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Performance Investigation of a Dual Element IFA Array at 3 GHz for MIMO Terminals

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Abstract—The distance or separation between antenna elements is small in case of modern compact Multiple-Input Multiple-Output (MIMO) terminals and this is the most critical parameter affecting mutual coupling. Mutual coupling has been a subject of interest in MIMO communications, since it influences the channel matrix, and thus, the capacity of the MIMO system. Although it is a well known subject in antenna theory it has not been studied in as much detail from the MIMO terminals perspective. In this paper the impact of different antenna placements (both position and orientation) inside the MIMO terminal on the mutual coupling between two antenna elements and hence their diversity performance is evaluated and investigated in detail. The antenna element employed is a pair of inverted-F antennas (IFAs) working at 3 GHz and is placed in various orthogonal and parallel configuration on a PCB ground plane with dimensions that are comparable with a mobile phone. The optimal position and orientation for the IFA antennas inside the MIMO terminal with low mutual coupling which leads to good diversity performance is addressed. It is found that some configurations are capable of providing high isolation between the IFA array elements. The EM simulation was carried out by using the Computer Simulation Technology (CST) Microwave Studio package, which utilizes the finite integral technique (FIT) for electromagnetic computation.

Keywords: MIMO; small antennas; mutual coupling; antenna diversity.

I. INTRODUCTION

Due to the necessity of both obtaining higher data rates in wireless communications and extending the network capacity in order to accommodate increasing traffic and a growing number of users, Multiple Input Multiple Output (MIMO) has been developed. MIMO systems have attracted considerable interest as an effective way of improving reliability and increasing the channel capacity [1, 2]. MIMO technology is suitable for the 4th generation mobile communication systems requiring high speed and high quality transmission involving large amount of data transfer. Wireless LAN systems can achieve data transmission speeds of greater than 100 Mbits/sec using MIMO technology [3].

Mobile terminals in indoor and urban environments can experience performance deterioration due to multipath effects. By employing two or more antennas, the system can take advantage of pattern and polarization diversity. This reduces the fading minima of the signal. Therefore, the signal-to-noise ratio (SNR) is improved and the system link budget can be reduced [4].

The advantage of using a MIMO antenna system is that the correlation between received signals can be reduced. The mutual coupling is the electromagnetic coupling that exists between antennas on the same platform and this has a high level of dependency on the overall performance. The proximity of additional antennas can affect the radiation patterns and efficiency of each antenna element. Therefore, it is desirable to position the antenna elements to be at least half a wavelength away from each other to minimize the mutual coupling. However, in the case of small available space, in modern MIMO devices, different techniques have been investigated to reduce mutual coupling and to increase the electrical separation between two antennas including orientation of the two antennas.

In this paper the impact of different antenna placements (both position and orientation) inside the MIMO terminal on the mutual coupling between two antenna elements is evaluated and investigated in detail. The optimal position and orientation for the IFA antennas inside the MIMO terminal with low mutual coupling which leads to good diversity performance is addressed.

II. A DUAL IFA ARRAY DESIGN AND MUTUAL COUPLING INVESTIGATION

This section will investigate different antenna geometries to find the relationship between their positions and the minimal mutual coupling with uncorrelated electric fields. These signals are then processed to improve the signal using techniques including switched or selection diversity, or maximal ratio combining [5, 6]. MIMO systems can improve the channel capacity of wireless systems without increasing the transmission bandwidth or the power resources. The MIMO channel capacity is affected by the mutual coupling. The geometry and dimensions of the investigated IFA antennas are depicted in Fig. 1.
The Inverted-F Antenna (IFA) typically consists of a linear metallic wire located above a ground plane, a short circuiting plate or pin, and a feeding mechanism for the planar element. The designed ground plane has the dimension 50 mm × 100 mm × 0.8 mm, which is commonly used in mobile phones. The dimensions of the designed antennas has the length \( L = 25 \text{ mm} \), height \( h = 5 \text{ mm} \), and the space between the ground point and feed point is \( G = 6.5 \text{ mm} \). The antenna wire radius is 1 mm as depicted in Fig. 1 with its calculated return loss in Fig. 2 and the 3D simulated directivity pattern in Fig. 3 with directivity of 4.85 dBi.

To study the impact of antenna placement position on the mutual coupling of two IFA antennas inside the MIMO terminal, several geometries were simulated. The essential electronics including the battery, the camera, the RF module, the speaker, and other components are typically located in the centre of the phone; the antenna elements are often restricted to the edge of the mobile phone. Note these electronic components have not been included in this investigation.

In this section we will focus on the relation between mutual coupling and the distance between the two IFA antennas. For the parallel case, one antenna is mounted on the top corner of the ground plane, and the second antenna is placed either on the left, or the right side of the PCB, the distance between the antennas is changed by moving the second antenna along the X-shift line as shown in Fig. 4 (a). As the distance is changed, the mutual coupling will change as well. In case A, the two antennas are placed with the same orientation. One of the antennas was placed at one corner of the PCB board; the other antenna is placed on the opposite side of the PCB and moved toward the other corner along the PCB side as shown in Fig. 4 (a). In case B, the second IFA antenna is placed on the same side of the first antenna with the same orientation and moved toward the end of the PCB board along the PCB side as shown in Fig. 4 (b).

The mutual coupling for all cases are evaluated and presented in Fig. 5 and Fig. 6 for different separations between the antennas.

In case C, the two antennas are placed parallel to each other along the smaller length of the PCB board as shown in Fig. 4 (c). One of the antennas is moved different distances along width of the PCB. In the other two cases, D and E, the two antennas mounted in such a way that they are orthogonal to each other with one of the antennas placed on the same PCB side (Case D) or on the opposite side (Case E). The value of the isolation level of each case are presented in Table I for different separations between the IFA array elements. It was observed that some placements give a high isolation between the antennas and in some cases it is close to -30 dB as in Case C with 10 mm separation and Case E with 75 mm separation.

Figure 7 shows the current distribution produced by antenna #1 when the other antenna is terminated to 50-Ω load. In Fig. 7 (a), the current distribution on the PCB board and antenna #2 is presented; this case is the case has the lowest mutual coupling value. It is clear that a very weak current is produced on antenna #2 and so a low mutual coupling level is obtained. Fig. 7 (b) presents the current distribution for the worst case with the highest mutual coupling level. As can be noticed in Fig. 5 for the mutual coupling level of the array orientation in Fig. 7 (a), the array exhibits better isolation properties primarily due to the reduction of ground surface currents and the direction of the radiation patterns. Antenna #1 does not have maximum gain toward antenna #2 which is located at the corner. This particular pattern shape helps, to some extent, get lower coupling induced by the patterns. Reduced ground surface currents further help minimize coupling between the two ports.
Fig. 4 IFA array placements considered in this study.

Fig. 5 Mutual coupling curves for cases A, B and C.
In this paper the effect of antenna placement (both orientation and position) on the mutual coupling between the elements of dual inverted-F antennas inside MIMO terminal having the same size as the mobile phone is presented and investigated in details. It was found that not only the distance between the antennas will effect on the level of isolation but the antenna orientation as well. The optimal position of the two antennas inside the MIMO terminal with high isolation is addressed where in some cases the level of isolation is reached to -30 dB as in case C and case E.

### REFERENCES


