Design and Performance Analysis of a Novel Home-Shaped Microstrip Patch Antenna for C Band Applications

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***Abstract*—The increasing demand for compactable and efficient antennas which used in wireless communication systems has led to the exploration of innovative patch geometries and creative designs. In this work, a house-shaped microstrip patch antenna is designed and it is analyzed for operation at 4.15 GHz. The proposed antenna is developed on an FR-4 substrate and simulated using HFSS software (High Frequency Structure Software). The unique and innovative structure, which includes a triangular roof and rectangular base with some slot modifications, which enhances the surface current distribution and improves impedance matching. Simulation results show return loss of approximately -23 dB and a VSWR close to 1.17 at 4.15 GHz, indicating efficient radiation characteristics. The antenna also exhibits good gain and directional radiation behavior, making it suitable for C band applications.**

***Index Terms*—Microstrip antenna, Home-shaped patch, HFSS, 4.15 GHz, Return loss, VSWR, Gain.**

I. INTRODUCTION

Antennas are the most important parts of wireless communication systems. They connect guided electrical signals to radiated electromagnetic waves in free space. They are very important because they make it possible for signals to be sent and received reliably over many different types of communication networks, such as mobile networks, satellite communication, radar systems, and IoT apps. Microstrip patch antennas have gotten a lot of attention because they are low-profile, light, easy to make, not too complicated, and work well with printed circuit board technology. These benefits and uses make them great for use in small, portable electronic devices.

However, conventional microstrip patch antennas, typically designed with simple geometric shapes such as rectangular or circular, suffer from certain limitations such as narrow bandwidth, moderate gain, and reduced efficiency. These limitations become the demand for compact and high-performance antennas increases in modern communication systems. To overcome these limitations, researchers have explored various techniques such as slot loading, stacked configurations, and geometrical shape modifications of the radiating patch.

This paper presents a new way to improve the performance and efficiency of antennas by designing a home-shaped microstrip patch antenna. The design adds a triangular roof and slots to change the way the current flows and make the electrical path longer. This antenna is made to work at 4.15 GHz, which is in the middle of the frequency band used for many wireless communication applications. The proposed design geometry makes the antenna's impedance and radiation characteristics better without making it bigger, which makes it possible to use in real life. antenna size, making it suitable for practical implementation.

II. LITERATURE SURVEY

Microstrip patch antennas are really popular because they are small and easy to make. But the regular rectangular ones have some problems. They can only. Receive signals over a small range of frequencies and they do not send the signal very far. This is an issue, for modern wireless communication systems. So a lot of people have been trying to come up with ways to design Microstrip patch antennas like changing their shape to make them work better. Microstrip patch antennas need to be improved to work well in wireless communication systems.

In a research paper [1] Balanis talked about the theory and design principles of microstrip antennas. He said that things like the material of the substrate the size of the patch and how you feed the antenna are very important, for how the antenna works. Later another researcher named Pozar [2] discussed some real-life problems with microstrip antennas. He said that these antennas have some limitations and that we need to improve how well they match impedance and how efficiently they radiate.

Several studies have looked at changing shapes to make them work better. One study in [3] made a kind of antenna called a microstrip array antenna for high frequency uses. This antenna got a signal but it was harder to design. Some other studies like the one in [4] used antennas, with shapes. These antennas worked well for ranges of frequencies because of their special shapes. However, making these shaped antennas was still tricky.

The people who made microstrip antennas wanted to make them work better. So, they tried something in [5]. They added slots to the microstrip antennas. This helped the antennas work with the impedance and have more bandwidth. These new antennas worked better than the ones. The people who made them had to be very careful when they chose the size of the slots. Someone else did a study in [6]. They made microstrip antennas that could work on than one frequency. This meant the antennas could work in bands. The problem was that these antennas were often bigger than the old ones. Microstrip antennas are still a choice. They need to be made carefully. Microstrip antennas like the ones, in [5] and [6] are important.

Recent studies have also looked at patch shapes like lamp-shaped and other unusual shapes. These shapes help spread the current and allow the antenna to work on multiple bands. This shows that changing the shape of the antenna can make it work better without making it much bigger.

From what we have read many techniques can make antennas work better. We still need antennas that are simple, small and efficient. This is why we propose a microstrip patch antenna shaped like a home. It is designed to match the impedance have a higher gain and give stable radiation performance

III. ANTENNA DESIGN METHODOLOGY

Microstrip patch antennas are very common in wireless communication systems because they are small, easy to make, and work with flat surfaces. However, traditional microstrip antennas, especially rectangular patch designs, often have problems like a narrow bandwidth, moderate gain, and less effective impedance matching. There are a number of design ideas that have been put forward to get around these problems. These include slot loading, changing the shape, and using multi-resonant structures.

In the beginning of this project, a standard rectangular microstrip patch antenna was designed to work at around 4.15 GHz as a reference model. The rectangular patch was chosen because it is a simple analytical base and is commonly used as a starting point in antenna design. The first design was built on a FR-4 substrate that was 1.6 mm thick and had a dielectric constant of 4.4. Using standard design equations, we figured out the basic dimensions of the rectangular patch. For the desired frequency, the patch should be about 30–35 mm wide and 20–25 mm long.

The simulation results of the standard rectangular antenna showed some problems. The return loss was not low enough, and the VSWR was higher than it should have been. The gain was average, which means the antenna could perform better. These observations indicated the need for a different antenna design.

The rectangular patch was changed into a home-shaped geometry to make it work better. This is the main new thing about this work. The new structure has a triangular roof section and a rectangular base. Adding the triangular section makes the current path's effective electrical length longer without making the antenna bigger. This helps improve resonance and radiation properties.

The antenna is connected to a microstrip line feed. This feed is supposed to give the antenna a kind of impedance which is 50 Ω. The feed line is 2 mm wide

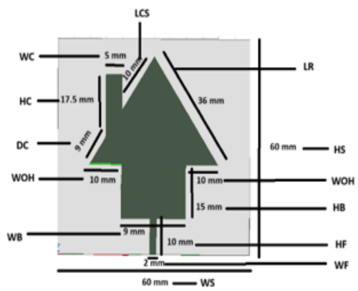

Fig. 1. Microstrip antenna geometry

so, it fits well with the transmission line. We also moved the feed line to the spot so that the antenna gets the most power and there is less reflection. The antenna and the feed line and the slot structures all work together to make the antenna work well.

TABLE I: ANTENNA PARAMETERS

Parameter	Description	Value (mm)
LS	Substrate Length	60
WS	Substrate Width	60
LR	Roof Slant Length	36
WC	Chimney Width	5
HC	Chimney Height	17.5
DC	Chimney Depth / Offset from Peak	10
WOH	Roof Overhang	15
HB	House Side Height	15
WB	House Base Width	20
WF	Feedline Width	
LF	Feedline Length	10
h	Substrate Thickness (FR-4)	1.6
(εr)	Dielectric Constant	4.4
(t)	Copper Thickness	0.035

Table I lays out the geometric parameters for our home-shaped microstrip patch antenna. We optimized these dimensions through iterative simulations. Our aim was to hit 4.15 GHz resonance, improve impedance matching, and boost radiation characteristics. A compact substrate keeps the form factor small, yet doesn't compromise performance.

The antenna's home shape, with a triangular roof over a rectangular base, changes the current distribution compared to standard rectangular patches. Its roof section increases the effective electrical path length, letting it resonate without needing a larger antenna. What's more, the chimney and slot features act as tuning elements. They improve impedance matching and cut down on return loss. We designed the microstrip feed line for 50 Ω impedance to ensure efficient power transfer and minimal reflection.

In the end, these optimized parameters yield low return loss, a VSWR close to unity, and better gain. It goes to show that modifying geometry is an effective way to boost antenna performance

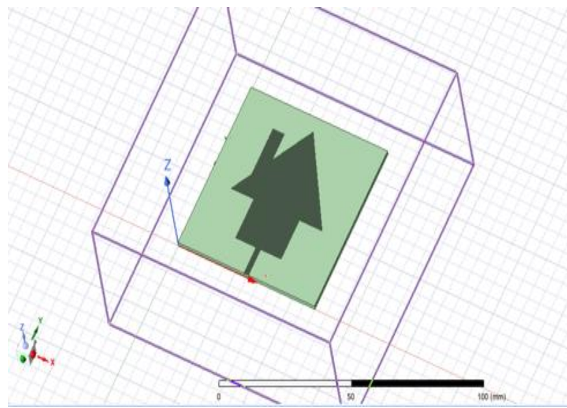

Fig 2 Microstrip antenna in HFSS

The proposed home-shaped microstrip patch antenna is designed and analysed using ANSYS HFSS, a finite element method (FEM)-based electromagnetic simulation tool. The antenna is modelled on an FR-4 substrate with a dielectric constant of 4.4 and a thickness of 1.6 mm, providing a balance between performance and cost. The substrate dimensions are maintained at 60 mm × 60 mm, with a copper ground plane on the bottom layer. The radiating patch is created on the top layer with a home-shaped geometry consisting of a triangular roof, rectangular base, and a chimney structure for tuning. Key dimensions include a roof slant length of 36 mm, chimney width of 5 mm, chimney height of 17.5 mm, and base width of 20 mm. A microstrip feed line of width 2 mm and length 10 mm is used to provide a 50 Ω impedance match. The antenna is excited using a wave port, and radiation boundaries are assigned to simulate free-space conditions. The design is optimized through multiple iterations to achieve resonance near 4.15 GHz with improved impedance matching and radiation performance.

IV. RESULTS AND DISCUSSION

The home-shaped microstrip patch antenna is tested to see how well it works. We use ANSYS HFSS simulation to do this. The results show that the new shape of the home-shaped microstrip patch antenna really helps to improve how well the antenna works.

We look at the home-shaped microstrip patch antenna to see how it does in a few areas. These areas include return loss, Voltage Standing Wave Ratio, gain, radiation pattern and bandwidth. All of these things together help us figure out if the home-shaped microstrip patch antenna is good, for communication.
The return loss, also known as S11 is very important. It shows how well the antenna matches with the transmission line. A lower return loss value means matching and less power reflection. The simulated S11 results show the antenna works best at around 4.15 GHz. This is close to the 4.1 GHz we wanted. At this frequency the return loss is −23 db. This is much lower than the −10 dB limit. So only a little power is reflected back. Most of the power goes into the air. The sharp drop in the S11 curve shows resonance. This means the antenna behaves well. The return loss characteristics are shown in Fig. 2. It helps to see the frequency and impedance bandwidth clearly. This information helps us understand how well the antenna works. The antennas return loss is good. It radiates power into space. The return loss value is very low. This is a sign, for antenna performance.

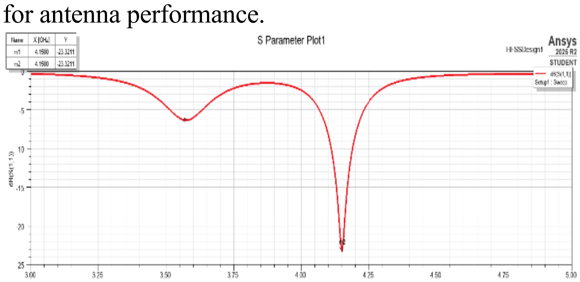

Fig 3 S parameter

Apart from the return loss, we also look at bandwidth - this shows us over what range of frequencies the antenna is performing well. On the S11 plot we pick out the frequencies over which the return loss is less than 10 dB, which is the bandwidth. From our result we get an approximate bandwidth of 200 MHz around the main frequency of the antenna, showing that the performance is consistent over this frequency range. This is adequate for mid-band wireless communications. We also see that the antenna has a fairly flat performance over this bandwidth, despite the changes in frequency.
VSWR (Voltage Standing Wave Ratio) is also a crucial parameter that determines the impedance matching between the antenna and feed line. VSWR close to 1 determines the best matching whereas greater than 2 reveals the matching and reflecting are not very good. In this case, the simulated VSWR for proposed antenna is very close to ideal VSWR which is approximately 1.17 at 4.15 GHz, which means this antenna has very good impedance matching and effective power delivery. The VSWR should be displayed as Fig. 3

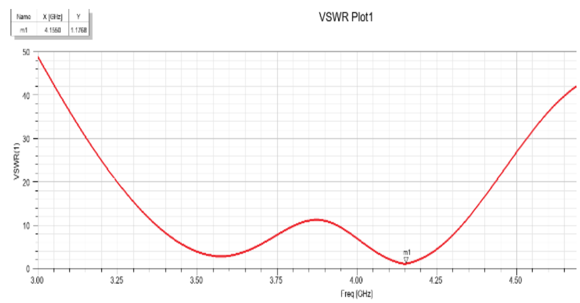

Fig 4 VSWR

Another important parameter is the gain of the antenna, which expresses the ability of the antenna to radiate in a particular direction. The proposed antenna has an obtained gain of around 8.69 dB which is considered good for typical microstrip patch antennas. This rise in gain may be the result of the geometry of the new home shaped geometry, that improves the surface currents distribution and makes the radiation to be oriented toward a particular direction. The triangular shape of the roof and chimney may increase the path of the currents and improve the radiation efficiency.

Additional gain evidence is provided by the antenna radiation pattern, demonstrating the directional nature of the radiation. The simulated 3D radiation pattern shown below clearly indicates a direction of maximum radiated energy, proving the suitability of the antenna for applications which involve directional signal transmission. The pattern also exhibits good steady-state behavior with no significant side lobes, contributing to the efficient transmission of the signal. The 3D radiation pattern should be represented as Fig. 4 following the gain discussion to depict the distribution of radiated energy in the form of a 3D pattern.

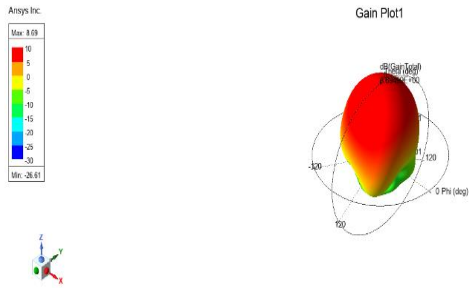

Fig 5 Gain

In conclusion, the overall performance of the antenna shows the benefits of the home-shape geometry; by comparing to a traditional rectangular patch antenna, electrical characteristics of antenna have been considerably improved. Integration of changing shape and tuning through the slots has produced more efficient matching in impedance, lower return loss, better VSWR and better gain as well as keeping a smaller size for the modern mobile devices.

The simulation has showed that the antenna has efficiently radiated power and obtained good matching at mid-band with high gain; thus, this proposed antenna is good for mid-band wireless systems and IoT applications and mobile communications devices with small size

V. PERFORMANCE SUMMARY AND COMPARISON

Table I shows the performance details of the home-shaped microstrip patch antenna that we made and it also includes some other antenna designs, from books and studies that work with similar microwave frequencies.

TABLE I. Comparison of the Proposed Antenna with Reference Designs

Reference	Frequency (GHz)	S11 (dB)	VSWR	Patch Shape
[3]	5.90	−10.5	1.88	Rectangular
[5]	8.50	−10.1	1.92	Fractal Slot
[7]	5.80	−12.0	1.75	Modified Patch
Proposed Work	4.15	−23	1.17	Home-Shaped

VI. CONCLUSION

In this paper, a new microstrip patch antenna shaped like home has been successfully designed and analyzed to resonate at 4.15 GHz using ANSYS HFSS software. The presented shape with a triangle roof, slot and chimney successfully altered surface currents distribution and improved the antenna performances. The simulation shows a return loss about -23 dB at the resonant frequency around 4.15 GHz (VSWR = 1.17), which is very well impedance matched. A good gain about 8.69 dB has been obtained, as well as a stable directional radiation pattern. This characteristic will make this antenna be suitable for wireless communication. The overall study proves that this antenna has good performance and is a good solution instead of the traditional antenna due to the very compact size and the good electrical behaviors obtained. This work has shown how the geometry modification of a patch antenna can greatly improve the overall antenna performance in a very simple way.

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