Volume 10, Issue 3
June 2021

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

Design of Wideband Bowtie Antenna using Tapered Balun for Industrial, Scientific and Medical Band Application

Pravin Dalvadi[1], Amrut Patel[2], D. H. Patel[3], G. D. Makwana[4]

[1]Research Scholar, Ganpat University & EC Department, GP Gandhinagar, Gujarat

[2]EC Department, U.V. Patel College of Engineering, Ganpat University, Gujarat

[3]Research Scholar, Sankalchand Patel University & EC Department, GEC Gandhinagar, Gujarat

[4]Gujarat Technological University-Graduate School of Engineering and Technology, Ahmedabad, Gujarat

E-mail: [1]pravindalvadi3187@gmail.com, [2]amrut.patel@ganpatuniversity.ac.in, [3]pateldevendrah@gmail.com

[4]gmakwana@gmail.com

ABSTRACT

In this paper, a wideband bowtie antenna is proposed for Industrial, Scientific and Medical (ISM) band application. To feed the bowtie antenna, the tapered balun is designed which provides impedance matching between coaxial input source and bowtie antenna. The proposed antenna is fabricated on the Glass Epoxy FR4 substrate of thickness 1.6mm, and dielectric constant of 4.4. The size of the proposed bowtie antenna is 70mm × 40mm. Here, the simulated results have been compared with the measured results and found that both results are well-matched to each other. The proposed antenna obtained 38% bandwidth for S_{11} < -10 dB, more than 2 dB gain and VSWR < 2 for the entire bandwidth.

Keywords: Bowtie antenna, Tapered balun, Bandwidth, Gain, and ISM band.

1. INTRODUCTION

In recent years, wireless communication applications have a huge demand for the design and development of wideband, compact and lightweight antennas. To achieve the aforementioned requirement, the microstrip antenna plays the forefront role in antenna development due to its own advantages [1]. The ISM band is freely available portion of the radio spectrum dedicated for the Industrial, Scientific and Medical purpose. The commonly used ISM band applications are WLAN, Bluetooth, ZigBee, WiMAX, Wi-fi etc.

There is a huge demand of the antenna that operates either in a wideband covering several different services or in a multi-band for specific applications. The bowtie antenna has received huge interest for the research due to its wideband and compact nature as compared to the dipole antenna. The bowtie antenna consists of two triangular sheets of metal as radiating element on the same axis which is fed at the vertex [2-3]. In some designs, both arms of bowtie antenna are printed on the same plane of the substrate [2-3, 5-7] while in others; they are printed on both sides of the substrate [4, 11]. To get better efficiency, there should be maximum power transfer from source to antenna. For obtaining maximum power transfer, feeding technique plays important role by means of impedance matching. The bowtie antenna can be fed by various feeding techniques like; Microstrip feed [2-6, 14-15], Tapered balun [5, 9-15], simplified balanced feed [8, 15], coplanar waveguide feed [7, 15], and many more.

In [6], a bowtie patch antenna is presented using a microstrip feeding technique for indoor application. The antenna is fabricated on the top of the substrate with a dielectric constant 6. It obtained a high gain of 8.7dB with a limited bandwidth of 2% only. In [7], the bowtie antenna is designed using Coplanar Stripline (CPS) feeding method for 2.4 GHz ISM band application. Designed antenna obtained 13.4% bandwidth with peak gain of 1.6 dB over the frequency band, but this feeding method has a complicated balun structure that is major drawback of the method. In [8], bowtie antenna is designed using simplified balanced feeding method. It achieved 68% bandwidth using Rogers RT/6010LM substrate. This feeding method requires large ground plane. The result is increased size of the antenna which hinders its use in applications where compact size antenna is needed. To achieve wide bandwidth, a dipole antenna is presented using the tapered balun feeding method. The antenna is printed on both sides of the substrate with a dielectric constant of 4.4. It achieves 19% bandwidth with 2.5dB gain [9]. In [11], a planer dipole antenna (bowtie shape) is developed using a large size of tapered balun for impedance matching between the antenna and coaxial feed. The antenna achieved broadband of 0.1GHz to 2.2 GHz with -15 to 4dB gain. This antenna requires a large tapered balun and hence overall antenna size becomes large. The gain varies in a wide range which is also not desirable.

In this paper, a wideband bowtie antenna is presented using simple tapered balun feeding method. The proposed antenna is designed on FR4 substrate with ε_r of 4.4 and thickness of 1.6mm. The antenna analysis is presented with performance parameters such as gain, return loss, bandwidth, radiation pattern, VSWR, and smith chart. Moreover, a parametric study of a proposed antenna at various angles with constant antenna length and with variable antenna length is also presented in proposed paper.

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2. BOWTIE ANTENNA

A bowtie antenna consist two triangular sheets of metal and the feed at the vertex. In bowtie antenna, the bandwidth is determined by the length of the antenna and the impedance is determined by the angle of the antenna [5]. Figure 1 shows bowtie antenna for 2.4 GHz, where antenna is fed at centre by Tapered balun and its arms are designed on both side of substrate. The proposed bowtie antenna is designed on either side of the substrate. This antenna is completely defined by its length L and angle θ. Here antenna design parameters are chosen using parametric study which are mentioned as follow: Length (L) = 19 mm, Width (W) = 26 mm, Length of tapered balun (L_f) = 21.5 mm, Top width of Tapered balun at point 1 (W_{t1}) = 3 mm, Bottom width of Tapered balun at point 1 (W_{b1}) = 15 mm, Top & bottom width of Tapered balun at point 2 (W_{t2} & W_{b2}) = 2 mm, and bowtie antenna angle (θ) = 68°.

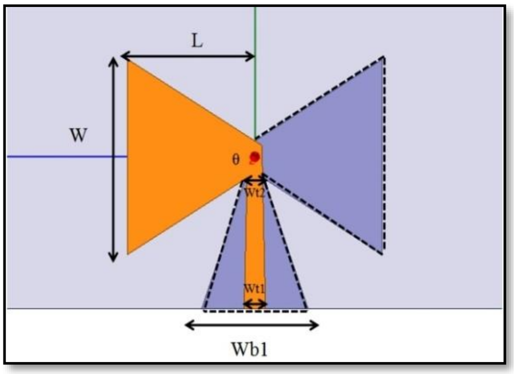

Fig.1. Bowtie antenna (Top – Orange Color, Bottom - Blue Color)

To feed the proposed antenna, the tapered balun is designed which is shown in figure 2. A gradual tapering of width of the top and bottom conductor is carried out for impedance matching between source and antenna.

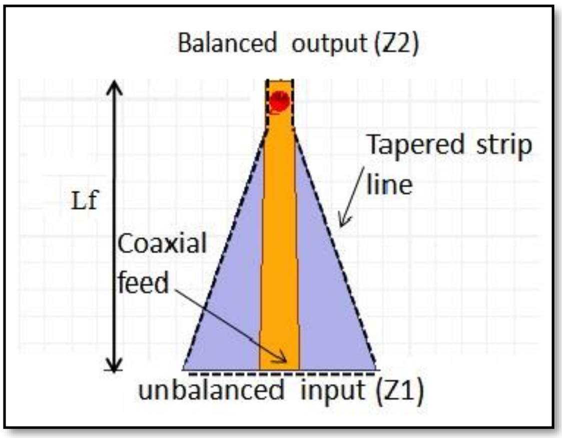

Fig.2. Tapered Balun (Top – Orange Color, Bottom - Blue Color)

A tapered balun is formed like a slowly peeled coaxial cable and reshaped until it is a balanced transmission line. The characteristic impedance (Z) of the tapered balun depends on length (L_f) from unbalanced input point Z_1 to balanced output point Z_2 [14-15]. The Top width of Tapered balun at point 1 (W_{t1}) and Length of tapered balun (L_f) is taken in such a way that it provides 50Ω input impedance matching and a compact taper balun respectively. In the proposed design, a ratio of W_{b1}/W_{t1}= 5 is considered.

3. RESULTS AND DISCUSSION

The proposed antenna is simulated using Ansys HFSS and fabricated on low-cost glass Epoxy FR4 substrate by using standard photolithography as shown in figure 3a and figure 3b.

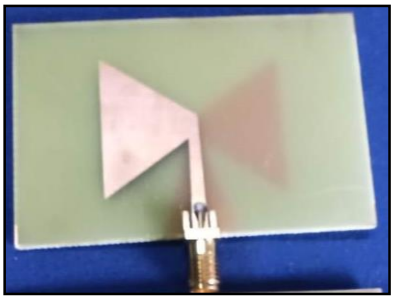

Fig.3a. Proposed antenna – Top view

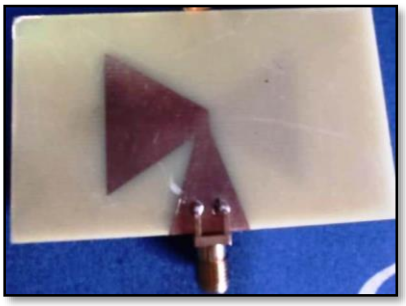

Fig.3b. Proposed antenna – Bottom view

The return loss and VSWR are measured by Anritsu Vector Network Analyser (VNA) master. The measured and simulated results are shown in figure 4 and figure 5 respectively.

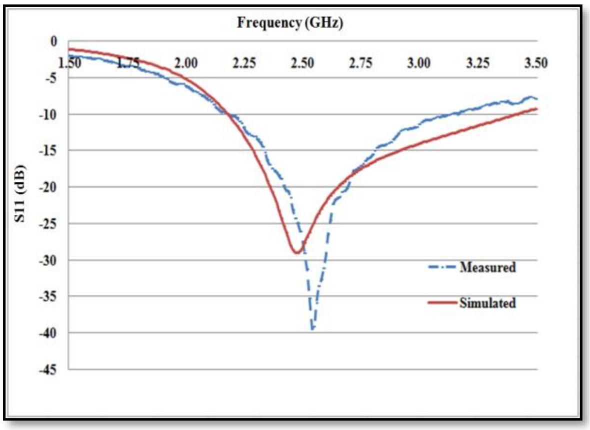

Fig.4. Return Loss of bowtie antenna

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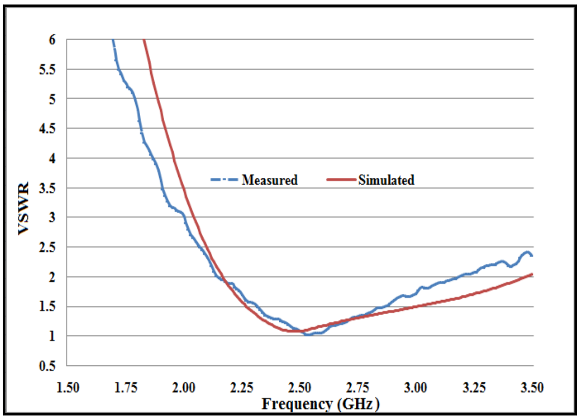

Fig.5. VSWR of bowtie antenna

From the results, it is noted that there is a good agreement between measured and simulated results of return loss and VSWR. From the measured results, it is found that the proposed antenna obtained 38% bandwidth (2.15 to 3.15 GHz) while in simulated result antenna obtained 44% bandwidth (2.18 to 3.42 GHz). The proposed antenna achieves VSWR < 2 for the entire bandwidth. The simulated gain in 0° and 180° direction are 2.299 dB and 2.280 dB respectively as shown in figure 6.

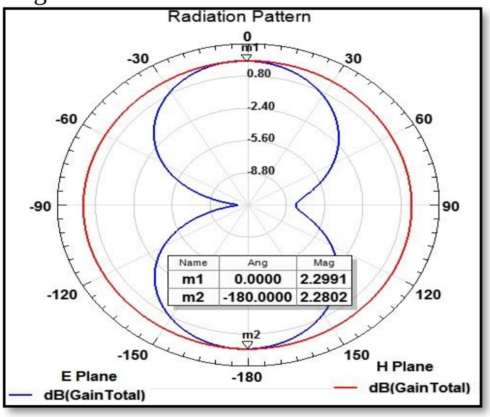

Fig.6. Gain of bowtie antenna

Figure 7 shows smith chart of bowtie antenna which gives impedance location on different frequencies. The antenna operated on real axis and also made a loop on unity circle in Smith chart which indicates impedance matching for wide bandwidth.

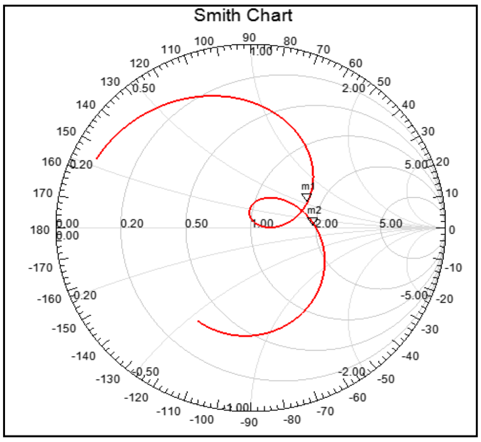

Fig.7. Smith chart for bowtie antenna

Figure 8 shows Gain V/s Frequency for bowtie antenna. The maximum gain is 2.45 dB with less than 0.6 dB variations over the bandwidth. This antenna design is suitable for broadband applications in ISM band.

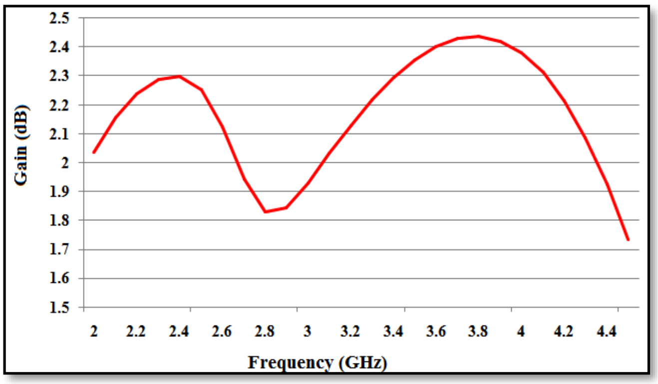

Fig.8. Gain V/s Frequency for bowtie antenna

The parametric study of return loss of bowtie antennas at different angles with constant length is carried out as shown in figure 9 and the achieved results are mentioned in table 1.

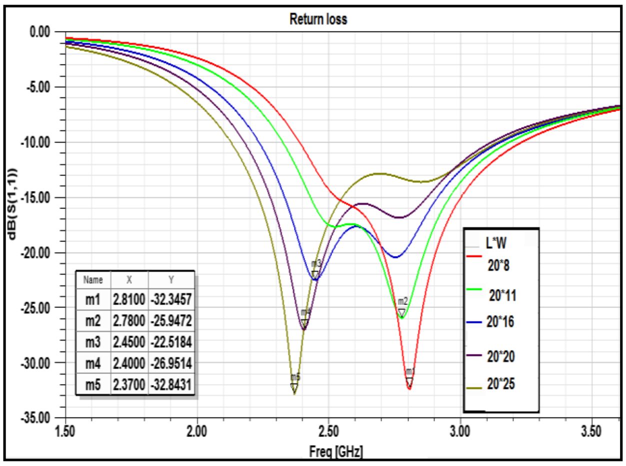

Fig.9. Return loss of bowtie antennas for different angles with constant length

Table 1: Bowtie antennas at different angles with constant length

L × W (mm)	Antenna angle (θ)	Bandwidth (%)	Resonance Frequency (GHz)	Operational Frequency Range (GHz)
20 × 8	23	30	2.81	2.38 to 3.23
20 × 11	31	31	2.78	2.32 to 3.18
20 × 16	44	35	2.45	2.23 to 3.16
20 × 20	53	36	2.41	2.17 to 3.12
20 × 25	64	37	2.37	2.13 to 3.10

Above results reflects that as the angle of bowtie antenna is increased, the bandwidth is also increased and the resonance frequency is decreased. Hence, the length of bowtie antenna has to be varied as per application. To operate the bowtie antennas at 2.4 GHz, antennas are designed at different angles with various lengths as mentioned in table 2 and its return loss is shown in figure.10.

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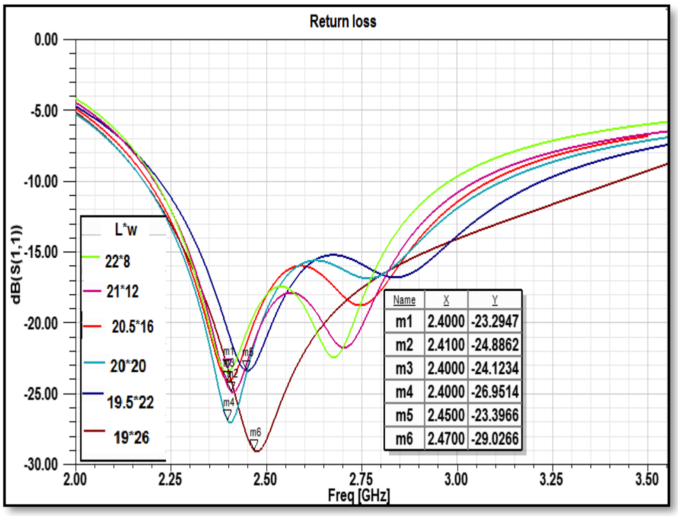

Fig.10. Return loss of bowtie antennas for different angles with a change in length

Table 2: Bowtie antennas at different angles with a change in length

L × W (mm)	Antenna angle (θ)	Bandwidth (%)	Operational Frequency Range (GHz)	Resonance Frequency (GHz)
22 × 8	21	30	2.40	2.20 to 2.98
21 × 12	32	32	2.41	2.21 to 3.02
20.5 × 16	43	34	2.40	2.19 to 3.08
20 × 20	53	36	2.40	2.17 to 3.12
19.5 × 22	59	37	2.45	2.22 to 3.22
19 × 26	68	44	2.48	2.18 to 3.42

4. CONCLUSION

The wideband bowtie antenna using tapered balun feeding technique has been designed for ISM band. From the study, it is found that the bowtie antenna using tapered balun obtained 38% bandwidth with more than 2 dB gain for the entire frequency band. The practically measured results of the proposed antenna are well matched with the simulated results. The proposed antenna achieved a wideband frequency range which will help antenna designers and researchers to design and optimize the antennas for wideband application in 2.4GHz.

ACKNOWLEDGEMENT

The authors would like to thank Dr. J M Rathod– Professor and In-charge - Electromagnetics and Antenna research centre (ELARC), Birla Vishvakarma Mahavidhyalaya, Anand, Gujarat who permitted to test the antenna in their LAB.

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AUTHOR PROFILES

Pravin Dalvadi completed B.Tech in EC from U.V. Patel College of Engineering, Ganpat University in 2010. He completed Master of Engineering in EC from C. U. Shah College of Engineering and Technology, Wadhwan, Gujarat Technological University, Gujarat in 2012. He is pursuing Ph.D. in EC (Antenna Domain) from U. V. Patel College of Engineering, Ganpat University, Gujarat. Currently, he is working as a lecturer in EC Department at Government Polytechnic College Gandhinagar, Gujarat. He has more than 8 years of teaching experience. He has published 5 papers in various journals and conferences. His research interests include Antenna Design and Microwave engineering.

Amrut Patel completed B.E. in EC from H.N.G.U, Gujarat in 2002, M.E. From DDU-Nadiad, Gujarat in 2004. He was awarded Ph.D by Ganpat University in 2017. He has more than 18 Years of Teaching Experience. Currently, he is working as an Associate Professor in EC department in U. V. Patel College of Engineering, Ganpat University, Gujarat. He has published more than 10 papers in various journals and conferences. His area of interest is digital image processing, Antenna Design and Development, and microwave engineering.

D. H. Patel received B.E. (Electronics & Communication Engineering) degree from Saurashtra University Rajkot, M.E. (Electronics & Communication Engineering -Communication Systems Engineering)degree from Gujarat University Ahmedabad and pursuing Ph.D. from Sankalchand Patel University Visnagar. He is currently working as an Assistant Professor in the Electronics & Communication Engineering Department at Government Engineering College, Gandhinagar. His research interests include Antenna Design and Development, VLSI Design, Embedded Systems and Image Processing.

G. D. Makwana received B.E. (Electronics) degree from SVNIT Surat, M.E. (Telecommunication) degree from IISC Bangalore and Ph.D. (Electronics & Communication Engineering) from DA-IICT Gandhinagar. He is currently working as an Associate Professor at Gujarat Technological University-Graduate School of Engineering, Ahmedabad. His research interests include Antenna Design and Development, RF and Microwave and Wireless Communication. He has published more than 20 research articles in peer-reviewed international journals and presented 12 research papers at renowned international conferences as authors and co-authors. He is serving as reviewers in 06 SCI and Scopus index International Journals and 3 reputed International Conferences. He is also serving as Editorial Board Member of International Journal of Electrical Electronics Communications and Computer Science Engineering, South Africa & Journal of Electronics and Communication.

Volume 10, Issue 3
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ITEE Journal
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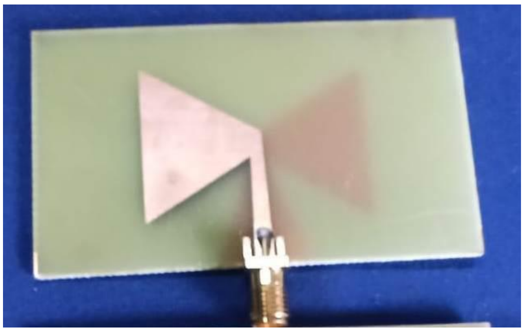
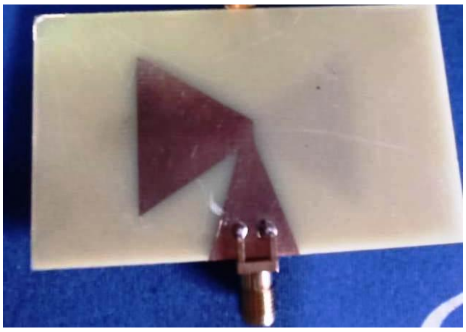
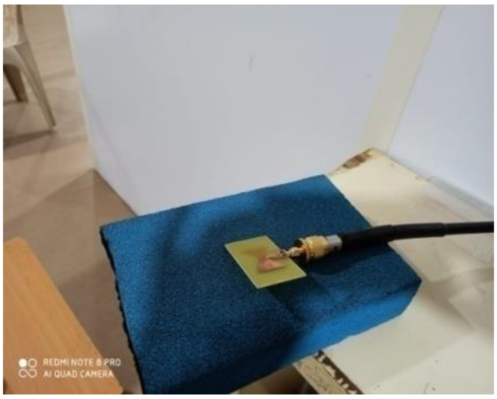
ISSN: - 2306-708X

APPENDIX


Proposed Antenna-Top view

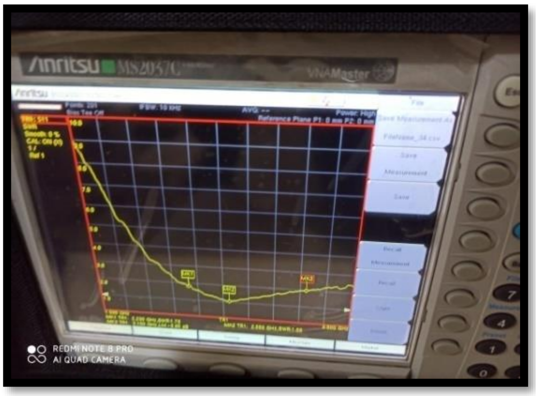

Proposed Antenna-Bottom view

Testing on Anritsu VNA Master



Bowtie antenna using Taper balun

Measured Return loss



Measured VSWR