Compact Co-Planar Waveguide MIMO Antenna with Neutralization Line and Extended Ground for LTE Applications

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Abstract— the paper proposes a planar monopole antenna with a dual element Multiple-Inputs-Multiple-Outputs (MIMO) system. The main focus of the study was to propose a highly compact antenna as low as 15.5mm x 18mm x 1.6mm with very high isolation and low return loss. Isolation higher than 31dB is achieved with the implementation of a Neutralization Line (NL) and an extended ground structure. The return loss is also calculated as high as -25dB. The system works in the operating bandwidth of 2.72 GHz – 2.93 GHz (covering 210 MHz frequency). Firstly, the proposed design is implemented without any decoupling structures. Then, a NL is introduced and analyzed. This is followed by an extended ground structure. Finally, the above structures are compared and analysis and results are drafted.

Key words: Extended Ground Structure, LTE 2600 Band, MIMO Antennas, Neutralization Line, Planar Monopole Antenna

I. INTRODUCTION

With the increase in the number of antennas in a particular device such as a mobile handset, where compactness and bandwidth are the important considerations, a strong isolation between the antennas is desirable. As a result, Multiple-Inputs-Multiple-Outputs (MIMO) antennas are extensively used in today's wireless applications due to many crucial factors such as high data rate without consuming additional bandwidth and power [1, 2]. Though data rate increases with the use of multiple antenna system, strong electromagnetic coupling may occur as a result of the antennas operating together in a limited compact environment. Thus, to achieve a high isolation without compromising with the data rate, bandwidth and cost becomes a challenging task for any wireless device [3, 4].

Previous studies have tried to implement planar antennas with various decoupling structures such as Defected Ground Structures (DGS) [5] and Electromagnetic Band-Gap Structures [6, 7]. Though implementation of DGS provides a significant improvement in isolation, their performance gets reduced when operated in a conductive environment. The use of EBG structures are complex to implement and is impractical to use for very small structures, as the isolation is enhanced by suppressing the surface waves [6,7]. Some studies have implemented resonators such as Complementary Split Ring Resonator [8] and Meandered Line Resonators [9.10] which reduces isolation but also require complex calculations and high precisions for fabrications. Also, these structures operate only at a particular resonant frequency.

The main objective of the current study is to propose a MIMO antenna structure which is compact in nature, easy to fabricate and at the same time, provides a very high isolation and low return loss. The proposed design of the MIMO Antenna is shown in Fig. 1. The overall dimension of the proposed system is 15.5mm x 18mm x 1.6mm, which is suitable for any handset system. The design covers the LTE 2600 band and provides an isolation as high as 31dB and a return loss higher than -25dB. Due to its simple design, high efficiency and compact nature, the proposed system finds many uses in the mobile handset applications.

Fig. 1: Proposed Antenna Design

II. ANTENNA DESIGN

The design proposes a 2x2 planar monopole MIMO Antenna system, build on a 1.6mm thick FR4 substrate. The design incorporates Co-Planar Waveguide feeding technique in which the patch and the ground are on the same side of the substrate. To achieve a high isolation between the antennas, decoupling techniques such as a Neutralization Line (NL) connecting both the antennas and an extended ground structure are adapted. These structures are easy to fabricate and does not consume additional space. The design parameters have been referred from the model studied in [11] and have been tabulated in TABLE 1. The initial design structure is shown in Fig. 2. It consists of two patch antennas separated by a distance of 7.8mm, while the two inner ground planes are separated by a distance of 2.6mm.

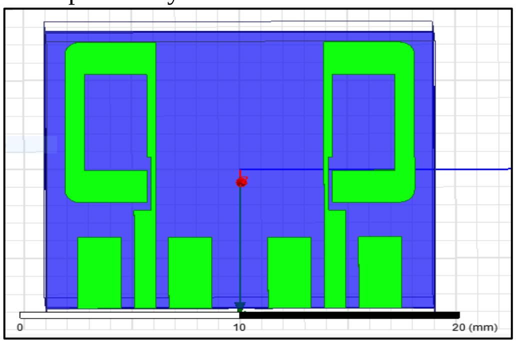
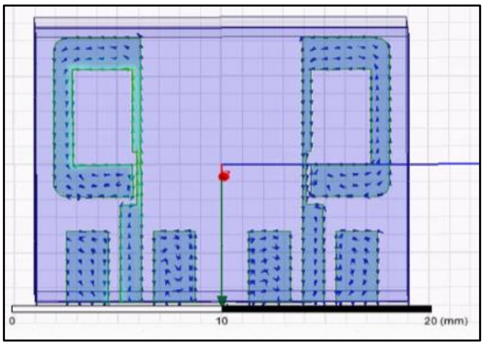
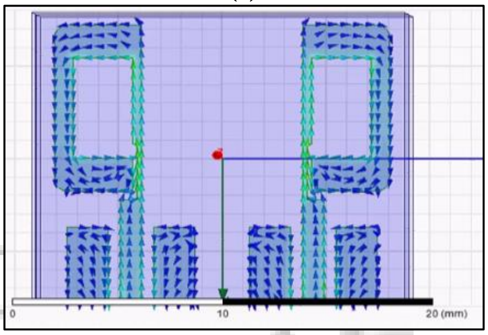


Fig. 2: Initial Design without De-Coupling techniques

Fig. 3(a) shows the corresponding surface current density when only one port is excited. It has been observed in [11] that the isolation is affected by the separation between the antennas as well as the rotations of the surface currents on the patch. As separation increases, the isolation reduces drastically. But as the current study demands high compactness, minimal separation is desired. Also, due to skin effect, when only one antenna is excited at the operating frequency, the surface current orientations in the other antenna is the same as that of the excited antenna. Both the antennas have the same rotation of the surface current density.



(a)



(b)

Fig. 3: Surface Current Density with (a) Single Port Excitation (b) Dual Port Excitation

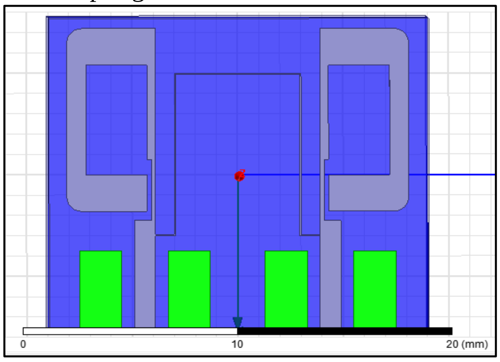
The above design gave an isolation of 9dB and a return loss of -11dB at the operating frequency of 2.8GHz.

Fig. 3(b) depicts the proposed design, but with both the antennas excited at the operating frequency. If done so, both the antennas orient with opposite surface current densities. In addition, it can also be seen that the coupling between the two gets reduced to a certain extent [11].

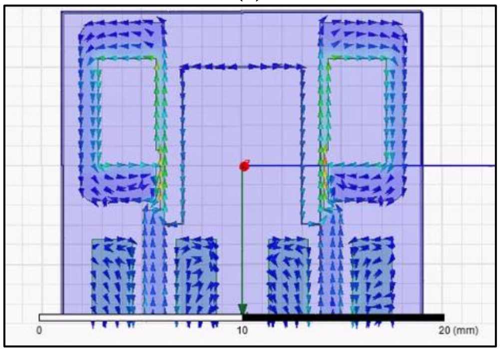
In order to improve the isolation and the return loss, a Neutralization Line (NL) of suitable length is implemented. Based on the surface current density, a suitable point on the patch is selected such that the impedance is minimum and the current is maximum at that location. Then, its phase is reversed by choosing a suitable length for the Neutralization Line and is connected to the other patch. This introduces certain current in the NL and reduces the mutual coupling between the two patch antennas [12].

Fig. 4(a) shows the design with the Neutralization Line (NL) implemented. The overall dimensions of the Neutralization Line (NL) is shown in TABLE 2. The surface current density of the design is shown in Fig 4(b) with both the ports excited. It can be observed that the current density at the Neutralization Line (NL) is reversed and fed to the other antenna. The isolation with the Neutralization Line (NL) gets improved to 16dB and a return loss of -14dB is achieved at the operating frequency of 2.8GHz.

In addition to the Neutralization Line, to improve both the isolation and the return loss of the design, the inner ground planes of the system is extended to short the Neutralization Line (NL). This creates a closed path between the ground and the Neutralization Line (NL) and drastically reduces the coupling between the two antennas.

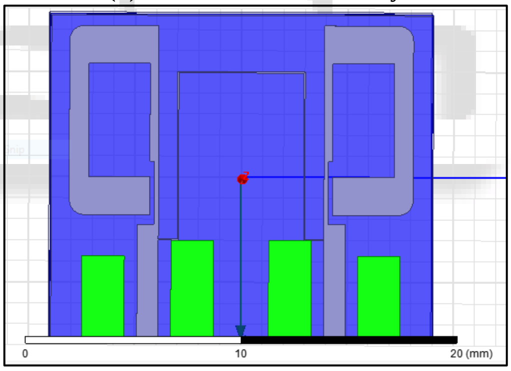


(a)

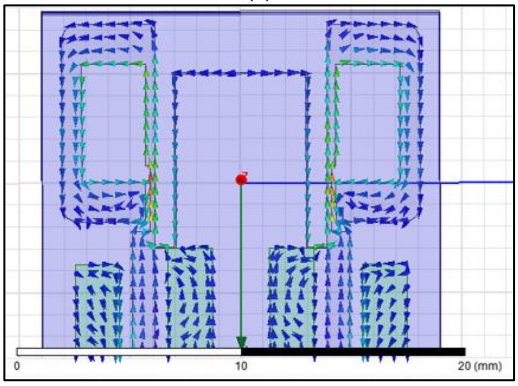


(b)

Fig. 4. Design of Antenna (a) with Neutralization Line (b) Surface Current Density



(a)



(b)

Fig. 5: Design of Antenna (a) with Neutralization Line and Extended Ground (b) Surface Current Density

Fig. 5(a) shows the design of the antennas with both the Neutralization Line (NL) and the extended ground structure. Fig. 5(b) shows the surface current density of the same. TABLE 3 shows the overall dimensions of the Extended Ground structure. The dimensions of the outer ground planes are kept same as that of the reference model. This can be seen in Fig. 5(a). Also, as both the ports are excited, the rotation of the surface current density is opposite as seen in the Fig. 5(b).

The isolation with the Neutralization Line (NL) in addition to the Extended Ground increases to 31dB and a return loss as low as -25dB is achieved at 2.8GHz. The ground shorts the Neutralization Line (NL) which can be clearly seen by plotting the surface current density of the same as shown in Fig. 5(b). This not only helps to reduce the electromagnetic coupling from one patch to the other by improvising the effect caused by the Neutralization Line (NL) but also shows a drastic improvement in the return Loss factor as well. Such an isolation is largely desired for multiple antennas systems such as handset which incorporates multi-tasking features at the desired frequency range.

III. DESIGN TABLES

Parameter	Value	Parameter	Value
Substrate length	18 mm	wp	4.6 mm
Substrate width	15.5 mm	l1	5.4 mm
w0	1.8 mm	l3	4 mm
w1	3.3 mm	lf	5.5 mm
w3	2 mm	lg	7.8 mm
w3	0.6 mm	lm	2.6 mm
w4	0.9 mm	ln	3 mm
wf	0.4 mm	thickness	1.6 mm
wg	0.2 mm	Patch thickness	0.05 mm
wm	1 mm	(Thickness) air box	20*thickness
wn	0.2 mm	(Width and length) air box	Same as substrate

Table 1: Overall Dimensions of the Base Model

Parameter	Value
Overall length of the Neutralization Line (NL=N1+N2+N3)	26 mm
Width of the Neutralization Line, Np	0.5 mm

Table 2: Overall Dimensions of the Neutralization Line (Nl)

Parameter	Value
Length of the Extended Ground, L2	4.75 mm
Width of the Extended Ground, W2	2 mm

Table 3: Overall Dimensions of the Extended Ground Structure

IV. RESULTS – SIMULATIONS AND COMPARISON

The simulation graphs of each individual design are discussed below. All the designs showed considerable reduction in mutual coupling and return loss lower than the reference design. All the simulations were carried out in the Ansoft HFSS v13.0 tool. In the proposed design without any decoupling structure, the simulation gave an isolation of 9dB and a return loss of -11dB when operated at 2.8GHz. Fig. 5 shows the simulation graph of the design without any decoupling structure.

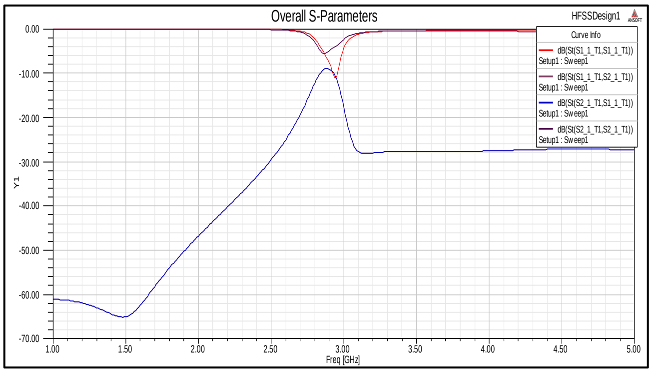


Fig. 5: Simulation Graph of the design without any decoupling structure

When simulated with the implementation of the Neutralization Line (NL) alone as shown in Fig. 6, the graph showed an improvement in the isolation of 16dB and return loss of -14dB in the desired frequency.

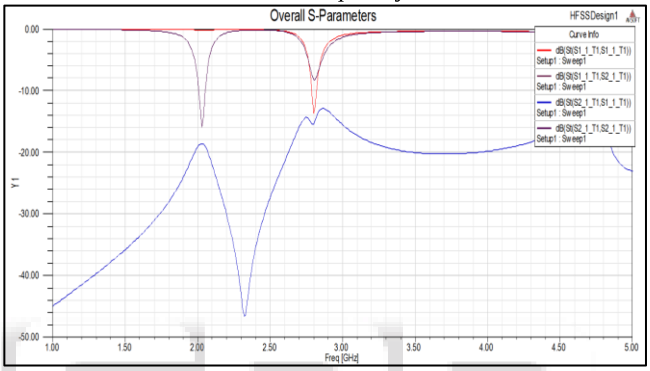


Fig. 6: Simulation Graph of the design with Neutralization Line (NL)

The implementation of the extended ground structure further reduced the coupling and the return loss to a greater extend. With both the Neutralization Line and the extended ground structure, isolation as high as 31dB and a return loss of about -25dB is achieved at the operating frequency of 2.8GHz. This result shows a drastic improvement as compared to the initial model which is implemented without any decoupling structure. Fig. 7 shows the simulation graph of the structure implemented with both the Neutralization Line and the Extended Ground.

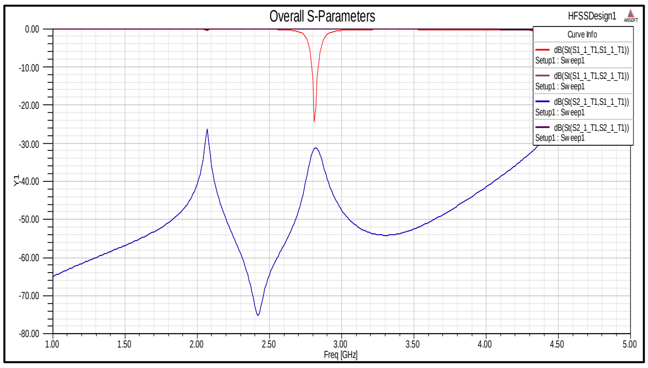


Fig. 7: Simulation Graph of the design with Neutralization Line (NL) and Extended Ground structure

Table 4 shows a tabular description of the simulation results of the various scenarios. It is clear from the table that with the addition of the Neutralization Line (NL) and Extended Ground structure shows significant improvement in both the isolation and the return loss over its initial designs.

Hence, this design has been proposed for various handset applications at the desired frequency range.

Design	Isolation (dB)	Return Loss(dB)	Volume (m^3)
Without Decoupling Structures	9dB	-11dB	15.5mm x 18mm x 1.6mm
With Neutralization Line (NL)	16dB	-14dB	15.5mm x 18mm x 1.6mm
With Neutralization Line (NL) and Extended Ground Structure	31dB	25dB	15.5mm x 18mm x 1.6mm

Table 4: Comparison between Different Simulation Models

V. CONCLUSION

Thus, a compact and simple 2x2 MIMO system has been designed giving a very high isolation and low return loss which makes it suitable for handset applications in the desired frequency range. Further improvements can be made by implementing a 4x4 antenna of the same model and analyzing its gain and isolation. The study can further be extended by changing the electrical length of the system and analyzing the design in the LTE 2300 band.

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REFERENCES

[1] T. Kokkinos, E. Liakou, and A. P. Feresidis, “Decoupling antenna elements of PIFA arrays on handheld devices,” Electronics Letters, vol. 44, no. 25, pp. 1442–1444, 2008.
[2] H. Li, J. Xiong, Z. Ying, and S. L.He, “Compact and low profile co-located MIMO antenna structure with polarisation diversity and high port isolation,” Electronics Letters, vol. 46, no. 2, pp. 108–110, 2010.
[3] S. Zhang, P. Zetterberg, and S. He, “Printed MIMO antenna system of four closely-spaced elements with large bandwidth and high isolation,” Electronics Letters, vol. 46, no. 15, pp. 1052–1053, 2010.
[4] S. Park and C. Jung, “Compact MIMO antenna with high isolation performance,” Electronics Letters, vol. 46, no. 6, pp. 390–391, 2010.
[5] A. Habashi, J. Nourinia, and C. Ghobadi, “A rectangular defected ground structure (DGS) for reduction of mutual coupling between closely-spaced microstrip antennas,” in Proceedings of the 20th Iranian Conference on Electrical Engineering (ICEE ’12), pp. 1347–1350, IEEE, Tehran, Iran, May 2012.
[6] H. S. Farahani, M. Veysi, M. Kamyab, and A. Tadjalli, “Mutual coupling reduction in patch antenna arrays using a UC-EBG superstrate,” IEEE Antennas and Wireless Propagation Letters, vol. 9, pp. 57–59, 2010.
[7] G. Exp´osito-Dom´ınguez, J. M. Fern´andez-Gonz´alez, P. Padilla, and M. Sierra-Castaner, “New EBG solutions for mutual coupling reduction,” in Proceedings of the 6th European Conference on Antennas and Propagation (EUCAP ’12), pp. 2841–2844, IEEE, Prague, Czech Republic, March 2012.
[8] Shruti Dhamankar and Snehal Lopes, “Mutual Coupling Reduction Techniques in Microstrip Patch Antennas: A Survey”, International Research Journal of Engineering and Technology (IRJET), pp. 1064-1069, Vol. 03, March 2016.
[9] M. G. N. Alsath, M. Kanagasabai, and B. Balasubramanian, “Implementation of slotted meander-line resonators for isolation enhancement in microstrip patch antenna arrays,” IEEE Antennas and Wireless Propagation Letters, vol. 12, pp. 15–18, 2013.
[10] H. Arun, A. K. Sarma, M. Kanagasabai, S. Velan, C. Raviteja, and M. G. N. Alsath, “Deployment of modified serpentine structure for mutual coupling reduction in MIMO antennas,” IEEE Antennas and Wireless Propagation Letters, vol. 13, pp. 277–280, 2014.
[11] Lingsheng Yang, Tao Li and Su Yan, “Highly Compact MIMO Antenna System for LTE/ISM Applications”, International Journal of Antennas and Propagation, Vol. 2015.
[12] A. Christina Josephine Malathi and D. Thiripurasundari, “Review on Isolation Techniques in MIMO Antenna Systems”, Indian Journal of Science and Technology, Vol 9(35), September 2016