Performance Analysis and Enhancement of Probe Feed Patch Antenna using Parametric Analysis in HFSS

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***Abstract*- Antenna is one of the main components in Wireless Communication. Microstrip Antennas play a very major role in recent wireless communication systems because of their low profile, low cost and easy compatibility with circuit board technology which can be used for applications like mobile communications, satellite communication, radars, navigation systems etc. The main objective is to design a Probe Feed Patch Antenna and perform Parametric Analysis in HFSS to enhance the performance of an antenna by obtaining the desired antenna parameters such as Return Loss, VSWR, Gain etc. Rectangular patch antenna is designed with Probe Feed mechanism at a frequency of 10GHz with a dielectric constant of 2.2 having substrate thickness of 0.1588cm. After the design of antenna, based on the results obtained, Parametric Analysis is performed to make the antenna resonate at the designed frequency. Parametric Analysis is a process where any number of design parameters of an antenna can be varied, considering them as variables by varying them within a certain range to obtain the desired results. Parametric Analysis is performed as well to enhance the bandwidth percentage. Wider bandwidth can be obtained with the increase in dielectric substrate thickness.**

***KEYWORDS*: Probe Feed Patch Antenna, HFSS, Parametric Analysis, Antenna Parameters.**

1. INTRODUCTION

Antenna is a metallic device which is used to transmit and receive EM fields. Microstrip antenna consists of a very thin metallic strip placed on a ground plane with a dielectric material in between. The patch or microstrip can be of any shape like rectangular, square, triangular, circular etc. The excitation to the antenna is given with the help of feed lines connected through the patch. There are several feeding mechanisms for patch antennas. Few are coaxial probe, microstrip line, aperture coupling and proximity coupling. The coaxial feed or probe feed is one of the most common techniques used for feeding microstrip antennas. This type of feeding mechanism gives an advantage of positioning the feed at any desired position inside the patch to obtain impedance matching. Ansys HFSS software is used for designing and simulating high-frequency electronic products such as antennas, antenna arrays, filters, microwave components etc [5]. The performance of an antenna mainly depends on patch length, width, substrate dielectric constant and thickness. At resonant frequency, maximum power is delivered to the patch when impedance matching is done between feed-line and patch. Because of variations in the effective length of the patch due to fringing field, antenna may not resonate at the designed frequency. With Parametric Analysis, the dimensions of an antenna like patch width and length are varied which leads to shift in resonant frequency and variation in return loss. Variation of substrate thickness along with patch dimensions within certain limit gives desired bandwidth, as bandwidth is proportional to substrate thickness.

2. RELATED WORK

K.V.ROP et al. presented the performance analysis of rectangular microstrip patch antenna for different dielectric substrates. For higher values of dielectric constant, gain and bandwidth gets reduced. A substrate with lower dielectric constant gives better antenna performance [3].

Hemant Kumar Varshney et al. presented different feeding mechanisms for the antenna design, such as microstrip feed line, coaxial feed, aperture couple feed, proximity coupled feed and dual feed [4].

Angana Sarma et al. proposed a wide band high directive slotted microstrip patch antenna operating at 2.4GHz, which gives low return loss and high bandwidth. The

microstrip patch antenna is designed using FR4epoxy substrate with a dielectric constant of 4.4 and with inset feed mechanism [6].

3. PROPOSED MODEL

In this paper, the design of patch antenna with probe feed mechanism is proposed at a frequency of 10GHz. The dielectric material mounted on a ground plane is Rogers RT/duroid 5880 substrate with a dielectric constant (ϵ_r) of 2.2 and thickness (h) of 0.1588cm. In probe feed mechanism, the inner conductor of coaxial cable is connected to the microstrip patch of an antenna and the outer one is connected to the ground plane. Formulae [2] to obtain the dimensions of proposed Probe Feed Patch Antenna are shown and described. Based on the obtained results of designed Probe Feed Patch antenna, Parametric Analysis is performed to make the antenna resonate at a frequency of 10GHz and to improve the bandwidth percentage.

Probe Feed Patch Antenna Dimensions Formulae:

f_r = 10GHz, ϵ_r = 2.2, h = 0.1588cm

Width of Patch (W)

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

Where c= Velocity of light in free space in cm.
f_r= Resonant frequency.
ϵ_r = Dielectric constant.

Effective dielectric constant (ϵ_{reff})

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

Effective length of the patch (L_{eff})

$$L_{eff} = \frac{c}{2f_r\sqrt{\epsilon_{reff}}}$$

Length extension (ΔL)

$$\Delta L = h\left[0.412\ \frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}\right]$$

Length of the Patch(L)

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

Length of the substrate (L_s) and ground plane (L_g)

$$L_s = L_g = 6h + L$$

Width of the substrate (W_s) and ground plane (W_g)

$$W_s = W_g = 6h + W$$

Table 1:Calculated Dimensions of Probe Feed Patch Antenna

Parameter	Value in cm
Ground Length	1.8588
Ground width	2.1388
Substrate length	1.8588
Substrate width	2.1388
Patch length	0.906
Patch width	1.186
Outer radius of the feed	0.12
Inner radius of the feed	0.06

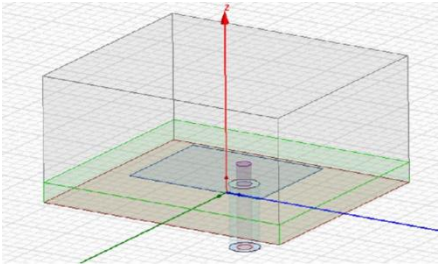

Fig.1:Designed Probe Feed Patch Antenna in HFSS

4. Results and Discussions

The probe feed patch antenna is designed based on the dimensions shown in Table 1 at frequency of 10 GHz, ϵ_r of 2.2 and substrate thickness of 0.1588cm. After simulation, it is observed that the antenna is resonated at 10.2GHz with a Return Loss value of -16.2419dB and bandwidth percentage of 8.8% as shown in figure 2. Obtained VSWR value is 1.3644. The designed antenna's radiation pattern is shown in figure 3.

Bandwidth Percentage (BW)

$$BW = \left(\frac{f_H - f_L}{f_c}\right)\text{x } 100$$

where

f_H = Higher frequency
f_L = Lower frequency
f_c = Centre frequency

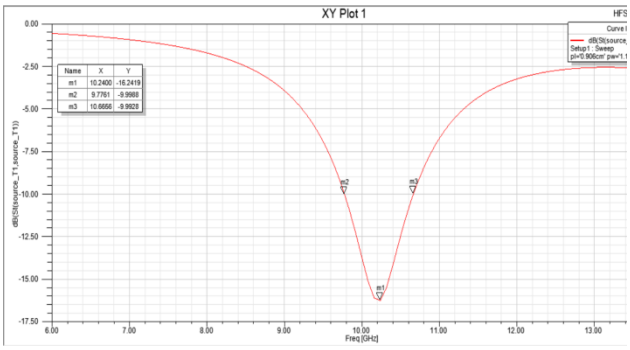

Fig.2:Return Loss plot of Designed Probe Feed Patch Antenna

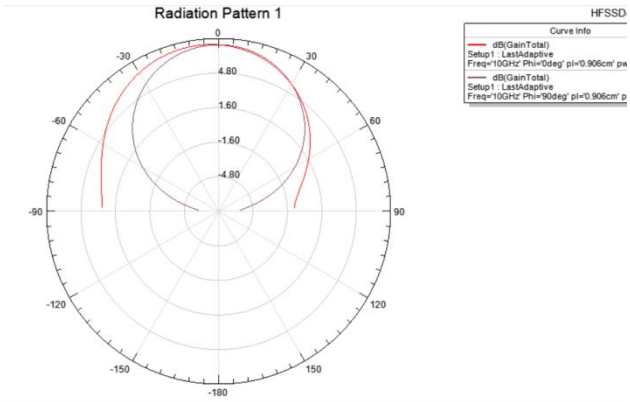

Fig.3:Radiation Pattern of Designed Probe Feed Patch Antenna

As seen from figure 2, the antenna is not resonated at 10GHz. So, Parametric Analysis is performed for the design to make the antenna resonate at 10GHz. In Parametric analysis, patch length and width are considered as variables and varied.
Considered range of dimensions:

Patch Length: 0.89cm to 0.92cm
Patch Width: 1.18cm to 1.21cm.

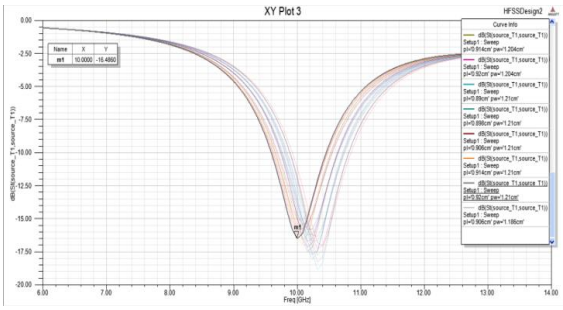

Fig.4: Return Loss Plot after Parametric Analysis

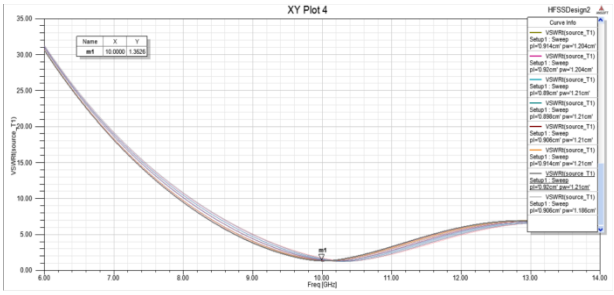

Fig.5: VSWR Plot after Parametric Analysis

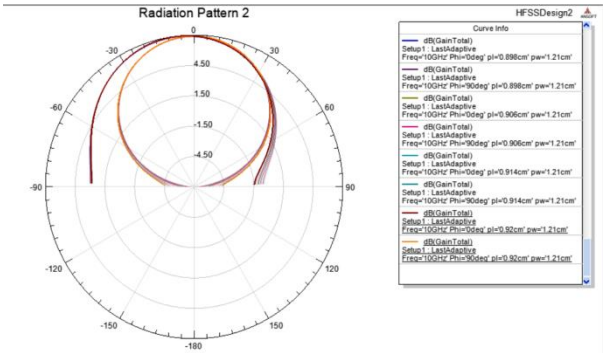

Fig.6: Radiation Pattern after Parametric Analysis

From figure 4, it is observed that for patch dimensions of length 0.92cm and width 1.21cm, antenna is resonated at 10GHz with a Return Loss value of -16.4860dB and VSWR of 1.3526 as shown in figure 5. The corresponding radiation pattern is shown in figure 6.
Parametric Analysis is done as well to enhance the bandwidth percentage. To achieve this, substrate thickness (h), patch length and width are considered as variables and varied for the range of dimensions given.

Substrate thickness (h): 0.15cm to 0.17cm
Patch length: 0.89cm to 0.92cm
Patch width: 1.15cm to 1.17cm.

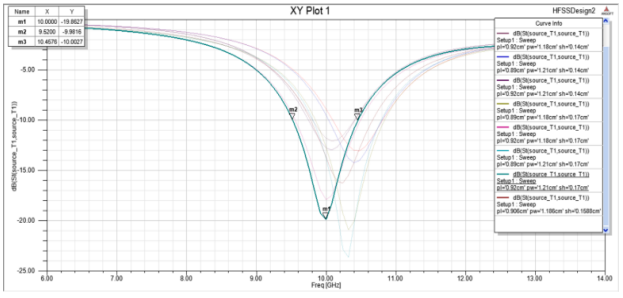

Fig.7: Return Loss Plot after Parametric Analysis including Substrate Thickness for Bandwidth Percentage Enhancement

As shown in figure 7, the antenna is resonated at a frequency of 10GHz for substrate thickness of 0.17cm, patch length of 0.92cm and patch width of 1.21cm with

a return loss of -19.9dB and bandwidth percentage of 9.3%.

5. CONCLUSION

The Probe Feed Patch Antenna is designed at a frequency of 10GHz. Based on the results obtained, parametric analysis is performed in HFSS. In parametric analysis, patch length and width are varied within certain range to make the antenna resonate at the desired frequency. To enhance the bandwidth percentage, substrate thickness is varied along with patch dimensions using parametric analysis. Hence, antenna performance can be enhanced by parametric variations.

6. FUTURE SCOPE

This antenna can be further used to design array of Probe Feed Patch Antenna to improve the gain and performance of the antenna. Optimization can be performed to obtain the required results or desired values which enhance antenna performance.

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