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

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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 S11 < -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 εr 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.
2. BOWTIE ANTENNA

A bowtie antenna consists of 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 center by Tapered balun and its arms are designed on both sides 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 \( \theta \). Here antenna design parameters are chosen using parametric study which are mentioned as follow: Length \( (L) = 19 \text{ mm} \), Width \( (W) = 26 \text{ mm} \), Length of tapered balun \( (L_f) = 21.5 \text{ mm} \), Top width of Tapered balun at point 1 \( (W_{t1}) = 3 \text{ mm} \), Bottom width of Tapered balun at point 1 \( (W_{b1}) = 15 \text{ mm} \), Top & bottom width of Tapered balun at point 2 \( (W_{t2} & W_{b2}) = 2 \text{ mm} \), and bowtie antenna angle \( \theta = 68^\circ \).

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.

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. 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.
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.

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.

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.

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.
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 hand. 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.

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REFERENCES


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APPENDIX

Proposed Antenna - Top view

Proposed Antenna - Bottom view

Testing on Anritsu VNA Master

Bowtie antenna using Taper balun

Measured Return loss

Measured VSWR