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High Isolation Antenna Array for Mobile Communication with LTE MIMO Operation

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***Abstract*— An antenna array with highly isolated elements is designed in this work for handsets of wireless mobile communication. Antenna system contains radiator antenna and MIMO antenna. Radiator antenna covers the low and high frequency bands and MIMO antenna is used for higher frequency bands. Proposed antenna system with high isolation supports the LTE(700), GSM(850), GSM(900), GSM(1800), GSM(1900), UMTS(1900), UMTS(2100), LTE(2300), and LTE(2500). The two operation bands of the phone antenna 0.69-1.04 GHz and 1.67-2.70 GHz respectively are achieved. Coupled-feed and monopole antennas are employed in antenna system to provide higher bandwidth. Meandered strip inductor is used in the antenna system along with the radiator antenna to get the required resonant frequency. A high isolation is possible with this system due to the proposed MIMO elements placed at the upper corners of the system board with sufficient separation. They also produce the radiation pattern in different directions. Further isolation problem also minimized by introducing slits in the ground plane. Both experimental and simulated results are presented and compared.**

***Index Terms*— Isolation, Capacitive-Coupled feed antenna, Meandered inductive strip, MIMO.**

I. INTRODUCTION

The order of today's mobile technologies is to increase the data rate and bandwidth. LTE technology is going to stand in the front line in the selection of mobile communication technologies for the future requirements of mobile user, such as the higher band width, and higher data rates for multimedia applications. LTE technology uses smart antennas for improving the bandwidth, i.e., Multi Input Multi Output technique in which multiple antennas are used to collect the faded signal. For the mobile phone antennas the basic criteria to be satisfied is low profile. That means with the small size antenna, a wide frequency band should be achieved. With the small size, the micro strip patch antennas give small band widths. To get higher band width, the length of the antenna should be sufficiently longer, which occupies a large area in the Mobile phone which is a major concern. To cover the GSM operation in the 900 M Hz band the radiating plate in the monopole also requires large area.

This limitation of larger area can be overcome by embedding inductive elements in the design of the antenna. Inductor may be implemented as chip inductor or as distributed inductive strip with equivalent length with proper inductance.

In addition to this, instead of directly feeding the radiating strip, couple feeding method is used here. Feeding the radiating strip using T-section feeding strip is advantageous, since it increases the bandwidth.

Moreover shorting the radiating strip to ground also affects the bandwidth. Ground plane area also affects the bandwidth. The positioning of two antennas is also selected carefully as SAR of the antenna array greatly depends on the position of the antennas [12]. Locating two antennas at the bottom edge corners of the system board is advantageous when compared to placing the antennas at other possible positions on the system board. Moreover it also creates a possibility to accommodate many other necessary peripherals in the mobile phone.

II. PROPOSED ANTENNA ARRAY

Proposed antenna array contains two antennas namely main antenna and auxiliary antenna [5]. Both are coupled feed loop and monopole antennas to provide required wide frequency bands one at lower part of the frequency scale to cover LTE-700, GSM-850, GSM-900, and other at higher part of frequency scale to cover the GSM-1800, GSM-1900, UMTS-1900, UMTS-2100, LTS-2300, and LTE-2500 [9]-[10].

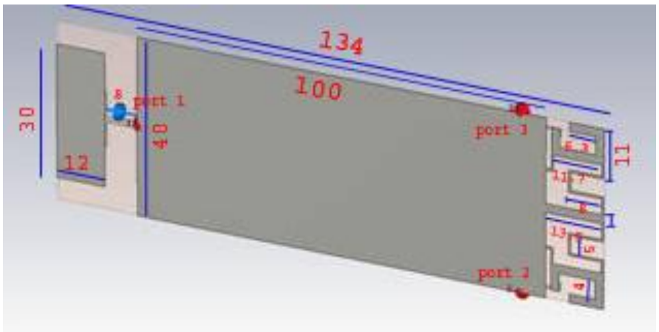
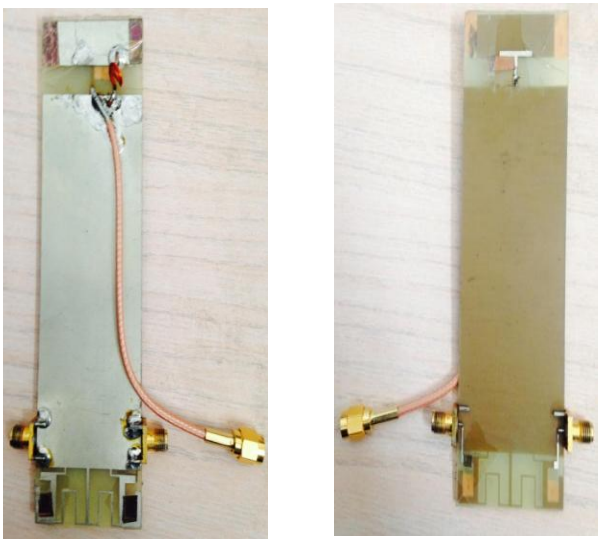


Fig. 1. Proposed antenna Structure. All units are in mm.

Figure 1 shows the structural details of the proposed antenna. As shown in figure the proposed antenna arrangement consists of main antenna, auxiliary antenna, system board, ground plane and feed lines. A 134 X 40-mm^2

system board is used for the design. FR4 substrate with $\varepsilon_r = 4.4$ and 0.8 mm thickness is considered for the system board. On the front side of system board, two antennas are fabricated and on the backside, a ground sheet is formed over an area of 12X 30 mm^2. Main antenna and auxiliary antennas are arranged on 12 X 30 mm^2 and 13.5 X 40 mm^2 no ground portions of the system board respectively. To include the body effect of the mobile phone casing in the results, a plastic casing is introduced with $\epsilon_r = 3$ and conductance of 0.02 Siemens in the simulation process. Printed monopole is embedded in the design to have wide lower band. Widened end part of monopole is responsible for lower frequency band. The resonant mode generated by monopole, is directly depends on the physical length of monopole[7]. To generate desired resonant mode, formation of strip with required length on the system board, where only limited space is available, is not the best method. This constraint can be overcome here by using an inductive element to generate the desired resonant mode. Implementation of inductive element in design is possible either by equivalent length or by chip inductor.



(a) (b)

Fig. 2. Fabricated structures: a) Front View. b) Back View

In this antenna arrangement structure, a chip inductor is selected in such a way that it compensates the capacitive effect caused by decreasing the physical length. Usage of chip inductor makes an easy way of accommodating monopole having less length then the required length yet capable of generating the desired resonant mode. Moreover, widened end portion of monopole is folded to get low profile, which is desirable in case of modern mobile phones. This portion of monopole radiates the energy. Folded radiating strip width is selected properly since it will shift the obtained frequency bands. Printed coupled feed loop antenna is responsible for generating both low band and upper bands. In this design instead of directly feeding the loop, T-section coupling strip is used. This type of feeding enhances the width of lower and upper bands. A spacing of 0.3 mm is used to feed the loop with T-section coupling strip, whose length and width plays an important role in impedance matching to generate the appropriate resonant modes.

To enhance the bandwidth, the antenna is shorted with the ground plane, which makes use of ground plane as a radiator. The simulation results confirmed the importance of ground plane as a radiating element in generating the higher bandwidths. This proposed antenna arrangement eliminates the protruded ground [1], [2]. As protruded ground is removed, the middle portion of the upper band gives less S_{11} value [1], [2]. Figure 2 shows the fabricated structure.

III. Results And Observations

Figure 3.a) shows the S11 value over the frequency scale. From the graph, it is observed that the proposed antenna array supports required lower and upper frequency bands to cover specified bands. From Figure 3.b) the measured S11 value for 698-998MHz and 1710-2690MHz bands is less than -6dB which is the industrial constraint. The S-parameter graph shows lower and upper supporting bands with 0.35GHz and 1.02GHz bandwidth respectively, which are wider than the lower and upper bandwidths that are obtained in [1].

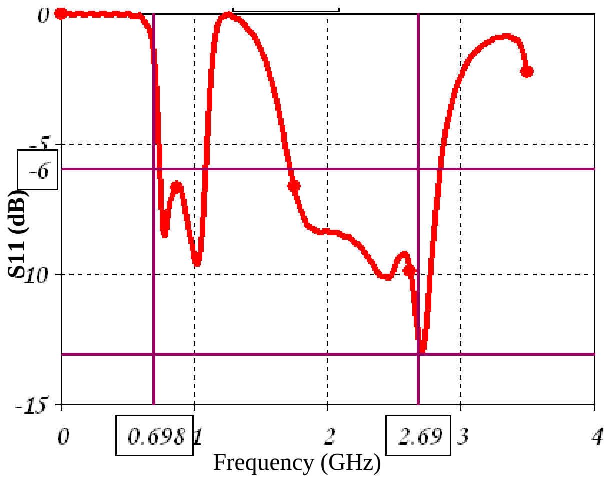


Fig. 3. a) Simulated S11 Parameters

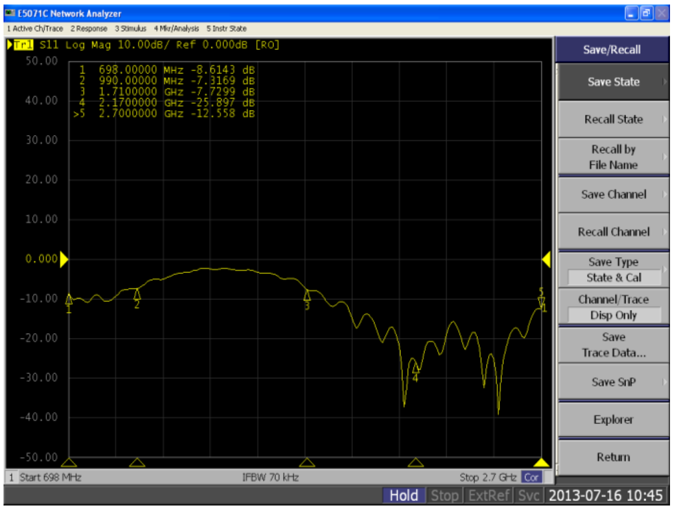


Fig. 3. b). Measured S11 parameters.

The effect of the feed line is obvious from the graphs shown in Figure 4. As the length of the feed line increases the lower band may not be obtained. As the length of the feed line decreases to the lower values, required lower band may be obtained. A different length of 50mm and 30mm is used for feed line in the simulation.

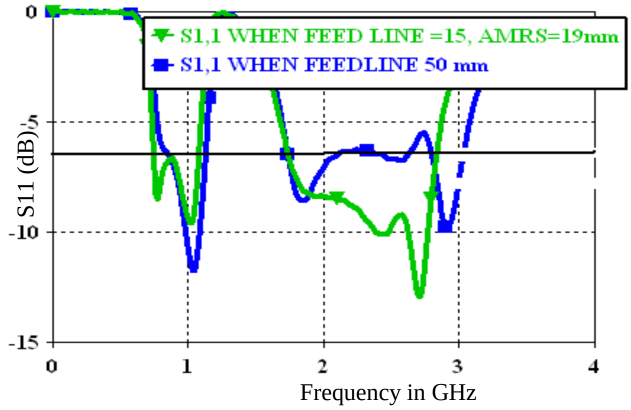


Fig. 4. Effect of Feed line and radiating strip lengths on S11.

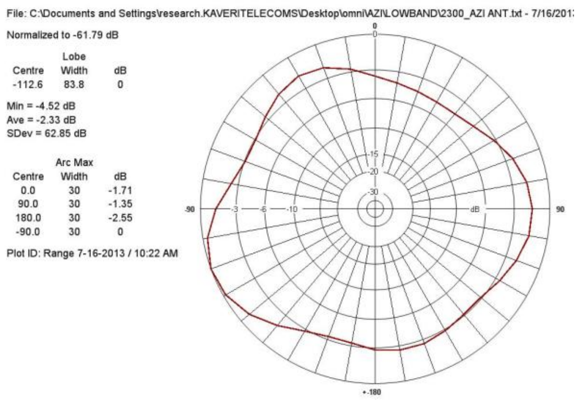
When Feed Line length is 50mm the impedance matching is not proper, hence the lower and upper bands are not sufficiently wide enough to cover the required bands. The variable feed line and radiating strip lengths show the effect on the S11 parameter values. When the Folded Radiating strip length is 14mm; it is not able to provide the required wide bandwidths. As the folded Radiating Strip length is made 19mm long, the length of the radiating strip is enough to provide the required lower and upper band widths to cover all frequency bands. A first or lowest resonant mode contributed to the antenna's lower band, a second mode at about 1700 MHz, and third dual-resonant modes at about 3000 MHz are seen. The second and third modes contributed to the antenna's upper band to achieve a very wide bandwidth of larger than 1.02 GHz in this study.

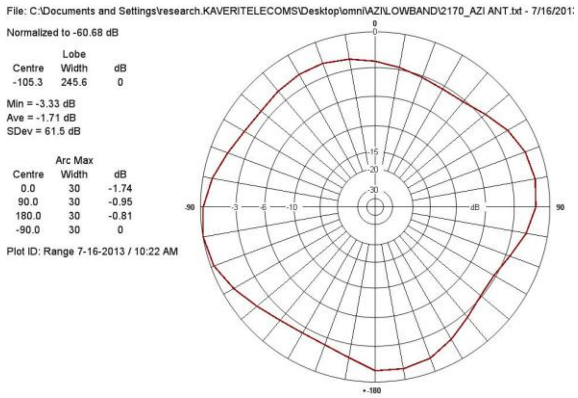
Results clearly indicate that the two widened portions are crucial in achieving good impedance matching of the two resonant modes in the antenna's lower band, and the impedance matching improvement for frequencies over the antenna's upper band is also obtained as well.

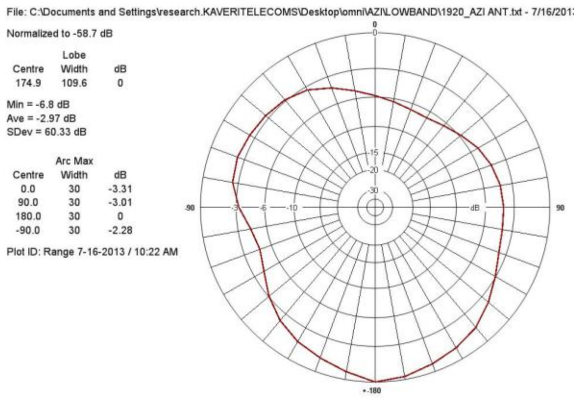
Figure 6 shows the radiation characteristics of the proposed antenna array. It is obvious from the Figures 7 and 8 that the antenna array exhibits the omni-directional radiation characteristics. And the radiation efficiency is -0.16dB, indicating that the antenna array is capable to transmit more than 50% of the applied power. Radiation efficiency value near to -3dB are acceptable for commercial applications. But the radiation efficiency decrease in the presence of human hand and head.

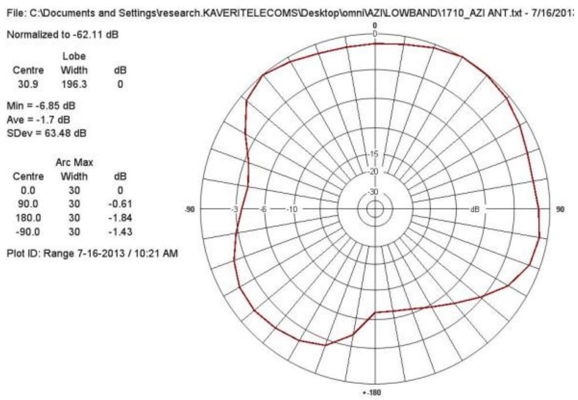
The simulated Specific Absorption Rate distribution at 0.85GHz frequency is shown in Figure 9. The maximum radiation absorption value is 0.186593 W/KG for 10g of head tissue. The obtained value is less than the minimum allowable limit value.

The simulated Specific Absorption Rate distribution at 2GHz frequency is shown in Figure 10. The maximum radiation absorption value is 0.349998 W/KG for 10g of head tissue. The obtained value is less than the minimum allowable limit value.









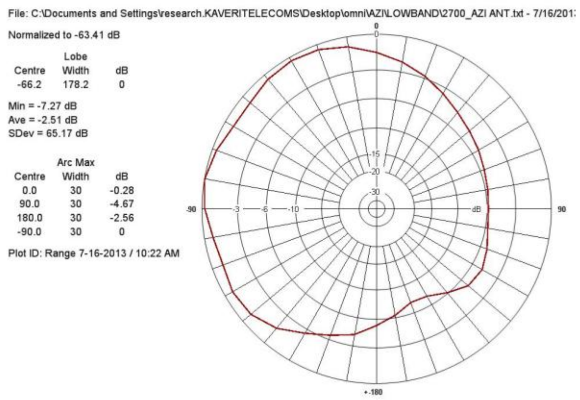


Fig. 5. Radiation patterns at different frequencies

IV. CONCLUSION

The proposed design has high isolation and wide frequency band support and the design is compact in size. This paper presents the method to implement a set of two antennas namely main and auxiliary antenna in a small area to meet the design constraints of modern mobile phones in which area for each functional element is limited. Removal of the potributed ground in between main and auxiliary antenna enhanced the S11 value in the middle portion of the upper frequency band which makes the design suitable for the UMTS-2100 band. Folded radiating strip made the structure into low profile, which is a desirable feature for mobile phones.

In addition to this, usage of chip inductor in the design reduces the physical length required to generate the resonant modes. The inductive strip is responsible for the widened bandwidth in the lower portion of the frequency scale.

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