Design of Microstrip Patch Antenna at 10.3 GHz for X-Band Applications

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Abstract. In this study, an E shaped microstrip patch antenna is proposed which is designed using FR4 - epoxy substrate. The designed antenna has a return loss of -29.21 dB and works with X band. The design is simulated using a software tool called HFSS (High Frequency Structure Simulator). The antenna has been designed for 10.3 GHz frequency applications and the return loss, VSWR and the radiation plot of the designed antenna has been evaluated. The aim is to achieve a high directivity with better gain and reduced losses particularly for X band applications.

Keywords - HFSS, microstrip patch antenna, FR-4, microstrip feed

1. Introduction

The microstrip antenna is designed for low profile radiators. The traditional antenna has been outdated and replaced by sophisticated techniques that have been tried for improving its performance. The need for conventional antennas has reduced which is taken up by the microstrip antennas towards the personal and mobile communications. The proposed patch antennas have more promising applications in ultra wide band applications. The cost of production is less and can be combined with a transceiver. A microstrip patch antenna with radiating patch has dielectric substrate on one side and the other side with ground plane as indicated in Fig. 1.

Figure 1. Basic Structure of Microstrip Patch Antenna.

The proposed dimension of E-shaped antenna with the physical measurements and fringing effects are shown in Fig. 2. Further the antenna length has been extended by ΔL focusing the resonant frequency and dielectric constant values. The study has a design for the use of an X-band in combination of two inverted E-shape structures. The operational frequency for the X-band design is aimed to have a return loss of -29.21 dB and a gain of 6.63 dB at 10.3 GHz.
2. Literature Survey
Because of its many appealing features, the microstrip antenna has attracted the attention of many researchers. In the 21st century, research on microstrip antennas aimed to reduce size, increase gain, more bandwidth, multiple functionality and convergence at the device level. The demand for small and broadband antennas has greatly increased with the widespread utility of wireless communication technology in recent years. The microstrip antenna deals with conductive rectangular shaped patches on one side and dielectric base having thickness \( h \) and \( \varepsilon_r \) dielectric constant.

To feed EMR in the rectangular patch antenna, several techniques are available. Further to improve the antenna inputs, efficient impedance matching operation is performed. The two important techniques for feeding utilised in this study are contact and non-contact. In the first method the rectangular patch is integrated with RF power using microstrip lines. In the second method, the rectangular patch is subjected to electromagnetic coupling through feed lines. Multiple feeding techniques were adapted using microstrip lines, inset feed and coupled feed are used in this study.

3. Dimensions of the E-shaped Microstrip Patch Antenna
Figure 3 displays the geometry of the proposed E shaped antenna. To constitute the single structure of the patch, two E shaped structures are combined together. The conducting medium (copper) is mounted on the non-conductive medium (epoxy) in the patch antenna. As it is a capacitive structure formation, a ground plane is required for the patch antenna. The dimension of the middle rectangle is 3.8 mm X 20 mm and the substrate used is FR4_epoxy having dielectric constant value 4.4. FR4 is preferred because it has less loss. For conducting material copper (0.0347) is used. The thickness of the substrate is 2.5 mm. The outer box is designed to conform to the environmental conditions using air materials. The antenna is fed using microstrip line feed. The impedance matching is done by varying the position of the microstrip line. The length of the patch antenna is \( \lambda/2 \). Radiation occurs only on the width side. The radiation increases as the thickness of the dielectric medium increases. Height is \( h < 0.05\lambda \). If there is no proper matching i.e. impedance of source and antenna and free space, the signal gets lost. There is loss due to conductor and dielectric mismatch. Radiating efficiency is increased by increasing the radiation resistance of the antenna.
Figure 3. Design of E-shaped Microstrip Patch Antenna

Due to excellent radiating characteristics, the microstrip antenna has been preferred because of its less weight and \( t << 0.03\lambda_0 \). It is also cost effective and can be fabricated in printed circuit technique. It can also be linked with other planar circuits and is highly versatile in nature by improved impedance, reasonable resonant frequency and polarization during operations.

4. Applications and importance of HFSS tool
HFSS is one of the tools used for design of high quality antennas and complex designs of RF electronic circuits with filters, transmission and packaging. The Ansoft High Frequency Structure Simulator (HFSS) software package is used in calculations and study on 3-D structure behaviour.

5. Results and Discussion

a) Return Loss
The simulation studies were conducted using HFSS software using maximum source of power the return loss -10 dB (Fig. 4.) is obtained at the antenna. The power delivered by the antenna is measured. The simulated results indicated with the matched impedance at X-band frequency. Further, the estimated return loss is found to be less than -10 dB. The operational frequency identified from the simulation is reported as 8 GHz to 12 GHz. The return loss measured at 10.3 GHz is reported as -29.21 dB.
Figure 4. Return Loss of the E-shaped Microstrip Patch Antenna

b) VSWR Ratio
From the radiation pattern, it is clearly visible that the antenna works as omnidirectional. It radiates in a specific direction. The range of the obtained gain is from 4 dB to 6 dB approximately that validates the 3 dB gain margin. Voltage Standing Wave Ratio is used to find out the ratio between the transmitted and reflected voltage. It shows how efficiently the RF power is transmitted from source through transmission line into load. High VSWR may damage the antenna and decrease the antenna efficiency so it must be below 2. Radiation pattern is omnidirectional, which is designed to get the signal in all directions.

Figure 5. VSWR Ratio of the E-shaped Microstrip Patch Antenna

c) Radiation Pattern
It radiates in the plane and it has no back lobe. Directivity can be understood from radiation patterns. Gain is the input power to the antenna and directivity is radiated power by the antenna. At the operating frequency of 10.3 GHz the antenna has a gain of 5.01 dB.
6. Conclusion
In this research work, an E shaped microstrip patch antenna has been designed with X band configuration. The operating band frequency used in this study is 10.3 GHz. Based on HFSS computations and simulations, impedance for the design is matched towards minimising the return loss for the set limit of -10 dB. The design has resulted in gain range from 4 dB to 6 dB with enhanced radiating characteristics of the designed antenna. The designed antenna can be utilised in smart watches, WLAN and smart computing.

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