Design and Analysis of Slotted Triangular Uniplanar Antenna

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Abstract

In this paper, a uniplanar triangular antenna and a uniplanar slotted triangular antenna is presented, both demonstrating excellent reflection and radiation characteristics. The proposed antenna designs achieve an enhanced gain of 5.41dBi at 2.45 GHz, outperforming the conventional Bow-Tie antenna while maintaining the same footprint and eliminating the need for additional matching networks. The slotted triangular antenna incorporates strategically placed slot, which further improve impedance matching and bandwidth. Antenna offers an omnidirectional radiation pattern. Comprehensive simulations confirm the superior performance of these antennas in terms of gain, radiation pattern, and VSWR, making them suitable for a wide range of wireless communication applications.

Keywords : Bow-Tie antenna, Uniplanar antenna, Omnidirectional antenna, Slotted antennas.

1. Introduction

The revolutionary growth of wireless communication technologies caused the increased demand of miniaturized antennas. The most accepted among them is microstrip patch antenna due to its low profile and lightweight, versatility, multiband applications, conformability and ease of design [1]. There are various fields of applications for microstrip antennas such as medical application, satelite, and military applications [2-9]. Uniplanar patch antennas are those antennas whose patch and ground are on the same plane. These types of antennas are highly demanded for on chip applications, with the advantage that it can be fabricated in a single step process [10]. Bow-Tie antenna is a type of uniplanar patch antenna having a butterfly structure in which both radiating element and ground plane lie on the same surface [11 -13]. It consists of two triangular patches combined together having a gap between them, in such a way that one patch looks like the mirror image of the other. Conventional Bow-Tie antenna provides an absolute gain of 2.7 dBi, having bandwidth of 0.6 GHz [14].

In this paper, conventional Bow-Tie antenna is extended to a novel design of triangular uniplanar antenna and slotted uniplanar triangular patch antenna. In the first proposed structure, two triangular patches are combined in such a way that the bases face each other having a gap between them. The feeding location, the gap, and the size of the substrate affect the reflection and radiation characteristics. Parametric analysis is carried out and optimized for better antenna characteristics. An enhanced gain of 3.31 dBi with a bandwidth of 0.8 GHz at 2.45 GHz is obtained for this configuration. The design is next extended to a slotted uniplanar triangular antenna which provides an enhanced gain of 4.39 dBi with a bandwidth of 0.7 GHz at resonant frequency of 2.45 GHz.

2. Proposed Antennas

Conventional bowtie antenna is shown in Fig.1.

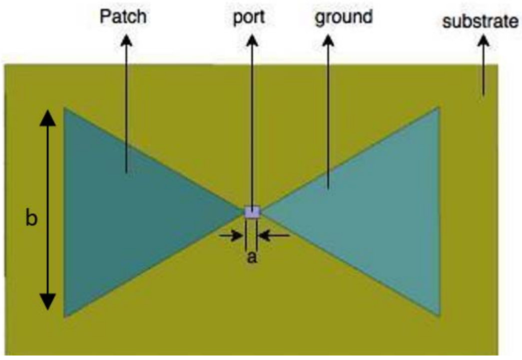

Figure 1: Layout of Conventional Bow-Tie antenna

Initially a triangular shaped bowtie antenna with a side length (b) of 18 mm is implemented using ansys electronic suite. The triangles are separated by a distance (a) equal to 1 mm. The antenna is designed on FR4 epoxy substrate having dielectric constant ε_r= 4.4, thickness = 1.6mm. The simulation results show that the bowtie antenna provides a gain of 2.7 dBi and a bandwidth of 0.6

GHz (2.3 GHz to 2.9 GHz) at the resonant frequency. The proposed structure of the triangular patch antenna, which is the extended design of the Bow-Tie antenna, is given in Fig.2. The antenna is modeled on the same substrate with the same thickness, and an enhanced gain of 3.31 dBi is observed at the 2.45 GHz. The improved design of the uniplanar slotted triangular patch antenna is shown in Fig.3. The antenna also has been designed on the same substrate having the same thickness. An improved gain of 4.39 dBi is obtained at 2.45 GHz.

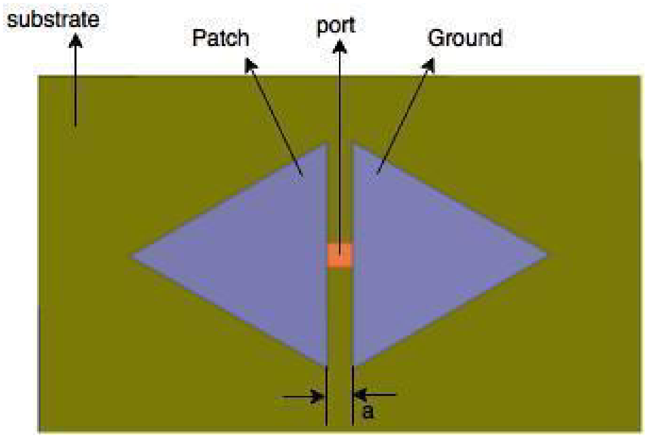

Figure 2: Triangular uniplanar antenna

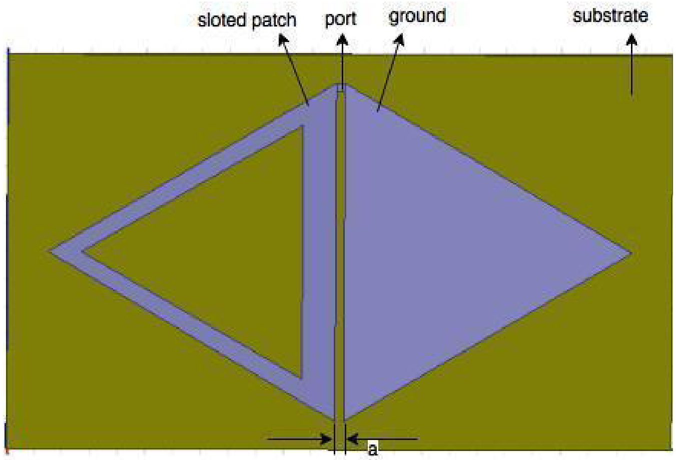

Figure 3: Slotted triangular patch antenna

2.1 Comparison of the proposed antennas with the existing ones

The comparison of the radiation characteristics and reflection characteristics of the proposed designs with the reference Bow-Tie antenna is given in table 1 and figure 4 respectively.

Type of antenna	Gain (dBi)	Bandwidth (GHz)
Conventional Bow-Tie	2.7	0.6
Triangular coplanar antenna	3.31	0.8
Slotted triangular coplanar antenna	4.39	0.5

Table 1: Comparison of the radiating characteristics

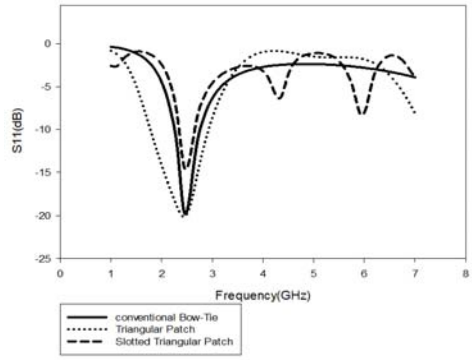

Figure 4: Simulated reflection characteristics of the antennas

From the comparison results of the designed structures, it can be inferred that better radiating and reflection performance is obtained for the proposed structures.

3. Analysis of Proposed Design Structures

The radiating and reflection characteristics vary with the variation in the gap between the ground and the radiating element, and the feed location in the coplanar antenna design. As the gap increases the resonant frequency also gets increased and the gain gets enhanced. When the feed location is moved away from the center position in figure 2 and figure 3 the gain gets enhanced again and the resonant frequency also gets increased. In the design of slotted triangular patch antennas, the size of the slot also affects the characteristics.

3.1 Triangular Coplanar antenna

The variation of the gap between patches in the coplanar design and the radiation characteristics is analyzed in table 2.

Feed gap (mm)	Resonant Frequency (GHz)	Bandwidth (GHz)	Gain (dBi)
2	2.25	0.36	3.1
3	2.35	0.95	3.31
4	2.4	0.8	3.31
4.25	2.45	1.15	3.28
4.5	2.45	1.13	3.25
5	2.49	1.35	3.27
5.5	2.6	1.4	3.34

Table 2: Effect of the gap between the patches on the radiation characteristics of the coplanar antenna

From the results, the optimum feed gap is chosen as 4.25mm. The feed location also has an effect on the radiation characteristics, which is shown in table 3.

Table 3 : Effect of feed location in the radiation characteristics of the antenna.

Feed location	Resonant frequency (GHz)	Bandwidth (GHz)	Gain (dBi)
(0,0)	2.45	1.15	3.28
(0,4.25)	2.16	0.98	3.26
(0,8.5)	4.19	0.80	2.6
(0,19)	4.4	0.41	3

From the results, the optimum feed location for this design is taken. The gain of the proposed structure and the radiation pattern are shown in Fig.5. and Fig.6.

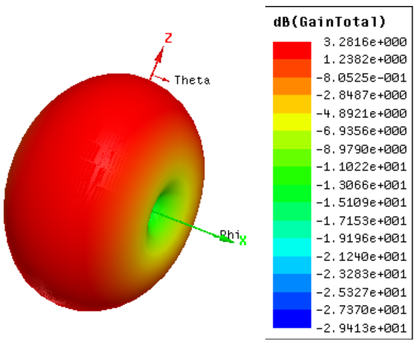

Figure 5: Gain of triangular coplanar antenna

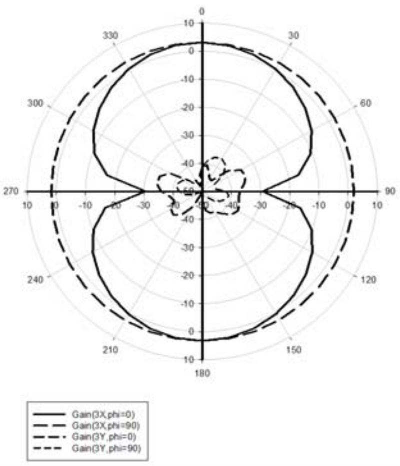

Figure 6 : Radiation pattern of triangular coplanar antenna

From the analysis of the radiating characteristics, the half power beam width is found to be 60^0

3.2 Slotted triangular coplanar antenna

As an extension to the proposed design, a slotted coplanar antenna is designed that provides an enhanced gain of 4.39dBi at frequency 2.45GHz. The radiation performance is found to be affected by the gap between the radiating element and the ground, the feed location, and also the size of the slot. All the parameters varied to get the best design. The analysis of the effects of various parameters on the radiation performance is given in tables below.

Feed gap (mm)	Resonant frequency(GHz)	Bandwidth (GHz)	Gain(dB)
1	2.34	0.45	4.47
1.5	2.45	0.50	4.39
2	2.51	0.60	4.58
2.5	2.52	0.65	4.34
3	2.7	0.50	4.44
4	2.8	0.25	4.24

Table 4: Effect of gap between the patches on the radiation characteristics

From the analyzed results, the optimum gap between the radiating element and the ground is taken as 1.5mm.

Feed position	Resonant frequency(GHz)	Bandwidth (GHz)	Gain (dB)
(0,0)	1.35	0.35	4.81
(0,3)	1.36	0.4	5.05
(0,9)	1.41	0.2	4.37
(0,18)	3.5	0.2	4.22
(0,25)	2.55	0.45	4.38
(0,31)	2.45	0.55	4.50

Table 5: Effect of feed position on the radiation characteristics

From the analyzed simulation results, the optimum feed position is taken as (0,31), that is the edge of the patch, when the length of the side of the triangle is 62mm.

Slot size (mm)	Resonant frequency(GHz)	Bandwidth (GHz)	Gain(dBi)
2	2.45	0.45	4.16
4	2.4	0.4	4.51
6	2.45	0.4	5.415
8	2.4	0.35	5.04

From the analyzed simulation results, an optimum slot size of 6mm is chosen to get the best radiation characteristics. The gain enhancement of 5.415 dBi at frequency 2.45 is obtained for the final simulated structure, which is far better than the conventional uniplanar antennas. The bandwidth obtained is 0.4 GHz. The radiation characteristics for the frequency 2.45GHz is plotted below.

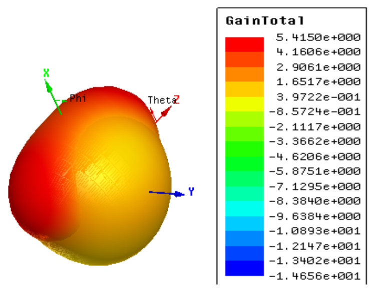

Figure 7: Gain of the proposed slotted triangular coplanar antenna

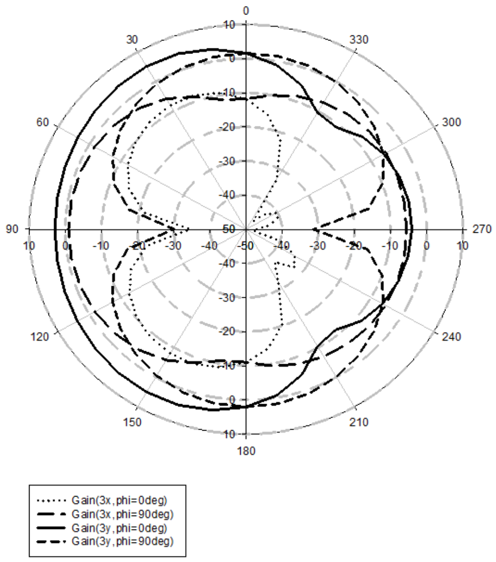

Figure 8: Radiation Pattern of uniplanar slotted triangular antenna.

4. Conclusion

In this study, we explored the Bow-Tie antenna and extended its design to novel configurations: the triangular uniplanar antenna and the slotted triangular antenna. These new designs achieve a gain enhancement of more than 3 dBi at the same operational frequency of 2.45 GHz. Key parameters influencing the radiating and reflection characteristics, such as patch dimensions, slot configurations, and feed point location, were thoroughly analyzed. The proposed designs offer a compact, efficient solution with improved gain, suitable for a wide range of wireless communication applications.

5. Acknowledgements

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7. References

[1] Huque, Md Tanvir Ishtaique-ul, Md Kamal Hosain, Md Shihabul Islam, and Md Al-Amin Chowdhury. "Design and performance analysis of microstrip array antennas with optimum parameters for X-band applications." International journal of advanced computer science and applications 2, no. 4 (2011).

[2] Akan, Volkan, and Erdem Yazgan. "Antennas for space applications: A review." Advanced Radio Frequency Antennas for Modern Communication and Medical Systems (2020): 139-171.

[3] Al-Janabi, Farooq, Mandeep Jit Singh, and Amar Partap Singh Pharwaha. "Development of Microstrip Antenna for Satellite Application at Ku/Ka Band." J. Commun. 16, no. 4 (2021): 118-125.

[4] Karim, Rashid, Adnan Iftikhar, Bilal Ijaz, and Ismail Ben Mabrouk. "The potentials, challenges, and future directions of on-chip-antennas for emerging wireless applications—A comprehensive survey." IEEE Access 7 (2019): 173897-173934.

[5] Rana, Md Sohel, Sifat Hossain, Shuvashis Biswas Rana, and Md Mostafizur Rahman. "Microstrip patch antennas for various applications: a review." Indonesian journal of Electrical Engineering and computer science 29, no. 3 (2023): 1511-1519.

[6] Aiswarya, S., L. Meenu, KA Unnikrishna Menon, Massimo Donelli, and Sreedevi K. Menon. "A Novel Microstrip Sensor Based on Closed Loop Antenna for Adulteration Detection of Liquid Samples." IEEE Sensors Journal (2023).

[7] Nair, Bhuvana, P. S. Shilpa, Sreedevi K. Menon, and Massimo Donelli. "Asymmetric Coplanar Stripline fed Dual Band Monopole as Radiolytic Sensor." In 2020 URSI Regional Conference on Radio Science (URSI-RCRS), pp. 1-4. IEEE, 2020.

[8] Meenu, L., S. Aiswarya, and Sreedevi K. Menon. "A novel and effective technique to reduce electromagnetic radiation absorption on biotic components at 2.45 GHz." Electromagnetic biology and medicine 41, no. 2 (2022): 184-200.

[9] Ajithlal, T. A., R. Gandhiraj, G. A. Shanmugha Sundaram, and K. A. Pradeep Kumar. "Enhanced Performance of Novel Patch Antenna Sub-array Design for Use in L-Band Ground Station Receiver Terminals Linked to Aerospace Platforms." In Information and Communication Technology for Competitive Strategies (ICTCS 2020) Intelligent Strategies for ICT, pp. 1175-1184. Springer Singapore, 2021.

[10] Pandey, Anil. Practical microstrip and printed antenna design. Artech House, 2019.

[11] Ravichandran, Harish, V. M. Jayakrishnan, and Sethuraman N. Rao. "Novel Optimized Pyramidal Horn Antenna for UWB Applications." In 2019 2nd International Conference on Signal Processing and Communication (ICSPC), pp. 281-285. IEEE, 2019.

[12] TA, Surya Dhanush, A. V. K. Sruthi, Srinidhi Ravichandran, and V. Mekaladevi. "Broadband Substrate Integrated Waveguide Cavity-Backed Irregular Shaped Slot Antenna using Particle Swarm Optimization." In 2020 4th International Conference on Trends in Electronics and Informatics (ICOEI)(48184), pp. 866-870. IEEE, 2020.

[13] Singh, Ashish, Krishnananda Shet, Durga Prasad, Satheesh Rao, Anil Kumar Bhat, and Ramya Shetty. "A Review: Microstrip Patch Antennas for Ultra-Wideband." Microstrip Antenna Design for Wireless Applications (2021): 13-24.

[14] Wong, Sai-Wai, Guang-Hua Sun, Lei Zhu, Zhi Ning Chen, and Qing-Xin Chu. "Integration of wireless coil and Bluetooth antenna for high charging and radiation efficiencies." IEEE Transactions on Components, Packaging and Manufacturing Technology 8, no. 7 (2018): 1292-1299.