Grenze International Journal of Engineering and Technology, Jan Issue

Compact Dual Band and Tri-Band Slot Loaded Rectangular Microstrip Patch Antennas

Koyel Hazra[1], Anita Mahato[2], Biplab Bag[3] and Susmita Bala[4]
[1-2,4]Vidyasagar University, Midnapore, West Bengal, India.
Email: koyel-hazra1998@gmail.com, anitamahata5678@gmail.com, susmitabala@mail.vidyasagar.ac.in
[3]Murshidabad Institute of Engineering and Technology, Murshidabad, West Bengal, India
Email: susmitabala@mail.vidyasagar.ac.in

***Abstract*— A dual frequency band and a triple frequency band rectangular-shaped microstrip antenna will be discussed in this research study. The proposed antennas' microstrip patch has slots that have been loaded to provide them dual frequency band and triple frequency band features. The proposed antenna-(1) provides two resonance frequencies of 3.47 GHz and 4.78 GHz. At 3.47 GHz and 4.78 GHz, respectively, the simulated peak gains are 3.65 dBi and 2.8 dBi. The proposed antenna-(2) provides three resonant frequencies of 2.1 GHz, 3.26 GHz, and 5.48 GHz with simulated peak gains of 4.05 dBi, 1.55 dBi, and 1.53 dBi respectively. The proposed antenna-(1) has obtained a compactness of 51.10% in terms of its first resonance frequency, whereas the proposed antenna-(2) has acquired a compactness of 82.06% in terms of its first resonance frequency. At the two suggested antennas' various resonate frequencies, the radiation patterns (E and H plane) are good. High Frequency Structure Simulator (HFSS) software was used to construct and model the suggested antennas, and the simulated results (reflection co-efficient (dB)), peak gain, and normalized (E-H plane radiation patterns) are presented here. There are a variety of wirelessly efficient applications that could be benefitted from the suggested antennas.**

***Index Terms*— rectangular patch antenna, dual-frequency, triple-frequency, compactness, slot, reflection co-efficient, gain and radiation patterns**

I. Introduction

The demand for multiband electronics devices, low size requirements, and wireless systems is expanding quickly today. For integrated electronics systems, a smaller multi-band antenna is required. Compactness and multiband nature are thought to be well-suited requirements for low profile microstrip antennas. The patch must be shrunk while retaining its properties, including resonance frequency, reflection coefficient, gain, and radiation patterns, among others. Together, many scientists are tackling this challenging endeavour over the course of several days.
For WLAN and WiMAX applications, a dual band microstrip antenna with a coaxial probe feed was published in [3]. For various wireless applications, a one-layer coaxial probe feed microstrip antenna was described in [4]. Dual band for navigation purposes was achieved in [5] using slots and the short sheet loading method. Triband applications were implemented in [6] using a dual pair of slots. In [7], information about a triple band microstrip antenna for various wireless applications was provided. For wireless applications, a triband microstrip antenna utilizing slots was presented in [8]. For WLAN and HIPERLAN applications, a dual band microstrip antenna with a shorting mechanism was described in [9]. For various wireless applications, a multiband reduced size microstrip

Grenze ID: 01.GIJET.10.1.301

antenna for various wireless applications was provided. For wireless applications, a triband microstrip antenna utilizing slots was presented in [8]. For WLAN and HIPERLAN applications, a dual band microstrip antenna with a shorting mechanism was described in [9]. For various wireless applications, a multiband reduced size microstrip antenna was designed and reported in [10]. In [11], it was revealed that a patch antenna with a hexagonal shape supports dual band for wireless applications. Triband microstrip antenna was announced for 5G usage in [12]. That antenna employs an asymmetric feed approach for patch for excitation. For WLAN applications, a dual band microstrip antenna was presented in [13]. The harmonic suppression property of that antenna is evident. For triband applications, an L-shaped and pulse-shaped microstrip antenna was described in [14].

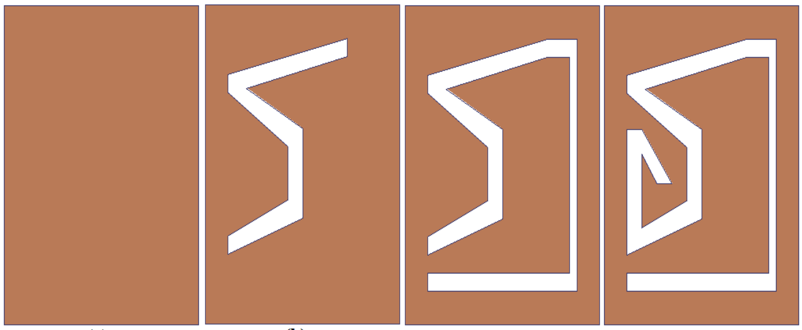
In this paper, miniature two- and three-frequency band rectangular microstrip antennas are proposed. The antennas are designed using snake-like slots in the microstrip patch. The proposed antenna-(1) offers double frequency and 51.10% compactness. The proposed antenna-(2) obtains three resonant frequencies with 82.06% compactness. The two proposed antennas-(1) and the proposed antenna-(2) get a good reflection coefficient value and maximum gain.

II. Constructional Details Of Antennas

The two proposed antennas are modelled and simulated using HFSS software. FR4 is chosen as the basic material for the construction of the proposed structures. We use FR4 with a relative permeability (εr) of 4.4 and a height of 1.6 mm. FR4 material has a loss tangent of 0.02. The coaxial feed mechanism was used to excite the proposed antennas. The design details of the proposed antenna-(1) are shown in Figure (1). The parameters of the proposed antennas are listed in Table (I). The design procedure of the proposed antenna-(1) is shown in Figure (2) (a-d). The first step of the proposed antenna-(1) starts with a rectangular microstrip antenna. Its length (L) = 13 mm, width (D) = 17.75 mm. The first step is shown in Figure (2) (a). For step (2), the modified V slot and the modified U slot are connected in Figure (2) (b). In step (3), an L-type slot is placed in the radiating patch (Figure (2) (c)). Finally, the hook-shaped slot is connected in step (3) to complete the proposed antenna-(1) (Figure (2) (d)). The surface current distribution (vector (J_surface)) (step (1)) of the rectangular microstrip antenna is shown in Figure (3) (a). After insertion of the snake-like slot geometry, the current path of the antenna increases in a different way, which can mean that the electrical length of the patch increases, which causes the resonant frequency to change from the higher frequency region to the lower frequency region, which is clearly shown in Figure (3) (b). In this way, the compactness of the proposed antenna-(1) was achieved. Here, the first resonant frequency of the proposed antenna-(1) was considered with the compactness of the proposed antenna. This geometry is also responsible for the dual band nature. The reflection coefficients of different steps of the proposed antenna-(1) with respect to frequency are shown in Figure (4) and their results are listed in TABLE (II). The design details of the proposed antenna-(2) are shown in Figure (5). The parameters of the proposed antenna-(2) are listed in TABLE (III). The design procedure of the proposed antenna-(2) is shown in Figure (6) (a-d). The first steps of the proposed antenna-(2) starts with a rectangular microstrip antenna. Its length (L) = 13 mm and width (D) = 17.75 mm. The first step is shown in Figure (6) (a). In step (2), the spiral-type long span of the initial antenna shown in Figure (6) (b) is loaded. In step (3), a small slot is inserted into the radiating patch (Figure (6) (c)). Finally, step (3) connects another small slot to complete the proposed antenna (2) (Figure (6) (d)). The surface current distribution (vector (J_surface)) of the proposed antenna-(2) is shown in Figure ((7) (a)-(b)). The reflection coefficients of the different steps of the proposed antenna-(2) with respect to frequency are shown in Figure (8) and their results are listed in TABLE (IV). After comparing the results of different steps of the proposed antenna-(2), step (4) is considered as the proposed antenna-(2).

TABLE (I): Dimensions of different parameters of the proposed antenna-(1) in mm

A	B	C	D	E	F	G	H
50	50	13	17.75	14	8	2	1
I	J	K	L	M	N	O	P
2.75	5	3	1.6	5	1	10	7



(a) (b) (c) (d)

Fig-(2) (a-d): Design procedure of the proposed antenna-(1) (a) step (1) (b) step (2) (c) step (3) and (d) step (4) (proposed antenna-(1))

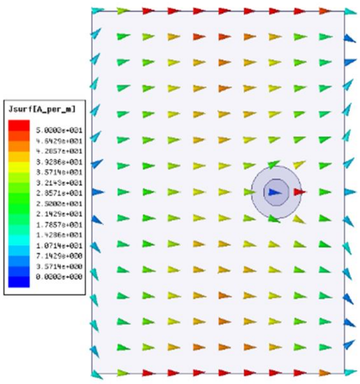


Fig-(3) (a): Surface current distribution of the basic geometry (step-(1)) of the proposed antenna-(1)

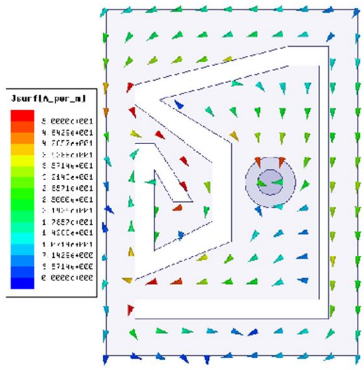


Fig-(3) (b): Surface current distribution of the proposed antenna-(1) (step (4))

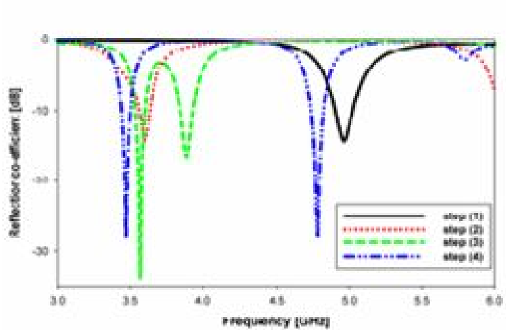


Fig-(4): Reflection co-efficient vs. frequency results of the different steps of the proposed antenna-(1)

TABLE (II): RESULTS OF DIFFERENT STEPS OF THE PROPOSED ANTENNA-(1)

Various steps	Resonate Frequency (GHz)	Magnitude of the reflection co-efficient (dB)
step (1)	4.96	-14.26
step (2)	3.6	-14.16
step (3)	3.57 and 3.89	-33.69 and -16.88
step (4) (proposed antenna-(1))	3.47 and 4.78	-28.43 and -28.07

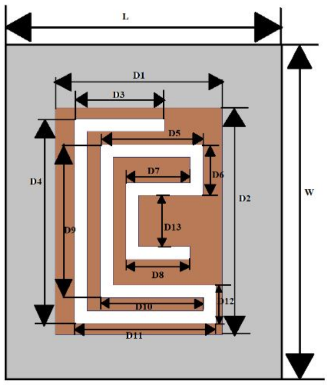


Fig-(5):Geometry of the proposed antenna-(2)

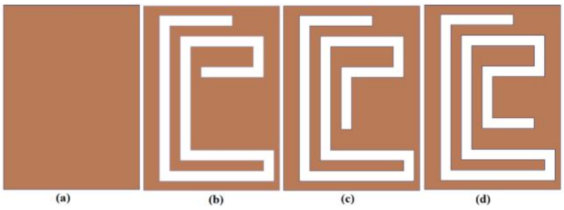


Fig-(6) (a-d): Design procedure of the proposed antenna- (2) (a) step (1) (b) step (2) (c) step (3) and (d) step (4) (proposed antenna-(2))

TABLE (III): DIMENSIONS OF THE DIFFERENT PARAMETERS OF THE PROPOSED ANTENNA-(2) IN MM

D1	D2	D3	D4	D5
13	17.75	7	16	8
D6	D7	D8	D9	D10
4	5	5	12	8
D11	D12	D13	L	W
11	3	4	50	50

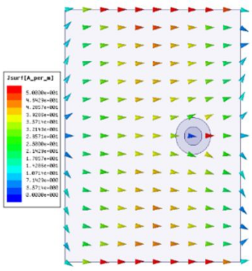


Fig-(7) (a): Surface current distribution of the basic geometry (step-(1)) of the proposed antenna-(2)

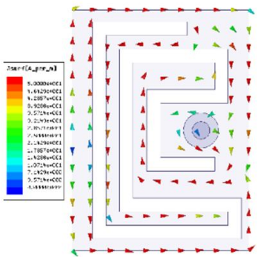


Fig-(7) (b): Surface current distribution of the proposed antenna-(2)

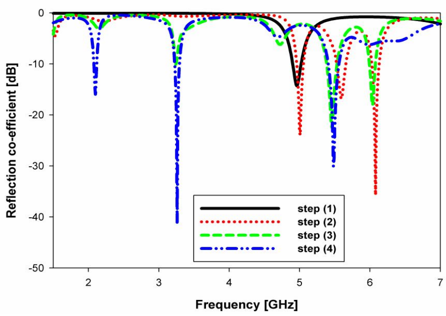


Fig-(8): Reflection co-efficient vs. frequency results of the different steps of the proposed antenna-(2)

TABLE (IV): RESULTS OF DIFFERENT STEPS OF THE PROPOSED ANTENNA-(2)

Various steps	Resonate Frequency (GHz)	Magnitude of the reflection co-efficient (dB)
step (1)	4.96	-16.81
step (2)	4.96, 5.6 and 6.09	-25.03, -16.76 and -34.97
step (3)	3.25, 5.47 and 6.05	-10.63, -21.97 and -19.13
step (4) (proposed antenna-(2))	2.1, 3.26 and 5.48	-15.95, -40.97 and -30.06

III. SIMULATED RESULTS OF ANTENNAS

In this section, the simulated results of the proposed antenna-(1) and the proposed antenna-(2) are discussed. Antennas are simulated using HFSS software. The reflection coefficient curve of the proposed antenna-(1) is shown in Figure (9). The gain curve of the proposed antenna-(1) is shown in Figure (10). The E- and H-plane radiation patterns of the proposed antenna-(1) are shown in Fig. ((11)-(12)). The proposed antenna (1) offers two resonant frequencies of 3.47 GHz and 4.78 GHz with magnitudes of -28.43 dB and -28.0 dB. The gain of the proposed antenna-(1) at their resonant frequencies of 3.47 GHz and 4.78 GHz is 3.65 dBi and 2.79 dBi, respectively. The radiation patterns of the proposed antenna-(1) at 3.47 GHz and 4.78 GHz are shown in Figures (11) and (12). The reflection coefficient curve of the proposed antenna-(2) is shown in Figure (13). It offers three resonant frequencies of 2.1 GHz, 3.26 GHz and 5.48 GHz with reflection coefficient values of -15.95 dB, -40.97 dB and -30.06 dB. The gain curve of the proposed antenna- (2) is shown in figure (14). Peak gain of 4.05 dBi, 1.55 dBi and 1.53 dBi are obtained at 2.1 GHz, 3.26 GHz and 5.48 GHz. The E- and H-plane radiation patterns of the proposed antenna-(2) at 2.1 GHz, 3.26 GHz and 5.48 GHz are shown in Figures (15), Figures (16) and (17) respectively.

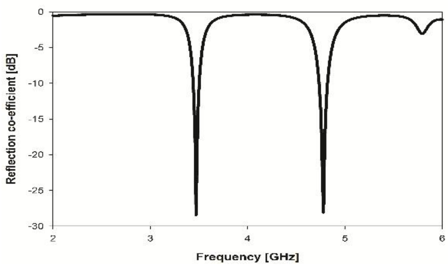


Fig-(9): Reflection co-efficient vs. Frequency plot of the proposed antenna-(1)

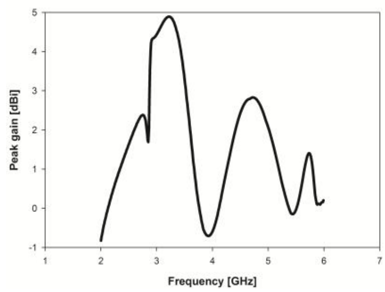


Fig-(10): Gain plot of the proposed antenna-(1)

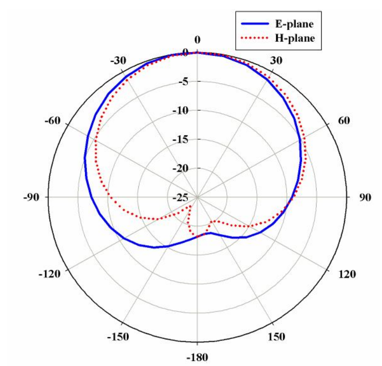


Fig-(11): Radiation patterns of the proposed antenna-(1) at 3.47 GHz

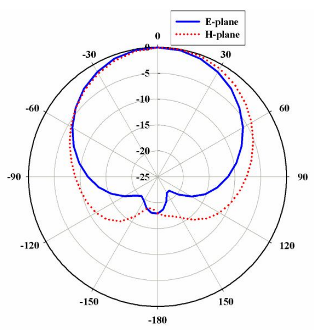


Fig-(12): Radiation patterns of the proposed antenna-(1) at 4.78 GHz

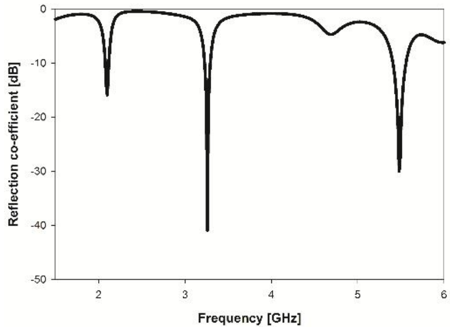


Fig-(13): Reflection co-efficient vs. Frequency plot of the proposed antenna-(2)

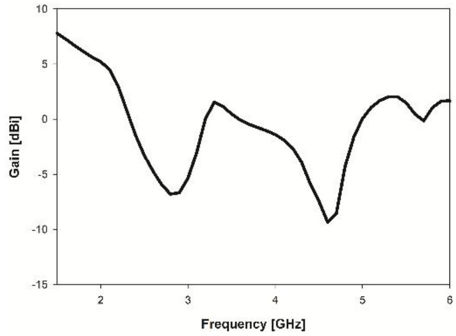


Fig-(14): Gain plot of the proposed antenna-(2)

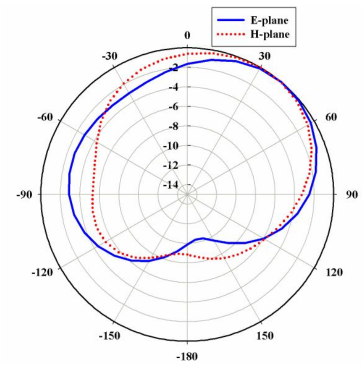


Fig-(15): Radiation patterns of the proposed antenna-(2) at 2.1 GHz

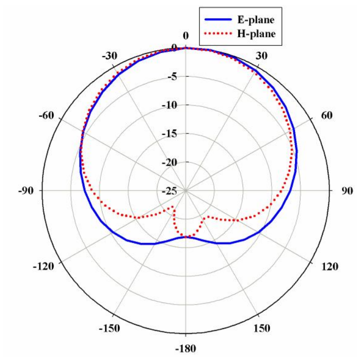


Fig-(16): Radiation patterns of the proposed antenna-(2) at 3.26 GHz

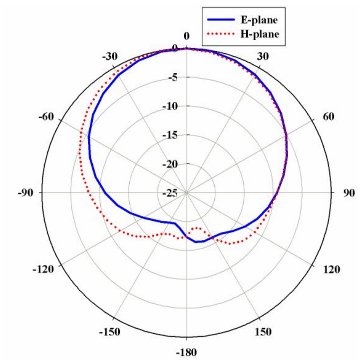


Fig-(17): Radiation patterns of the proposed antenna-(2) at 5.48 GHz

IV. CONCLUSION

In this paper, two compact rectangular microstrip antennas are proposed. One antenna offers two-frequency band and 51.10% compactness and the other antenna offers three-frequency band and 82.06% compactness. Both antennas use a snake-like slots for compact, multi-band capability. Dual band of 3.47 GHz and 4.78 GHz are obtained by loading slots to the proposed antenna-(1). A triple band with frequencies of 2.1 GHz, 3.26 GHz and 5.48 GHz is obtained by inserting slots in the proposed antenna-(2). Good peak gain was achieved at the resonant frequencies of the two proposed antennas. E-plane and H-plane radiation patterns are also given in the previous section. The proposed antennas are designed by using HFSS software. Both antennas use small and simple geometries. The two antennas can be useful for wireless applications such as WLAN and WiMAX.

REFERENCES

[1] C.A. Balanis, "Antenna Theory: Analysis and Design" 3rd edition, pp.722-784, 2005.

[2] G. Kumar and K. P. Ray, "Broadband Microstrip Antennas" ISBN 1-58053-244-6, 7871.67.M5 K85, 2003

[3] Bao-shan Yan; Lu Wang ; Zhi-quan Luo; Dong-min Deng; Li-ying Feng; Hong-xing Zheng, "Dual-band microstrip antenna fed by coaxial probe" 2016 11th International Symposium on Antennas, Propagation and EM Theory (ISAPE), Guilin, China, 18-21 October 2016.

[4] Gerard Djengomemgoto; Reha Altunok; Cem Karabacak; Ş. Taha İmeci; Tahsin Durak, "Dual-band gemini-shaped microstrip patch antenna for C-band and X-band applications" 2017 International Applied Computational Electromagnetics Society Symposium - Italy (ACES), Firenze, Italy, 26-30 March 2017.

[5] Zhi-quan Luo;Lu Wang;Dong-min Deng;Bao-shan Yan;Li-ying Feng;Hong-xing Zheng, "A dual-band microstrip antenna for aviation and mobile application"2016 11th International Symposium on Antennas, Propagation and EM Theory (ISAPE), 18-21 October 2016, Guilin, China

[6] Hai Wen Liu;Hao Jiang;Xuehui Guan;JiuHuai Lei;Shen Li, "Single-Feed Slotted Bowtie Antenna for Triband Applications" IEEE Antennas and Wireless Propagation Letters, Vol.12, pp. 1658 – 1661, 2013.

[7] Hector Kaschel;Cristian Ahumada, “Design of Triband Microstrip antenna for WLAN/WiMAX applications” IEEE International Conference on Automation/XXV Congress of the Chilean Association of Automatic Control (ICA-ACCA), Curicó, Chile, 24-28 October 2022.
[8] Shatrughna Kumar;Chandan Kumar;Milan Mazumdar;M. K. Mondal, “Single-feed slotted antenna for triband applications”,2014 IEEE International Conference on Advanced Communications, Control and Computing TechnologiesRamanathapuram, India, 08-10 May 2014.
[9] Hao-Chun Tung, Kin-Lu Wong, “A shorted microstrip antenna for 2.4/5.2 GHz dual-band operation”Microwave and Optical Technology LettersVolume 30, Issue 6, pp. 401-402,2001.
[10] SK. Moinul Haque, Hashibul Alam, “Miniaturized dual-band slot antenna design for GPS, amateur radio and WLAN applications” ,International Journal of RF and Microwave Computer-Aided Engineering, vol 30, Issue 4, 2020.
[11] Thiyagarajan Krishnan, Sankar Sennan, Vinayakumar Ravi, Dwarakacharla Harshavardhan Reddy, “A dual-band circular patch antenna using hexagon-shaped slots”, International Journal of Communication Systems, vol. 35, Issue 9, 2022.
[12] Ce Lakpo Bamy, Pierre Moukala Mpele, “Asymmetric-fed triband antenna for military radars and 5G applications using microstrip technology”The Journal of Engineering, Vol. 2022, Issue 7, 2022.
[13] Funda Cırık Acıkaya, Bahadır S. Yıldırım, “A dual-band microstrip patch antenna for 2.45/5-GHz WLAN applications” AEU - International Journal of Electronics and Communications, Vol.141, 2021.
[14] K. Naveen, Praveen V. Naidu, K. Jaya Lakshmi, “A small size triband dual l-shaped and pulse shaped compact size monopole antenna for 5G/wireless portable devices”, Materials Today: Proceedings, Vol. 74, Part 2, 2023, Pp. 141-145.