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DESIGN OF SINGLE AND DUAL ELEMENT MICRO-STRIP PATCH ANTENNA FOR WI-FI APPLICATIONS

Prakash Gani and Shriram P. Hegde
Department of Electronics and Communication Engineering, SDM Institute of Technology, India

Abstract

Antenna is designed with the primary motive to achieve good gain and bandwidth for the applications to which it is integrated. But, this motive would not be feasible through the use of a single patch antenna. The purpose of this study is to design a single element microstrip patch antenna for WiFi application. This antenna is to constitute a dielectric constant $\varepsilon = 4.4$, and is purposed to function in 4.7GHz frequency. Studies on single and dual microstrip patches reveal that the gain doubles when the number of patch elements are increased. So, while retaining the size of the single patch, doubling the number of patches would also eventually double the gain achieved. Such antennas have wide applications for feeding networks and RF radiation in the communication field. The main advantages of patch antenna are its low cost, good performance, easy installation, and low profile. The patch antennas are designed using appropriate design equations and are tested against practical results to ensure that its simulated results match the practical results. This paper documents the designing of single and dual element patch antenna using the appropriate equations for application in Wi-Fi communication. The antenna is fabricated using the FR4 substrate and its simulated results of gain, return loss, impedance and VSWR are compared with the practical results. This type of antenna was originally designed for radio but now it is also used for 802.11 network systems, and in wireless routers and gadgets that work on WiFi network. The advantage of these antennas is that they are typically very directive and useful for point-to-point and point-to-multipoint connections.

Keywords:

Feeding Network, Patch Antenna, Low Profile and FR4 Substrate

1. INTRODUCTION

The patch antenna has a physical structure derived from a transmission line, making the transmission line module to be the obvious choice for its analysis and design. The patch antenna is modeled as transmission line of characteristic impedance Z_0 and propagation constant. The first step is to select the dielectric material as a substrate with appropriate thickness and loss of tangent. The thicker substrate is mechanically strong and also increases radiation power, reduces conduction loss, improves antenna efficiency, bandwidth and gain of the antenna [18]. Using FR-4 substrate which has dielectric constant $\varepsilon_r = 4.4$ and loss of tangent 0.0245 (dielectric absorption). The idea is to design microstrip patch antenna that operates with resonating frequency 4.7GHz. In this paper, it is shown that gain and other related parameters of the antenna can be doubled with the number of patches [13]-[16].

Nowadays the communication is going wireless and digital. So, this antenna is designed with probe feeding technique, targeting the Wi-Fi applications. We are using the dielectric FR4 as it is readily available and the cost is also less compared to other dielectrics like RT Duroid, Taconic etc. This antenna can be used in wireless routers for the LAN networks in school, college or building. First, we design single patch, then the same is extended to dual patch microstrip antenna, considering the same operating frequency; then comparing their output gain, return loss, impedance matched, etc [17].

In this paper, we design a single and dual element patch antenna using the appropriate equations for application in Wi-Fi communication. The antenna is fabricated using the FR4 substrate and its simulated results of gain, return loss, impedance and VSWR are compared with the practical results. This type of antenna was originally designed for radio but now it is also used for 802.11 network systems, and in wireless routers and gadgets that work on WiFi network.

The purpose of this study is to design a single element microstrip patch antenna for WiFi application. This antenna is to constitute a dielectric constant operating at 4.7GHz frequency. Studies on single and dual microstrip patches reveal that the gain doubles when the number of patch elements are increased. So, while retaining the size of the single patch, doubling the number of patches would also eventually double the gain achieved. Such antennas have wide applications for feeding networks and RF radiation in the communication field. The main advantages of patch antenna are its low cost, good performance, easy installation, and low profile. The patch antennas are designed using appropriate design equations and are tested against practical results to ensure that its simulated results match the practical results.

2. SINGLE PATCH DESIGN

Microstrip antennas are usually produced by grabbing the patch from a printed circuit board with the driver on both sides. A dielectric substrate is used to support the top metallic flat region called the patch antenna. The power is provided by a feeder, and the substratum is supported by the ground plane at the bottom of the patch antenna.

A charge distribution becomes available on the microstrip surface and on the ground plane when a current is injected into a microstrip antenna. Most of the current lies on the lower part of the microstrip and on the top of the ground plane for thin microstrip. The magnetic field component which is tangential to the edge of the patch is therefore small.

Both the reactive and resistive components are presented in the input impedance of the antenna. The antennas are radiating power because of its resistive components. The presence of complex poles means that the imaginary components of these poles account for the loss of power due to radiation and loss of power and conduction. The actual component and antenna poles depend on the form of their modal distribution.

The single strip patch antenna designed to operate in the resonating frequency 4.7GHz, a dielectric constant 4.4, and a suitable loss of tangent 0.0245. Knowing the values and considering thickness of the patch, 1.6mm, we design the length and width of the patch. Drawing the layout with correct dimensions and simulating it using the IE3D software [1]-[4], the antenna is resonating at 4.7GHz. Some of the basic equations used in the process are as follows:

$$\text{Width of an element } W = \frac{C}{2f_r}\left[\frac{\varepsilon_r+1}{2}\right]^{0.5} \tag{1}$$

$$\text{Length of an element } L = \frac{C}{2f_r\sqrt{\varepsilon_r}} - 2\Delta L \tag{2}$$

where.

$$\Delta L = \frac{h}{\sqrt{\varepsilon_e}}$$

H is the thickness of patch,

ε_e is effective dielectric value is given by the following equation,

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-0.5} \tag{3}$$

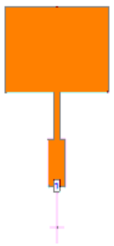

Fig.1. Geometry of microstrip patch antenna for single element

Table.1. Design specifications

Parameters	Value
Substrate	FR4
Resonating Frequency	4.7GHz
Substrate thickness	1.6mm
Dielectric constant	4.4
Loss of tangent	0.0245

The Fig.1 shows the geometry for single element patch antenna, obtained using the appropriate design and dimensions. Over the dielectric substrate FR4 a thin copper layer patch is established to form single patch. As it is a probe feed antenna, SMA connectors are used. This antenna is designed using IE3D software. The microstrip feed line is also a conducting strip, usually of much smaller width compared to the patch. The microstrip line feeding is easy to fabricate, simple to match the impedance and simple to model. Thus, microstrip line feeding technique is used. The Table.1 shows various design specifications used to design the microstrip antenna. The Fig.2 shows the top view of fabricated, probe feed single patch microstrip antenna.

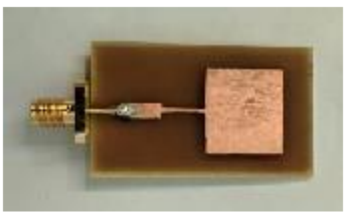

Fig.2. Top view of Microstrip patch antenna for single element

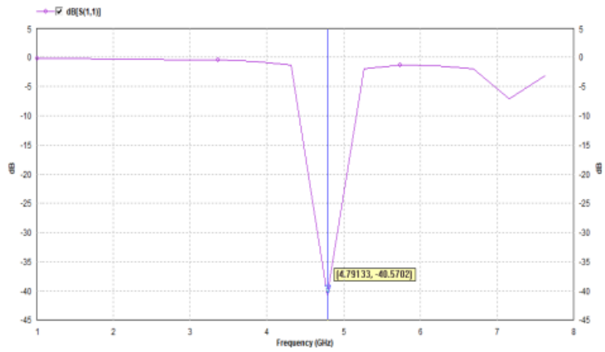

Fig.3. Return loss characteristic of single element

The Fig.3 shows the return loss of a single patch microstrip antenna with the resonating frequency 4.7GHz. From the figure, it is clear that the return loss for single element patch antenna is -40.5dB, which is far greater than the -10dB.

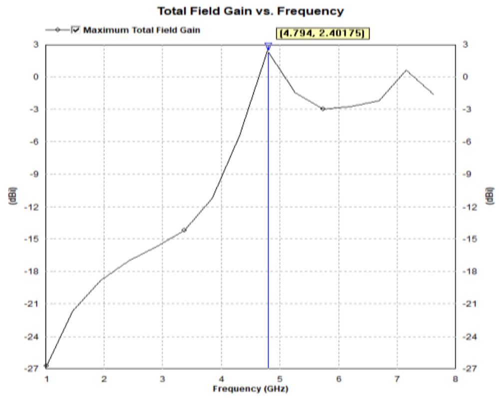

Fig.4. Gain v/s Frequency characteristic of single element

The Fig.4 shows the graph of gain vs. frequency for a single patch microstrip antenna. From the figure, it is clear that at resonating frequency, the gain obtained is 2.4dB.

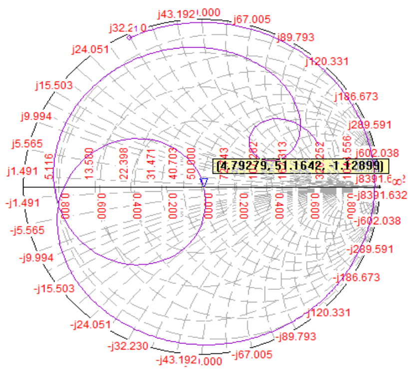

Fig.5. Smith chart of Single Patch Microstrip antenna

Similarly, as displayed by Fig.5, the smith chart for impedance matching, we can see that the matched impedance is 51.1Ω at the resonating frequency. Also, Fig.6 shows that the impedance value in the smith chart is almost matching with the practical impedance of 52Ω in smith chart [5]-[8].

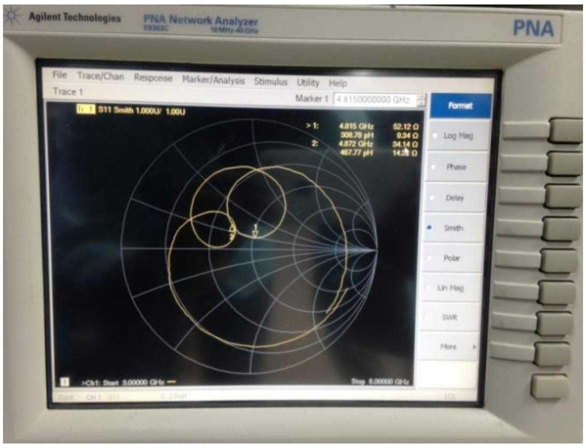

Fig.6. Smith chart of Single Patch Microstrip antenna

3. RESULT AND DISCUSSION OF DUAL ELEMENT MICROSTRIP PATCH ANTENNA

Let us design the dual element microstrip patch antenna for the resonating frequency 4.7GHz, using a dielectric constant 4.4, and a suitable loss of tangent 0.0245. Considering the values mentioned above and the 1.6mm thickness of the patch, the single patch dimension is extended to dual patch antenna. Drawing the layout with correct dimensions and simulating it using the IE3D software, the antenna is resonating at 4.7GHz. Some of the following figures show the output results [9]-[10],

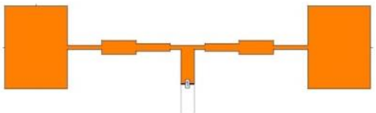

Fig.7. Dual element Geometry of Microstrip patch antenna

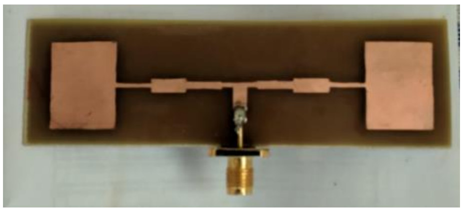

Fig.8. Top view of Dual Element Microstrip patch antenna

The Fig.7 shows the geometry of the dual element patch antenna is designed using the same dimensions as that of single patch. The replica of the single patch is used on the other side and common probe feeding is given to the combination.

The Fig.8 shows the top view of fabricated, probe feed dual patch microstrip antenna on the dielectric material. It consists of two patch elements with the same dimensions and a common probe feeding.

The Fig.9 shows the return loss for a dual patch microstrip antenna, which is -41.9dB at the resonating frequency 4.7GHz. From the Fig.9, it is clear that the return loss for dual element patch antenna is -41.9dB, which is far greater and acceptable.

The Fig.10 shows the graph of gain vs. frequency for a dual patch microstrip antenna. From the Fig.10 it is clear that, at resonating frequency the gain obtained is 5.03dB, which is two times the gain obtained for the single patch antenna. Similarly, the impedance matching obtained is 51.3Ω [11]-[12].

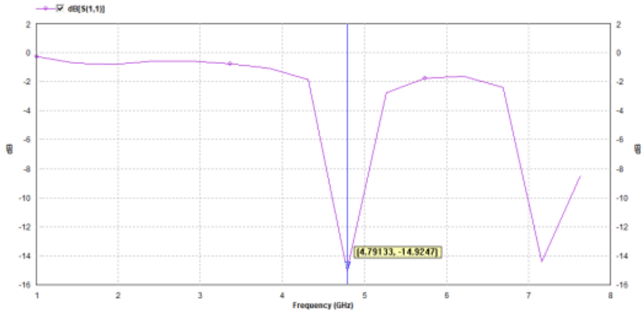

Fig.9. Return loss characteristic of Dual Element Microstrip Patch Antenna

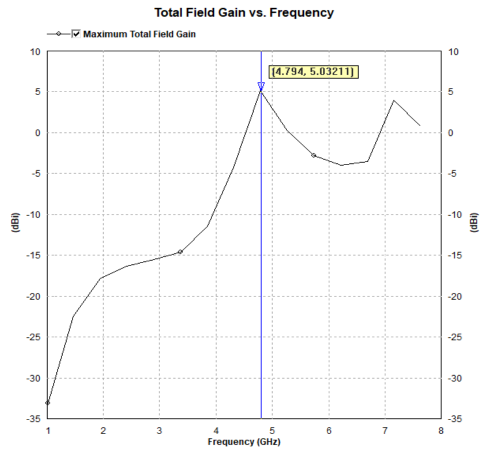

Fig.10. Gain v/s Frequency Characteristic of Dual Element Microstrip Antenna

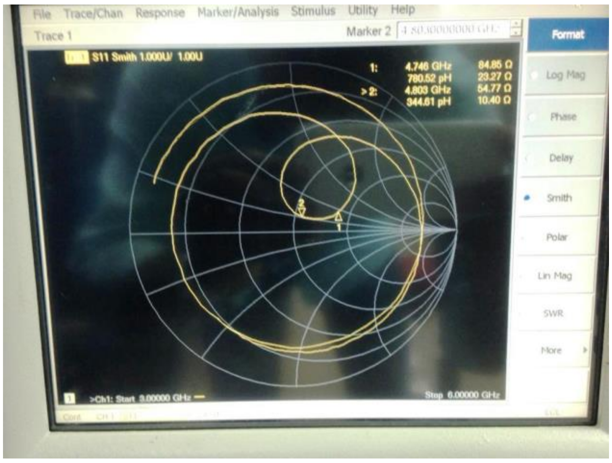

Fig.11. Smith chart of Dual Element Microstrip Antenna showing resonating impedance 54.77Ω

From the Fig.11 we observe that the impedance value obtained for dual patch antenna using simulation tool 51.32Ω is almost nearer to the practically taken impedance value reading 54.77Ω in the network analyzer.

3.1 EXPERIMENTAL INVESTIGATION

In this paper, we obtained and compared gain, return loss, VSWR, and the impedance of both the single and dual patch microstrip antenna. As the numbers of elements are doubled from one to two, the gain and bandwidth are also increased. The bandwidth of the patch antenna depends largely on the permittivity and thickness of the dielectric substrate. Thus, by increasing the number of elements, gain and percentage of bandwidth also increases.

The dielectric constant plays a major role in the overall performance of a patch array antenna. We may get even better results if we used the dielectrics like RT Duroid. The gain and return loss of the patch antenna also depends largely on the permittivity and thickness of the dielectric substrate. As per Table.2(a), Table.2(b) and Table.3(a), Table.3(b) of this paper, it is evident that gain can be increased by increasing the number of elements.

Table.2(a). Simulation results on Return Loss and Impedance

Antenna Type	Resonating Frequency (GHz)	Return loss (dB)	Impedance (Ω)
Single patch	4.79	-40.5702	51.1642
Dual patch	4.79	-41.9247	51.3277

Table.2(b). Simulation results on Gain and VSWR

Antenna Type	Resonating Frequency (GHz)	Gain (dB)	VSWR
Single patch	4.79	2.4017	1.0499
Dual patch	4.79	5.0321	1.4533

Table.3(a). Experimental Results on Return Loss and Impedance

Antenna Type	Resonating Frequency (GHz)	Return loss (dB)	Impedance (Ω)
Single patch	4.81	-19.6	52.12
Dual patch	4.8	-19.0	54.77

Table.3(b). Experimental Results on Return Loss and Impedance

Antenna Type	Resonating Frequency (GHz)	Gain (dB)	VSWR
Single patch	4.81	1.9	1.23
Dual patch	4.8	4.8	1.24

4. CONCLUSION

As disclosed by the preceding parts of this paper, from the design and analysis of microstrip patch antennas for single and dual patch structures, we can conclude that the results obtained for gain are doubled by doubling the patch. For the single patch antenna, it is observed that the gain is minimum. So, to get high gain, the number of patch is doubled. In the first case, we got a gain of around 2.5dB at resonating frequency with the return loss of -19.6dB. In the second case, we got a gain of around 5.1dB at the resonating frequency with the return loss of -41.9dB without affecting the original size of the antenna.

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