Designing a Compact MIMO System with High Isolation using Meandered Line Antennas for LTE Handset Applications

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Abstract— this paper focuses on the designing of a MIMO system with an aim of obtaining high isolation between the antennas and thus maintaining a compact structure suitable for use in the limited space offered by mobile handsets. To achieve the desired results different arrangements have been studied upon. The paper brings out the effect on the isolation of the MIMO system with respect to different defects created in the ground structure and also the changes observed with respect to the shape of the antennas used in the MIMO system. Results have shown better isolation with the coupling co-efficient lower than -18 dB and -6 dB bandwidth of 40 MHz in the desired frequency range of 745-785MHz. The volume of the MIMO system is found to be 64 X 80 X 1.6 mm^3.

Key words: Compactness, Coupling Co-Efficient, Defected Ground Structure (DGS), Isolation, Multiple Input Multiple Output (MIMO)

I. Introduction

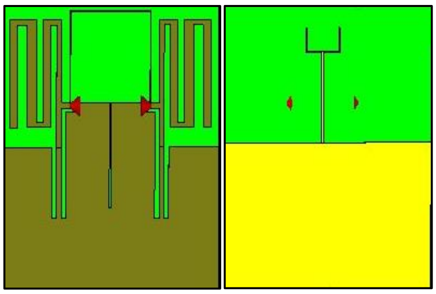
The highly applicative background of multiple input multiple output (MIMO) antennas is the background behind this study. With the ever increasing demand of mobile handsets and its associated need of improved wireless communication, makes Long Term Evolution (LTE) a highly important topic to be worked upon. MIMO systems have found its application in LTE mobile communications field. High Isolation and compactness of the antenna system are two key factors for the use of MIMO system in LTE handset applications. However one of the drawbacks of MIMO antennas is the mutual coupling that occurs between the antennas in the system. Mutual coupling occurs between nearby antennas placed in a system due to signal leakage from one antenna to the other.

Thus overcoming the issue of mutual coupling is one of the important factor for the use of a MIMO system. Different studies have been brought how to overcome the issue of mutual coupling. Recent use of MIMO systems for LTE application is studied [1-4]. The use of decoupling networks and hybrid couplers and how they restrict operations in certain frequencies is studied and have found to improve the isolation [5-6]. The use of a floating parasitic decoupling structure for ultra-wide band antenna has been seen to provide wideband isolation characteristics of about 20 dB [7]. In [8], a neutralization line inserted between two antennas is seen to invoke current on the line which creates an electromagnetic field between the antennas which reduces the mutual coupling. How a neutralization line can be used to reduce mutual coupling in between two F shaped monopole antennas have been studied in [9]. To further understand the effect of different shapes of antennas design, different antenna designs used in MIMO systems have been studied. The use of P – shaped monopole antennas for a suitable MIMO antenna system has been studied in [10]. The use of a fork shaped design in the ground plane for UWB planar antennas to improve the isolation has been studied [11-12]. The method of creating defects in the ground structure has been studied and how they affect the isolation has been studied [13-14]. Different defects created in form of slits and dumbbell shapes has been studied [15-17]. The MIMO antenna design using a combination of neutralization line, slits in antenna ground and fork shaped structures in the ground plane to obtain coupling of about -12 dB is studied in [18].

In this paper, a 2 X 2 MIMO system has been designed using two meandered line antennas that are closely placed to each other. After applying different decoupling techniques like the neutralization line technique, creation of slits in the antenna ground and implementing fork shaped design in the ground plane, different studies were practiced upon to improve the isolation of the system. The effect of a T-shaped defect in the ground plane, an Electromagnetic Band Gap (EBG) inspired defect in the ground plane and effects on introduction of stub line in the antennas have been worked on in this paper. A comparison between the results is made and the model providing the most decent agreement with respect to isolation and compactness of the system has been proposed.

II. Design of MIMO System

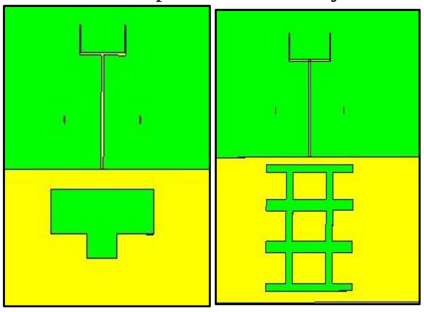
The paper proposes a 2 X 2 MIMO system in which two meandered line antennas are closely placed to each other to obtain a compact structure. The two antennas are designed on a FR-4 substrate with a dielectric constant of 4.3. To obtain better isolation in between the antennas different decoupling techniques like the use of a neutralization line between the antennas, slits in the antenna ground and implementing a fork shaped structure in the ground plane. The design parameters of each element has been referred from the model suggested in [18]. The initial antenna structure is shown in the figure given below:



(a) (b)

Fig. 1: Initial antenna design without defects and stubs. a) Front view. b) Back view.

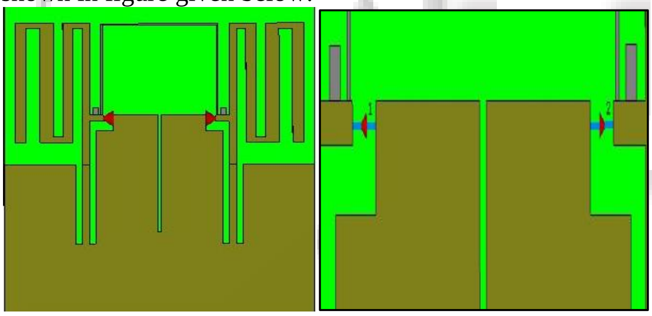
With the above techniques it was found that the coupling coefficient was about -12 dB in the frequency range of 745-785 MHz and a volume of 65 X 110 X 1.6 mm^3. The proposed models suggested in this paper brings out the changes brought about with introduction of defects in the ground plane and addition of stubs in the antenna structure. The corresponding results show improvement with respect to the isolation and the compactness of the system.



(a) (b)

Fig. (2): Ground plane a) with T-shaped DGS. b) With EBG inspired DGS with gap=0.

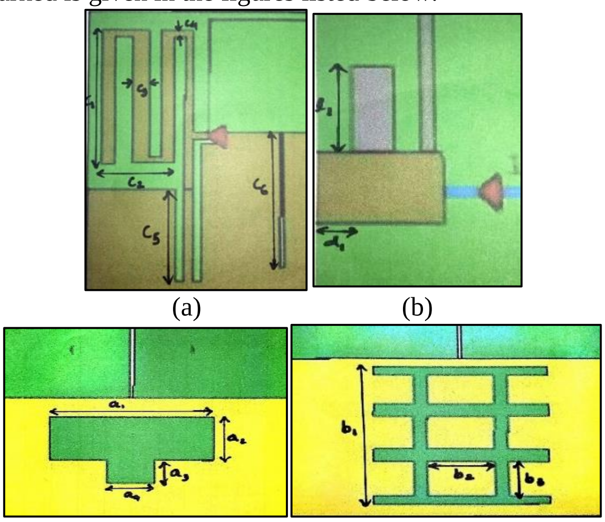
Fig 2(a) shows the implementation of a T-shaped shaped defect in the ground plane while 2(b) shows the implementation of an Electromagnetic Band Gap (EBG) inspired defect in the ground. To further improve the isolation and study the effect of stubs, two stub wire lines were added to the respective antenna structure. It was observed that the model resulted in further improvement of the isolation maintaining a stable bandwidth in the desired frequency range. The stubs were implemented along with the T-shaped DGS in the ground plane. The antenna structure with stubs is shown in figure given below:



(a) (b)

Fig. (3): (a) Model with stubs (b) Focussed view of the location of the stubs.

The focussed view of the antenna, stub line, T-shaped DGS and the EBG inspired defect with dimensions marked is given in the figures listed below:



(c) (d)

Fig. 4: Design specifications of a)Antenna b) Stub line C) T-shaped DGS d) EBG inspired DGS.

The design speciafications of the antenna has been given in the Table (1) given below:

Parameter	Dimension (mm)
a_1	28
a_2	10
a_3	6
a_4	8
b_1	30
b_2	8
b_3	7.5
c_1	32
c_2	15
c_3	3
c_4	1
c_5	21
c_6	31
l_1	2
d_1	1
g	0

Table 1: Dimensions of the proposed model

III. SIMULATION AND COMPARISON

Each of the above designed models were individually simulated. It was found that all the simualtion results showed considerable improvements with respect to the isolation and compactness of the design from previous related works. In the design with a T-shaped DGS in the ground plane, the coupling co-efficient was found to be at value lower than -17 dB at all frequencies in the desired range of 745-785 MHZ as shown in figure 5(a).

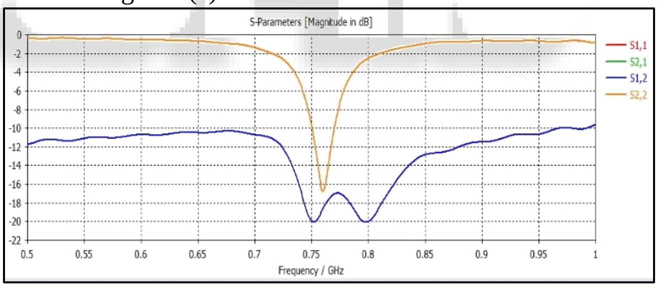


Fig. 5(a): simulation results with T-shaped DGS.

With the implementation of the DGS the volume of the antenna was successfully reduced to 64 X 80 X 1.6 mm^3. While the model with EBG inspired DGS showed a coupling lower than -13 dB in the desired frequency range with a volume of 65 X 86 X 1.6 mm^3. This is shown in figure 5(b) given below:

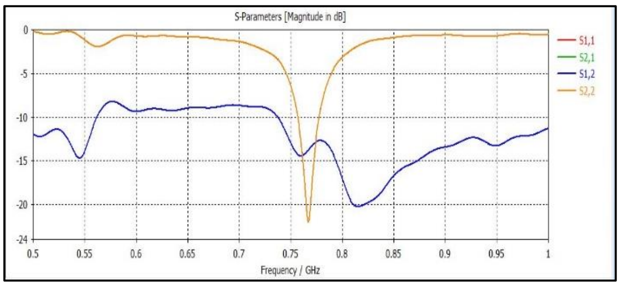


Fig. 5(b): Simulation results with EBG inspired DGS

The implementation of stubs in the DGS implemented model further reduced the coupling to a value lower than -18 dB in the frequency range of 745-785 MHz with the same volume as in the latter case . The output of the model is given in the figure 4(c):

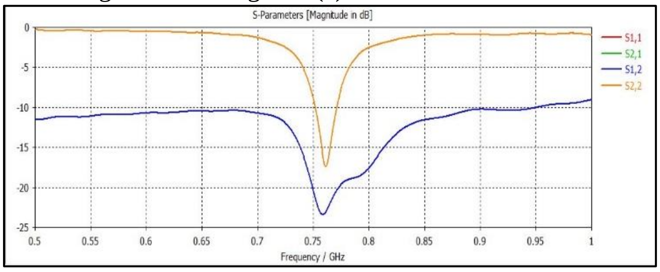


Fig. 5(c): Simulation results with stub lines and T-shaped DGS.

A clearer analysis of the reuslts obtained by different structures is shown in the comparison table in TABLE (2) as shown below:

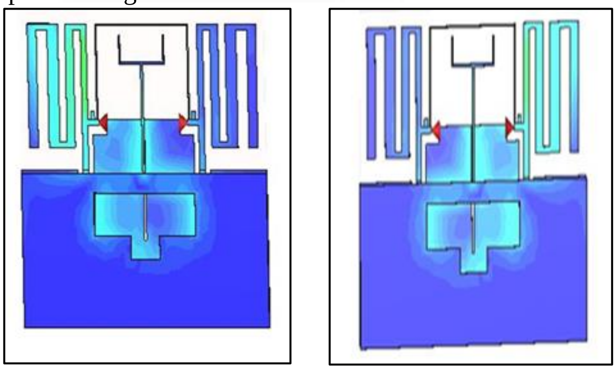
Design	Coupling	Volume (mm^3)	Frequency of operation
Without defects	-12 dB	65 X 110 X 1.6	745-785 MHz
With T-shaped DGS	<-17 dB	64 X 80 X 1.6	745-785 MHz
With EBG structure	<-13 dB	65 X 86 X 1.6	745-790 MHz
With Stubs	<-18 dB	64 X 80 X 1.6	745-7985 MHz

Table 2:Comparison between presented models

From the above table it can be concluded that the model with the implemented stubs in the antenna model and the T – shaped DGS in the ground plane gives the best results showing an improvement of – 6 dB with respect to the coupling in the antennas.

IV. RESULTS

To further analyse the proposed model, the current distribution during excited state of each antenna has been depicted in figure 6.



(a) (b)

Fig. (6): Current Distribution (a) When antenna 1 is excited (b) When antenna 2 is excited.

It can be understood from figure 5(a) that when antenna one (right side antenna) is excited, there is no effect on antenna two (right side antenna). Similarly when antenna two (right side antenna) is excited there is no effect on the first antenna (right side antenna). This proves the point of reduced coupling in between the two antennas.

The calculated envelope correlation coefficient between the antennas is less than (0.15) over the band 745-785 MHz and its minimum value is (0.002) at the frequency (775) MHz, as shown in Figure (7) which meets the required specification of (ECC < 0.5).

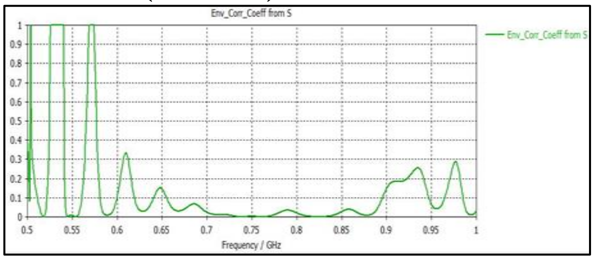


Fig. 7: Envelope correlation coefficient of the proposed model

V. CONCLUSION

Thus a 2 X 2 antenna MIMO system with different ground defects and stub arrangements has been proposed. The highly compact structure of the design and the high isolation makes the design appropriate for the use in LTE handsets. Further the low frequency operation band of the proposed model makes it suitable for LTE-700 band applications.

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