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Review Paper

Microstrip Patch Antenna

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Abstract

There are various types of antenna which are presently used for many applications. These antennas are generally printed antennas which are rigid and hard. An antenna consists of copper printed at the top and the bottom of dielectric substrate. The copper print on the upper part of the dielectric substrate represents the radiating part and the print on the lower part of the substrate represents the ground plane of an antenna. In this review paper we have furnished the pros and cons of a rectangular microstrip patch antenna.

Keywords: Effective dielectric constant, Fringing, Loss tangent, Resonant frequency, Quality factor.

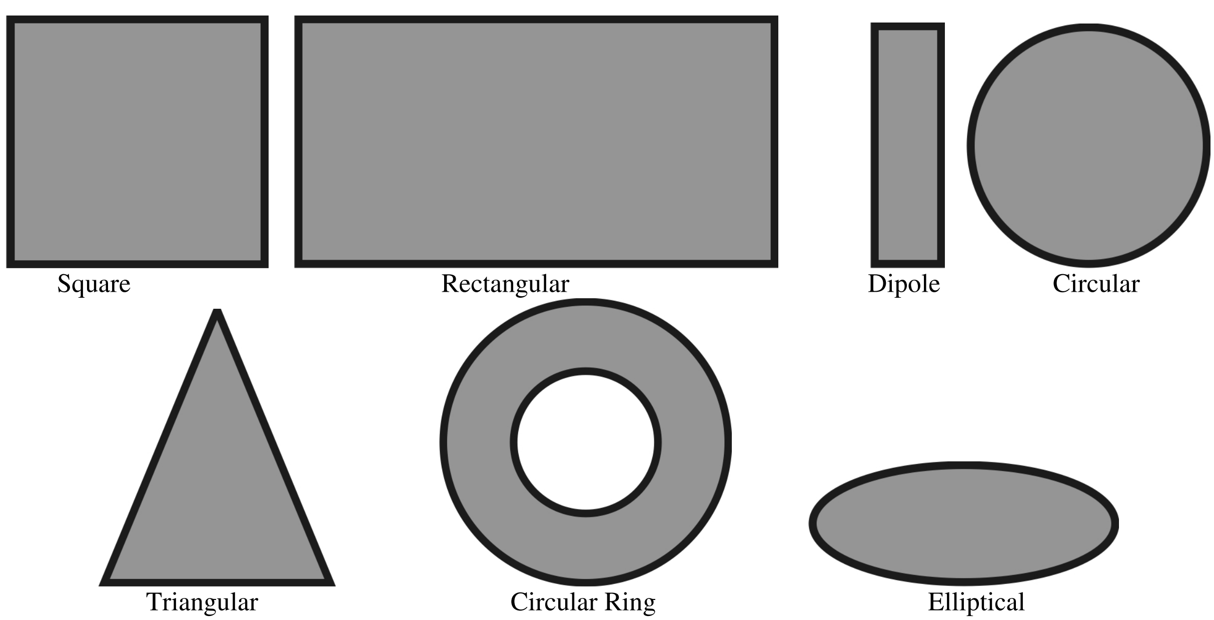
Introduction

A microstrip patch antenna consists of a conducting plane and a metallic ground plane. A dielectric material remains in between them. Electromagnetic waves can propagate through these planes. Maximum transmission takes place in a direction normal to the patch. A microstrip antenna may be of different shapes. As revealed from its ingredients or parts, mentioned above, a microstrip antenna can be easily prepared. Its cost is also not at all high. Its weight is also small. It becomes robust only when it is made on a PCB. In general, even if a large array of antennas is made, still its weight remains quite small. An antenna may be made flexible also. Antennas may possess different impedances and so different resonant frequencies[1].

For a microstrip antenna the length of the patch is chosen in between $\lambda/3$ and $\lambda/2$, where λ is the wave-length. The dielectric constant of the dielectric substrate lies between 2.2 and 12. In general, the bandwidth of a microstrip antenna is small. This bandwidth can be increased by applying some techniques. The simplest technique is to increase the height of the substrate. This gives rise to an improvement in the efficiency of the antenna. But there is a limitation of this technique. The more the height of the substrate the more is the surface wave, thereby decreasing the polarisation property of the antenna[2].

Designing

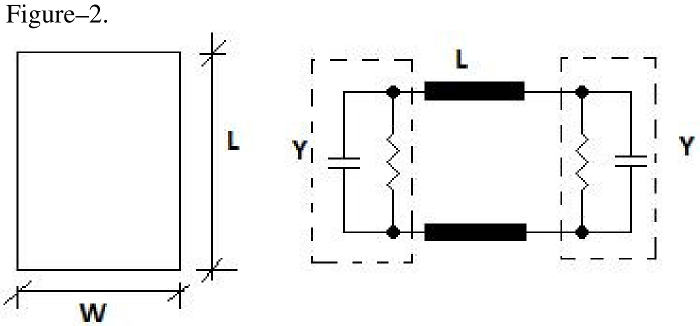
A microstrip patch antenna may be of different shapes.



Figure–1: Different structures of microstrip patch antenna.

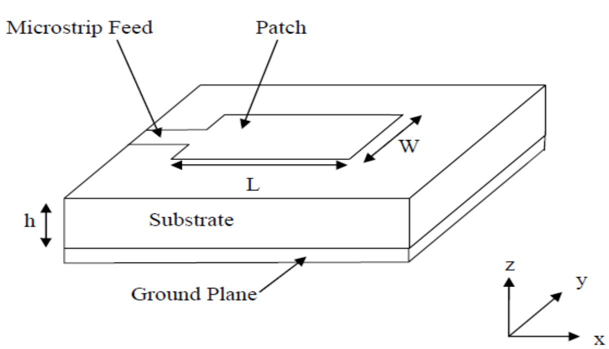
Out of all the designs here the rectangular antenna is our matter of interest. A rectangular microstrip patch antenna is a widely used antenna because it is easy to manufacture and also very suitable for thin substrate. However, some parameters should be considered before designing such an antenna. A rectangular patch antenna can be furnished as either transmission line model or cavity model.

Transmission Line Model: In this model a rectangular microstrip antenna is considered as if a combination of two slots through which radiation takes place under low impedance vide Figure–2.



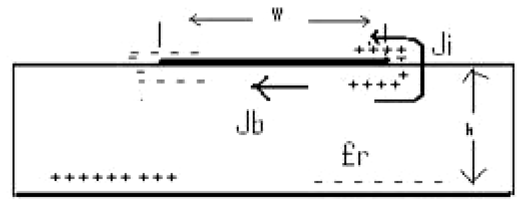
Figure–2: Transmission line equivalent of an unloaded microstrip rectangular patch.

Feeding a microstrip antenna at the input gives rise to an electric field. Due to finite shape of the patch of the antenna there happens fringing. This fringing takes place at the edges of the patch. It depends upon different factors e.g. length and breadth of the patch, height of the substrate etc[3]. Such fringing of electric field must be reduced. This can be done by increasing the length of the patch considerably in comparison with the height of the subtrate. Then side by side it gives rise to a change in the resonating length. An impact of fringing is the apparent increase in the length and breadth of the patch. So, in course of calculation of the resonating frequency one should consider the effective length and effective width. Fringing also gives rise to a change in the dielectric constant.



Figure–3: Microstrip line on a dielectric substrate.

Cavity Model: For an antenna the transmission line model is easy to design but it ignores the field variation in the radiating patch. A different approach of analysis concludes the leftover part in transmission line model. This approach is the cavity model. In this model the separation between the upper and lower surfaces of the dielectric is considered in charged condition. When the substrate height is quite small, it is presumed, as if, there is a cavity between these two charged surfaces. When the microstrip patch is energised, charge distribution takes place as shown in Figure–4.



Figure–4: Charge distribution and current density in microstrip patch.

The distribution of charge gives rise to both attraction and repulsion[4]. Due to repulsion between like charges on the lower surface of the patch some charge is drifted to the edges of the dielectric as well as towards the upper surface. This leads to a small current at the top of the dielectric. To remove this current the height of the substrate should be small and the width of the patch considerably large in comparison with the height. This will also remove the tangential field at the edges. Thus the sides of the dielectric behave as magnetic walls which do not disturb the electric or magnetic field within the subtrate.

However, to be very specific, tangential magnetic field cannot be totally wiped away. Thus to address loss in cavity model a parameter called *loss tangent* (tan δ) is introduced. This value is appropriately chosen to consider the losses due to cavity. It is inversely proportional to the quality factor of an antenna.

Measurements

When the width to height ratio is very high and the dielectric constant has also a large value, there happens an accumulation of charge in the subtrate. This gives rise to an apparent increase in the size of the patch. Low frequency does not, practically, affect the dielectric constant. But at UHF we are to consider the effective dielectric constant instead of dielectric constant[3]:

$$K_{eff} = \frac{K+1}{2} + \frac{K-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}.$$

The width of the microstrip patch is calculated by[3]

$$W = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0}}\sqrt{\frac{2}{K+1}}.$$

Due to fringing the apparent increase in length of the patch[3],

$$\Delta L = 0.412h\frac{(K_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(K_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}.$$

On both sides of the patch the length is apparently increased. So, the effective length is given as[3]

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

$$\therefore L = L_{eff} - 2\Delta L = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0 K_{eff}}} - 2\Delta L$$

The resonant frequency for the microstrip antenna is given by

$$f_r = \frac{1}{2L\sqrt{\varepsilon_0\mu_0 K}}.$$

When the fringing affects the resonance, in that case the resonant frequency,

$$f_{rc} = \frac{1}{2L_{eff}\sqrt{\varepsilon_0\mu_0 K_{eff}}}.$$

Resonant Input Resistance: The admittance of a radiating slot is given by[3]
$Y = G + jB.$

There should be a separation of 0.5λ between the two radiating slots. But due to fringing effect the length of the patch is chosen in between 0.48λ and 0.49λ. The total input admittance can be found out by a transformation of admittance from slot 2 to 1. Thus the transformed impedance is given by[4]

$$Y_2' = G_2' + jB_2',$$

Where: $B_1 = B_2'$ and $G_1 = -G_2'$.

The reactive part is annulled at resonance. So, the total admittance,

$$Y_{in} = Y_1 + Y_2 = 2G_1,$$

Where: $G_1 = \frac{1}{2R_{in}}$.

Considering the mutual effect between the slots, the resonant input resistance can be written as[3]

$$R_{in} = \frac{1}{2(G_1 \mp G_{12})},$$

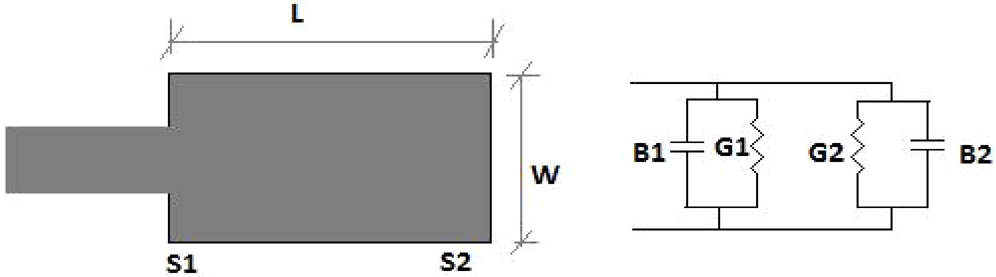
Where: G_1 is the conductance of single slot and G_{12} the mutual conductance of the radiating slot of the antenna.

This R_{in} gives the resonant input resistance at Y=0. But, in fact, this value gives a mismatch with the resonating frequency. In order to get perfect matching of the radiating patch with the transmission line R_{in} is varied through the introduction of an inset feed at some particular distance from Y=0. The value of R_{in} at $Y=Y_0$ is given by[3]

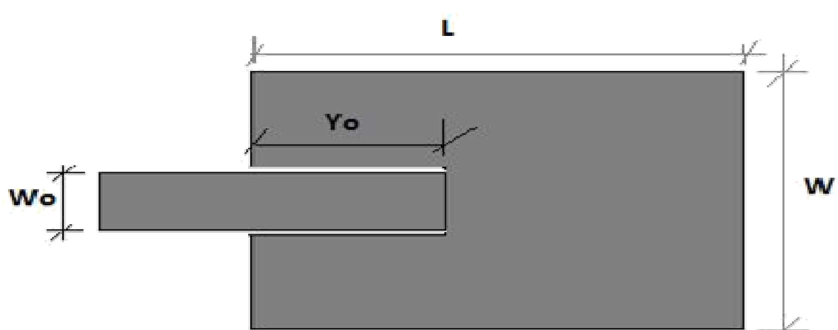
$$R_{in}(Y = Y_0) = \frac{1}{2(G_1 \pm G_{12})}\cos^2\frac{\pi}{L_0}Y_0.$$

From the last two equations we find

$$R_{in}(Y = Y_0) = R_{in}(Y = 0)\cos^2\frac{\pi}{L_0}Y_0.$$



Figure–5: Microstrip patch with equivalent circuit model.



Figure–6: Inset feed microstrip patch resonating at a distance Y_0 with the resonant input resistance $R_{in}(Y=Y_0)$.

Conclusion

The present era is electronics era. In this era the earth is, as if, shrunk into a tiny globe. This has happened due to tremendous development in telecommunication. In telecommunication antenna plays a vital role. The more efficient the antenna the more effective is the communication. The present paper is a glimpse on this aspect with regard to rectangular microstrip patch antenna.

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