IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.
PP 01-06
www.iosrjournals.org

Improvement of Efficiency Parameter of a Microstrip Patch Antenna operating at 2.4 GHz for WLAN

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Abstract: *Wireless technology is one of the main areas of research in the world of communication systems today and the study of communication systems is incomplete without an understanding of the operation and fabrication processes of antennas. In present age, communication system is going to be space efficient because of advancement of IC circuit technology. Because of low weight and low profile of microstrip patch antenna, these are being vastly used as printed antenna for wireless communication, satellite communication, microwave communication, cell phones etc. Microstrip antenna provides a space efficient structure for the circuit where space is very important parameter. This paper is focused on the design and simulation of patch antenna (which is widely used in cell phones today) with an emphasis on optimization of a 2.4 GHz rectangular patch antenna considering radiation efficiency and total efficiency as the parameters. In proposed technique for designing of a microstrip patch antenna for 2.4 GHz resonating frequency, as the length of patch is decreasing the resonating frequency shift to the desired resonating frequency. This technique also improves the radiation efficiency parameter. The proposed antenna is analyzed and designed using CST-MWS. The simulated results shows the optimization of radiation efficiency from -3.807 db to -1.659 db and total efficiency also improved from -8.857 db to -5.146 db.*

Keywords - *Radiation efficiency, Rectangular microstrip patch antenna, Resonating frequency, Total efficiency, WLAN.*

I. INTRODUCTION

In recent years there is a need for more compact antennas due to rapid decrease in size of personal communication devices. As communication devices become smaller due to greater integration of electronics, the antenna becomes a significantly larger part of the overall package volume. This results in a demand for similar reductions in antenna size. In addition to this, low profile antenna designs are also important for fixed wireless application. In radio telecommunications, among the antenna designs there are many different categories of micro strip antennas which are also known by the name printed antennas, the most common of which is the micro strip patch antenna or patch antenna. A patch antenna (also known as a rectangular micro strip antenna) is a type of radio antenna with a low profile, which can be constructed on a flat surface. It consists of a flat rectangular metallic sheet or "patch" of metal, mounted over a larger metallic sheet called a ground plane. The assembly is usually covered by a plastic radome, which saves the antenna structure from damage. Patch antennas are very simple to be fabricated and easy to be modified and customized. They are the original type of micro strip antennas which were given by Howell in the year 1972 in which the two metal sheets together produce resonance and form a resonant piece of micro strip transmission line with a length which is around one half wavelengths of the radio waves. [1]

A simple and easiest patch antenna of this category radiates a linearly polarized wave. The radiation can be considered as being produced by a number of the “radiating slots’’ at top and bottom, or simultaneously as a result of the current flowing on the patch and the ground plane. Commonly made micro strip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible and can be created. Some patch antennas do not use a dielectric substrate and instead are made by using a metal patch mounted above a ground plane using dielectric spacers; the resulting structure is less rugged but the bandwidth is much wider. Now as such antennas have a very low profile, are mechanically rugged and can be shaped and designed to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated and operated into electronic devices such mobile radio communication equipments. The rectangular microstrip patch antenna is the widely used of all the types of microstrip antennas that are present The substrate material, dimension of antenna, feeding technique will determines the performance of microstrip antenna. [1][3]

II. MICROSTRIP PATCH ANTENNA DESIGN

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, elliptical or some other common shape. For a rectangular patch, the length L of the patch is usually $0.3333\lambda o < L < 0.5\lambda o$, where λo is the free space wavelength. The patch is selected to be very thin such that $t \ll \lambda o$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\ \lambda o \leq h \leq 0.05\ \lambda o$. The dielectric constant of the substrate (εr) is typically in the range $2.2 \leq \varepsilon r \leq 12$. The most popular models for the analysis of microstrip patch antennas are the transmission line model, cavity model and full wave model. The transmission line model is the simplest of all and it gives good physical insight but it is less accurate [2].

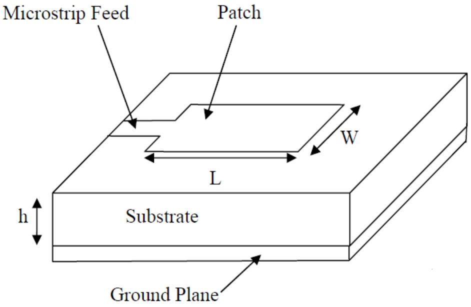

Fig.1. Geometry of microstrip patch antenna

The width of the microstrip patch antenna was computed with the following equation: [3][6]

$$W = \frac{c}{2 \times f_r} \times \sqrt{\frac{2}{E_r+1}}$$

where c is the speed of light (3×10^8 m/s), fr is the operating frequency of 2.4 GHz and Er is the dielectric permittivity of 4.3. The length of microstrip patch antenna is given by the following equations:[3]

$$E_{reff} = \frac{E_r+1}{2} + \frac{E_r-1}{2}\left(1 + 12 \times \frac{h}{W}\right)^{-\frac{1}{2}}$$

$$L_{eff}(eff.length) = \frac{c}{2 \times f_r \times \sqrt{E_{reff}}}, \quad \Delta L = 0.412 \times h \times \frac{(E_{reff}+0.3)}{(E_{reff}-0.258)} \times \frac{\left(\frac{W}{h}+0.264\right)}{\left(\frac{W}{h}+0.8\right)}$$

where Ereff is the effective dielectric constant and h is the thickness of the dielectric substrate.
In the equation above ΔL stands for length extension. Therefore, the actual length of the microstrip patch antenna is given by: [3]

$$L = L_{eff} - 2 \times \Delta L$$

Calculation of impedance of patch by given formula [6]

$$Zo = \frac{90}{\varepsilon r - 1}\left[\frac{\varepsilon r\, L}{W}\right]^2$$

Calculation of inset feed distance (Yo) for 50 ohm value [6]

$$50 = Zo\left[\cos\left(\frac{\pi\, Yo}{L}\right)\right]^2$$

Calculation of effective impedance of microstrip line so that impedance can be matched at inset point at a distance Yo from edge of patch for 50 ohm value. The impedance of microstrip line is more than 50 ohm because of mutual coupling between patch and line and is given by [3][6]

$$Z = \sqrt{50 * Zo}$$

Calculation of ratio of width of microstrip line to height of substrate as we know the effective impedance of the line Z, by given formula [6].

$$Zo = \frac{87}{\sqrt{\varepsilon r + 1}} ln\left[\frac{5.98\, h}{.8Wo + t}\right]$$

Fig.2, fig.3 and fig.4 showing the clear picture about all the above parameter values in microstrip patch antenna.

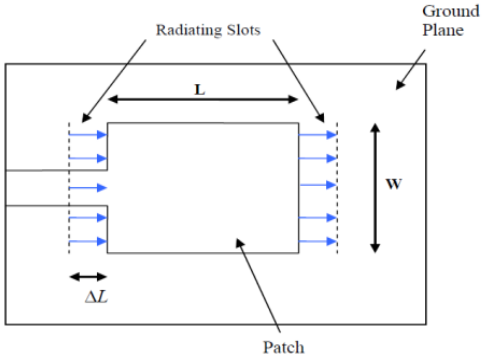

Fig. 2: Top view of antenna

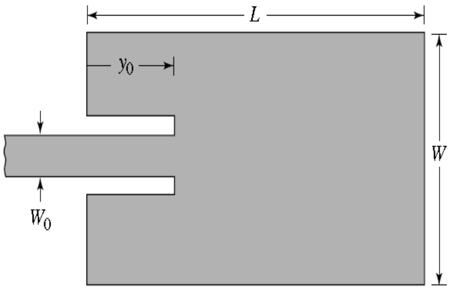

Fig. 3: Distance Yo from edge of patch so that patch impedance at this point is 50 ohm

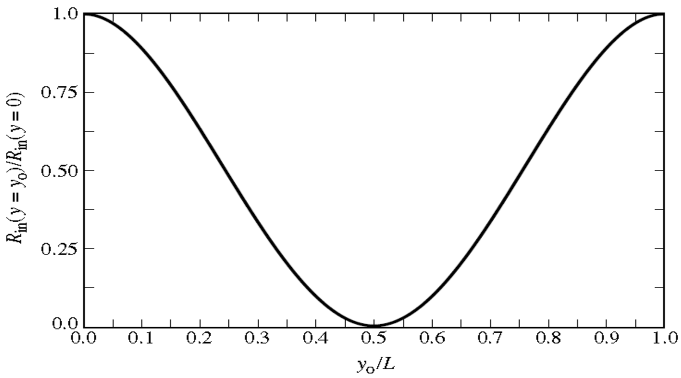

Fig. 4: Variation of patch impedance with distance from edge of patch

Table 1& 2: Dimensions of calculated and proposed patch antenna for 2.4 GHz Resonating frequency

1	Resonating frequency	2.4 GHz	1	Resonating frequency	2.4 GHz
2	Substrate	$\varepsilon_r = 4.3$	2	Substrate	$\varepsilon_r = 4.3$
3	Thickness of ground plane	.3mm	3	Thickness of ground plane	.3mm
4	Thickness of substrate	1.4mm	4	Thickness of substrate	1.4mm
5	Width of patch, W	38.39mm	5	Width of patch, W	38.39mm
6	Length of patch,L (Calculated)	29.849mm	6	Length of patch,L (Optimized)	28.67mm
7	Width of substrate (generally double of patch)	80mm	7	Width of substrate (generally double of patch)	80mm
8	Length of substrate (generally double of patch)	60mm	8	Length of substrate (generally double of patch)	60mm
9	Thickness of patch, t	.07mm	9	Thickness of patch, t	.07mm
10	Inset feed distance , Yo	10.96mm	10	Inset feed distance , Yo	10.96mm
11	Width of microstrip feed line,Wo	.26mm	11	Width of microstrip feed line,Wo	.26mm

III. SIMULATION RESULTS AND DISCUSSION

The resonant properties of the designed microstrip patch antenna are studied by adjusting the different values of parameters using CST-MWS. The S11 parameter calculated. The effects of variation of patch length (L) of designed antenna also studied. From calculated patch length i.e. L = 29.849 mm, the return loss parameter obtained is shown in fig. 5. Here return loss parameter is not minimum at resonant frequency 2.4 GHz as the approximate formula for calculation of parameters of antenna structure is used.

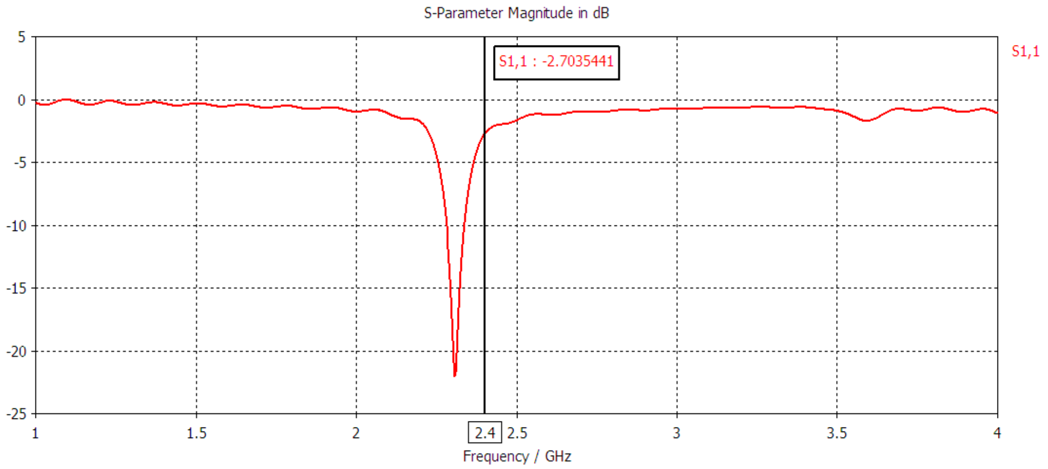

Fig. 5:Return loss parameter for 2.4GHz resonating antenna with L = 29.849 mm

If minimum of return loss parameter is on left side of resonant frequency Keep Yo fixed and reduces the length of patch in step size then this minima will shift towards resonant frequency and we can obtain the minimum of return loss parameter at specified resonant frequency and can be seen from fig. 6.

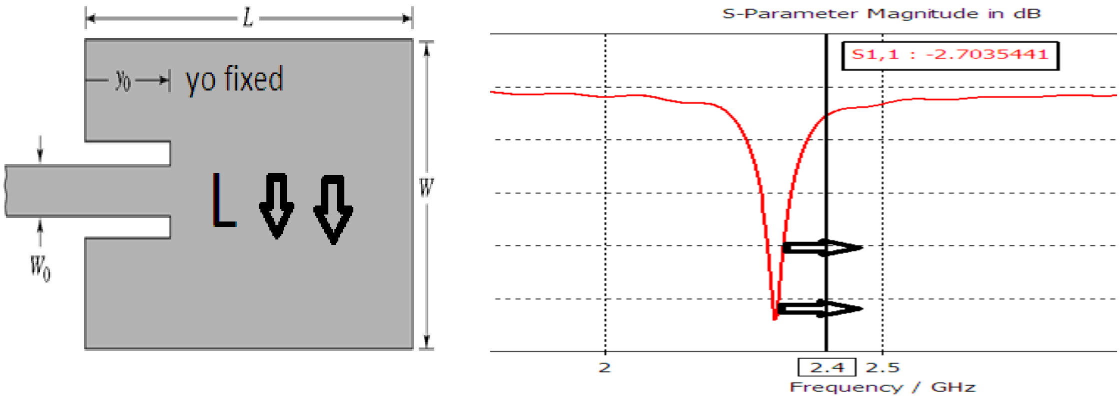

Fig. 6: L is decreasing keeping yo fixed return loss minima approaches resonant frequency

As moving from L = 29.849 mm to L = 28.67mm the resonating frequency shifted from 2.308 GHz to 2.4 GHz keeping y_0 fixed. Also return loss minimum is -28.27 db which was -23.8 db, result shown in fig. 7

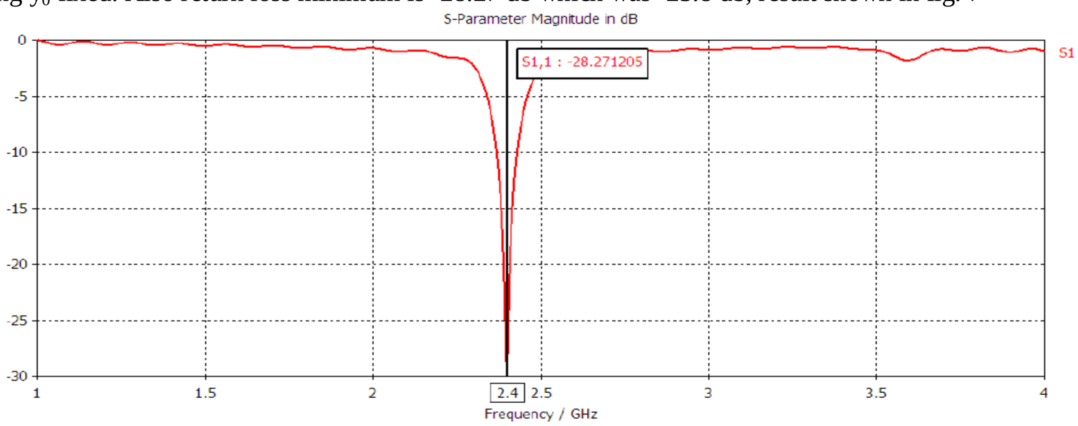

Fig. 7: Return loss parameter for 2.4GHz resonating antenna with L = 28.67 mm

Voltage Standing Wave Ratio (VSWR) value is very close to ~ 1 at resonating frequency shown in fig. 8

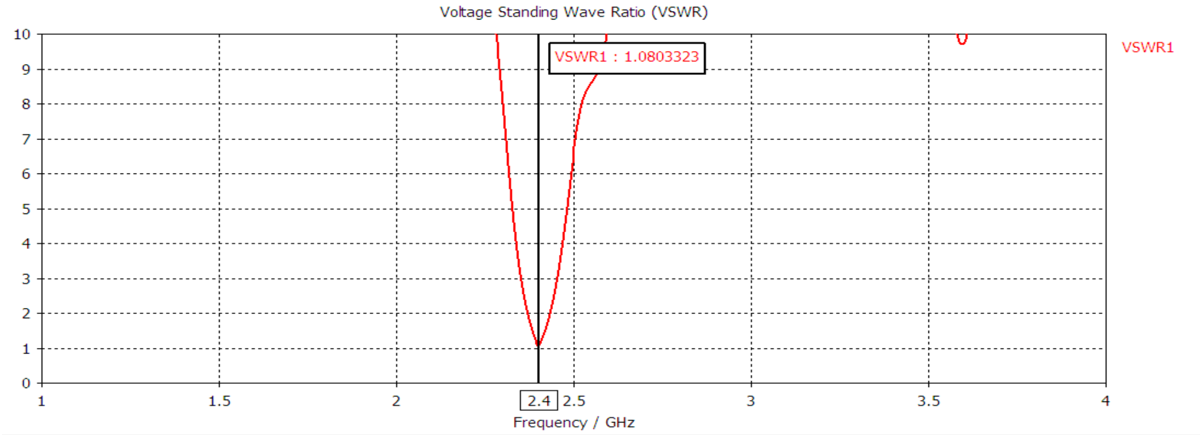

Fig. 8: VSWR parameter for 2.4 GHz resonating frequency with L = 28.67 mm

The 3-D radiation pattern observed for the values of patch length L = 29.849mm and L = 28.67mm shown in fig. 9 and fig. 10 respectively. Here radiation efficiency is increased from -3.807 db to -1.659 db and total efficiency also increased from -8.857 to -5.146 db. It means now radiation pattern is far better than without optimization. Directivity is found to be 7.006 db.

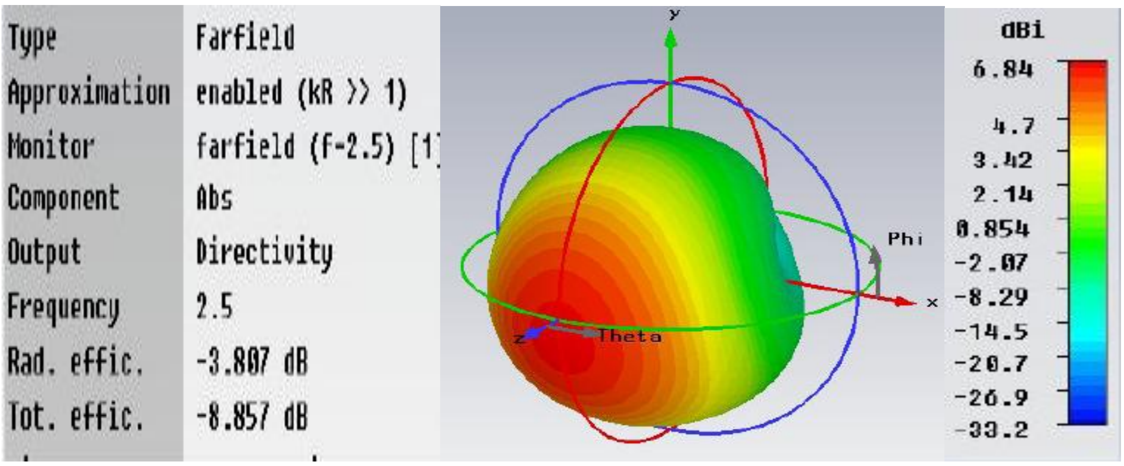

Fig. 9: 3-D Radiation pattern for 2.4GHz resonating antenna with L = 29.849mm

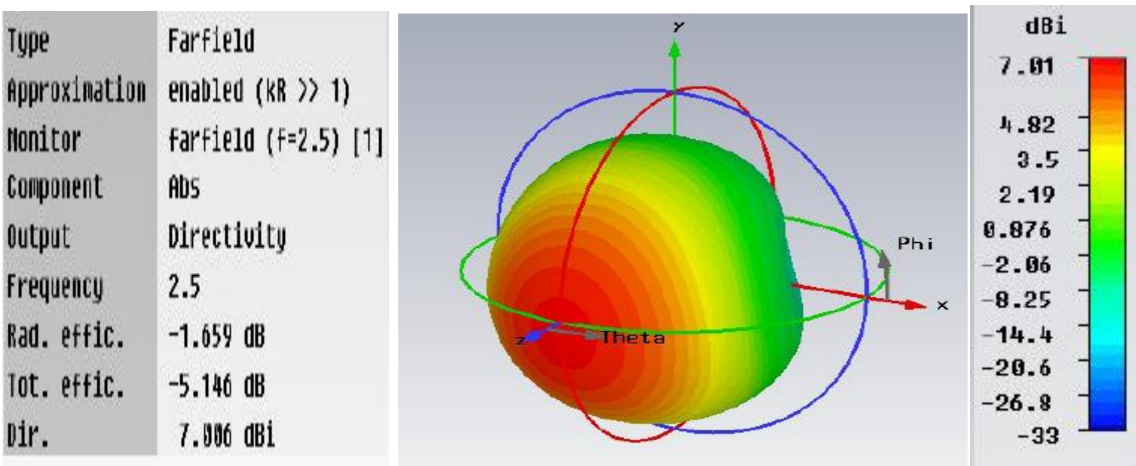

Fig. 10: 3-D Radiation pattern for 2.4GHz resonating antenna with L = 28.67mm

IV. CONCLUSION

With the rapid development of wireless technology in recent years, various wireless systems such as GSM, WCDMA/UMTS, Bluetooth, WLANs, and GPS have been highly integrated into the mobile equipments, and in order to fulfill the RF system requirements using the different frequency band, antenna technology is required to wideband characteristics. This paper presents the designing of a microstrip patch antenna for 2.4 GHz and the effect of variation of resonating frequency with length of micro strip patch is also observed. As length is decreased resonating frequency is approaching towards desired resonating frequency (2.4 GHz) from lower frequency. By using this property optimization of the results for resonating frequency 2.4 GHz and improvement of efficiency parameter is also observed. Other antenna parameters like main lobe level, side lobe level, directivity etc can also be observed from the simulation result and far-field pattern for proposed microstrip patch antenna.

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