DESIGN OF A QUASI-RHOMBOID SHAPED ANTENNA WITH CYLINDRICAL PARABOLIC REFLECTOR FOR ULTRA WIDEBAND COMMUNICATIONS

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ABSTRACT

In this paper, we present a quasi-rhomboid antenna with cylindrical parabolic reflector for ultra-wideband communications. The parabolic reflector was modified to a quasi-rhomboid shaped antenna and placed in front of the parabolic reflector at length of about $\lambda/4$ of center frequency, the RF signal that radiates to free space were reflected back to the front by parabolic reflector for increased antenna directivity and improved of radiation patterns. It is designed by using parabolic shaped on aluminum sheet which has important dimensional includes width (D), length (L) and depth (d). This quasi-rhomboid shaped antenna with a 50 Ω microstrip feed line was fabricated on dielectric substrate (FR-4) and antenna analysis was conducted by using the Computer Simulation Technology (CST Studio). The proposed antenna is realized, easy fabrication and low manufacturing cost. In measurement, it is found that the proposed antenna has return loss, less than -10 dB and impedance bandwidth of 118.2 % (2:1 VSWR) which covered frequency range 2.82-10.84 GHz. This antenna has unidirectional pattern.

1. INTRODUCTION

Ultra wideband (UWB) microwave technology has become increasingly popular for high-speed wireless connectivity and high-data because the rise of information consumer. The frequency range for civil UWB communications is between 3.1 GHz and 10.6 GHz promulgated by United State Federal Communications Commission (FCC) in 2002. Originally, UWB technology was mainly used in military precision ranging of radar, angle measurement and convert communication. Compared with the conventional antenna, ultra-wideband antenna has such advantages as small size, light weight, wide bandwidth, low loss, one of the most important applications of UWB is high data rate wireless communication. There are many types of antenna to choose for applying in the appropriate function and system. But one the major requirement of ultra-wideband application is a compact and extremely wideband antenna covering the ultra-wideband spectrum. Micro-strip patch antenna are well candidates for ultra-wideband application due to their exhibit low manufacturing cost (R. Azim & M. T. Islam, 2013), small size and easy method of fabrication (A. Kr Gautam, et al., 2013), (B. Gupta, et al., 2012). However, the radiation pattern of UWB antenna is non-uniform in each frequency because of its wide bandwidth (A. Kr Gautam, et al., 2013). Which, it will affect the gain of antenna, because of it has no definite directivity. Therefore, the goal ultra-wideband antenna designer is to make antenna with unidirectional pattern, simple structure that produces low distortions but can provide large bandwidth.

Recently ultra-wideband antenna development tends to focus on small planar antennas such as slot antennas (P. Gao, et al., 2014), bow-tie antennas (Q. Zhang, et al., 2014), (O. Yurduseven, et al., 2013), (C. Lin, 2012) and elliptical antennas (Vikas, et al., 2014), (Ashraf A. Adam, et al., 2013), (S. Maitil, et al., 2012). Most of the reported all these antennas have Omni-directional radiation patterns and the gain of these antennas are relatively low, about 2-4 dB. When these Omni-directional antennas are attached to wall or metals, it is suspected that the antenna performances can be degraded due to the Omni-directionality. In order to avoid degradation of the antenna performance, we considered placing a parabolic reflector the quasi rhomboid shaped bow-tie antenna. In addition, if the directivity of the ultra-wideband antenna increases as a result of the reflector, higher speed and lower power consumption (R. Azim & M. T. Islam, 2013) communication system can be realized.

This paper presents a quasi-rhomboid shaped bow-tie antenna. The proposed antenna consists of single quasi-rhomboid shaped antenna and aluminum cylindrical parabolic reflector. This antenna is designed on FR-4 substrate and antenna analysis was conducted by using the CST Studio program.

2. ANTENNA DESIGN

The main objective of this antenna is designed to provide large impedance bandwidth. This antenna design was performed for FR-4 substrate, containing metallization on both sides. The most of parameters of using for antenna design such as operating frequency, thickness of substrate and relative permittivity of substrate. The thickness (*t*) and relative permittivity of substrate is 1.6 mm and 4.5, respectively. The analysis and design of dimensions were optimized by using the CST studio program.

2.1 Single Element Quasi-Rhomboid Shaped Bow-tie Antenna

The simulation result by CST studio program, include impedance matching antenna length λ / 4 (λ it means wavelength in substrate.) of center frequency at 6.85 GHz. The antenna dimensional parameters after adjustments are w_0 = 35.5, w_1 = 2.25, w_2 = 2.95, w_3 = 2.35, w_4 = 1.59, w_5 = 4.95, w_6 = 15.69, l_0 = 20.5, l_1 = 20.5, l_2 = 7.75, l_3 = 0.5, l_4 = 2.5, l_5 = 1.25, l_6 = 7.8, l_Θ = 4.8, unit all in millimeter, and edge chamfer = 45˚. This antenna consists of two identical printed patches, one on the top and one on the bottom of the substrate material. The detailed geometry and parameters of the proposed antenna are illustrated in Fig. 1.

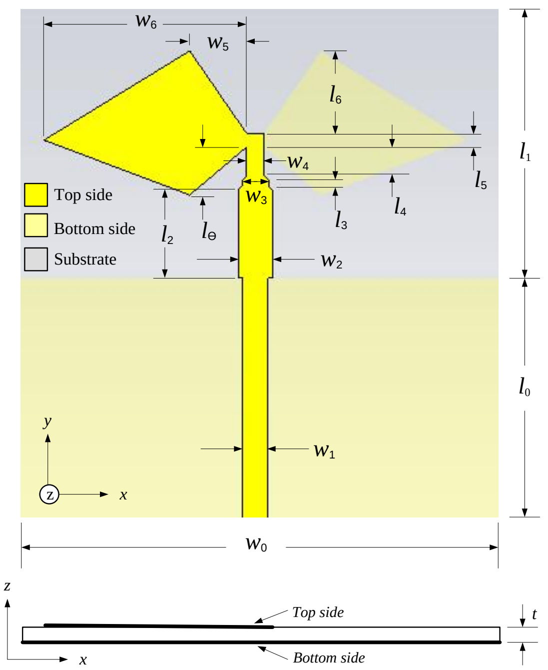


Fig. 1 Structure and parameter of a single quasi-rhomboid shaped bow-tie antenna

2.2 Single Element Quasi-Rhomboid Shaped Bow-tie Antenna with Parabolic Reflector

The parabolic reflector shaped was designed on aluminum sheet has dimensional width (D), length (L) and depth (d) is shown in Fig. 2. The dimension of reflector was calculated by radius which reflector size is depend on radius and angle of sector (Ө).

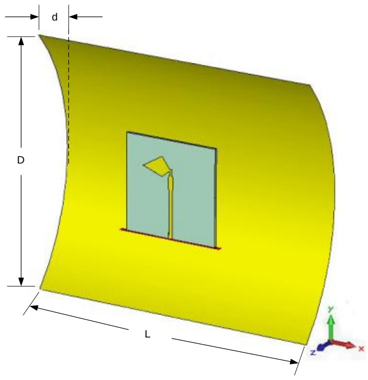


Fig. 2 Structure and parameter of a single quasi-rhomboid shaped bow-tie antenna with reflector

A prototype of a quasi-rhomboid shaped bow-tie antenna with parabolic reflector presented in Fig. 3

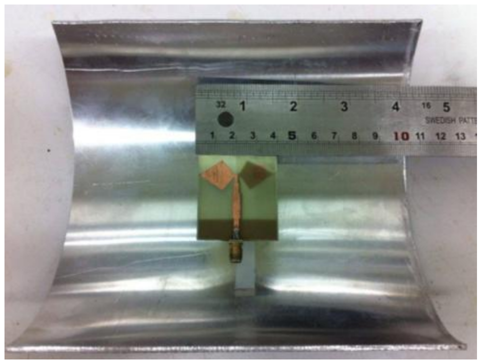
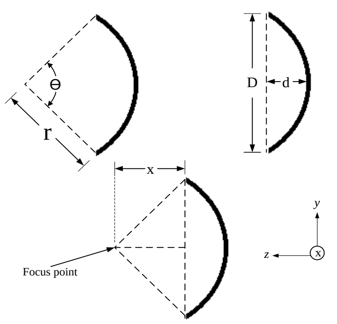


Fig. 3 Fabricated prototype of a single quasi-rhomboid shaped bow-tie antenna with reflector

2.3 Parabolic Reflector Calculation

The reflector was designed by used circle part shaped which it like parabolic but not altogether because of parabolic shaped it is variable squared, thus the reflector was designed by circle part due to it is easy. The detailed geometry and parameters of a reflector are illustrated in Fig. 4.



$$D = 2r\sin\theta/2$$

$$x = r\cos\theta/2$$

$$d = r - x$$

Fig. 4 Structure and parameter of a parabolic reflector

Determine the parameter of reflector L= $4w_0$ and D = $3(l_0 + l_1)$ that reflector to provide cover for the antenna, the single element antenna was located in front of the parabolic reflector at length of about $1/4$ lambda (λ) of center frequency (f_c). This antenna has center frequency at 6.5 GHz. The various parameter of parabolic reflector can be calculated as follows, when the angle of sector was determined by $\Theta = 90^\circ$, L = 142, D = 123, r = 86.9, d = 25.4 and $\lambda/4$ = 11.5, unit all in millimeter. The position between reflector and single element antenna is shown in Fig. 5.

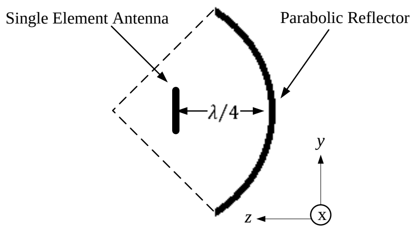


Fig. 5 Structure and position of a single element antenna and parabolic reflector

3. MEASUREMENT AND RESULTS

3.1 Return Loss

Fig. 6 plot both single element antenna without reflector and single element antenna with reflector for input return loss. The return loss of the proposed antenna is measured by using a HP8722D vector network analyzer. The measured return loss has a bandwidth cover frequency range of 2.83-10.95 GHz, 2.82-10.84 GHz for single element antenna without reflector and single element antenna with reflector, respectively. This shown that the bandwidth achieved in single element antenna with reflector using a parabolic reflector is less than the single element antenna without reflector about 1.2%.

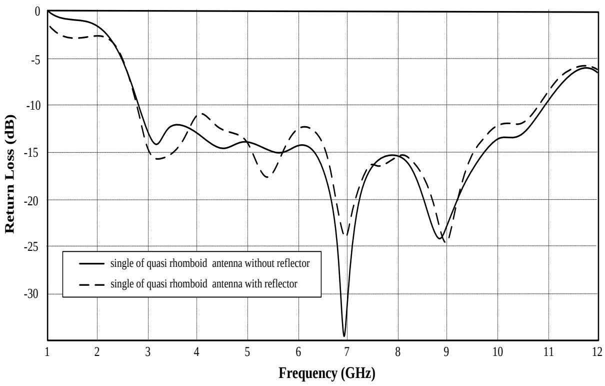


Fig. 6 Return loss for single element antenna without reflector and single element antenna with reflector

3.2 GAIN

Fig. 7 shows the gain of the both antennas is measured by using vector network analyzer. The measured two port by using identical antennas and the distance between the two antennas about 20 cm. From this fig. 7, reasonable average gain level is about 4 dB and 6 dB for a single element antenna without reflector and single element antenna using parabolic reflector, respectively. In measurement, it found that a single element antenna has average gain less than the single element with reflector about 2 dB.

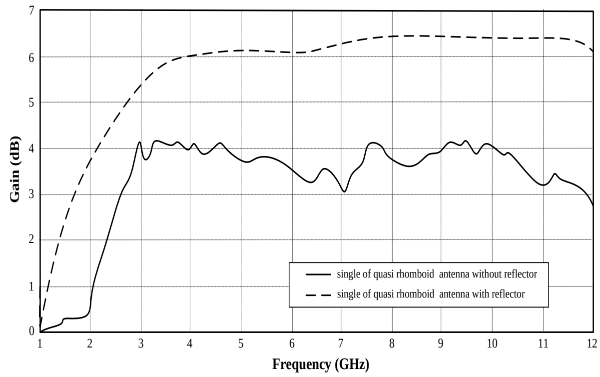


Fig. 7 The measured gain for a single element antenna without reflector and single element antenna with parabolic reflector

3.2 RADIATION PATTERNS

The far-field radiation patterns were measured in an anechoic chamber. The antenna patterns are measured at selective frequencies that cover the entire operating band, and the results are presented in Fig. 8 a) and b) in the E-plane and H-plane at frequency 3.1, and 9.1 GHz. When is received at 45 cm, 65 cm from the transmitting antenna for a single element antenna and a single element with reflector, respectively. The proposed antennas are their stable radiation patterns. It can be seen that the quasi rhomboid shaped without reflector is satisfactorily omnidirectional patterns in azimuth plane and the quasi rhomboid shaped with reflector have unidirectional patterns.

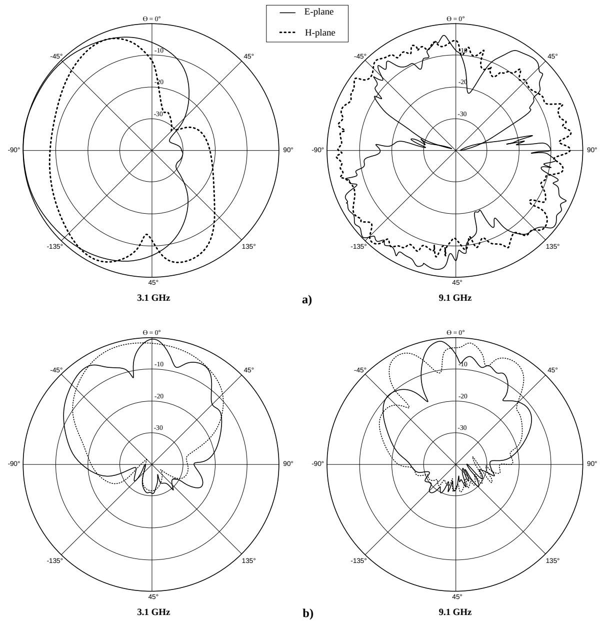


Fig. 8 the measured E and H plane radiation patterns for a quasi-rhomboid shaped at 3.1, and 9.1 GHz, a) single element antenna without reflector, b) single element antenna by using parabolic reflector

CONCLUSION

In this paper, a quasi-rhomboid shaped element bowtie antenna designed by using a parabolic reflector is presented. The proposed antenna provides a wide impedance bandwidth covered frequency range 2.82-10.84 GHz. The proposed antenna has a measured return loss less than -10 dB over the operating frequency for ultra-wideband applications. This antenna pattern has unidirectional radiation patterns at the considered frequency band. The quasi rhomboid shaped antenna with reflector has average gain more than the quasi rhomboid shaped without reflector about 2 dB. The proposed antenna is designed on FR-4 substrate, since it is small size, easy construction and very low cost. For lead to use benefit in designed receiver-transmit system of ultra-wideband technology.

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NOMENCLATURE

a : directivity
b : Omni-directional
c : decibel [dB]

Subscripts

UWB : ultra-wideband

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