User Proximity Analysis of Compact PIFA for MIMO Applications

Hari Shankar Singh
Department of Electronics and Communication Engineering
Thapar Institute of Engineering and Technology
Patiala-147 001, India
hrarishankar1990@gmail.com

Raed M. Shubair
Research Laboratory of Electronics
Massachusetts Institute of Technology (MIT)
Cambridge, MA, USA
rshubair@mit.edu

Abstract— **In this paper, the effect of user's body is studied over previously proposed antenna. The effect of "Specific Anthropomorphic Mannequin (SAM) head and PDA hand (Talk mode)", "Personal Digital Assistants (PDA) hand (Data mode)", and "Dual hands (Read mode)" are studied for diversity performances. There are two different positions of the antenna over mobile circuit board is considered i.e., antenna at the top position and bottom position of the mobile circuit board. In the user proximity, the optimal location of the antenna over circuit board is chosen for real application based on the antenna performance parameters i.e. diversity parameters. The specific absorption rate (SAR) for American standard (1.6W/kg average over 1g tissues) and European standard (2W/kg average over 10g tissues) is calculated for the top and bottom position of the MIMO antenna elements and it is found that the values of SAR are well below the standard limit of FCC as well as European standard. Based on the study, it is found that antenna at the top position of mobile circuit board shows overall better performance in the presence of user's body.**

Keywords— diversity antenna, MIMO antenna, planar inverted-F antenna, user proximity

I. Introduction

In the recent time, the trends of the mobile terminal are towards the slimness and high performances. High performances associated with better audio/video quality, high-speed communication, reduced multipath fading, and the most important better user proximity performance. The Multiple-Input Multiple-Output (MIMO) technique, using multiple antennas at both the transmitting and receiving ends of a communication system, promises to deliver robust communication with enhanced data rates without increasing power and spectrum requirements [1]. It is well known, since, the antenna parameters (antenna network parameters and radiation parameters) may change in the presence of user proximity. Therefore, it is important to design the compact antenna which will provide better performances in the surrounding of user proximity as well.

Some of the researchers have been studied the performances of the antenna in the presence of user proximity by keeping the antenna at the top as well bottom of the mobile circuit board [2-3]. In [4-5], multi-band diversity antenna is analyzed in the presence of the user (Only hand is considered). Recently, Singh *et al.* in [6] proposed MIMO/Diversity antenna for smart mobile phones and investigation carried out in the presence of user proximity. In [6], the only top position of the antenna over mobile circuit board is considered. So, it would be more convenient, when we study the performances of the same antenna by considering the different location (top and bottom) over the mobile circuit board. Meanwhile, an adaptive quad element antenna array is proposed by Zhang *et al.* [7]. The four antenna elements over PCB leads complex situation during the implementation on the actual platform. Since all the above-reported literature have been investigated for the fixed single position of the antenna over the mobile circuit board. Therefore, it is very hard to identify the best optimized location of PIFA over the mobile circuit board. Moreover, to solve this issue we can investigate the performances of the same designed antenna by placing the top and bottom position of mobile phone PCB. By the trade-off between the results of different antenna parameters, optimal location of the multi-antenna system over PCB of the mobile phone can be selected.

In this paper, a compact planar inverted-F antenna is considered from previously published paper and placed over the top and bottom of the mobile circuit board for the performance investigation of the same. Three kinds of user proximity are considered i.e. Talk mode, Data mode, and Read mode. All the diversity parameters and investigated and further specific absorption rate (SAR) is calculated. Based on the calculated parameters for top and bottom position of the antenna, we can decide the best suitable position of the antenna over the mobile circuit board.

II. User Proximity Environment

The free space antenna configuration is given in [8]. All the dimensions are clearly elaborated in the published article and results are also well presented. When we consider the antenna in the near-field environment then some of the other mobile phone components are present near to the antenna elements. As mentioned earlier, a smartphone has a number of components besides system circuit board as considered in [2]. Further, three kinds of user proximity are considered as shown in Fig. 1. The mobile phone is placed near to the user proximity placing the antenna in mobile phone environment (camera, battery, LCD, buttons, speaker, microphones, and connectors). The placement of the antenna in close proximity of user is in accordance with the cellular telecommunication industry association (CTIA) [9].

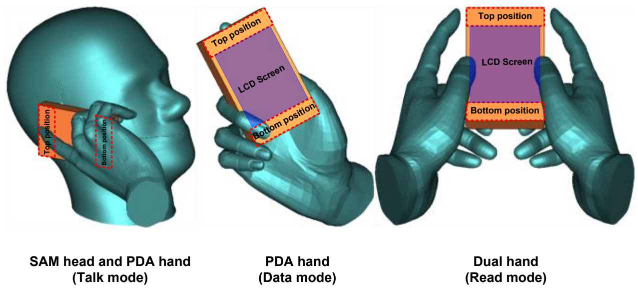

Fig. 1. Three kinds of user proximity (talk mode, data mode, and read mode) with a mobile phone.

III. Simulated Results and Discussion

All the results have been simulated on the computer simulation technology microwave studio (CST MWS) [10]. All the performances parameters i.e. diversity parameters have been derived and referred in [2]. The discussion of only results obtained from the antenna in user proximity is given below.

The *S*-parameters, radiation performances, and envelope correlation of the antenna in free space have already been studied in [8]. Moreover, other diversity parameters like mean effective gain (MEG), ECC in user proximity need to be investigated. The calculated values of MEG and ECC in free space and user proximity are given in Table I.

It is observed that the drop of the MEG values for the bottom-placed antennas is slightly more than the top located antennas. However, the ratio of MEG is close to unity which fulfills the criteria of the diversity antenna. Moreover, calculated values of the ECC are well below 0.5 over both the operating frequency. Although, it is observed that with the less body coverage and symmetrical placement of the hand around the antenna elements give the lowest value of ECC for the top position. In the case of bottom position, the ECC is slightly higher than top position because human body covers a larger area in comparison to top position but still it is well below 0.05.

Further, SAR is calculated for top and bottom position and given in Table 2. The simulation setup for SAR calculation is same as in [2]. The calculated values are well below the standard limit set by FCC and European standard.

TABLE I. Calculated Values of MEG and ECC in the Free Space and User Proximity

Frequency (GHz)		Antenna at Top		Antenna at Bottom		ECC (Top)
		MEG 1 (dBi)	MEG 2 (dBi)	MEG 1 (dBi)	MEG 2 (dBi)	
1.8	Free space	-8.9	-8.9	-8.9	-8.9	0.0019
	Talk mode	-2.5	-2.59	-1.95	-1.98	0.004
	Data mode	-3.6	-3.56	-2.29	-2.1	0.09
	Read mode	-1.99	-2.1	-1.59	-1.98	0.002
3.5	Free space	-3.5	-3.5	-3.5	-3.5	0.0019
	Talk mode	-4.5	-4.8	-3.2	-3.1	0.03
	Data mode	-2.9	-3.1	-1.5	-1.9	0.06
	Read mode	-3.51	-3.5	-1.6	-1.61	0.01

TABLE II. Calculated SAR Values

Top position			
Frequency → / ↓ Antenna		1.8 GHz	3.5 GHz
Ant. 1 (W/kg)	FCC	0.23	0.21
	European	0.19	0.17
Ant. 2 (W/kg)	FCC	0.21	0.22
	European	0.13	0.12
Bottom position			
Ant. 1 (W/kg)	FCC	0.16	0.17
	European	0.12	0.13
Ant. 2 (W/kg)	FCC	0.19	0.15
	European	0.10	0.11

IV. Conclusion

In this paper, the effect of user proximity on mobile phone antenna performances in terms of over the air (OTA) parameters was studied with two different location (top and bottom) of the antenna over the mobile circuit board. All the calculated parameters for top position are showing better than the bottom position except SAR. The SAR is less for bottom-placed antenna due to non-planar nature of the SAM head. By the trade-off between antenna performances parameters and SAR values, top location can be a better choice for antenna placement over the mobile phone circuit.

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