UWB Beveled Edge Rounded Bowtie Antenna

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ABSTRACT:
Beveled edge rounded bowtie antenna is proposed for UWB applications in this paper. Beveling technique is employed to increase the bandwidth of classical bowtie antenna. The simulated bandwidth is from 3 GHz to 11 GHz in order to observe the bandwidth enhancement in the frequency range of interest for UWB applications. Effective parameters of the antenna, including Return Loss (S_{11}), Voltage Standing Wave Ratio (VSWR) and radiation pattern are examined for the proposed structure. Then behavior of the designed antenna is compared with the classical bowtie antenna and rounded bowtie antenna characteristics to verify the enhancement due to the beveled edge structure. Besides, it is demonstrated that the proposed antenna satisfies UWB requirements by providing return loss less than -10 dB and VSWR less than 2, respectively during the enhancement process. Beveled edge rounded bowtie antenna model is designed by using CST Microwave Studio Program which is an electromagnetic simulation auxiliary tool.

KEYWORDS: Antenna Design, Beveling Technique, Bowtie Antenna, CST Microwave Studio, Ultra-Wideband.

1. INTRODUCTION

Ultra-wideband antenna design has been a challenging topic in recent years due to its advantageous features, namely simple planar structures, broadband performance, low cost, ease of installation and ability to print on the same board as transceiver and receiver etc. These advantages enable the bowtie antenna to be used in a great number of applications such as wireless communication, microwave imaging, microwave radar and UWB communications, etc. [1]-[4]. Several bowtie antenna configurations have been proposed in the literature [5]-[8]. Most of the design methodologies are trial and error methods to obtain the UWB requirements by tailoring corners, tips, slots etc. [9].

In this paper, rounded bowtie antenna which has been presented in [10] is modified in order to enhance the antenna performance. First of all, the enhancement is performed by beveling each arm edge to reduce the overall metallic area. The main point here is that cutting slots increase the bandwidth. Slotted bow-tie antennas provide wider bandwidth and better radiation performance depending on the position of the slots in each arm since antenna losses are prevented (the current reflection is mitigated) by decreasing the metallic area [6]. Furthermore, the return loss, VSWR and radiation pattern are improved simultaneously by altering the current distribution on the radiation surface of the proposed antenna due to the existence of beveled corners. On the other hand, the bandwidth characteristics depend on relative permittivity and thickness of the substrate. The paper secondly includes reducing only the relative permittivity in order to improve bandwidth. As the structural parameters of the proposed antenna are adjusted to meet bandwidth requirements according to FCC regulations, then the antenna parameters such as VSWR, return loss and radiation pattern are also affected. Therefore, these effects are also examined and observed during the simulation process.

UWB provides a great deal of valuable properties which are applicable for radar and sensors e.g. the detection of hidden objects, medical anomalies, soil moisture and water pollution [11]-[15]. The proposed UWB radar and sensors are advantageous owing to the fact that these key components provide broader bandwidth and yield finer time resolution than classical narrowband radar and sensors including infrared and ultrasound etc.

In this paper, characteristics of the beveled edge rounded bow tie antenna are investigated in terms of antenna parameters such as VSWR, S_{11}, radiation pattern and antenna impedance. Additionally, bandwidth of the beveled edge rounded bowtie antenna is compared with classical and rounded bow tie antenna structures. CST Microwave Studio (CST MWS) is used during the design and modeling of the structures.

2. BEVELED EDGE ROUNDED BOWTIE ANTENNA

The present section deals with the characteristics of beveled edge rounded bowtie antenna, so as to enhance the performance of classical bowtie antenna, including better return loss (S_{11}), lower VSWR, flatter input impedance and radiation pattern with less distortion. Inasmuch as the other configurations of classical bowtie antenna are not yet ample to cover the whole UWB frequency band (3.1-10.6 GHz), a different approach, namely beveling, is provided to overcome this drawback of antenna design. A great deal of literature survey is available in journals, magazines and conference papers discussing miscellaneous bowtie antennas. The effect of beveled corner is investigated in [6], [16], [17]. Liu et al. [6] investigated the corner effect on the antenna performance by using three different prototypes. Qu and Ruan [16] also focused on three bowtie antenna configurations including quadrate, rounded-edge and triangular shapes. The work of Qu et al. reveals that the existence of the rounded corners has significant effects on the classical bowtie antenna. Kaur and Solanki [17] analyzed also three various shapes of bowtie antenna so as to improve the antenna performance by modifying the edge of each arm. In [17], the flare angle and rounded corner radius effects are examined whether trade-off condition occurs or not. It is also stated that the radius of the rounded corners cannot be changed beyond a certain value due to trade-off condition. In other words, increasing the radius beyond a certain value doesn't make the antenna parameters improve significantly.

In this section, beveling technique is applied for rounded bowtie antenna which has been already simulated and examined in [13]. By using CST Microwave Studio, Transmission Line Method is applied while the effective antenna structure dimensions are preserved so as to compare with other examined bowtie antenna configurations [3], [13]. The proposed bow tie consists of several physical parameters, namely the ground plane, dielectric substrate and two metal arms.

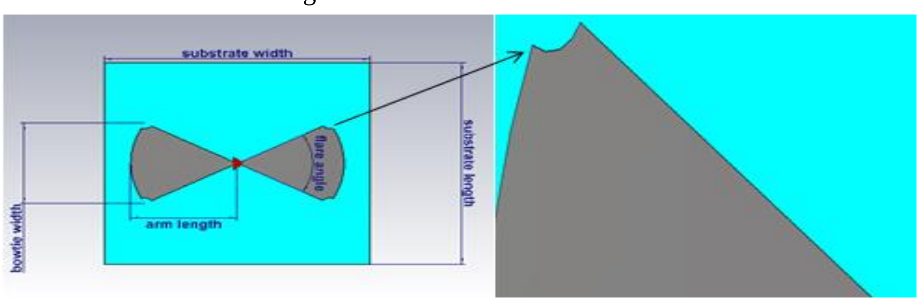
2.1. Antenna Geometry

Figure 1 illustrates front view of the beveled edge rounded bowtie antenna structure which is designed via CST Microwave Studio. Table 1 lists physical parameters of different bowtie antenna configurations with their dimensions.

Beveled Edge Rounded Bow Tie Antenna dimensions are chosen identical with the classical and rounded bowtie antenna configurations [3], [10] in order to observe the improvements in bandwidth and antenna characteristic (Table 1). Gaussian pulse is applied into the port as an excitation signal.

Table 1. Different Bowtie Antenna Structures with Dimensions

Physical Parameters	Classical Bowtie Antenna [3]	Rounded Bowtie Antenna[10]	Beveled Edge Rounded Bowtie Antenna
Arm length (l_e)	55 mm	55 mm	55 mm
Feed gap	0.67 mm	0.67 mm	0.67 mm
Feed width	0.67 mm	0.67 mm	0.67 mm
Metal thickness	0.044 mm	0.044 mm	0.044 mm
Substrate thickness (*H-d*)	0.5 mm	0.5 mm	0.5 mm
Substrate length (*L*)	178.75 mm	137.5 mm	137.55 mm
Substrate width (*W*)	110 mm	137.5 mm	137.5 mm
Relative Permittivity	2	2	2
Flare angle (α)	60^o	60^o	60^o



a) b)

Fig. 1. Beveled edge rounded bowtie antenna's a) front view and b) edge corner view.

2.2. Antenna Simulation & Results

The results obtained from the simulation program are presented in this section. According to Figure 2, -10 dB bandwidth covers the whole UWB frequency range. In fact, -10 dB bandwidth is 8 GHz, extending from 3 GHz to 11 GHz. Figure 2 also illustrates the minimum return loss value which occurs at 4.098 GHz. The numerical value of the minimum return loss is -27.958 dB. Similarly, VSWR in Figure 3 is below 2 (in fact less than 1.55) in the frequency range of interest. Minimum VSWR is 1.083 at 4.098 GHz. Then, figures 2 and 3 indicate that the return loss and VSWR of the proposed antenna meet the UWB requirements defined by FCC.

The real and imaginary parts of the antenna impedance which are plotted by using CST MWS for the proposed antenna are shown in Figure 4. The solid line with squares stands for the real part of the antenna impedance and the dashed line with circles stands for imaginary part of the antenna impedance. Both Imaginary and Real Parts don't fluctuate severely. Besides, it is apparent that the antenna resistance is almost stable and the antenna reactance is considerably small and hence negligible as compared to the resistance in the UWB frequency range. Consequently, the load impedance or transmission line impedance ought to be adjusted by using the antenna impedance shown in Figure 4 in order to achieve the matching condition.

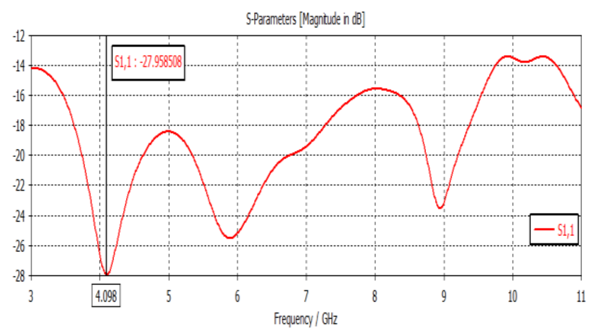


Fig. 2. Return loss characteristic of the beveled edge rounded bow tie antenna.

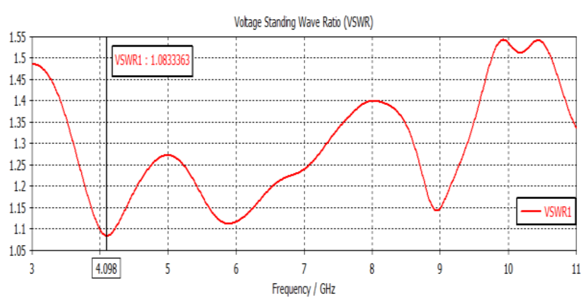


Fig. 3. VSWR plot for the proposed antenna.

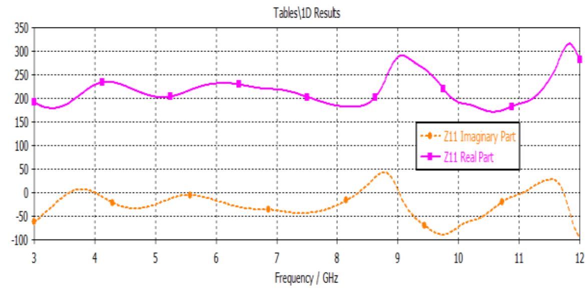


Fig. 4. Real and Imaginary Parts of the Antenna Impedance.

Figure 5 shows the Cartesian representation for the proposed antenna's radiation pattern at the UWB center frequency of 6.85 GHz. Similarly, Figure 6 shows the polar representation for the radiation pattern at the frequency of 6.85 GHz. Figures of 5 and 6 reveal that the main direction of the radiation pattern occurs at ±90°, 3 dB beam width is 59.9°, main lobe magnitude is 2.2 dB and side lobe level is -1.7 dB.

Figures 7 and 8 illustrate the Cartesian and polar representations of the radiation pattern at 10.275 GHz, respectively. According to the figures, the main direction of the radiation pattern occurs at ±90°, 3 dB beamwidth is 18.2°, main lobe magnitude is 6.55 dB, and side lobe level is -7.2 dB. Figure 8 indicates that the radiation pattern characteristic is almost omnidirectional with less distortion which is suitable for UWB applications.

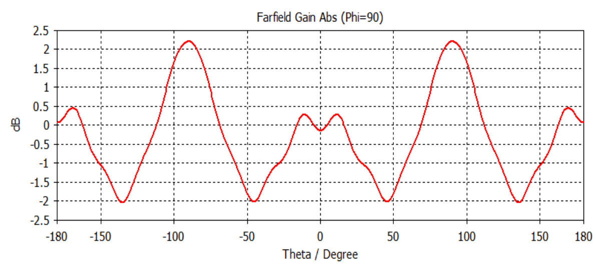


Fig. 5. The Cartesian representation of the radiation pattern at 6.85 GHz.

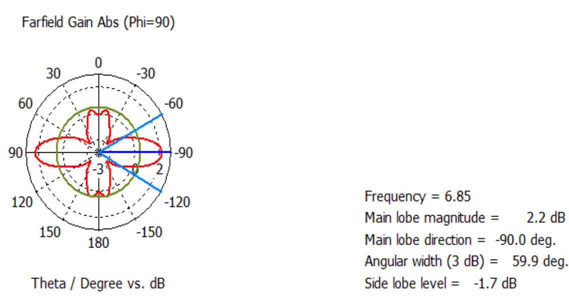


Fig. 6. The polar representation of the radiation pattern at 6.85 GHz.

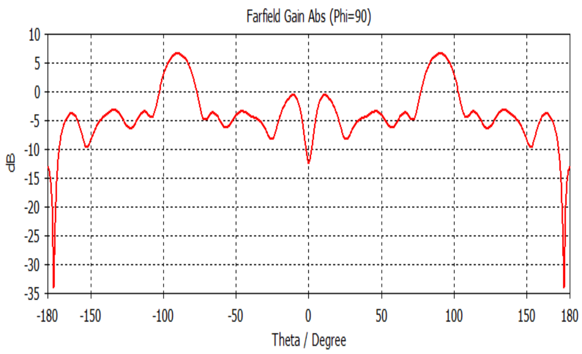


Fig. 7. The Cartesian representation of the radiation pattern at 10.275 GHz.

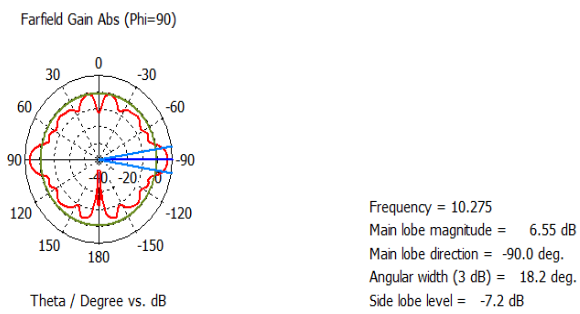


Fig. 8. The Polar representation of the radiation pattern at 10.275 GHz.

2.3. Comparison of Different Structures

Figures 9 and 10 depict the -10 dB bandwidths for the classical bowtie antenna and rounded bowtie antenna, respectively [3], [10]. It is clear from these two figures that the bandwidth of classical bow tie antenna is 7.5 GHz which spans from 3.1 GHz to 10.6 GHz and the bandwidth of rounded bowtie antenna is 7.31 GHz which ranges from 3 to 10.31 GHz. Additionally, as Table 2 indicates, -10 dB bandwidth is improved by beveling the bowtie antenna arm edges as compared to classical bow tie and rounded bowtie antenna structures [3], [10]. Further, the analysis shows that the beveled edge rounded bowtie antenna bandwidth reaches 8 GHz. The resulting bandwidth spans from 3 GHz to 11 GHz which already exceeds UWB frequency range defined by FCC regulations. As a result, the most significant improvement is achieved in bandwidth when the beveled edge rounded bowtie antenna is designed, since there is a strong positive correlation among S_{11}, VSWR and bandwidth for the proposed antenna.

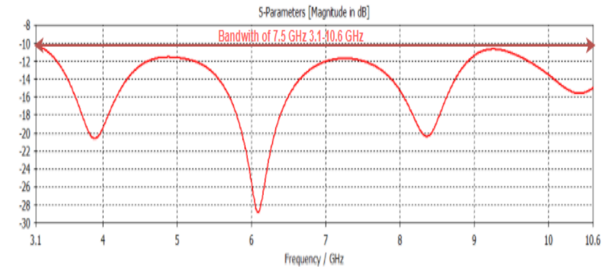


Fig. 9. -10 dB Bandwidth of Classical Bowtie Antenna [3].

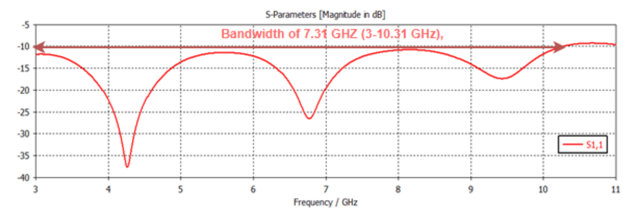


Fig. 10. -10 dB bandwidth of rounded bowtie antenna [10].

Table 2. Comparison of the -10 dB bandwidth of three different antenna structures

Antenna Types	Classical Bow Tie Antenna [3]	Rounded Bow Tie Antenna [10]	Beveled Edge Rounded Bow Tie Antenna
-10 dB Band-width	7.5 GHz (3.1-10.6 GHz)	7.31 GHz (3-10.31 GHz)	8 GHz (3-11 GHz)

3. CONCLUSIONS

In this study, beveled edge rounded bowtie antenna is designed and its characteristic is investigated in order to improve the antenna performance for UWB applications. Behavior of the proposed antenna is examined by observing important antenna parameters such as Return Loss, VSWR, and radiation pattern. Besides, bandwidth of the beveled edge rounded bowtie antenna is compared with classical and rounded bow tie antenna structures. It is deduced from the results that, the proposed antenna performance can be increased significantly by using beveling technique. When radiation pattern for the designed structure is considered, it is observed that the antenna has consistent radiation pattern at each selected frequency. Thus, it is concluded that, the proposed beveled edge rounded bowtie antenna appears to be a good candidate for UWB applications.

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