GEOMETRICAL PARAMETERS OF V-SHAPED MICROSTRIP PATCH ANTENNA

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ABSTRACT

The goal of this paper is to study how the performance of the antenna depends on various parameters of the V-shaped microstrip patch antenna. This is a simulation based study. A series of parametric study were carried out to show the dependence of the characteristics of the antenna on its various geometrical parameters. The various geometrical parameters of the antenna are the included angle between the arms, the length and width of the arms of the patch. The design and simulation of the antenna was carried out using Ansoft HFSS v-11 simulation software, which is based on the finite-element method (FEM). First, the antenna is designed at 2.4 GHz using the basic concepts of electromagnetics. The simulated resonant frequency is obtained at 2.4 GHz with an impedance bandwidth of 50 MHz. Later, the bandwidth of the antenna is enhanced by increasing the substrate thickness. The measured resonant frequency is obtained at 2.49 GHz. The measured bandwidth of the antenna is 80 MHz. The possible cause of the difference between the simulated and measured results is also provided. Then, the effects of varying the parameters of the antenna on its performance are investigated.

Keywords: ***Microstrip, Antenna, Parametric, Simulation***

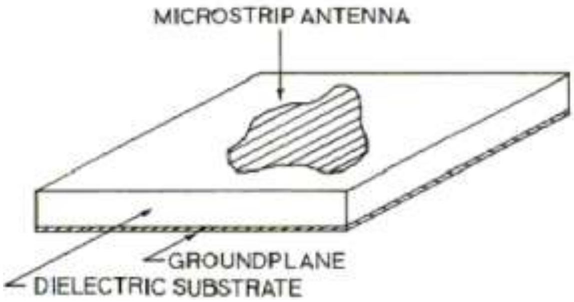
I. INTRODUCTION

An antenna is an element used for radiating or receiving electromagnetic wave. Although antennas may seem to be available in numerous different shapes and sizes, they all operate according to the same basic principles of electromagnetics. Many types of portable electronic devices, such as cellular phones, GPS receivers, palm electronic devices, pagers, laptop computers, and telematics unit in vehicles, need an effective and efficient antenna for communicating wirelessly with other fixed or mobile communication units. Advances in digital and radio electronics have resulted in the production of a new breed of personal communications equipment posing special problems for antenna designers. Personal wireless communication devices have created an increased demand for compact antennas. The increase in satellite communication has also increased the demand for antennas that are compact and provide reliable transmission. In addition, the expansion of wireless local area networks at home and work has also necessitated the demand for antennas that are compact and inexpensive.

A microstrip patch antenna is a type of antenna that offers a low profile, i.e. thin and easy manufacturability, which provides a great advantage over traditional antennas [1], [2]. Patch antennas are planar antennas used in wireless links and other microwave applications. Microstrip can be fabricated using photolithographic techniques. It is easily fabricated into linear or planar arrays and readily integrated with microwave integrated circuits. Microstrip patch antennas are attractive due to their compact structure; light weight due to theabsence of heavy metal stamped or machined parts, and low manufacturing cost using printed circuit technology. They also provide low profiles, conformity to surfaces and direct integration with microwave circuitry. Consequently, microstrip patch antennas are used widely in antenna arrays. Additionally, the planar structure of a microstrip antenna permits the microstrip antenna to be conformed to a variety of surfaces having different shapes. Microstrip antennas can be designed to produce a wide variety of patterns and polarizations, depending on the mode excited and the particular shape of the radiating element used. This results in the microstrip antenna being applicable to many military and commercial devices, such as use on aircraft or space antennas. There is an increasing demand for the use of microstrip antennas in wireless communication due to their inherently low back radiation, ease of conformity and high gain as compared to wire antennas. The goal of this thesis is to study how the performance of the antenna depends on various parameters of the V-shaped microstrip patch antenna. This is a simulation based study. First, the antenna is designed at 2.4 GHz. Ansoft HFSS software tool is used for the design and simulation of the antenna. Then, the antenna parameters are varied to study the effect of variation of the antenna parameters on the antenna performance. Later, the bandwidth of the designed antenna is increased by increasing the thickness of the substrate.

II. THEORY OF MICROSTRIP ANTENNA

Microstrip antennas received considerable attention starting in the 1970s. Microstrip antennas, as shown in Figure 2.1, consist of a very thin (thickness, $t \ll \lambda 0$ where $\lambda 0$ is the free-space wavelength) metallic strip (patch) placed a small fraction of a wavelength ($h \ll \lambda 0$, usually $0.003\lambda 0 \leq h \leq 0.05\lambda 0$) above a ground plane [1]. The microstrip patch is designed so that its pattern maximum is normal to the patch (broadside radiator). This is accomplished by properly choosing the mode (field configuration) of excitation beneath the patch. End-fire radiation can also be accomplished by judicious mode selection.



Microstrip Antenna Geometry

For a rectangular patch, the length L of the element is usually $\lambda 0/3 < L < \lambda 0/2$. The strip (patch) and the ground plane are separated by a dielectric sheet (referred to as the substrate).

There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants are usually in the range of $2.2 \leq \varepsilon r \leq 12$. The ones that are most desirable for antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size

III. MICROSTRIP ANTENNA ANALYSIS TECHNIQUES

Various methods are there to analyze impendence and radiation properties with elaborate analytical techniques. Somerfield-type integral equation method is one popular technique. Some of the methods have one thing in common; they assume that the dielectric substrate and the supporting ground plane are infinite in extent. The solutions are therefore valid for infinite geometries, or when substrate and ground plane dimensions are relatively large. The assumption does not introduce a severe difficulty in impedance calculation since microstrip geometries are inherently resonant structures and their impedance characteristics are primarily controlled by the printed elements.

However, difficulty arises in predicting the radiation patterns, where for small antenna dimensions diffraction effects alter the side and back radiations. Consequently, the Geometrical Theory of Diffraction is occasionally used in conjunction with these methods to improve the radiation-pattern predictions. Different models proposed for the microstrip antennas are the transmission-line, cavity, and full wave (which include primarily Integral Equations /Method of Moments). Both Transmission Line & Cavity Models are approximate ones. Only full wave solutions are accurate.

IV. SIMULATION TOOL USED: HFSS

HFSS is high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes the advantage of the familiar Microsoft Windows user interface [3]. It is an interactive software package for calculating the electromagnetic behavior of a structure. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give unparalleled performance and insight to all 3D EM problems.

Ansoft HFSS can be used to compute:

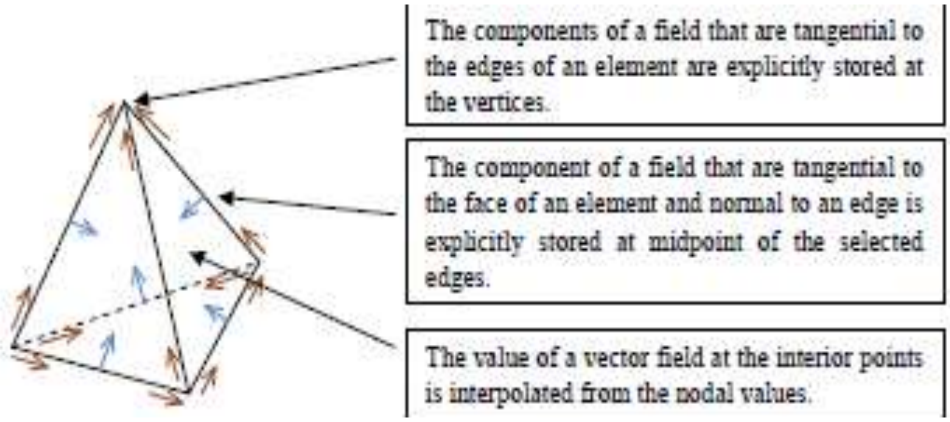
• Basic electromagnetic field quantities.

• Characteristic port impedances and propagation constants.

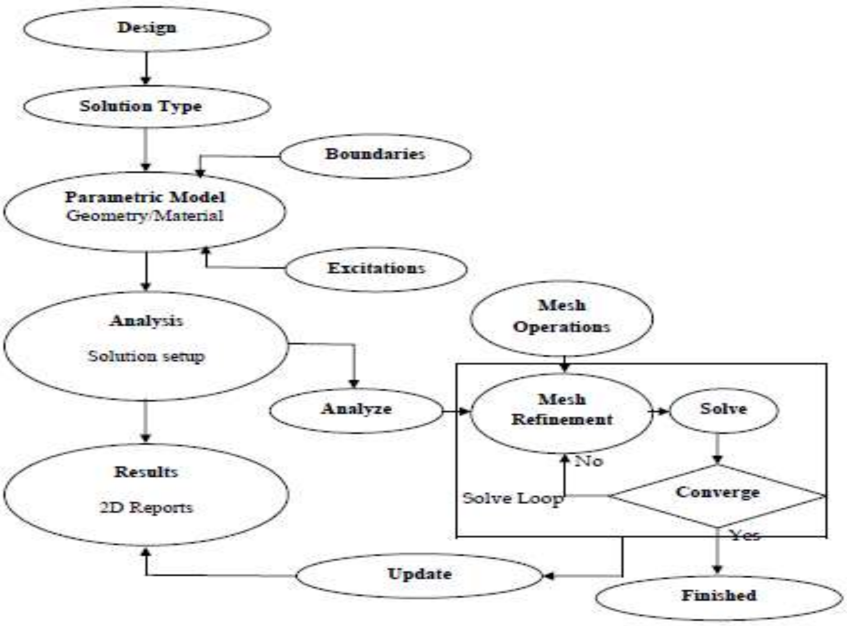
• Generalized S-parameters and S-parameters renormalized to specific port impedances.

• Eigen-modes or resonants of a structure.

HFSS employs the Finite Element Method (FEM). In general, the FEM divides the full problem space into thousands of smaller regions and represents the field in each sub-region (element) with a local function.



To produce an optimal mesh, HFSS uses an iterative process in which the mesh is automatically refined in critical regions. First, it generates a solution based on a coarse initial mesh. Then, it refines the mesh based on suitable error criteria and generates a new solution. When S-parameters converge within a desired limit, the iterative process ends. This limit is defined as Delta Error on the options available on HFSS. In this simulation, the Delta Error is chosen as 0.02 which defines convergence within 2% limit.



HFSS Solution Process Overview

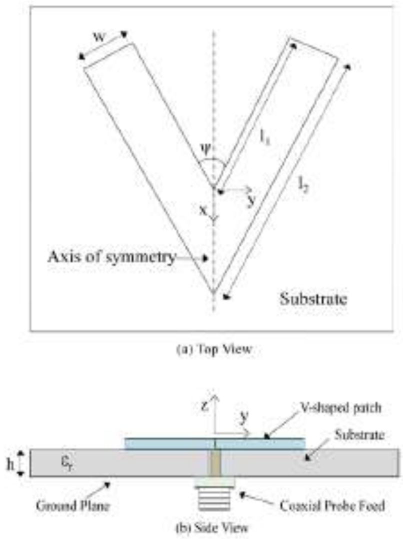
The geometry of the V-shaped microstrip patch antenna is described and the methodology for design of the antenna at 2.4 GHz is also discussed. 2.4 GHz ISM band i.e. Industrial, Scientific and Medical band is chosen because it is an unlicensed band which is used for wireless communication applications like WLAN, Bluetooth, Wi-Fi, etc

4.1 Antenna Geometry

There is a V-shaped metal patch on top of a grounded dielectric substrate. The geometry of the antenna is symmetrical and the length of the arms is equal. The various parameters of the V-shaped patch are:-

- w: width of the arms of the patch.
- l1: inner length of the arms of the patch.
- l2: outer length of the arms of the patch.
- ψ: included angle between the arms of the patch.

The thickness of the dielectric substrate below the patch is h and εr is its dielectric constant.



V-Shaped Patch Antenna Geometry

V. BANDWIDTH ENHANCEMENT

There are numerous and well-known methods to increase the bandwidth of antennas, including increase of the substrate thickness, the use of a low dielectric substrate, the use of various impedance matching and feeding techniques, the use of multiple resonators, and the use of slot antenna geometry [5]-[8]. However, the bandwidth and the size of an antenna are generally mutually conflicting properties, that is, improvement of one of the characteristics normally results in degradation of the other. There are several other techniques that have been proposed to enhance the bandwidth. A novel single layer wide-band rectangular patch antenna with achievable impedance bandwidth of greater than 20% has been demonstrated [8]. Utilizing the shorting pins or shorting walls on the unequal arms of a U-shaped patch, U-slot patch, or L-probe feed patch antennas, wideband and dual-band impedance bandwidth have been achieved with electrically small size in [9], [10]. Other techniques involve employing multilayer structures with parasitic patches of various geometries such as E and H shapes, which excites multiple resonant modes [11], [12].

VI. BANDWIDTH ENHANCEMENT BY INCREASING SUBSTRATE THICKNESS

Here, the impedance bandwidth of the V-shaped microstrip patch antenna is increased by using the technique of increasing the thickness of the substrate. This technique is very common which requires less complication. So, as the thickness of the substrate is increased keeping the width of the arms constant, the w/h ratio decreases.

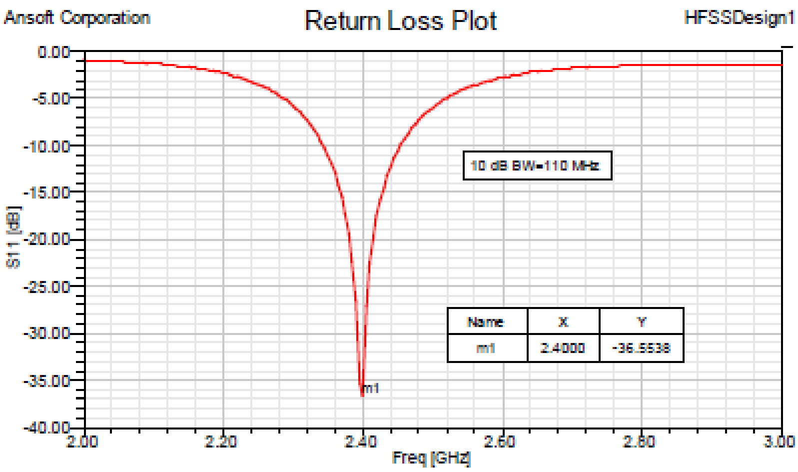
Effect of Variation of Substrate Thickness on Bandwidth

ε_r=4.78, w=4.5 mm, ψ =16°, f_r=2.4 GHz.

Substrate Thickness, h (mm)	Inner Length of Arms, l_1 (mm)	Outer Length of Arms, l_2 (mm)	Probe Feed Position, p_{pos} (mm)	Bandwidth (MHz)
3.0	33.7	65.7	7.7	81
3.5	33.6	65.6	7.6	100
4.0	33.5	65.5	7.6	110
4.5	33.5	65.5	7.2	130
5.0	33.4	65.4	7.1	145
5.5	33.3	65.3	6.8	158
6.0	33.2	65.2	6.6	174

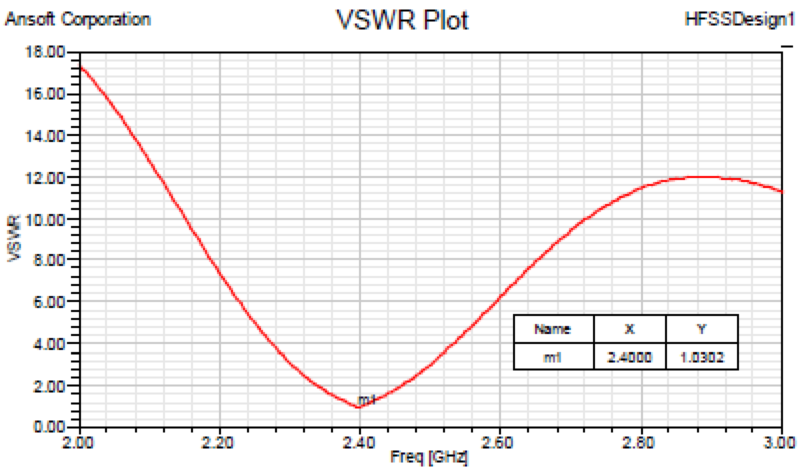
The thickness of the substrate is increased from h=3.0 mm to h=6.0 mm. At the same time, the inner and outer lengths of the arms and the probe feed position are adjusted to get the resonant at 2.4 GHz. It is noticed that as h is increased from 3.0 mm to 6.0 mm, the impedance bandwidth increases from 81MHz to 174 MHz. So, by increasing the substrate thickness, the bandwidth can be enhanced. But, the substrate thickness cannot be increased to very much extent as the surface waves become dominant. Therefore, the substrate thickness has to be judicially selected to get more bandwidth.

The simulated results are given for the V-shaped microstrip patch antenna with the following parameters: εr=4.78, h=4 mm, w=4.5 mm, l1= 33.5 mm, l2=65.5 mm and ψ= 16°.thisshows the simulated return loss plot of the antenna. The resonant frequency of the patch is 2.4 GHz and the value of return loss at this frequency is -36.5 dB. The 10 dB return loss impedance bandwidth is found to be 110 MHz (4.6%).

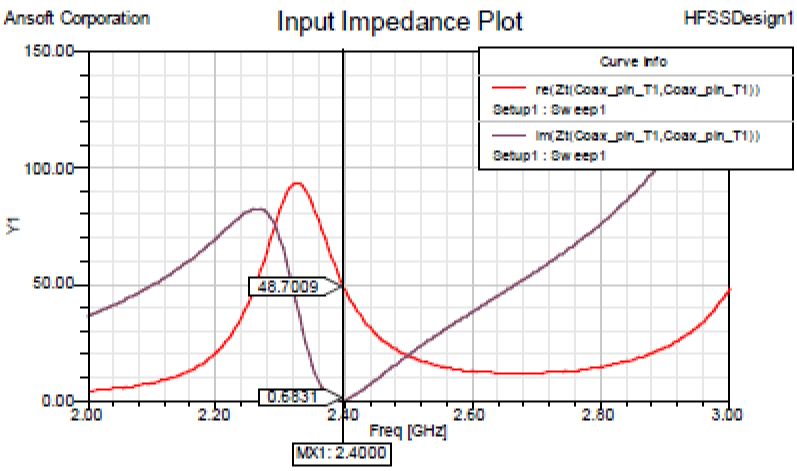


Simulated VSWR vs. Frequency Plot

It shows the simulated input impedance plot of the antenna. The obtained value of VSWR at 2.4 GHz is 1.03. The input impedance of the antenna is found to be 48.7 + j0.68 Ω. Fig. 6.4 shows the normalized E-field pattern at 2.4 GHz of the antenna.



Simulated VSWR vs. Frequency Plot.



Simulated Input Impedance vs. Frequency Plot.

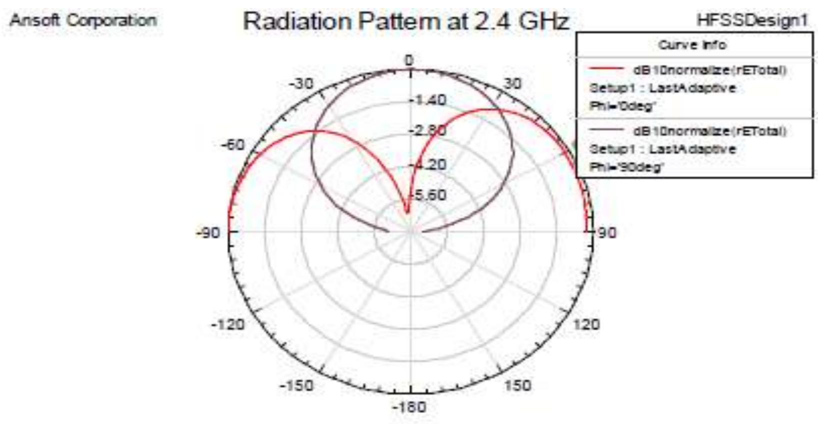


Fig. 6.4 Normalized E-field Pattern at 2.4 GHz.

Normalized E-field Pattern at 2.4 GHz.

VII. CONCLUSIONS

It describes about the parametric study that is done on V-shaped microstrip patch antenna. Ansoft HFSS software tool is used to implement and simulate the designs of the antenna. At first, the V-shaped microstrip patch antenna is designed at 2.4 GHz using some basics concepts of electromagnetic. 2.4 GHz ISM band is chosen because it is an unlicensed band which is used for wireless communication applications like WLAN, Bluetooth, Wi-Fi, etc.

VIII. SCOPE OF FUTURE WORK

It is a preliminary study of V-shaped microstrip patch antenna. So, a common feed i.e. coaxial probe feed is used. The characteristics of the antenna can be improved by using the other feeding techniques described in Chapter 2. The bandwidth can be further enhanced by using the various techniques described in Chapter 6. In the thesis, it is discussed how the performance of the antenna depends on various parameters of the V-shaped microstrip patch antenna. A thorough analysis of the antenna is required and provides a design formula for the V-shaped patch antenna.

REFERENCES

[1] C. A. Balanis, Antenna Theory: Analysis and Design, 2nd Edition, Wiley, 2008.

[2] I.J.Bahl, P.Bhartia, Microstrip Antennas, Artech House, Inc., 1980.

[3] Ansoft High Frequency Structure Simulator v 11, “Getting Started with HFSS”.

[4] http://www.wikipedia.org

[5] D.M. Pozar, D.H. Schaubert, *Microstrip Antennas*. New York: IEEE press,1995.

[6] S.H. Wi, Y.B. Sun, I.S. Song, S.H. Choa, I.S Koh, Y.S Lee, J.G. Yook, “Package-Level integrated antennas based on LTCC technology”, IEEE Transactions on Antennas and Propagation. 54(8), 2190-2197, 2006.

[7] S.H. Wi, J.M. Kim, T.H. Yoo, H.J. Lee, J.Y. Park, J.G. Yook, H.K. Park, “Bow- tie shaped meander slot antenna for 5 GHz application”, in Proc. IEEE Int. Symp. Antenna and Propagation. 2, 456-459, 2002.

[8] F. Yang, X.Zhang, Y.Rahmat-Samii, "Wide-band E-shaped patch antennas for wireless communications", IEEE Transactions on Antennas and Propagation. 49(7), 1094-1100, 2001.

[9] Y.X. Guo, K.M. Luk, K.F. Lee, R. Chair, "A quarter-wave U-shaped antenna with two unequal arms for wideband and dual-frequency operation", IEEE Transactions on Antennas and Propagation. 50, 1082–1087, 2002.

[10] R. Chair, C.L. Mak, K.F. Lee, K.M. Luk, A.A. Kishk, "Miniature wide-band half U-slot and half E-shaped patch antennas", IEEE Transactions on Antennas and Propagation. 53, 2645–2652, 2005.

[11] X.L. Bao, M.J. Ammann, "Small pacth/slot antenna with 53% input impedance bandwidth", Electronics Letters. 43(3), 146-147, 2007.

[12] M. Tariqul Islam, N. Misran, K.G. Ng , "A 4×1 L-probe fed Inverted Hybrid E-H Microstrip Patch Antenna Array for 3G Application", American Journal of Applied Sciences. 4(11) 897-901, 2007.