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Feed line calculations of microstrip antenna

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Abstract*— A patch antenna is a type of radio antenna with a low profile, which can be mounted on a flat surface. It consists of a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane. This thesis presents the idea of recent developments and advancements in the field of wireless technology to realize high-speed communications which are performed in wideband technology. In this graduate qualification, work the wideband patch antenna is designed to analyze the results. The most commonly designed microstrip antenna is a rectangular patch. The rectangular patch antenna is a one-half wavelength long strip of rectangular microstrip transmission line that is shown in this work. The simulation is done using CST STUDIO SUITE simulation software.
***Keywords*— CST STUDIO SUITE simulation software, WCDMA, UMTS, Bluetooth, WLANs, and GPS**

I. INTRODUCTION

Antenna's features such as frequency, radiation pattern, polarization are reconfigured to achieve the demands for agile radio applications. Many focus on frequency reconfiguration as future communication systems such as cognitive radio needs an antenna that can do spectrum sensing and communication. In designing of reconfigurable frequency antennas, recently a reconfigurable wideband to agile narrowband frequencies, using a printed log periodic dipole array antenna, was developed. A wideband slotted antenna has been produced using multifunctional reconfigurable frequency characteristics for various applications such Wireless LAN, WIMAX, Ultra-wideband and UMTS have been proposed in a frequency reconfigurable antenna, made up of two structural elements ; one is an ultra-wide band (UWB) and other is a frequency reconfigurable triangular shaped antenna, is proposed for cognitive radio applications. Ultra-wide band antennas have already been used in applications such as satellite communication, remote sensing, ultra wide band radar technology and so on. Currently, the wireless area network (WLAN) in the 2.4-GHz (2.4-2.485 GHz) and 5-GHz (5.l5-5.875 GHz) bands is the most renowned networks for accessing the internet and also the antenna for an AP not only requires dual-band operation but also needs to have an appropriate radiation profile in both bands, namely equal gain, wide beam width, and high front-to-back ratio. Wireless communications are enjoying exponential growth in Industrial, Scientific, and Medical (ISM) band. The future generation wireless networks require systems with broadband capabilities in various environments to satisfy numerous applications as smart grid, personal communications, home, car, and office networking.

II. MAIN TITLE

Fed with a Half-Wavelength Transmission Line Previously, the patch antenna was fed at the end. Since this typically yields a high input impedance, we would like to modify the feed. Since the current is low at the ends of a half-wave patch and increases in magnitude toward the center, the input impedance (Z=V/I) could be reduced if the patch was fed closer to the center. One method of doing this is by using an inset feed (a distance R from the end) as shown in Figure 1.

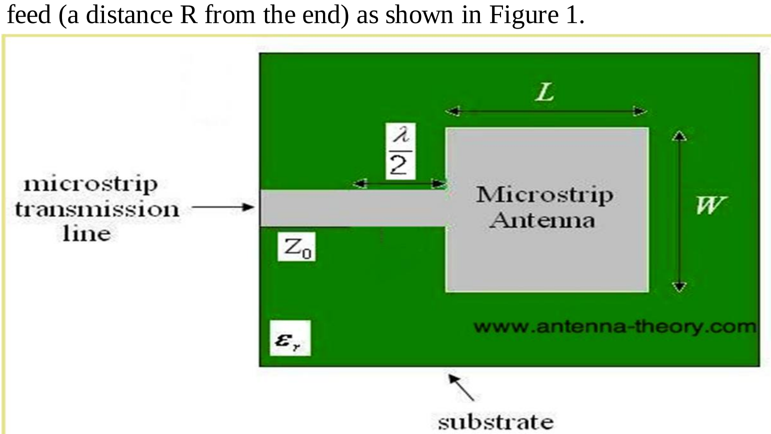

Fig. 1. Patch Antenna with an Inset Feed.

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At the source end of the line, $Z' = l$, the generator looking into the line sees an *input impedance* Z_i.

$$Z_i = (Z)x_{y^2}Z_{\substack{z=0 \\ z'=l}} = Z_0 \frac{Z_L + Z_0 tanh\gamma l}{Z_0 + Z_L tanh\gamma l} \ (\Omega) \quad (1)$$

In most cases, transmission-line segments can be considered losses:$\gamma = j\beta$,$Z_0 = R_0$, and.$\gamma l = \tanh(j\beta l) = jtan\beta l$ The formula in Eq. (1) for the input impedance Z_i.of a lossless line of length l terminated in becomesZ_L

$$Z_i = R_0 \frac{Z_L + jR_0 tanh\beta l}{Z_0 + jR_L tanh\beta l} \ (\Omega). \quad (2)$$

In a half-wave section $l = \frac{\lambda}{2}$,$\beta l = \pi$, when the length of a line is an integral multiple of $\frac{\lambda}{2}$, $l = n\lambda/2$,

$(n = 1,2,3, \dots\dots)$,$\beta l = \frac{2\pi}{\lambda\left(\frac{n\lambda}{2}\right)} = n\pi$, $tan\beta l = 0$ and Eq. (2) reduces to $Z_i = Z_L$(Half-wave line).

Since the current has a sinusoidal distribution, moving in a distance R from the end will increase the current by $\cos(\pi * \frac{R}{L})$ - this is just noting that the wavelength is $2 * L$, and so the phase difference is $2 * \pi * \frac{R}{2*L} = \pi * \frac{R}{L}$ The voltage also decreases in magnitude by the same amount that the current increases. Hence, using Z=V/I, the input impedance scales as:

$$Z_{in}(R) = cos^2(\frac{\pi R}{L})Z_{in}(0) \quad (3)$$

In the above equation, Zin(0) is the input impedance if the patch was fed at the end. Hence, by feeding the patch antenna as shown, the input impedance can be decreased. As an example, If $R = L/4$ then $\cos\left(\pi * \frac{R}{L}\right) = \cos(\pi/4)$, so that $\cos(\pi/4)^2$ =1/2. Hence, a (1/8)-wavelength inset would decrease the input impedance by 50%. This method can be used to tune the input impedance to the desired value.

Fed with a Quarter-Wavelength Transmission Line**.** The microstrip antenna can also be matched to a transmission line of characteristic impedance Z0 by using a quarter-wavelength transmission line of characteristic impedance Z1 as shown in Figure 2.

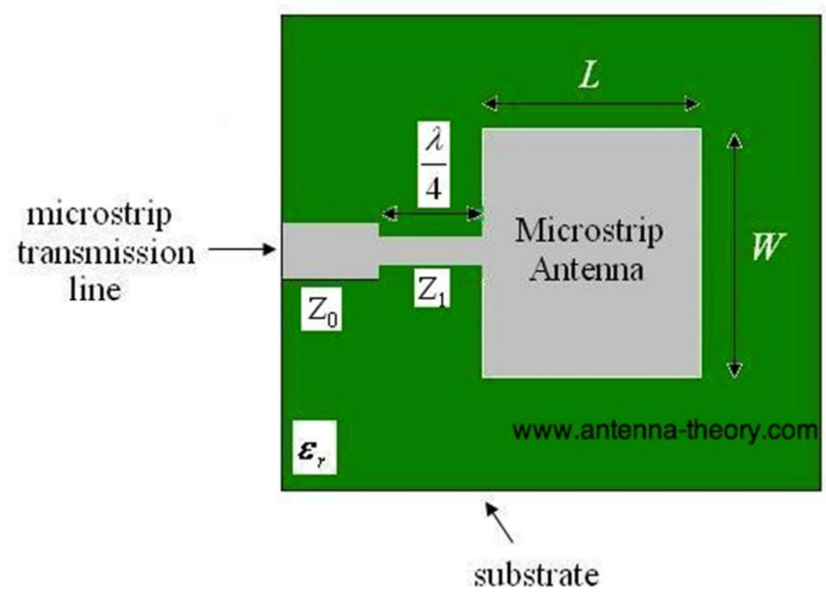

Fig. 2 Patch antenna with a quarter-wavelength matching section.

In a quarter-wave section $l = \frac{\lambda}{4}$, $\beta l = \pi/2$. When the length of a line is an odd multiple of$\lambda/4$, $l = \frac{(2n-1)\lambda}{4}$, $n = 1,2,3, \dots)$

$\beta l = \frac{2\pi}{\lambda}(2n-1)\frac{\lambda}{4} = (2n-1)\frac{\pi}{2}$, $tan\beta l = \tan\left[(2n-1)\frac{\pi}{2}\right] \rightarrow \pm\infty$ and the Eq. (2) becomes $Z_i = \frac{R_0^2}{Z_L}$ $(Quarter - wave\ section)$

The goal is to match the input impedance (Zin) to the transmission line (Z0). If the impedance of the antenna is ZA, then the input impedance viewed from the beginning of the quarter-wavelength line becomes

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$$Z_{in} = Z_0 = \frac{Z_1^2}{Z_A} \quad (4)$$

This input impedance Z_{in} can be altered by selection of the Z1, so that $Z_{in} = Z_0$ and the antenna is impedance matched. The parameter Z1 can be altered by changing the width of the quarter-wavelength strip. The wider the strip is, the lower the characteristic impedance (Z0) is for that section of line.

III. INPUT IMPEDANCE CALCULATIONS OF EACH PATCH

Neglecting the effect of higher order modes, the input resistance of the patch at resonance (as seen by the coaxial feed probe) is then

$$R_{in} \cong -A_{10} b \sin(\frac{\pi x_f}{L}) \quad (5)$$

The result is $R_{in} = 90 \frac{e_r}{pc_1} \varepsilon_r \mu_r \left(\frac{L}{W}\right)^2 \sin^2(\frac{\pi x_f}{L})$ (2) Where R_{in} is expressed in ohms. According to Equation (2), the typical impedance at the edge of a resonant rectangular patch ranges from 100 to 400 Ω, the radiation impedance of a patch at the edge can be approximated as

$$Z_a \approx 90 \frac{\varepsilon_r^2}{\varepsilon_r - 1} \left(\frac{L}{W}\right)^2 (\Omega) \quad (6)$$

Here the radiation efficiency (a function of the thickness) is assumed 100%. Thus, the impedance is determined by three parameters. For a PTFE (Teflon) based substrate with a relative permittivity of 2.1, to obtain a 50 Ω input impedance we need (L/W) = 0.3723. Since L = 0.49λ, we have W = 1.316λ.

It has been found that an empirical formula can be used to estimate the impedance fractional bandwidth for VSWR < 2

$$\frac{\Delta f}{f_0} = \frac{16}{3\sqrt{2}} \frac{\varepsilon_r - 1}{\varepsilon_r^2} \frac{Ld}{\lambda W} \approx 3.77 \frac{\varepsilon_r - 1}{\varepsilon_r^2} \frac{Ld}{\lambda W} \quad (7)$$

Thus, the bandwidth is proportional to the thickness of the substrate. This also indicates that the higher the permittivity, the smaller the bandwidth, which means there is a trade-off between the size (Ld/W) and bandwidth.

This method of feeding is very widely used because it is very simple to design and analyze, and very easy to manufacture. Figure (1) shows a patch with microstrip line feed from the side of the patch.

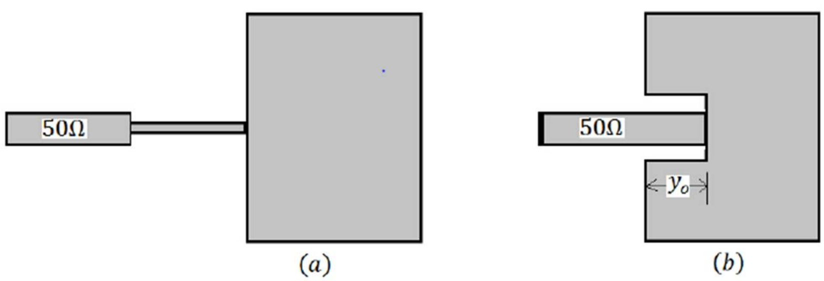

Fig. 3 Microstrip patches antenna with feed from side

The position of the feed point (y_0) of the patch in figure (1b) has been discussed in details in the section of Impedance Matching. It is widely used in both one patch antenna and multi-patches (array) antennas.

The characteristic impedance of the transition section should be:

$$Z_T = \sqrt{50 + Z_a} \quad (8)$$

The width of the transition line is $Z_T = \frac{60}{\sqrt{\varepsilon_r}} \ln(\frac{8d}{W_T} + \frac{W_T}{4d})$ (9)

The width of the 50Ω microstrip feed can be found using the equation (7) below

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon reff}(1.393 + \frac{W}{h} + \frac{2}{3}\ln(\frac{W}{h} + 1.444))} \quad (10)$$

The main goal of this thesis was designing a patch antenna for Wi-Fi router which works in the range of 5 GHz. Feeding a patch antenna from the edge leads to a very high input impedance, causing an undesirable impedance mismatch if a conventional 50 Ω line is directly connected. For achieving the goal we decided that the patches were the impedance of Z1/Z2/Z3/Z4=500/125/125/500 (Fig.1). Parameters of the patches are given in Table 1.

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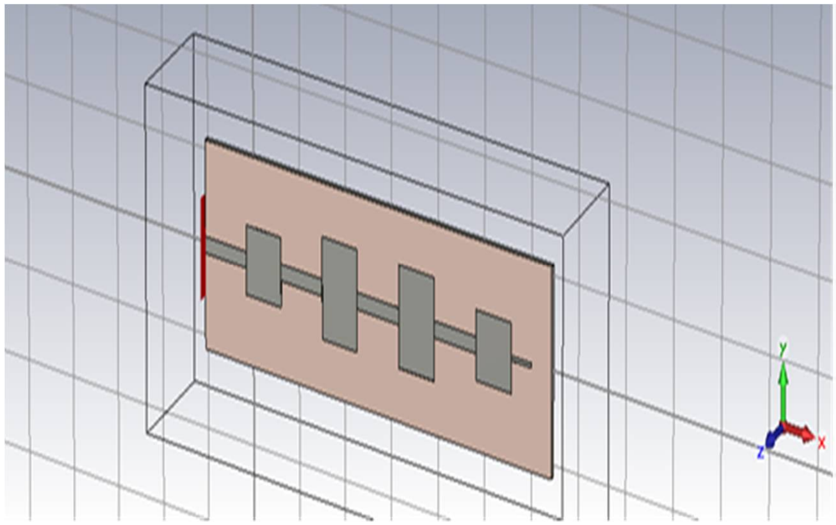


Fig. 4 Series of microstrip patch antenna.

TABLE I
PARAMETERS OF THE PATCHES.

Width of Substrate	Length of the feed line	Width of the feed line	Length of the patch	Width of the patch 1 and patch 4	Width of the patch 2 and patch 3	Permittivity
1.6 mm	17.9 mm	3.6mm	13mm	15mm	22mm	ε=3.55

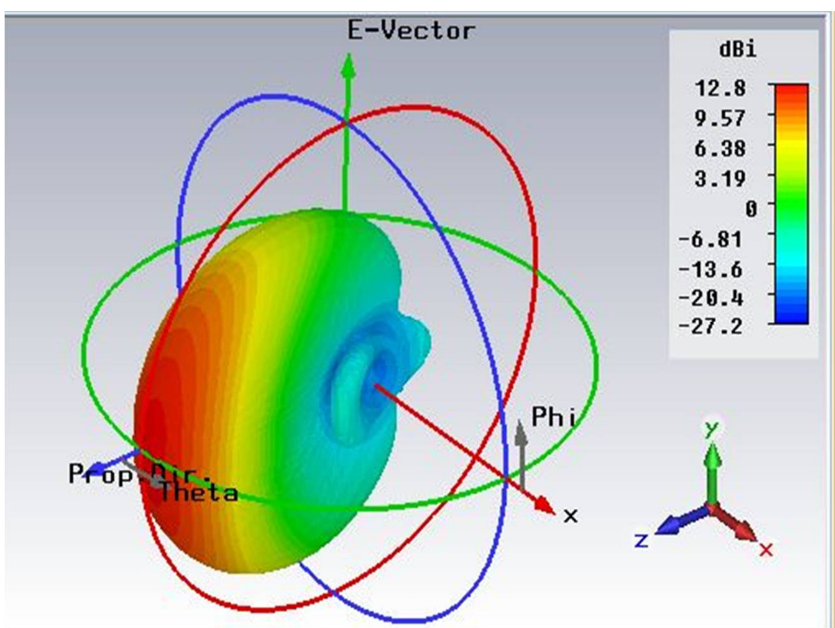


Fig. 5 Far-field for series microstrip patch antenna the 5GHz. In the Fig.3, there is shown the spread of electrical field at each patch and strapline.

Performing mathematical problems (from last part), we can see the spread of electric field in our program (Fig.5).Smith Chart results

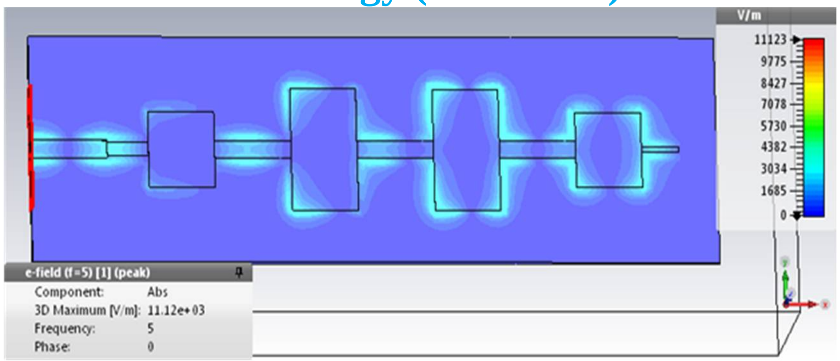


Fig.6 E-field for a series microstrip patch antenna and 5GHz.

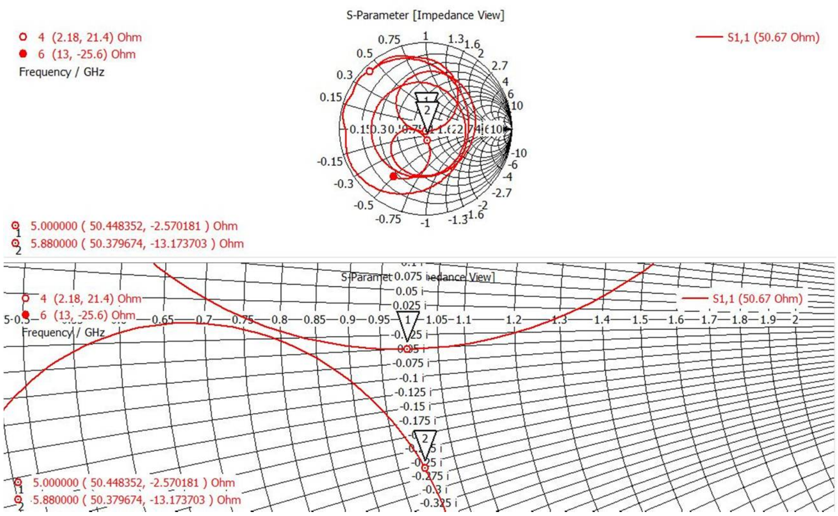
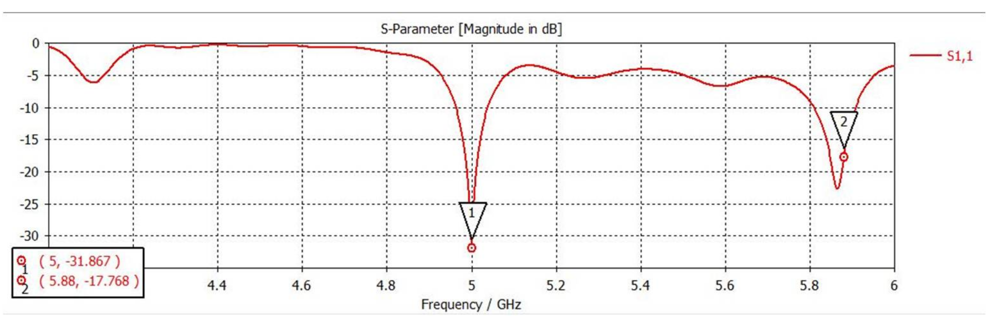
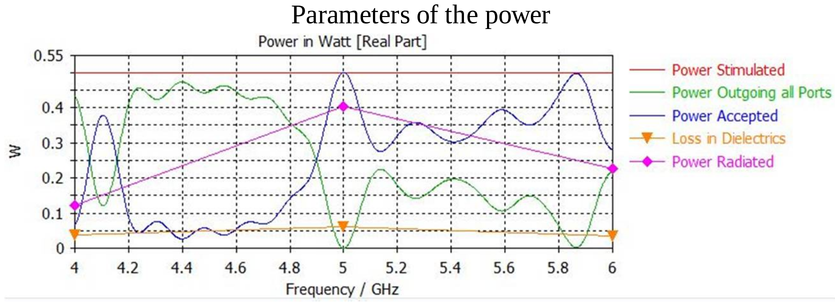


Fig.7 Radiation band for series microstrip patch antenna a the 5GHz.

In the Fig. 7 is given radiation bandwidth in the range of 5 GHz isn’t more than 3%, it means that antenna is functional for the Wi-Fi router and modeling antenna by the CST program is comfortable and economically useful.



Parameters of the power



Wave propagation in a medium

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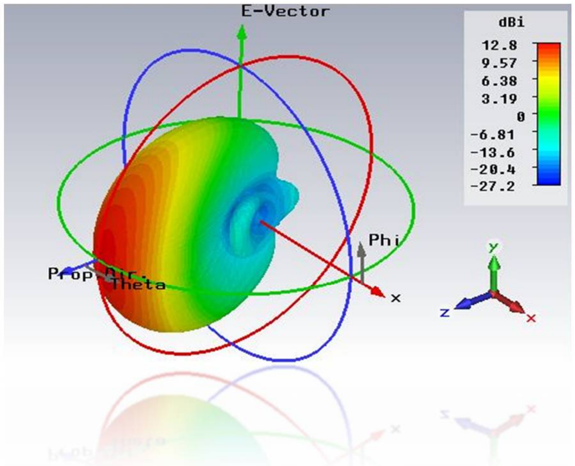

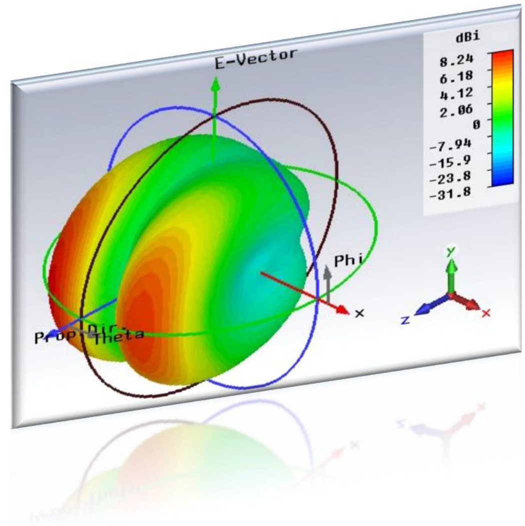

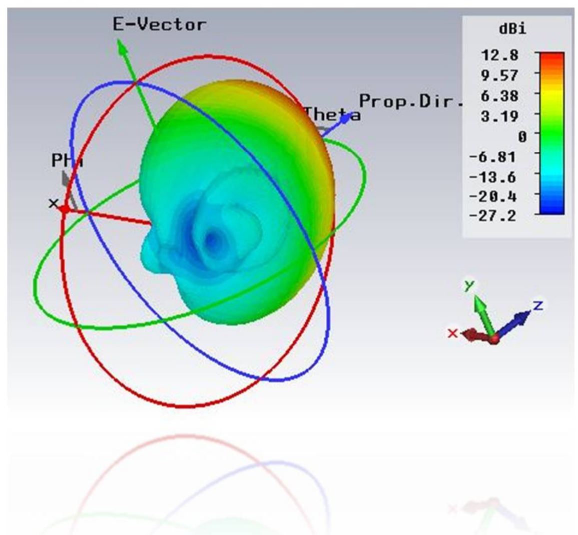

IV. CONCLUSION

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 equipment, and in order to fulfill the RF system requirements using the different frequency band, antenna technology is required to wideband characteristics .On the other hand, many modern wireless communication systems such as radar, navigation, satellite, and mobile applications use the circular polarized (CP) radiation pattern. The attractive features of the CP antenna are existed as follows. Firstly, since the CP antennas transmit and receive in all planes all around, it is strong for the reflection and absorption of the radio signal. In the multi-path fading channel environment, the CP antenna overcomes out of phase problem which can create dead spots, decreased throughput, reduced overall system performance. Further advancements could be done by using antenna substrates with higher dielectric constants in order to minimize the size a broadband wide beam circular polarization microstrip antenna. The configuration of the antenna is the simplest and easiest to be fabricated as compared with conventional microstrip antenna, the radiation beam is broadened a lot. Further research on circularly polarized wideband microstrip antenna is required as it gives the best performance and overall improvement of antenna parameters.

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