Compact Coax Fed MIMO Antenna for LTE-Advanced and IEEE 802.16m Operations in 4G Mobile Terminals

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ABSTRACT
A compact 2-port coax feed MIMO antenna is presented in this paper to operate LTE and WiMAX frequency bands for the application of compact smart mobile terminals. The overall dimension of proposed slot antenna can reach 44mm×50mm. The proposed antenna structure contains two layers, which has a rectangular patch, a pair of small-N shaped strips and two G- shaped antenna structures. The previously mentioned structures are simulated with the suitable FR4 substrate to achieve operating frequencies at 1.8 GHz and 2.3 GHz. In the proposed antenna design, certain parts of the patch respectively excited the two resonant frequencies of LTE and WiMAX operations. Here, one resonant frequency operation can be flexibly adjusted with minute effect on the other frequency. The parametric study on the antenna performance and principle of operation are provided in this letter. Simulation results illustrate the excellent radiation patterns for all the two bands and recommend that the proposed 2-port MIMO antenna is suitable for the LTE and WiMAX operations in compact mobile terminal.

Keywords
Long Term Evolution (LTE), Worldwide Interoperability for Microwave Access (WiMAX), MIMO antenna, Compact mobile terminal, Dual-band antenna.

1. INTRODUCTION
In recent years, Long Term Evolution (LTE) and the Worldwide Interoperability for Microwave Access (WiMAX) systems have been used extensively in telecommunication and other commercial applications. Nowadays, such wireless communication systems are widely developed in the present world, which stands to a huge demand in designing low-cast, compact and multiband antennas for convenient devices in modern wireless terminals. Also, these wireless communication devices are competent for both LTE and WiMAX to be used as a single system.

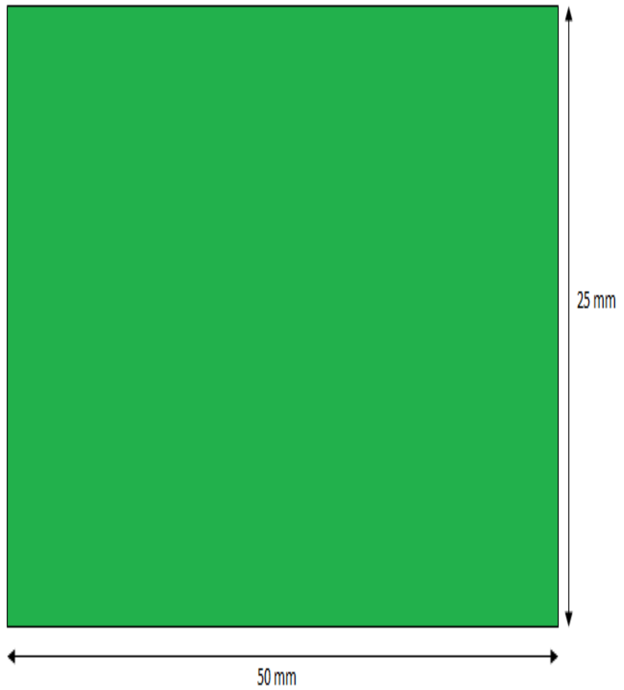
To satisfy these necessities, various antenna structures have been reported [1]-[10]. To design an antenna for these applications, various methodologies have been applied to develop radiation characteristics of the narrowband MIMO antenna [3-12]. In [3, 4], there is good radiation pattern achieved by addition of parasitic rudiments, which can generate the reverse coupling for decrease mutual coupling. Though, the ways of adding together parasitic elements are perceptive to the position of parasitic rudiments. A counteract line is introduce between the two PIFAs in [5, 6]. This way can establish some neutralization current line and generate an supplementary electromagnetic field pattern to the enhance isolation between two ports. However, it is a challenge to find out the less impedance area, which suits for the counteract line. Here, make use of electromagnetic band gap (EBG) is capable to hold back the surface wavelength propagation [7, 8], and there is improve the radiation characteristics between radiating rudiments. Though, these techniques engage important areas. Further isolation enhanced method, like integrate a obtrude ground between the various antennas [9, 10] introduce slits through the ground [11], applying multiple port conjugate match [12], can be used.

Initially, the proposed antenna was developed from the models reported above and we achieved enough bandwidth by designing the various types of structure with two layers. Then the proposed antenna, compared to the previously mentioned antennas with the similar operations has many advantages. For instance, the size of an antenna is much smaller and it can efficiently offer broad impedance bandwidth. Each structure in the proposed antenna can generate different operating frequencies respectively. Additionally, this 2-port MIMO antenna has wide frequency tuning capability that is much helpful in a mixture of applications.

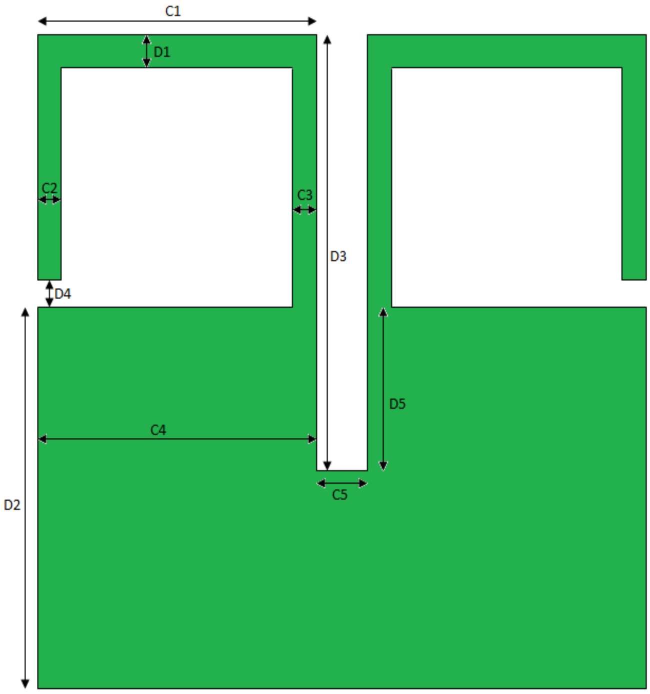
In this report, a compact coax fed multi port MIMO antenna for 4G mobile devices covering LTE-Advanced at 1.8GHz and WiMAX-IEEE 802.16m at 2.5GHz is proposed. The proposed antenna can act as LTE and WiMAX MIMO antenna with low size and cost. It has an efficient bandwidth with $S11$ and S22 more than -20 dB from 1.8 and 2.5 GHz. We utilize the way, combining and adding the ground branches for etching slot in the typical ground to develop isolation. The proposed antenna has been simulated and the result shows excellent impedance matching at the LTE and WiMAX frequency bands and lower return loss, all of which makes the proposed coax feed MIMO antenna as a well match for wireless communication applications such as mobile phones. This letter will discuss the following aspects. In Section II, the structure and detailed principle of operation for the proposed slot antenna are addressed. The simulated results of the antenna profiles are established in Section III. Finally, section IV gives the conclusion of this paper.

2. ANTENNA CONFIGURATION
To achieve the dual band operation for LTE-Advanced and WiMAX-IEEE 802.16m operations, the proposed antenna design process is exposed in Fig.1 and it is fed by coax feeding method. The proposed 2-port MIMO antenna contains two layers. Here, the bottom layer has the rectangular patch and two small N shaped strips placed on top of the rectangular patch. The top layer consists of a G shaped antenna structure followed by its lateral image structure on the right hand side and both have same dimensions. Both, top and bottom layer

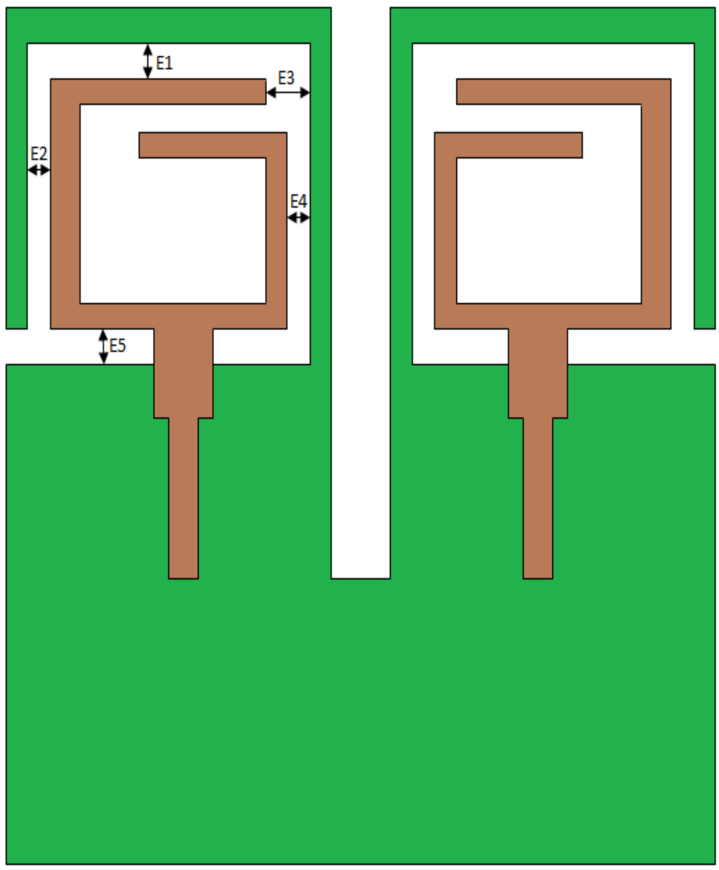
are connected by coax feeding technique which provides sufficient radiation pattern. The substrate design of an antenna consist a single layer comprising of FR4 substrate with the thickness of 0.4 mm, relative dielectric constant of 3.0 and the loss tangent of 0.01. The dimension of the overall antenna structure is 50 mm x 44 mm, which is smaller than the existing antennas presented in [1-13]. The Coax fed MIMO antenna design process is given as follows,



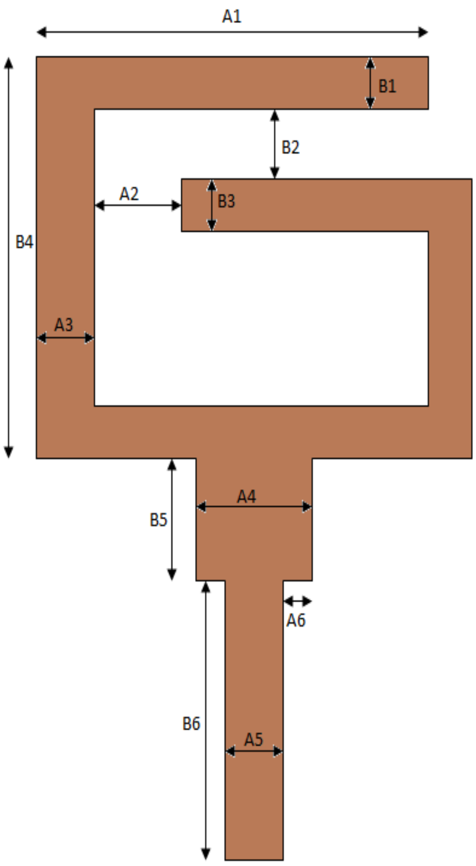
(a) Step-1: Rectangular Patch



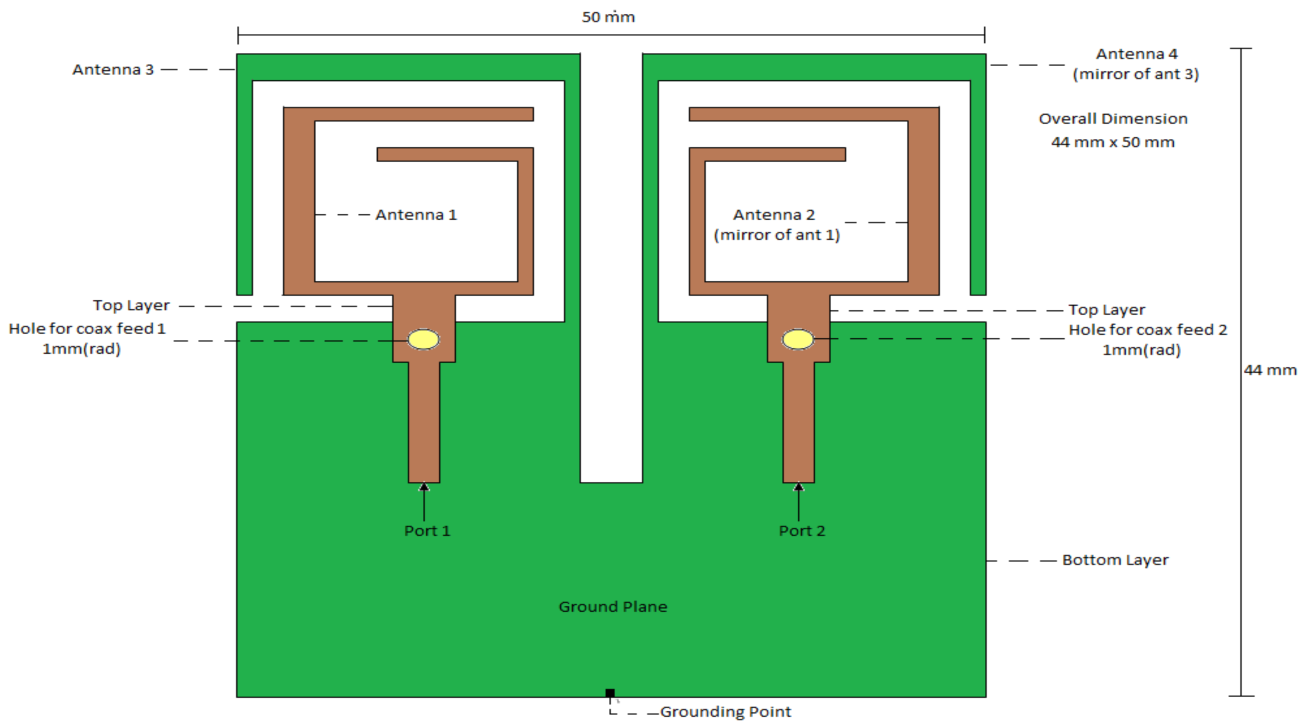
(b) Step-2: Rectangular Patch with small N-shaped Strips

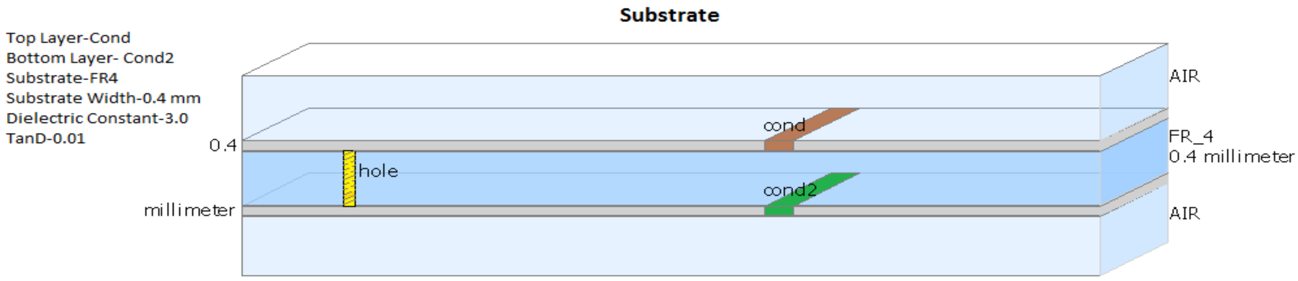


(c) Step-3: G-Shaped strip and its mirror shape placed on bottom layer



(d) Measurements of G-Shaped Antenna Structure





(e) Overall structure of proposed MIMO antenna

Fig 1: Coax fed MIMO antenna design process

Table 1. Measurements of proposed MIMO antenna design

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
A1	14.5	C2, C3	1.5
A2	3	C4	23.5
A3	2	C5	3
A4	3.5	D1	2
A5	1.5	D2	25
A6	1	D3	29.5
B1, B3	1.5	D4	1.5
B2	2	D5	10.5
B4	14.5	E1, E4	2
B5	4.5	E2	2.5
B6	7.5	E3	3.5
C1	23.5	E5	1.5

3. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed antenna designed by using Advanced Design System (ADS). The simulated scattering parameters are shown in Fig. 2. The observed S_{11} and S_{22} curves of simulated antenna are almost most accepted that the importance of S_{22} higher than the S_{11}. It can be observed from Fig. 3 then the two-branch antenna produced two resonant modes around the 1.8 and 2.5 GHz. In addition, both the S_{11} and S_{22} are smaller than -30 dB.

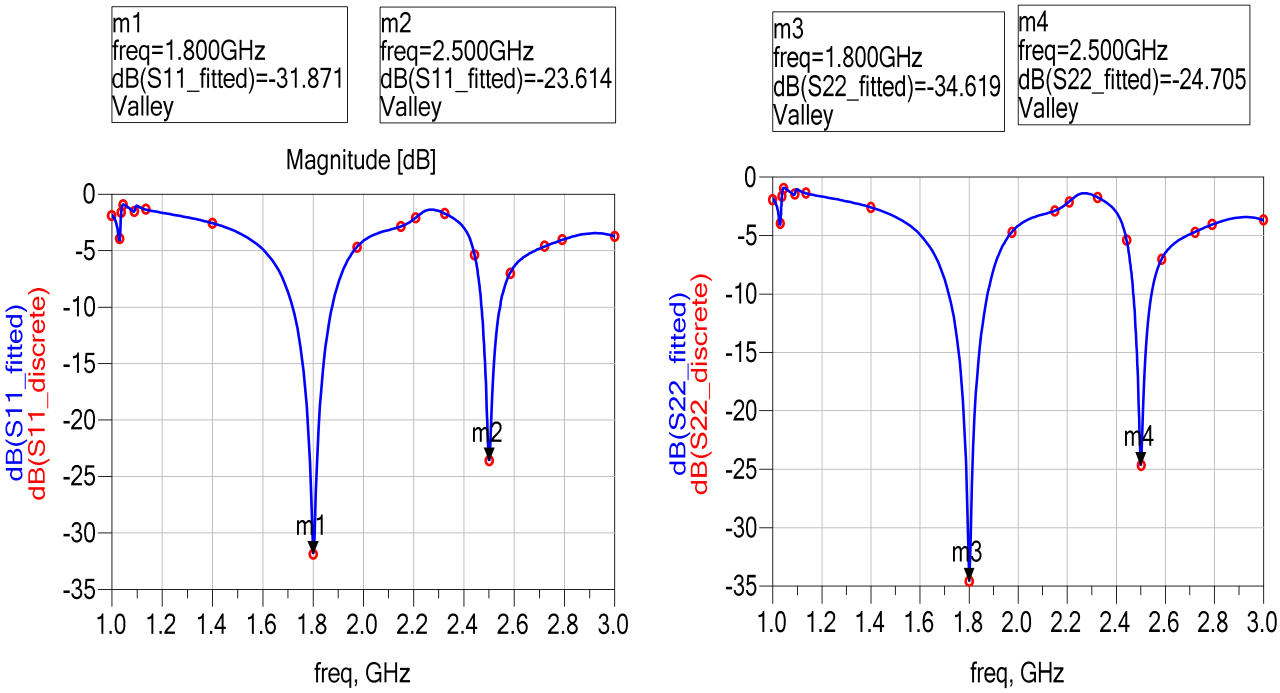
The given design process of the MIMO antenna can be developed into the following concepts:

1) Design a multiple antenna element that has broadband operation. Our proposal is depends on integrating several closed frequency resonant mode, which gives broadband operation. The major issue is design the lengths of branch 1 and branch 2, which straightly find out whether the broadband aspect can be produced or not.

2) Use the ground branches to increase isolation in low operating band. It is complicated to increase the isolation in lower operating band, so we consider the low-band property. The major obsession is to establish the position of small N shaped branches that minute affect the S_{11} when addition to these two antenna branches.

3) Increase the high band radiation by etching the T slot in ground. The original thought is part of the T-slot, which created by two ground branches and the arrangement of these two used to improving the isolation concepts. The slot's horizontal length is created near half wavelength at 2.5 GHz.

As represented in Fig. 1, we designed a multi port MIMO antenna that has convention ground. It has two different branches and forms a G-shape. We can compute the half wave resonant mode of two branches. Figure 2 illustrate simulated replicate coefficients of the single MIMO antenna branch 1 and branch 2, respectively. From the Fig. 4, it can be observed the half wavelength resonant mode at 1.8 GHz and 2.5 GHz, respectively.



(a) Return Loss at port-1 **(b) Return Loss at port-1**

Fig 2: S-Parameter Calculation

The simulated resonant mode gives the good radiation characteristics. The physical antenna stub used to explain the MIMO signed as dotted oval in Fig. 1, which perform as a matching stub and also be unlocking shunt stub which makes the lower resonance. The two structures cannot be close because of strapping coupling depreciate the antenna. It can be notice that G-Shape resonant mode at 1.8 GHz and 2.5 GHz transfer large when the two twigs arrange jointly. Moreover, two more number of new superior frequency modes of operation is formed. The antenna explained in [13] has similar types of broadband mechanism which utilize the method which makes several resonant modes of operations arranged closely. We abandoned the lower band around 1.8 GHz because of some practical use in this narrow band combination. We can shape the MIMO antenna by utilize two different antenna coupling elements without decoupled process. Throughout surveying the left picture of current allocation at 1.8 GHz in Fig.3, it can be mentioned the current contemplate between the left bottom part of the branch 1 and the up average of ground, which appear like a slotted antenna. When the measurement of the slot antenna is 10mm it can able to resonate at 2.5 GHz. Therefore the current cannot flow to the supplementary antenna structure, and produce high isolation can produced without the decoupling method at 1.8 GHz. Initially, we attempt to use ground division method that is broadly used to increase the radiation between the two G-Shaped antennas. Two upturned L branches are additional to the extending form of ground and it can be used two different reflectors that reproduce the breathing space wave back. The calculated length of all small N strips is 30.3mm which is between the heights of branch 1 and branch 2; therefore it can work in between these two different half wave resonant mode operation. We can ideally find simply improve the separation of antennas in low band, but there is diminutive authority in high band. Next, in order to increase the isolation in higher band, we furthermore introduce a small N-slot etched in the place of ground. In diminutive, the grouping of small-N branches and small N-slots, there is a radiation pattern in the all band particularly high band is considerably improved.

Figure.3 explained the current circulation of the predictable grounded MIMO antenna structure and the proposed MIMO antenna at 1.8 and 2.5 GHz respectively. As demonstrated in Fig. 3, the current is mostly reflect by the left side of upturned small N-branch close to the thrilled antenna and blocked stopped by the G-shaped structure at 1.8 GHz inverted N branch has the no current distribution or coupling rather than the gap between two overturned small N-branches nearly 0.025 half wavelength at 2.5 GHz. From the iteration, anticipated antenna design with coupling model, it can be seen that the coupling structure have great effect on improves radiation characteristics. Our main goal is examine the relevant pattern which makes the better thoughtful preposition by the decoupling model. Then the current distribution makes the antenna to radiate effectively.

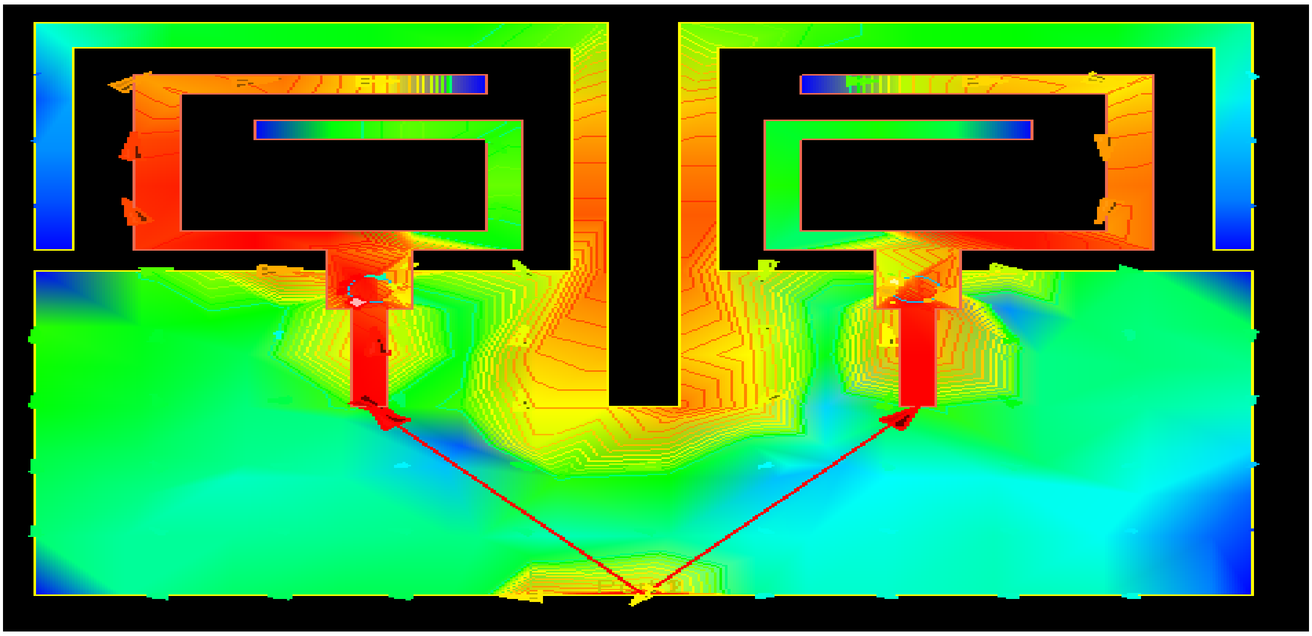
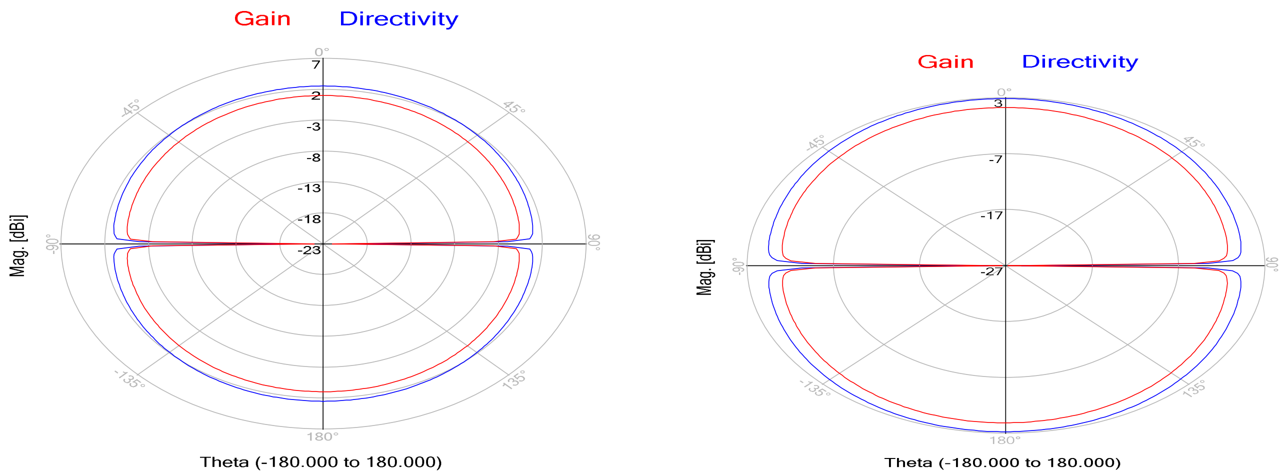


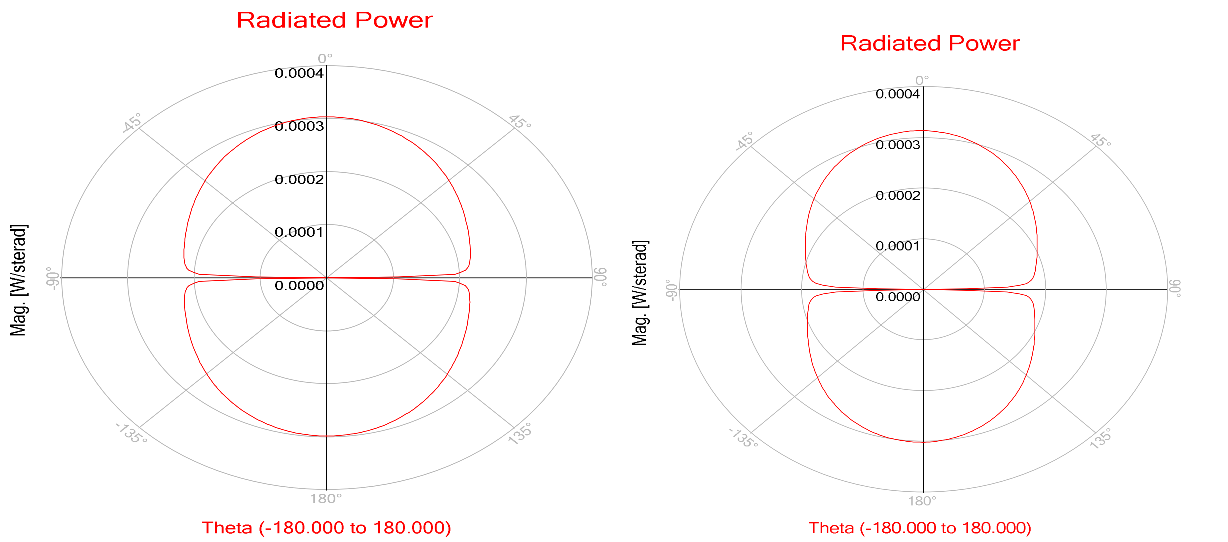
Fig 3: Current distribution of the conventional ground proposed MIMO antenna

The simulated radiation patterns of the proposed MIMO antenna with the monopole excited port 1 and port 2 terminated (with a 50 Ω load) at 1.8 GHz are exposed in Fig. 4, and the antenna gains have been standardized.

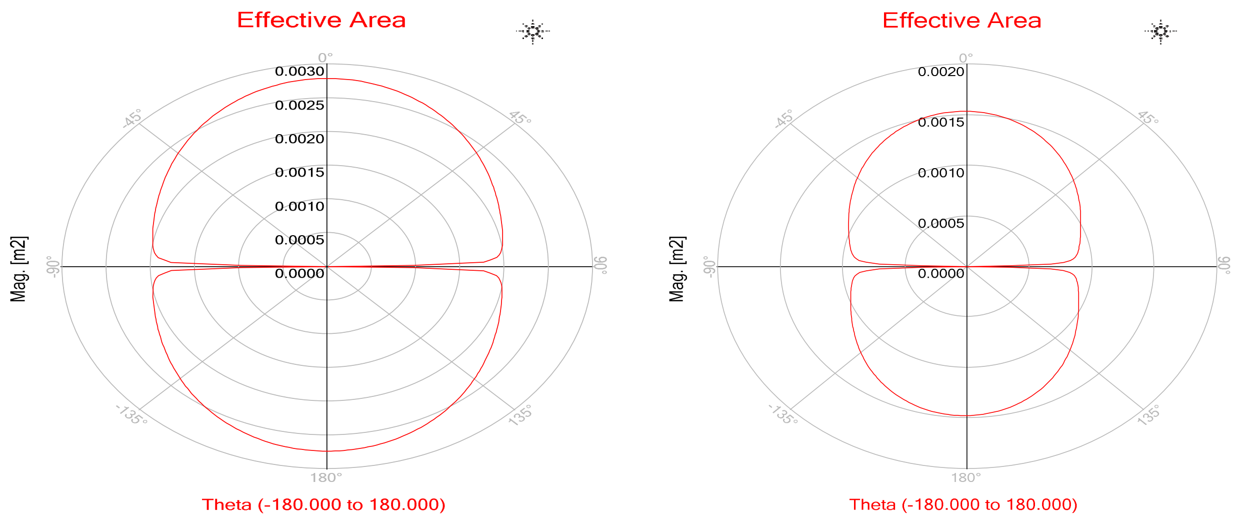
It can be able to expose in Fig. 4 that the simulated radiation patterns at 2.5 GHz have well agreement. The simulated iterations get nearer from our experimental model such as angle deviation which can causes the effective deviation between well simulated phi patterns in *x-y* plane. Furthermore, in minute antenna analysis, it is frequently complex to the feeding wires to stay away from currents subsequent on their external part, and these wires is very complex to uphold perfectly parallel to length of the PCB design owing to the weight and proximity of the metal chokes. We decide to analyze the mean effective gain and relative coefficient of proposed antenna system. Mean effective gains are calculate by using the sequence of the assumption explained, and the designed mean effective gain at 1.8 and 2.5 GHz are exposed in Table 2. The total efficiencies and gain are have been scheduled in Table 2. It can be able to observe the proposed MIMO antenna can be easily satisfies the diversity criteria model.



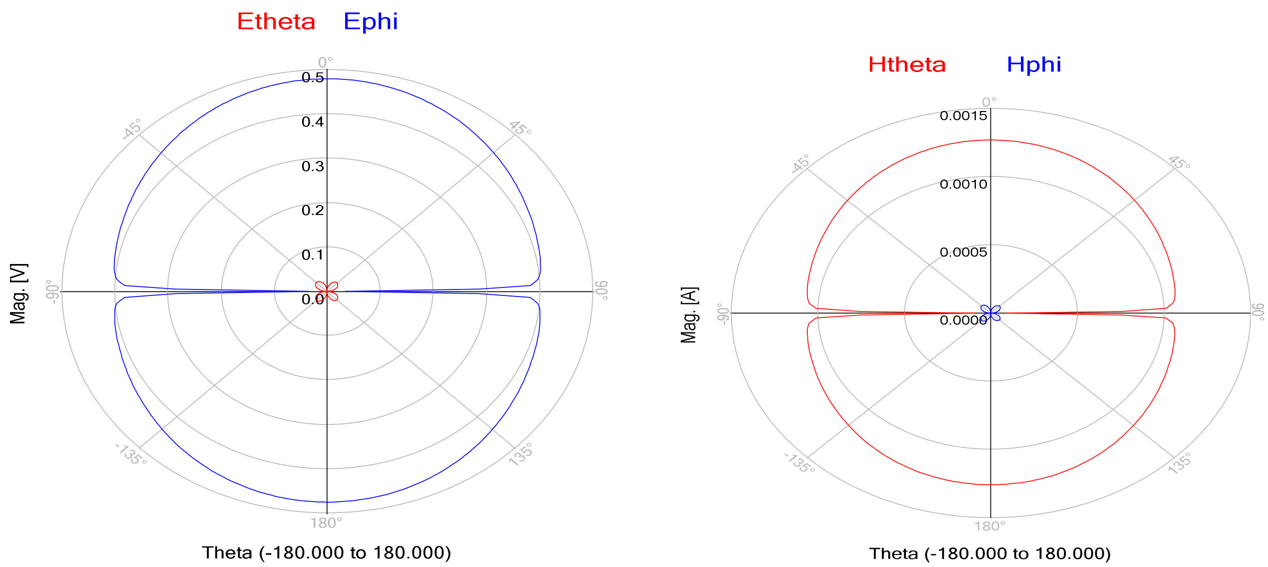
(a) Gain and Directivity at 1.8 and 2.5 GHz



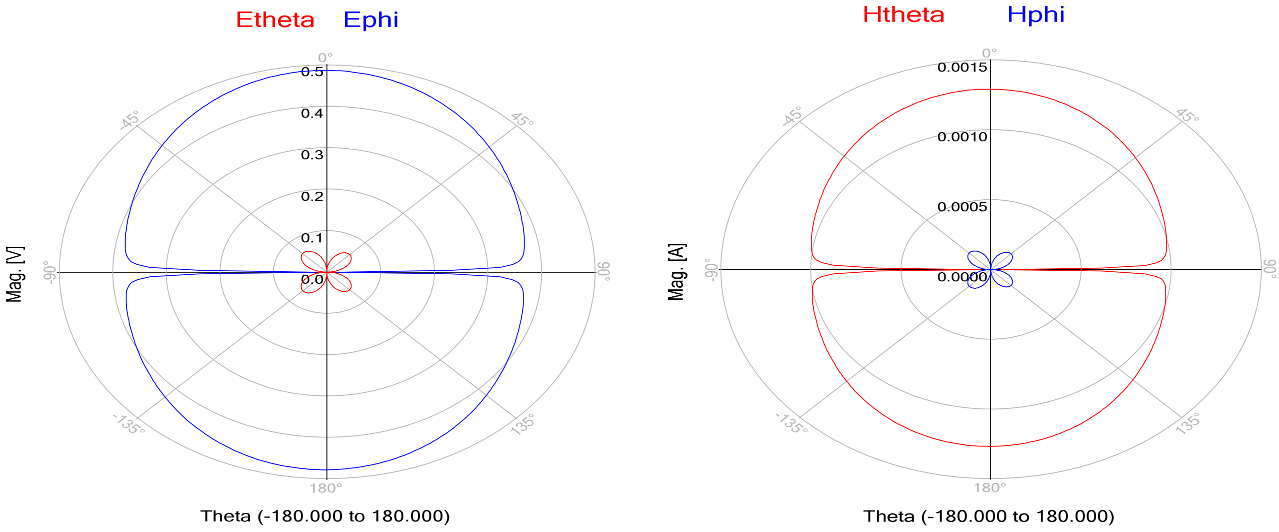
(b) Radiated Power at 1.8 and 2.5 GHz



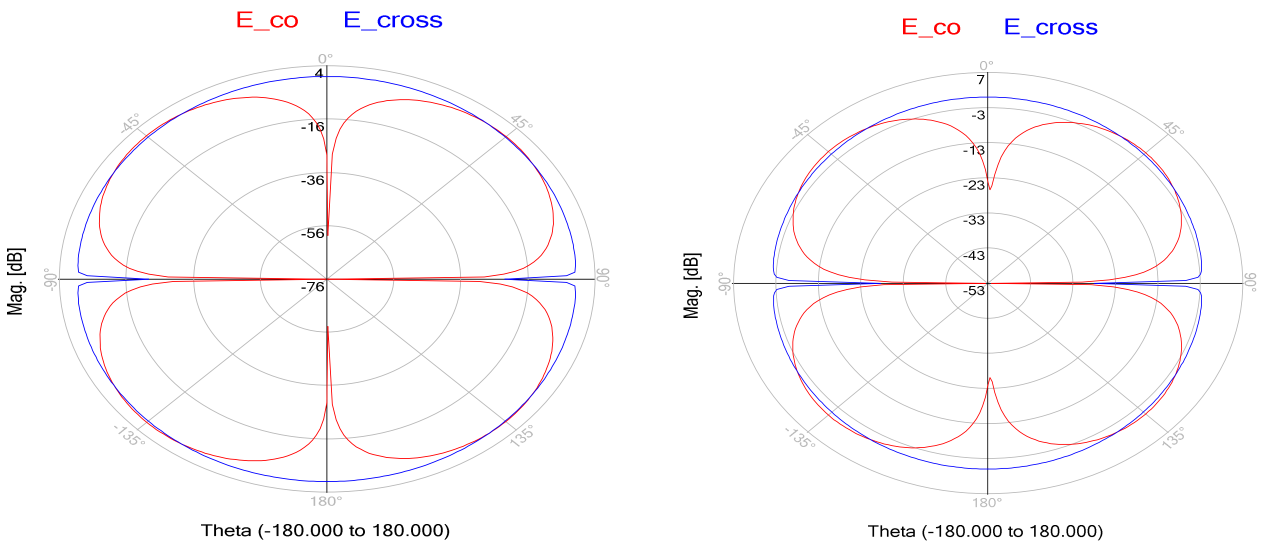
(c) Effective Area at 1.8 and 2.5 GHz



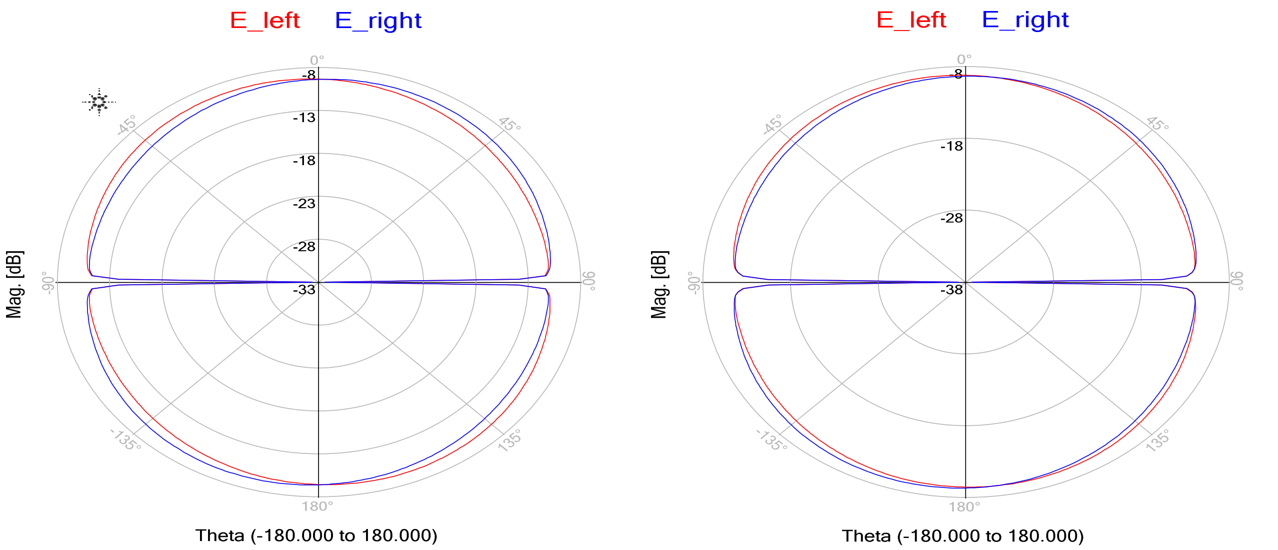
(d) Absolute E Field and H Field at 1.8 GHz



(e) Absolute E Field and H Field at 2.5 GHz



(f) Linear Polarization at 1.8 and 2.5 GHz



(g) Circular Polarization at 1.8 and 2.5 GHz

Fig 4: Simulated radiation patterns at 1.8 and 2.5 GHz

Table 2. Measurements of radiation parameters

Frequency in GHz	Radiated Power in Watts	Effective Angle in Steradians	Directivity in dBi	Gain in dBi
1.8	0.00212566	6.84751	2.63677	1.0988
2.5	0.00203868	6.35909	2.95815	1.36697

4. CONCLUSION

In this paper, a new coax fed MIMO antenna for LTE-Advanced and IEEE 802.16 m operations has been proposed. The new methodology has been taken to develop the isolation of two nearby G-shaped antennas. The arrangement of the small N-shaped strip and small L-shaped strip etched in the ground to reduces significant mutual coupling. The designed effective MIMO antenna to be simulated and it produce the dual band operation at 1.8 GHz and 2.5 GHz for LTE-Advanced and IEEE 802.16m (WiMAX Release-2) with the efficiency of 70.178% and 69.742%.The result shows that the return loss in the operation band is less than -20 dB. Multiple factors have studied on the result of $S11$, $S22$. The surrounding correlation and the antenna rudiments have been calculated to estimate the performance of diversity in proposed MIMO antenna. The observed results show the reasonable agreement, due to the better radiation characteristics, then the proposed antenna is suitable and competent for 4G mobile terminals. In future, we have to fabricate the proposed MIMO antenna design with FR4 substrate material and measure its radiation pattern and return loss by using network simulator. After that we have to compare the simulated and measured results, because it only shows the antenna how much effective for proposed applications.

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