

Design and Improvement of a Modified Patch Antenna of Microstrip with an Integrated Filter and L-Shaped Slot for ISM-Band Applications

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ABSTRACT- The microstrip antennas are often used in the wireless communications due to their size and the ease with which they can be made. Nonetheless, their performance is greatly affected by modifications in engineering and physical properties. So, the simple microstrip antenna was designed in this research and the analysis of the most important variables was conducted. This involves modification of the substrate thickness, feed width, type of insulating material and ground level parameters. The experiment involved the study on its influence on bandwidth, antenna gain, and impedance matching within the 2.4 GHz ISM frequency range. The simulation was done via CST software along with the FR-4 insulating material was 1.6 mm thick. Various configurations were experimented to come up with the most appropriate parameter settings. On the basis of these findings, A novel antenna design is created that encompasses an L-shaped aperture as well as a filter in order to enhance radiation efficiency, undesirable out of band responses as well as enhancement of impedance behavior. It was demonstrated in the simulation that the patch dimensions could be altered to bring about an optimal value of the antenna performance as the frequency of operation was 2.4 GHz resulting in a standing wave voltage ratio (VSWR) of 1.178, a directivity of 6.6 dBi, a bandwidth of 96.3 MHz, a realized gain of 2.484 dBi and a reflection coefficient (S11) of -21.729 dB. Due to these results, the proposed antenna becomes an appropriate choice in the case of the ISM-band, Wi-Fi, and Internet of Things wireless networks.

Keywords: Patch antenna, slots, Filter, ISM, Directivity, Gain.

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1. INTRODUCTION

Communication systems are the pillars of the modern digital infrastructure of the present digital age, to which they offer straightforward connectivity to cloud computing, artificial intelligence, and sensor-driven applications. The rapid shift in the traditional signal transmission models to intelligent and adaptive communication platforms has made antennas an important enabling factor in the wireless communication systems, satellite, radar, and space communication systems [1]. Antennas are used as transducers to convert transmission line directed electrical signals into emitted electromagnetic waves (and the reverse) [2]. Antennas, such as linear, loop, and microstrip patch antennas, as well as omnidirectional and directional radiation patterns, can be categorized according to

their structure, form, and radiation characteristics. Among these types, microstrip patch antennas are considered one of the most significant because of their planar structure, ease of manufacture, and compact size, which make them suitable for contemporary wireless connectivity systems [3]. A solution is provided by microstrip patch antennas, The Microstrip Patch Antenna (MPA) is a kind of antenna with a straightforward, flat electrical structure that is utilized in wireless communication applications. Because of its qualities, it is frequently utilized in electrical devices and printed on the substrate board. This antenna consists of a small metal piece that represents the radiating part of the antenna, *i.e.* the part that transmits and receives electromagnetic waves, it consists of an insulating layer placed under the radiating part, *i.e.* it represents the middle layer, The grounding layer is below the insulating layer and is made of metal foil, and feedline. Typically, conductive materials like copper are used to make the radiating portion; the industry provides a range of dielectric materials. Each dielectric has distinct properties, including different dielectric constants, conduction properties, etc., that affect the fringing waves of the patch antenna and enhance its general properties. For example, FR_4 or Rogers are used to make the insulating layer, and copper is used to make the ground layer. The feed line is also made of copper [4][5]. In this section, an overview of related research is presented. compares its performance using three

substrates: FR4, Rogers RT-Duroid, and Taconic TLP-5. The results show that Taconic TLP-5 provides the best S11 (-44.2 dB) and highest efficiency (94.7%), followed by RT-Duroid (91.2%) and FR4 (34.43%). Gains and directivity are also significantly higher for the low-loss substrates. However [6]. Antoinette S. R. Mhiripiri (2025) investigated the effect of different geometric notches on a rectangular microstrip patch antenna using HFSS. Several notch shapes—triangular, rectangular, hexagonal—and notch placements on two or four corners are evaluated. The results showed that two-corner notches and hexagonal notches provided the most significant performance enhancement. However, adding notches on all four corners caused over-modulation, which degraded S11. The antenna gain remained nearly constant (2.9–3.1 dB), indicating that the notches mainly affected beamwidth and pattern symmetry rather than total radiated power [7]. SAETIAW and colleagues developed a star-shaped microstrip antenna using a 3D-printed PLA substrate combined with copper thin films and a half-elliptical modified ground plane. For use in the 2.45 GHz ISM band, the antenna was suggested as an economical and ecologically friendly substitute for traditional FR4-based designs. Impedance matching was improved by the modified ground plane, whereas a wider operational bandwidth was made possible by the star-shaped radiating patch. The enhanced bandwidth performance of the PLA-based antenna over its FR4 equivalent was validated by both modeling and experimental data. The design produced a bandwidth of 2.0007–3.0823 GHz and a simulated gain of 2.32 dB, in contrast, testing revealed a bandwidth of 2.1741–3.1086 GHz and a gain of 2.13 dB. The change in the resonance frequency of PLA antenna was approximately 1.6%. All these findings indicate that the PLA-based antenna is a viable competitor in the IoT and modern wireless communications incorporation as it has a better bandwidth, similar radiative performance, and significant sustainability and manufacturability advantages [8]. To reach such systems as Wi-Fi and Bluetooth, T. Shrivaya Sree et al. (2024) developed a circular patch antenna made of microstrip in a patch form that operates within the WLAN in 2.45 GHz. Due to its resistance to fire, the antenna was placed on a FR-4 substrate and Ansys HFSS was adopted to test the performance of the antenna. Some of the results are -19.73 dB loss at the return, 4.40 dB gain, 92 percent efficiency and 6.57 dBi directivity [9]. Ramanda Grace Aulia employed the use of simulation, fabrication, and measurement to design a 2.4 GHz patch antenna made of microstrip. The design was fabricated on an FR-4 substrate that was over 1.6 mm in thickness and predicted to achieve traditional values of less than -10 dB return loss and VSWR of 2 or less. There was good agreement between the measured and simulated result. The simulation showed a return loss of -13.38 dB and VSWR of 1.545 and 2.808 dB gain and a bandwidth of 71.4 MHz in the 2.35-2.42 GHz range. The VSWR and loss at return were measured as -12.193dB and 1.6 respectively. In general, the antenna met the required functionalities of the operation, which proved the design by the experiment and simulation tests [10]. There are many research works done on patch antennas on the ISM band which are

microstrip patch antennas where the enhancement of gain and multiband operation as well as bandwidth are enhanced using defective ground structures and slots. Although these techniques have demonstrated improvements in performance, there hasn't been much focus on a comprehensive parametric study of feed-line width, substrate properties, and ground-plane dimensions in conjunction with impedance matching optimization at 2.4 GHz. This research deficit is the driving force behind the current endeavor.

2. ANTENNA DESIGN

Because they significantly affect performance, a few important parameters, including substrate material, thickness, and dielectric constant, must be carefully considered while designing a patch antenna. Using FR4 as the substrate material, which has a permittivity of 4.3 and a thickness of 1.6, this study explores the construction of a novel antenna with a resonant frequency of 2.4. Considering the dielectric qualities and the necessary resonance frequency of the proposed antenna, the patch length and breadth mostly influence the antenna's operating characteristics. The transmission line model is used to assess its size in the following: manner

$$Wp = \frac{c}{2fr} \sqrt{\left(\frac{2}{\epsilon r + 1}\right)} \quad (1)$$

where c is the light speed. We must determine the substrate's effective dielectric constant, which is provided by, in order to determine the patch's length.

$$\epsilon r_{eff} = \frac{\epsilon r + 1}{2} + \frac{\epsilon r - 1}{2} \left[1 + \frac{12h}{W} \right]^{\frac{1}{2}} \quad (2)$$

The following formula can be used to determine the patch's final length:

$$L_{pt} = \frac{c}{2fr\sqrt{\epsilon r_{eff}}} - 2\Delta L \quad (3)$$

where ΔL is the extension of the length of the patch in millimeters and can be determined using formula

$$\frac{\Delta L}{h} = 0.412 \frac{(\epsilon r_{eff} + 0.3) \left(\frac{W}{h} + 0.264\right)}{(\epsilon r_{eff} - 0.258) \left(\frac{W}{h} + 0.8\right)} \quad (4)$$

The width and length of the rectangular patch for the 2.45 GHz frequency can be determined using the calculations above. Based on computations.

Following that, the dimensions of the rectangular microstrip patch, as well as the length and width of the ground plane, may be determined as *eq. (5)* and *eq. (6)*.

$$L_{gr} = 6hs + L_{pt} \quad (5)$$

$$W_{gr} = 6hs + W_{pt} \quad (6)$$

Where: W_{pt} : stands for patch width, L_{pt} : stands for patch length, Fr : stands for resonant frequency,

To begin with, the patch width (W) was determined by using equation (1). The effective dielectric constant was then calculated by using equation (2). The patch length (L) was calculated by means of the equation. This is represented by the ideal rectangular microstrip antenna model in equation (3): Following this, a trial-and-error method was used to adjust the size of the antennas. Lastly, CST was used to optimize the initial dimensions by means of parametric analysis to obtain the desired performance.

3. RESULTS AND DISCUSSION

A 2.4 GHz microstrip patch antenna was designed using CST Suite Studio, and a comparison was made in several cases to choose the perfect design including (change of feed line width, change of ground and substrate dimensions, change of insulation layer thickness, change of insulation material type).

Case 1: In the first case, the feed width was changed with preserving dimensions of antenna fixed, and FR4 insulating material was used at a frequency of 2.4 GHz. The results were as shown in the following table 1 and figure 1.

Table 1. Change width of feed(mm)

Feed width (mm)	Fr (GHZ)	S11 (dB)	VSWR	Z11 (Ω)	G (dBi)	D (dBi)
1.5	2.444	-17.876	1.292	54.37	2.128	5.959
0.75	2.436	-44.093	1.012	93.50	2.191	5.942
0.35	2.432	-18.835	1.258	148.75	2.223	5.931
0.25	2.432	-16.847	1.335	170.11	2.211	5.930
0.05	2.432	-16.905	1.333	228.13	2.213	5.931

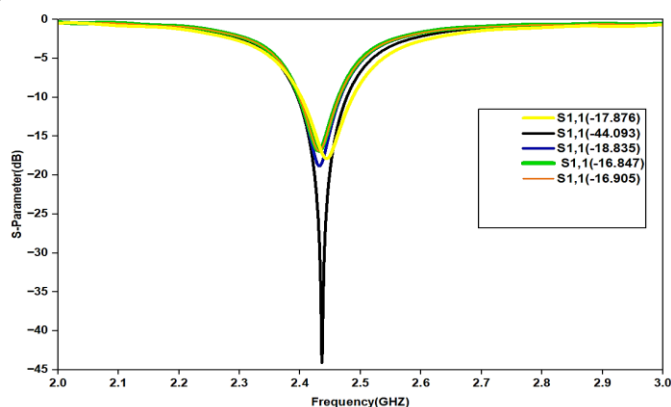


Figure 1. Reflection Coefficient Comparison for Various Feed Line Width

An objective investigation of the relationship between the feed line's width and each of S11, VSWR, Z11, G, and D reveals that altering the feed width has an impact on S11 and Z11 values. This implies that altering the feed line's width is necessary to increase the value of return loss or impedance *i.e.*, it has an inverse relationship with impedance and S11. There is a very minor change in its association with G, D, F, and VSWR, indicating that it has no direct effect on them.

Case 2: In the second case, the thickness of the insulating material was changed while keeping the dimensions constant, and an FR4 insulating material was used at a frequency of 2.4 GHz. The results were as shown in the following table 2 and figure 2:

Table 2. Comparison based on the thickness of Substrate (mm)

Thickness (mm)	Fr (GHZ)	S11 (dB)	VSWR	Z11 (Ω)	G (dBi)	D (dBi)
1	2.4791	-19.0016	1.252	44.59	1.588	6.156
1.6	2.444	-17.876	1.292	54.37	2.128	5.959
2.5	2.4006	-16.552	1.349	63.46	1.790	5.697
3	2.3751	-15.596	1.398	65.44	1.657	5.765

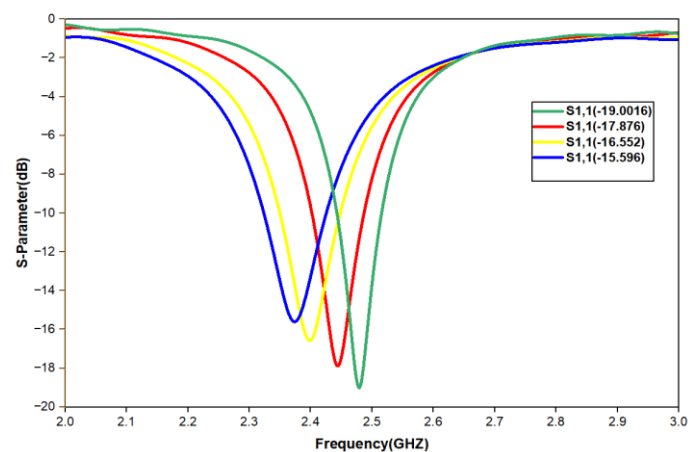


Figure 2. Parametric Analysis of Substrate Thickness on S11 Performance

When conducting an objective study on the relationship between the height of the insulating layer and frequency, S11, VSWR, Z11, gain (G), and directivity (D), we find that thickness has an inverse relationship with frequency; specifically, as the height increases, frequency decrease. As for its relationship with Z11, and VSWR, it is a direct relationship, its relationship with S11 magnitude increases, while its effect on gain and directivity is slight.

Case 3: In the third case, the length and width of the ground layer and the insulating layer were modified. FR4 insulation material, 1.6 mm thick, was used at a frequency of 2.4 GHz. The results are as shown in the following table 3 and figure 3.

Table 3. Comparison based of the dimensions of ground plane

(W, L) (mm)	Fr (GHZ)	S11 (dB)	VSWR	Z11 (Ω)	G (dBi)	D (dBi)
50	2.444	-17.875	1.292	55.37	2.128	5.959
55	2.444	-16.987	1.329	54.06	2.275	6.087
60	2.444	-16.829	1.336	53.78	2.321	6.157
49	2.444	-17.856	1.293	54.32	2.095	5.930

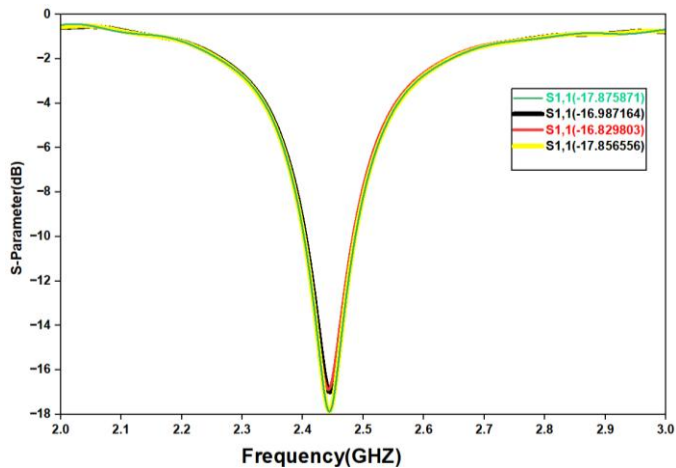


Figure 3. Reflection Coefficient Comparison for Various Ground Plane Width and Length Values

We conclude that differences in the dimensions of the ground plane and the substrate have a slight effect on the performance of the S11, while the resonant frequency remains almost unchanged.

Case 4: In the fourth case, the type of insulating material is changed to have fixed dimensions, a resonant frequency of 2.4 GHz, and a thickness of 1.6 mm. The results were shown as shown in the following *table 4*:

Table 4. Comparative analysis for change in type of material

Type of material	ϵ_r	Fr (GHZ)	S11 (dB)	VSW R	Z11 (Ω)	G (dBi)	D (dBi)
RogersRO30 06 (lossy)	6.5	6.4401	-12.049	1.669	34.752	4.155	6.492
		7.944	-23.864	1.136	53.70	7.664	8.815
		9.207	-17.094	1.326	44.100	6.01	8.126
		5.0451	-18.844	1.257	91.72	6.99	7.494
RogersRT58 80 (lossy)	2.2	6.3	-12.845	1.590	144.026	5.344	5.817
		6.696	-38.255	6.696	94.382	8.142	8.883
		8.616	-16.765	1.339	90.78	6.460	7.049
		2.4566	-18.767	1.260	55.69	2.11	6.021
		3.6481	-16.036	1.374	71.46	-2.07	4.845
		4.568	-27.391	1.089	75.41	-1.601	5.318
FR4(lossy)	4.3	6.28	-41.830	1.061	68.77	-2.78	4.059
		7.288	-17.222	1.319	89.22	5.2	10.69
		7.8362	-12.653	1.607	112.23	0.338	7.306
		8.3598	-25.257	1.115	77.48	0.502	8.235
		9	-16.392	1.357	76.62	1.37	6.407
		6.3784	-16.556	1.349	53.98	6.7	8.520
		7.4	-33.892	1.041	48.66	3.99	7.212

ArlonAD1000	10.2	8.008	-14.165	1.486	32.74	5.61	9.357
		9.6161	-11.028	1.781	57.83	7.195	9.512
		9.824	-22.760	1.156	45.23	1.03	4.974

It finds that when the material type is changed, the frequency changes as well as the values of S11, VSWR, Z11, G, and D, but the dimensions stay the same, suggesting an inverse link between the frequency and the dielectric constant.

Accordingly, the dimensions presented in the following *table 5* were selected for the proposed antenna configuration illustrated in *figure 4*, as it provides the most favorable overall performance. Under these optimized conditions, the antenna achieved a return loss (S11) of -17.876 dB, a voltage standing wave ratio (VSWR) of 1.292, an input impedance (Z11) of 54.37 Ω , a realized gain of 2.128 dBi, and a directivity of 5.959 dBi. An enhanced antenna configuration with an integrated filtering structure and an L-shaped slot was then developed using the findings of this parametric analysis.

Table 5. Design parameters of the designed antenna at 2.4 GHZ

Design parameters of the designed antenna at 2.4 GHZ	
Center frequency, fo	2.45 GHZ
Substrate	FR4
Substrate height, hs	1.6 mm
dielectric constant, ϵ_r	4.3
Thickness of the patch, t	0.027 mm

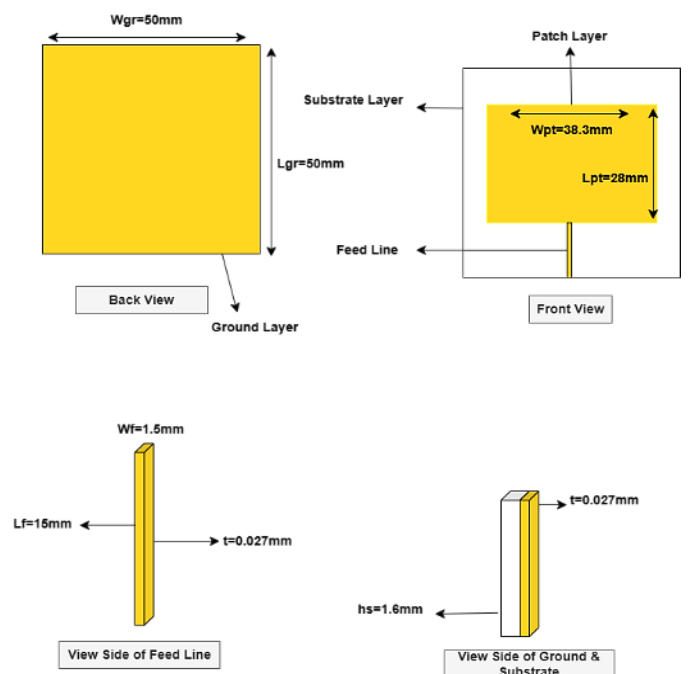


Figure 4. Proposed Antenna

These antennas are famous to be lightweight, not costly to manufacture, easy to customize, and with a simple design. They however also have a limited power handling capability, a small

frequency spectrum, and a fairly small gain amongst other inherent performance constraints. The limitations are overcome by a well-thought L-shaped aperture and a filtering structure, as illustrated in *figure 5*, which are very obvious in the proposed design *figure 4*. This improves frequency band properties of the antenna, decreases unwanted response and overall increase in gain.

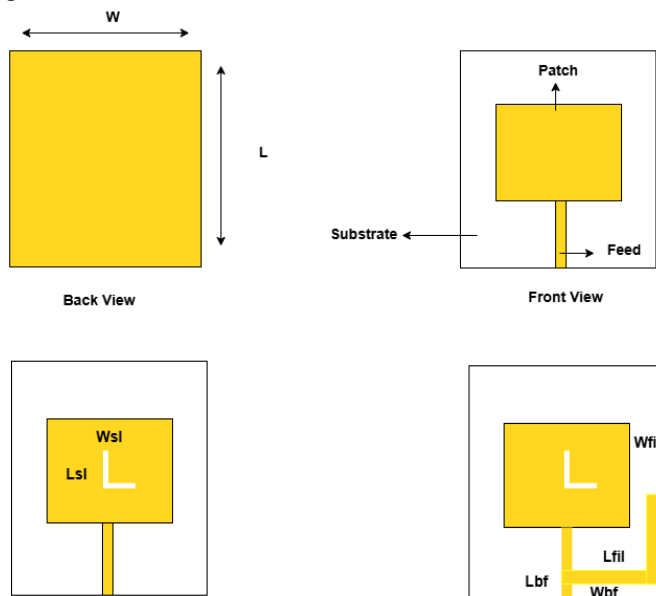


Figure 5. Modified Antenna

The findings will be presented as *figures 6* and *7*. The modification dimensions that were used in *table 6* were used to evaluate the performance of the antenna.

Table 6. Dimensions of the modified antenna for 2.4 GHz

Parameter Symbol	Modification Antenna Dimensions	Value (Unit mm)
Wpt	Width of Patch	38
Lpt	Length of Patch	27.70
Wgr	Width of Ground	60
Lgr	Length of Ground	60
WF	Width of Feed	0.80
LF	Length of Feed	17
H	Thickness of substrate	1.6
T	Thickness of Ground	0.027
Wsl	Width of Slot	1
Lsl	Length of Slot	14.5
Wfil	Width of Filter	2
Lfil	Length of Filter	17
Wbf	Width of Bandpass Filter	22.90
Lbf	Length of Bandpass Filter	2

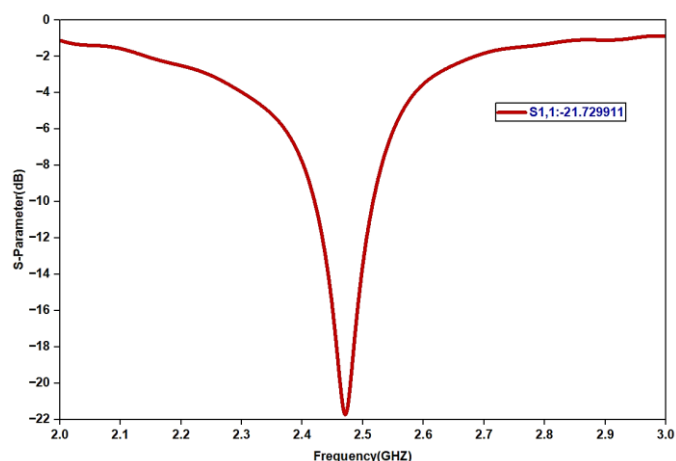


Figure 6. Reflection Coefficient (S11) of the Modified Antenna

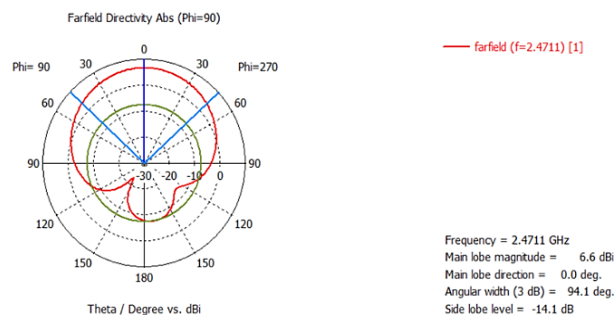


Figure 7. The directivity of the far-field radiation of the modified antenna at 2.4 GHz

According to the observed statistics, the antenna has a voltage standing wave ratio (VSWR) of 1.178 a return loss (S11) of -21.729 dB, an actual gain of 2.484 dBi, an input impedance of 54.82 Ohms, and a directivity of 6.6 dBi on this setup. These results indicate a visible enhancement of the performance of the antenna as in *figure 5*.

The parametric analysis conducted in the given study shows clear evidence that it is evident that the performance of the proposed microstrip patch antenna is highly reliant on some of the critical design parameters, among them, being the width of the feed-line, the substrate thickness, the dielectric constant and the ground-plane dimensions. The results obtained suggest that the proper adjustment of these parameters is extremely important in the realization of optimal impedance matching and radiation properties. To begin with, the width of the feed-line was identified as the most manipulative factor in the impedance matching. Of the feed-line widths that were studied, 1.5 mm was found to be the best, since it provided a reasonable balance between the characteristics of a proper impedance matching with the characteristics of the radiation. At this dimension, an input impedance was close to the ideal value of 50 ohms (54.37 ohms) with the lowest S11 of -17.876 dB and the lowest VSWR standing at 1.292. This supports the fact that a feed width of 1.5 mm is a good way of maintaining constant operation and minimizing the losses due to reflection communication systems. This validates proper design of feed-line is critical to reduction of reflection losses. Secondly, the difference in substrate

thickness indicated an inverse dependence of substrate height and resonant frequency. Thickening of the substrate resulted in a decreasing shift in operating frequency and a minor matching deterioration of impedance. A trade-off between frequency stability and radiation performance was thus chosen as 1.6 mm to give an optimal thickness. Thirdly, the change of ground plane and substrate dimensions had a significant small effect on resonant frequency, but a small effect on impedance matching and gain. This suggests light variations in the size of ground plane do not pose a serious problem to the workings of the antenna as long as the patch is kept the same size. In addition, the resonant frequency and radiation characteristics were largely affected by the change in dielectric material. Lower dielectric constant materials were better radiation efficiency and gain but high permittivity materials were smaller in radius at the cost of bandwidth and impedance. This proves the close negative correlation between dielectric constant and operating frequency. On the basis of these observations a reference design was chosen which was further optimized with addition of L-shaped slot and filtering structure. This modification resulted in observable changes in impedance matching, bandwidth selectivity as well as radiation efficiency. This last antenna design resulted in a return loss of -21.729 dB, VSWR of 1.178, gain of 2.484 dBi and directivity of 6.6 dBi which is a clear improvement to the conventional design. All in all, the findings indicate that the systematic parametrical optimization and structural adaptation are effective in crafting high-performance microstrip antennas used in the ISM band. The design offered achieves a compromise between small size, matching impedance and radiation properties, thus suitability to real-world wireless communication systems.

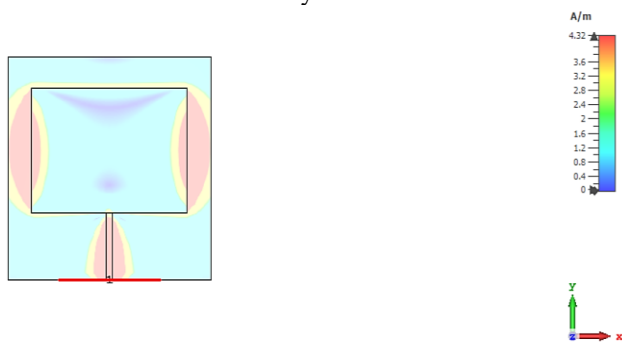
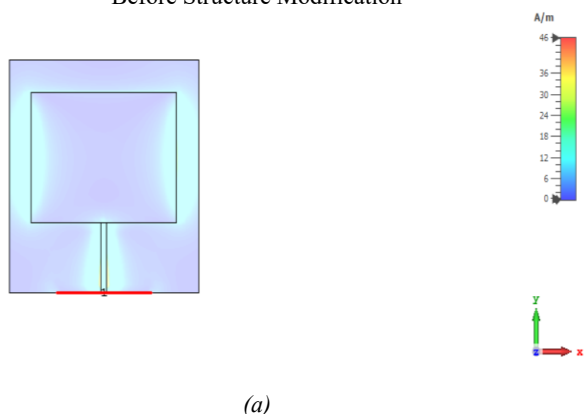
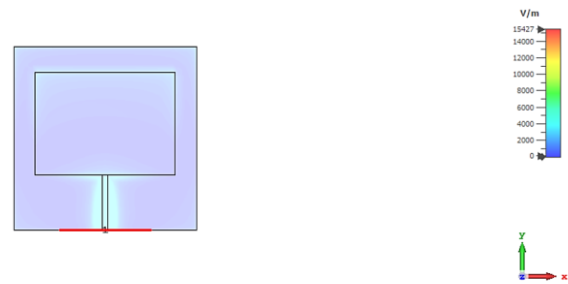


Figure 8. Surface Current Distribution of the Conventional Antenna Before Structure Modification



(a)



(b)

Figure 9. Magnetic and Electric Field Intensity Distributions of the Conventional Patch Antenna Prior to Structural Reconfiguration: (a) Magnetic Field (H-field); (b) Electric Field (E-field)

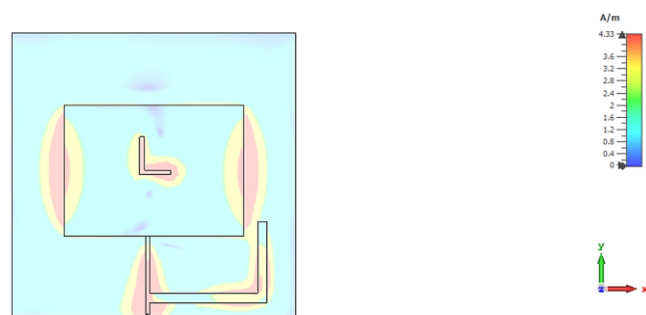


Figure 10. Surface Current Redistribution of the Modified Patch Antenna with a Built-in Integrated Filter and L-shaped slot

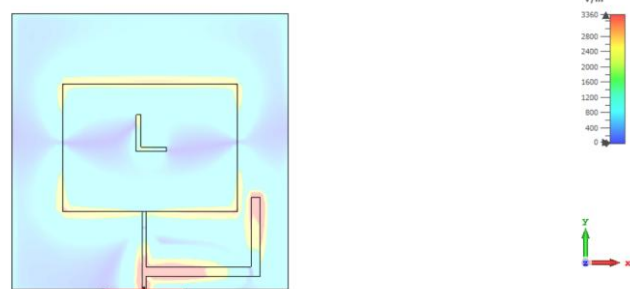
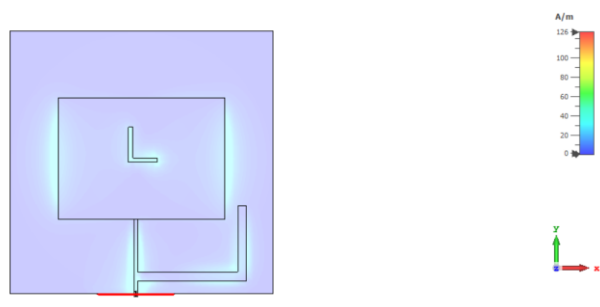


Figure 11. Distribution of Magnetic and Electric Field Intensity in the Proposed Modified Patch Antenna that Show electromagnetic reconfiguration: (a) H-field Distribution; (b) E-field Distribution

An electromagnetic study in comparison between the traditional and modified design shows that it possesses an apparent structural-field interaction process, which leads to the performance improvement observed. In the traditional design, the current distribution on the surface is classical TM₀, i.e. the feed current directly flows to the radiating edges without

secondary current loops. This is due to the fact that the electric and magnetic fields are symmetrically distributed, which implies the lack of confinement of energy and the presence of resonance behaviour that is dependent on the dimensions only. On the contrary, the suggested altered structure adds a different redistribution of surface current over the integrated filtering route and L-shaped slot. The current does not assume a straight course but curves throughout long conductive paths which in effect adds length to the electrical dimensions but not the physical one. The result of such redistribution is a change in the electric and magnetic field circulation, which allows better storage of electromagnetic energy and the controlled interaction of the radiating structure. Inductively, the built in filter is an inductive reactive loading element but the L-slot is a disturber of the field symmetry leading to increased impedance transition and reduced reflection. This mechanism is the direct cause of the numerical improvements of the return loss, stability of impedance gain, and directivity. The reduced values of S_{11} and the better radiation properties in the results section can be attributed to the increased field confinement and current reconfiguration. Hence, the novelty of the suggested antenna is not a geometrical adjustment only, but a deliberate electromagnetic redesigning made by structural integration. The design is set to work as a radiating object and an internal filter of its own in an attempt to redefine the internal current flow and field interactions without having to make the antenna larger. This is a diagnostic dual-purpose electromagnetic restructuring which sets the proposed work apart the traditional microstrip patch antennas found in literature. The proposed antenna presents an L-shaped microstrip resonant stub in the feeding network making it a compact filtering antenna design. This is in contrast to traditional designs where an external filter is cascaded to the antenna, the filtering capability in the proposed design is inherently incorporated into the geometry of the antenna. This built in configuration does not require added filtering circuit and minimizes system complexity, insertion loss and size. To allow a structure that is more effective as a frequency-selective filtering element, the implemented structure is designed to be more of a resonator as opposed to a traditional low-pass filter. Electrically, the L-shaped open-ended stub is similar to a parallel resonant circuit coupled to the 50-ohm feed line. The reactive components that are introduced by the stub at the required frequency (2.471 GHz) cancel the input reactance to yield better impedance matching and minimum return loss of -21.7 dB. The resonant structure generates the high input impedance factor of the frequencies not within the operating band, hushpuppies the undesired frequency bands and enhances frequency selectivity. This unified filtering system improves performance and is small in size and structure.

4. COMPATOR WITH RELATED WORK

The standard and modified antenna performance is related to the current researches in regard to the operational frequency, size, gain, directivity, and the application. According to the results, the modified antenna has better impedance matching, radiation properties and compactness in comparison with the traditional one. Moreover, the suggested antenna is competitive

in terms of performance with Wi-Fi and IoT systems because the design is competitive with the existing ones.

Table 7. Comparison of the Proposed Antenna with the Related works in terms of performance

Ref.	Fr (GHz)	Size (mm)	D (dBi)	Ga (dBi)	Applications
[11]	2.4	28.00×21.00	–	2.09	4G and IoT
[12]	2.4–2.48	10 × 10	–	-17.3	Brain implant
[13]	2.45	58×92	5.483	3.019 (dB)	Radio Frequency Identification Application (RFID)
[14]	2.4 – 2.5	36.00×46.00	5.18	3.18 (dB)	WLAN
[15]	2.45	29 × 20	–	1.75	IoT devices, short-range communication systems, and wireless sensor networks.
[16]	2.45–5.8	33x25 (mm ²)	–	2.30–4.45 (dB)	RFID
This Work	2.4	50x50	5.959	2.128	Wi-Fi,biomedical, and IoT systems
Modified Work	2.4	60x60	6.6	2.484	Wi-Fi,biomedical, and IoT systems

5. CONCLUSION

In this research, the design, optimization, and performance improvement of a 2.4 GHz rectangular patch antenna made of microstrip on a rectangular patch were introduced and done in the ISM-band. The influences of feed-line width, substrate thickness, dielectric material, and ground-plane size on the antenna performance were thoroughly realized in terms of a systematic study of the parameters. The optimized traditional scheme with FR-4 substrate reached a qualifying outcome with a return loss of -17.876 dB, VSWR of 1.292, input impedance 54.37 ohms, gain 2.128 dBi, and directivity 5.959 dBi. Then a modified antenna plan consisting of a built-in filtering element and an L-shaped slot was generated on the basis of the results to have a better result on impedance matching and radiations. The optimized design had better performance with a return loss value of -21.729 dB, VSWR of 1.178, input impedance of 54.82, gain of 2.484 dBi and directivity of 6.6 dBi. These findings support the notion that the suggested structural changes are useful in quenching undesirable responses as well as enhance the overall performance of the microstrip antennas in ISM-band systems through systematic parametric optimization and structural enhancement. The suggested antenna has a stable working process, a small size, and enhanced radiation properties, it can be used in practice in Wi-Fi, Internet of Things (IoT), and other short-range wireless communication systems. Experimental fabrication and validation of measurement will be done in the future, and the proposed method of design will be

extended to multiband and reconfigurable antenna structure in case of new wireless technologies. This paper has shown that by combining a filtering structure and an L-shaped slot, it offers a viable and easy way to simultaneously enhance both impedance matching and radiation properties but without the need to increase the size of the antenna.

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