DESIGN OF FOUR AND EIGHT ELEMENT MICROSTRIP ARRAY ANTENNA FOR WLAN COMMUNICATION

[1]Prakash Gani, [2]Shriram P Hegde,

[1]Assistant Professor, [2]Professor,
Department of Electronics and Communication Engineering,
S D M Institute of Technology, Ujire, India

Abstract: This study interprets the design and analysis of four element and eight element microstrip array antenna for C-band applications such as, many satellite communication transmissions, some Wi-Fi devices, some cordless telephones as well as some surveillance and weather radar systems. The performance and few advantages of microstrip antenna made them an area of interest for wireless power transmission applications. In this paper an attempt is made to improve the return loss and gain of an antenna by designing and comparing the return loss, and gain results of the two arrays involving four element and eight element microstrip patch antenna. It is an extended work of the single element antenna designed for the operating frequency of 4.7 GHz. The idea of microstrip array antenna is due the main advantages of microstrip antenna like light weight and low volume. It has low profile configuration which can be easily conformal to the host surface. The fabrication cost is low hence, can be manufactured in large quantities. It supports linear and circular polarization, and it can be easily integrated with microwave integrated circuits. It is also capable of dual and triple frequency operations. Thus, Microstrip array antenna is mechanically robust when mounted on rigid surfaces.

Index Terms **– FR4, arrays, return loss, gain.**

I. INTRODUCTION

An antenna is an electric conductor that acts as both transmitter and receiver where transmitter radiates electromagnetic energy into the space and receiver collects electromagnetic energy from the space. The major parameters considered for a designed antenna are antenna gain, return loss and bandwidth. Gain is the measure of the ability of the antenna to direct the input power into the radiation in a direction which is measured at peak intensity radiation. Return loss is the parameter that indicates the amount of power that is lost to the load and does not return as a reflection. Similarly, Bandwidth is the range of frequencies over which an antenna produces a level of performance. Thus, in this paper it is focused on these three parameters and their improvement. In this paper the design is restricted to the array antennas. Since the arrays are versatile and used to synthesize required pattern that cannot be achieved with a single element. In addition to this, arrays are used to increase directivity, and perform various other functions which would be difficult with one single element. Thus, the Four element and Eight element microstrip array antennas are designed to improve the gain, return loss, Bandwidth, and overall performance of the array than that obtained for single patch antennas. As it is array antenna, corporate feeding is used to provide power splits of 2^n, where n=2, 4, 6, 8…, etc.

II. Design of Single Patch antenna

The first design step is to select a suitable dielectric substrate of appropriate thickness. For a dielectric substrate of thickness h, the width of the antenna is calculated for an operating frequency f_r. Using,

$$W = \frac{C}{2f_r}\left(\frac{\epsilon_r + 1}{2}\right)^{-1/2}$$

Where C = velocity of light

Once W is known, the effective dielectric constant ϵ_e and the line extension Δl is calculated using the expression respectively,

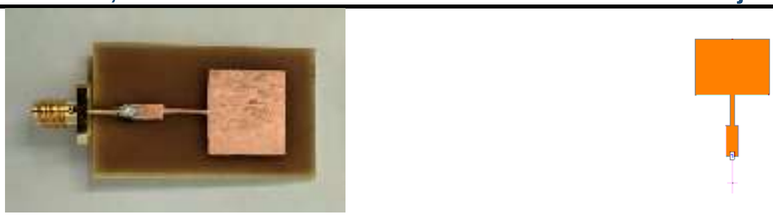
$$\epsilon_e = \frac{\epsilon_e+1}{2} + \frac{\epsilon_e-1}{2}\left(1+\frac{12h}{W}\right)^{-1/2}$$

$$(\Delta l) = 0.412h\,\frac{(\epsilon_e + 0.3)(W/h + 0.264)}{(\epsilon_e - 0.258)(W/h + 0.8)}$$

Now the length of the resonant patch is then calculated using the relation given below,

$$L = \frac{C}{2f_r\sqrt{\epsilon_e}} - 2\Delta l$$

The length and width both decreases with increase in operating frequency. A simple microstrip patch antenna consists of a very thin metal patch of dimensions $L \times W$ placed on a dielectric substrate fabricated on a metallic ground plane as shown in figure 1. The antenna is designed using IE3D software with FR4 material as a substrate with a dielectric constant of 4.4 and has a thickness of 1.6 mm. The antenna has a compact structure having the dimension of the patch 14.1 mm and 18.64 mm. These dimensions are calculated using above expressions equations.



(a) (b)

Fig. 1 (a) Top view of Microstrip patch antenna for single element, (b) Geometry of microstrip patch antenna for single element

The bandwidth of microstrip patch antenna is large for a given frequency if the thicker substrate is used. The bandwidth can also be improved by lower value of $\in_r$. The bandwidth can also be increased by increasing the inductance by cutting holes or slots in it. The gain for a substrate with given $\in_r$, increases with substrate thickness h and decreases with increase in $\in_r$.

III. Results of single patch.

Fig. 2 shows the return loss of a single patch microstrip antenna with the resonating frequency 4.7GHz. From the figure, the return loss for single element patch antenna is -40.5 dB, which is far greater than the -10 dB.

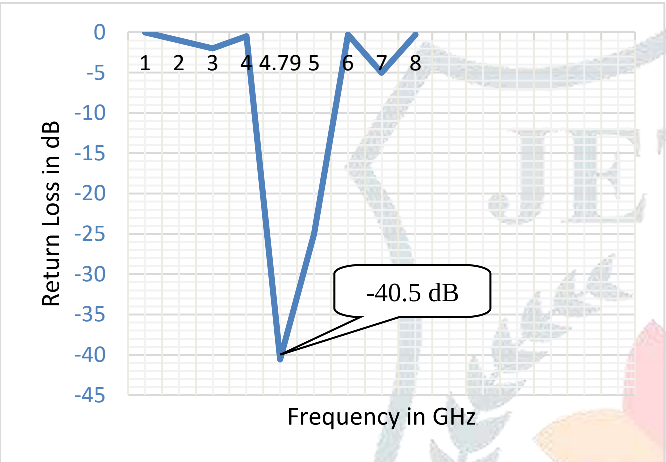


Fig. 2 Return loss characteristic of single element

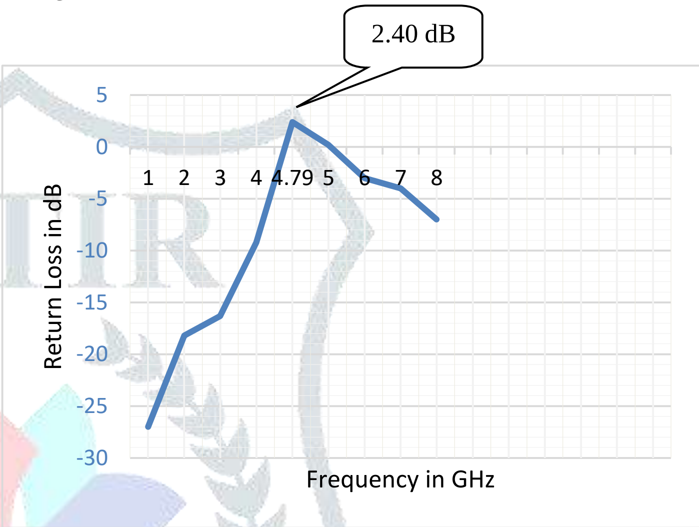


Fig. 3 Gain v/s Frequency characteristic of single element

Figure 3 shows the graph of gain vs frequency for a single patch microstrip antenna. From the figure, at resonating frequency. It is observed that for the given substrate with $\in_r$, the gain increases as the substrate thickness h and decreases with increase in $\in_r$

Table 1

Simulation results						
Sl. No	**Antenna Type**	**Resonating Freq In GHz**	**Return loss. In dB**	**Impedance in Ω**	**Gain in dB**	**VSWR**
1	Single patch	4.79	-40.5702	51.1642	2.4017	1.0499
Experimented results						
1	Single patch	4.81	-19.6	52.12	1.9	1.23

IV. Four Element array antenna

Taking the reference of above single patch and its results, an array of 4 element microstrip antenna is designed. A simple microstrip patch is used and it is extended to 4 elements. The design of four element microstrip array antenna is performed to obtain the improved results of gain and antenna efficiency. The design is simulated using the tool IE3D and the design is so simple that it can be easily fabricated using the dielectric substrate FR4. One of the recurring problems in the design of printed microstrip patch antenna is the selection of the feeding method. The Coaxial feeding can be used but it is often preferred to use microstrip line feeding which allows several elements to be excited parallelly at the same time, particularly in case of an antenna array. Moreover, the advantage of using microstrip line feeding is the simplicity of implementation and easy fabrication as only one substrate is used here. Thus, in this paper microstrip feed line is used. Further, the 4-element microstrip array antenna is resonating at frequency 4.79 GHz, which is an extended form of single patch antenna.

Figure 4 shows the antenna geometry and Fig.5 shows the top view of fabricated, probe feed four element patch array microstrip antenna. It consists of four patches of same dimensions and a common probe feeding. During the fabrication equal distance is maintained between each element to fulfill the symmetry of the array structure. Fig. 6 shows the return loss for four patch microstrip array antenna, which is -12.56 dB at the resonating frequency 4.7GHz, the resonance of the antenna can be seen by observing the Dip in the return loss. It has a gain equal to 7.97 dB as shown in figure 7. Here it is observed that the gain is almost double to that of the dual element antenna obtained in our previous research [].

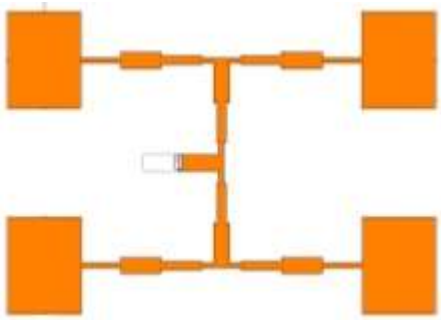


Fig. 4 Geometry of Microstrip patch antenna for 2*2 element

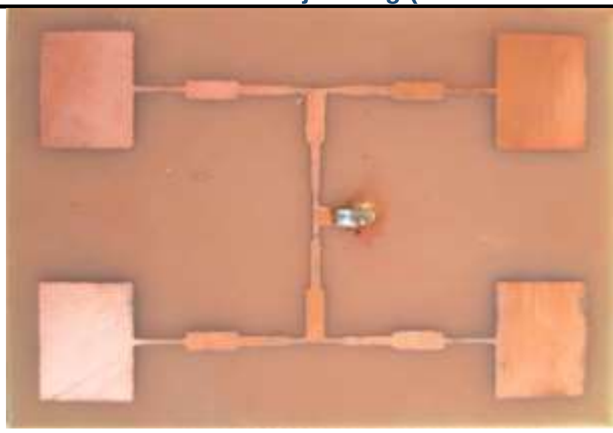


Fig. 5 Top view of Microstrip patch antenna for 2*2 element

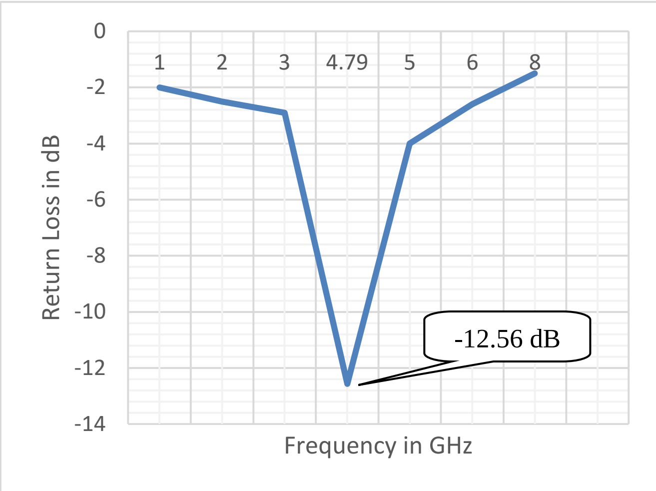


Fig. 6 Return loss characteristic of 2*2 element

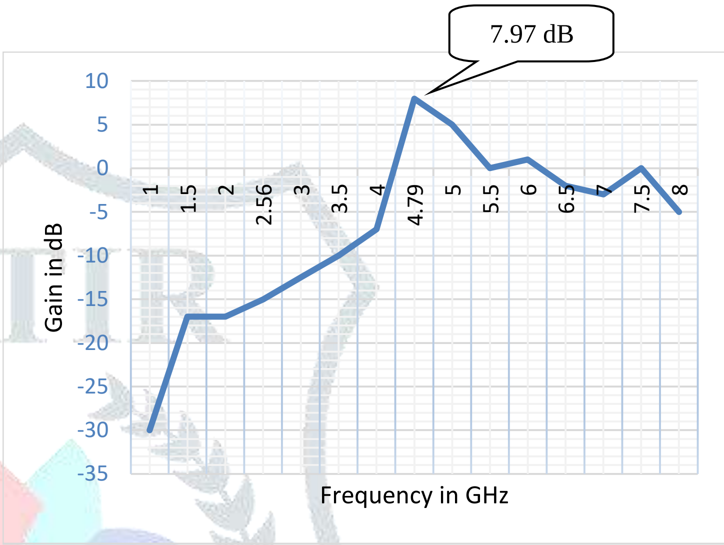


Fig. 7 Gain v/s Frequency characteristic of 2*2 element

The results of the design are tabulated as below in table 2, there is a close matching of the simulation results and measurement results for the four-element antenna. Since, the antenna is having good impedance matching, thereby increasing good radiation efficiency and antenna efficiency. The VSWR is 1.23, which is less than it 2 this indicates there is good impedance matching.

Table 2

Simulation results						
Sl. No	**Antenna Type**	**Resonating Frequency In GHz**	**Return loss. In dB**	**Impedance in Ω**	**Gain in dB**	**VSWR**
1	4 element Patch array antenna	4.79	-12.56	51.38	7.97	1.63
Measurement results						
1	4 element patch array antenna	4.80	-19.6	52.12	8	1.23

V. Eight Element array antenna

After successfully implementing the 4-element array antenna, also comparing their results we observed that the gain doubles as the number of rectangular patches are increased. In this section, it is extended further one step to obtain 8-element array antenna. With the help of the dimensions obtained for the single element rectangular microstrip patch antenna, with the same patch it is extended to 8-elements to obtain 8-element microstrip rectangular array antenna. in other words, two 4-element array antennas are combined to obtain the 8-element array. Each rectangular patch is placed at equidistance from one another to maintain the linearity in the array antenna. impedance matching is done suitably to get VSWR less than 2. It is then simulated using the IE3D RF signals simulation tool. From the simulation results it is observed that the designed antenna is resonating at the frequency under consideration.

Then, the antenna is fabricated using the copper for patch and glass-Epoxy for dielectric with the calculated correct dimensions of length and width of the patch. SMA connectors are used to provide corporate coaxial feeding at a time to all the elements. The practical result parameters are noted and tabulated as shown in table 3.

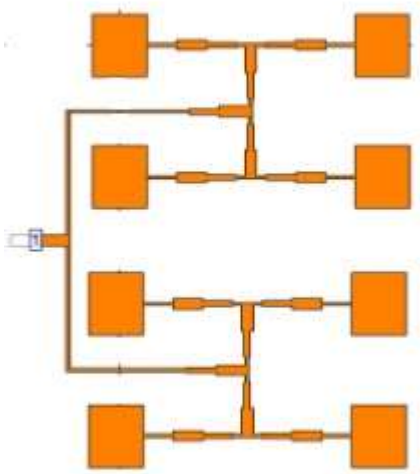


Fig. 8 Geometry of Microstrip patch antenna for 8-element array

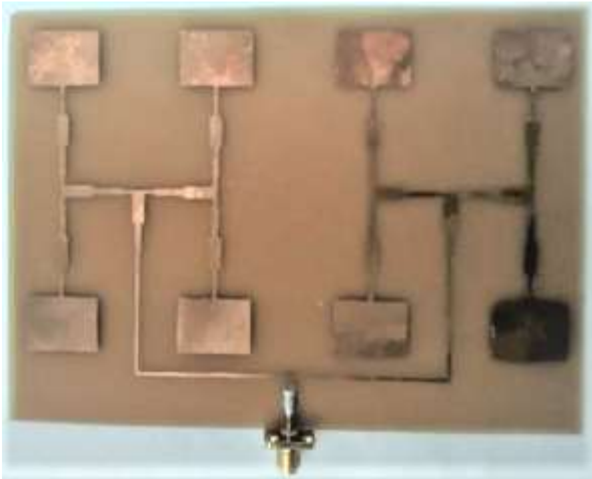


Fig. 9 Top view of 8-element microstrip patch array

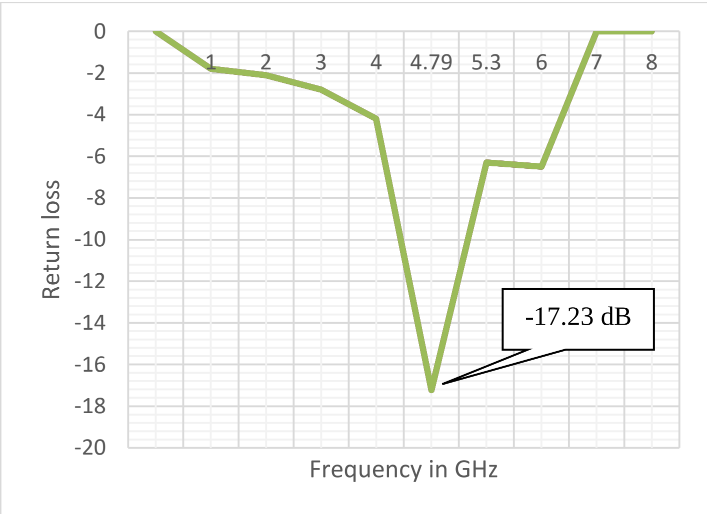


Fig. 10 Return loss characteristic of 8-element array

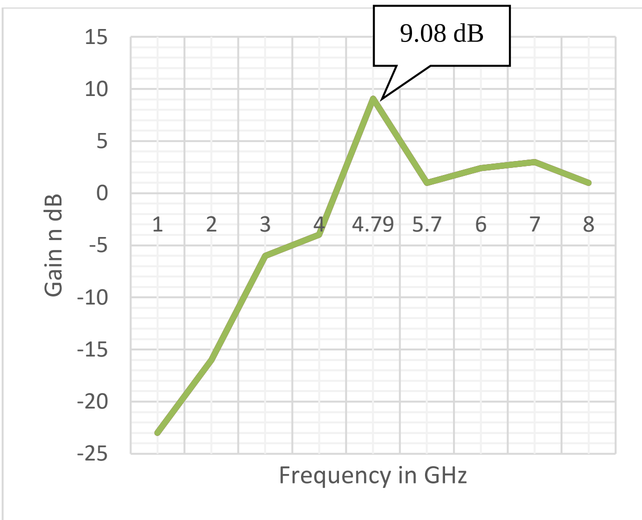


Fig. 11 Gain v/s Frequency characteristic of 8-element array

Figure 8 shows the simulated layout of 8-element microstrip array antenna design. On the other side figure 9 shows the top view of fabricated 8-elment array antenna. From the figure 10, it is observed that the designed antenna is exactly resonating at the frequency 4.79 GHz which is the designed frequency. At resonating frequency, the return loss obtained during simulation is equal to -17.23 dB. Further, figure 11 shows the total gain versus frequency curve, from this curve it is observed that the total gain obtained is 9.08 dB at the resonating frequency 4.79 GHz. The results obtained with simulation and practical are tabulated in the below table 3.

Table 3

Simulation results						
Sl. No	**Antenna Type**	**Resonating Frequency In GHz**	**Return loss In dB**	**Impedance in Ω**	**Gain in dB**	**VSWR**
1	8 element Patch array antenna	4.79	-17.23	48.10	9.08	1.33
Measurement results						
1	8 element patch array antenna	4.62	-20.74	56.61	12	1.21

VI. Experimental Investigations

In this paper, as mentioned in the above, in each section, single patch design is extended to the four elements array and eight elements array antenna. First the simulation results are obtained for single patch, it is fabricated, and the practical readings are taken. Similarly for four and eight elements. later after fabrication of the antennas with accurate dimensions, the practical results are taken with the help of Vector Network Analyzer (VNA). The output curves obtained for return loss and Gain are shown for each type of antenna separately. From the above results it is clear that, to obtain higher gain the number of patch elements in the array are doubled.

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