Analysis and Simulation of Wide band 24 GHz Planar Microstrip Monopole Antenna

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ABSTRACT
A navel 24 GHz Microstrip Patch antenna that provides 2 GHz bandwidth is proposed and designed. The antenna has simple configuration, light weight and low profile. The proposed antenna can be easily fed by using 50 Ω microstrip line and provide maximum directivity of 5.5 dB. A special type of substrate RT/ Duroid is used to produce 24 GHz resonance fequency. Bandwidth can be increased by increasing height of the substrate. The antenna supports UWB applicatons.

General Terms
Microstrip Patch Antenna

Keywords
24 GHz, UWB, RT/Duroid.

1. INTRODUCTION
Antenna is an essential device in wireless communication system. Need for wireless devices with Wideband are increasing day by day. The rapid development of wireless communication encourages the need for high throughput or high data rate in almost all communications. United States (U.S) Federal Communication Commission (FCC) allocates frequency bands for commercial use [5]. The frequency bands near 2.4 GHz, 24 GHz and 60 GHz were declared as unlicensed by the FCC [2]. The FCC defines fractional bandwidth is greater than 0.25 or bandwidth occupies more than 1.5 GHz of frequency spectrum as UWB [3], [9]. Microstrip antenna provides interesting features like low profile, light weight, low production cost and good aerodynamic profile. The antennas can be integrated with the feeding network on the same substrate, resulting structures are compact and very useful in practical applications. An important drawback of microstrip. antennas is their low radiation efficiency mainly caused by high concentration of field in the dielectric substrate which adds both dielectric and ohmic losses. Impedance mismatch can occur at feed point hence losses also occur during the feeding of microstrip lines. Different types of feeding methods are possible to microstrip antennas. Out of them transmission line feed and coaxial feed are simpler and mostly used [7]. A Goubau microstrip line is a classical line formed by a metallic rod coated by a dielectric layer [4]. RT/Duroid 5880 microwave material is used as substrate material for high frequency antennas to get perfect resonance [10]. The antenna is analyzed and designed using Ansoft HFSS software. Rectangular plot (to analyze return loss), radiation pattern and field pattern can be obtained using the software and hence bandwidth, directivity and total power can be measured.

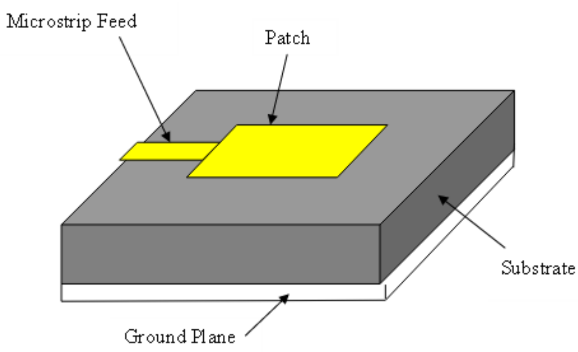

Fig. 1 Microstrip patch geometry

Figure 1 shows a model of rectangular microstrip antenna with microstrip feed (line feed). In general, microstrip antenna contains ground plane, dielectric substrate and a patch with feed as shown in figure.1 [7].

2. MICROSTRIP ANTENNA ANALYSIS
There are many methods of analysis for microstrip antennas. The most popular methods are transmission line, cavity, and fullwave models. The transmission line model is the easiest of all which gives good physical insight but less accurate and coupling is more difficult for this model. Cavity model is more accurate than the transmission-line model at the same time more complex. However, it also gives good physical insight and is difficult to model coupling. In general, the full wave model is very accurate and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. They are the most complex and usually gives less physical insight. Rectangular and circular patch configurations are most popular. There are many configurations that can be used to feed microstrip patch antennas. The four most popular feeds are the microstrip line, coaxial probe, aperture coupling and proximity coupling.

3. DESIGN EQUATIONS
A noval microstrip antenna for 24 GHz applications is proposed in this paper. The antenna dimensions are calculated using design equations. Dielectric constant (ε_r) and height (h) of the substrate is chosen to get the maximum radiation at desired frequency. The design equations are given below.

3.1 Patch Width

Patch width of microstrip antenna is calculated using the equation (2.1) [1], [7], [8].

$$W = \frac{C_0}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (2.1)$$

Where C_0 - speed of light

ε_r – Relative dielectric constant of substrate

f_r – Radiation frequency of the patch.

Patch width is calculated using resonant frequency of the antenna and relative dielectric constant of substrate material. The ε_r values lies between 2.2 and 12.

3.2 Effective dielectric constant

Effective dielectric constant of the substrate is calculated using the equation (2.2) [1], [7], [8].

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1\backslash 2} \qquad (2.2)$$

Where h – Height of the substrate. Usually the height is very much lesser than wavelength of signal and W/h >1.

Effective relative dielectric constant is the actual relative dielectric constant of the substrate during radiation and it is calculated using width of the patch and height of the substrate.

3.3 Hammersted Formula

Increase in patch length is 2ΔL and ΔL is calculated using the equation 2.3 [1], [7], [8].

$$\Delta L = 0.412h\left[\frac{\varepsilon reff + 0.3}{\varepsilon reff - 0.258}\right]\left[\frac{\frac{W}{h} + 0.264}{\frac{w}{h} + 0.813}\right] \qquad (2.3)$$

Increase in patch length occurs due to fringing effect at radiating edges of the patch [7].

3.4 Patch Length

Length of the patch is calculated using the equation (2.4) [1], [7], [8].

$$L = \frac{C_0}{2 f_r \sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (2.4)$$

Where the ratio W/L is between 1 and 1.5

Effective Patch Length is calculated using the equation

$L_{eff} = L + 2\Delta L$.

3.5 Conductance & Susceptance

Each radiating slot is represented by a parallel equivalent admittance Y with conductance and susceptance and is calculated using the equation (2.5) [7], [8].

$$Y = G + B \qquad (2.5)$$

Where for a slot of finite width W

$$G = \frac{W}{120\lambda}\left[1 - \frac{1}{24}(kh)^2\right], \quad \frac{h}{\lambda} < \frac{1}{10}$$

$$B = \frac{W}{120\lambda}\left[1 - 0.636\ln(kh)\right], \quad \frac{h}{\lambda} < \frac{1}{10}$$

3.6 Input Impedance

Finally the input impedance of the microstrip feed line is calculated using the equation (2.6) [7], [8].

$$Zin = \frac{1}{Yin} = Rin = \frac{1}{2G} \qquad (2.6)$$

The input impedance is needed to know what type of transmission line can be connected to obtain impedance matched condition.

4. SIMULATION OF 24 GHZ MICROSTRIP PATCH

Based on design equations, various dimensions of 24 GHz microstrip patch antenna is calculated. The following are the initial specifications for 24 GHz resonant frequency microstrip patch antenna that are analyzed and fixed.

Relative dielectric constant of substrate, ε_r =2.2. Substrate material is RT/Duroid 5880 with height 0.787 mm, loss tangent (tanδ) = 0.0009.

Table 1. Design Parameters

Λ	0.0125 (=1.25 cm)
W	0.004941 (=4.94 mm)
ε_{reff}	1.951646
ΔL/h	0.505335
L	0.003678 (= 3.678 mm)
W/L	1.343251
Zin	126 Ω

Table 1 shows the calculated values of wavelength, patch width, effective relative dielectric constant of the substrate, patch length, W/L ratio and input impedance of line feed for 24GHz radiation.

The 24 GHz microstrip patch antenna has been designed using Ansoft HFSS for the above tabulated dimensions. RT/Duroid 5880 substrate with dielectric constant of 2.2, height 0.787, and tanδ of 0.0009 is used [10]. Copper material is chosen for patch and ground plane design. The thickness of the copper patch is taken as 70 microns. The microstrip line is used feed the designed patch.

The simulated top view of the design is shown in figure 2.

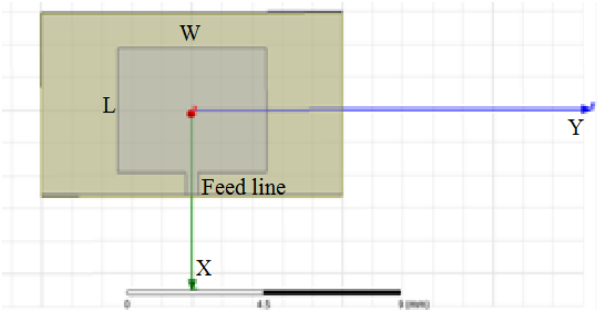

Fig.2. Simulated 24 GHz microstrip patch (Top view) using Ansoft HFSS

The side view of the design is shown in figure 3.

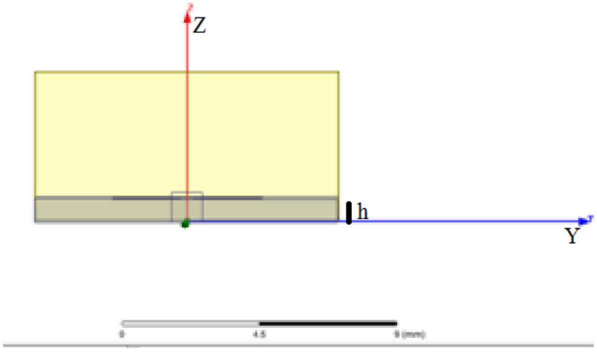

Fig.3. Simulated 24 GHz microstrip patch (Side view) using Ansoft HFSS

5. EXPERIMENTAL RESULTS

The proposed microstrip antenna was designed and simulated using Ansoft HFSS 13.0 and antenna parameters resonant frequency, E- field strength, Radiation Pattern, Directivity and total gain are obtained.

Fig.4. Rectangular plot (Frequency Vs S_{11}(dB)) of 24 GHz microstrip patch using Ansoft HFSS

The rectangular plot shown in figure 4 shows return loss (S_{11}) is very minimum at 24.17 GHz which is very near to the resonant frequency. The bandwidth of 2.3 GHz can be obtained from the plot. The frequency band which provides less than -10 dB return loss is considered as bandwidth. Radiation pattern and gain pattern of the proposed antenna are obtained and given in figures 5 and figure 6 respectively.

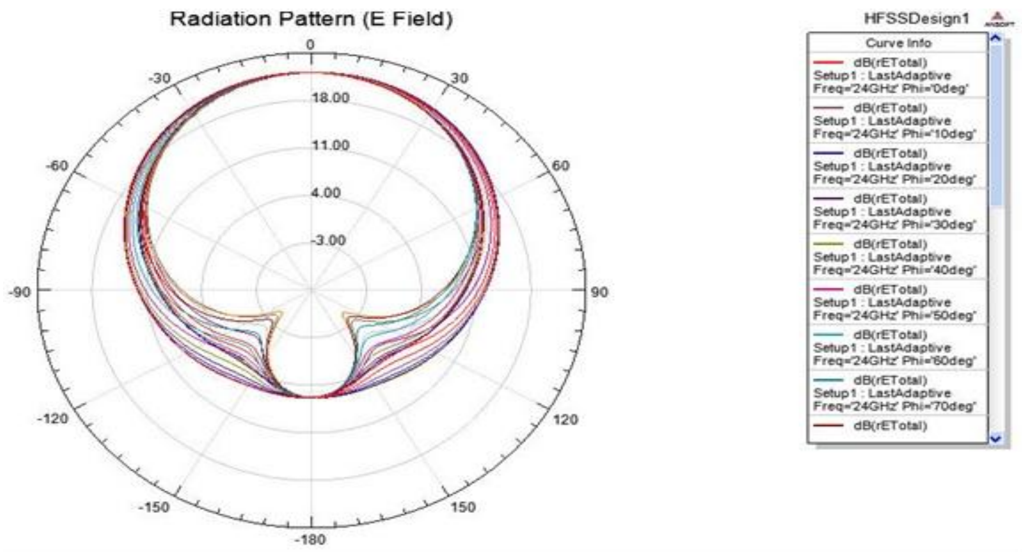

Fig.5 Radiation pattern of 24 GHz microstrip patch using Ansoft HFSS

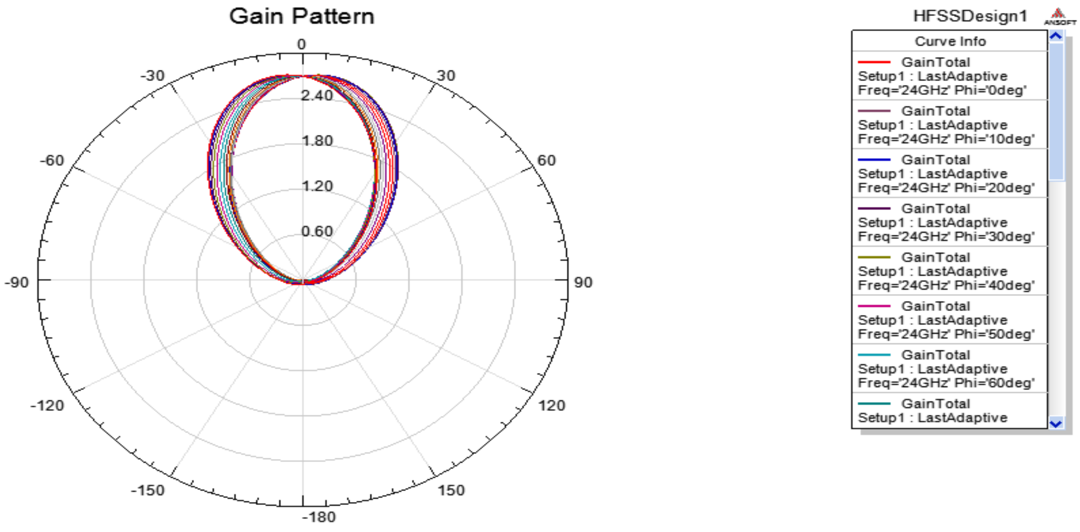

Fig.6 Total gain pattern of 24 GHz microstrip patch using Ansoft HFSS

The radiation pattern provides direction of maximum radiation and maximum radiated power of 5.5 dB. This also gives Half Power Beamwidth (HPBW).

The gain pattern represents the total gain of radiation in phi angle step size of 10.

6. CONCLUSION

A novel compact UWB microstrip patch antenna was presented. The proposed antenna is used rectangular patch with microstrip line feed. It resonates at 24.17 GHz. It provides 2.3 GHz bandwidth which can be considered as UWB as per definition given by FCC, USA. The antenna can be used for wideband applications where high data rate or high throughput is required.

7. REFERENCES

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