quad (3)$$

By using the above mentioned equation we can find the value of actual length of the patch as [4]

$$L = \frac{c}{2fr \sqrt{\epsilon_{\text{reff}}}} - 2\Delta L \quad (4)$$

The length and the width of the ground plane can be calculated a [4]

$$L_g = 6h + L \quad (5)$$

$$W_g = 6h + W \quad (6)$$

A. Calculation for Square Patch

It is known that equal areas provide equal radiations. So by equating the areas of rectangular and square patches we get

$$L \times W = A^2$$

Where L and W is the length and width of the rectangle respectively and A is the side of square.

IV. ANTENNA DESIGN SPECIFICATIONS

The proposed antenna is designed by using glass epoxy substrate which has a dielectric constant of 4.4 and the design frequency 2.4 GHz. The dimensions of the rectangular patch are 38.39 mm and 29.82 mm but for the square patch it comes out to be 33.83 mm. The ground plane length and width are taken 43.83 mm and 43.83mm respectively.. Length and width of feed network is 15mmx2mm respectively. Dimensions of the line feed are 8mmx4mm. Height of the dielectric substrate is 1.6mm and loss tangent $\tan \delta$ is .0013. Simulation work is done by using IE3D simulation software. All the specifications are given in the table1.

V. ANTENNA DESIGN PROCEDURE

All the dimensions of proposed antenna and antenna arrays should be calculated very carefully by using the equations 1, 2, 3, 4, 5 and 6. Design frequency of 2.4 GHz is selected for making the proposed microstrip antenna array. The geometry of proposed antenna array is shown in fig 1, fig 4 & fig 9. Line feed is used to achieve the maximum gain while designing the proposed antenna array on IE3D.

S. No.	Parameters	Value (mm)
1.	design frequency f_r	2.4
2.	dielectric constant ϵ_r	4.4
3.	substrate height	1.6
4.	patch width	38.39
5.	patch length	29.82
6.	ground plane width	43.83
7.	ground plane length	43.83
8.	Width of feed network for series array	2
9.	Side of square	33.83

Table: 1 antenna design specifications

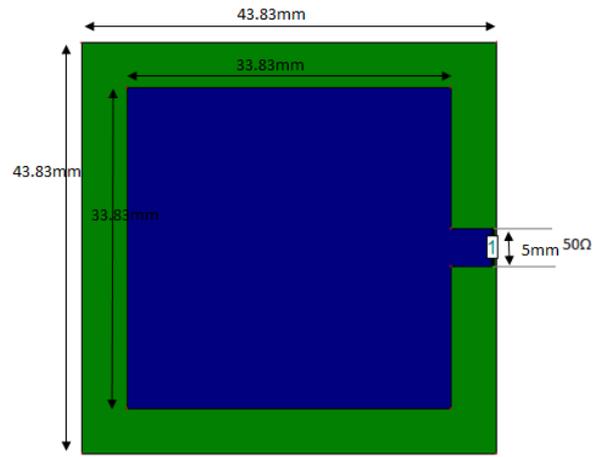


Fig. 1: Single antenna

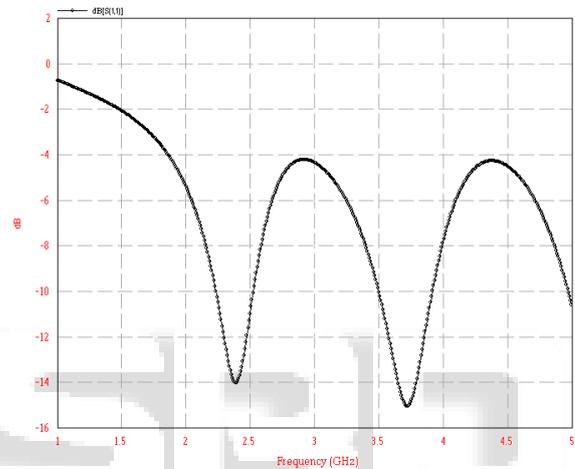


Fig. 2: Return loss v/s frequency graph

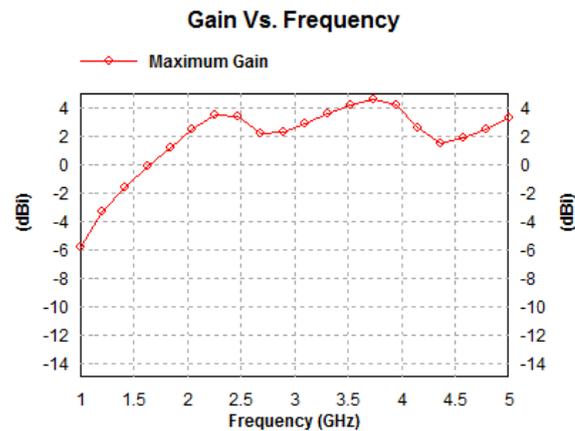


Fig. 3: Gain v/s frequency graph

First band operating range = 2.25-2.52

Second band operating range = 3.50-3.82
Gain = 5 dB

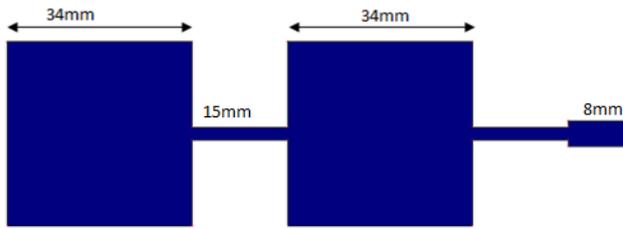


Fig. 4: 2x1 Series feed Microstrip antenna array

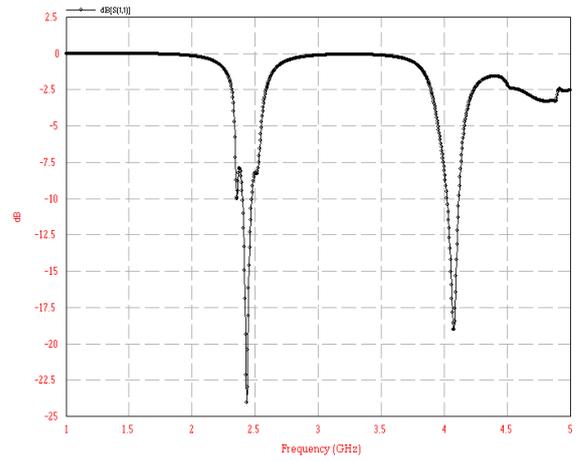


Fig. 7: Return loss v/s frequency graph

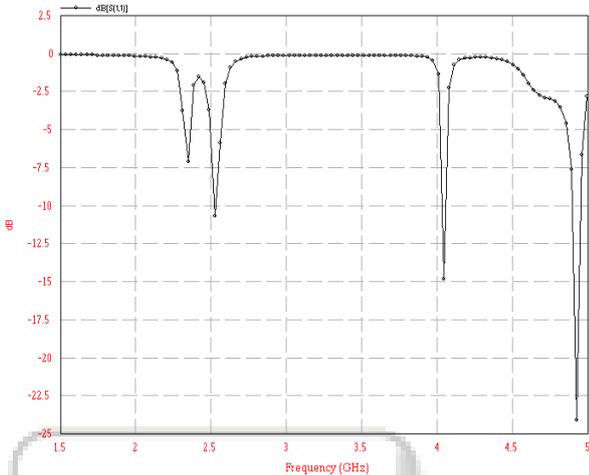


Fig. 5: Return loss v/s frequency graph

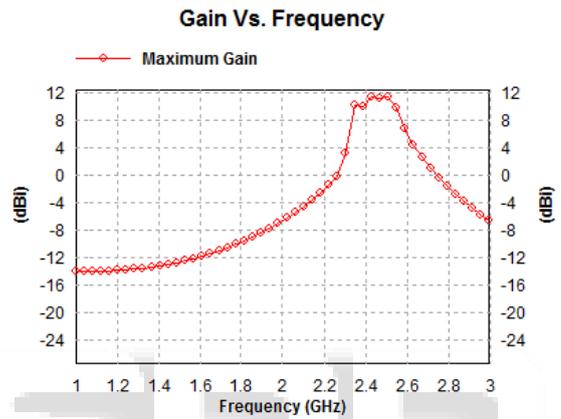


Fig. 8: gain v/s frequency

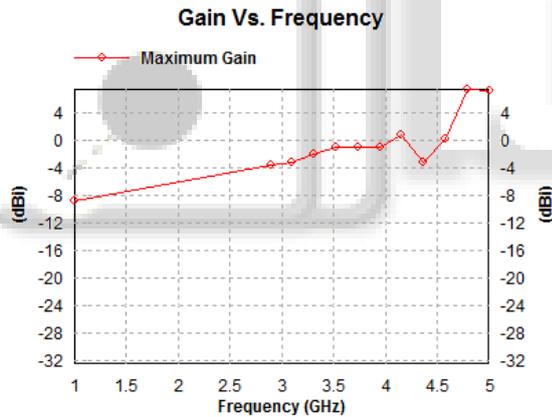


Fig. 6: gain v/s frequency graph

First band Operating range = 2.39 – 2.47
Second band operating range = 4.023 – 4.12
Gain = 11.50 dB

First band Operating range = 2.52-2.53
Second band operating range = 4.82-4.9
Gain = 7.9 dB



Fig. 9: 4x1 series feed Microstrip antenna array.

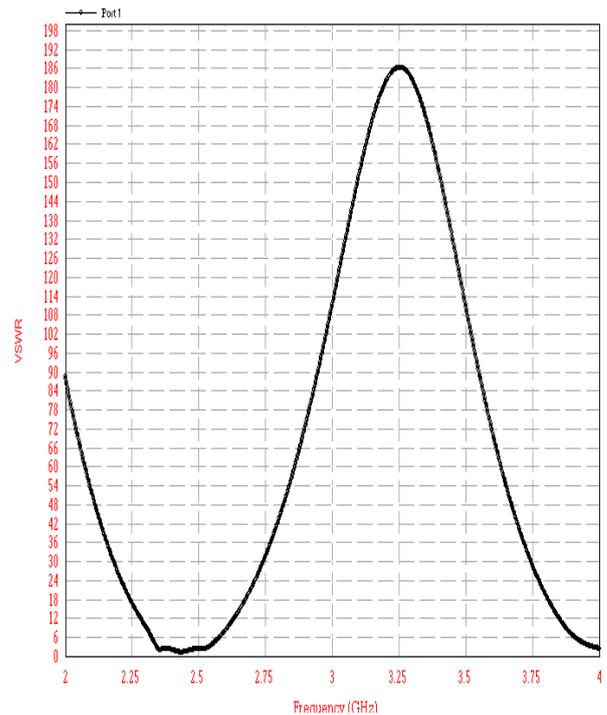


Fig. 10: VSWR of 4x1 series feed antenna array figures

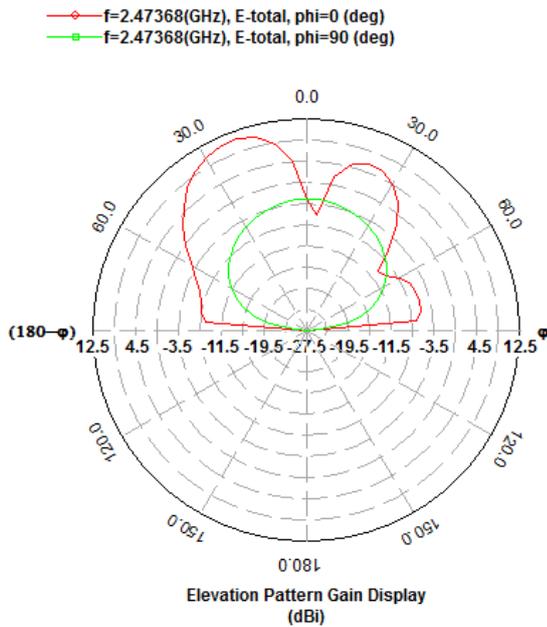
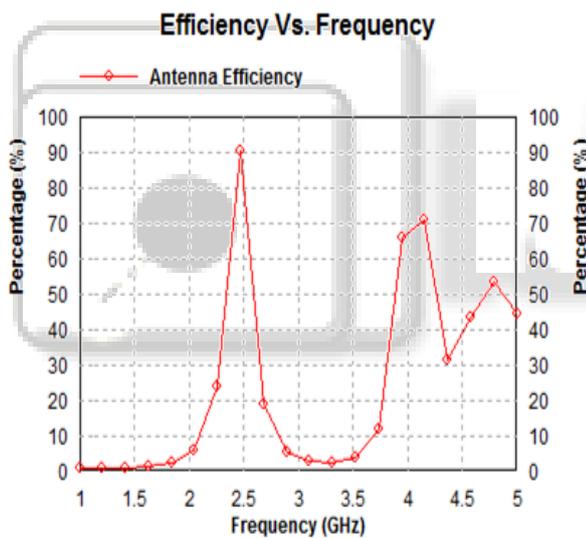


Fig. 11: Radiation pattern of 4x1 series feed antenna array



VI. RESULT AND DISCUSSION

Low gain of microstrip patch antenna is one of the major drawback that restrict its wide usage. In the present work the gain of microstrip square patch array is enhanced by different series feed designs. The operating range of single antenna is 2.25 to 2.53 & 3.50 to 3.82GHz & gain is 5db, for 2x1 antenna array operating range is 4.02 to 4.07 & 4.82 to 4.92 GHz & gain is 7.9db & for 4x1 antenna array operating range is 2.39 to 2.47 & 4.02 to 4.12GHz, and gain is 11.50db. The efficiency of proposed antenna array is found to be 90%. The VSWR of the antenna array is between 1 to 2 at resonant frequency.

The simulation performance of proposed microstrip square patch antenna array is analyzed by using IE3D version 9.0 software at the design frequency of 2.4 GHz. The performance specifications like bandwidth, radiation pattern, gain etc are shown via graphs. The results of

different antennas designed are gathered and shown in the following table.

Array	Operating range	Return loss	Gain	No. of band
Single antenna	2.25-2.52, 3.50-3.821	-14, -15	5	2
Series feed 2x1	2.25-2.53, 4.82-4.92	-14.9, -24	7.9	2
Series feed 4x1	2.33-2.48, 4.023-4.12	-24, -19	11.50	2

VII. CONCLUSION

The characteristics of single square patch antenna, 2x1 & 4x1 series feed antenna arrays are studied. As we can see in above table the gain of the 4x1 antenna array is maximum as compared to other two antenna arrays so we can conclude that gain is increased by increasing the no. patches in series feed. These arrays can be useful for both s and c bands. The proposed antenna array has been designed on glass epoxy substrate to give a maximum radiating efficiency of about 90% and gain of 11.50 dB using series feed 4x1 microstrip antenna array.

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