Designing and Testing of Microstrip Patch Antenna with Accurate Dimensions using MATLAB and Antenna Toolbox

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Abstract

In the modern era where the communication devices are becoming compact which leads towards an immediate requirement of prominent low profile, simple and yet more effective, high performance microstrip patch antenna over a frequency ranging for multiple applications. In this paper, we have proposed a microstrip patch antenna frequency ranging between 1GHz to 5GHz with a critical frequency of 2.5GHz. The antenna patch is designed using rectangular, circular, triangular and square patterns which are calibrated using MATLAB v R2021a. The dimensions are also compared with the traditional equations and tested using antenna toolbox of MATLAB against Ansoft High Frequency Structured Simulations (HFSS). The performance of antenna is analysed with the parameters such as impedance, S11, VSWR and gain of the antenna.

Introduction

Latest research has provided the information that for majority of wireless communications, the best suitable antenna is the microstrip patch antenna as it is low weight, low profile, compact in nature, with a lot of improvements on the structure and easy to fabricate using a low profile CNC Machine [1]. The antenna patch can be a rectangular, square, triangular, elliptical or even fractal geometry based model which shows direct impact on the performance of the antenna. In the recent developments almost in all the major communication applications, microstrip patch antenna is predominantly used such as in vehicular communications [2], in bio medical engineering [3], in almost all the IoT applications [4]. Most of the applications uses the frequency ranging between 1GHz and 5GHz. The resonance frequency is considered at 2.4GHz for Bluetooth and wireless LAN. Patch antenna dimensions are calculated using hit and trail method or with the help of online dimension calculators which are not much efficient, limited only to provide the dimensions of a rectangular patch [5].In government and private sectors a serious research is carried out in order to provide a small and portable antenna for various applications. Many researchers provided various geometrical shapes for the design such as dipole, triangle, square, rectangular, pentagon, hexagon, circle, ellipse, semi-circular ring, circular ring, cross junction, star, U-shaped, rectangular ring, trapezoid, H-shaped and L-shaped [6-10]. If the size is compromised, even multi array antennas are used in various communication applications [11]. The table 1 provides a complete summary of the microstrip patch antenna which includes advantages, drawbacks and the area of applications.

Table 1: Microstrip patch antenna Summary [6-11]

Advantages	Disadvantages	Area of Application
Light weight, less space occupancy	Narrow Bandwidth	Vehicular Communications
Low Fabrication cost	Lower Gain	Bio medical
Compact in Size	Difficult Polarization	Mobile Communication
Multi-Frequency range operation	Excess Radiation at feed junction	Satellite Communications
Perfectly matched with solid state devices	Power Handling is low	Radar Systems
Easy to design and simulate	Poor End fire radiation	Global Positioning System (GPS)

In the proposed work, section II covers the description of the antenna geometry. Section III describes the implementation aspects of the antenna design using the MATLAB codes and HFSS simulator. In section IV, results have been discussed and evaluated. Finally work is concluded.

II. Antenna geometry and design parameters: In this section we will configure the microstrip patch antenna using various patterns of patch as discussed in the introduction section. The various different patches are as shown in the figure 1.

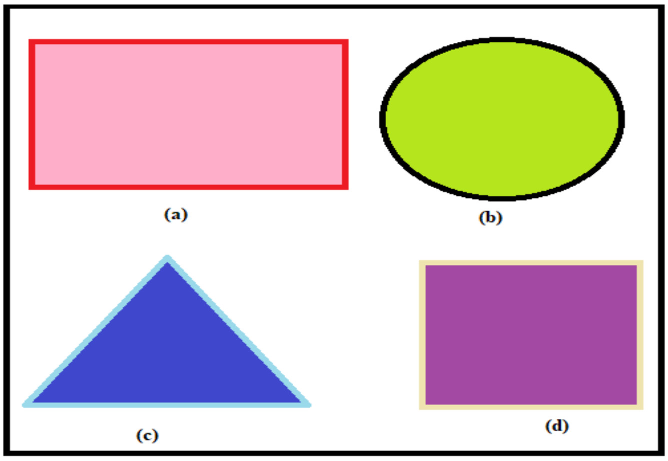


Fig1: Different shapes of Patches used in microstrip antennas [5].

Feed line is provided to the patch of any shape as indicated in figure 1 and these shapes dimensions are configured using various equations, as in this paper we will evaluate using MATLAB R2021a. FR4 Epoxy material is used as a substrate whose thickness is 1.6mm and the dielectric constant 4.4 and loss tangent with 0.025 is selected. Various feed lines techniques are proposed by various researchers, one of the most famous is lumped port with rectangular feed line, and the same feed line is used in our design.The dimensions of antenna are calibrated in two ways, first the dimensions are acquired using the online websites available, where the substrate height, impedance and frequency is provided [12]. The impedance is set at 50 ohms, with frequency of 2.5GHz with substrate height of 1.6mm, fig 2 provides the dimensions of the patch obtained using the online simulator available. The drawback of the online simulators are, they provide only the dimensions of a rectangular patch, which is just a basic dimension. It won't provide the complete specifications of the antenna. The resultant patch consist of patch width of 36.49mm and Length if 28.22mm.

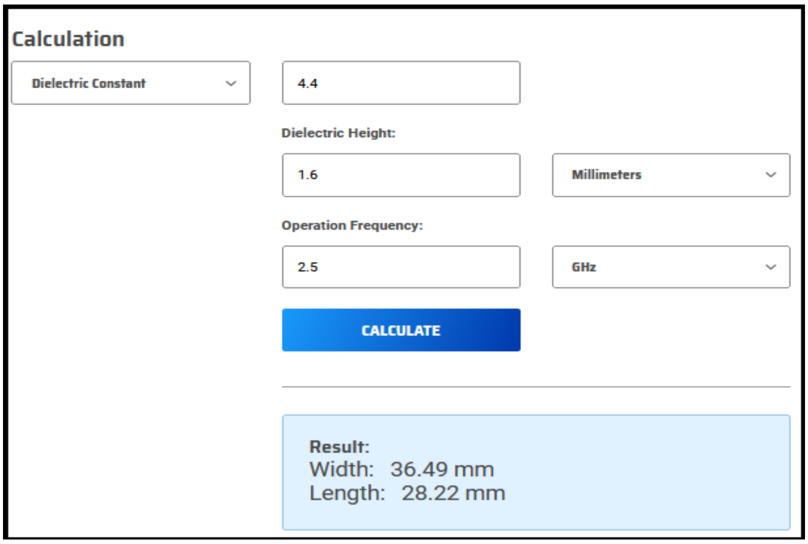


Fig2: Dimensions of Antenna using online Simulator

The second way in which the dimensions are obtained using MATLAB, where all the specifications are obtained with more accuracy and complete information needed to design an antenna. Fig 3 provides the dimensions obtained using MATLAB where the calculations are made not only for rectangular patch but also for other types of patches.

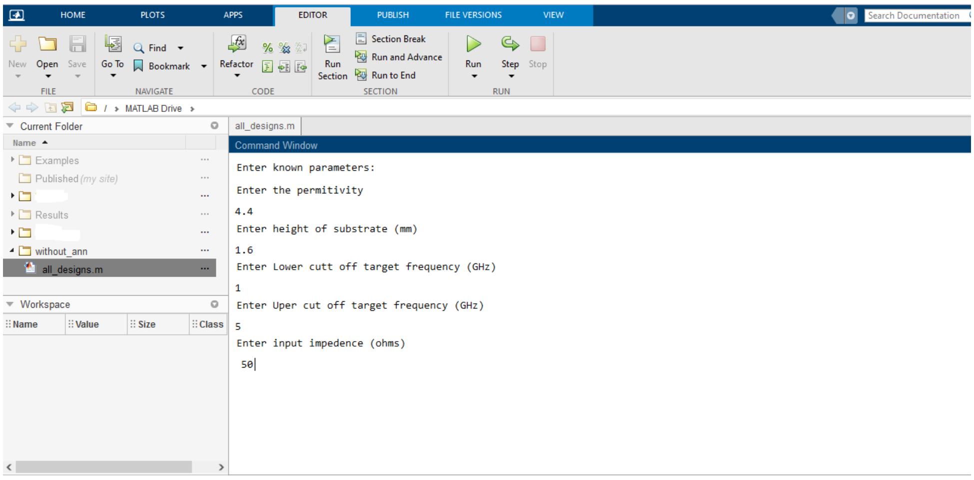


Fig3: Providing inputs to MATLAB Simulator

Fig 4 provides the calculated results of Patch antenna where not only the patch dimensions, Substrate length and width is obtained. Along with these measurements, Inset, Inset Gap, Radiation Width, Radiation Length, Radiation Height, Feed Width, Feed Length, Square patch each side, Triangle patch each side and circle patch radius are obtained. These help in designing the antenna more accurately such that the performance of antenna can be better as compared to the design using online calculators available. For different shapes of patches only the dimensions of the patch are different while the rest of the specifications are kept constant such that the design of the antenna is simple yet effective. These obtained values are provided to the antenna toolbox simulator to get the Antenna in MATLAB.

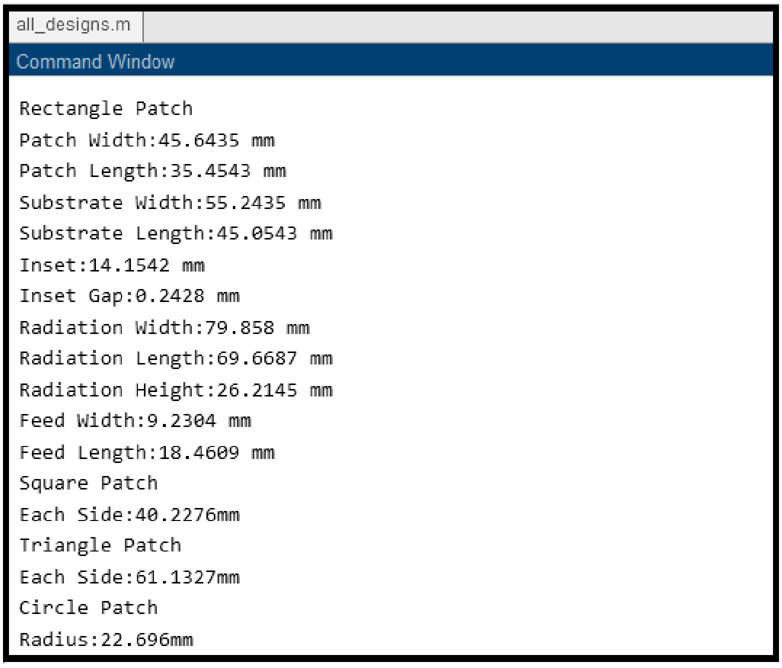
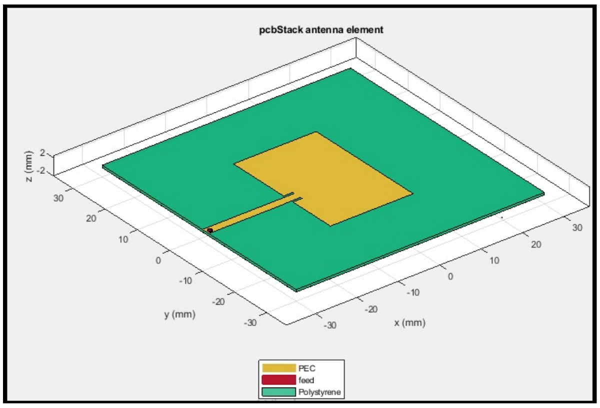
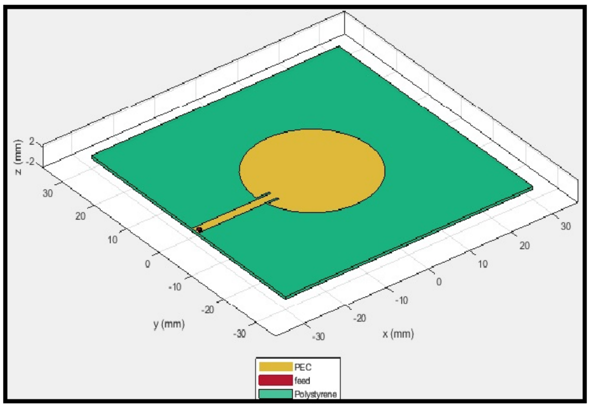


Fig4: Obtained Parameters of antenna using MATLAB

III. Design implementation: With the help of MATLAB R2021a, the dimensions of antenna are calculated, which are fed to antenna toolbox. The antenna tool box consist of pre-defined commands to generate a patch antenna. The specifications obtained are directly linked to the tool box, which creates the antenna depending on the coordinates provided. Fig5 (A) provides the design of rectangular patch antenna and Fig5 (B) provides the design of Circular patch antenna using antenna toolbox. The tool box provides various commands to design various shapes of the patch out of which two patterns are discussed in this paper.





(A) **(B)**

Fig 5: a) Rectangular Patch b) Circular Patch using Antenna ToolBox

IV. Results and discussion: The simulation is performed both in HFSS v15 and MATLAB R2021a, the frequency selected is in the range of 1GHz to 5GHz and critical frequency is set at 2.5GHz. The antenna substrate is selected as FR4_Epoxy with the height of the substrate as 1.6mm. The patch dimensions are provided by the MATLAB which are designed using both simulators and comparison is achieved. The analysis comparison is performed for return loss, VSWR, total gain and radiation of the antenna. Return loss is one of the key aspect of any antenna under test, and threshold value is -10dB or less than that, with multiple resonating points such that the antenna can be used for multiple applications. Fig 6 provides a comparison of return loss for both the simulations using HFSS and MATLAB. The minimum return loss achieved using HFSS is -15.92dB at 3.2GHz with a Band width of 230MHz, which can be used for a single wireless application and using MATLAB multiple resonating points are achieved where the minimum return loss is registered as -24dB at 4.8Ghz. The total Bandwidth achieved is 750MHz.

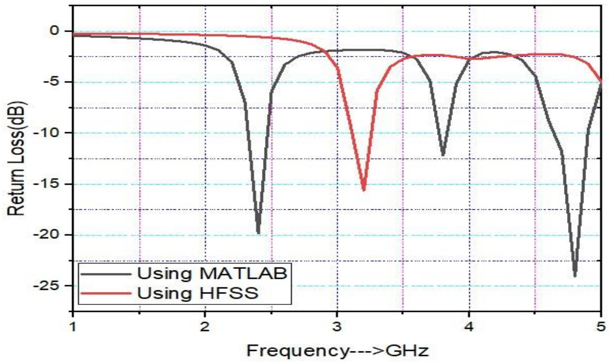


Fig 6: Return Loss achieved using both HFSS and MATLAB

Standing wave ratio is another important key aspect in antenna in use, and the range must be in between 1dB and 4dB. The VSWR using HFSS was fluctuating in the range, whereas using MATLAB the values were in the range for the entire frequency band, which makes the antenna design ideal for applications. Fig 7 provides the comparison between the designs using both the software’s.

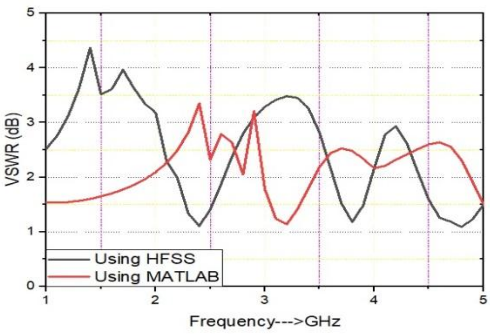


Fig7: VSWR using both HFSS and MATLAB

Another important key feature of the antenna is the total Gain achieved by the antenna which is calibrated using threshold value of 3dB or more than that. The maximum gain achieved with the antenna designed in HFSS is 4.35dB at 2.1GHz and the maximum gain achieved using MATLAB is 6.9dB at 3.4GHz and if we closely observe fig 8, we can see that almost for majority of frequencies, antenna designed using MATLAB possesses better gain.

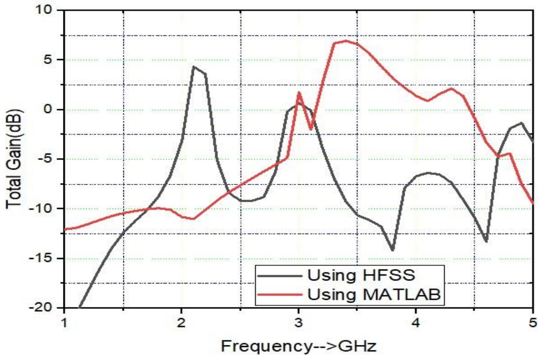


Fig 8: Total Gain achieved using HFSS and MATLAB

The last comparison we are making in this paper is about the impedance matching of the antenna for the entire frequency range. The impedance must be very much near to 50 ohms such that the errors in connectivity will be as minimum as possible. Fig9 provides the comparison of impedance matching between both the simulations.

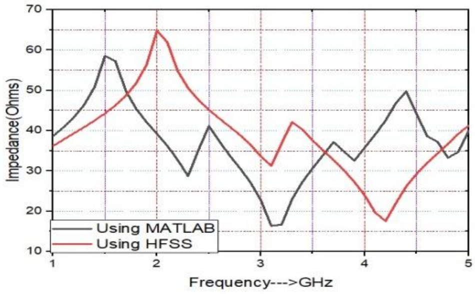


Fig9: Impedance achieved using HFSS and MATLAB

Conclusion

With the help of MATLAB R2021a, the antenna parameters were calculated and were implemented using HFSS v15 as well as antenna toolbox. Both the simulation outputs were compared in this paper where the minimum return loss achieved using HFSS is -15.92dB at 3.2GHz with a bandwidth of 230MHz and -24dB at 4.8Ghz with a bandwidth of 750MHz using antenna toolbox. The maximum total gain achieved using HFSS is 4.35dB, whereas using antenna toolbox it is 6.9dB. Almost for the entire range of frequencies, the impedance is matched for the antenna designed using toolbox. With this work, we can conclude that if the antenna parameters are calculated using MATLAB and simulation is done using antenna toolbox, then the performance of antenna is enhanced as compared to the traditional hit and trial method. The future work can be carried out by implementing the deep learning and artificial neural networks to enhance the performance of the antenna under MATLAB environment.

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