Design of Planar Microstrip Patch Antenna for GPS Applications

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Design of Planar Microstrip Patch Antenna for GPS Application

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Abstract : The ever increasing demand of communication equipment and the emergence of new technologies require an efficient design of antenna that is of smaller size for range of frequency such as GPS. Because of the various advantages like low profile, ease of integration, low cost etc. microstrip antenna found vast application in communication system. Here we report the investigation on planar microstrip patch antenna for GPS and other wireless application using probe feed technique. Analysis is done on the two different substrate that is the FR-4 and RT Duroid 5880 with dielectric constant 4.3and 2.2 respectively. The antenna is simulated using HFSS v2012 and the antenna parameter like return loss, VSWR, Gain, Bandwidth would be analyzed. The design procedure for planar microstrip patch antenna for GPS and other wireless application is illustrated.
Keywords : GPS, Planar microstrip antenna, VSWR, Return loss

1. INTRODUCTION

An antenna is a device which converts electric powers into electromagnetic wave and vice versa.[1] There are many types of antenna are available in the market but due to various advantages here selected the planar microstrip antenna (MSTPA).[2] The Planar Microstrip Patch antenna have very small conducting patch, ground plane and substrate, in which substrate is sandwiched between the ground plane and the radiating patch.[3] The concept of microstrip patch antenna was developed during the revolution in electronics circuit miniaturization and large-scale integration in 1970s.[4] Because of the various disadvantage of the other conventional antenna like bulkiness, cost etc. microstrip patch antenna comes into the picture and it has advantages like low cost, light weight and also these antennas are integrated with microwave integrated circuits.[5] The telemetry and communication antenna used onboard missiles need to be thin and conformal. Another very important and essential application of microstrip patch antenna is in satellite communication.[6] Typically the microstrip patch antennas are characterized by their length, width, gain and radiation patterns etc.[6] Various parameters of the microstrip patch antenna and their design considerations are discussed in the subsequent sections. Section II describes the introduction to microstrip patch antenna.[7] Section III describes the design consideration and the design specification.[11] Next section IV describes the simulation results and comparison of the simulation results for two different substrate i.e. FR-4 and RT Duroid and in last section V gives the conclusion.

2. MICROSTRIP PATCH ANTENNA

The radiating metallic patch can be designed of any shape theoretically, but mostly conventional shape likes circular and Rectangular is used [7]. There is some other configurations used, which are complex for analysis and it requires very large numerical calculations. In its most common form, a MSTPA have a radiating patch on top of a dielectric substrate material

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which has a ground plane on the bottom of it. It is illustrated below in figure 1.

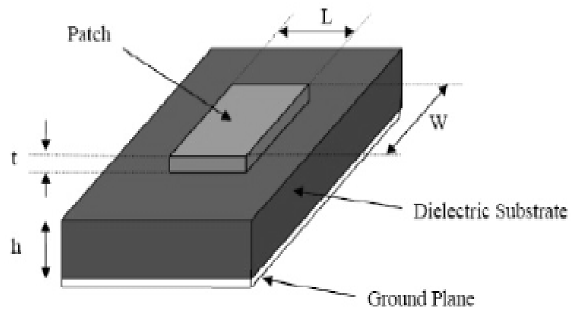

Figure 1: Structure of microstrip patch antenna

The patch is usually made of conducting radiating materials such as gold, copper etc. and it can be of any possible shape.[8] The Radiating metallic patch and the feed lines of probe are usually photo etched on top of substrate material. The MSTPA radiate mainly because of the fringing fields effect between the ground plane surface and patch edge of antenna.[9] For a top patch of rectangular shape, the length L of the top patch is $0.3333\lambda 0 < L < 0.5\ \lambda 0$, where λ0 denoted by the wavelength of free space. The rectangular patch is selected such as very thin like $t << \lambda 0$ (t is the thickness of top patch). The height (h) of the dielectric substrate material is $0.003\ \lambda 0 \leq h \leq 0.05\ \lambda 0$. The constant of the dielectric substrate (εr) is defined typically in the range $2.2 \leq \varepsilon r \leq 12$.[10]

3. DESIGN SPECIFICATION AND PROCEDURE

A. Design Specification

There are three important parameters which are to be considered carefully for the designing of a rectangular microstrip patch antenna for various communication application.[11]

- Resonant Frequency (f_r): The Mobile Communication Systems (GPS) uses the frequency range from 1000-2000 MHz. [11] So the designed antenna must be able to operate for this desired frequency range. The default resonant frequency chosen for this research design simulation is 1.565 GHz.
- Dielectric constant of the substrate material (ε_r): The dielectric material chosen for this design is RT Duroid and FR-4 which has dielectric constants of 2.2 and 4.3 respectively.
- Height of dielectric substrate (h): For the Microstrip patch antenna to be used in communication system, it is very essential that the antenna is kept light and compact in size. [12] Hence, the height of the dielectric substrate is chosen as 1.6 mm.

Hence, the design specification for the mentioned design are chosen as fr=1.565 GHz, $\varepsilon_{r(\text{RT Duroid})}$ =2.2, $\varepsilon_{r(\text{FR-4})}$ =4.3 and h=1.6mm

B. Design Procedure

Step 1: Calculation of Width (W) of top Patch[13]
The width of the MSTPA is given by

$$W = \frac{c}{2 * f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

By substituting $C = 3\times10^8$ m/s, $\varepsilon_r = 2.2$ and $f_r = 1.565$ GHz, it can be easily determined that W = 0.058 m = 58 mm and if $\varepsilon_r = 4.3$ than W= 0.072 m, so W =72 mm.

Step 2: Determine the effective dielectric constant (ε_{reff})[13]
Here the below equation is gives the effective dielectric constant,

$$\varepsilon_{reff} = \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2}\sqrt{1+12\frac{h}{w}}$$

By substituting $\varepsilon_r = 2.2$, W = 58 mm and h = 1.565 mm, it can be determined that $\varepsilon_{reff} = 2.234$ and for $\varepsilon_r = 4.3$, W = 72 mm we get $\varepsilon_{reff} = 4.507$.

Step 3: Defined the effective length (L_{eff})[13]
For finding of effective length is given by

$$L_{eff} = \frac{c}{2\ f_{r\sqrt{\varepsilon_{reff}}}}$$

By substituting $\varepsilon_{reff} = 2.234$, $c = 3\times10^8$ m/s and $f_r = 1.565$ GHz, it can determined that L_{eff} = 46.66 mm and for FR-4 we get L_{eff} =65.66 mm.

Step 4: Determination of the length extension (ΔL)[13]
The length of extension may be given by

$$\Delta L = 0.412h\frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{w}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{w}{h} + 0.8\right)}$$

By substituting $\varepsilon_{reff} = 2.234$ and other corresponding value it can be determined ΔL = 0.833 mm.

Step 5: Determination of actual length of top patch (L):[13]
The actual length of top patch is obtained by using expression

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

By substituting L_{eff} = 46.66 mm and length extension ΔL = 0.833 mm, the actual length can defined as L = 45 mm and for L_{eff} = 65.6666 mm andlength extension ΔL = 0.833 mm, the actual length can defined as L = 64 mm.

From the above mathematical calculation, the patch Parameters has been calculated for the substrate RT Duroid with dielectric constant 2.2. In similar manner the patch parameters are calculated for the substrate FR-4 with dielectric constant 4.3 by using the above equations. Here we have used h=1.6. The results are summarized in table 1 given below.

Table 1: Comparison of patch parameter for different Substrate material

Patch Parameter	RT Duroid($\varepsilon_{r=2.2}$)	FR-4($\varepsilon_{r=2.2}$)
Length(L)	45	64
Width(W)	58	72

From the above one can say that the substrate with low dielectric constant leads to a larger size of antenna. So that design for the microstrip antenna mostly substrate with higher dielectric constant is chosen.

4. SIMULATION RESULTS

Here the antenna is simulated with two different substrate i.e. Duroid and FR-4 and the result is simulated using HFSS (High Frequency Software Simulations) and using HFSS antenna parameter like Return loss(S_{11}), Bandwidth(MHz),gain and VSWR(Voltage Standing Wave Ratio) are analyzed.[14] Figure below shows the coaxial feed Planar microstrip patch antenna using HFSS.

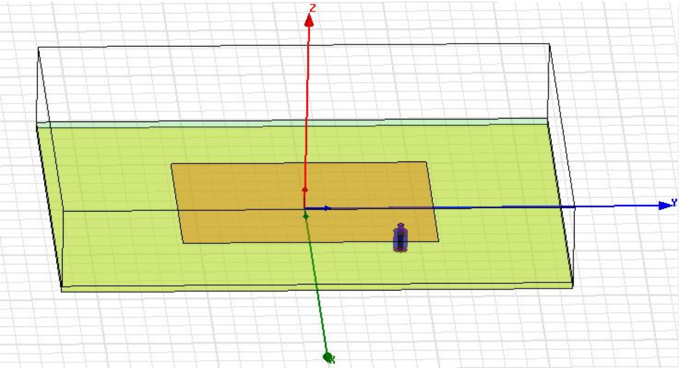

Figure 2: Planar Microstrip patch antenna designed using HFSS

A. Return Loss

A frequency range of 1 GHz to 2 GHz is chosen to obtain the above results. The resonate frequency is determine as the one at which the return loss has minimum value also the bandwidth can be determined from the return loss plot or the VSWR graph. [15] The antenna bandwidth(BW) is said to be that range of frequencies where the return loss (S_{11}) is greater than -10.0 dB (-10.0 dB S_{11} corresponds to a VSWR value of 2 which is an acceptable figure) as shown in figure 5. For the substrate RT Duroid (ε_r = 2.2) an return loss of -18.73 dB is obtained at the resonant frequency as shown in table II also it can be seen that for the substrate FR-4 the return loss is of -27.22 dB obtained at the frequency 1.56 GHz.For both the substrate the return loss Vs frequency graph is given below.

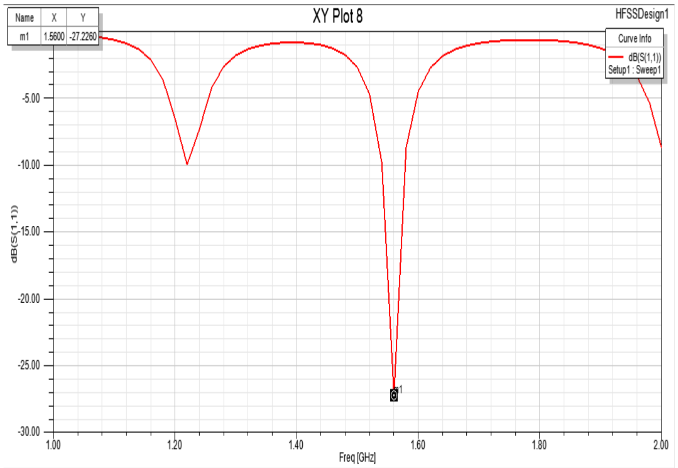

Figure 3: Return loss Vs Frequency graph for FR-4

From the figure 3 we can say that the proposed antenna using FR-4 substrate is resonates at two different band of frequency i.e. 1.22 GHz, 1.565 GHz and the corresponding return loss is -10.01 dB,-27.22 dB respectively.

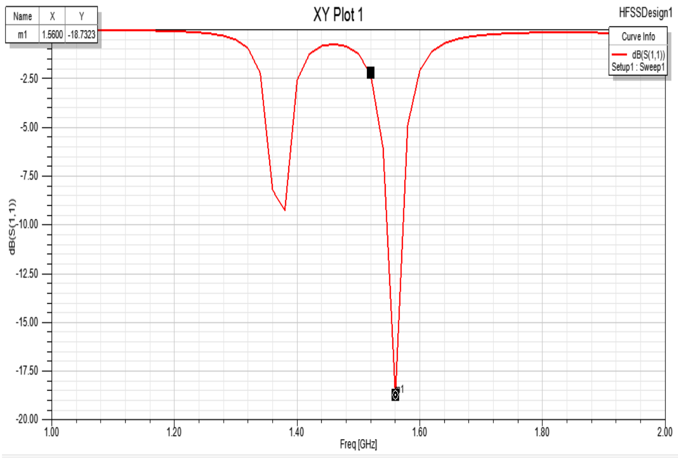

Figure 4: Return loss Vs Frequency graph for RT Duriod

Above figure 4 shows the return loss Vs frequency graph for the rectangular patch antenna with substrate RT Duroid. From the above figure one can say that the antenna will resonates at two different band of frequency i.e. 1.39 , 1.565 GHz with return loss -9 dB, -18.73 dB respectively.

B. VSWR

VSWR plot for both the RT Duroid and FR-4 substrate is given below.

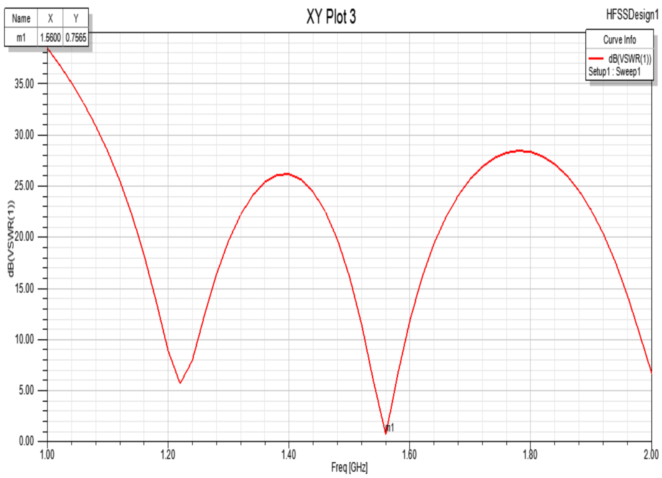

Figure 5: VSWR plot for the substrate FR-4

Here in both the figure 5 and figure 6 measure line is shows for the resonate frequency and which is used for the GPS (Global Positioning System) and other wireless application because the proposed antenna is resonate at multiband of frequency.

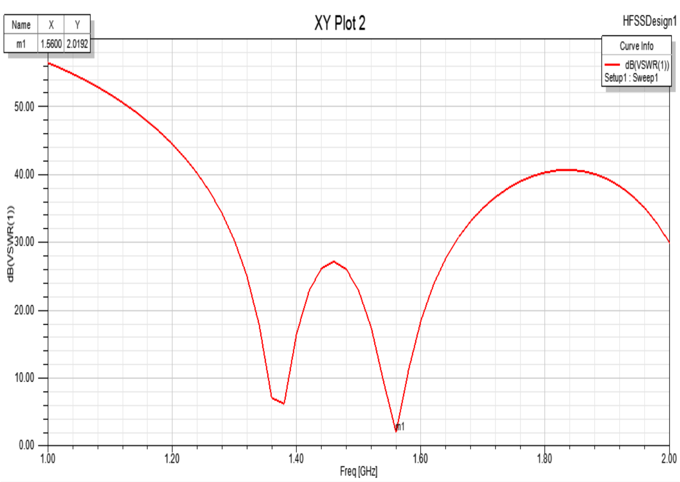

Figure 6: VSWR plot for the substrate RT Duroid

From the figure 6, we can say that antenna has a good impedance match at 1.565 GHz because the VSWR for that is 0.756 and which is very good.

Table II: Comparison of Simulation result for different dielectric substrate material

Patch Parameter	Return Loss S_{11} (dB)	VSWR	Band width (MHz)	Gain (dB)	Directivity (dBi)
FR-4 (ε_r = 4.3)	-27.22	0.756	40	0.62	4.55
RT Duroid (ε_r = 2.2)	-18.73	1.902	30	4.11	4.33

5. CONCLUSION

The microstrip patch antenna is designed and simulated using HFSS. The analysis is carried on two different substrate namely FR-4 epoxy and RT Duroid whose permittivity varies. Coaxial feeding is used as the antenna provides acceptable return loss , Gain, VSWR, Bandwidth etc. In the proposed model GPS band is obtained for the antenna in which the substrate is chosen as RT Duroid gives better efficiency in term of return loss(-27.22dB), Gain(4.11dB), Bandwidth(40MHz) when compared to antenna designed using FR-4 epoxy. The antenna will resonates at multiband of frequency which includes our research work frequency 1.565 GHz. So, it is applicable to GPS and other wireless application.

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6. REFERENCES

[1]. Balanis C. A, "Microstrip Antennas", Antenna Theory, Analysis and Design, Third Edition, John Wiley & Sons, pp-811-876, 2010

[2]. David M. Pozar ," Microwave Engineering", Fourth Edition, John Wiley & Sons, pp-96-379,2012

[3]. Ramesh Garg , Inder Bahl, Apisak Ittipiboon, Prakash Bhartia, " Microstrip Antenna Design Handbook", Artech House Inc. Norwood, MA, pp. 1-68, 253-316, 2001.

[4]. Dr M.Kulkarni,"Microwave and Radar Engineering", Fifth Edition, John Wiley & Sons, pp 61-262,2014

[5]. Prakash Kumar Mishra,Preeti Maddhyeshia,Rajesh Kumar Vishwakarma,Ritu Raaj, "Design of Dual Band Slot Loaded Rectangular Microstrip Antenna for GPS", 2013 International Conference on Communication Systems and Network Technologies.

[6]. Jagdish. M. Rathod, " Comparative study of Microstrip Patch antenna for GPS Application", International Journal of Innovation Vol.1,No.2, June 2010.

[7]. Weiwei Wu,Jiaxian Yin, Naichang Yuan, "Design of an efficient XBand Waveguide-Fed Microstrip Patch array", IEEE Transactions on Antennas and Propagation, July 2007, Vol.55, No.7. pp (1933-1939).

[8]. Syed Imran Hussain Shah, Shahid Bashir," Miniaturization of microstrip patch antenna with multiband response for portable communication systems", *DIPED*,2013

[9]. Ruchi Kadwane , Vinaya Gohokar," Design and chara-cteristics investigation of Multi-Band microstrip patch Antenna for Wireless Applications",*International Journal of Emerging Engineering Research and Technology*, Volume 2, Issue 3,pp 61-66,June 2014

[10]. S.Sreenath Kashyap , B,Saisandeep,"Designed and developedment of microstrip patch antenna for 2.4 GHz",*International Journal of Scientific and Engineearing research*,June 2012

[12]. S. Sreenath Kashyap , Dr. Vedvyas Dwivedi,"Stacked Swastik shaped microstrip patch antenna for Terahertz application" IEEE conference prociding of ET2ECN 2014,SVNIT Surat, December 2014

[13]. Osama M. Haraz,Abdel-RazikSebak," Quadband Planar PCB Antenna for WLAN and Mobile WiMAX Applications",*IEEE*,pp. 416-418,2011

[14]. FitriYuliZulkifli, HilmanHalim, and EkoTjiptoRahardjo," A Compact Multiband Microstrip Antenna Using U And S Slots ", *IEEE, 2008*

[15]. Muhammad R. Khan, Mohamed M. Morsy, Muhamm-adZ.Khan and Frances J. Harackiewicz," Miniaturized Multiband Planar Antenna for GSM, UMTS,WLAN, and WiMAX bands",*IEEE*,pp. 1387-1389,2011

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