2018 3rd International Electrical Engineering Conference (IEEC 2018)
Feb, 2018 at IEP Centre, Karachi, Pakistan

Design and Analysis of UWB-MIMO Antenna with Enhanced Isolation

Muhammad Abid Ur Rehman[1], Sajid Ali[2], Amjad Iqbal[3*] and Muhammad Hameed Khan[4]

[1,2,3] Department of Electrical Engineering, CECOS University of IT and Emerging Sciences, Peshawar, Pakistan
(amjad730@gmail.com) *Corresponding author.
[4] Department of Electrical Engineering, Abasyn University, Islamabad, Pakistan.

Abstract: An efficient and useful technique of mutual coupling reduction between Multiple Input Multiple Output (MIMO) antenna elements has been presented in this paper. Mutual coupling of the proposed ultra wideband antenna has been reduced by introducing a slotted ground plane. The proposed two elements MIMO antenna operates in ultra-wideband (UWB) range with edge to edge separation of 3mm. Isolation of 9dB between the MIMO elements is achieved by introducing slotted ground between the radiating elements. Transmission coefficient [S_{21}] up to 36dB and reflection coefficient [S_{11}] up to 20dB is realized for the proposed antenna. The proposed antenna has very low mutual coupling of $|S_{12}/S_{21}$<-20.14dB| over the entire UWB range. The proposed antenna is studied in term of S-parameters, radiation pattern, diversity gain, channel capacity loss (CCL) and envelop correlation coefficient (ECC).

Keywords: MIMO, UWB, Reflection coefficient.

I. INTRODUCTION

High data rates and low fabrication cost is the advantage of UWB [1-2] antennas, but reflection and refraction always cause multipath fading. To overcome the disadvantage of multipath fading, MIMO technology is introduced. Mutual coupling is always associated with MIMO antennas.

A MIMO antenna comprises of no less than two transmitting components, put at certain separation to have high separation between them, yet the accessible space is extremely restricted in the advanced wireless front-ends. Mutual coupling has direct impression on the performance of the Multiple Input Multiple Output (MIMO) antenna and antenna array system. This communication between the array elements/MIMO elements reduces the system performance by increasing the mutual coupling, increasing envelop correlation coefficient, increasing channel capacity loss, decreasing diversity gain and distorting radiation pattern.

A lot of techniques have been presented in the literature to overcome the problem of mutual coupling. L-shaped stubs are used in the ground plane for the mutual coupling reduction in perpendicularly placed antennas [3]. F-shaped stubs in ground plane are inserted in [4] to reduce the coupled current in the nearby radiator. Isolation between the MIMO elements is created by inserting a rectangular stub diagonally between the radiating elements [5]. Mutual coupling of perpendicularly placed radiators has been reduced using stubs on the ground plane with a compact size antenna in [6]. The EBG design is enhanced and inserted between the monopole antennas to reduce mutual coupling between them [7]. In [8], a compact MIMO antenna of two elements with high isolation is designed using electric-LC resonator.

A highly isolated UWB-MIMO antenna is presented in the proposed work with high diversity gain and low envelop correlation coefficient.

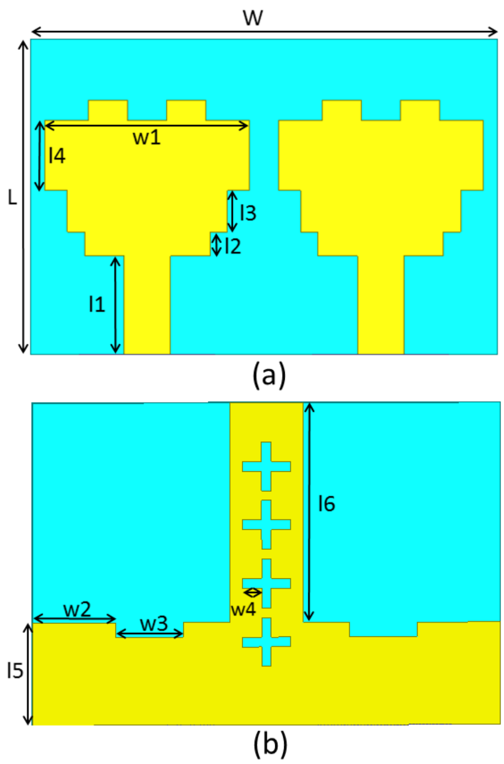

Fig. 1 (a) Top (b) Bottom view of the proposed MIMO antenna.

II. ANTENNA DESIGN

Fig.1 shows the graphic configuration of the UWB MIMO antenna, which is designed on the Rogers (Ro5880) substrate having relative permittivity ε_r=2.2 and height h=1.575mm. In this paper the radiating elements uses the microstrip transmission line, which has width of 4.78mm to have 50Ω characteristics impedance. The radiating elements and transmission line are designed above on the substrate and the ground plane is designed on the base of the substrate. Edge to edge separation between the radiating elements of the MIMO antenna is kept as 3mm.

Table 1 presents the optimized parameters of the proposed MIMO antenna.

Table 1: Optimized Parameters of the Antenna

Parameters (Top side)	Value (mm)	Parameters (Bottom side)	Value (mm)
W	48	w2	8.5
L	33	w3	7
l1	10.3	w4	2
l2	2.54	l5	10.5
l3	4.31	l6	22.5
l4	7.35		
w1	21		

III. RESULTS AND DISCUSSIONS

The proposed MIMO antenna is designed on Rogers Ro5880 substrate having relative permittivity ε_r=2.2 and height hs = 1.575mm. High Frequency Structure Simulator (HFSS) is used for simulation and optimization of the proposed antenna.

A. S-Parameters

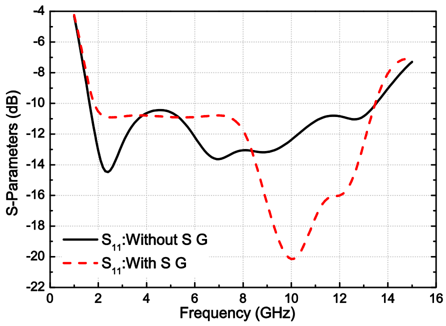

Fig. 2 Reflection coefficient (S_{11}) with and without slotted ground

Simulated return loss (S_{11}) and insertion loss (S_{21}) with and without slotted ground are shown in Fig. 2 and Fig. 3 respectively. It is clear from the Fig. 2 that return loss (S_{11}) of MIMO antenna with and without slotted ground is operating at the same bandwidth. For good performance of MIMO antenna, it is worth noticing that low mutual coupling is desired. It is clear from Fig. 3 that antenna without slotted ground has poor isolation over the whole UWB range. Mutual coupling between the radiating elements has been degraded by inserting a slotted ground.

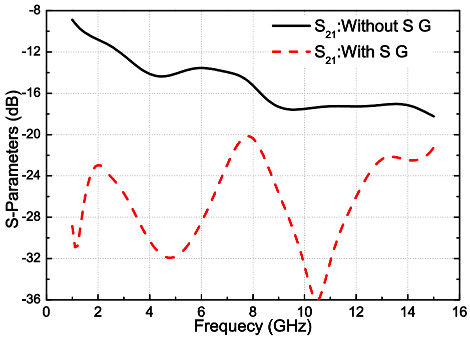

Fig. 3 Transmission coefficient (S_{21}) with and without slotted ground

B. Surface Current Density

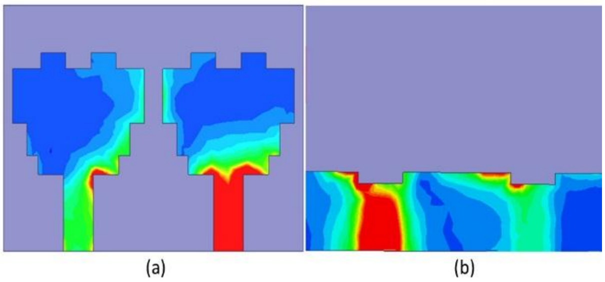

Fig. 4 Surface current density: (a) Front side (b) Back side without Slotted ground.

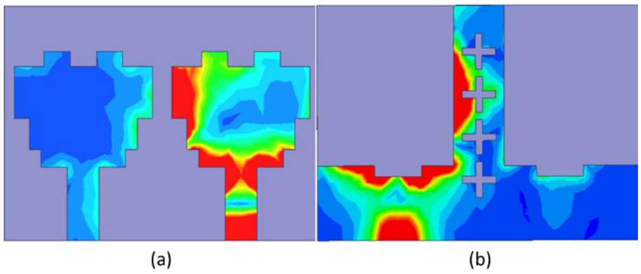

Fig. 5 Surface current density: (a) Front side (b) Back side with Slotted ground

Fig. 4 shows that a high mutual coupling is realized between the radiating elements as current is highly coupled with another radiator when port 1 is excited.

By inserting plus (+) shaped slotted ground, the mutual coupling has been reduced between the radiating elements as well as fewer current is coupled with another radiator and hence yield greater isolation between the antennas as shown is Fig. 5.

C. Radiation Pattern

The simulated result of the proposed MIMO antenna with and without Slotted ground are shown in Fig. 6 and Fig. 7. It is very clear from the Fig. 6 and Fig. 7 that the radiation pattern are not much deviated by the insertion of Slotted ground.

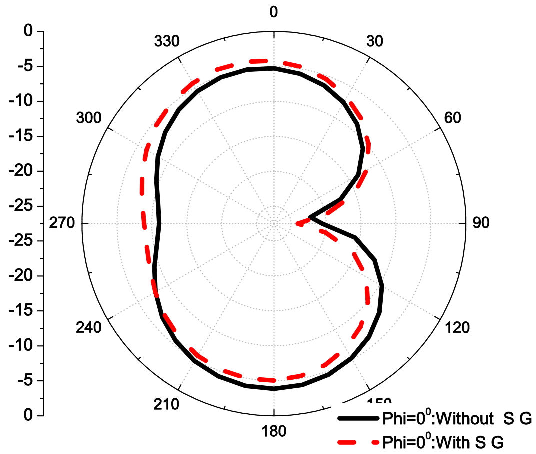

Fig. 6 Radiation Pattern with and without Slotted ground at phi=0

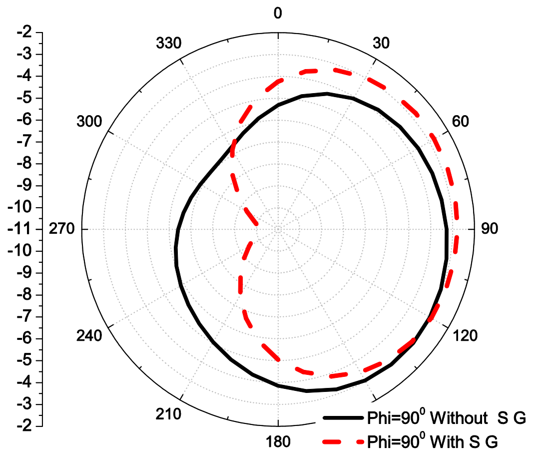

Fig. 7 Radiation Pattern with and without Slotted ground at phi=90

D. Envelop Correlation Coefficient (ECC)

To approve the ability and execution of the proposed Antenna, it is important to have low correlation coefficient (ECC). The ECC can be assessed utilizing S-parameters by the following relation.

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

Ideally ECC equal to zero (ECC=0), which shows zero coupling between the radiating elements. However practice limit of ECC<0.5 is set for uncorrelated MIMO elements. Fig. 8 shows the ECC of the proposed UWB-MIMO antenna. It can be seen from the Fig. 8 that the proposed antenna has ECC<0.05 for the whole UWB range.

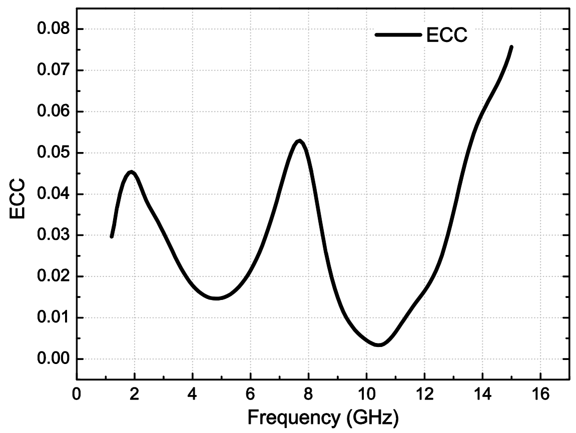

Fig. 8 ECC of the proposed antenna

E. Diversity Gain (DG)

Diversity gain (DG) is an important parameter for evaluating the performance of MIMO antenna. It can be calculated by the following relation for MIMO antenna.

$$DG = 10\sqrt{1-(ECC)^2} \quad (2)$$

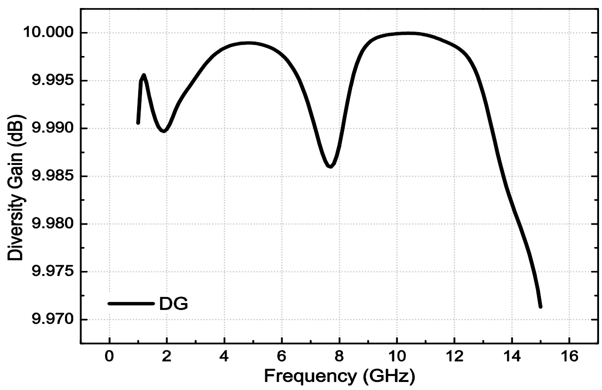

Fig. 9 Diversity Gain of the proposed antenna

It can be seen from equation 2 that diversity gain is dependent upon on ECC value, lower ECC value is desire for high diversity gain. Fig. 9 demonstrates the DG against frequency. It is noted from Fig. 9 that the proposed antenna has decent diversity gain (DG>9.98dB) for the whole UWB range.

F. Channel Capacity Loss (CCL)

Channel capacity loss (CCL) is also an essential factor for recognizing the performance of MIMO antenna. CCL can be calculated by the following relation for MIMO antenna as

$$CCL = -log_2(1 - |S_{ii}|^2 - |S_{ij}|^2) \quad (3)$$

The value of i=1,2 and j=1,2 as the system consist of two elements. MIMO antenna having CCL esteems under 0.5 bits/s/Hz is consider as good MIMO antenna. The simulated CCL computed from s-parameters is presented in Fig. 10.

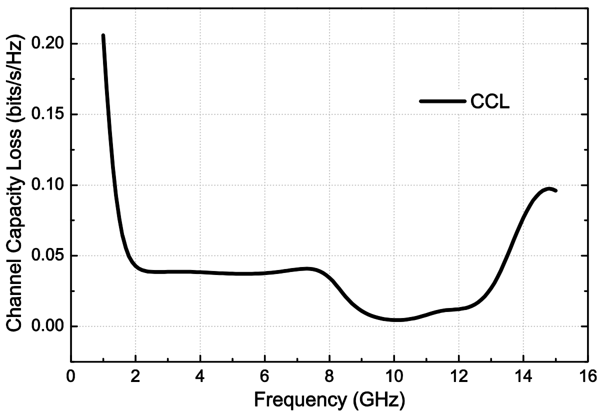

Fig. 10 CCL of the proposed antenna

V. CONCLUSION

A smaller two elements MIMO antenna working over UWB range has been proposed in this paper .The proposed antenna has simple structure and minimized size of 48×33 mm^2. High isolation between the MIMO elements is accomplished by presenting slotted stub in the ground plane of the MIMO antenna. Simulated result for Envelop Correlation Coefficient (ECC<0.05) and Diversity gain (DG>9.98 dB) demonstrates that the antenna is great possibility for UWB-MIMO range.

REFERENCES

[1] A. Iqbal, and O. A Saraereh "Maple Leaf Shaped UWB Monopole Antenna with Dual Band Notch Functionality," Progress in Electromagnetic Research C, Vol. 71, 169-175, 2017.

[2] S. A. Omar, A. Iqbal, O. A. Saraereh, and A. Basir," An Array of M-shaped Vivaldi Antennas for UWB Applications," Progress in Electromagnetic Research Letters, Vol. 68, 67-72, 2017.

[3] Ren, J., Hu, W., Yin, Y., and Fan, R.: 'Compact Printed MIMO Antenna for UWB Applications', IEEE Antenna wireless propag. Lett., 2014, 13, pp. 1547-1520.

[4] A. Iqbal, O. A. Saraereh, A. W. Ahmad and S. Bashir, "Mutual Coupling Reduction Using F-Shaped Stubs in UWB-MIMO Antenna," in IEEE Access, vol. PP, no. 99, pp. 1-1. doi: 10.1109/ACCESS.2017.2785232

[5] Liu, Y. F., Wand, P., and Qin, H.: 'Compact ACS-fed UWB antenna for diversity applications', IET electronic Lett., Sep. 2014, 50, (19), pp. 1336- 1338.

[6] Liu, L., Cheung, S. W., and Yuk, T. I.: 'Compact MIMO Antenna for Portable devices in UWB Applications', IEEE Trans. Antennas Propag., Aug. 2013, 61, (8), pp. 4257-4264.

[7] D. H. Margaret, M. R. Subasree, S. Susithra, S. S. Keerthika and B. Manimegalai, "Mutual coupling reduction in MIMO antenna system using EBG structures," 2012 International Conference on Signal Processing and Communications (SPCOM), Bangalore, 2012, pp. 1-5.

[8] Pandit, Soumen, Akhilesh Mohan, and Priyadip Ray. "A compact planar MIMO monopole antenna with reduced mutual coupling for WLAN applications using ELC resonator." Microwave Conference (APMC), 2016 Asia-Pacific. IEEE, 2016.