© Universiti Tun Hussein Onn Malaysia Publisher's Office

JAITA

http://publisher.uthm.edu.my/ojs/index.php/jaita

e-ISSN : 2716-7097

Journal of Advanced Industrial Technology and Application

Two-Element MIMO Crack Finger Microstrip Antenna for Hand-Held Devices

Nassrin I. M. Elamin[1], Loai A. A. Alabid[1], Mohammed S. M. Gismalla[2*], Najib Al-Fadhali[2]

[1]Department of Electronic and Electrical Engineering, Faculty of Engineering, International University of Africa, Khartoum 12223, SUDAN

[2]Department of Communication Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Skudai, MALAYSIA

[3]Department of Electrical Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Panchor, Johor, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/jaita.2022.03.02.003
Received 3 September 2022; Accepted 01 November 2022; Available online 8 December 2022

Abstract: In this paper, we studied the effect of mutual coupling between MIMO antennas and a method is proposed to reduce it between 2-element micro-strip MIMO antenna systems for handheld devices. To reduce mutual coupling between the MIMO antenna element a separate ground plane is designed and the two elements are positioned on the edges of the 2-element MIMO antenna system. A novel idea defined in order to reduce mutual coupling between the closely spaced micro-strip patch elements is adding finger shapes at the edge of each patch antenna to design a new crack finger micro-strip the fingers generate capacitance in between which improved the matching between the patch and the Micro-strip transmission line as well as the mutual coupling reduced from -25 dB to -40 dB. The simulation results showed that the 2-element MIMO system covered the frequency of 2.4 GHz, and the gain and directivity are 6.149 dB and 4.399All the simulations were carried out in CST Microwave Studio.

Keywords: Crack finger, micro-strip antenna, MIMO, 2-elemnt, 2.4 GHz antenna

1. Introduction

Multiple-Input Multiple-Output (MIMO) technology is a wireless technology that uses multiple transmitters and receivers in the wireless device to transfer more data at the same time. MIMO technology takes advantage of a radio-wave phenomenon called multipath where transmitted information bounces off walls, ceilings, and other objects, reaching the receiving antenna multiple times via different angles and at slightly different times. It also leverages multipath behavior by using multiple smart transmitters and receivers with an added spatial dimension to dramatically increase performance and range [1]-[7].

Because of the limited size of handheld devices, mutual coupling between antennas is easy to occur. That mutual coupling is typically undesirable because it reduces data rates and energy that should be radiated away is absorbed by a nearby antenna. Similarly, the energy that could have been captured by one antenna is instead absorbed by a nearby antenna. Hence, mutual coupling reduces antennas' antenna efficiency and performance in both the transmit and receive modes [4], [8]-[10].

*Corresponding author: moh151gismalla@gmail.com

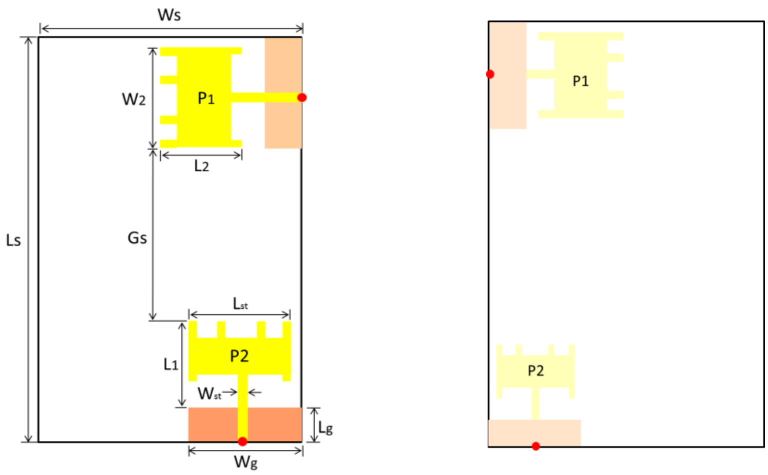
2. Antenna Design

2.1 Design and simulation of two-element MIMO antennas

The objective of this study is to reduce mutual coupling in micro-strip antenna arrays for MIMO applications. Mutual coupling and return loss are very significant factors that must be considered in the design of array radiating elements. As one array element radiates, a portion of its emitted power is eaten by other elements and induces a current on them and leading to problems such as degradation of the array radiation pattern, change in the array manifold (the received element voltages), change in the matching characteristic of the radiating elements (change the input impedances) so input power is wasted. So, the effect of mutual coupling must be reduced in the array radiating elements design. The induced current derived a voltage at the terminals of other elements. Mutual coupling is the energy absorbed by one radiating element when another nearby radiating element is operating. It is typically undesirable because the energy that should be radiated away is absorbed by nearby radiating elements. Similarly, the energy that could have been captured by one radiating element is instead absorbed by nearby radiating elements. Hence, mutual coupling reduces the radiating elements efficiency and performance of radiating elements in both the transmit and receive modes [11]-[14]. In this work, we have only study about mutual coupling and how it affects the S parameters of the micro-strip antenna using CST Microwave studio as it is based upon Finite Integration in Technique (FIT) and is also popular among antenna designers due to ease in simulations [15-19].

The design method started by choosing the materials used as well as the feeding technique. Then the operating frequencies and the patch shape were chosen. Finally, the length of the component was optimized in order to obtain the resonance at the intended frequencies, and there was also a readjustment of the antenna's overall size, to make it as small as possible.

The basic element that was designed in order to build the proposed MIMO system is presented in Fig. 1. To obtain the corresponding designed dimensions, several parameters such as the slots length and the spacing between the strip line and the ground plane had to be adjusted. In order to tune the frequencies for the required application and increase the resonance on these frequencies, the element is composed of a rectangular radiating patch with finger slots on the top and bottom of each patch which ensures resonance on the desired frequencies.



(a) (b)

Fig. 1 - (a) The geometry of the designed antenna (front side); (b) The geometry of the designed antenna (bottom side)

For the structure presented there is an analysis of its performance in terms of S-parameter, correlation coefficient, and diversity gains., a relative analysis of the radiation pattern is also performed.

As we know, printed antennas have been widely used in wireless communication devices. They are very popular for volume-limited and wideband applications. The structure of the proposed multiband MIMO antenna is shown in Fig. 1. This antenna is printed on an FR-4 substrate with relative permittivity of 4.4 and a thickness of 1.6 mm. The two identical antenna elements have the same structure and dimensions. The antenna has two layers, the top layer, and the bottom layer. On the bottom layer, there are the grounds with length L_g and width W_g. On the top layer is the microstrip patch antenna. The antenna is fed by a micro-strip line with a width of 3 mm to match 50 Ω. The antenna is square in width W_2 and length L_1 and L_2. The loaded micro-strip line has width W_{st} and length of one path L_{st} The two antenna elements are spaced with a gap G_s. The detailed antenna dimensions are listed in Tab. 1.

Table 1 - Antenna dimensions

Dimension	Size (mm)
L_s	166.5
W_s	83
L_g	21.5
W_g	41
L_1	32
L_2	32
W_2	39
L_{st}	5
W_{st}	3
G_s	80

In addition to the traditional antenna parameters, such as gain, radiation pattern, and reflection coefficients, new parameters and aspects have to be included in the design for MIMO systems. Mutual coupling between antenna elements is a key factor to achieve high antenna performance in the MIMO antenna configuration. For a low mutual coupling, antennas must be far away from each other. But the space for the internal antenna is not enough to obtain low correlation and mutual coupling [20]-[22]. In this research, we present a structure for the MIMO antenna elements, in which the identical two antenna elements are orthogonally placed. Then the two antenna elements have orthogonal polarization which can reduce the mutual coupling between the two antennas. Fig. 3 shows the simulated 3D radiation patterns of the two antenna elements. It can be seen that the two antenna elements have orthogonal polarizations.

3. Simulated Results

The S-parameter characteristics of the proposed 2.4 GHz 2-element MIMO antenna satisfying VSWR (−6 dB) for LTE (2.305 GHz to 2.400 GHz), and 2.4 GHz WLAN (2.400 GHz to 2.484 GHz)

The two antennas were first separated in the CST software environment. Thus, we get two S parameters results for the software simulation as shown in Fig. 2.

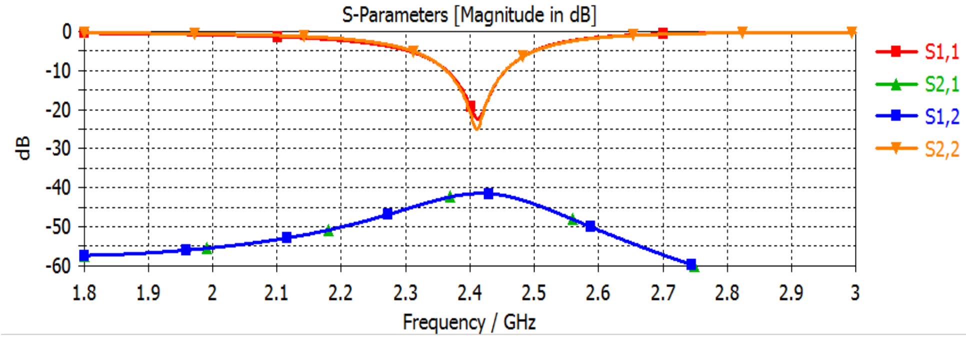
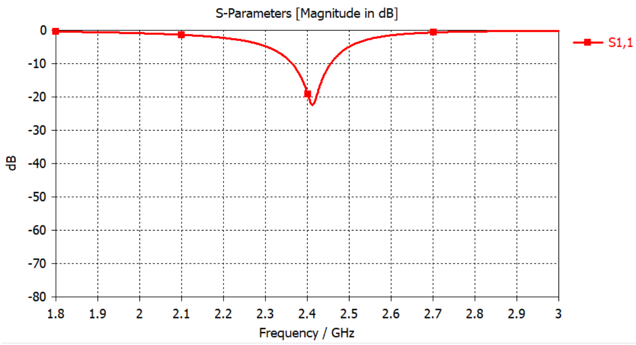
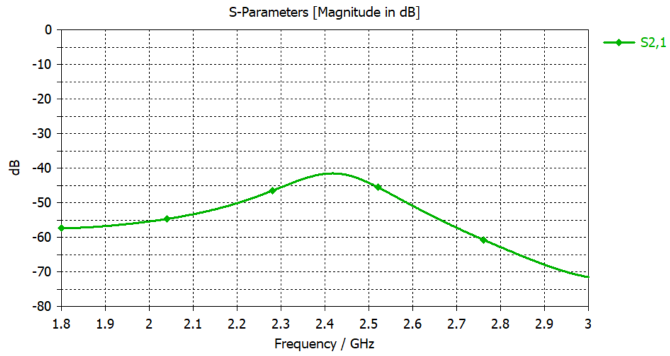


Fig. 2 - Plot of Simulated S parameters

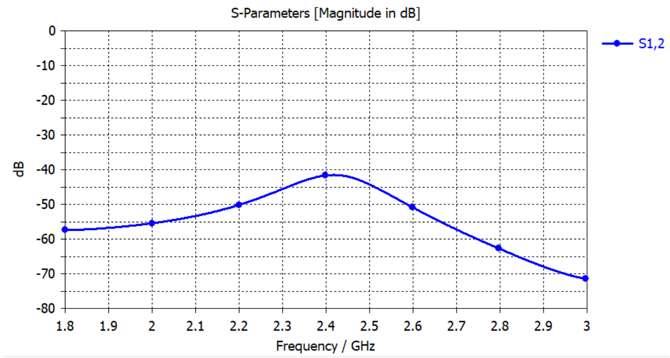
Distance far less than λ/2 is considered to be the effect of mutual coupling. If distance is equal to or greater than λ/2 then there will be no mutual coupling between antennas. Input is provided through a port of impedance 5.0 Ω and then S_{12}, S_{21} which is mutual coupling and S_{11}, S_{22}that is return loss is calculated using CST microwave studio Tool. It is noticed that S_{11} and S_{22} = -25dB and S_{12}, and S_{21}=-40dB at frequency 2.4 GHz and gain = 6.149 dB and directivity = 4.399 dB.



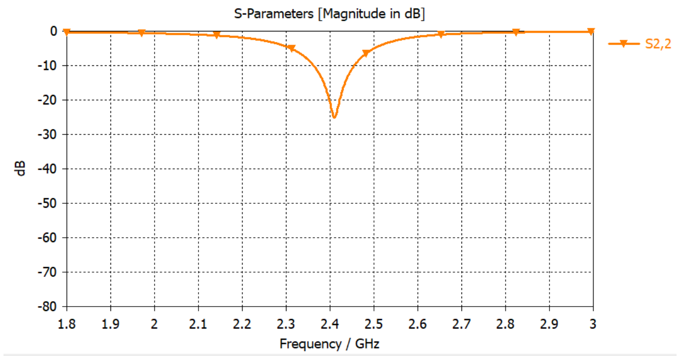
(a)



(b)



(c)



(d)

Fig. 3 - Plots for simulation of MIMO antenna (a) S11; (b) S21; (c) S12; (d) S22

The radiation patterns measured at 2.4 GHz is shown in Fig. 4; 3D views of the total radiation patterns from 2-element measured and plotted. The antenna 1 has an omnidirectional vertically polarized pattern in x-z plane and the antenna 2 generates horizontally polarized radiation in y-z plane.

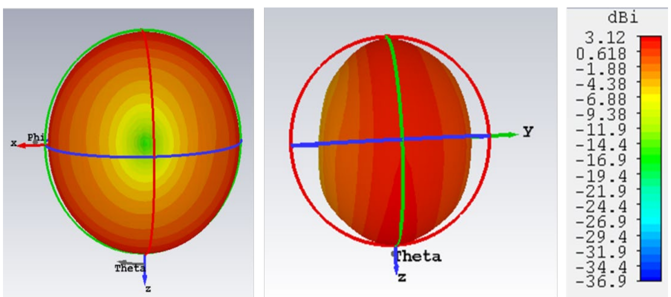


Fig. 4 - Far field directivity in 3D form

The omnidirectional patterns can enhance and increase the channel capacity. Thus, the proposed antenna is more attractive for 2.4 GHz 2-element MIMO antennas.

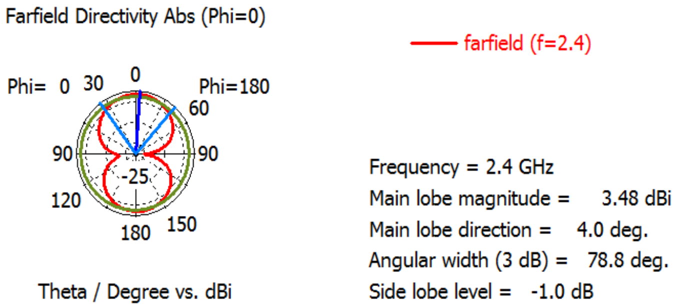
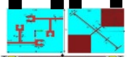
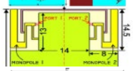


Fig. 5 - Far field directivity in polar form

The isolation between two polarizations is affected by the dimension of spacing Gs. In principle, the larger the spacing is, the lower the mutual coupling. Tab. 2 summaries the comparison of the proposed 2-element MIMO antenna with previous works, and the comparison performed based on size, frequency, isolation, and shape. It is clear that the proposed 2-element MIMO antenna provides better isolation of −25 dB.

Table 1 - Comparison of proposed MIMO antennas with other 2-element designs

Reference	Size	Frequency	Isolation	Shape
[10]	2x2	2.4	15	
[11]	2x2	2.4	19 dB	
[12]	2x2	2.38 – 2.47 GHz	20 dB	
[13]	2x2	2.31–2.51 GHz	17 dB	
Proposed antenna	2x2	2.4	25 dB	

4. Conclusion

In this research, we have talked about designing 2-element MIMO antennas for Handheld devices, and the reduction of mutual coupling between radiating elements for MIMO application as all communication system is based on antennas and designing optimum antennas with good efficiency is the main work nowadays. We have designed patch antenna with less spacing between them to see the effect of mutual coupling with help of the CST Microwave Studio Tool. The basic idea defined in order to reduce mutual coupling is to increase the distance between the closely spaced patch and we have further used small rectangular shapes at the edge of each patch antenna, so that maximum power can be transmitted using microstrip antenna arrays and to improve gain and directivity.

This method not only cancels mutual coupling but also increases the return loss with very less spacing between the antennas. The gain and directivity are also increased with 2x2 arrays which are designed and can be used to implement spatial diversity.

References

[1] Rodrigo, Rangam Fundamental Parameters of Antennas, Hindawi 2010, (2010): 2-19

[2] Elamin, Nassrin and Rahman, Tharek, Limited Size MIMO Antenna Systems and Mutual Coupling Challenge.Wideband, Multiband, and Smart Reconfigurable Antennas for Modern Wireless Communications 2016, (2016): 176-202

[3] Yao, Yuan, Xing Wang and Junsheng Yu. "Multiband Planar Monopole Antenna for Lte Mimo Systems." International Journal of Antennas and Propagation 2012, (2012): 1-6.

[4] Zhao, Xing, Youngki Lee and Jaehoon Choi. "Design of a Compact Mimo Antenna Using Coupled Feed for Lte Mobile Applications." International Journal of Antennas and Propagation 2013, (2013): 1-8.

[5] Wong, H. S., S. Kibria, M. T. Islam, J. S. Mandeep and N. Misran. "Quad Band Handset Antenna for Lte Mimo and Wlan Application." International Journal of Antennas and Propagation 2014, (2014): 1-7.

[6] Dong, Jian, Xiaping Yu and Guoqiang Hu. "Design of a Compact Quad-Band Slot Antenna for Integrated Mobile Devices." International Journal of Antennas and Propagation 2016, (2016): 1-9.

[7] Mokhlis, Nur Abilla, Najib Al-Fadhali, Huda Majid, Mohammed Salih Mohammed, Jameel AA Mukred, Nayef Alduais, Adel Aship, and Najmaddin Abo Mosali. "Truncated Patch Antenna with two different substrate materials for GPS application." Journal of Advanced Industrial Technology and Application 3, no. 1 (2022): 39-49.

[8] Xu, Ziyu, Qisheng Zhang and Linyan Guo. "A Compact 5g Decoupling Mimo Antenna Based on Split-Ring Resonators." International Journal of Antennas and Propagation 2019, (2019): 1-10.

[9] Ryu, J. and H. Kim, “Compact MIMO antenna for application to smart glasses using T-shaped ground plane, Microwave and Optical Technology Letters, Vol. 60, No. 8, 2010–2013, 2018.

[10] Tiwari, R. N., P. Singh, B. K. Kanaujia, and K. Srivastava, Neutralization technique based two and four port high isolation MIMO antennas for UWB communication, AEU-International Journal of Electronics and Communications, Vol. 110, 152828, 2019.

[11] Su, S., C. Lee, and F. Chang, “Printed MIMO-antenna system using neutralization-line technique for wireless USB-dongle applications, IEEE Transactions on Antennas and Propagation, Vol. 60, No. 2, 456–463, Feb. 2012.

[12] Anuvind, R., S. D. Joseph, and A. Kothari, 2 × 2 MIMO antenna at 2.4 GHz for WLAN applications, 2015 International Conference on Microwave, Optical and Communication Engineering (ICMOCE), 80–83, Dec. 2015.

[13] Malviya, L., R. K. Panigrahi, and M. V. Kartikeyan, 2 × 2 MIMO antenna for ISM band application, 2016 11th International Conference on Industrial and Information System (ICIIS), 794–797, 2016.

[14] Kumar, S., R. Kumar, R. K. Vishwakarma, and K. Srivastava, An improved compact MIMO antenna for wireless applications with bandnotched characteristics, AEU International Journal of Electronics and Communications, Vol. 90, 20–29, 2018.

[15] Al-Fadhali, Najib, et al. "Wideband (22-30GHz) mm-Wave Substrate Integrated Waveguide (SIW) Antenna for 5G Applications." *2019 IEEE conference on antenna measurements & applications (CAMA)*. IEEE, 2019.

[16] AL-Fadhali, Najib Mohammed Ahmed, et al. "Frequency reconfigurable substrate integrated waveguide (SIW) cavity F-shaped slot antenna." *Indonesian Journal of Electrical Engineering and Informatics (IJEEI)* 7.1 (2019): 135-142.

[17] Najib, AL-Fadhali, et al. "A compact ultra-wideband (42-54 GHz) mm-Wave Substrate Integrated Waveguide (SIW) cavity slot antenna for of future wireless communications."

[18] AL-Fadhali, Najib, et al. "Substrate integrated waveguide cavity backed frequency reconfigurable antenna for cognitive radio applies to internet of things applications." *International Journal of RF and Microwave Computer-Aided Engineering* 30.1 (2020): e22020.

[19] Al-Fadhali, Najib, Huda Majid, and Rosli Omar. "Multiband frequency reconfigurable substrate integrated waveguide antenna using copper strip for cognitive radio applicable to internet of things application." *Telecommunication Systems* 76.3 (2021): 345-358.

[20] Lim, J., Z. Jin, C. Song, and T. Yun, Simultaneous frequency and isolation reconfigurable MIMO PIFA using pin diodes, IEEE Transactions on Antennas and Propagation, Vol. 60, No. 12, 5939– 5946, Dec. 2012.

[21] Jeong, G.-T., S. Choi, K. Hak, and W. S. Kim, Low-profile dual wideband MIMO antenna with low ECC for LTE and Wi-Fi applications,International Journal of Antennas and Propagation, Vol. 2014, 6 pages, May 2014

[22] Azizan, Syakir Syahiran, Najib Mohammed Ahmed Al-Fadhali, Huda Majid, M. S. M. Gismalla, Jameel AA Mukred, Adel YI Ashyap, B. A. F. Ismail, and N. A. M. Alduais. "Design A Wideband (25-40ghz) Mm-Wave Microstrip Antenna for 5g Applications." Progress in Engineering Application and Technology 2, no. 2 (2021): 609-620.