Hybridized CPW-Fed Printed Wide-Slot Antenna Applying Various Fractal Boundaries

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Abstract— This paper presents CPW fed dual and triple band wide-slot antennas hybridized with various geometries such as modified Moore, Koch and Minkowski fractals designed at the edges of wide-slot. Three different structures consist of tuning stub embedded with and without a U-shaped slot have been examined and their comparative analysis is also shown in the paper. These antennas are designed and simulated using High Frequency Structure Simulator (HFSS) Ansoft on FR4 substrate. They have compact size of 28.5 x 33.5 mm². The insertion of tuning stub to the wide-slot structures has reduced antenna resonant frequency. Simulated results demonstrate that the proposed antennas are well suited for the WLAN/WiMAX wireless applications, ISM bands, X-band and radar engineering.

Keywords: CPW-fed slot antenna, modified Moore fractal antenna, Koch, Minkowski fractal antenna, impedance bandwidth

I. Introduction

The multiband antennas including dual band and triple band antennas have increased the demand and interest to be employed for WLAN (wireless local area network) and WiMAX (worldwide interoperability for microwave access) applications [1]. The Federal Communications Commission (FCC) has assigned frequency band from 3.1 to 10.6 GHz for UWB applications in February 2002. This has aroused the challenge and opportunities for antenna developers [2].

A multiband antenna with a composite structure is laborious to design due to its complex structure, highly varying impedance bandwidth and operates complex process [3]-[4]. A printed planar monopole antenna can have a single frequency band along with wideband performance, by etching a slot like structure from the radiating element was shown in [5]-[7].

The coplanar waveguide (CPW) was first given by C. P. Wen, in 1969 which owns one metallic layer structure, low radiation loss, simple fabrication [1]. Moreover, CPW-fed printed wide-slot antenna possesses wider impedance bandwidth than printed patch antenna [8]. Slot antennas have benefits of compact sizes, simple fabrication and are cheap [9].

This paper presents CPW-fed dual and triple band wide-slot antennas hybridized with different fractal geometries such as modified Moore, Koch and Minkowski designed at the edges of wide-slot. A tuning stub with and without U-shaped slot is inserted in these wide slot antennas. They are designed and simulated using HFSS Ansoft. The comparison between these wide slot antennas is shown in this paper on the basis of their return loss characteristics, VSWR and impedance bandwidth.

They can have application in wireless local area network (WLAN) in 5.15–5.35 GHz, and 5.725–5.825 GHz WLAN bands, and also covers 5.25–5.85 GHz worldwide interoperability for microwave access (WiMAX) bands [11]. The dual-band antenna operates in 2.4 GHz (2.4–2.48 GHz) and 5.0 GHz (5.15–5.35 GHz and 5.725–5.825GHz (in the United States) and 5.15–5.35 and 5.47–5.725 GHz (in Europe) frequency bands [11].

Development of these multiple designs are suitable for 6-7 GHz Satellite communication bands. Also they find utilization in ISM band 2.4 and 5.8 GHZ for fixed satellite, radiolocation, mobile, amateur & amateur-satellite services. In addition to this, they cover X band (7.0 to 11.2 GHz). The Radio Regulations of the International Telecommunication Union permit 10 to 10.5 GHz for amateur radio operations, and in the range 10.450 to 10.500 GHz amateur satellite operations are allowed [12]. In radar engineering, the frequency range is specified by the IEEE at 8.0 to 12.0 GHz. In Europe, the frequencies include two parts: from 3.4 GHz to 4.8 GHz and 6 GHz to 8.5 GHz for UWB applications [11].

II. Design

The various geometries of the proposed wide-slot antenna for dual and triple band operations are illustrated in Fig. 3. It presumes an FR4 substrate having loss tangent = 0.02 and dielectric constant= 4.4. The size is compact, that is, only L x W x H = 33.5 x 28.5 x 1.6 in mm. A U-shaped slot inserted in the tuning stub, is centered on the bottom side of an FR4 board where it is fed with 50Ω coplanar waveguide (CPW). The square of size P x P mm² called wide-slot (where P = 27mm) is removed from the substrate and then the different geometries such as Koch, Minkowski and modified Moore fractals are designed on the edges of the wide-slot. As the number of iterations increase the resonant frequency of the slot antenna reduces. The antenna resonant frequency also reduces because of the additional radiating path by the insertion of tuning stub to the wide-slot structure. The dimensions of the tuning stub and U-shaped slot in mm are given in Fig. 2.

Fig. 3. (a) displays the Minkowski fractal geometry implemented on the edges of wide-slot . A square patch is an initial geometry of Minkowski fractal and its further iterations are achieved by substituting each of the four straight sides of the initial square with the generator with indentation factor i. As given in Fig. 1. Indentation factor is ratio of indentation width (s) to indentation length which can vary from 0 to 1 [10].

The modified wide-slot Moore antenna with U-shaped slot is presented in Fig. 3. (b). Moore curve is a loop version of Hilbert curve and can be formed by combining four copies of the Hilbert curve so that their endpoints coincide [10].

Fig. 1: Minkowski second iteration geometry.

The wide-slot antenna designed with Koch fractal geometry with U-shaped slot is shown in Fig. 3. (c). The second iteration of Koch fractal shape has been applied at the edges of wide-slot. The initial length is divided in three equal parts in the first iteration and this iterative process is recurred again to get second iteration [12]. The wide-slot Minkowski, modified Moore and Koch fractal antennas without U-shaped slot are presented in Fig. 4.

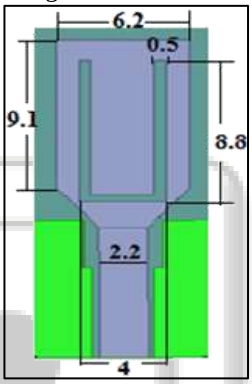
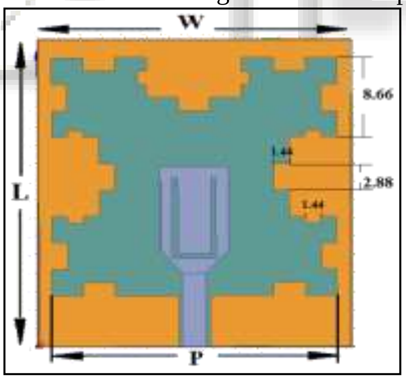


Fig. 2: Dimensions of tuning stub and U-shaped slot



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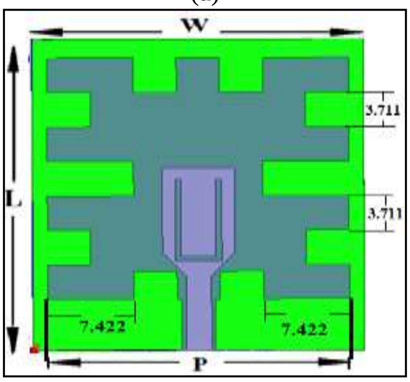

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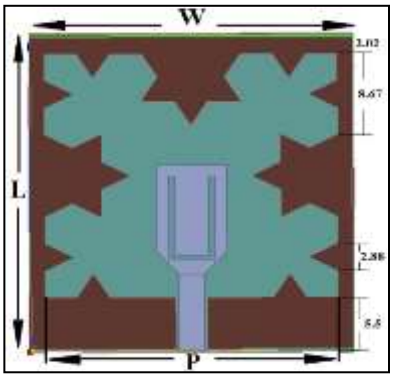
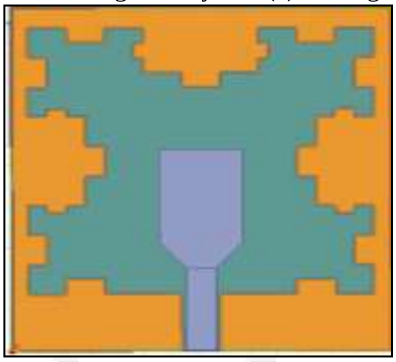


(c)

Fig. 3: Geometries of proposed CPW fed wide-slot antennas with U-shaped slot (a) Minkowski fractal geometry (b) Modified Moore geometry and (c) Koch geometry



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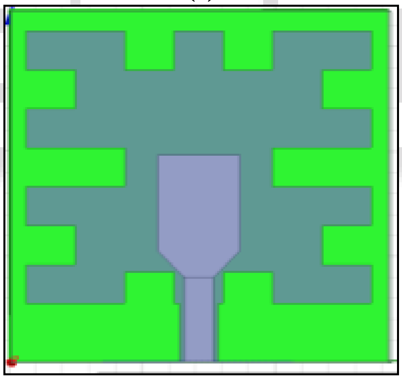

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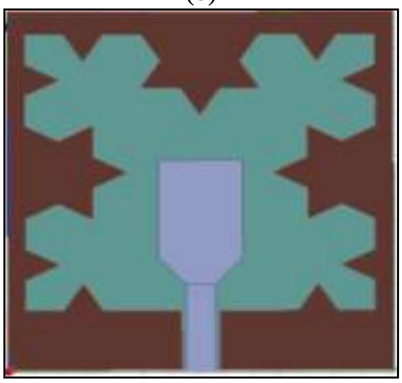

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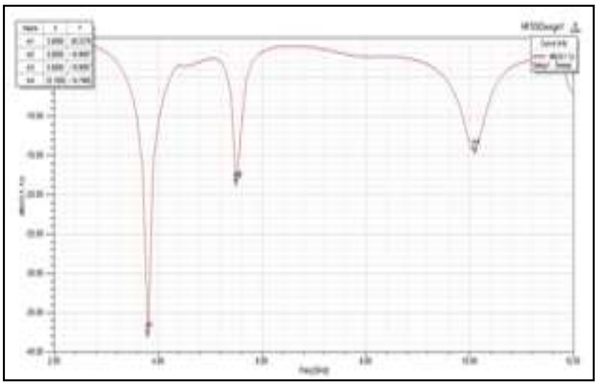
Fig. 4: Geometries of proposed CPW fed wide-slot antennas (without U-shaped slot) (a) Minkowski geometry (b) Modified Moore geometry and (c) Koch geometry



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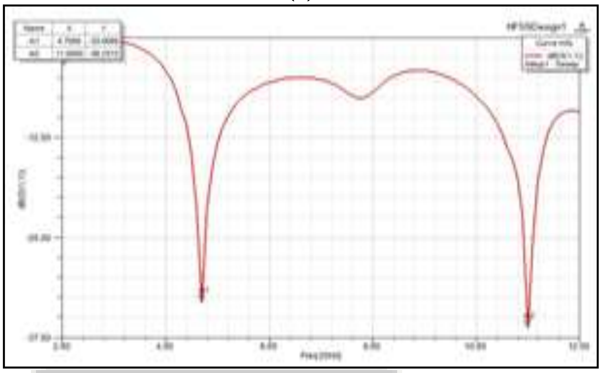
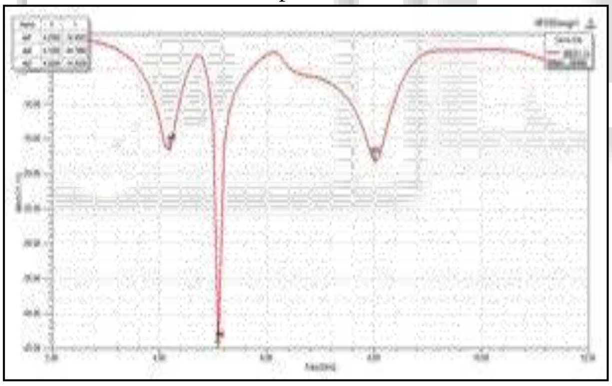


(b)

Fig. 5: Return loss characteristics of modified wide-slot Moore antenna (a) with U-shaped slot and (b) without U-shaped slot.



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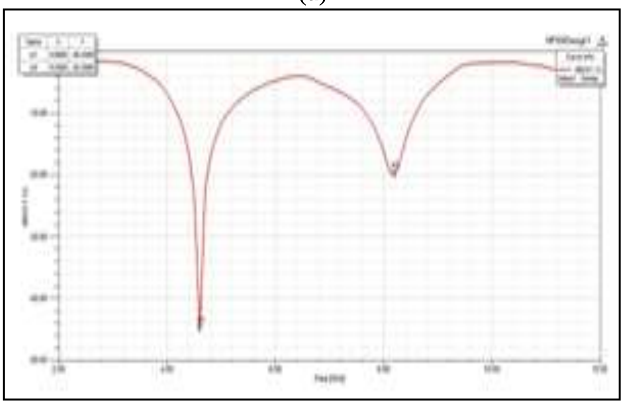

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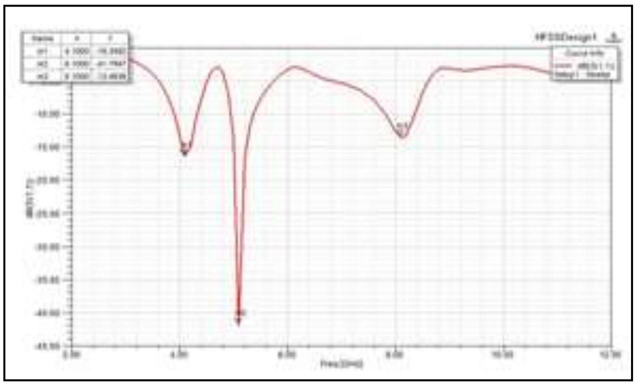
Fig. 6: Return loss characteristics of wide-slot Koch antenna (a) with U-shaped slot and (b) without U-shaped slot.



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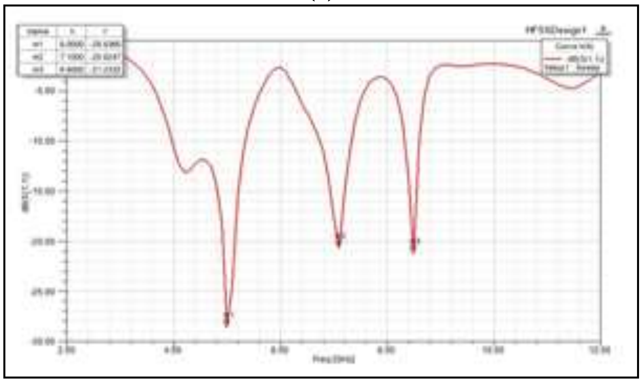

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Fig. 7: Return loss characteristics of wide-slot Minkowski antenna (a) with U-shaped slot and (b) without U-shaped slot.

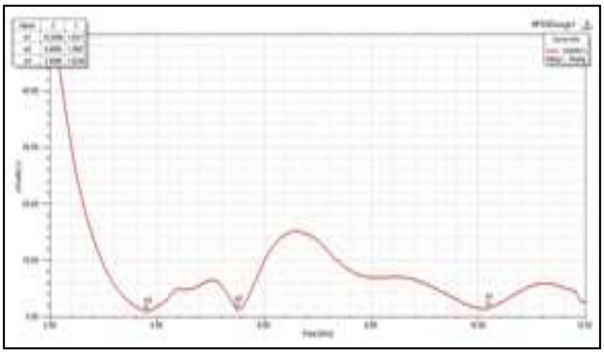
III. SIMULATED RESULTS

The wide-slot antennas are simulated with the High Frequency Structure Simulator (HFSS) from Ansoft. The simulation results reveal that these antennas offer triple band and dual band characteristics within the sweep frequency of 1–12 GHz. Fig. 5, 6 and 7 produces the return loss characteristics of modified Moore, Koch and Minkowski fractal wide-slot antennas with and without U-shaped slot, respectively. The data given in Table I give the values of antenna parameters such as resonant frequencies, return loss, VSWR and -10 dB bandwidths. It also depicts the comparative analysis between all the three geometries.

A. Comparative Analysis

It is observed that modified wide-slot Moore antenna and wide-slot Minkowski antenna with U-shaped slot have better return loss characteristics but lower bandwidth as compared to wide-slot Moore and Minkowski antenna without U-shaped slot, respectively. Modified wide-slot Moore antenna with U-shaped slot has triple-band response and modified wide-slot Moore antenna without U-shaped slot has dual-band response. On the other hand, wide-slot Minkowski antenna has triple-band characteristics for both with and without U-shaped slot configurations.

It is noted that wide-slot Koch antenna with U-shaped slot has triple band characteristics. Wide-slot Koch antenna without U-shaped slot possesses dual-band characteristics and has improved bandwidth up to 20.48% as compared to wide-slot Koch wide-slot antenna with U-shaped slot.



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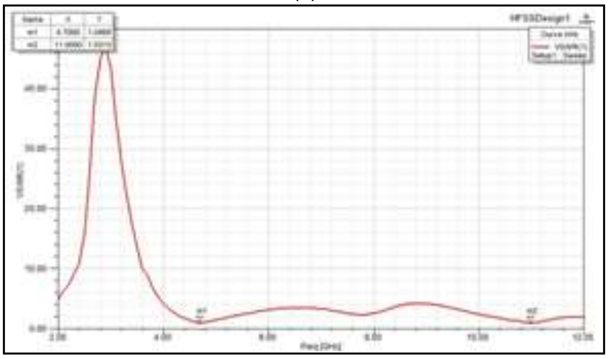

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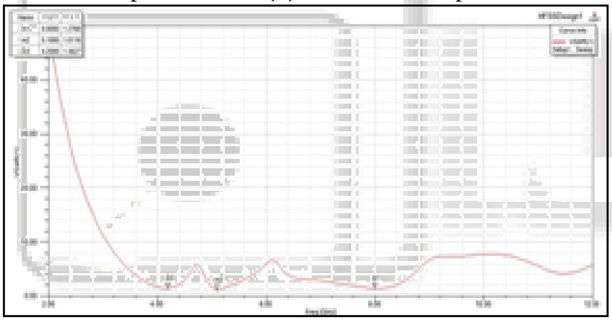
Fig. 8: VSWR of modified wide-slot Moore antenna (a) with U-shaped slot and (b) without U-shaped slot.



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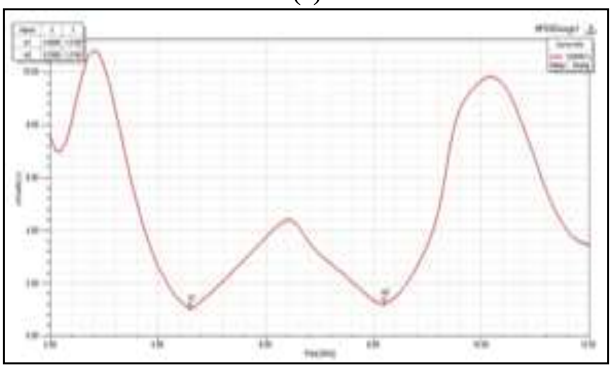

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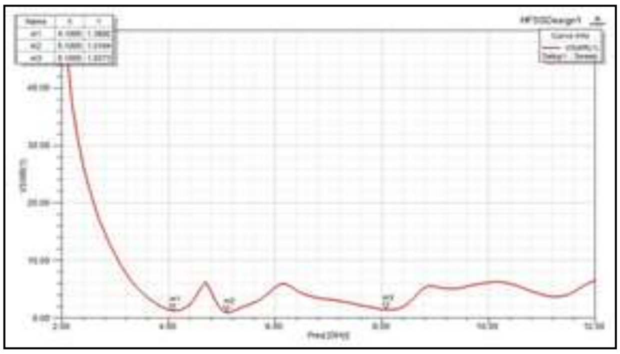
Fig. 9: VSWR of wide-slot Koch antenna (a) with U-shaped slot and (b) without U-shaped slot.



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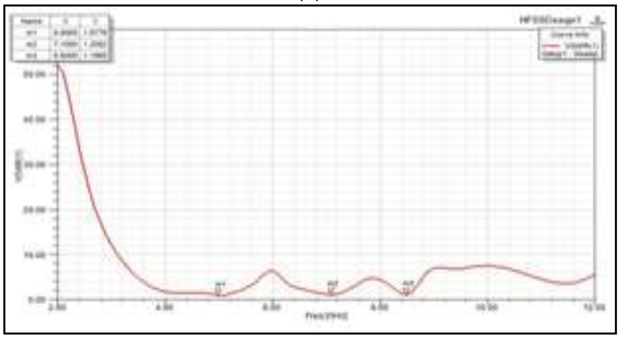

(b)

Fig. 10: VSWR of wide-slot Minkowski antenna (a) with U-shaped slot and (b) without U-shaped slot.

The values of VSWR<2 of wide-slot modified Moore, Koch and Minkowski antennas with and without U-shaped slot, are represented in Fig. 8, 9 and 10, respectively.

B. Discussion

On the basis of simulated results shown in Table I, it is concluded that by removing U- shaped slot from tuning stub of Minkowski wide-slot antenna maximum bandwidth of 27.498% (3.97-5.34GHz) at 5.0 GHz resonant frequency has been achieved. Also it is noted that wide-slot Koch antenna with U-shaped slot has lowest value of return loss equal to -45.4349 dB having minimum 1.0108 VSWR at 4.6GHz operating frequency.

These designs have application in 6-7 GHz Satellite communication bands. Also they cover ISM band 2.4 and 5.8 GHZ for fixed satellite, radiolocation, mobile, amateur & amateur-satellite services. In addition to this, they can also operate in X band (7.0 to 11.2 GHz). The Radio Regulations of the International Telecommunication Union permit 10 to 10.5 GHz for amateur radio operations, and in the range 10.450 to 10.500 GHz amateur satellite operations are allowed. IEEE has specified the frequency range of 8.0 to 12.0 GHz for radar engineering. In Europe, 3.4 GHz to 4.8 GHz and 6 GHz to 8.5 GHz frequency bands are applicable for UWB applications. They find utilization in wireless local area network (WLAN) 2.4/5.2/5.8GHz and worldwide interoperability for microwave access (WiMAX) 2.3/3.5/5.5GHz operations.

S.no	Name of Fractal Antenna	Resonant frequency (GHz)	S-parameter (dB)	VSWR	Bandwidth (%)
1.	Modified Moore geometry (with U-shaped slot)	3.8	-38.2279	1.0248	11.6
		5.5	-18.9097	1.2557	3.57
		10.10	-14.7460	1.6317	4.28

2.	Modified Moore geometry (without U-shaped slot)	4.7	-33.0065	1.0458	17.806
		11.0	-36.2312	1.0313	11.0440
3.	Minkowski geometry (with U-shaped slot)	4.1	-16.3492	1.3592	10.44
		5.1	-41.7947	1.0164	8.4
		8.1	-13.4835	1.5373	6.8
4.	Minkowski geometry (without U-shaped slot)	5.0	-28.5360	1.0778	27.498
		7.1	-20.6247	1.2052	8.3352
		8.5	-21.2332	1.19	3.1341
5.	Koch geometry (with U-shaped slot)	4.2	-16.4843	1.3527	10.77
		5.1	-44.786	1.016	7.66
		8.0	-18.3039	1.2768	9.94
6.	Koch geometry (without U-shaped slot)	4.6	-45.4349	1.0108	20.48
		8.2	-20.2588	1.2150	17.23

Table 1: Performance Comparison of CPW-Fed Printed Wide-Slot Antenna with Different Fractal Geometries

IV. Conclusion

In this paper, the performance comparison of CPW fed printed wide-slot antenna hybridized with different fractal geometries such as modified Moore, Koch and Minkowski designed at the edges of wide-slot has been presented. The comparison between these antennas has been done on the basis of their return loss characteristics, VSWR and impedance bandwidth. It has been concluded that wide-slot Minkowski antenna without U-shaped slot has attained maximum bandwidth of 27.498% (3.97-5.34GHz) at 5.0 GHz as compared to the Koch and modified Moore wide-slot antennas. Moreover wide-slot Koch antenna with U-shaped slot has minimum value of return loss equal to -45.4349 dB with lowest 1.0108 VSWR at 4.6GHz operating frequency in comparison with wide-slot Minkowski and modified Moore antennas. The simulated results have shown that these wide-slot antennas are suitable for dual and triple band operations. The insertion of tuning stub to the wide-slot structure has reduced antenna resonant frequency. The proposed antennas are well acceptable for the WLAN/WiMAX wireless applications, ISM bands, X band and radar engineering.

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