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BANDWIDTH ENHANCEMENT OF MICROSTRIP LINE AND CPW-FED ASYMMETRICAL SLOT ANTENNAS

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Abstract—In this paper, a bandwidth enhancement technique of asymmetrical slot antenna with two different excitation methods is presented. One method of excitation is the microstrip line feed, and the other is the coplanar waveguide feed. The rectangular slot excited by microstrip line feed gives an impedance bandwidth of 14.76% ($|S_{11}| < -10\,\text{dB}$). When the rectangular slot is excited by a coplanar waveguide (CPW), it gives an impedance bandwidth of 26.61%. Both impedance and radiation characteristics of these antennas are studied.

1. INTRODUCTION

In antenna design, the desirable factors are higher bandwidth, small size, fabrication simplicity, low cost, and ability to integrate with monolithic microwave integrated circuits. Intensive research has been carried out to develop the bandwidth enhancement technique by keeping the size of the antenna as small as possible. A broadband microstrip antenna is very useful in the commercial applications such as wireless local area network (WLAN), and Bluetooth personal network. Therefore, various designs have been proposed to improve their bandwidth including different shapes of patch [1, 2], stacked patch [3, 4] and shorted patch antenna [5]. Recently several interesting designs of the slot antenna with different geometric configurations for the bandwidth enhancement and the size reduction have been widely studied [6, 7]. Several papers have been published on various key design configurations for broadband operation. Recently, wideband slot antennas [8–15] have received much attention in wireless communication system, owing to their attractive merits, such as low

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profile, low cost, easy fabrication, and wide impedance bandwidth. In these type of antenna design, different configurations are introduced for bandwidth enhancement, such as H-slot [8], T-slot [9], E-slot [10], wide rectangular slot with U shaped tuning stub [11], open L-slot [12], wide slot [13], multi-via holes [14], rectangular stub to the circular radiating Patch [15]. When the antenna is fed by a microstrip line, misalignment can result because etching is required on both sides of the dielectric substrate but there is no alignment error in CPW-fed slot antenna as the slot and the feed is on the same plane. In antenna design the main challenge is to develop techniques to increase the bandwidth without significantly increasing their size. This can be accomplished by increasing the number of resonances of single resonant antenna such as a half-wavelength slot.

In this paper, we investigate CPW and microstrip fed asymmetric rectangular slot antennas to obtain broad impedance bandwidth along with stability of the radiation patterns. Dual resonance nature is observed in the asymmetric slot antenna and these resonances can be merged to achieve a higher bandwidth. The rectangular slot excited by microstrip line feed and CPW fed gives an impedance bandwidth of 14.76% and 26.61% respectively. The effect of the asymmetry on radiation patterns is also shown in this paper. The paper is organized into two main sections. The first section is concerned with the slot antenna excited by microstrip line and the second section is on the CPW fed structures.

2. MICROSTRIP LINE FED SLOT ANTENNA

2.1. Design

Figure 1(a) shows the geometry of the proposed microstrip fed slot antenna. The antenna is excited by a $50\,\Omega$ microstrip line. A dielectric substrate of $\varepsilon_r = 4.4$ and thickness $h = 1.6\,\text{mm}$ is used.

The width and the length of the $50\,\Omega$ microstrip line is $W_{strip} = 3.08\,\text{mm}$ and $L_{\mu strip} = L + W_{slot} + L_m = 52\,\text{mm}$ respectively. The slot dimensions are $L_{slot1} = 17.2\,\text{mm}$, $L_{slot2} = 15.2\,\text{mm}$, $W_{slot} = 1.2\,\text{mm}$ and gap between the slots $g = 0.6\,\text{mm}$. The dimension of the dielectric substrate is $90\,\text{mm} \times 90\,\text{mm}$. Detail dimensions are shown in Table 1.

Table 1. Dimensions (in mm) for microstrip fed asymmetric slot.

W_{GND}	L_{GND}	W_{slot}	L_{slot1}	L_{slot2}	g	L	L_m	h
90	90	1.2	17.2	15.2	0.6	44.4	6.4	1.6

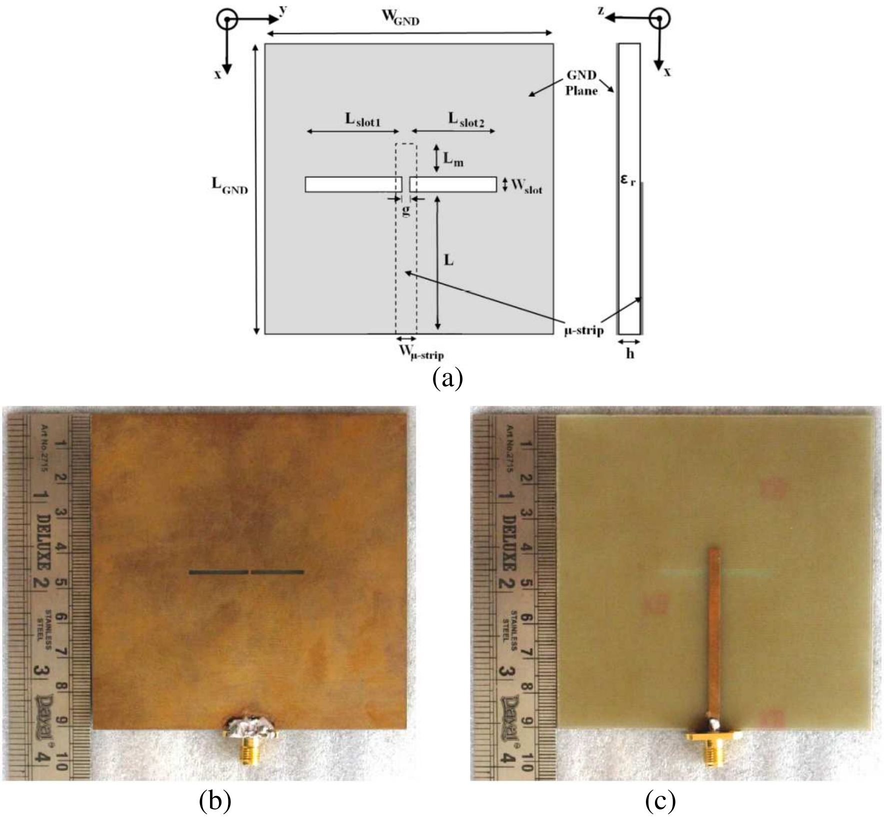


Figure 1. Microstrip line fed asymmetric slot antenna (a) Geometry of the proposed structure, (b) & (c) fabricated antenna, top and bottom view respectively.

The fabricated antenna, top and bottom view is shown in Figures 1(b) & (c).

2.2. Results

The antenna was simulated using Ansoft High-frequency structure simulator (HFSS) software [16] and the reflection coefficients (S_{11}) of the antenna are measured using a calibrated vector network analyzer (N5230A) Simulated and measured input return losses are shown and compared in Figure 2.

The microstrip fed asymmetric slots generate dual resonance nature. The length ratio of the asymmetric slots, microstrip stub

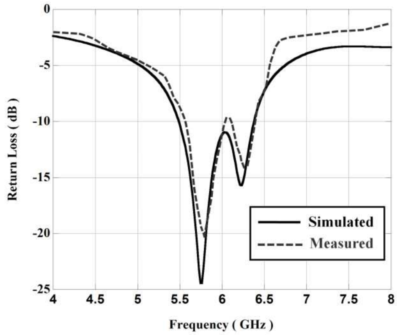


Figure 2. Simulated and measured return loss variation of microstrip fed asymmetric slot.

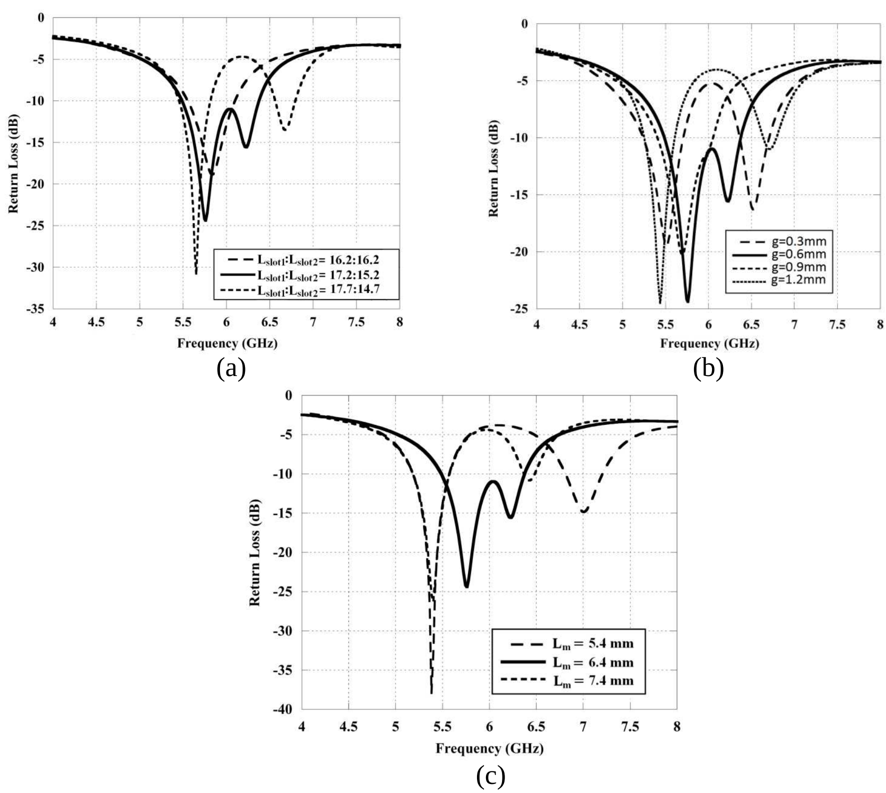


Figure 3. (a) Simulated return loss variation with length ratio of slots. (b) Simulated return loss variation with gap (g) between the slots. (c) Simulated return loss variation with length of the microstrip line stub (L_m).

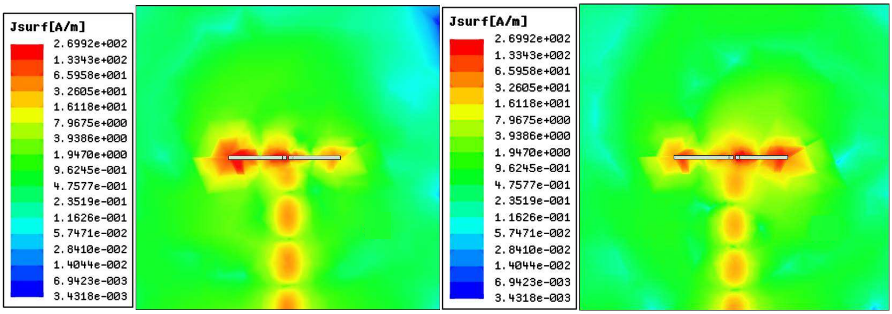


Figure 4. Simulated current distributions for microstrip line fed asymmetric slot at (a) 5.76 and (b) 6.23 GHz respectively.

length and gap distance between the two slots, are the parameters that affect the existence and location of the resonances. From proper parametric variation it is seen that the two resonances can merge thus results in a larger bandwidth. From Figure 3, it is seen that highest bandwidth can be achieved for slot length ratio 17.2 : 15.2, gap between the slots 0.6 mm and length of the microstrip line stub $L_m = 6.4$ mm. By observing the influence of various parameters on the performance of antenna, it was found that the dominant factor in the proposed antenna design for broadband application is the slot length ratio. Surface current distribution is shown in Figure 4. Induced current density is larger in the proposed antenna than the symmetric slot radiator.

The radiation patterns of the antenna was measured in the anechoic chamber at two different frequencies 5.76 GHz and 6.21 GHz. Figure 5 shows the E-plane and H-plane radiation patterns with co and cross-polarizations. Since the slots are asymmetrical, its electric field distribution is anti-symmetric with respect to the center of the antenna. It can radiate rather efficiently but little distort the overall radiation pattern. It can also be seen from Table 3 that at higher frequency antenna gain is quite high.

3. CPW FED SLOT ANTENNA

3.1. Design

In this section, it is investigated that the similar technique could be used to increase the bandwidth of a planar slot using different feed technique. The proposed antenna structure shown in Figure 6.

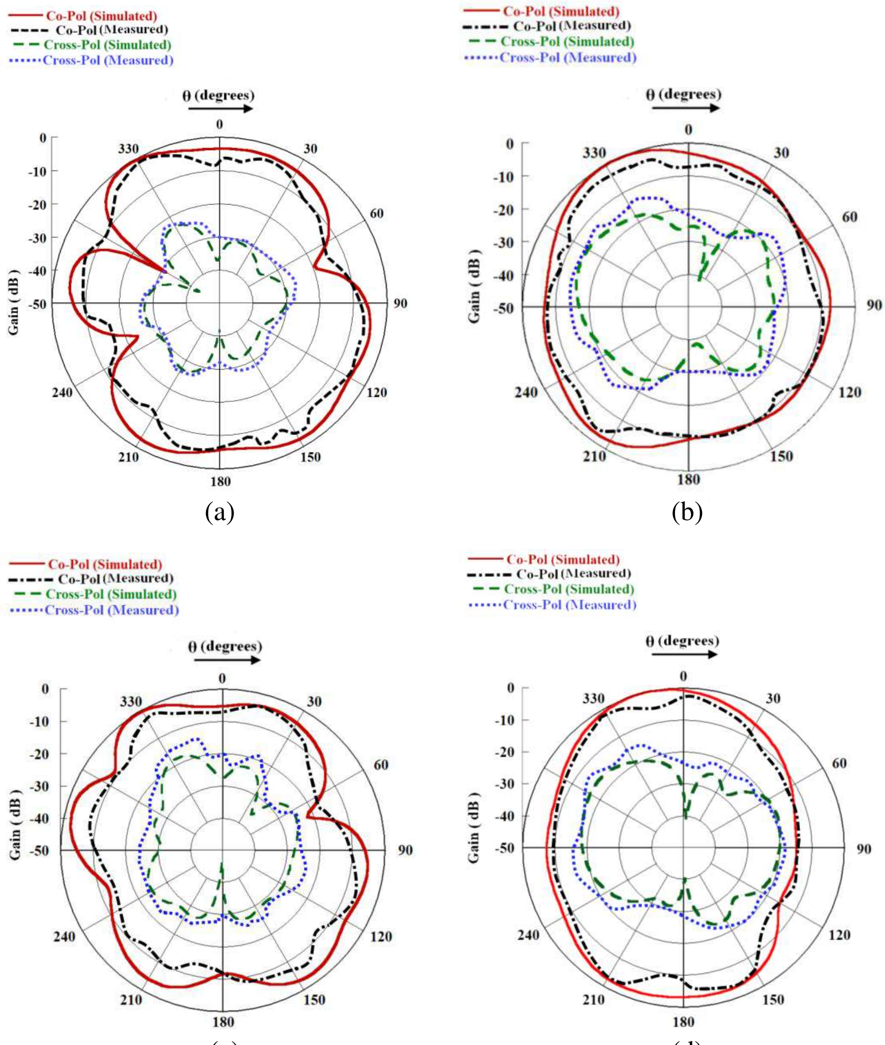
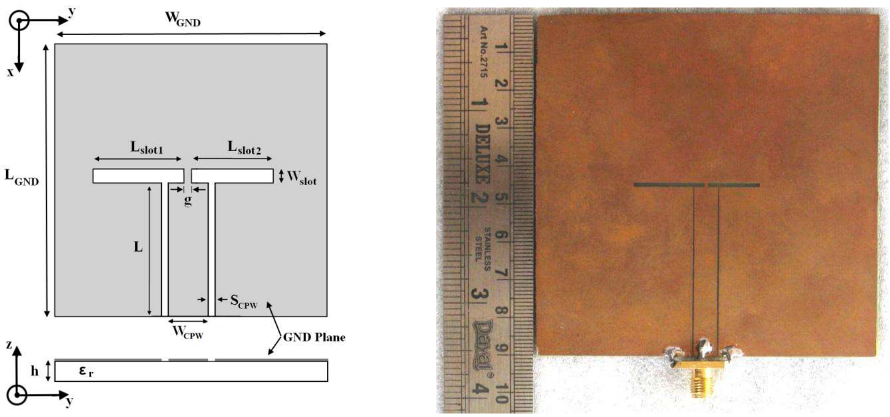


Figure 5. Measured and simulated radiation patterns: (a) E plane at 5.76 GHz, (b) H plane at 5.76 GHz, (c) E plane at 6.21 GHz, (d) H plane at 6.21 GHz.

The slot antenna is fed by a CPW line, which affords a uni-planar design, and allows us to compare the structure with the microstrip feed slot presented in the previous section. The proposed antennas consist of two slots, and a single layer metallic structure built on an inexpensive FR4 dielectric substrate with a thickness (h) of 1.6 mm,

Table 2. Dimensions (in mm) for CPW fed asymmetric slot.

W_{GND}	L_{GND}	W_{slot}	L_{slot1}	L_{slot2}	g	L	S_{CPW}	W_{CPW}	h
90	90	1.2	17.2	15.2	0.6	44.4	0.5	6	1.6



(a) (b)

Figure 6. Design of CPW fed asymmetric slots (a) geometry of the proposed antenna, (b) fabricated structure.

loss tangent of 0.02, and relative permittivity (ε_r) of 4.4. A 50-Ω CPW transmission line is used to excite the two slots of asymmetric length. For the given values of substrate parameters, the CPW dimensions are calculated. The calculated value of width and spacing of the CPW line are $W_{CPW} = 6$ mm and $S_{CPW} = 0.5$ mm respectively. Detailed dimensions of the proposed structure are shown in Table 2. The fabricated prototype structure is shown in Figure 6(b).

3.2. Results and Discussions

Simulated and measured input return losses are shown and compared in Figure 7. Now that the broad-band behavior of the CPW-fed slot antenna is shown, the effect of the slot length that affects its double-resonant behavior must also be examined. The Return Loss comparison with slot length ratio is shown in Figure 8. By observing the influence of various parameters on the antenna performance, it was found that the dominant factor in the proposed antenna designs for broadband applications is the slot length ratio similar to that of microstrip fed slot. Surface current distributions are shown in

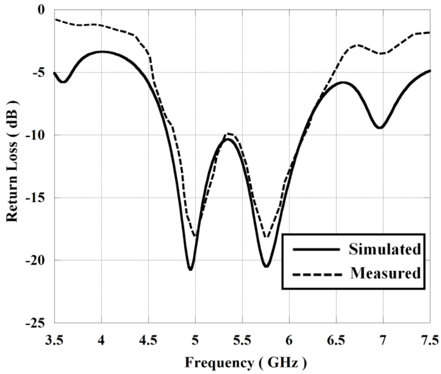


Figure 7. Simulated and measured return loss for CPW fed asymmetrical slot.

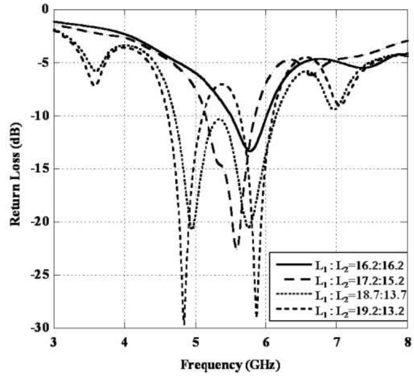


Figure 8. Return Loss comparison for CPW fed asymmetrical slot with length ratio variation (Here L_1 and L_2 represents L_{slot1} and L_{slot2} respectively).

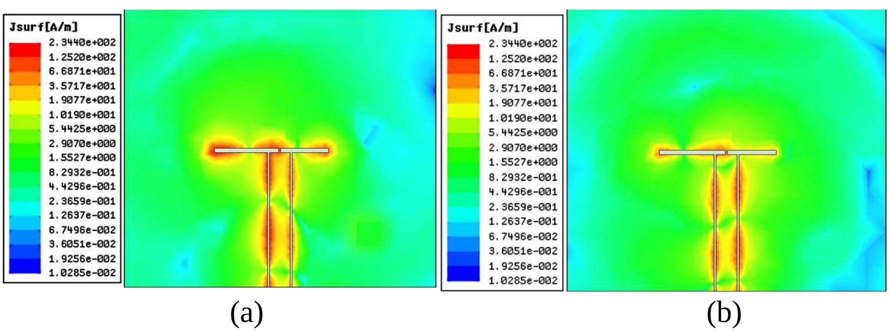


Figure 9. Simulated current distributions for CPW fed asymmetric slot with length ratio 18.7 : 13.7, at (a) 4.95 and (b) 5.76 GHz respectively.

Figure 9. The radiation patterns of the antenna were measured in the anechoic chamber at two different frequencies. The radiation characteristics are also investigated. Figure 10 shows the simulated and measured E-plane and H-plane radiation patterns with co-pol and cross-polarizations. The results show that the radiation patterns of the antenna are bidirectional in the E-plane and nearly omnidirectional in the H-plane.

A detailed simulation is conducted to understand its behavior and optimize for broadband operation. From the simulated results,

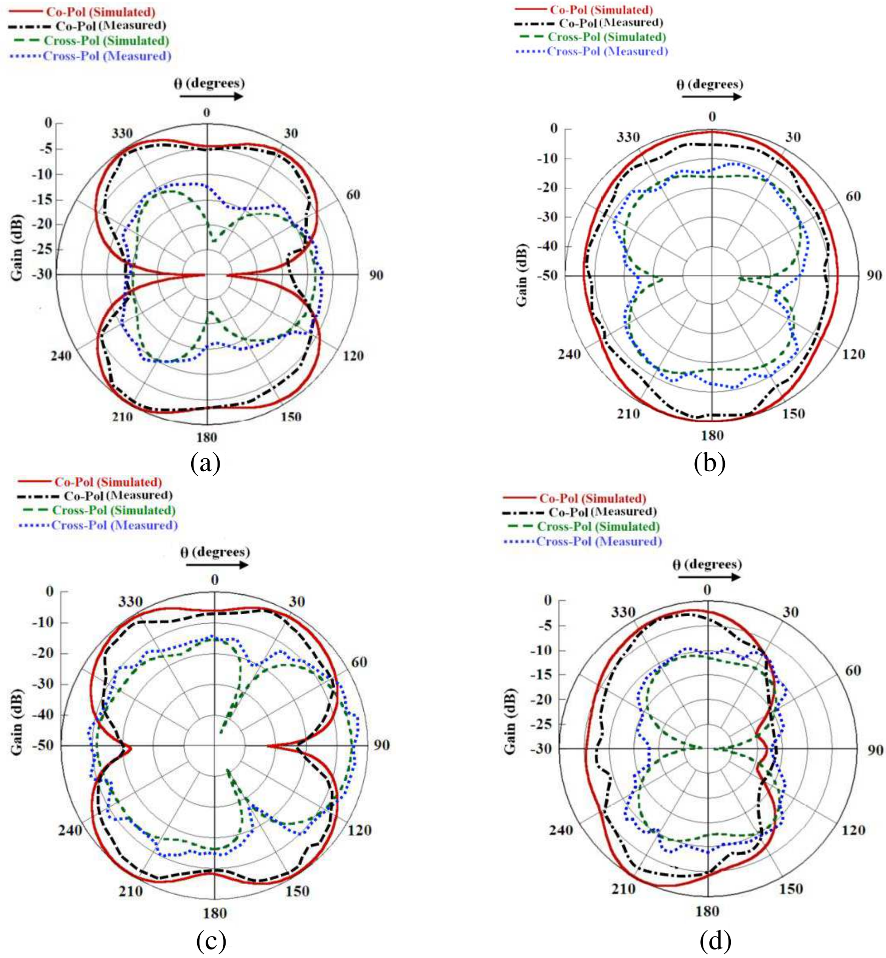


Figure 10. Measured and simulated radiation patterns: (a) E plane at 4.95 GHz, (b) H plane at 4.95 GHz, (c) E plane at 5.76 GHz, (d) H plane at 5.76 GHz.

the obtained impedance bandwidth (determined from 10-dB return loss) of the proposed antenna can operate from 5.49 to 6.37 GHz (for microstrip fed) and 4.71 to 6.14 GHz (for CPW fed) covering the 5.2/5.8-GHz wireless local area network (WLAN) bands and 5.5-GHz worldwide interoperability for microwave access (WiMAX) bands [17]. Also, stable radiation pattern and low cross polarization in the entire operating bandwidth can be achieved. The simulated peak antenna gains for both the antennas are also presented in Table 3.

Table 3. Characteristics of the proposed antenna with two different feed.

Type	Resonant Frequency (GHz)	Gain (dB)	Efficiency (%)	Bandwidth (%)
Microstrip fed slot antenna	5.76	4.53	68.68	14.76
	6.23	4.79	61.99	
CPW fed slot antenna	4.95	3.37	81.53	26.61
	5.76	3.08	75.38	

4. CONCLUSION

In this paper, a novel Broad-band operation of slot antenna has been demonstrated using two different types of feeding technique, microstrip line as well as CPW line. It is observed that a broadband behavior was achieved mainly by using asymmetrical slot length for both the cases of feed. The maximum impedance bandwidth reaches about 26.61% for CPW feed. The average gain, obtained from simulation, is 4.66 dB and 3.225 dB for microstrip and CPW fed respectively and the efficiency of the antenna is quite high for CPW fed slot with respect to microstrip fed slot as seen in Table 3. It is also noted that, the radiation patterns of the proposed slot antennas are good, which make the antennas suitable for practical application.

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