Design of an UWB Quasi Rhomboid Shaped Element Bowtie Antenna for MIMO Applications

T. Phairat and T. Chanchai

Abstract—**An ultra wideband quasi rhomboid shaped element bowtie antenna design for MIMO applications is presented. The regular dipole antenna and bow-tie shape are modified to a quasi rhomboid shape. This antenna is designed on FR-4 substrate and antenna analysis was conducted by using the Computer Simulation Technology (CST Studio) program. The proposed antenna is realized and experimentally examined, since it is small size, light weight, easy method fabrication and low manufacturing cost. In measurement, it is found that the proposed antenna has a return loss less than -10 dB and impedance bandwidth of 130.93 % (2.4-11.5 GHz) with an isolation characteristic below -20 dB all over the operating frequency. Additionally, the envelop correlation coefficient is lower than -35 dB. The advantage of the quasi rhomboid shaped element bowtie antenna is that it can be used to MIMO, WiBro, WiMax and Bluetooth applications.**

Index Terms— **quasi rhomboid, ultra wideband, MIMO, WiBro, WiMax, MIMO, Bluetooth**

I. Introduction

THE demands for broadband services by wireless communication systems are rapidly growing. Future wireless systems will provide various services such as broadband multimedia and high speed access. Large channel capacity and high spectral efficiency are essential factors in providing various multimedia services for current mobile communication systems. A wireless communication system in which multiple antennas are used within a small device is one solution to satisfy these demands. A solution for this requirement is Multiple-Input Multiple-Output (MIMO) radio systems that can transmit several parallel data streams simultaneously. It can increase the capacity of a system enormously. By increasing the number of antenna elements and the spacing between them, the capacity of such a system for a large angular-spread environment increases [1]. But, increasing signal correlation, as more antennas are placed into the array, significantly degrades MIMO performance, because mutual coupling exerts tremendous influence on this system which led ultimately to poor performance. [2].

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However, it is very difficult to reduce the mutual coupling between antenna elements in a multi-input multi-output (MIMO) system as antennas must be installed within the limited space inside a handheld device. Recently, various research efforts have been attempted to solve this problem. In an environment of limited space, MIMO system can be accomplished by utilizing the independence of the propagation paths of the two different polarizations [3]. Dong et al. [4] simulated the channel capacity of MIMO system by exploiting multiple polarizations with a tri-monopole antenna. This kind of antenna offers channel capacity that approaches the capacity of an uncorrelated MIMO Rayleigh channel. Moreover, it was shown that the increase in channel capacity is due mainly to polarization diversity, not pattern diversity. Waldschmidt et al. [5] showed that a system based on the combination of polarization and spatial diversity is best-suited for the situation where a trade-off between space and capacity has to be made. Furthermore, can be accomplished by using a ground wall and cancelling field [6], [7], utilize a slot cut on the ground [8].

In this paper, a quasi rhomboid shaped element bowtie antenna designed with good isolation, intended for ultra wideband MIMO applications, is proposed. The antenna consists of two identical antenna elements. The configuration of the proposed ultra-wideband (UWB) MIMO antenna is shown in section II. This antenna is designed on FR-4 substrate and antenna analysis was conducted by using the CST Studio program. The conventional characteristics of antennas like impedance matching, S-parameter, radiation patterns, mutual coupling and correlation as well as preview the evaluation capacity have been presented. The proposed antenna is realized and experimentally examined, since it is small size, light weight, easy method fabrication and low manufacturing cost. In measurement, it is found that the proposed antenna has a return loss less than -10 dB and impedance bandwidth covered the frequency range of 2.4-11.5 GHz with mutual coupling below -20 dB all over the operating frequency. Additionally, the envelop correlation coefficient is (ECC) lower than -35 dB. The advantage of this antenna is that it can be used to MIMO, WiBro, WiMax and Bluetooth applications.

II. Antenna Design and Fabrication

The main objective of UWB MIMO antenna designed is to provide large impedance bandwidth, compact and low mutual coupling. The proposed antenna design was performed for

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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 and relative permittivity of the substrate is 1.6 mm and 4.5, respectively. The analysis and design of antenna dimensions were optimized by using the CST Studio program.

The simulation result by CST Studio program, include impedance matching antenna length $\lambda/4$ (λ it mean wavelength in substrate.) of center frequency at 6.85 GHz. The antenna dimensional parameters after adjustments are w = 36.9, w_1 = 1.95, w_2 = 2.95, w_3 = 2.65, w_4 = 1.59, w_5 = 4.95, w_6 = 11.69, l = 10.55, l_1 = 30.5, l_2 = 11.95, l_3 = 3.65, l_4 = 2.5, l_5 = 1.25, l_6 = 7.8, unit in millimeter, $\theta_1 = 45^\circ$ and $\theta_1 = 115^\circ$. 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.

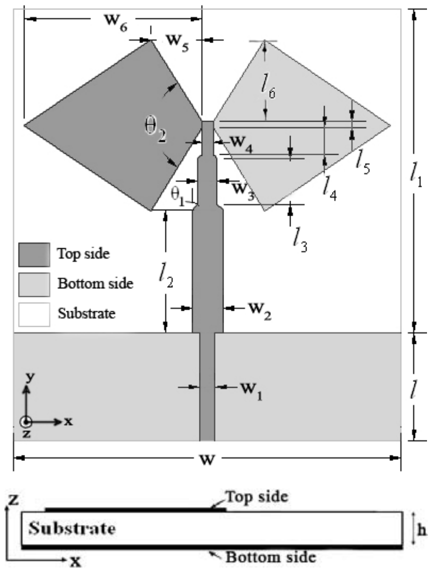

Fig. 1. Structure and parameter of a quasi rhomboid shaped element bowtie antenna.

The configuration of the proposed ultra-wideband (UWB) MIMO antenna is shown in Fig. 2. The antenna consists of two identical antenna elements located symmetrically with respect to the axis. The antenna dimensional parameters after adjustments are w = 83.45, w_1 = 45.95, w_2 = 1.5 unit in millimeter,

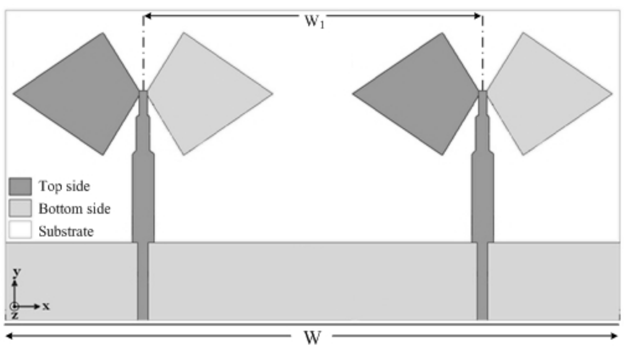

Fig. 2. Configuration of the quasi rhomboid shaped element bowtie antenna for ultra wideband MIMO applications.

A prototype of quasi rhomboid shaped element bowtie antenna and built with the dimensions presented in Fig. 1 is shown in Fig. 3.

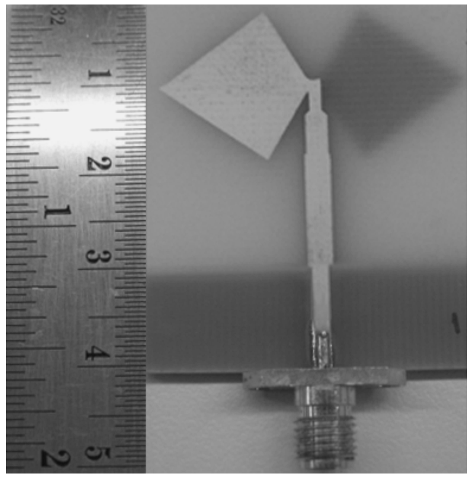

Fig. 3. Fabricated prototype of a quasi rhomboid shaped element bowtie antenna

The configuration of quasi rhomboid shaped element bowtie array antenna for ultra wideband MIMO applications built with the dimensions presented in Fig. 2 is shown in Fig. 4

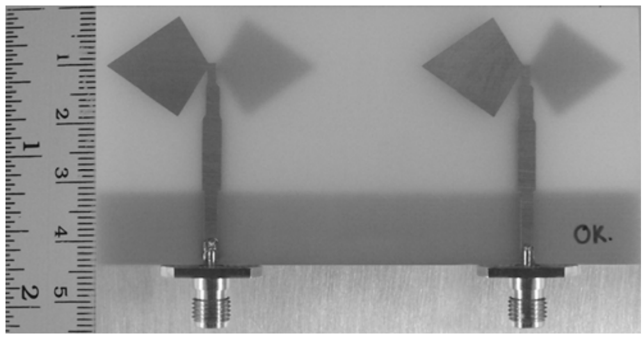

Fig. 4. Fabricated prototype of two elements array antenna for ultra wideband MIMO applications.

III. Measurement and Results Discussion

A. *S-Parameter Characteristic*

The design of antenna systems on the basis of idea of using MIMO techniques combined with UWB systems has been discussed. The conventional characteristics of antennas like impedance matching, S-parameter and mutual coupling. Fig. 5 Illustrate the S-parameter characteristics of quasi rhomboid shaped element bowtie antenna prototype. The S-parameter characteristics of the fabricated antenna are measured by using a HP 8722D vector network analyzer. The measured input return loss (S_{11}) has a bandwidth (VSWR < 2:1) of 134.54% covered frequency range of 2.4-11.5 GHz. The measured results show that the -10-dB S-parameter requirement is satisfied over the frequency band of 2.4–11.5 GHz, and the isolation characteristic between the two antennas is less than -20 dB over the entire bandwidth, which is shown in Fig. 6. In addition, it presented the results of gain, radiation patterns, correlation coefficient and capacity evaluation in the next subsection.

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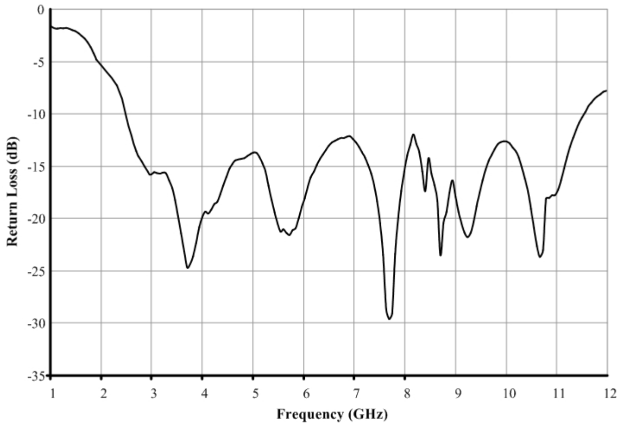

Fig. 5. The measured return loss (S_{11}) for a quasi rhomboid shaped element bowtie antenna prototype.

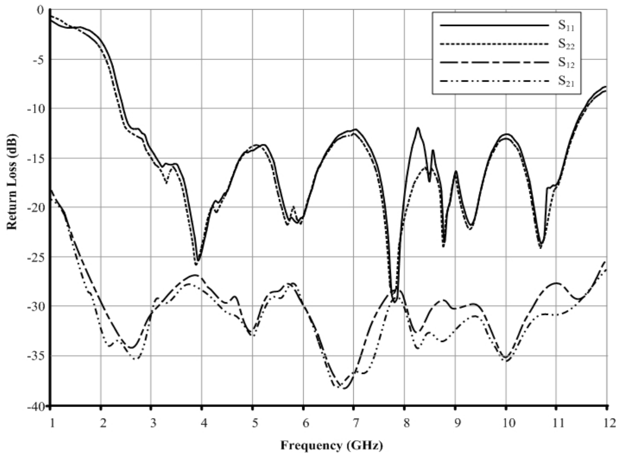

Fig. 6. Measured S-parameter characteristics of two elements array antenna for ultra wideband MIMO applications.

B. Gain

Fig. 7 shows the measured average gains of each antenna are measured by using vector network analyzer. From this figure, reasonable average gain level is about 4 dB indicates that the proposed antennas have good gain flatness.

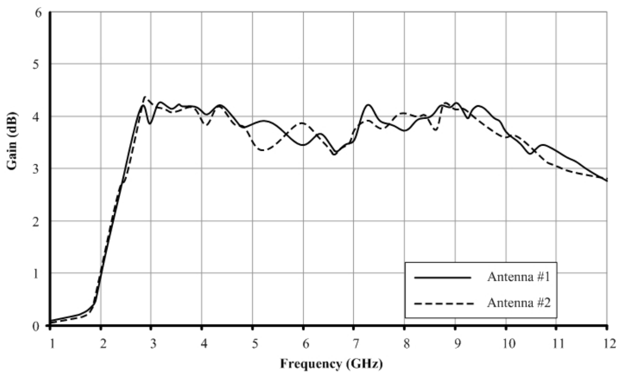

Fig. 7. Measured average gain of two elements array antenna for ultra wideband MIMO applications.

C. Radiation Pattern

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 in the E-plane and H-plane, respectively, at frequency 2.5, 5 and 9 GHz. When is received at 65 cm from the transmitting antenna of each antenna are measured by using vector network analyzer. The proposed antennas are their stable radiation patterns. It can be seen that the antenna is satisfactorily in the considered frequency band. Referring to the Fig. 8 the measured E and H planes cross-polarization is not show because it is very low.

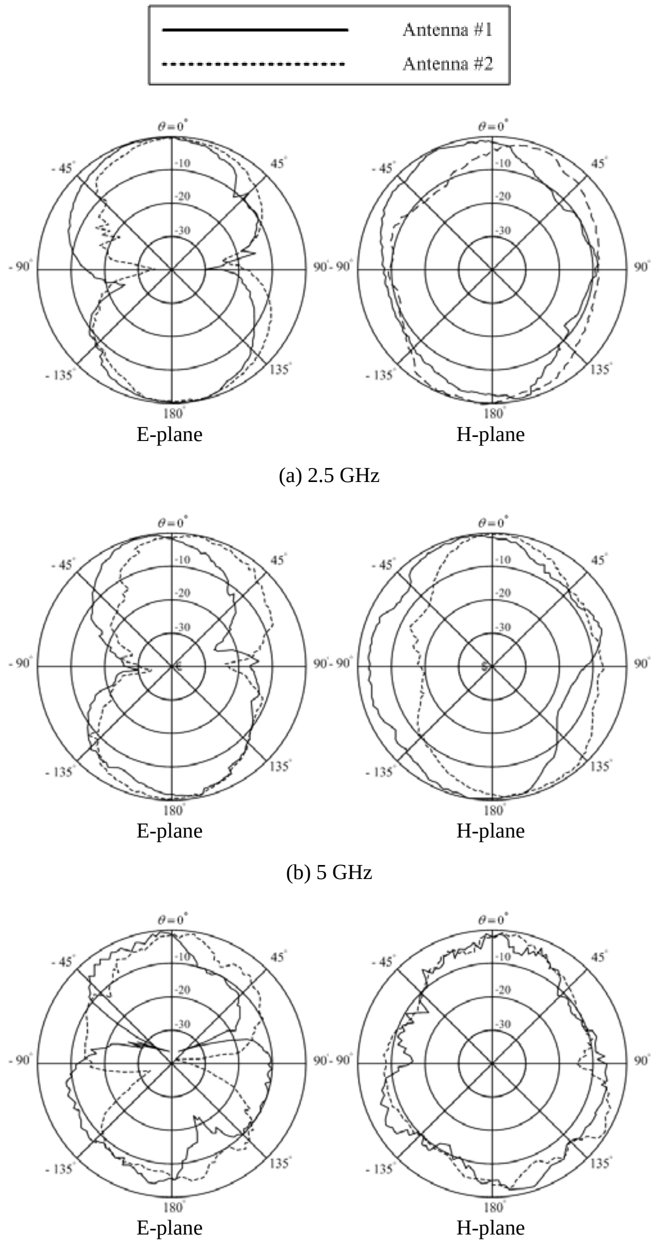

Fig. 8. The measured radiation patterns of the proposed antenna at 2.5, 5 and 9 GHz.

For a MIMO application, the degree of correlation between two antenna elements becomes important to evaluate the diversity capabilities for MIMO applications. To evaluate the MIMO capabilities of a multiple antenna system, the envelope correlation coefficient (ECC) is typically evaluated. It is required to minimize the correlation because the relationship of the correlation with diversity gain is that the lower the correlation, the higher will be the

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diversity gain and vice versa. The correlation coefficient can be calculated from radiation patterns or scattering parameters. For a simple two-port network, assuming uniform multipath environment, the envelope correlation (ρ), simply square of the correlation coefficient, can be calculated conveniently and quickly from *S*-parameters [9], using Eq. (1) given as.

$$\rho = \left| \frac{S_{11}^{*}S_{12} + S_{12}^{*}S_{22}}{(\sqrt{1-|S_{11}|^{2}-|S_{21}|^{2}})\cdot(\sqrt{1-|S_{22}|^{2}-|S_{12}|^{2}})} \right|^{2} \qquad (1)$$

The envelope correlation coefficient is shown in Fig. 9. It is calculated from the measured S-parameters of the proposed antenna using Eq. (1). As per results, very low value of correlation coefficient ensures high diversity gain.

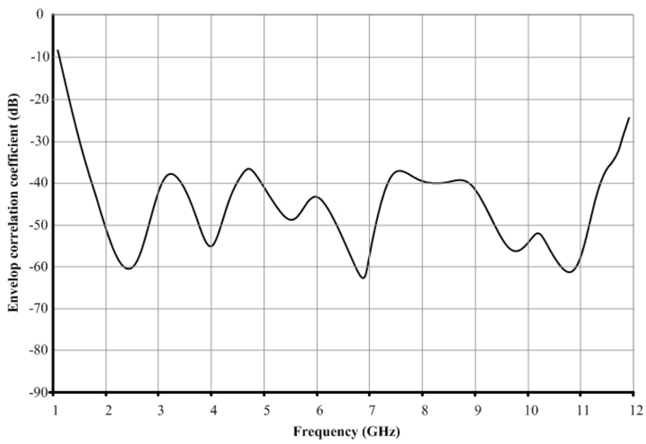

Fig. 9. The envelope correlation coefficient characteristics for the proposed antenna.

Fig. 10 shows the example measured CCDF of capacity of a quasi rhomboid shaped element bowtie antenna for MIMO application (2.45 GHz and 5.8 GHz) are measured by using signal analyzer (MXA N9020A). The proposed antenna has a CCDF of capacity at a frequency of 5.8 GHz more than the frequency 2.45 GHz, because the again of the proposed antenna at a frequency of 5.8 GHz greater than the frequency 2.45 GHz.

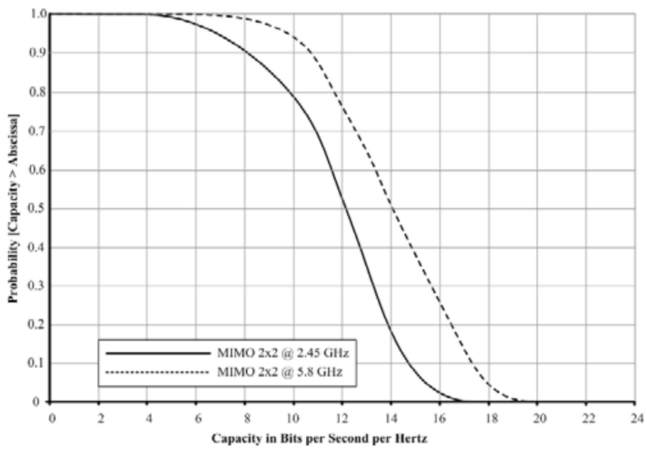

Fig. 10. CCDF of capacity for a quasi rhomboid shaped element bowtie antenna.

IV. Conclusions

In this paper, a quasi rhomboid shaped element bowtie antenna designed with good isolation, intended for ultra wideband MIMO applications, is proposed. The antenna consists of two identical antenna elements located symmetrically with respect to the axis. This antenna is designed on FR-4 substrate and antenna analysis was conducted by using the CST Studio program. The proposed antenna is realized and experimentally examined, since it is small size, light weight, easy method fabrication and low manufacturing cost. The design of antenna systems on the basis of idea of using MIMO techniques combined with UWB systems has been discussed. The conventional characteristics of antennas like impedance matching, S-parameter, radiation patterns, mutual coupling and correlation as well as preview the evaluation capacity have been presented. In measurement, it is found that the proposed antenna has a return loss less than -10 dB. The designed antenna systems work efficiently in the band of 2.4-11.5 GHz with mutual coupling below -20 dB all over the operating frequency. Additionally, the envelop correlation coefficient is (ECC) lower than -35 dB. These antenna systems can be employed in MIMO, WiBro, WiMax and Bluetooth applications.

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