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Microstrip Planar Antennas for C-Band Wireless Applications

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Abstract: In recent years, wireless communications have evolved significantly, and many mobile devices have reduced in size. The antennas used in mobile terminals must be lowered in size to fulfil the downsizing standards. Planar antennas, like microstrip and printed antennas, have a low profile, compact size, and conformability to mounting hosts, making them particularly desirable candidates for achieving these needs. Additionally, planar antennas are also being used in communication devices for 2.4 GHz (2400 – 2484 MHz) and 5.2 GHz wireless local area network (WLAN) systems (5150). In wireless applications, an antenna is a crucial component. At the transmitter, it transforms electrical signals into RF signals, and at the receiver, it converts RF signals to electrical signals. The patch inside the antenna is made of a conducting material such as Cu (Copper) or Au (Gold), and it can be rectangular, round, triangular, or elliptical. Two unique designs of microstrip planar antennas with an operating frequency of 5.2 GHz having S11 parameters as -16.0 dB and -15.7 dB have been offered and their performance has been studied in this research article.

Introduction

An antenna is a member of the transducer family that transforms radio-frequency (RF) fields to alternating current (AC) or vice versa, as well as a component of a transmitting or receiving system for sending or receiving electromagnetic waves (Stutzman, 2012; Rakhe et al., 2023). A microstrip antenna has a small metal wire connected to a grounded dielectric substrate. Microstrip patch antenna dimensions reduction is crucial in a variety of contemporary applications, including Wireless Local Area Networks (WLANs), global interoperability for Microwave Access (WiMAX), and other wireless terminal-based approaches. Microstrip antennas are appealing due to their low profile, less weight, conformability to ground targets and simple construction. Microstrip antennas for wireless applications have been developed in large numbers (Gupta, 2009; Li et al., 2008; Yang et al., 2001). It has multiple applications as military, radar systems, mobile communications, and remote detection.

By deleting a slit at the right location on the microstrip route, the antenna's size is successfully reduced. The goal of this article is to use HFSS EM modelling to construct and analyze a microstrip patch antenna. On an FR4-epoxy substrate with a depth of 1.6mm and Ɛr=4.4, this antenna is designed to function on the frequency of 5.2GHz. In its simplest form, a microstrip antenna is a layered structure with two parallel probes separated by a dielectric substrate and that probe. The top component is referred to as a patch and it is responsible for radioactivity, while the below section serves as a ground plane. A microstrip patch antenna

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appears with a ground plane (Cu) and a radiating patch on opposite sides of a dielectric substrate (FR4). A rectangular microstrip antenna has a very small radiating metal patch to one side of the dielectric substrate, while the opposite plane is taken as ground. A Microstrip is usually made out of a rectangular radiating patch element supplied by a coaxial line, with the length being the most important dimension and the dielectric substrate being somewhat less than half wavelength. A Microstrip antenna's radiating patch can be a rectangular, circular, elliptical, square, annular ring, and so on. The HFSS software tool is used here for creating and analyzing the proposed antenna.

Literature survey

This section describes the existing literature on the domain of patch antennas. A survey has been proposed considering the effect of the different designs and sizes of the patch antenna for 5G communications (Kumar et al., 2023). Because of their versatility and variety of applications, wireless networks are one of the most promising research fields. Nonetheless, it has some obstacles that are being researched and evaluated. It displays a quadrangular microstrip patch antenna for WCDMA that is fed by a probe and uses particle swarm optimisations and soft computing. Using Sonnet 13.52, a substrate having a $\varepsilon_r$of 4.4, a height of 1.588 mm and a feed site at a midpoint frequency of 1.95 GHz. This design has been evaluated as the Voltage Standing Wave Ratio (VSWR) and return loss (Ramna, 2013). It suggested a 2.4 GHz resonance frequency antenna for a WLAN. There are many antenna forms in this design, and this antenna is built for the aforementioned resonance frequency. In addition, these antennas are mounted on a FR 4 Epoxy dielectric-type substrate and tested for return loss and VSWR (Adegoke and Eltoum, 2014). It also demonstrated a simple microstrip patch antenna, which comprises a substrate—a dielectric average—and a metallic patch and ground. At a resonance frequency of 2.4 GHz, a simple microstrip patch antenna is developed. This antenna has a gain of 8.27 dB and a VSWR of 1.18 (Afridi, 2015). Additionally, the IE3D simulator programmer is used to examine the performance and gain of the microstrip patch antenna. Mobile phones use the patch antenna technique and simulation. Along with the radiation style, the return loss and alternative gain plots were examined (Bhalla and Bansal, 2013). It proposed a compact rectangular microstrip antenna with one feed and two bands. This antenna's resonance frequencies are 3.68 GHz and 5.74 GHz, in that order. An MoM-based electromagnetic solution called IE3D is used to examine this design's characteristics. A detailed analysis of the recommended antenna's return loss, redaction pattern, gain, and efficacy (Santawani et al., 2017). Using the Bi-polar process, it presented a small microstrip antenna with good gain and broad bandwidth. The surface of the product is enhanced, and losses are decreased, thanks to this technique. These antennas employ the MATLAB simulator to determine the parameters, and the findings show that by applying this technology, the bandwidth is increased, and the antenna has been assessed in terms of return loss (Devi and Kumar, 2016). The survey will be used to develop and install a Rectangular microstrip Patch Antenna that will resonate in the ISM Band at 2.4 GHz. A work related to the ISM band is acknowledged (Jadhav and Veeresh, 2017). The suggested antenna was constructed by ADS simulation software and the antenna characteristics were evaluated utilizing a network analyzer tool (Prabhakar et al., 2013) based on the following inputs. This is a very young field of antenna design. Microstrip patches are popular because of their lightweight, compact size, and ability to operate with low-cost components. With printed microstrip line feed, antennas may be inter-connected via networks and with active devices. The radiation characteristics of microstrip structures drew attention in the 1950s. In general, radiators in electronic communication systems are large and expensive, A patch antenna has a top side that is coloured on a dielectric substrate and a bottom side that is ground. Copper material is used on both sides. On the dielectric substrates, the radiating patch and microstrip feed lines are constructed (Jadhav and Veeresh, 2017). The antenna (Kapoor and Parkash, 2012) is fed by microstrips and was created using the IE3D application. IEEE 802.11 WLAN standards operating at 5.2/5.8 GHz and WiMAX standards operating at 5.5 GHz can both benefit from the recommended antenna. A novel microstrip patch antenna has been proposed (Noor et al., 2023), based on FR-4 substrate with aiming to get a wider bandwidth and higher gain for wireless communications. A triangular patch-based antenna has been suggested (Atif et al., 2023) for 5.8 GHz and a broader bandwidth of 100 MHz for ISM band applications. Ezzulddin et al. (2022) have proposed an antenna of dimensions in mm^3 for wireless-based applications.

Overview of microstrip planar antenna

This antenna is built with a microstrip process on a PCB. It is a type of internal antenna. These are broadly utilized in microwave frequencies. The discrete micro-strip antenna comprises a multi-layered cone of copper (boat antenna) above the plane of the PCB, which has a metallic band level on one side of that PCB. Utmost

Microstrip antennas contain several clips in a 2D array. The antenna is frequently linked to the transmitter or receiver via the transmission line of the microstrip foil. The typical category of microstrip antenna is the skin antenna. The pool antenna is a small, broad-angle in shape, made of attaching an antenna pattern to a metal trace that is attached to the base of the input shaft, similar to a Printed Circuit Board, with a continual steel plate tied with the front part of the surface of the ground. A typical microstrip antenna shape is square, rectangular, spherical, and left, nonetheless any continual shape is attainable. These don't utilize a dielectric substrate and are then again made with metal boats assembled on the ground using a dielectric spacer; The final construction is slightly behind however has a wide bandwidth. Since such horns maintain a very low profile, they are curved and possibly be customized to fit the skin of a curved car, often mounted on an aeroplane and in space, or mounted on mobile radio communication devices.

Materials and Methods

In this paper, we have proposed two different models for the micro-strip planar antenna. Here we are designing for the micro-strip planar antenna having a resonant frequency or we can say operating frequency equals 5.2 GHz and we are taking here the value of the dielectric constant that is equal to 4.4 and this antenna having a height of 1.6 mm. Using these given values, we can easily calculate the value dimensions (length and breadth) of the patch of the micro-strip planar antenna. With the help of the dimensions of the patch of the microstrip planar antenna, we can calculate the value of the dimensions of the substrate of the microstrip planar antenna. This is because the dimension of the patch of an antenna is double the dimension of dimensions of the substrate (Nawale and Zope, 2014).

Table 1. Dimensions of the proposed antenna (attached in a separate file)

$$Width = \frac{c}{2f_0\sqrt{\frac{\varepsilon_R+1}{2}}} \quad (1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{w}\right)}}\right. \quad (2)$$

$$Length = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{w}{h}+0.8\right)}\right) \quad (3)$$

The basic formulas for finding the dimensions of patch antennae are given:

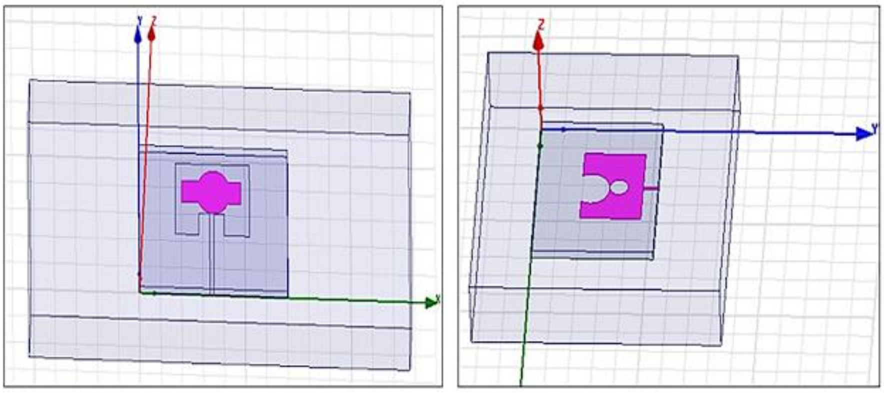
Proposed Antenna

Design 1 (Circular t-shape):

In Figure 1 (a), we first cut the rectangular slot from the patch and then take a circular slot and that circular portion gets united to make this shape of microstrip planar antenna. These all processes were done only to increase or enhance the impedance matching and hence its S11 parameter will improve.

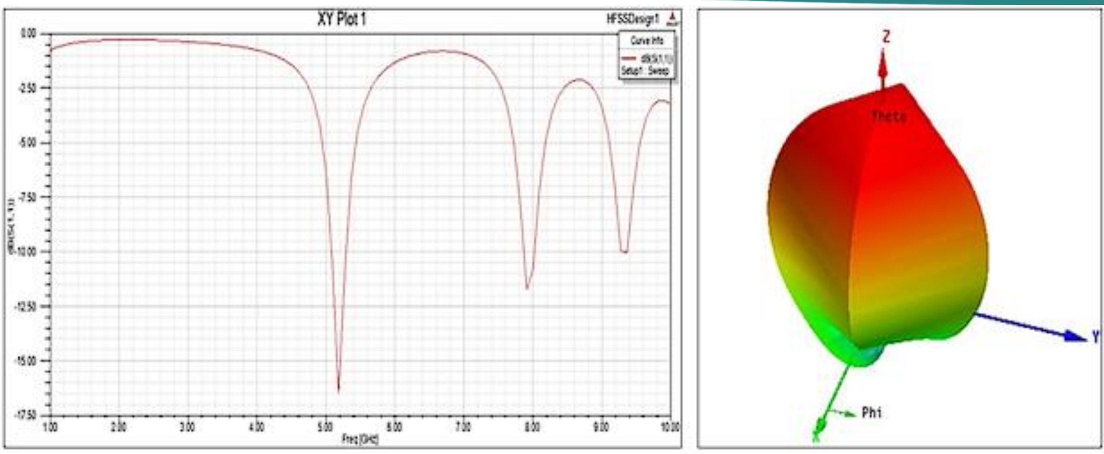
Design 2 (Half-full moon shape):

In Figure 1 (b), we have cut the two slots. The first one is the full circle and another is of a semi-circle but having different radii. The main purpose of cutting two different slots is to increase the input impedance matching and hence the improvements in the S11 parameter.



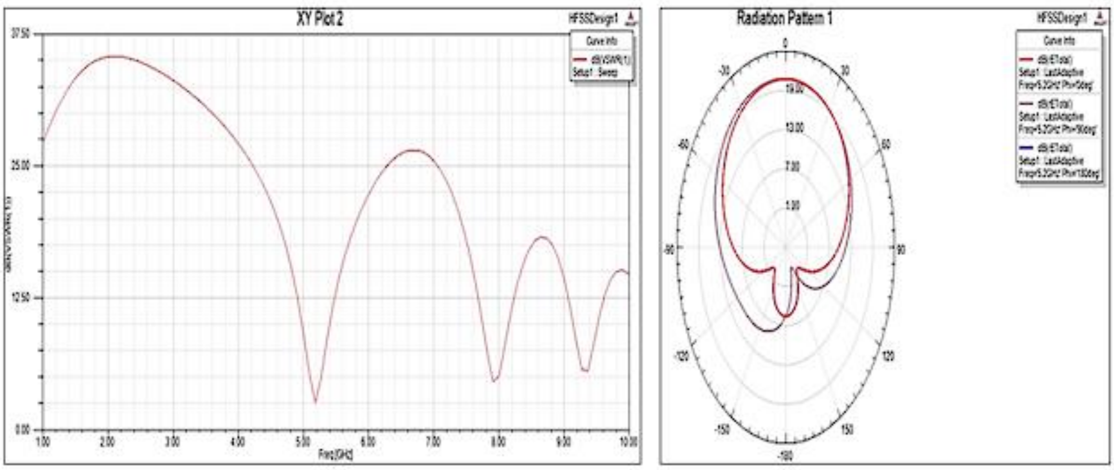
(a) (b)

Figure 1 (a & b). Circular T- Shape and Half-full Moon Shape.



(a) (b)

Figure 2 (a & b). S11 Parameter and 3D Polar Plot.



(a) (b)

Figure 3 (a & b). VSWR and Radiation Pattern.

Results and discussion

Design 1 (Circular t-shape):

In an electrical system, the input-output connection between ports (or terminals) is described by return loss or S-parameters. Any location where we can provide voltage and current may be broadly referred to as a port. In actuality, S11 is the parameter that is most often cited when discussing antennas. S11, sometimes referred to as the return loss or reflection coefficient, is a measurement of the amount of power that is reflected from the antenna. The reflection coefficient of the proposed antenna-01 has been presented in Figure 2(a). The first proposed antenna is named as circular t-shape antenna which is resonating at 5.2 GHz with a reflection coefficient value of -16 dB. The 3D polar plot of the antenna-01 has been presented in Figure 2 (b), having a gain of 5dBi.

The evaluation of the impedance matching between the antenna and radio or transmission line is called the voltage standing wave ratio, or VSWR. It shows the maximum power that an antenna can receive without risk of damage. It has a range of 1 to ∞. On the other hand, a low VSWR value is acceptable as it indicates a better impedance match and more effective power transfer from the radio or transmission line to the antenna. Poorer impedance matching results in a greater VSWR value, which reduces the amount of power that is effectively delivered from the radio or transmission line to the antenna. The VSWR of the proposed antenna-01 has been presented in Figure 3(a), with a VSWR value of 2.

How radio waves are distributed in various directions is represented by an antenna's radiation pattern. When an antenna is said to have a gain of X dBi, it indicates that it outperforms an isotropic radiator in that direction. dBi is the unit used to represent antenna gain with an isotropic radiator. The radiation pattern of the antenna-01 has been presented in Figure 3 (b).

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Design 1 (Half- full moon shape):

The reflection coefficient of the proposed antenna-02 has been presented in Figure. 4(a). The second proposed antenna is named as a half-full moon-shaped antenna which is resonating at 5.2 GHz with a reflection coefficient value of -15.7 dB. The 3D polar plot of the antenna-02 has been presented in Figure 4 (b), having a gain of 4 dBi.

The VSWR of the proposed antenna-02 has been presented in Figure 5 (a), with a VSWR value of 2.2 and the radiation pattern of the antenna-02 has been presented in Figure 5 (b).

Conclusion

The study and design of the compact microstrip antenna system of the GPS and satellite TV signal as well as to read the two-dimensional television series has been done successfully. Changing the feed holder can change the size of the antenna as shown in our first example. The compression between the calculated results and our estimates indicates a good rectangular bond. According to the theory, the space between the peak should be more than half the wavelength to make it (the region of space) not the radius. If the space is less than half the wavelength then the capture will have an impact on each

Table 2. Performance of the proposed antennae (attached in a separate file).

Sl. No.	Proposed Antenna Name	fo (GHz)	Gain (dB)	S11 Parameter	VSWR
01	Circular T-Shape	5.2	5	-16.0	2
02	Half-Full Moon Design	5.2	4	-15.7	1.9

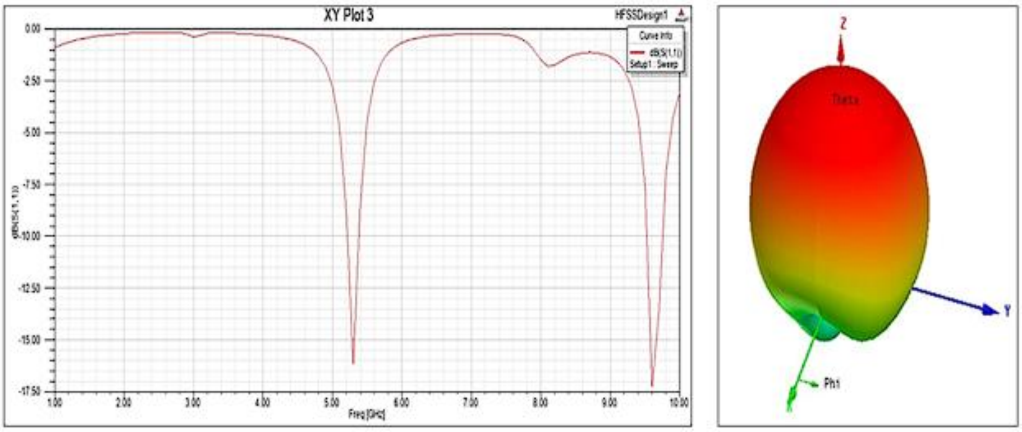
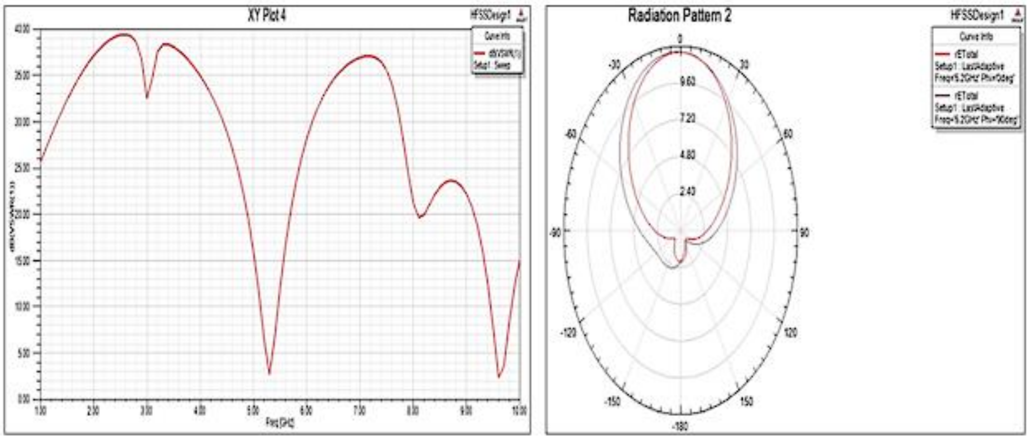


Figure 4 (a & b). S11 Parameter and 3D Polar Plot.



(a) (b)

Figure 5 (a & b). VSWR and Radiation Pattern.

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other and this will require a new calculation on the antenna parameters such as block, parking area, and pattern. To adjust for and cure faulty circumstances caused by changing horn conditions, temperature fluctuations, voltage loss, voltage change, and volume-to-unit variations, an antenna mating system is necessary. An incorrect impedance design game can result in a startling increase in radiated power (TRP), link width, PA performance, PA efficiency, and antenna efficiency (gain) while reducing current utilization. Because of the lack of free space, the received signal may be weak, and the antenna may absorb noisy signals from the sky, the ground, the weather, and man-made natural sound sources.

Additional work in this area for future work is to increase the magnitude of the antenna conversion ability to obtain the longest VSWR for a proper wireless event using this type of antenna, another task that may be completed is to identify better ways to keep the inductor coils utilized while integrating the antenna network system.

Conflict of interest

The authors declare that there is no conflict of interest.

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