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Design and Implementation of a Wideband Antenna for Simultaneous Receiving and Transmitting Signal with an Improved Isolation

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Abstract:

This paper proposes a dual-layer, microstrip patch antenna for simultaneous sending and receiving in the telecommunications industry. In this design, the harmonic suppression method is used. The proposed antenna has two ports with improved isolation and combines several telecommunication elements, including filters, duplexers, and radiators, into a single device, which reduces size, weight, and cost. The proposed antenna is designed, fabricated, and measured at C-band to verify and design methodology. The measurement results agree with the simulation results, which represent a complete two-way antenna in the frequency bands of (4.56-5) GHz (9.2%) and (6.25-7.39) GHz (16.8%) with an isolation of over 33 dB. The proposed antenna gain for the first and second bands is 5.6 dBi and 6.3 dBi, and the 3-dB beamwidths in two frequencies (f = 4.8 GHz and f = 6.8 GHz) are 83° and 85°, and the cross-polarization levels are −22 and −23 dB in the E- and H-planes, respectively. The antenna exhibits pure linear polarization with minimal cross-polarization levels observed in both E- and H-planes.

Keywords:

Microstrip Patch Antenna, Send And Receive Simultaneously, C-Band, Wideband Antenna, Satellite Communication.

1. Introduction

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Wireless communication systems, particularly mobile communications and Intelligent Transportation Systems (ITS) have experienced quick growth over the past decades. In telecommunication stations, where the uplink and downlink channels utilize two separate frequency bands, a duplexer is often used to share an antenna between the transmitter and receiver, as shown in Figure 1 [1, 2]. The use of duplexers in ITS is another application of this principle [1]. In duplexers, there should be high isolation between the ports, where the transmitter and receiver are jointed, to prevent harm to the receiver module [1, 2]. For the past several years, scholars have been trying to complement telecommunication elements such as filters, duplexers, and radiators into a single system, and several instances of this are reviewed here. In [2], the authors introduce a novel strategy for designing a compact and integrated planar duplex antenna aimed at enhancing the efficiency of wireless communication systems. The primary objective is to reduce antenna size while ensuring high integration, proper isolation, and stable radiation characteristics across dual frequency bands. To achieve this, the design merges a resonator-based duplexer with a dual-band patch antenna. The duplexer utilizes split-ring resonators as frequency-selective filters, connected via a dual-mode stub-loaded resonator acting as the central node. The antenna section is formed by coupling a radiating patch to a hairpin resonator through a slot in the ground plane, maintaining consistent radiation in both bands. These two components are then directly integrated by connecting the hairpin resonator to the duplexer's central junction, which removes the need for external matching networks. This direct coupling not only simplifies the structure but also contributes to a more compact and efficient RF front end, offering better performance than traditional cascaded designs. In [1], the authors introduce a compact dual-band full-duplex antenna system developed for vehicular communication and Intelligent Transportation System (ITS) applications. The core idea is to support simultaneous transmission and reception on two separate frequency bands using a single antenna with two well-isolated ports. This approach not only enables full-duplex operation but also addresses the need for high data rates and limited space in modern vehicles. To enhance efficiency, the proposed design integrates several RF functions—such as filtering, duplexing, and radiation—into one compact unit. This integration helps eliminate the need for separate components like

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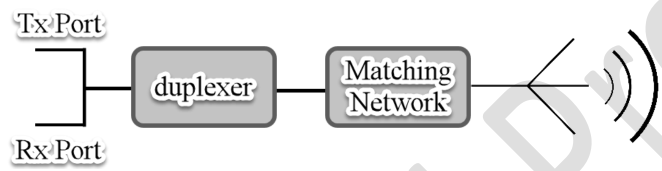
external filters and duplexers, resulting in a simplified RF front-end with reduced size, cost, and complexity. The design also improves signal isolation between transmission and reception paths, which is a critical requirement for maintaining reliable communication in dynamic automotive environments. In [3], the authors propose a new concept of integrating filtering and diplexing functions directly into the antenna design to enable efficient dual-band operation. The main idea is to embed the filtering mechanism



(a)

(b)

Fig. 1. Block diagrams of (a) separated subsystem and (b) integrated subsystem.

within the antenna structure itself, which ensures consistent radiation patterns and low cross-polarization levels across both frequency bands. This approach reduces the need for separate filtering components, leading to a more compact and simplified system. The antenna design includes a slot-loaded patch coupled with two resonators sharing a common ground, where dog-bone-shaped slots create broadside magnetic coupling to improve isolation between bands. The design is based on second-order Chebyshev bandpass filter synthesis, providing an effective solution for dual-band wireless applications requiring high performance and minimal interference. In [4], the authors propose a broadband filtering duplex patch

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antenna designed to provide high isolation between transmit and receive channels. The main idea is to integrate filtering functions directly into the antenna's feeding structure, which consists of a single radiating patch coupled with two resonator-based filtering networks. This design leverages multi-mode resonators to achieve wideband operation, while using separate resonator sets to enhance isolation between the two frequency channels. Embedding filtering and duplexing within the antenna simplifies the system by removing the need for additional external components, resulting in a compact and efficient solution ideal for modern wireless communication systems that require both broad bandwidth and strong signal isolation. In [5], the authors propose a novel planar self-diplexing antenna based on Substrate Integrated Waveguide (SIW) technology, featuring a cavity-backed bow-tie slot design. The main idea is to integrate diplexing and radiation functions into a single compact antenna element, which eliminates the need for external diplexers and simplifies the system architecture. The antenna is fed by two separate lines, enabling dual-band operation within the X-band with high isolation between ports, exceeding 25 dB. This is achieved through careful optimization of the antenna dimensions and analysis of cavity modes using half-mode theory. The proposed design offers an efficient and space-saving solution suitable for applications where minimizing size and complexity is crucial. This paper is organized as follows. Section 2 presents the geometry and operating basis design. Section 3 presents the final designed antenna and the corresponding results, followed by the conclusions in Section 4.

2. Geometry And Operating Basis

The proposed two-layer microstrip patch antenna with bandwidth increase is shown in Figure 2. The antenna is composed of two rectangular patches and four λ/4 resonators in the feeding line section. The two λ/4 resonators share a shorting pin with a radius of *Dx(i)*. The dimensions of the patches are *L(i)*×*W(i)* and those of each λ/4 resonators are *G(i)*×*T(i)*. All of them can be fabricated on a two-layer substrate with a thickness of h = 1.6 mm and a relative permittivity of ε_r = 2.2. The dimensions of the antenna patches embedded in the bottom of the antenna are the same as *L(i)*×*W(i)*. The diameter of the pins embedded in the second substrate is *Dy(i)*. The radius of the apertures created on the ground plane are *Rx(i)*×*Ry(i)*. It is

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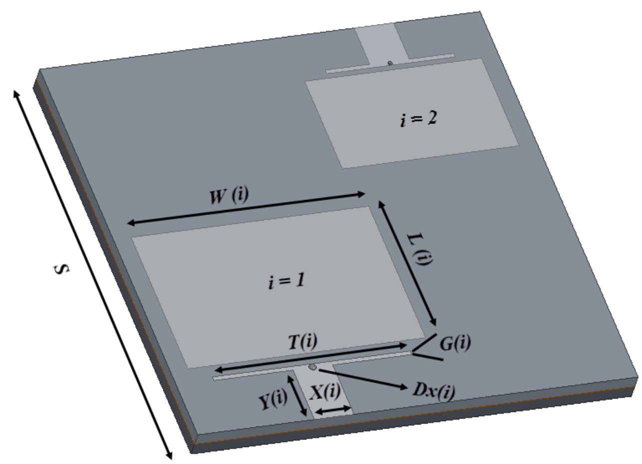
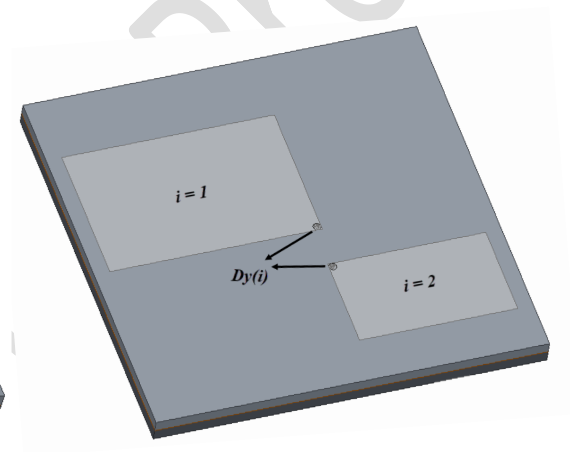
worth noting that the patch installed on the bottom of the antenna is in the same position as the patch on the top of the antenna, and the apertures created on the ground plane are in the same center as the patch on the top of the antenna. The designed antenna executes in two frequencies (f_1 = 4.78 GHz, f_2 = 6.82 GHz). For this cause, two harmonic suppressor antennas are used to achieve simultaneous transmitting and receiving by an antenna without a separate diplexer. The proposed antenna in this article is based on the relationships and the proposed antenna in [6]. In this reference, the basis and action of the harmonic suppressor antenna used in this article are explained. In order to increase the bandwidth of microstrip antennas, the Q factor must be reduced. This factor is related to the resistance, inductor, and capacitor elements.



(a)



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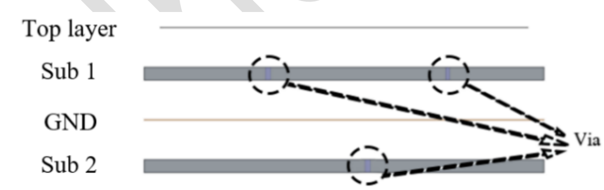

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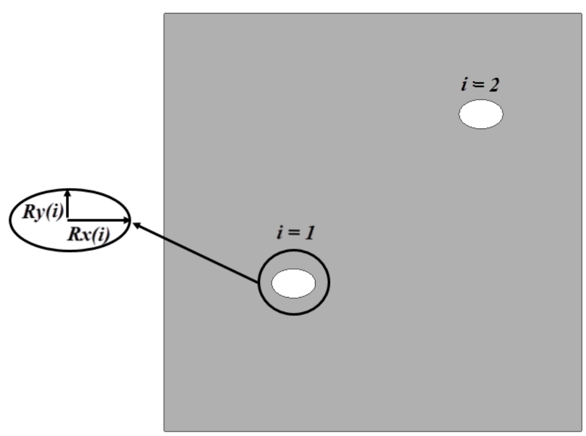

(d)

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Fig. 2. Configuration of the proposed antenna: (a) top view (-Z), (b) bottom view (+Z), (c) side view, and (d) ground view (-Z).

Therefore, based on the circuit model mentioned in Figure 3, by optimizing the dimensions of the apertures, a fit bandwidth can be achieved. Also, to prevent the formation of back lobes, the patches installed on the bottom of the antenna are connected to the ground plane via some pins. Table 1 shows the parameter values.

Table 1. Dimensions of the Proposed Antenna

Parameter	*W (1)*	*W (2)*	*L (1)*	*L (2)*	*X (1)*	*X (2)*	*Y (1)*	*Y (2)*	*T (1)*
Value (mm)	27	20.1	18	12	4.5	4.5	6.75	4.95	22.5
Parameter	*T (2)*	*G (1)*	*G (2)*	*Dx (1)*	*Dx (2)*	*S*	*H*	*Dy (1)*	*Dy (2)*
Value (mm)	14.6	.5	.5	.8	.5	50	1.57	1	1
Parameter	*Rx (1)*	*Rx (2)*	*Ry (1)*	*Ry (2)*					
Value (mm)	2.625	2.625	1.75	1.75					

3. Design, Simulation, and Validation

Figure 3 shows the equivalent circuit model of the proposed antenna. As shown in Figure 3, the proposed electrical circuit has several categories, each of which is tantamount to a section of the proposed antenna. Herein, the shorting pin is represented by a reactance, whose value can be calculated by the relation mentioned in [6]. Each λ/4 resonator, is represented by a lossless resonator, whose values can be calculated from [7]. Small splits between the paired λ/4 resonators and the radiating patch, and between the two radiation patches are represented by a π-type network.

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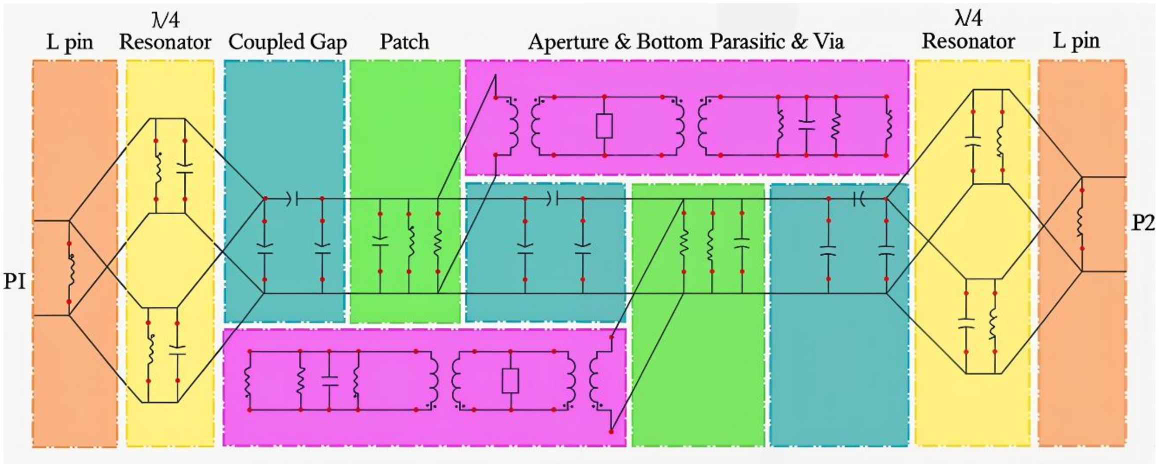


Fig. 3. Equivalent circuit model of the proposed antenna in Figure 2.

The split spacing has been reached by optimizing, and the capacitor values can be calculated from [7]. The rectangular patch is offered by a lossy resonator of RLC, whose values can be calculated by the transmission-line relations. The aperture created on the ground plane is modeled by two transformers and an admittance, the values of which can be obtained from [7]. The proposed antenna is simulated in HFSS and compared with the fabrication results shown in Figure 4. As shown in Figure 4, the measurement results verify the simulation results. The proposed wideband antenna for simultaneous receiving and transmitting signal, was fabricated and shown in Figure 5. The impedance bandwidths for the first and second bands are respectively equal to (4.56 - 5) GHz (9.2%) and (6.25 - 7.39) GHz (16.8%). The gain values for the first and second bands are 5.6 dBi and 6.3 dBi, respectively. The radiation patterns of the proposed antenna are measured too. The simulated and measured results in the $\varphi = 0°$ and $\varphi = 90°$ planes are plotted in Figure 6. The 3-dB beamwidths of the proposed antenna in two frequencies (f = 4.8 GHz and f = 6.8 GHz) are 83° and 85°, respectively. It can be seen that the same radiation characteristics at two operational bands are achieved. The antenna shows a very high polarization sincerity, and the measurements show that the cross-polarizations are less than -22 dB at 4.78 GHz, and less than 23 dB at 6.82 GHz in both E-planes and H-planes, this indicates a pure linear polarization in both frequency bands. Figure 7 (a)-(b) and Figure 7 (c)-(d) show the simulated current distribution and electric field distribution on the patch when the antenna works at 4.78 GHz (Port 1 is excited) and 6.82 GHz (Port 2 is excited), respectively, as shown in Figure7(a), when Port 1 is excited at 4.78 GHz, the pair of λ/4 resonators of the channel-1 have powerful currents, whereas current distribution on the pair of λ/4 resonators of the channel-2 are inactive, also, Figure 7(b), when Port 2 is excited at 6.82 GHz, the pair of λ/4 resonators of the channel-2 have powerful currents,

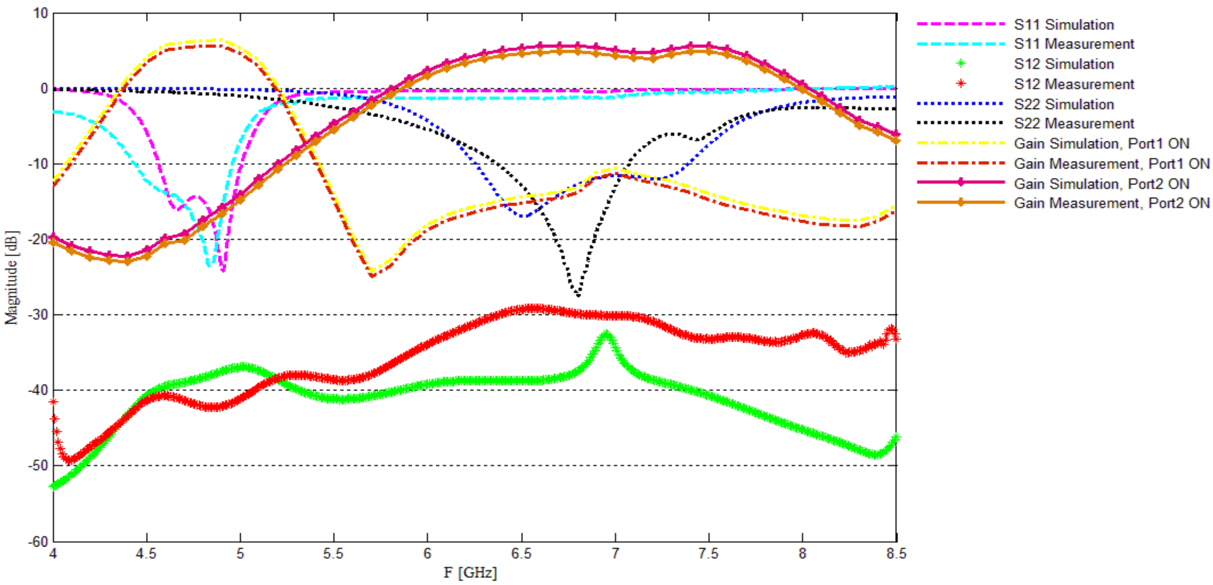
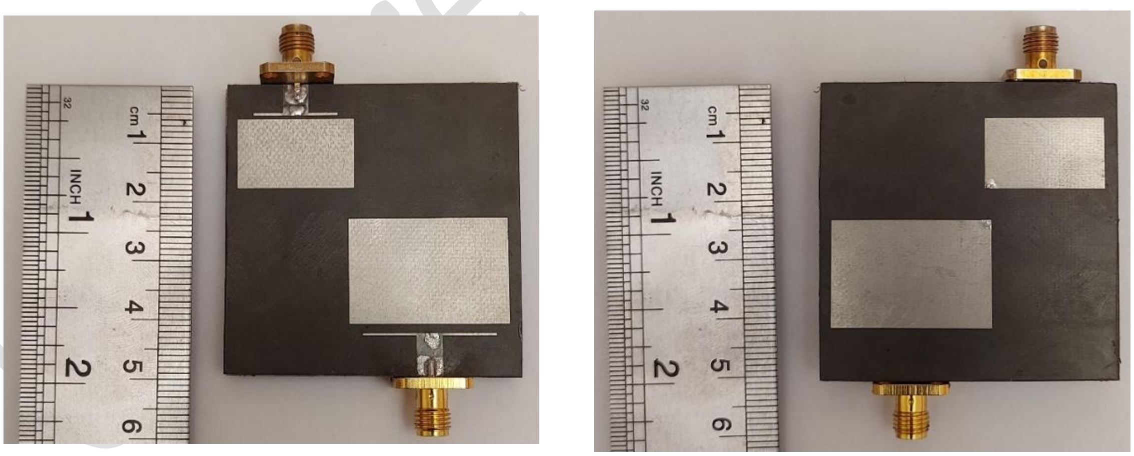


Fig. 4. Simulated and measured S-parameters and gains of the proposed antenna.



(a) (b)

Fig. 5. Fabricated antenna: (a) top-view, (b) bottom-view.

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whereas current distribution on the pair of λ/4 resonators of the channel-1 are inactive. Based on the Figure 7 (c)-(d), two patch antennas are both operating at TM10 mode.

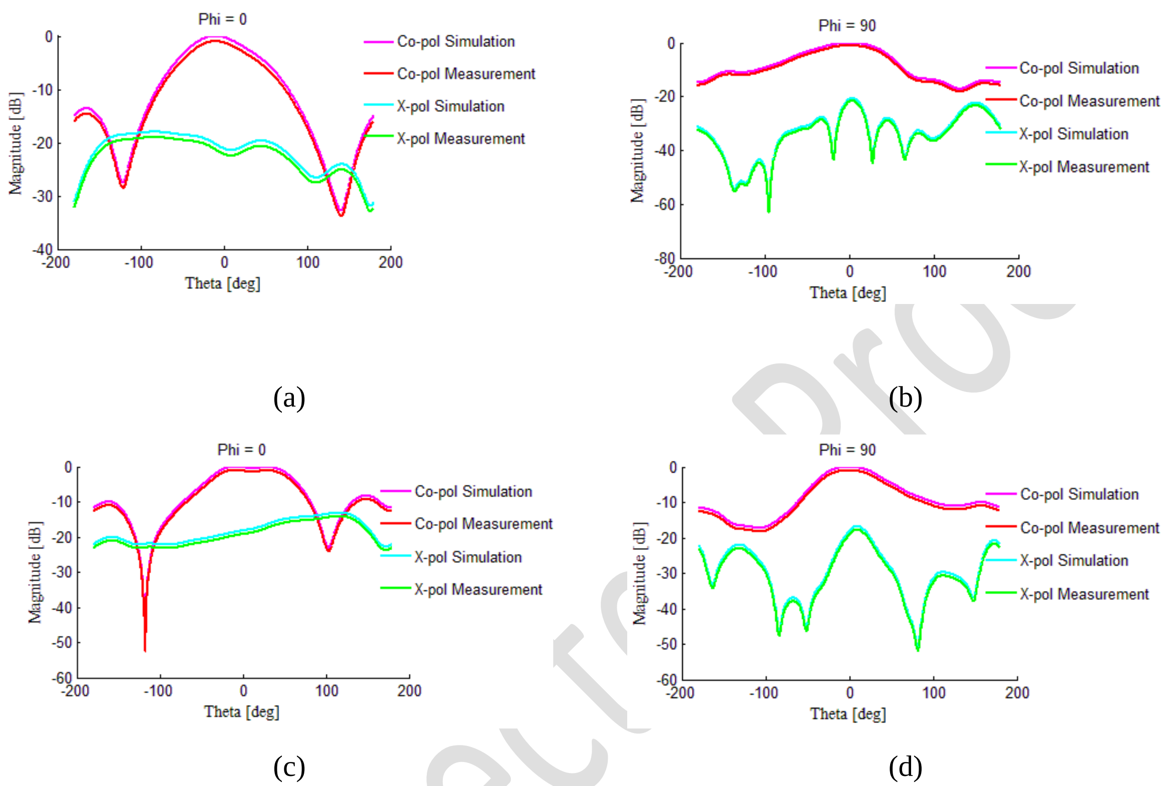

Fig. 6. Radiation patterns of the proposed antenna. (a) and (b) f = 4.8 GHz, φ = 0° and φ = 90°. (c) and (d) f = 6.8 GHz , φ = 0° and φ = 90°.

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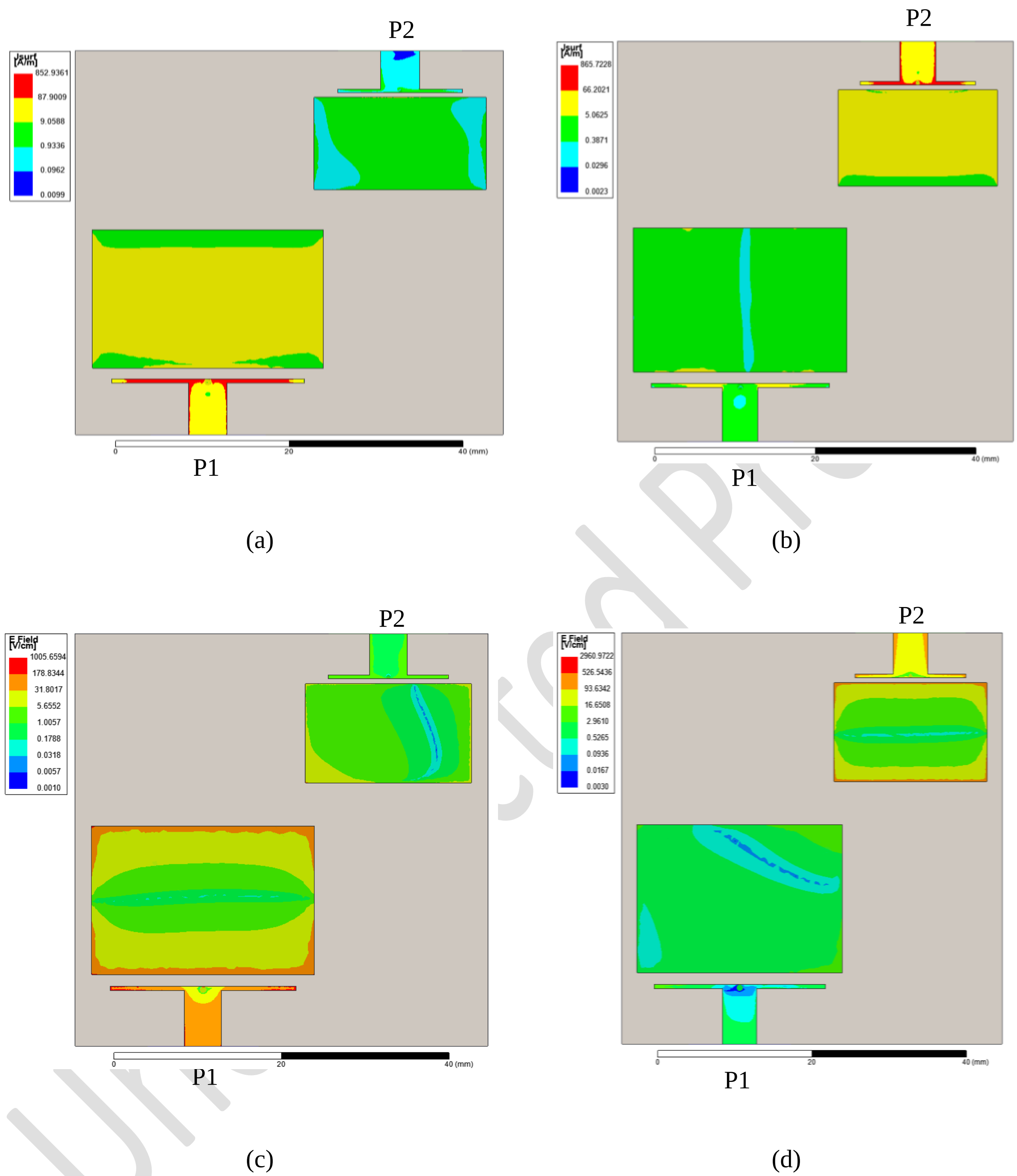

Fig. 7. Simulated Current Distribution and Electric Field Distribution on the patch: (a) and (c) Port 1 is excited @ 4.78 GHz, (b) and (d) Port 2 is excited @ 6.82 GHz.

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The efficiency of the proposed antenna is compared with that of other antennas (Table 2). Features of the proposed antenna include broad impedance bandwidth, high isolation between ports, and high gain.

Table 2. Comparison of efficiency of the proposed antenna with some previous works

Ref.	f1, f2 (GHz)	Isolation (dB)	Bandwirth (%)	Gain (dBi)
[1]	4.7, 6	32, 30	5.1, 5.4	6.7, 8
[2]	2.58, 2.87	32, 42	5, 4.2	5, 4.5
[3]	2.45, 5.25	>21	4.5, 5.5	2.3, 3.6
[4]	2.06, 2.6	>45	10.6, 6.9	5.4, 4.2
[5]	9, 11.2	>25	-	4.3,4.2
[8]	4.47, 5.7	24, 35	4.7, 7.3	6, 8
[9]	1.8, 2.045	>20	8, 12	7, 7.2
[10]	9.5, 10.5	>29	1.32, 1.46	5.75, 5.95
[11]	7.47, 8.12	>27	7.3, 6.7	14.5, 15
[12]	4.36, 4.83	23, 25	3.2, 3.9	4.56, 5.18
This Work	4.8, 6.8	>33	9.2, 16.8	5.6, 6.3

4. Conclusion

In this paper, a dual-layer patch antenna fed with a microstrip for simultaneous sending and receiving in the telecommunications industry has been proposed. In the offered model, the transmitter and receiver antennas have been combined, and the separate diplexer and filter have been removed. In such a design, the volume and cost of Tx/Rx modules have been reduced. In this article, the concept, design method, and basis of antenna action were offered in detail. The measured results verified the design concepts, representation the high efficiency in terms of bandwidths, fit isolation, harmonics suppression and radiation

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characteristics. Simulation results confirm that the linear polarization remains pure, with low levels of cross-polarization maintained across both the E- and H-planes.

5. References

[1] C.-X. Mao, S. Gao, Y. Wang, Dual-Band Full-Duplex Tx/Rx Antennas for Vehicular Communications, IEEE Transactions on Vehicular Technology, 67(5) (2018) 4059-4070.

[2] C.-X. Mao, S. Gao, Y. Wang, F. Qin, Q.-X. Chu, Compact Highly Integrated Planar Duplex Antenna for Wireless Communications, IEEE Transactions on Microwave Theory and Techniques, 64(7) (2016) 2006-2013.

[3] Y.-J. Lee, J.-H. Tarng, S.-J. Chung, A Filtering Diplexing Antenna for Dual-Band Operation With Similar Radiation Patterns and Low Cross-Polarization Levels, IEEE Antennas and Wireless Propagation Letters, 16 (2017) 58-61.

[4] X.-J. Lin, Z.-M. Xie, P.-S. Zhang, Y. Zhang, A Broadband Filtering Duplex Patch Antenna With High Isolation, IEEE Antennas and Wireless Propagation Letters, 16 (2017) 1937-1940.

[5] S. Mukherjee, A. Biswas, Design of Self-Diplexing Substrate Integrated Waveguide Cavity-Backed Slot Antenna, IEEE Antennas and Wireless Propagation Letters, 15 (2016) 1775-1778.

[6] J.-D. Zhang, L. Zhu, Q.-S. Wu, N.-W. Liu, W. Wu, A Compact Microstrip-Fed Patch Antenna With Enhanced Bandwidth and Harmonic Suppression, IEEE Transactions on Antennas and Propagation, 64(12) (2016) 5030-5037.

[7] D.M. Pozar, Microwave Engineering, Wiley (John Wiley & Sons), 1997.

[8] J.-F. Li, D.-L. Wu, G. Zhang, Y.-J. Wu, C.-X. Mao, A Left/Right-Handed Dual Circularly-Polarized Antenna With Duplexing and Filtering Performance, IEEE Access, 7 (2019) 35431-35437.

10.22060/EEJ.2025.23986.5644

[9] J.-F. Li, D.-L. Wu, G. Zhang, Y.-J. Wu, C.-X. Mao, Compact Dual-Polarized Antenna for Dual-Band Full-Duplex Base Station Applications, IEEE Access, 7 (2019) 72761-72769.

[10] A.A. Khan, M.K. Mandal, Compact Self-Diplexing Antenna Using Dual-Mode SIW Square Cavity, IEEE Antennas and Wireless Propagation Letters, 18(2) (2019) 343-347.

[11] C.-X. Mao, Z.H. Jiang, D.H. Werner, S.S. Gao, W. Hong, Compact Self-Diplexing Dual-Band Dual-Sense Circularly Polarized Array Antenna With Closely Spaced Operating Frequencies, IEEE Transactions on Antennas and Propagation, 67(7) (2019) 4617-4625.

[12] K.-Z. Hu, M.-C. Tang, Y. Wang, D. Li, M. Li, Compact, Vertically Integrated Duplex Filtenna With Common Feeding and Radiating SIW Cavities, IEEE Transactions on Antennas and Propagation, 69(1) (2021) 502-507.