IJournals International Journal of Software & Hardware Research in Engineering
ISSN No: 2347-4890 Volume 2 Issue 8, August 2014

DESIGN OF RECTANGULAR MICROSTRIP PATCH ANTENNAS TO HIGH FREQUENCIES

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ABSTRACT

Microstrip antennas have been one of the most innovative topics in antenna theory and design in recent years. Microstrip antennas may be of any geometrical shape and dimensions. Rectangular patch is the most widely used configuration. There are many methods of analysis for microstrip antennas. The most popular models are the transmission line, cavity and full wave. The transmission line model is the easiest of all. It gives good physical insight. This paper focuses on the transmission line model for designing rectangular microstrip antennas. The key factors considered in the design include operating frequency, dielectric constant of substrate and height of the dielectric substrate. The antennas were designed in the X – band and Ku- band. The study showed that the higher the frequency of operation, the smaller will be the effective area of the microstrip patch antenna.

Keywords: Microstrip antenna, X-band, Ku-band, Transmission line model.

INTRODUCTION

Antenna is that part of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves. An antenna is a reciprocal device that is its directional pattern as receiving antenna is identical to its directional pattern when the same is used as transmitting antenna.

Microstrip antennas have been one of the most innovative topics in antenna theory and design in recent years, and are increasingly finding application in a wide range of modern microwave system. A microstrip antenna has capability to provide better performance. They are used in various systems such as radar, satellite, communication, missiles, space vehicles and various defense equipments because of their thin profile, low weight, planar configuration and easy integrability with other circuits. It has good gain as compared to other antenna because of its ability to concentrate of energy into a tight beam (expressed as narrow beam width) through a direction to provide better performance of radiation. These are suitable for mobile and government security systems where narrow bandwidth is priority. They are also used in laptops, microcomputers, mobile phones etc.

BRIEF REVIEW OF THE PAST WORK

Communication using electromagnetic radiation began early in the last century. Most of the systems used very long wavelengths (Low frequencies), which travelled great distances. Latter it was discovered that higher frequencies could bring other advantages to communications. Microwaves are easier to control because even small antennas could direct the waves very well. This control leads to confinement of energy into a tight beam (expressed as narrow beam width). This beam can be focused on another antenna dozens of miles away, making it very difficult for someone to intercept the conversion. Antenna concept dates back about 26 years to work in the U. S. A. by Deschamps [1] and in France by Gutton and Baissinot [2].Lewin investgated radiation from

Stripline discontinuities [3]. Additional studies were undertaken in the late 1960's by Kaloi, who studied basic rectangular and square configurations. However other than the original Deschamps report, work was not reported in the literature until the early 1970's, when a conducting strip radiator separated from a ground plane by a dielectric substrate was described by Byron [4]. Patch antennas first suggested by Munson [5]. Data on basic Rectangular and Circular microstrip patches were published by Howell [6]. A survey of microstrip antenna elements is presented by K. R. Carver and J. W. Mink [7].

The literature on microstrip antennas is vast and ever increasing. Now a day the different shapes of antennas were reported. Different attempts have been made to improve the bandwidth, gain, and efficiency of the microstrip antenna. These methods include variation in antenna dimensions, dielectric constant and patch shape and so on. T-shape patch [8, 12], swastika shape [9], Bow shaped Microstrip antenna [10], H shaped [11] were presented. X band active antenna was designed to overcome the disadvantages of antenna such as small bandwidth, large noise figure and large length [13].

Microstrip antennas may be of any geometrical shape and any dimensions. However all the microstrip antennas may be divided into following basic categories –

1) Microstrip patch antennas
2) Microstrip dipoles
3) Microstrip travelling wave antennas
4) Microstrip slot antennas

The simple configuration of microstrip antenna is a metallic radiator on a dielectric substrate as a support, with ground plane on the other side (Fig. 1).

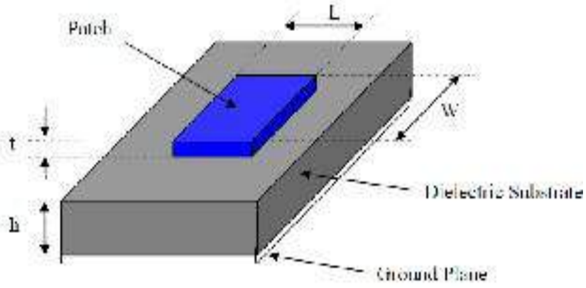

Fig. 1

The metal used is normally gold, copper or silver. Ideally the dielectric constant of the substrate should be low (ε_r= 2.5), so as to enhance the fringing fields, which account for radiation. The higher limit for value of ε_r is 13. Various types of substrates used are quartz, glass, sapphire, alumina etc. Alumina (Al_2O_3) is most commonly used because of higher thermal conductivity, strength and stability and good electrical properties. Microstrip antennas may be of any geometrical shape and dimensions.

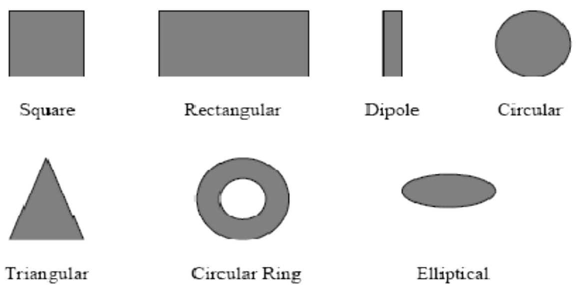

Fig. 2: common shapes of microstrip patch antennas.

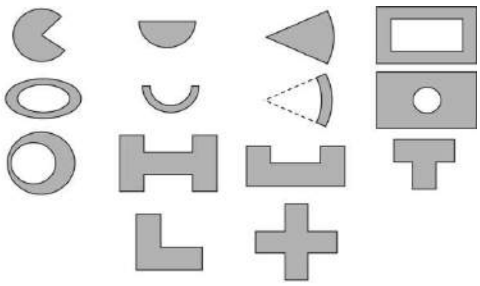

Fig.3 : Some other shapes of microstrip patch antennas.

There are several methods for analyzing the microstrip patches-

1) The vector potential approach
2) The Dynamic Green's Function Technique
3) The Wire Grid Model
4) The Radiating Aperture method
5) The cavity model
6) Modal Expansion model
7) The transmission Line model

Among all these models the transmission line model is more popular for their ease of calculation.

TRANSMISSION LINE MODEL

This model represents the microstrip antenna by two slots of width W and height h, separated by a transmission line of length L. The microstrip is essentially a non-homogeneous line of two dielectrics, typically the substrate and air.

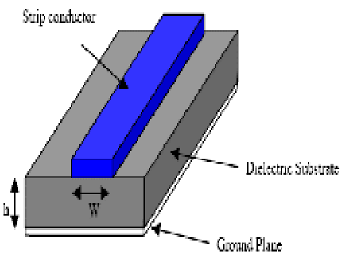

Fig (4) Microstrip Line

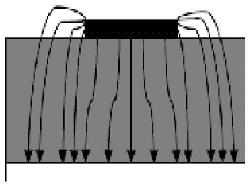

Fig (5). Electric Field Lines

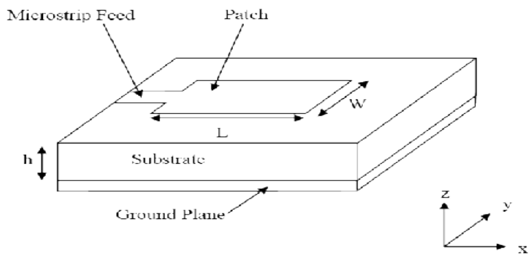

Fig.(6) Microstrip Patch Antenna

Hence, as seen from Fig. (4), most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse electro- magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε_{reff} is slightly less than ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in Fig.5 above.

The following calculation procedure was used to design Microstrip Patch antennas [14].

(a)Calculation of the antenna width (W)

This can be calculated using following equation

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

(b) Calculation of effective dielectric constant(ε_{reff})

This is calculated using following equation,

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

Where ε_r = Dielectric constant of substrate
h = Height of dielectric substrate
W = Width of the patch

(c) Calculation of effective length of the patch (L_{eff})

The effective patch length is calculated using the following equation-

$$L_{eff} = \frac{c}{2f0\ \sqrt{\varepsilon reff}}$$

(d)Calculation of the length extension (ΔL)

It is calculated using following equation

$$L = 0.412h\,\frac{(\varepsilon reff + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon reff - 0.258)(\frac{W}{h} + 0.8)}$$

(e) Calculation of the actual length of the patch

The actual length of the patch antenna is calculated using following equation

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

Fig. (6) shows a rectangular microstrip patch antenna of length L, width W resting on a substrate of height h. The co-ordinate axis is selected such that the length is along the x direction, width is along the y direction and the height is along the z direction.

RESULTS AND DISCUSSION

The antenna dimensions were calculated using above formulae. The frequency selected in the range of X band (8 – 12 GHz) and Ku band (12-18 GHz).The substrate selected is Alumina with dielectric constant ε_r= 9.6 and height h = 0.065 cm.The results are tabulated in table (1) and (2).

Fig. 7 shows the graph of frequency versus width of the patch. It shows that the width of the patch decreases with the operating frequency. At 8 GHz frequency the width of the patch becomes 0.814 cm and at 18 GHz frequency it becomes 0.362 cm.

Fig 8 shows the graph of frequency versus antenna patch length. From the graph it shows that as frequency increases, the patch length decreases. At 8 GHz frequency, the patch length is 0.606 cm and when frequency approaches 18 GHz, the patch length becomes 0.269 cm.

Table 1: Microstrip patch antenna dimensions in X band.

Frequency (f) (GHz)	ε_{reff}	Width (cm)	Patch Length (cm)	Wavelength λ= c/f
8	8.374	0.814	0.606	3.75
8.5	8.33	0.767	0.570	3.53
9	8.284	0.724	0.538	3.33
9.5	8.241	0.686	0.510	3.16
10	8.201	0.652	0.485	3
10.5	8.163	0.621	0.461	2.86
11	8.125	0.592	0.440	2.73
11.5	8.090	0.567	0.421	2.61

| 12 | 8.055 | 0.543 | 0.404 | 2.5 |

Table 2: Microstrip patch antenna dimensions in Ku band.

Frequency (f) (GHz)	ε_{reff}	Width (cm)	Patch Length (cm)	Wavelength λ= c/f
12	8.055	0.543	0.404	2.5
13	7.989	0.501	0.373	2.31
14	7.928	0.465	0.346	2.14
15	7.871	0.434	0.323	2
16	7.818	0.407	0.303	1.88
17	7.768	0.383	0.285	1.76
18	7.721	0.362	0.269	1.67

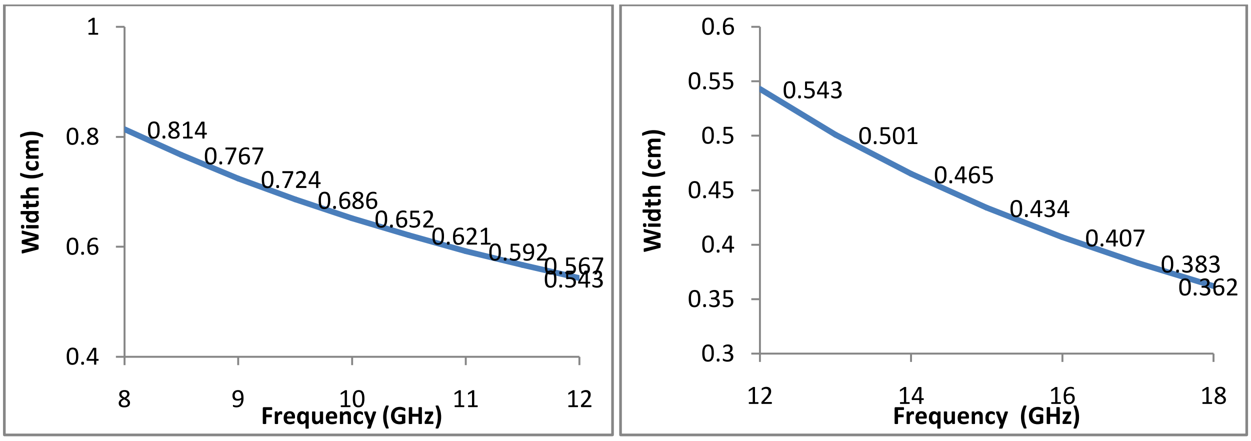

Fig. (7) The graph of Width of the patch against frequency

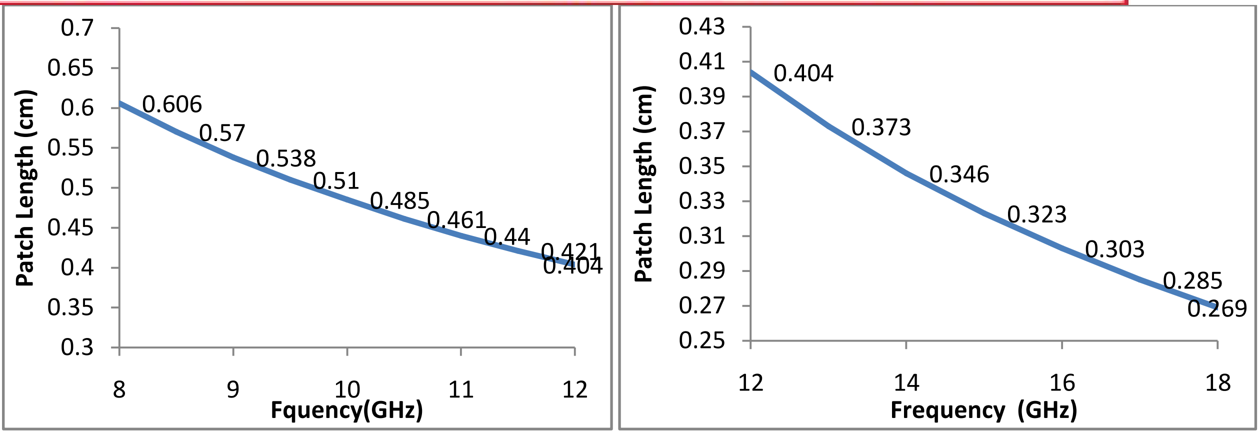

Fig. (8) The graph of Length of the patch against frequency

The variation of effective dielectric constant with patch length is shown in fig. 9. When effective dielectric constant is 8.374, the patch length is 0.606 cm and when effective dielectric constant is 7.721, the patch length is 0.269. From this it depicts that the higher the effective dielectric constant, the longer will be the patch length of the microstrip patch antenna.

From fig.10, it is shown that with increase in the width of rectangular patch antenna the length of the antenna increases. This means the effective area of the patch increases.

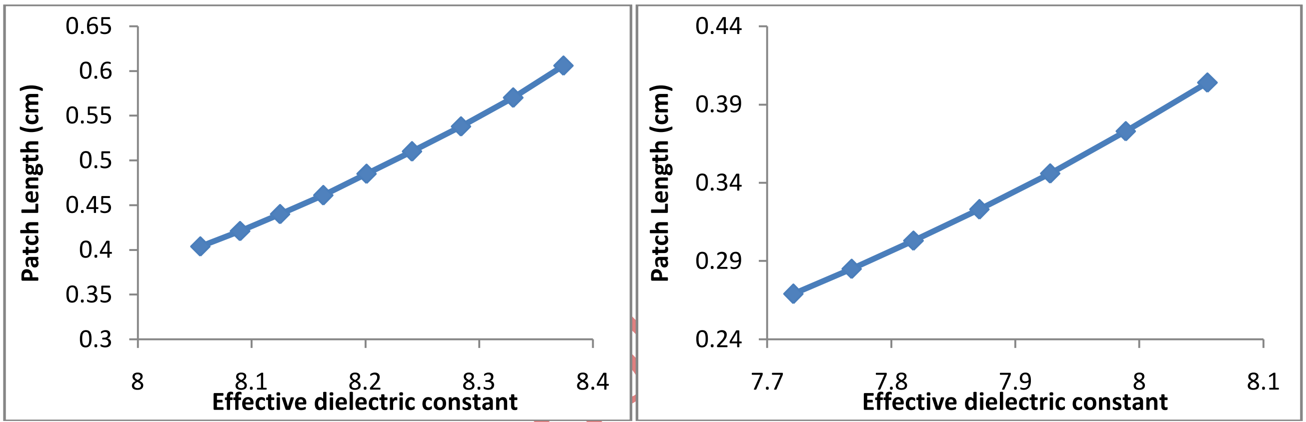

Fig. (9) The graph of patch length against Effective dielectric constant

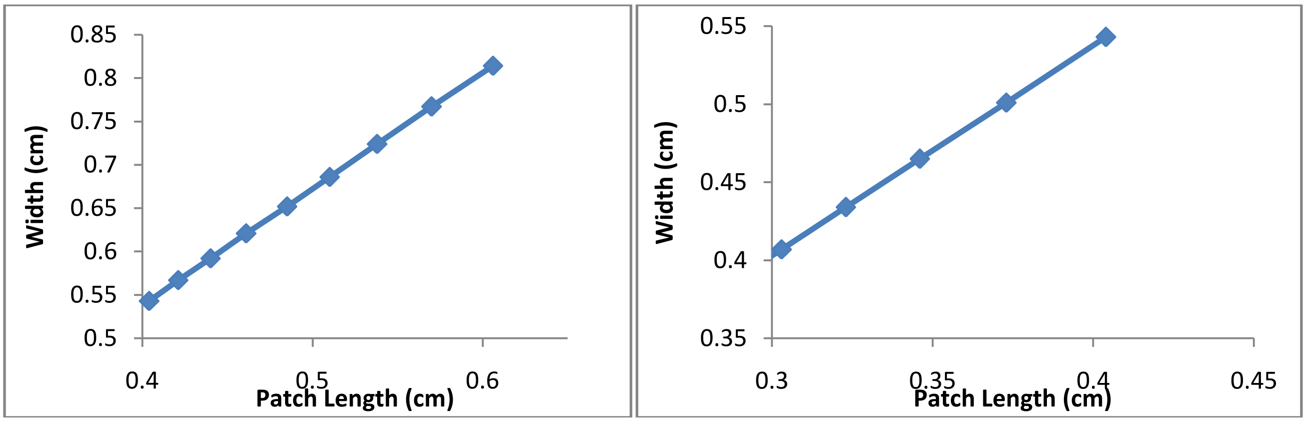

Fig. (10) The graph of Width of the patch against Patch length

Conclusion

This paper reports the step by step procedure of designing microstrip patch antenna using transmission line model. The effective area of the microstrip patch antenna is inversely proportional to the frequency of operation. The effective dielectric constant is a function of frequency. The alumina substrate has high dielectric constant. The advantage of a high dielectric constant substrate is in the size reduction factor.

Acknowledgement: Author wishes to acknowledge the financial support by UGC WRO Pune.

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iJournals International Journal of Software & Hardware Research in Engineering
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