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A Multiband MIMO Antenna with Enhanced Isolation for Wireless Applications

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Abstract

The article presents a compact dual-element multiband Multiple Input Multiple Output(MIMO) antenna suitable for wireless applications. The E shaped radiating element loaded with extra slots make it suitable to operate under different frequencies with enhanced isolation of -25dB or more for the entire bands. The E-shaped patch which is less vulnerable for mutual coupling and the orthogonal arrangement of radiating elements helps in achieving high isolation between elements over the entire operating band. The coaxially fed antenna can operate over DCS1800, PCS1900, LTE, WLAN, Bluetooth, WiMAX, and also in the sub-6 5G bands. The substrate used in the design is FR4 which has a relative permittivity of 4.4 and a loss tangent of 0.02. The proposed structure has an overall dimension of 78 x 40 x 1.6mm^3 with a spacing of 8 mm between the elements.

1 Introduction

With the rapid growth in wireless communication technology, the trend is to support multiple standards on a single device and its miniaturization. This resulted in the necessity of antennas that can handle multiple frequency bands with wide bandwidth overcoming the biggest disadvantage of the narrow bandwidth of the conventional microstrip patch antennas. Several techniques have been put forward to make the antennas into multiband with wide bandwidth to cover the entire application bands. The techniques include (1)use of air as a substrate or increased substrate size[1], (2) addition of parasitic patches stacked on the top of main patch [2], (3) patch antennas loaded with slots on its ground plane [3][4], (4) introducing slots into patches. Designs (1) and (2) will increase the overall size of the antenna which is not much desirable. The successful examples of design 4 include E-shaped patch antennas[5],[6],[7],[8], and U slot patch antenna[9]. Among these E shaped patches is less vulnerable to coupling when multiple ones have placed adjacently [8][10].

Modern wireless systems demanding a high bit rate and channel capacity for transferring enormous data of multimedia services. The MIMO technology is a promising solution for modern communication systems that utilize multipath transmission of signals through spatially parallel channels between isolated multiple antennas without utilizing extra power and bandwidth. The mobile communication standards such as LTE, WiMAX, WLAN, and all-new 5G incorporate MIMO technology [11].

One of the major challenges in designing a MIMO system is the mutual coupling that arises between antenna elements when it is placed on the same substrate. Placing the radiating elements far apart can reduce mutual coupling significantly [10] but it is not a practical solution in space-limited systems such as mobile terminals. Various decoupling structures such as (1) use of parasitic elements[11][12] (2) use of protruding grounded branch [13] (3) loading slots in patch and ground [14] etc are solutions for good isolation. All the above techniques employ decoupling structures that lead to additional design modifications in the overall antenna structure and thus increases the complexity. Mutual coupling between radiating elements can be reduced by the orthogonal arrangement of radiating elements [15]. This results in a better design even in the absence of decoupling structures without compromising the isolation between ports.

In this paper, a two-element MIMO design with modified E shaped antenna elements is proposed. High isolation between radiating elements is achieved by orthogonally placing them. The proposed design can operate under cellular, Wi-Fi, Bluetooth standards, etc.

2 Antenna Design

The proposed design is evolved from E shaped patch antenna. The design has a much wider bandwidth to operate under all the desired application bands under 6 GHz. The schematic diagram of the proposed design is shown in Figure 1. All the dimensions are indicated in the figure. Each dimension of the patch is fixed after rigorous optimizations for the best results. The radiating elements are placed at 90 degrees which ensures orthogonal polarizations and high isolation between ports of radiating elements. The antenna is designed on FR-4 substrate of relative permittivity 4.4, loss tangent 0.02, and a size of 41 mm x 78 mm x1.6mm with a spacing of 8 mm between the elements. The antenna elements are fed by a 50ohm coaxial probe feed technique through an SMA connector. The analysis has been done using Ansoft HFSS and measurements using the vector network analyzer PNA E862B.

3 Results and Discussion

The reflection coefficient of the proposed E-shaped antenna has been done at first and the authors have configured different orientations for MIMO implementation. The reflection coefficient of a single E-shaped antenna and the reflection and transmission coefficient of an orthogonally placed MIMO structure is shown in Figure 2. It shows isolation greater than -25dB for the operating bands. The proposed antenna covers the cellular standards such as 2G bands (DCS1800, PCS1900), 3G (UMTS2100),4G LTE bands(1.8-2.6GHz,3.5-3.7GHz), three WiMAX bands (2.30–2.36, 2.50–2.90, and 3.3–3.8 GHz)which also include 5G sub-6GHz band, the WLAN bands (2.40–2.485, 5.15–5.35, 5.725–5.825 GHz) and the Bluetooth bands(2.4GHz).

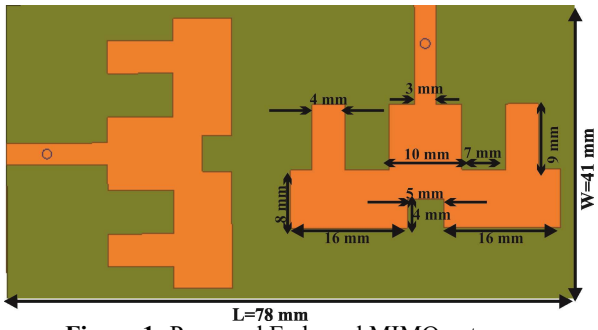

Figure 1: Proposed E-shaped MIMO antenna

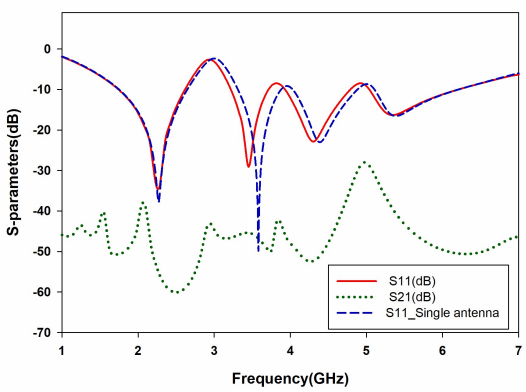

Figure 2: S-parameters of the proposed antenna

The MIMO structure is also designed by placing the two identical radiating elements side by side with side wings parallel to each other and radiating elements as mirror images to each other. The S-parameters for both the case are shown in Figure 3. The mutual coupling in both cases seems to be more than the orthogonal placement of antenna elements. Interference between two orthogonally polarized antennas is minimum which reduces the field coupling and thereby increasing isolation between closely placed antenna elements.

The main two causes of mutual coupling are surface wave coupling between antennas fabricated on a single substrate and current flowing through their shared ground. To study the reason for mutual coupling, the surface current at a frequency of 3.45 GHz has been plotted by separately exciting port 1 and port 2, and the plots are depicted in Figure 4. From the figure, the mutual coupling seems to be minimum between the antenna elements as they are orthogonal.

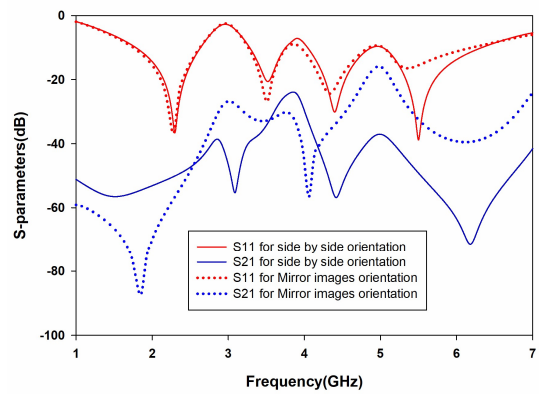

Figure 3: S-parameters for different orientations of antenna elements

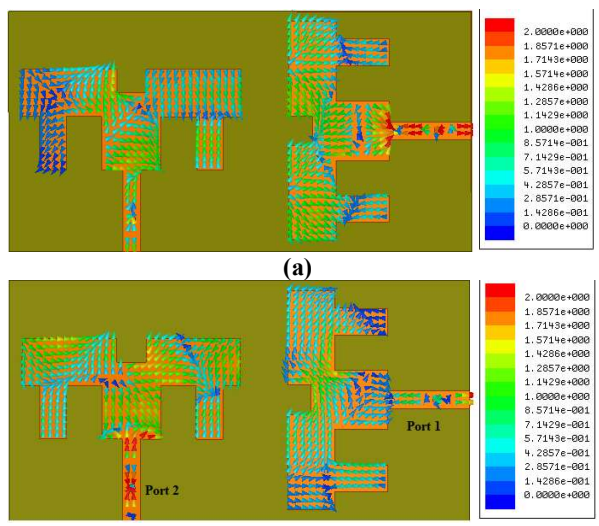

Figure 4: Surface current distribution when **(a)** port 1 is excited **(b)** port 2 is excited

The simulated 2D and 3D radiation pattern of the proposed MIMO antenna when excitation at port 1 & 2 at 3.4 GHz is shown in Figure 5. The radiations show the polarization diversity of the proposed antenna system. The variation in direction of radiation of the port 1 and 2 indicates pattern diversity as shown in Figure 5.

The diversity characteristic of the MIMO system can be explained by the Envelope Correlation Coefficient (ECC) which indicates the correlation between amplitudes of individual antenna elements. ECC is normally calculated from either S-parameters or far-field radiation patterns. Even though the ECC calculated from far-field radiation pattern is preferred for accurate results, ECC calculated from S-parameters are common due to its simple expression as shown in Equation (1).

$$ECC = \frac{|S_{11}^{*}S_{12}+S_{21}^{*}S_{22}|^{2}}{(1-(|S_{11}|^{2}+|S_{21}|^{2}))(1-(|S_{22}|^{2}+|S_{12}|^{2}))} \quad (1)$$

The ECC is calculated for the proposed design using the above expression and is depicted in Figure 6.

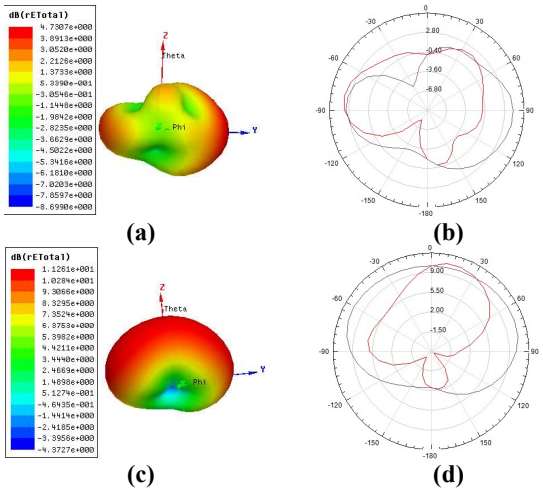

Figure 5: Radiation pattern at 3.4 GHz **(a)& (b)** when port 1 excited **(c)&(d)** when port 2 excited

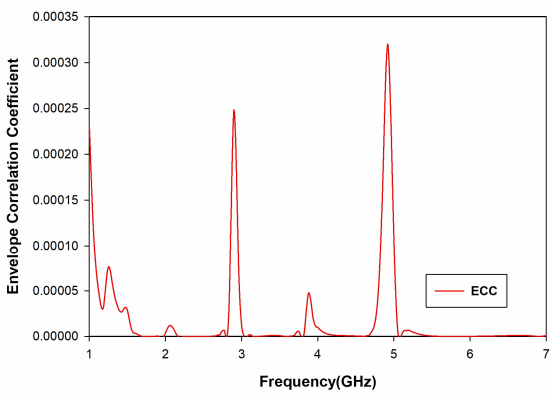

Figure 6: Envelope Correlation Coefficient(ECC) for the proposed antenna

The nearly zero value of ECC as shown in Figure 6 indicates decoupled ports and better diversity characteristics.

4 Conclusions

A multiband Multiple Input Multiple Output(MIMO) antenna with enhanced isolation for mobile terminals is presented. The proposed structure integrates 2G, 3G, 4G, Bluetooth, and Wi-Fi capabilities which helps in the reduction of the number of antennas in mobile terminals. High isolation of S21 <-25dB is achieved for entire operating bands by employing diversity technique. The absence of decoupling structures makes the proposed design simple and compatible.

5 References

1. A. F. A Ayoub., “Analysis of rectangular microstrip antennas with air substrates,” *Journal of Electromagnetic Waves and Applications*, 17, 12, 2003, pp1755–1766, doi.org/10.1163/156939303322760335.

2. D. M. Pozar, “Microstrip antenna coupled to a microstrip-line,” *Electron. Letters.*, 21, 2, Jan. 1985. pp. 49–50.

3. Singh S., Bharti, “A Multiband Antenna with Enhanced Bandwidth for Wireless Applications Using Defected Ground Structure”. *Recent Trends in Communication, Computing, and Electronics. Lecture Notes in Electrical Engineering,* 524,2017, pp.95-101 doi.org/10.1007/978-981-13-2685-1_11.

4. A. Mahesh, K. S. Shushrutha and R. K. Shukla, "Design of multi-band antennas for wireless communication applications," *2017 IEEE Applied Electromagnetics Conference (AEMC)*, Aurangabad, 2017, pp. 1-2, DOI: 10.1109/AEMC.2017.8325718.

5. Ang, Boon-Khai & Chung, Boon.,” A wideband E-shaped microstrip patch antenna for 5-6 GHz wireless communications”. *Progress In Electromagnetics Research.* 75, 2007, pp.397-407, 10.2528/PIER07061909 .

6. Abdelrazzak, Maher & Al-Nomay, Ibrahim.” A Modified E-Shaped Microstrip Antenna for Ultra-Wideband and ISM band applications”, 2010. IJCSNS. 10.

7. F. Yang, Xue-Xia Zhang, Xiaoning Ye and Y. Rahmat-Samii, "Wide-band E-shaped patch antennas for wireless communications," in *IEEE Transactions on Antennas and Propagation*, 49,7, July 2001, pp. 1094-1100, doi: 10.1109/8.933489.

8. M.B.Kadu, R.P.Labade, A.B.Nandgaonkar,” Analysis and Designing of E-Shape Microstrip Patch Antenna for MIMO Application”, *International Journal of Engineering and Innovative Technology (IJEIT)*,1, 2, February 2012.

9. K. F. Lee, K. M. Luk, K. F. Tong, S. M. Shum, T. Huynh and R. Q. Lee, "Experimental and simulation studies of the coaxially fed U-slot rectangular patch antenna," in *IEEE Proceedings - Microwaves, Antennas and Propagation*, 144, 5, Oct. 1997pp. 354-358, doi: 10.1049/ip-map:19971334.

10. Mallahzadeh, A. R. & Es, Sh & Alipour, A,” Design of an E-shaped MIMO antenna using IWO algorithm for wireless application at 5.8 GHz”, *Progress In Electromagnetics Research.*, 90, .pp.187-203. 10.2528/PIER08122704.

11. . Toktas and A. Akdagli, "Wideband MIMO antenna with enhanced isolation for LTE, WiMAX and WLAN mobile handsets," in *Electronics Letters*, 50, 10, May 2014, pp. 723-724, doi: 10.1049/el.2014.0686.

12. Ullah, Habib; Rahman, Saeed U.; Cao, Qunsheng; Khan, Ijaz; Ullah, Hamid. "Design of SWB MIMO Antenna with Extremely Wideband Isolation", *Electronics,* 9,1, 2020, 194. doi.org/10.3390/electronics9010194.

13. Prakash, J., Roshan Vijay, and S. Natarajamani. "MIMO antenna for mobile terminals with enhanced isolation in LTE band." *2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*. IEEE, 2017.

14. Liu, Xinyu, Muhammad Amin, and Jiajun Liang. "Wideband MIMO antenna with enhanced isolation for wireless communication application." *IEICE Electronics Express* ,2018, 15-20180948.

15. Y. Ge, K. P. Esselle and T. S. Bird, "E-shaped patch antennas for high-speed wireless networks," in *IEEE Transactions on Antennas and Propagation*, vol. 52, no. 12, pp. 3213-3219, Dec. 2004, doi: 10.1109/TAP.2004.836412.