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Design of Multiband Patch Antenna for WLAN Applications

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ABSTRACT

This article proposes a compact slot-loaded multiband rectangular-shaped microstrip patch antenna. The proposed antenna of overall dimensions 30 × 30 × 1.56 mm3 radiates at 3.3 GHz, 5.8 GHz, 7.2 GHz, and 9.01 GHz to accommodate WiMAX and WLAN wireless applications. The antenna is mounted on Rogers AD255C substrate with the relative permittivity $\mathcal{E}r$=2.5 and loss tangent tanδ < 0.002. The simulation results of return loss, gain, and bandwidth are examined for the proposed antenna. The proposed simple and low-profile antenna offers simulated return loss of -19.40 dB, -12.76 dB, -27.57 dB, -31.62 dB, VSWR of 1.7, 1.2, 1.1, 1.4, and Gain of 5.25 dBi, 7.17 dBi, 5.09 dBi 6.06 dBi at resonant frequencies.

Keywords: Multiband; Patch Antenna; Rectangular patch; Slot

1. Introduction

In the evolutionary era, the network plays a significant role worldwide for effective communication. Rapid variations within the devices must be checked to identify whether the new network is compatible. Thus, the necessity of designing an antenna working in the wireless communication range needs to be acknowledged [1, 2]. With the rapid development of present-day communication technologies, the utilization of microstrip antennas has expanded because of their low cost, low weight, and small size. The demand for dual-band or multiband antennas is apparent in modern, convenient wireless communication devices [3, 4]. Numerous dielectric substrates are used to design microstrip antennas, and their dielectric constants are usually 2.2 ≤ $\mathcal{E}r$ ≤ 12. The most desirable stage for good antenna performance is thick substrates with low dielectric constant

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because they provide better efficiency and larger bandwidth. Further, the microstrip patch antenna is used in various applications such as wireless

communication systems, GPS, cell phones, aircraft, radar, and satellite communications [5]. The allocated global mobile broadband services range in 3.3 GHz/5.8 GHz/7.2 GHz and 9.01 GHz bands for future or WLAN communications [6,7].

This paper proposes a multiband rectangular slot antenna with a radiating slot loaded with a horizontal and vertical stub and a strip connected to the upper edge of the patch.

The proposed antenna is designed for the WiMAX/WLAN band (3.3 GHz, 5.8 GHz, 7.2 GHz, and 9.01 GHz). This printed slot multiband antenna can be a good candidate due to its easy fabrication, cost-effectiveness, and low-profile benefits. The proposed configuration uses a standard simulation environment in CST Studio Suite 2020. The proposed antenna geometry and results are discussed in this paper. The proposed antenna is mounted on Rogers AD255C substrate, which provides a better gain than FR4 material due to the low relative permittivity and low loss tangent [8–10].

Microstrip slot antennas were invented in 1938 by Alan Blumlein [11, 12]. A slot radiator or slot antenna is used in the frequency range from 300MHz to 25GHz. The slot behaves as a radiator according to Babinet's principle. The microstrip slot antenna is simple in structure. Using different slots, we can improve the bandwidth, gain, return loss, Axial ratio, radiation pattern, and efficiency compared to conventional microstrip patch antenna [11, 12].

2. Materials and Methods

The proposed antenna is designed based on slot antenna methodology. The input impedance of the antenna is controlled by varying the feedline width (W). However, diminishing the input impedance to 50 Ohms frequently requires a wide patch antenna, which takes up a part of the necessary space, and the width of the antenna further controls the radiation pattern [13]. The height (h) of the substrate helps to maintain the bandwidth. It is noted that the substrate height is much smaller than the wavelength of operation but should be at most 0.025 of a wavelength (1/40th of a wavelength), or the antenna efficiency will be debased. Furthermore, the permittivity of the substrate controls the fringing areas, with lower permittivity and more extensive fringes that result in superior radiation.

Within the transmission line model, the radiating slots are accepted to be separated by half-wavelength. The fringing electric field amplifies up to a length of L on both sides along the patch size given in Eq. (2.1) [14–16].

$$\triangle L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.8)}. \tag{2.1}$$

The effective dielectric constant is given by Eq. (2.2)

$$\varepsilon_{reff} = \frac{\varepsilon_\gamma+1}{2}+\frac{\varepsilon_\gamma-1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}}. \tag{2.2}$$

The effective length of the patch is given by Eq. (2.3)

$$L_{eff} = L+2\triangle L, \tag{2.3}$$

where

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}}. \tag{2.4}$$

In step 1 of Fig. 1, the antenna dimensions length of a patch (L), the width of the patch (W), and the width of the feed line (fw) for the standard rectangular patch are first calculated using Eqs. (2.1)-(2.4), which offers resonance at 5.8 GHz and 7.6 GHz. In step 2, a horizontal slot is introduced on the right side of the patch, which provides resonance at 3.3 GHz, 5.8 GHz, 7.02 GHz, and 9.01 GHz. Additional modifications are required because this design does not obtain the desired bandwidth. In step 3, two vertical slots are introduced on the left side of the patch to improve the bandwidth, directivity, and gain. The antenna performance parameters are simulated in CST Studio Suite 2020.

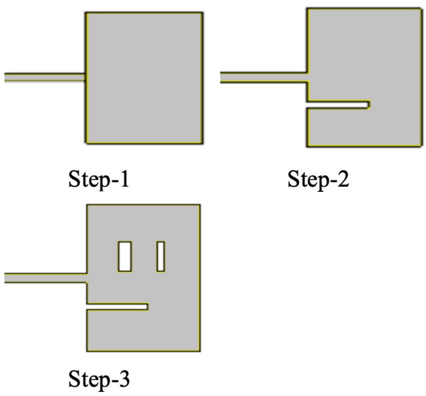

Fig. 1. Stepwise design of the proposed antenna.

2.1 Antenna configuration

The proposed antenna configuration is shown in Fig. 2. This antenna is mounted on Rogers AD255C dielectric substrate material having $\mathcal{E}r = 2.5$ and a thickness of 1.56 mm. The detailed dimensions of the antenna geometry are given in Table 1. Fig. 3 depicts the proposed fabricated antenna's top and bottom views.

3. Results and Discussion

The proposed multiband antenna operates at 3.3 GHz, 5.8 GHz, 7.2 GHz, and 9.01 GHz. The simulated results of return loss, VSWR, BW, HPBW, Gain, and Directivity are mentioned in Table 2. The simulated return loss at resonating frequencies is -12.65 dB, -20.56 dB, -33.22 dB & -14.19 dB, respectively, as shown in Fig. 4, measured return loss at resonating fre-

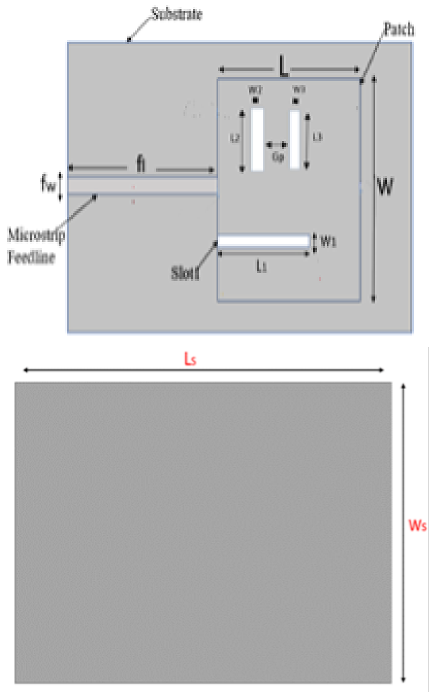

Fig. 2. Top view and bottom view of the proposed antenna.

Table 1. Dimension of proposed Microstrip Multiband Antenna.

Parameter	Dimension (in mm.)
L	23.00
W	14.50
F_L	12.00
F_W	01.40
L_1	07.81
W_1	01.00
L_2	04.70
W_2	01.50
L_S	30.00
W_S	30.00
h	01.56
$Ground$	0.035
Gp	03.30

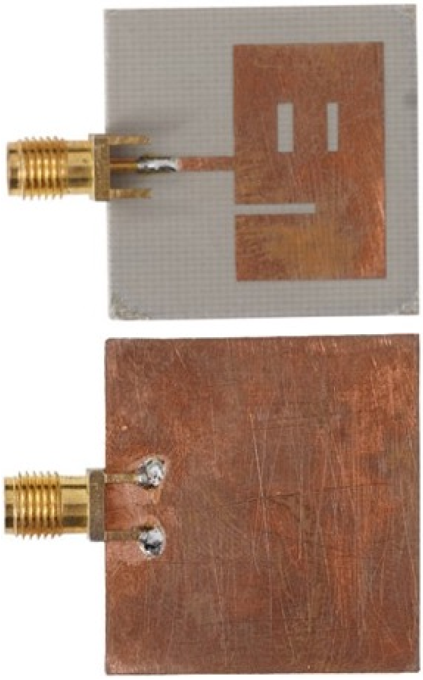

Fig. 3. Top view and bottom view of Proposed Antenna-Fabricated.

quencies 3.3 GHz, 5.9 GHz, 7.2 GHz and 9.03 GHz is -19.40 dB, -12.76 dB, -27.57 dB -31.62 dB, respectively. It can be observed that the simulated and measured results display a good agreement. The differences between the measured and simulated results are probably due to the fabrication tolerance, substrate losses, and measurement circumstances. The simulated VSWR are 1.7, 1.2, 1.1 & 1.4.

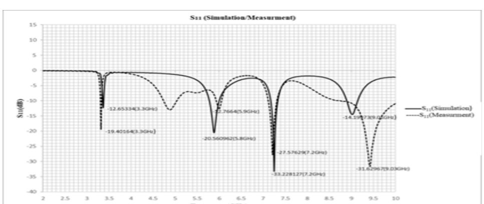

Fig. 4. Simulated and measured the Reflection Co-efficient of the proposed antenna.

Fig. 5 represents the radiation pattern at 3.3 GHz, 5.8 GHz, 7.2 GHz, and 9.01 GHz, respectively, which shows that the antenna radiated in broadside and is linearly polarized. The proposed antenna offers gain of 5.25 dBi, 7.17 dBi, 5.09 dBi, and 6.06 dBi at 3.3 GHz, 5.8 GHz, 7.2 GHz, and 9.01 GHz, respectively.

The simulated result of % BW, VSWR, HPBW, Gain, and Directivity is shown in Table 2. The comparison of the proposed antenna with the reported antenna designs in terms of patch size, operating frequency, the substrate used, feeding technique, slot technique, and gain (dBi) is shown in Table 3. The patch size of Lp of the reference antenna [17–25] is better than the proposed design, but their design structure is too complicated.

The patch size of Lw of the reference antenna [26] is better than the proposed design, but the gain of the reference antenna is less than that of the proposed antenna. From the comparison, it can be observed that the proposed antenna is a good contender for the WiMAX and WLAN wireless applications. The proposed multiband antenna offers a simple and low-complexity design. It also offers reasonable gain for the desired application.

4. Conclusion

This article proposes a rectangular slot-loaded compact microstrip antenna for WiMAX and WLAN band applications.

This antenna slot technique has been carried out to achieve multiband frequency operation at 3.3 GHz, 5.8 GHz,7.02 GHz, and 9.01 GHz. The proposed antenna has a patch dimension of 23 mm × 14.50 mm × 1.56 mm. It offers a return loss of -12.65dB, -20.56 dB, -33.22 dB, and -14.19 dB and gain of 5.25 dBi, 7.17 dBi, 5.09 dBi, and 6.06 dBi at a desired frequency, respectively.

The designed antenna was fabricated,

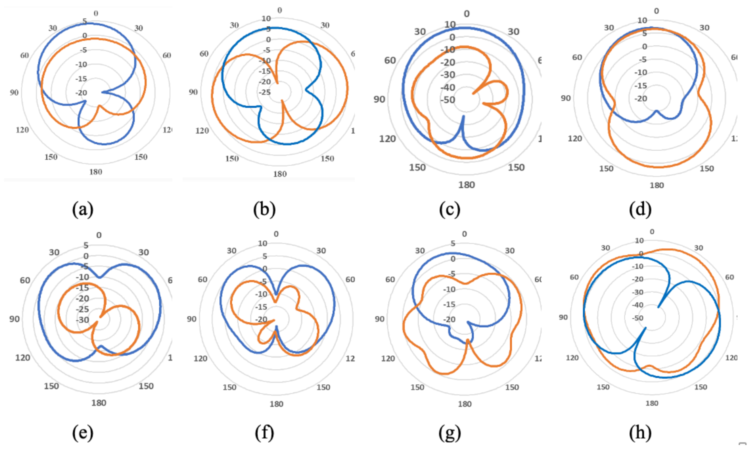

Fig. 5. Simulated far-field radiation patterns - Co-polarization (Blue Color) & Cross polarization (Orange Color) at (a) 3.3 GHz-E-plane (b) 3.3 GHz H-plane (c) 5.8 GHz E-plane (d) 5.8 GHz H-plane (e) 7.2 GHz E-plane (g) 7.2 GHz H-plane (g) 9.01 GHz E-plane (h) 9.01 GHz H-plane.

Table 2. Simulated Results.

Freq. (GHz)	S11 (dB)	VSWR	%BW	HPBW	Gain (dBi)	Directivity (dBi)
3.3	-12.65	1.7	6	95.6°	5.25	5.41
5.8	-20.56	1.2	36	77.7°	7.17	7.56
7.2	-33.22	1.1	63	64.2°	5.09	5.51
9.01	-14.19	1.4	81	57.2°	6.06	6.44

Table 3. Comparison of the proposed antenna with reported antennas.

Ref.	Patch Size (mm3)	Frequency/Band (GHz)	Substrate	Feed Technique	Slot Technique	Gain (dBi)
[26]	30 × 39.40 × 6	3.50-3.60/ 4.88-5.23/ 6.47-6.70	FR4	Co-axial feed	C-shape	6.8
[17]	16 × 20 × 1.5	3/ 5.3/8	FR4	Microstrip -feed	T-shaped and U-shaped	-
[18]	6 × 18.5 × 1.5	2.23-4.63/ 7.38-7.88/ 9.25-9.46	FR4	Microstrip-feed	SRR loaded half	2.8/ 3.5/3.0
[27]	26 × 30 × 1.6	3.3-3.6/ 3.8-4.2/ 5.1-5.8	FR4	Microstrip-feed	C-shape slot-CSRR	3.75/4.50/ 7.50
[19]	15.75 × 25.5 × 1.5	2.4/5.19/5.9	Roger RO 3003	Microstrip-feed	E-shape	8.18
[20]	19 × 25 × 1.6	2.0-2.76/ 3.04-4.0/ 5.2-6.0	FR4	Microstrip-feed	F-shape	1.50/1.70/ 3.05
[21]	16 × 16 × 1.6	3.8-4.2/ 5.1-5.8/ 7.3(3.1-10.6)	FR4	CPW-feed	L-shape & U-shape	6-7
[22]	15.37 × 19.64 × 1.0	5.8/ 6.2/8.4	PET	Microstrip-feed	S-shape	6.23/4.62/ 5.43
[23]	14 × 14 × 1.6	2.33(2.05-3.48)/ 5.10/ 7.11(4.72-7.39)	FR4	CPW-feed	I-shape fractal	0.225/3.030/2.850
[24]	18 × 11 × 0.5	4/7/ 11 (2.39-13.78)	Rogers 4350	Microstrip-feed	L-shape and I-shape	4.0-8.5
[25]	15.37 × 19.64 × 0.9	5.73/ 6.16/8.34	IJ-220PET	Microstrip-feed	L-shape	6.23/4.62/ 5.43
This Work	23.00 × 14.50 × 1.5	3.3/ 5.8/ 7.2/9.01	Rogers AD255C	Microstrip-feed	-	5.25/7.17/ 5.09/6.06

and measurements were carried out in an anechoic chamber.

The proposed simple, low-profile multiband antenna offers good radiation characteristics over desired wireless applications.

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