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U-Slot Microstrip Patch Antenna

M.Kaanchana[1], T. Adhilaksmi[2], B. Vaishnavi[3]
[1,2,3] *Dr. S.J.S Paul Memorial College of Engineering and Technology, Puducherry, India*

Abstract— The main objective of this paper is to simulate and design a single u-shaped microstrip patch antenna with operating frequency of 5.5GHz. This type of antenna has to be designed using a substrate having a low dielectric constant in order to achieve low return loss. The microstrip antenna consists of the rectangular patch on the top of the dielectric substrate and over which a u-shaped slot has been made to reduce the size of the antenna. The reduction in the size of the antenna results in improved gain and the return loss of the antenna. Therefore, the single u-shaped microstrip patch antenna has a broad bandwidth and can be used for wireless applications. The antenna has been simulated using HFSS (High frequency synthetic simulator) software, a 3D simulator which shows the accurate simulated result compared with other simulation software.
Index Terms—- single u-shaped slot, RT Duroid 5880 substrate, HFSS software, 3D simulator, gain, return loss.

I. INTRODUCTION

James Clark Maxwell, in 1860, has combined electricity and magnetism into electromagnetism and he predicted the existence of electromagnetic waves at radio frequencies which is at much lower frequencies than light. An early form of radio detector is called coheror which consists of a glass tube loosely filled with metal and its electrical resistance is decreased in the presence of radio waves. Coheror is used for the detection of electromagnetic waves.
Guglielmo Marconi grasped the hertz experiment and started his research with wireless telegraphy which lead to the discovery of wireless communication started with coheror. To the coheror, a long wave wire antenna is connected which can be used to transmit or receive the electromagnetic waves. The antenna which transmits and receives only in the horizontal direction is called as Omni-directional antenna and the antenna which transmits or receives in the particular direction is called as directional antenna.
Electric charges are the source of electromagnetic fields. When these sources are time varying, the electromagnetic waves propagate away from the source and radiation takes place. Radiation is the process of transmitting energy. Globally, there is a drastic revolution in the communication world. Therefore, in order to make effective communication, antennas play a major role. An antenna is generally a transducer which transmits and receives the electromagnetic waves. In other words, Antenna is defined as a device which converts electric current into electromagnetic waves at the transmitting side and vice versa at the receiving side.
The following are the types of antenna which includes wired antenna, aperture antenna, reflector antenna, microstrip antenna, Rhombic or travelling wave antenna, Pyramidal horn antenna, Parabolic dish reflector, coplanar strip horn antenna and each antenna have their specific characteristics. Due to its important characteristic of compact size, the microstrip antenna is chosen to fulfill the needs of the modern technologists.

A. Overview

The important parameters of antenna are the radiation pattern (field and power radiation pattern), Radiation intensity, Directive gain and directivity, power gain, antenna beam width and bandwidth, input impedance, effective length and effective aperture, antenna temperature and antenna polarization.
The dipole antenna, loop antenna and helical antenna are together called as wired antennas. The rhombic antenna is called as travelling wave antenna which is guided by dielectric antenna when the antenna is near the cut-off phase velocity. Dielectric antenna is useful for broadband signals and the resonant antenna with large aperture is called as horn antenna.
The parabolic dish reflector is used for the microwave radiation. The parabolic reflector works based on the principle that electromagnetic waves are reflected by conducting sheets. The antenna to be used with microwave integrated circuit may be placed on a dielectric substrate. The integrated circuit type antenna is in microstrip form.
The antenna is placed on the dielectric substrate and the integration of the patch on to the circuit is called as the microstrip antenna or microstrip patch antenna. This antenna is mostly used with microwave integrated circuits and hence it is sometimes called as integrated antenna.
Compared with other antennas, the microstrip antenna has the better advantages as expected by the modern technologists.
The microstrip antenna was first introduced in 1950, and it was developed after 1970's by Bob Munson. It has attractive advantages such as light weight, low cost, planar structure, ease of fabrication, portable and can be easily integrated with microwave integrated circuits. Microstrip patch antenna has widespread applications in the microprocessor market.
The microstrip antenna is classified into four types. They are the microstrip patch antenna, microstrip antenna, printed slot antenna, and microstrip twisted wire antenna.
The microstrip patch antenna is available in different shapes. The different shapes include the rectangular, circular, elliptical

microstrip antenna, ring shaped antenna, etc., to have better coupling, the rectangular microstrip antenna has been chosen.
The rectangular microstrip antenna is illustrated in the figure given below. The microstrip patch antenna consists of a radiating patch on one side of dielectric substrate and a ground plane on other side. A patch is generally made up of a conducting material such as copper, gold, etc.,
The patch antenna is otherwise called as rectangular microstrip patch antenna which is used mostly at the frequency ranges from 1 to 6 GHz and the antenna has been designed at 5.5GHz as its operating frequency.

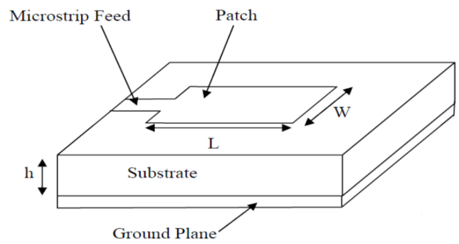

Fig 1 – Microstrip patch antenna

In order to achieve effective radiation of antenna, the designed antenna must have a substrate of low dielectric constant therefore RT duroid is chosen and which results in the better performance of antenna and provides better efficiency, larger bandwidth and better radiation with reduced number of side lobes.
The dielectric constant for the RT duroid 5880 is 2.2, which is comparatively smaller than the other substrates.
The input is given using different feed techniques and different feeding methods are available to feed microstrip patch antenna. The radio frequency power is fed directly to the radiating patch using microstrip line feed method. There are many feeding techniques, which includes microstrip line feed, coaxial line feed, aperture coupling and proximity coupling method.
In the microstrip line feed, a conducting strip is connected directly to the center of the patch by etching the substrate and the conducting strip should be smaller in width when compared with the width of the microstrip patch. The inset cut is made in the patch to increase the radiation of the antenna.
In the aperture coupled feed, the radiating patch and the microstrip feed line are separated by the ground plane. In this technique, the patch and the feed line is coupled with the ground plane through the slot. The slot should be placed at the centre in order to have low cross polarization but due to multiple layers and the increased thickness, the antenna fabrication is difficult.
In the proximity coupled feed, which is otherwise called as the electromagnetic coupling, two dielectric substrates are used and the feed line is between the two substrates among which the radiating patch is on the top of the upper substrate and the ground plane is on the lower substrate. Using this technique, the unwanted radiations can be eliminated but the antenna fabrication is difficult because of the two dielectric substrates.
Therefore, the microstrip line feed has been chosen for the rectangular microstrip antenna for better radiation and it is designed using the operating frequency of 5.5GHz and has been simulated using HFSS software.

II. EXISTING ANTENNA DESIGN AND STRUCTURE

Here the existing system design parameter has been calculated and the designed frequency of 5.5 GHz was simulated using HFSS software. The dielectric material selected for this design is RT duroid 5880. The design specifications for patch are below:

A. Dielectric constant-2.2
B. Height of the substate-1.2mm

And the feed line is realized on the same substrate layer.

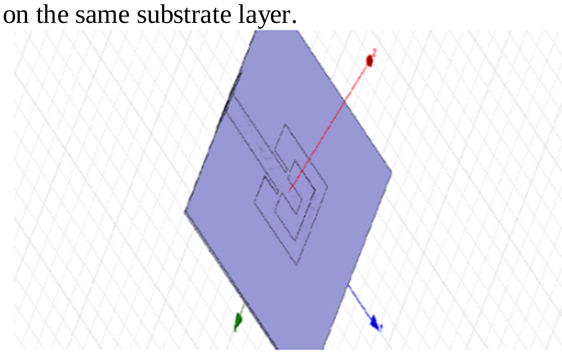

Fig 2- Design of U-shape microstrip antenna patch

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The microstrip antenna having single u-shaped slot on the patch is fed by 50Ω microstrip line and the main advantage of using the microstrip line feeding is that its ease of fabrication and the impedance matching is simple by controlling the inset cut position and the method is relatively simple.

B. The properties of substrates are

PARAMETER	**RT DUROID 5880**
sDielectric constant	2.2
Loss tangent	0.0004
Water absorption	0.2%
Tensile strength	450MP
Volume resistivity	2x10^7 mho(cm)
Surface resistivity	3x10^7mho(cm)
Breakdown voltage	>60 kV
Peel strength	5.5N/n(m)
Density	2200Kg/m^3

C. Design Parameters

The various design parameters are calculated as follows:

1) Width (W)
2) Effective permittivity (ε_{reff})
3) Effective length (Leff)
4) Delta length (ΔL)
5) Actual length (L)
6) Width of the ground (W_g)
7) Length of the ground (L_g)

These parameters are calculated for operating frequency of 5.5GHz has the length of 26.75mm and the delta length of 0.2367. It has RT duroid 4880 as the dielectric substrate which has the relative permittivity which is equal to 2.2.

D. Formula Used

WIDTH:

$$(W) = \frac{c}{2f_c\sqrt{\frac{\varepsilon_r + 1}{2}}}$$

DIELECTRIC CONSTANT:

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$$(\varepsilon_{reff}) = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r + 1}{2}[1 + \frac{12\,h}{W}]^{-\frac{1}{2}}$$

EFFECTIVE LENGTH:

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

DELTA LENGTH:

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

ACTUAL LENGTH:

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

WIDTH OF GROUND:

$$(W_g) = 6.h + W$$

LENGTH OF GROUND:

$$(L_g) = 6.h + L$$

III. PROPOSED SYSTEM SIMULATION RESULT AND DISCUSSION

There are some parameters that affect the antenna performance in which two of them have a very noticeable effect in determining the performance of the antenna. The return loss has become efficient according to the parameter changes and these parameter effects will be explained and summarized in this section.

A. Return Loss

The return loss for the proposed system is shown

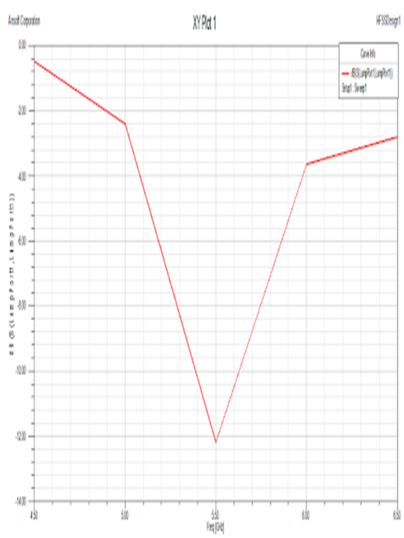

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Fig 3- Return loss for proposed system

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Fig 3 shows the return loss for the single u-slot antenna which is the simulated result. From the Fig 3, it can be shown that the U-slot microstrip patch antenna at 5.5GHz results in the broadening the bandwidth of the antenna. The graph is plotted for frequency in GHz versus return loss in dB. The graph is plotted for the frequency ranges from 4.50GHz to 6.50GHz and the return loss is shown from 0dB to -14dB.

Since the antenna has been designed for 5.5GHz and XYplot shows the return loss of -12.8dB at the operating frequency where there is more impedance matching and low return loss in order to achieve effective radiation pattern. The impedance mismatch occurs from 4.50GHz frequency to -5.23GHz and it results in somewhat low return loss and the frequency from 5.8GHz to 6.5GHz frequency, again due to impedance mismatch, the return loss increases and results in higher return loss which results in distortion and affects the effective radiation of the antenna.

B. Radiation Pattern

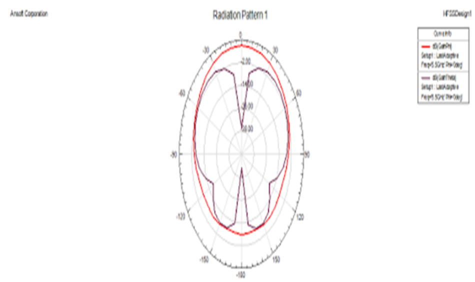

Fig 4- Radiation pattern for proposed system

The designed antenna is radiating all its power in one direction and therefore the optimized antenna has result with the effective radiation pattern and therefore the side lobes or nulls in the pattern has been minimized and the better directivity is achieved. The radiation pattern for the proposed system antenna has angles in phi and theta. In the figure, phi is represented in red color and theta is represented in purple color. The antenna is radiated from the angle of 45 degrees and has the magnitude of 7.108dB.

IV. CONCLUSION

The proposed antenna explains and illustrates the simulation of the microstrip antenna with single u-shaped slot on the patch. This antenna is compact, have a flexible structure and easy to use compared with other antennas. Thus, the very low return loss of less than -12dB is achieved which is suitable for the wireless applications and in the c-band of satellite communication systems. This antenna has been simulated for the frequency of 5.5GHz and is well known for its wideband characteristics.

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BIOGRAPHY

Ms. M.Kaanchana is a student who is pursuing B.Tech (Electronics and Communication Engineering) in Dr. S.J.S PAUL MEMORIAL COLLEGE OF ENGINEERING AND TECHNOLOGY. He is interested in Electro Magnetic wave theory, wave guides and antennas, Digital signal processing, signals and system.

Ms. T.Adhilakshmi is a student who is pursuing B.Tech (Electronics and Communication Engineering) in Dr. S.J.S PAUL MEMORIAL COLLEGE OF ENGINEERING AND TECHNOLOGY. He is interested in Digital circuits, Digital signal processing, and Electronic circuits.

Ms. B.Vaishnavi is a student who is pursuing B.Tech (Electronics and Communication Engineering) in Dr. S.J.S PAUL MEMORIAL COLLEGE OF ENGINEERING AND TECHNOLOGY. He is interested in VLSI design, Digital signal processing, and digital electronics.

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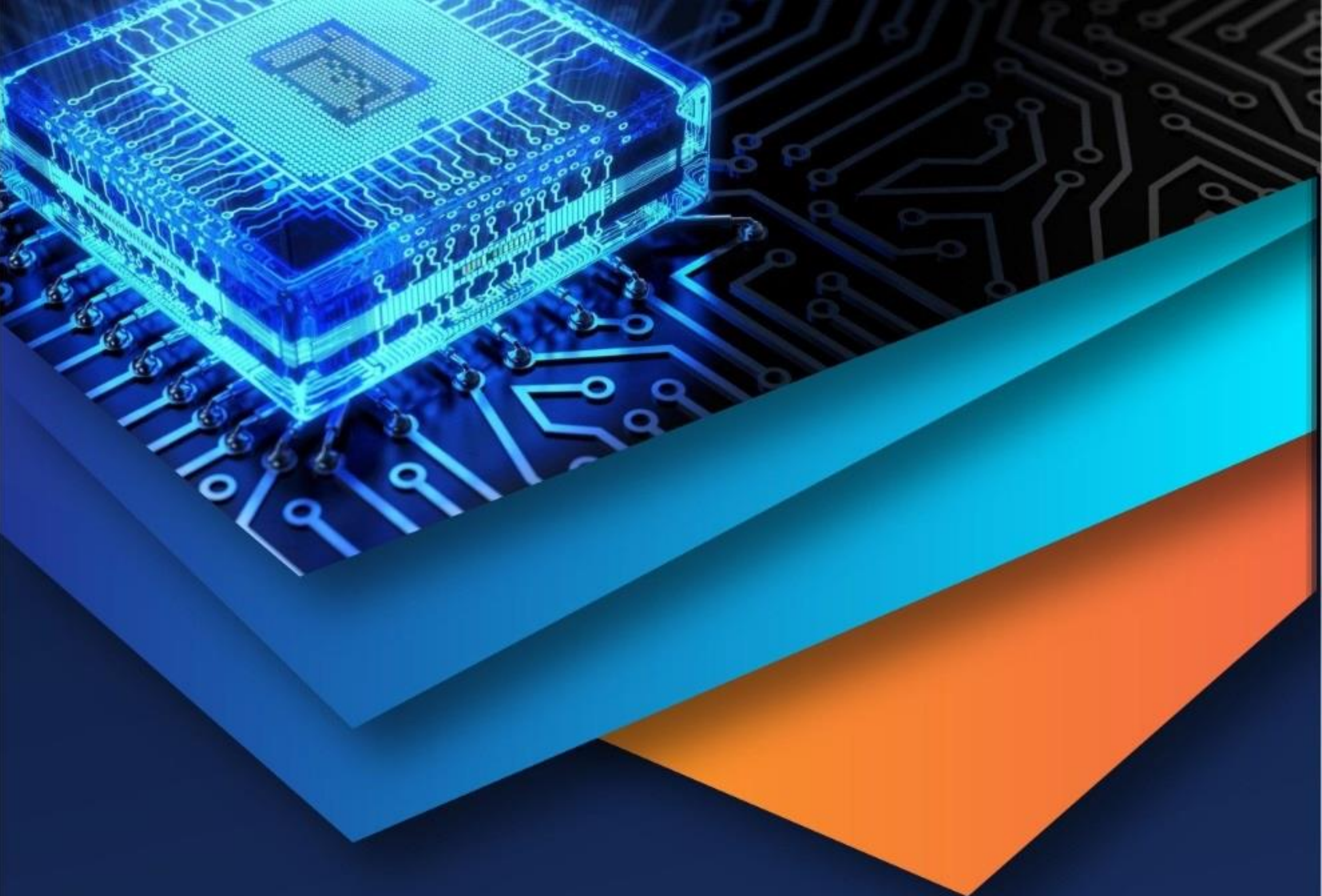

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