Review of Microstrip Patch Antenna for Wireless Applications

Priya Rawat[1], **Anas Iqbal**[2]

[1]*M Tech Scholar, Department of Electronics and Communication, All Saint's College of Technology, Bhopal*

[2]*Research Guide, Department of Electronics and Communication, All Saint's College of Technology, Bhopal*

Abstract - In this fast changing world in wireless communication, multiband antenna has been playing a significant role for wireless services. Wi Fi, Wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) have been widely applied in gadgets and mobile devices such as handheld computers and smart phones. These three techniques have been widely considered as a cost effective, reliable flexible and high speed data connectivity solution, enabling mobility of user. This paper presents a literature survey of multi band rectangular patch antenna for Wi Fi WLAN and WiMAX application with variety of dielectric substrate, feeding techniques and slots including Ground Slots. In this paper we also describe the basics concepts of microstrip antenna, various feeding methods, designing of model and antenna parameters with their advantages and disadvantages

Keywords- Microstrip Antenna, Design Equations of Microstrip Antenna, Radiation Mechanism, Compact Antenna Review on microstrip.

1. INTRODUCTION

The learning on microstrip patch antennas has made a enormous progress in the recent years. Compared with the usual antennas, microstrip patch antennas have other advantages and better prospects. In this period of next generation networks we need high data rate and size of devices are getting lesser day by day. In this development three important standards are Wi-Fi, WLAN and Wi-MAX. For success of all these three wireless applications we need competent and small antenna as wireless is getting more and more vital in our life. This is the case, portable antenna technology has developed along with mobile and cellular technologies. Microstrip antennas (MSA) have uniqueness like low cost and low profile which prove Microstrip antennas (MSA) to be well-matched for WiFi/WLAN/Wi MAX application systems. A Microstrip patch antenna consists of a radiating patch on one surface of a dielectric substrate which has a ground plane on the other surface and overview of MSA shown in fig 1. The patch is made of conducting material such as copper or gold and can take any possible shape shown in fig 2. The radiating patch & the feed lines are usually photo etched over the dielectric substrate. The EM waves fringing off the patch into the substrate and are radiated out into the air after reflecting from the ground plane. For better antenna, a thick dielectric substrate having with low dielectric constant is desirable as this provides better efficiency, bandwidth and better radiation.

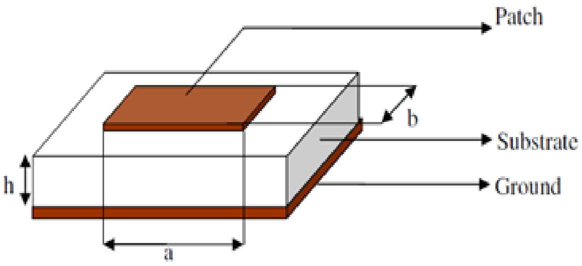


Figure 1 Structure of a Microstrip Patch Antenna

The dielectric substrates used are bakelite, (FR_4) Glass Epoxy, RO4003, Taconic TLC and Roger T Duroid. The height of the substrates is constant i.e., 1.5 to 1.6 mm

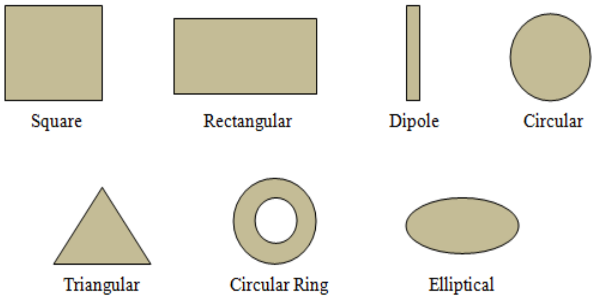
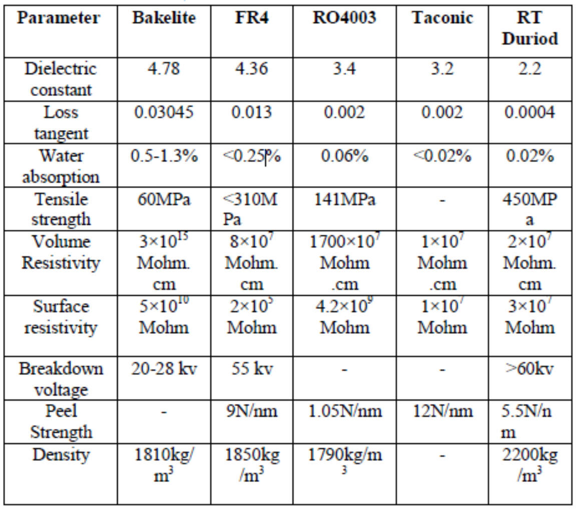


Figure 2 Common geometries of microstrip patch elements

Table 1 Properties of different substrates for microstrip patch antenna design



Parameter	Bakelite	FR4	RO4003	Taconic	RT Duriod
Dielectric constant	4.78	4.36	3.4	3.2	2.2
Loss tangent	0.03045	0.013	0.002	0.002	0.0004
Water absorption	0.5-1.3%	<0.25%	0.06%	<0.02%	0.02%
Tensile strength	60MPa	<310MPa	141MPa	-	450MPa
Volume Resistivity	3×10^{15} Mohm. cm	8×10^{7} Mohm. cm	1700×10^{7} Mohm .cm	1×10^{7} Mohm .cm	2×10^{7} Mohm. cm
Surface resistivity	5×10^{10} Mohm	2×10^{5} Mohm	4.2×10^{9} Mohm	1×10^{7} Mohm	3×10^{7} Mohm
Breakdown voltage	20-28 kv	55 kv	-	-	>60kv
Peel Strength	-	9N/nm	1.05N/nm	12N/nm	5.5N/nm
Density	1810kg/m^3	1850kg/m^3	1790kg/m^3	-	2200kg/m^3

2. RADIATION MECHANISM

At first look it might seem surprising that a microstrip antenna can work very well at all, since it consists of a horizontal electric surface current (parallel to the patch current) suspended (through substrate) a short distance above a ground plane. basic theory predicts that such a current will not radiate well. However, the microstrip patch & ground plane together make a resonant cavity (filled with the substrate). The cavity is lossy, not only to the material (conductor material and dielectric) loss, but in addition to the (desirable) radiation into space. Neglect material loss, the quality factor Q of the antenna is inversely relative to h which is substrate thickness, for a given substrate material, assuming the substrate is thin. Hence, bandwidth is proportional to h. The field inside the patch cavity at resonance from an current source inside the cavity (e.g., a fixed probe current) is proportional to Q. This means that the surface current on the patch (which is mainly on the lower side of the patch) is inversely proportional to substrate thickness h. This enhance in the amplitude of the surface current at resonance as the substrate get thinner just balances the image effect, which causes the radiation level to be reduced by a factor proportional to h (patch current radiating without the ground plane). Another point of view, the voltage at the boundaries of the patch (the electric field times h) for a resonant patch remains independent of h as the substrate gets thinner.

Therefore, without material losses, the patch remains a good radiator even for very thin substrate thicknesses, and it is possible to obtain a good impedance match even for a very thin substrate. In the lossless case, the lower limit on the substrate height would only be determined by the bandwidth one is willing to accept. In actuality, the Q is restricted by the material losses, so for sufficiently thin substrates it becomes difficult to obtain a good impedance matched (in this region the radiation efficiency will also be poor). However, even for substrates as thin as a good match may be obtained with a approximate efficiency of around 65 percent for a typical Teflon substrate and copper conductors [37].

Modes of Operation

For the rectangular patch, the TM_{mn} mode has a electric field that is given by

$$E_z^{mn}(x,y) = \cos(\frac{m\pi x}{L})\cos(\frac{n\pi y}{W}) \qquad 1$$

The common mode of functioning for a broadside pattern is the TM_{10} mode, which has no variation and has a length L that is approximately half wavelength in the dielectric. In this mode the patch basically acts as a wide microstrip line of width W that form a transmission-line resonator of length L. The width W is typically larger than the length L in order to increase the bandwidth. A ratio W/L = 1.5 is typical.

For the circular patch, the TM_{np} mode has a normalized electric field that is given by

$$E_z(p,\emptyset)=\cos(n\emptyset)\frac{j_n(\frac{x'_{np}\ p}{a})}{j_n(x'_{np})} \qquad 2$$

where, x'_{np} is the p^{th} root of the bessel function's (). The usual mode of operation is the TM_{11} mode with x'_{11} =1.841.This mode has the lowest resonance frequency and have a broadside pattern

Microstrip patch antennas are increasing in reputation for use in wireless applications due to their modest structure. Therefore they are really compatible for embedded antennas in handheld wireless devices such as tablets, cellular phones, pagers etc. The telemetry and communication antennas need to be thin, conformal and are often in the form of microstrip patch antennas. Another area where they have been used is satellite communication. Some of their major advantages discussed [1] are given below:

- Light weight and volume.
- Low planar configuration which can be easily made conformal.
- Supports, linear and circular polarization.
- Low fabrication cost, hence can be manufactured in large quantities.
- Can be easily integrated with integrated circuits (MMICs).
- Mechanically robust when mounted
- Capable of dual and triple and multiband frequency operations.

Microstrip patch antennas also suffer from drawbacks as compared to conventional antenna. Some of their major disadvantages [1] are given below:

- Narrow bandwidth.
- Low efficiency.
- Low Gain.
- Small power handling capacity.
- Extraneous radiation from feeds & junctions.
- Surface wave excitation.
- Poor end fire radiator except tapered slot antennas.

3. DESIGN EQUATIONS

After the correct selection of three parameters, i.e. frequency of operation, height of substrate and permittivity of dielectric material, the next step is to calculate width and length of the patch.

Step 1: Calculation of Width (W)

For an radiator, practical width that leads to good radiation efficiencies is:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}}$$
3

where, μ_0 is the free permeability, ε_0 is the free space permittivity and ε_r is relative permittivity.

Step 2: Calculation of (ε_{reff}) Effective Dielectric Coefficient The effective dielectric constant is

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1 + 12\frac{h}{W}]^{1/2}$$
4

Step 3: Calculation of Effective Length (Leff)

The effective length is

$$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}}$$
5

Step 4: Calculation of Length Extension (ΔL)

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{rff}-0.258)(\frac{W}{h}+0.8)}$$
6

Step 5: Calculation of actual Length of Patch (L)

The actual length of radiating patch is obtained by

$$L = L_{eff} - 2\Delta L \qquad 7$$

Step 6: Calculation of Ground Dimensions (Lg, Wg)

The transmission line model for calculation is applicable to infinite ground planes only. Though, for practical considerations, it is necessary to have a finite ground plane. The related results for finite and infinite ground plane can be achieved if the size of the ground plane is larger than the patch dimensions by approx. six times the substrate thickness all around the border given as:

$$L_g = 6h + L \ , \ W_g = 6h + W \qquad 8$$

To obtain simulated result, ground plane should take as infinite ground plane.

From simple circuit theory, the input impedance of the patch is then given by

$$\boldsymbol{Z_{in}} = j\omega L_p + \frac{R}{1+jQ\,(f_R-\frac{1}{f_R})} \qquad 9$$

where, the frequency ratio is defined as $f_R = f/f_0$, with f_0 being the resonance frequency of the patch cavity (the resonance frequency of the R-L-C circuit). This is not the same as the impedance frequency of the patch (the frequency for which input reactance is zero), denoted as f_R, due to the presence of the probe inductance. The R represents the input resistance of the patch at the cavity resonance frequency f_0 (f_R = 1), at which the input resistance is a maximum. CAD formulas for Lp, f_0, Q, and R are given. At the impedance resonance frequency: f_R, the input resistance will be slightly lower than the maximum value R according to the approximate formula

$$R_{in} = \frac{R}{1+(\frac{X_p}{R})^2} \qquad 10$$

where Xp = $\omega_0 L_p$ is the probe reactance. The probe reactance shifts the impedance resonance up from the cavity resonance by an amount Δf = $f_r - f_0$ given by the approximate formula

$$\frac{\Delta f}{f_0} = (BW)(\frac{1}{\sqrt{2}})(\frac{X_p}{R})$$
11

where,

$$BW = \frac{1}{\sqrt{2\,Q}}$$
12

BW is the bandwidth of the antenna (SWR < 2 definition) and Q is the total quality factor. The input impedance of the tank circuit along with its real and imaginary parts may be written in a normalized form as

$$Z_{RLC} = \frac{1}{1+jx} \qquad R_{RLC} = \frac{1}{1+x^2} \qquad X_{RLC} = \frac{-x}{1+x^2}$$
13

Where, $x = Q(f_R - \frac{1}{f_R}) \approx 2Q(f_R - 1)$
14

f_r is a normalized frequency term, and the bars over the impedance symbols shows that they have been normalized by dividing the impedances by R.

4. CONCLUSION

A theoretical review on microstrip patch antenna is presented in this paper. After study of various research papers it can be concluded that there will be effective match has to take while selecting the dielectric constant, height for rectangular patch. Particular microstrip patch antenna can be designed for each application and different merits are compared with usual microwave antenna.

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