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A SMALL SIZED PRINTED MIMO SLOT ANTENNA SYSTEM WITH MICROSTRIP FEED LINE FOR FUTURE WIDEBAND APPLICATIONS

Anjitha Suresh[1]

[1]*M.Tech Graduate, Electronics and Communication Engineering*

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Abstract - A compact MIMO slot antenna having a size of $22 \times 26 \times 0.8\, mm^3$ is proposed for future wideband applications. The proposed antenna consists of two cone-shaped radiating elements etched from the ground plane with a microstrip line feed placed on the upper part of the substrate (FR4). To mitigate mutual coupling between two radiating elements a line and T- slots are etched from the ground. The antenna has a peak gain of 2.74dB and efficiency of more than 90% is obtained from the simulation results.

***Key Words*: MIMO, ultra-wide band, mutual coupling, microstrip line feed**

1. INTRODUCTION

Smart systems become an essential part of our advanced life. To achieve high-speed data transmission and low power consumption for smart devices is a little bit difficult. Ultra-wideband (UWB) communication is an easy way to conquer this difficulty because of its high date rate and low spectral density radiator power [1]. Nevertheless, multipath fading and channel fading will cause instability of UWB technology. To solve this problem, multiple-input-multiple-output (MIMO) technology has been proposed. UWB antennas combined with MIMO technology become an excellent choice for smart gadgets. The antenna used for smart devices have compatible size. It is exceptionally challenging to realize UWB MIMO antennas in reduced size with high isolation. MIMO is a key innovation for UWB wireless communication systems.

In recent years, terminal devices tend to be miniaturized, and therefore serious mutual coupling will happen between antenna elements and other electronic components. Diverse techniques have been developed to decouple the radiating elements in UWB MIMO systems. In order to reduce the mutual coupling at a lower frequency, two bent slots are etched from the ground plane [2]. The antenna elements are placed oppositely in [3] and [4] to reduce mutual coupling in low frequency. Distinctive parasitic structures were investigated to increase the isolation in [5–8]. A small sized printed UWB MIMO antenna with high isolation is designed in [9], which is obtained by introducing slots and separating main radiation directions of two antenna elements, however, the impedance bandwidth isn't as wide as UWB requirements. Another difficulty of MIMO antennas is the electromagnetic interference in the UWB, which was broadcasted permission from 3.1 GHz to 10.6 GHz for UWB communications. To resolve this problem, researchers have developed an incredible number of antennas. Multiple-input multiple-output (MIMO) technology uses multiple transmitting and receiving antennas to provide multiplexing gain and diversity gain, which fundamentally reduces multipath fading and increases transmission capacity but placing multiple antennas in a small space will cause strong mutual coupling among the MIMO antennas. MIMO can be actualized in three different ways: beam forming, spatial multiplexing and diversity techniques. The constraints to exploit the diversity emerge when the antennas are placed in close vicinity. So, it is required to decorrelate their patterns, or in other words, mutual coupling ought to be limited.

Another challenge is the reduction of mutual coupling between MIMO antennas. Various methods have been concocted to enhance isolation between the components of a narrowband MIMO antenna. Mutual coupling defines as the energy absorbed by a proximate antenna when another antenna is radiating. Mutual coupling tends to change the radiation pattern, reflection coefficient and input impedance of the MIMO antennas. Different techniques used to reduce mutual coupling are use of defected ground structure, EBG structures, decoupling networks, neutralization lines, parasitic or slot elements and CSRR.

Defected ground structure (DGS) represents the defects or slots integrated on the ground plane of planar circuits or antennas [10]. It is an emerging technique for improving a few parameters of microwave MIMO antenna systems including narrow bandwidth, cross-polarization and low gain [11]. Further, this technique contributes altogether to reduce mutual coupling. Complementary Split ring Resonator (CSRRs) are generally periodic arrangements [13], [14] of a metallic ring, shunt strip or capacitive gap used to perform isolation improvements function and lower mutual coupling. Neutralization lines [15] are used to transmit the electromagnetic (EM) waves from one antenna to the other through a metallic slit or lumped element. Consequently, an opposite coupling is made to lower the mutual coupling at certain frequencies between the antennas. Decoupling networks [16] are utilized to obtain better isolation in the MIMO antenna systems. This is based on the principle of transformation of the cross-admittance term to purely imaginary value by adding transmission lines or by discrete components. Eigenmode decomposition [17], artificial structure [18], coupled-resonator [19] and inserted components [20] are the various decoupling schemes. Electromagnetic bandgap (EBG) structure can block electromagnetic waves of a particular frequency or acts as a medium for transmitting electromagnetic waves. Contingent upon on the field of application different stopband, passband and band gap frequencies can be recognized [21]. This EBG structure is a periodic arrangement of metallic or dielectric material so that periodicity in the structure and individual resonance of the elements can produce multiple band gaps. Printed parasitic or slot element antennas utilize two orthogonal modes to create a wide impedance bandwidth by coupling either in the radiating patch or in the ground plane. In this method, mutual coupling between antennas is minimized [22]. Further, one of the two coupling paths restricts the signal coming from the other coupling path, which prompts a reduction of mutual coupling. The main advantages of parasitic or slot antenna are the design simplicity, size and advantageous production using either PCB technology or waveguides.

This paper introduces a MIMO antenna in a compact volume using slotted ground for future wideband applications. The proposed antenna operating at frequencies from 3.1 GHz to 10.6 GHZ with peak gain of 2.74dB. Mutual coupling between antenna elements can be diminished by introducing slots on the ground plane.

2. ANTENNA DESIGN

The antenna system consists of two cone shaped radiating elements etched from the ground plane. The proposed design is fabricated on the FR4 substrate with relative permittivity of 4.4 as shown in figure 1. The antenna contains two slots, a line, and T slots etched from the ground plane. Use of slots on the ground provides ultra-wide bandwidth, miniaturization of an antenna, Omni-directional radiation and reduced mutual coupling between radiating elements. The detailed dimensions of the antenna are represented in figure 2.

Microstrip to slotted line feed transition technique is utilized. A microstrip-slot transition is a structure that uses a microstrip line on one side of a planar dielectric substrate and a slot line in the ground with a goal that a signal is passed between the two sides. In order to perform this function with negligible power losses, the microstrip line and the slot line must be orthogonal to one another and use suitable reactive terminations at their closures. The microstrip line is used to convey Electro-Magnetic Waves (EM waves) or microwave frequency signals. It comprises of 3 layers, conducting strip, dielectric and Ground plane. It is used to design and fabricate RF and microwave components, for example, directional coupler, power divider/combiner, filter, antenna, MMIC, etc. It provides return loss of about -10dB.

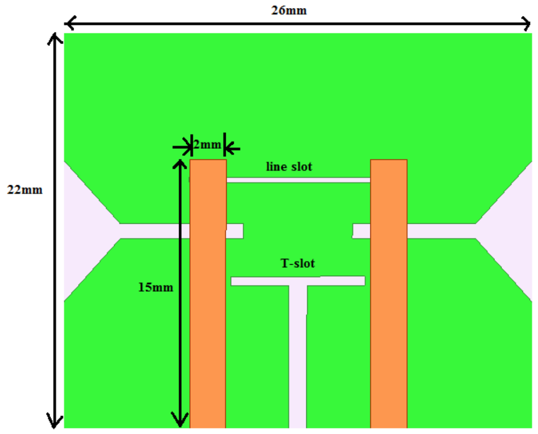


Figure 1. Proposed antenna design

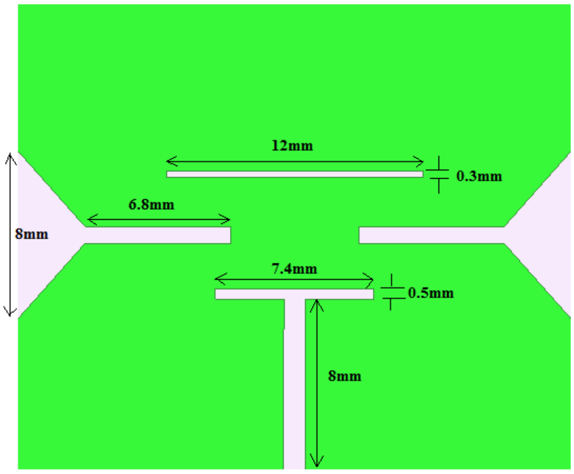
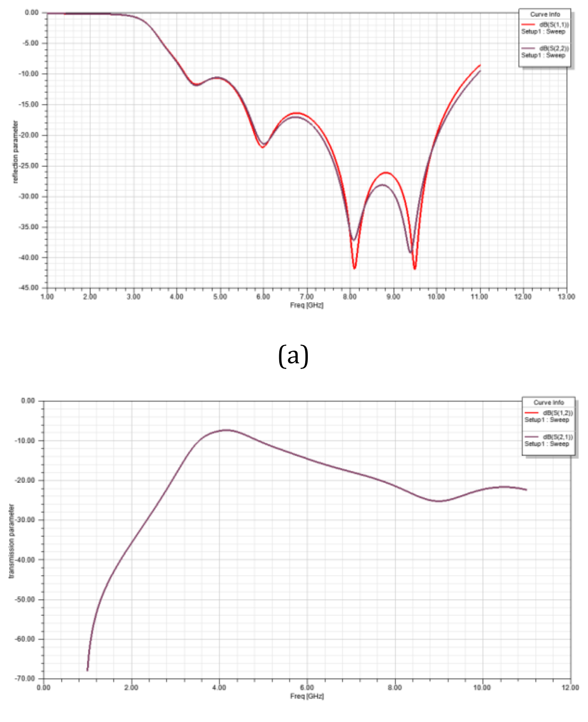


Figure 2. Detailed dimensions of the proposed antenna

3. SIMULATION RESULTS

The antenna system without slotted ground is analyzed. The S-parameters of the antenna without slots on the ground are shown in fig 3. The reflection parameters S(1,1) and S(2,2) are shown in fig 3(a). The operating frequency is ranging from 4.2 to 10.2 GHz. The transmission parameters S(1,2) and S(2,1) [fig 3(b)] shows that isolation between radiating elements is above -10 dB at frequency range from 3.6 to 4.8 GHz. The antenna has an impedance bandwidth of about 6 GHz without slotted ground. The gain of an antenna without slots is about 2.30 dB. The surface current distribution shown in figure 4. The mutual coupling between antennas can be easily analyzed from this figure.



(a)

(b)

Figure 3. (a) S(1,1) and S(2,2) and (b) S(1,2) and S(2,1) of the antenna without slots.

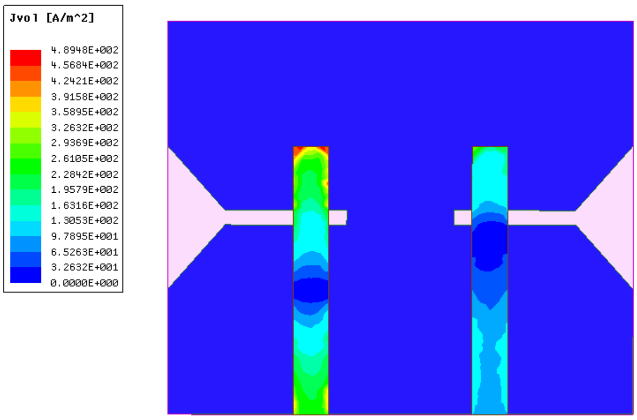
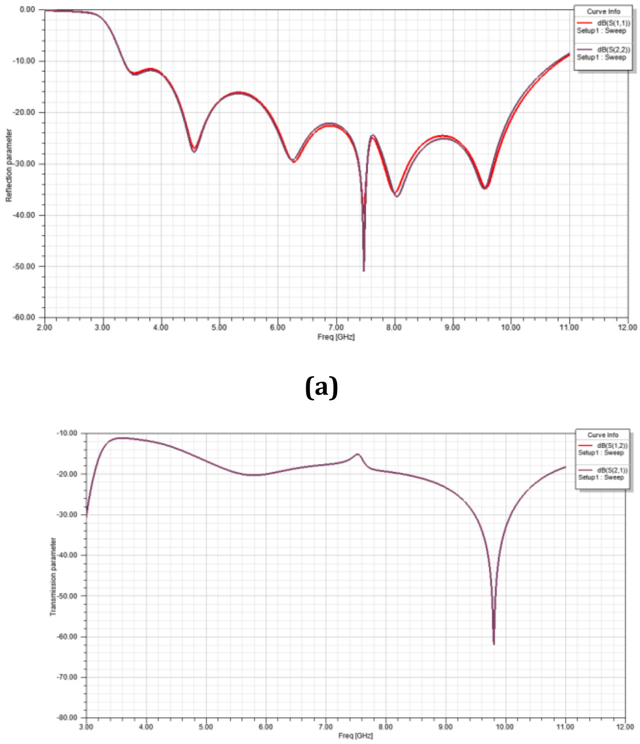


Figure 4. Surface current distribution of antenna without slotted ground

By etching slots from the ground give better isolation and wider operating bandwidth. The S parameters of the antenna with slotted ground structure as shown in figure 5. Reflection parameters are shown in figure 5(a). When slots are etched from the ground the operating frequency range is obtained as 3.1 to 10.6 GHz instead of range 4.2 to 10.2 GHz. The operating bandwidth of proposed antenna is 7.5 GHz. Transmission parameter plot shows that isolation between antennas are less than -10 dB.



(a)

(b)

Figure 5. (a) reflection parameter and (b) transmission parameter of proposed system

The 3 dimensional and 2 dimensional radiation plot of the proposed design as shown in fig 6. The radiation pattern of an antenna is a plot of the far-field radiation characteristics of an antenna as a function of the spatial coordinates which are determined by the elevation angle (θ) and the azimuth angle (φ). Omni directional radiation pattern is obtained with radiation efficiency more than 90%. The larger radiation is obtained towards +X direction over the operating bands.

The current distribution of the proposed design as appeared in fig 7. On account of antenna design without slotted ground, a strong surface current can be observed on the antenna on the right-hand side when the left side antenna is excited. This surface current stifled by the introduction of slots on the ground plane. The slots altogether disturb the fields and induced currents between the two antenna elements and reduce their mutual coupling. The current flow of UWB antenna with two slot structure is fundamentally diminished as compared to the UWB antenna with a conventional ground plane.

VSWR stands for voltage standing wave ratio and is likewise referred to as a standing wave ratio (SWR). VSWR is a function of the reflection coefficient, which depicts the power reflected from the antenna. Voltage standing wave ratio (VSWR) is an approach to measure transmission line imperfections. From fig 8 it is clear that VSWR is less than 2 within the higher frequency bands.

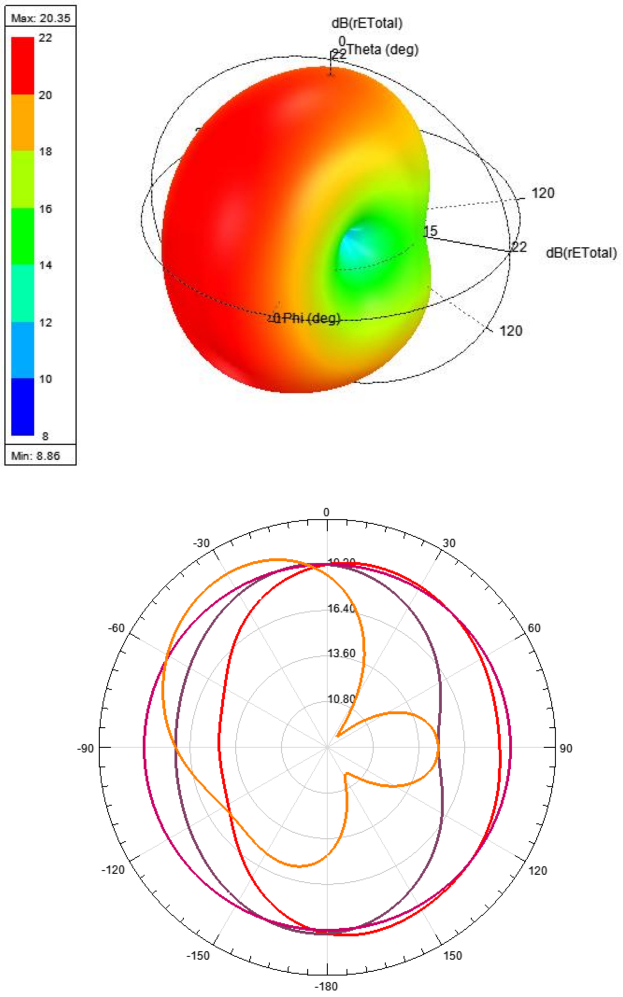


Figure 6. Simulated 3D and 2D radiation pattern of proposed antenna

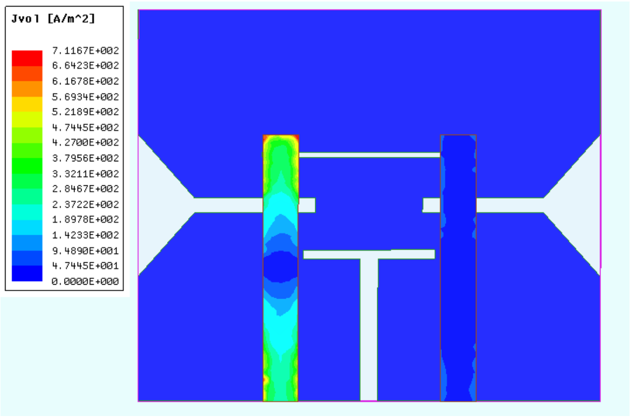


Figure 7. Surface current distribution of proposed antenna

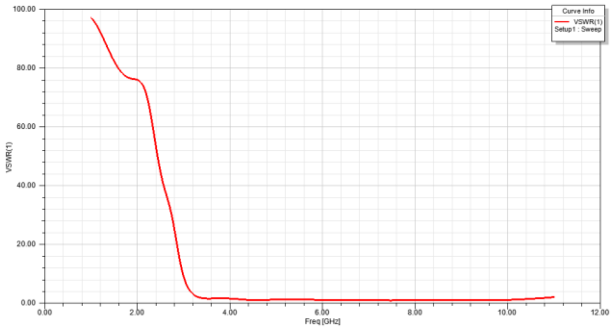


Figure 8. Simulated VSWR plot of proposed antenna

4. CONCLUSION

A compact MIMO antenna for future wideband applications is designed in this paper. The consists of two cone shaped radiating elements with slotted ground structure having a size of $22 \times 26 \times 0.8\, mm^3$. The proposed antenna has omni directional radiation pattern with peak gain of 2.74 dB. The simulated radiation efficiency of the antenna is above 90% with beam area 8 dB. FBR of the proposed design is 5.91. The mutual coupling between two radiating elements can be diminished by introducing slots on the ground plane. Slotted ground also provide omni directional radiation with high gain. VSWR is below 2 over the entire operating frequencies.

REFERENCES

[1] Federal Communications Commission (FCC), Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems First Rep. and Order, ET Docket 98-153, FCC 02-48, Adopted: Feb. 2002; Released.

[2] Li, J., Q. Chu, and T. Huang, "A compact wideband MIMO antenna with two novel bent slits," IEEE Transactions on Antennas and Propagation, Vol. 60, No. 2, 482–489, Feb. 2012.

[3] Ren, J., W. Hu, Y. Yin, and R. Fan, "Compact printed MIMO antenna for UWB applications," IEEE Antennas and Wireless Propagation Letters, Vol. 13, 1517–1520, 2014.

[4] Zhu, J., S. Li, S. Liao, and Q. Xue, "Wideband low-profile highly isolated MIMO antenna with artificial magnetic conductor," IEEE Antennas and Wireless Propagation Letters, Vol. 17, No. 3, 458–462, Mar. 2018. Progress In Electromagnetics Research C, Vol. 89, 2019 169

[5] Toktas, A., M. Yerlikaya, K. Sabanci, A. Kayabasi, E. Yigit, and M. Tekbas, "Reducing mutual coupling for a square UWB MIMO antenna using various parasitic structures," 2017 10th International Conference on Electrical and Electronics Engineering (ELECO), 982–986, Bursa, 2017.

[6] Iqbal, A., O. A. Saraereh, A. Bouazizi, and A. Basir, "Metamaterial based highly isolated MIMO antenna for

portable wireless communication," Electronics, Vol. 7, No. 10, 2018.

[7] Sokhi, I. K., R. Ramesh, and K. Usha Kiran, "Design of UWB-MIMO antenna for wireless applications," 2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), 962–966, Chennai, 2016.

[8] Joo, E., K. Kwon, J. Park, and J. Choi, "On-body UWB MIMO antenna for UWB application," 2013 Asia-Pacific Microwave Conference Proceedings (APMC), 1130–1132, Seoul, 2013.

[9] Low, X. N., Z. N. Chen, and T. S. P. See, "A UWB dipole antenna with enhanced impedance and gain performance," IEEE Transactions on Antennas and Propagation, Vol. 57, No. 10, Oct. 2009.

[10] M. K. Khandelwal, B. K. Kanaujia, and S. Kumar, "Defected Ground Structure: Fundamentals, Analysis, and Applications in Modern Wireless Trends," International Journal of Antennas and Propagation, 2017.

[11] A. K. Arya, M. V. Kartikeyan, and A. Patnaik, "Defected Ground Structure in the perspective of Microstrip Antennas: A Review," Frequenz, vol. 64, pp. 79–84, Jun. 2010.

[12] P. R. Prajapati, "Application of Defected Ground Structure to Suppress Out-of-Band Harmonics for WLAN Microstrip Antenna," International Journal of Microwave Science and Technology, 2015.

[13] J. Bonache, I. Gil, J. García-García, and F. Martín, "Complementary split rings resonators (CSRRs): Towards the miniaturization of microwave device design," J Comput Electron, vol. 5, no. 2–3, pp. 193–197, Jul. 2006.

[14] R. Selvaraju, M. H. Jamaluddin, M. R. Kamarudin, J. Nasir, and M. H. Dahri, "Complementary Split Ring Resonator for Isolation Enhancement in 5G Communication Antenna Array," Progress In Electromagnetics Research, vol. 83, pp. 217–228, 2018.

[15] Diallo, A., Luxey, C., Le Thuc, P., Staraj, R. and Kossiavas, G., "Study and Reduction of the Mutual Coupling Between Two Mobile Phone PIFAs Operating in the DCS1800 and UMTS Bands," IEEE Transactions on Antennas and Propagation, vol. 54, no. 11, pp. 3063–3074, 2006.

[16] M. Kahrizi, T. K. Sarkar, and Z. A. Maricevic, "Analysis of a wide radiating slot in the ground plane of a microstrip line," IEEE Transactions on Microwave Theory and Techniques, vol. 41, no. 1, pp. 29–37, Jan. 1993.

[17] S. T. Fan, Y. Z. Yin, B. Lee, W. Hu, and X. Yang, "Bandwidth Enhancement of a Printed Slot Antenna With a Pair of Parasitic Patches," IEEE Antennas and Wireless Propagation Letters, vol. 11, pp. 1230–1233, 2012.

[18] J. Row and S. Wu, "Circularly-Polarized Wide Slot Antenna Loaded With a Parasitic Patch," IEEE Transactions on Antennas and Propagation, vol. 56, no. 9, pp. 2826–2832, Sep. 2008.

[19] L. Zhao, L. K. Yeung, and K. Wu, "A novel second-order decoupling network for two-element compact antenna arrays," in 2012 Asia Pacific Microwave Conference Proceedings, 2012, pp. 1172–1174.

[20] M. S. Khan, A. Capobianco, A. I. Najam, I. Shoaib, E. Autizi, and M. F. Shafique, "Compact ultra-wideband diversity antenna with a floating parasitic digitated decoupling structure," Antennas Propagation IET Microwaves, vol. 8, no. 10, pp. 747–753, Jul. 2014.

[21] Y. Rahmat-Samii, "Electromagnetic band gap (EBG) structures in antenna engineering: From fundamentals to recent advances," in 2008 Asia-Pacific Microwave Conference, 2008, pp. 1–2.

[22] J. Row and S. Wu, "Circularly-Polarized Wide Slot Antenna Loaded With a Parasitic Patch," IEEE Transactions on Antennas and Propagation, vol. 56, no. 9, pp. 2826–2832, Sep. 2008.