Survey on MIMO antennas for mobile and compensating user's induced loss

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ABSTRACT

An analysis of MIMO antenna system in the development of LTE (Long Term Evolution) terminal and the compensation of user's induced loss is presented in this paper. MIMO wireless systems have antenna arrays at both the transmitter and receiver terminals. Multiple input multiple output (MIMO) technology has been regarded as a practical approach to achieve significant increase of wireless channel capacity and reliability. LTE terminal adopts MIMO technology to improve its performance.

Keywords- **LTE antenna, MIMO antenna, mobile terminal antenna, OTA performance, radiation efficiency**

I. INTRODUCTION

Mobile communications systems have become an integral part of the modern society. Improved performance and higher data rates are required of these systems to accommodate for various emerging applications. In a mobile communications link, the antenna is the means to couple the signal to the intermediary space between the two ends of the link. It is important to understand the effects that play a role in this coupling to be able to optimize the antenna design and thus improve the performance of the communications link.

An antenna is a device used for receiving and transmitting radio waves. Antennas are specially designed to transform guided waves (that propagate in non-radiating transmission lines) into free space waves, or vice versa, as effectively as possible.

An antenna is an essential part of the wireless radio frequency communication system. It works as a transformer between the guided electromagnetic wave inside the terminal and wave propagating in the air. Thus, every wireless portable device having data transmission capability that uses electromagnetic waves must have at least one antenna. The development of wireless communication systems has been very rapid during the past decade. New wireless communication systems and standards, for example 4G Long Term Evolution - Advanced (LTE-A) and Digital Video Broadcasting - Handheld (DVB-H), have characteristics that diverge from the previous systems from the mobile terminal antenna point of view.

II. MIMO ANTENNAS

Multiple-Input Multiple-Output (MIMO) wireless communication system, which is also called Multiple Antenna system, is well known as one of the most important technologies and widely studied nowadays. The main idea of MIMO wireless communication is to utilize the spatial degree of freedom of the wireless multi-path channel by adopting multiple antennas at both transmit and receive ends to improve spectrum efficiency and transmission quality of the wireless communication systems. MIMO technology is able to extremely improve the transmission data rates and alleviate the conflict between the increasing demand of wireless services and the scarce of electromagnetic spectrum. MIMO is the key technology for future wireless communication systems, such as 3GPP LTE, WiMAX 802.16, IEEE 802.20, IMT-Advanced and so on.

III. LITERATURE REVIEW

(1) In 2012, Zhinong Ying addressed the major challenges of the mobile handset antenna for communication were addressed. Some important multiband internal antenna technologies in mobile industry were reviewed. The mobile handset antennas need to be small in size; built-in to meet multiband, MIMO, and multi standard RF coexistence requirements; and fulfilling all standards and industry requirements with a nice appearance.

The recent research work of compact MIMO antennas includes different decoupling techniques such as the orthogonal mode, the localized mode, parasitic scatter, and impedance coupler, which were also discussed. The decoupling bandwidth is limited by size of the MIMO antenna array. For the multiband decoupling, the use of the optimal design of hybrid decoupling techniques or reconfigurable structures is required. The newly defined MIMO antenna multiplexing efficiency was described, which simply showed the relation of the MIMO performance and the efficiencies, and the correlation of the antenna elements. The practical issues of the human body impact, SAR, and HAC with single and multi-transmitter were described and discussed, and the related research is ongoing.

Due to the small size, integration, multiband, and multi standard requirements and human body effects, the antenna design of the mobile phone is always the art of compromising between the size, the phone appearance, and the performance. The future research will focus on the optimization of the MIMO, multi band, and reconfigurable multi antenna system to reduce the human body impact and enhance communication performances.

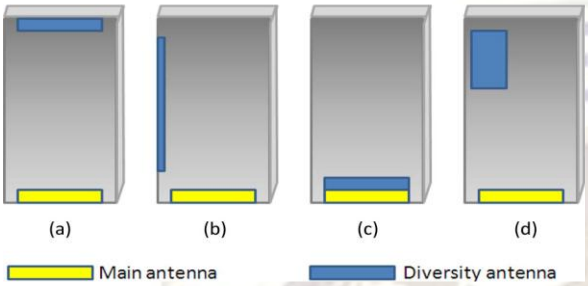

Fig1. Different LTE antenna designs in a mobile phone at the 700 MHz bands.

(a) Two monopoles. (b) Monopole and notch.
(c) Colocated loop. (d) Monopole and patch.

(2) In 2012, Masakazu Hirokawa, Masaharu Takahashi, Koichi Ito, Issei Kanno, Yoshiaki Amano, Masayuki Nakano, Akira Yamaguchi evaluated the antenna performance with the distributed terminals in order to show the effectiveness of the distributed MIMO antenna architecture through the comparison to a single terminal by the computer simulation. The efficiency, antenna correlation, and MIMO channel capacity are evavluated with FDTD (Finite Difference Time Domain) calculation.

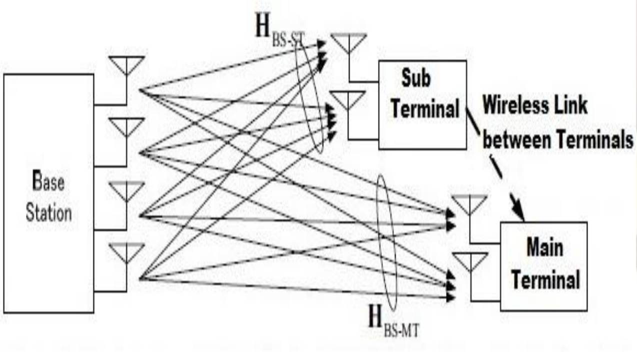

Fig2. Distributed MIMO antenna system for terminal

(3) In 2012, Liling Liu, Wenxiu Wang, Dan Shi, Yougang Gao presented a compact meander line dual element MIMO antenna system is designed to be used for LTE terminal. The antenna system operating in the 2.6 GHz band and covers the band from 2570–2620MHz. The designed MIMO antenna system has a high isolation of more than 30dB, a maximum gain of 4.5dBi and radiation efficiency of 85.6%. The MIMO antenna system's OTA performance is investigated and it turns out that it has a good OTA performance. In addition, additional antennas' impact on OTA of LTE terminal was investigated and it is found that introduced extra antenna reduces total radiated power and total isotropic sensitivity of the MIMO antenna system of LTE terminal, and thus worsen OTA performance of LTE terminal. The dimensions of the antennas are in mm and given by,
L=37, W=46 Lg=17, W1=15.5, W2=1.6, W3=1.05, W4=1.05, W5=1.05, W7=5, L0=110, L1=19, L2=5.

The antennas were etched on an FR-4 substrate with a thickness of 0.51mm. Antenna modeling and tuning was performed using Ansoft HFSS.

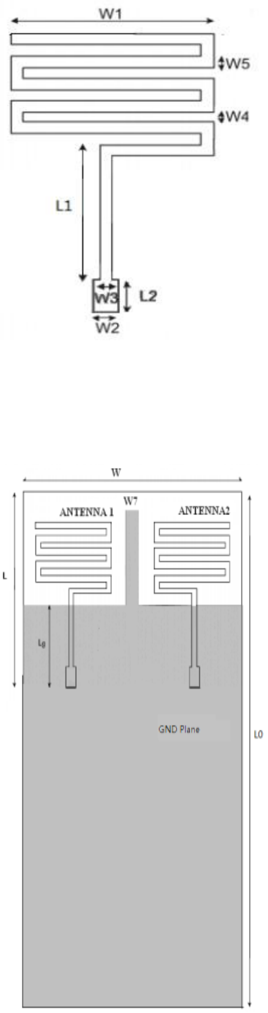

Fig3. Geometry of the MIMO antenna system

The paper also investigates the OTA performance of the MIMO antenna system and additional antennas' influence on OTA performance of LTE terminal. The evaluation was conducted using the FDTD based electromagnetic simulation tool SEMCAD. For this conventional interface, we export LTE terminal 3D model from HFSS and then import it into the SEMCAD to analyse its OTA performance. The dimension of the LTE terminal with MIMO antenna system is 110 × 50 × 1 mm^3. The cell of the terminal has the thickness of 0.5mm and permittivity of 3.01. 3GPP TS 36.521-1 defines the operating band of LTE TDD, in this paper operating band 38 is chose for study, whose frequency ranges from 2570 MHz to 2620MHz. In addition, 3GPP TS 36.508 introduces test frequencies for E-UTRA channel bandwidth for operating band 38. According to these standards, we choose test frequency of low range, midrange and high range for bandwidth of 10MHz and 20MHz separately to investigate LTE OTA performance. The simulated OTA performance of MIMO antennas in LTE is shown in Table1.

TABLE 1
SIMULATED OTA PERFORMANCE OF MIMO ANTENNAS IN LTE

BW MHz	Frequency		TRP dBm	TIS dBm	η_A
	ID	MHz			
10	Low Range	2575	24.58	-104.58	76.6%
	Mid Range	2595	24.35	-104.35	72.4%
	High Range	2615	24.06	-104.06	67.4%
20	Low Range	2580	24.53	-104.53	75.6%
	Mid Range	2595	24.35	-104.35	72.4%
	High Range	2610	24.14	-104.14	68.7%

(4) In 2012, M. Berg, M. Sonkki, S. Myllymäki, T. Tuovinen and E. Salonen presented the influence of the mobile terminal antenna efficiency on the RF power consumption of the terminal and on the link distance is evaluated. The increased antenna efficiency or the decreased user effect on the antenna can be utilized to decrease the RF TX power level of terminals. The efficiency of the terminal power amplifiers must be taken into account in order to gain the maximum benefit of high efficient antennas. Alternatively, the higher antenna efficiency can be used to increase the cell size in cellular networks. An equation connecting the link distance, path loss exponent and antenna efficiency is used for the evaluation of the effect of antenna efficiency on the link distance i.e. cell size. Increased efficiency has a significant effect on link distance particularly on the line-of-sight scenarios.

Radiation efficiency is an important figure of merit for antennas and it is defined as “the ratio of the total power radiated by an antenna to the net power accepted by the antenna from the connected transmitter”. Within mobile terminal antenna design, it is more practical to use the antenna total efficiency, which also takes into account the antenna impedance matching. A good mobile terminal antenna radiates roughly 50% of the power available from the transmitter. This paper aims to introduce the basic influence of the terminal antenna efficiency on the cellular network issues. At first, antenna efficiency and its enhancement are briefly discussed based on the open literature. Secondly, the effect of antenna efficiency is evaluated in relation to the terminal RF power consumption. Finally, the theoretical cell size is evaluated in relation to the antenna efficiency and the cell scenario by using the equation derived in this paper.

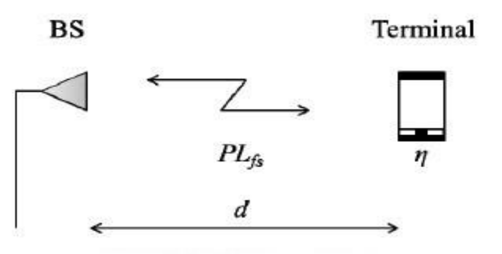

Fig4. Studied scenario

The graphical representation of the studied situation is shown in above fig., where
BS = mobile network base station,
PL_{fs} = patch loss in free space,
d = distance between BS and mobile terminal,
η = corresponds with antenna efficiency.

(5) In 2011, Janne Ilvonen, Outi Kivekäs, Jari Holopainen, Risto Valkonen, Kimmo Rasilainen, and Pertti Vainikainen presented a systematic study of the small changes in the dimensions and location of mobile terminal antennas on the absorption to a user’s hand, quality factor, and frequency detuning is presented. In general, decreasing the by increasing the CCE antenna height or area has only a minor effect on the. However, the higher the CCE height is or the larger the CCE area, the larger the is, resulting in decreased , but also in wider impedance bandwidth. For example, when decreasing the height and area of the CCE, it is possible to reduce the and maintain the at the cost of impedance bandwidth. Instead, when the is altered by changing the CCE location along the chassis, a distinct interconnection between the, and can be shown: A maxima in and a minima in occur when the has its maxima.

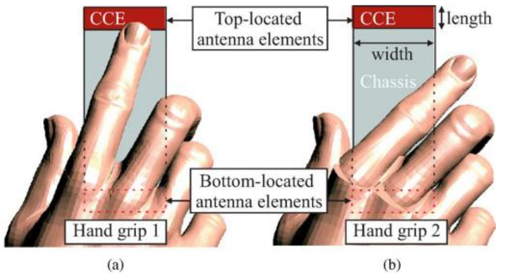

Fig5. Used hand grips. (a) grip1 and b) grip2. Antenna element is located either in the top or bottom part of the structure.

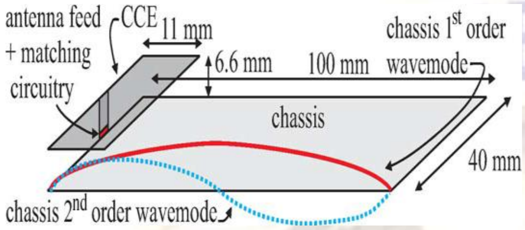

Fig6. CCE mounted on the chassis, with two principal current distributions of the lowest-order wave modes of the chassis.

IV . PROBLEM FORMULATION

(1) In 2012 , Zhinong Ying gives an overview of some important antenna designs and progress in mobile phones in the last 15 years, and presents the recent development on new antenna technology for LTE and compact multiple-input–multiple- output (MIMO) terminals.

(2) In 2012, Masakazu Hirokawa, Masaharu Takahashi, Koichi Ito, Issei Kanno, Yoshiaki Amano, Masayuki Nakano, Akira Yamaguchi evaluated the performance of the antennas distributed around near field through the comparison to that with the totally same numbers of antennas on a single terminal inorder to verify the effectiveness of the distribution deployment. The antenna correlation and the radiation efficiency can be improved by distributing and arranging the multiple antennas to terminals. As the results, the MIMO channel capacity is improved about 20 percent by the distribution. Furthermore, human body can absorb the electromagnetic wave and influence to the performance of MIMO antennas.

(3) In 2012, Liling Liu, Wenxiu Wang, Dan Shi, YougangGao gives a compact size dual element multiple-input–multiple- output (MIMO) antenna system operating in the 2.6 GHz band is proposed for long term evolution (LTE) terminal. The proposed MIMO antenna system is based on meander line antennas, and covers the band from 2570–2620MHz. With the introduction of a GND plane structure, the designed MIMO system has an isolation of more than 30dB and radiation efficiency of 85.6%.In addition, OTA performance of LTE terminal with the designed MIMO antenna system and additional antennas' impact on OTA performance of the LTE terminal are investigated. It is found that the designed LTE terminal has a good OTA performance and introduced extra antenna would decrease total radiated power and total isotropic sensitivity of the MIMO antenna system in LTE terminal, and thus worsen OTA performance of LTE terminal.

(4) In 2012, M. Berg, M. Sonkki, S. Myllymäki, T. Tuovinen and E. Salonen calculated the effect of the mobile terminal antenna efficiency on the RF power consumption and the link distance, that is cell radius, is discussed. An equation connecting the link distance, antenna efficiency, and path loss exponent is derived. Link distance is calculated with the different antenna efficiency values and with different cell scenarios based on 3GPP and ITU-A channel models. It is demonstrated that the compensation for the user effect has a positive impact both on the RF power consumption and on the theoretical link distance.

(5) In 2011, Janne Ilvonen, Outi Kivekäs, Jari Holopainen, Risto Valkonen, Kimmo Rasilainen, and Pertti Vainikainen calculated the performance of mobile terminal antennas in the vicinity of the user's hand. The effects of antenna dimensioning and antenna location on the ground plane of the device are demonstrated. The studied performance parameters are quality factor, radiation efficiency, and frequency detuning. Based on the results, beneficial approaches and general guidelines for antenna designs with a reduced effect of the user's hand can be given. For instance, it is shown that the radiation efficiency with the user's hand stays nearly constant (variation 0.2 dB) despite the changes in the antenna element height (2–6.6 mm at 900 and 2000 MHz).

The study is made at 900 and 2000 MHz frequencies with capacitive coupling element (CCE) antennas. The characteristics have been studied with a realistic phantom hand with two different grips. In addition, a large dielectric block model is used in certain cases to indicate the trends more straightforwardly. The obtained results are considered to represent the typical behavior of today's mobile terminals, and they can be applied to resonant-type antennas [e.g., a planar inverted-F antenna (PIFA)] and at other frequencies as well.

V. CONCLUSION

We conclude from this survey that the type of material used for antenna, antenna sizing, area and size of capacitive coupling elements, hands positioning can also affect the performance of mobile terminal antenna. The MIMO antennas are used in LTE terminal and OTA (Over The Air) performance is also evaluated. It is found that introduced extra antenna reduces total radiated power and total isotropic sensitivity of the MIMO antenna system of LTE terminal, and thus worsen OTA performance of LTE terminal.

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