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Felt based Performance Improvement of Patch Antenna for WLAN Applications

M. Pandimadevi[1], N. Logasri[2]

[1]Associate Professor, [2]Student, [1]Corresponding author

ECE, Sethu Institute of Technology, Kariapatti, India

Email: [1]devidevi64@gmail.com, [2]Logasrikrish@gmail.com

Abstract

The gain improvement of a patch antenna by using double E-shaped patch has been proposed in this research. Due to its low permittivity of 0.02 and low dielectric constant of 1.45, felt is used as the substrate for the antenna. The proposed research work aims in designing a low-cost antenna that is flexible with performance enhancement and suits all wireless applications. The proposed antenna with felt substrate is simulated and the parameters are analysed with different structures at the frequency of 5.64 GHz. The result shows that there is a gain enhancement (8.270 dBi) in the final structure designed, and thus the antenna design is appropriate for wireless applications.

Keywords: Patch Antenna, Felt, Gain, Directivity, Slot.

1. Introduction

One of the areas of the communications sector with the quickest growth right now is microstrip patch antennas [1-5], which have the potential to take over as the preferred form of communication in the future. Low profile antennas are critical in highly efficient applications where weight, dimension, price, reliability, and installation simplicity are all limitations. Microstrip patch antennas provide a number of benefits, including ease of fabrication, low profile, and light weight antennas, but they also have a number of drawbacks, including low gain, a narrow bandwidth, and low efficiency.

Many wireless applications that require tiny, conformal, and affordable antennas use microstrip antennas. However, they have significant drawbacks that severely constrict their

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versatility, such as a constrained impedance bandwidth and poor efficiency. For instance, a single patch antenna's gain is typically modest. An antenna's gain [6-8] is defined as the proportion of its power while radiating in an intended orientation to its isotropic radiation power. Numerous works have been carried out to increase the patch antenna gain utilising various strategies, concepts, and resources, to improve the patch antenna's gain value while maintaining its simplicity and effectiveness.

For gain enhancement, a I-shaped mushroom patch antenna in structure of Electromagnetic Band Gap (EBG) was used by Pongpat Ketkuntod et al. (2017) [9]. The typical microstrip patch antenna gain was increased via implementing enhancement techniques like EBG. According to the radiation pattern findings, the antenna's gain improved by about 2 dBi at 5.2 GHz frequency. Furthermore, the EBG structure's presence prevents side- and back-lobe radiation from being emitted.

Harshit Srivastava et al. [10] (2020) used a novel strategy that significantly improves both gain and bandwidth. The working frequency of the developed antenna was 9 GHz, which was utilized in electromagnetic system's X-band. HFSS software was used to model it on an RT Roger/duroid 5880 material with a dielectric constant of 2.2. RMPA has a gain of 6.92 dB, but by introducing slots, the gain increases to 19.88 dB, resulting in an improved value of 12.96 dB.

An antenna with a unidirectional limited bandwidth, having low profile and dual layer, was used by Anwer Sabah Mekki et al. [11] (2015). The antenna was created utilising a second Flame-Resistant layer (FR-4), covered on both sides with annealed copper measuring 0.035 mm, and 0.04 air gap acts like reflector. The use of a dual FR-4 substrate layer with a thickness of 1.6 mm, and a relative permittivity of 4.3 resulted in 5.2 dB gain, 7.6 dBi directivity, 9.5 dB F/B, and return loss of 18 dB to resonate at the frequency of 2.45GHz.

From the above research, it is known that by adding or implementing the complicated techniques like EBG, AMC, superstrate, air gap [12] using expensive substrate material, the gain is improved. In this work, the antenna gain is improved by simply varying the substrate, including a slot and by easy designing that has double E structure. Felt [13][14] is a textile that is created by matting, condensing, and pressing threads together. Natural fibres such as wool or animal fur can be used to make felt, as can synthetic fibres such as rayon made from wood pulp. It is fire-resistant and self-extinguishing, dampens vibrations and absorbs sound, and can hold a large amount of liquid without becoming wet. The dielectric constant of felt is 1.45 and the loss tangent is 0.02.

The following paper is organized as: Antenna Design in section 2 deals with the antenna design using standard equation, followed by antenna simulation in section 3. The discussion of results is presented in section 4 and then the conclusion is summarized in section 5.

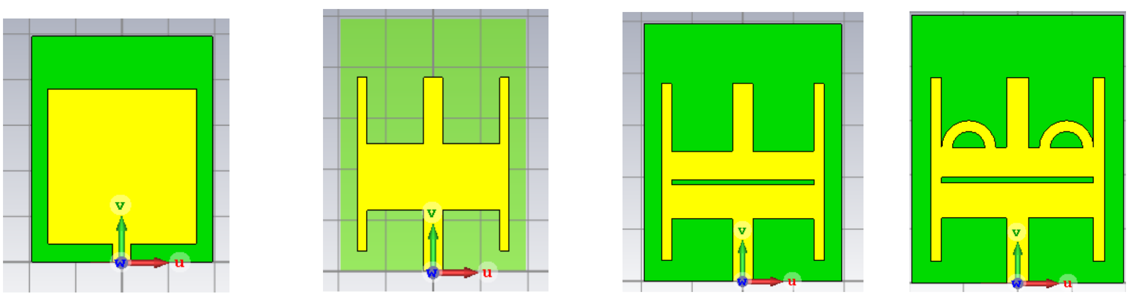
2. Antenna Design

The operating frequency should be selected along with substrate factors like dielectric constant ‘r’ and thickness ‘h’ when developing a patch antenna. Then the antenna dimensions are calculated from the standard equations [3], and the parameters are calculated as in Table 1.

Table 1. Dimensions of the antenna designed

Parameters	Dimension(mm)
Patch line	34X 32
Substrate	39x49.5
Ground Plane	39x49.5
Strip line and Patch Thickness	0.1
Substrate Thickness	1
Slot	28X1

The antenna is made up of a double E-structure with a slot. A 50 coaxial probe transmission line is used to excite port 1. The flexible micro strip patch antenna is constructed from "Felt," a flexible substrate. Felt has a low dielectric constant, resulting in minimal return loss. Copper is used for the ground plane, patch, and strip line. The felt sheet is fixed as the substrate on the ground plane, which is made of copper.



(a) (b) (c) (d)

Figure 1(a). Structure 1, **(b).** Structure 2, **(c).** Structure 3, **(d).** Structure 4 (proposed)

A slot in an antenna minimizes the antenna size. When an antenna's size is reduced, its gain improves. The patch and strip lines are made of copper and are then adhered to the foam substrate. The antenna is designed with step-by-step reduction of patch size at an operating frequency of 5.64 GHz as shown in figure 1.

3. Antenna Simulation

The substrate material is altered, and the simulation of the design is performed using the Computer Simulation Technology (CST) Studio suite software [15]. Figure 2 depicts the proposed design in CST software using a Felt substrate.

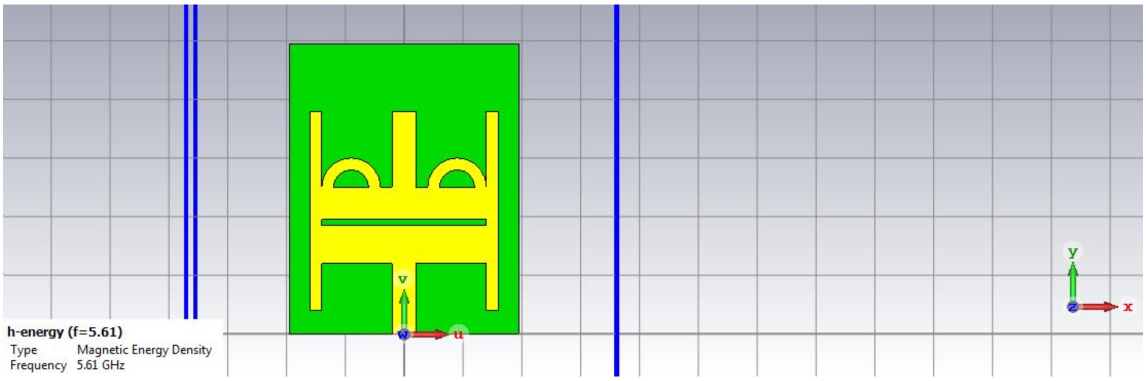


Figure 2. Structure of designed Antenna

3.1 S-Parameter of Simulated Antenna

S-parameters is otherwise known as Return Loss. The S-parameters describe the ports (or terminals) input-output relationship for an electrical system. S11 in antenna is a parameter that is antenna-related and most frequently cited. S11, also known as the reflection coefficient or return loss, measures the actual power an antenna reflects. It is expressed as dB.

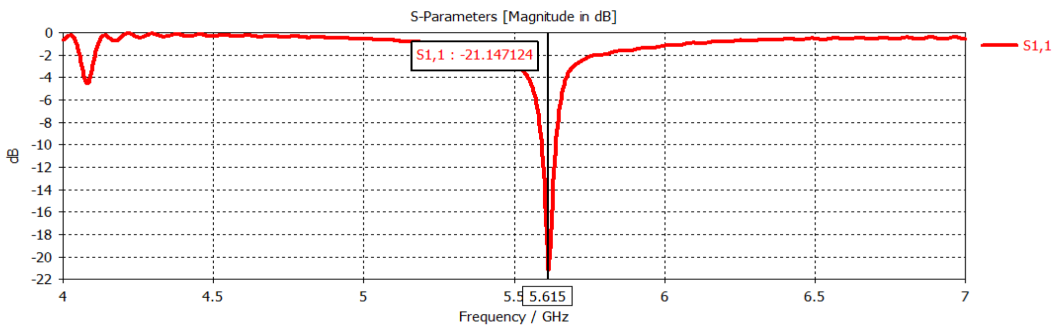


Figure 3. S-Parameter of simulated antenna

The software stimulated antenna's S-parameter results in -21.14 dB in its operating frequency 5.615 GHz as shown in figure 3.

3.2 VSWR of Simulated Antenna

Voltage Standing Wave Ratio is referred to as VSWR. The reflection coefficient, which specifies the power reflected from the antenna, is a function of VSWR. For antennas, the VSWR is always a precise and positive figure. VSWR must be at least 1.0. Figure 4 shows the VSWR is less than 2, as expected. The voltage along a transmission line leading to an antenna is used to calculate VSWR. It measures the difference between the peak and minimum amplitudes of a standing wave.

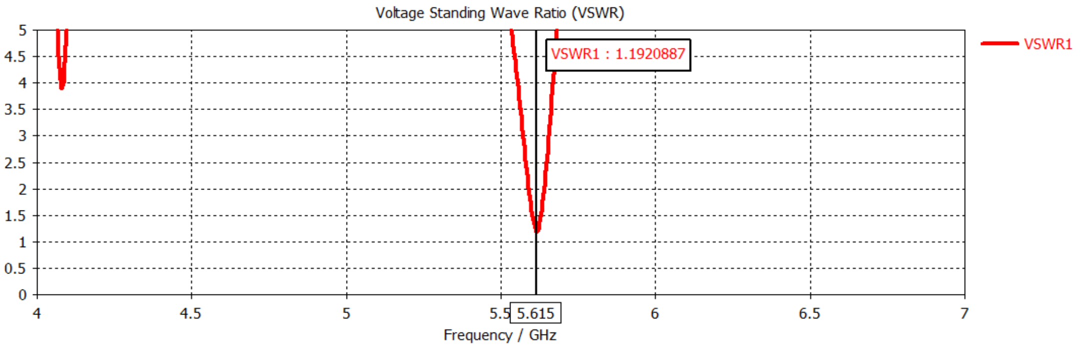


Figure 4. VSWR of simulated antenna

3.3 Gain of Simulated Antenna

Gain is a product of efficiency and directivity. In this case, efficiency takes into account any losses on the antenna, including those caused by manufacturing flaws, surface coating losses, dielectric, resistance, VSWR, or other factors. The gain of the software simulated antenna results in 8.270 dBi as in figure 5.

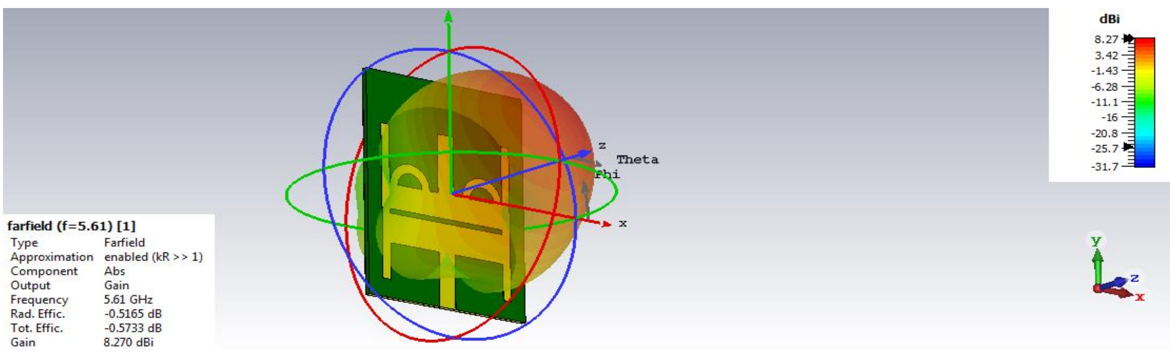


Figure 5. Gain of simulated antenna

3.4 Directivity of Simulated Antenna

The directivity of the software simulated antenna results in 8.78 dBi as shown in figure 6. The concentration of an antenna's radiation pattern in a certain direction is measured by its directivity. In dB, directivity is measured. The more directed or focussed an antenna's beam is, the higher its directivity. The beam will move farther if the directivity is higher.

Figure 7 depicts the antenna's radiation pattern. It's not always advantageous to have an antenna with a high directivity; for instance, many applications, including those involving mobile devices, call for omni-directional antennas, which necessitate low or no directivity antennas. In permanent installations like satellite television, where data must be transmitted and received over greater distances in a specific direction, high-directivity antennas are used.

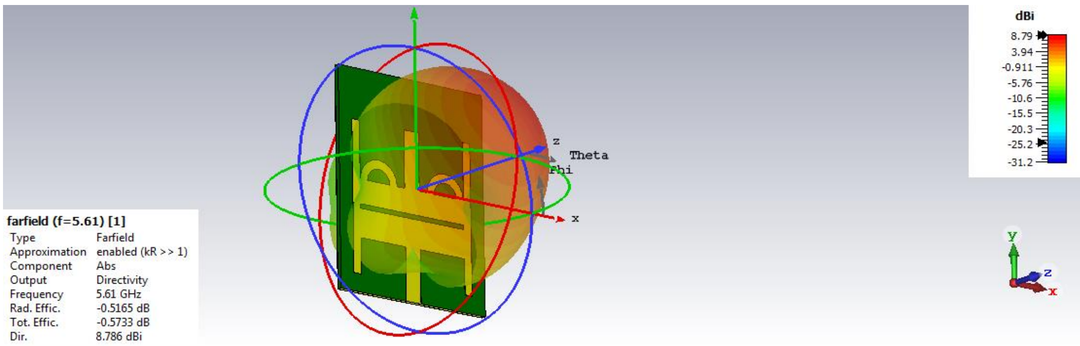


Figure 6. Directivity of simulated Antenna

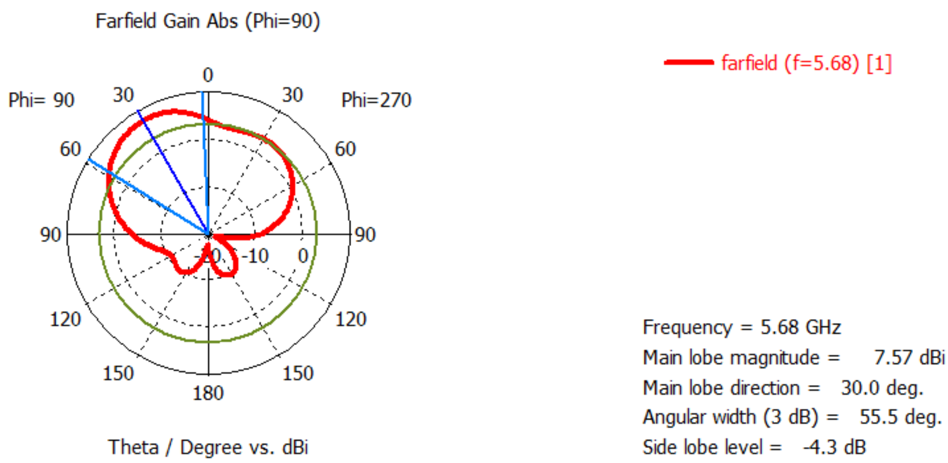


Figure 7. Radiation Pattern of simulated Antenna

4. Results and Discussion

The simulated antenna results for the three structures are compared in Table 2. From this, it is confirmed that the structure 4 antenna has better results. The gain is also enhanced upto 8.270 dBi.

Table 2. Comparison of Simulation results

PARAMETERS	STRUCTURE 1	STRUCTURE 2	STRUCTURE 3	STRUCTURE 4
Return Loss (dB)	-13.2	-24.2	-21.1	**-21.14**
VSWR	1.2	1.3	1.19	**1.19**
Gain(dBi)	2.67	5.56	7.687	**8.270**
Directivity (dBi)	5.34	6.43	8.469	**8.768**
Efficiency (%)	50	86.46	90.76	**94.32**

Even though the return loss value of structure 3 is higher than the structure 2, the other parameters like VSWR, Gain and Directivity have very much betterment that of the structures 1 and 2. The efficiency also improved upto 90.76% when compared to structure 1 and 2 which have 50% and 86.46% respectively.

5. Conclusion

The key approach for using felt as a flexible substrate for WLAN applications is the proposed antenna. Results demonstrate that the novel material is compatible for flexible applications. It is possible to substitute flexible substrate materials for rigid substrate materials because it is weightless, has minimized cost, has extended durability and minimal environmental impact. The outcomes for different parameters, including Return Loss -21.1 dB, VSWR 1.19, Gain 8.270 dBi, and Directivity 8.76 dBi, are shown to be sufficient for WLAN applications. The efficiency of 90.76% attained is acceptable. Additionally, the antenna can be reduced, and the bandwidth can be enhanced for 5G applications.

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