On Fast Estimation of SAR for Metallic Rim-based MIMO Handsets

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***Abstract*—Use of multiple-input-multiple-output (MIMO) antennas in a mobile handset helps to achieve an increased capacity and enhanced spectrum efficiency. Although, specific absorption rate (SAR) is one of the most important and widely used metrics for the characterisation of suitability, safety and compliance of commercial mobile handsets, its estimation for MIMO-enabled handsets is a complex and time consuming process. For the MIMO configurations, the SAR is the vector sum of E fields of individual antenna elements. The phase and amplitude of these E fields are dependent on MIMO precoding. Hence, SAR estimation for MIMO configurations becomes a lengthy and tedious analysis that makes it complex and rather impractical in real measurement scenarios. In this paper, a 2×2 MIMO configuration of the metallic rim antenna is analyzed to study the dependency of phase offset on SAR. The antenna elements are placed on the shorter edge of the metallic rim, resonating at 2.1 GHz. It is estimated that the maximum value of SAR is maintained at 0°, while the handset is used in talking position. This knowledge of phase offset reliance on SAR can help in reducing the overall time for SAR estimation as SAR needs not to be calculated for other phase offsets.**

***Index Terms*—Specific absorption rate (SAR), mobile handsets, metallic rim antenna, multiple-input-multiple-output (MIMO).**

I. Introduction

The use of multiple-input-multiple-output (MIMO) antennas in mobile handsets is rapidly increasing as it helps the system to attain an enhanced capacity. In an uplink MIMO communication link, all the antenna elements are simultaneously excited. These elements are required to comply with the exposure limits defined by International Commission on Non-Ionizing Radiation Protection (ICNIRP) (internationally) and Federal Communication Commission (FCC) (within the USA) for the health and safety of the user [1]. The exposure of the human user to electromagnetic fields (EMF) (radiated by a multi-antenna mobile handset in this case) is quantified through specific absorption rate (SAR), and is defined as [2]:

$$\text{SAR} = \frac{\rho \times |E|^2}{M_d} \quad (\text{W/kg}), \tag{1}$$

where, ρ is conductivity and M_d is the mass density of tissue. For a multi-antenna system, the electric field E is a vector sum of E fields radiated by each antenna element. The MIMO precoding, therefore, decides on the phase and amplitude of these complex E fields. Dependency of SAR on the phase offset and uplink transmit power is demonstrated in [3] [4]. A detailed investigation in [4] by varying the phase angle and uplink transmit power has lead to a more accurate mathematical representation of SAR. These dependencies make the SAR measurement for multi-antenna systems a lengthy and complex process that becomes unusable in real working scenarios.

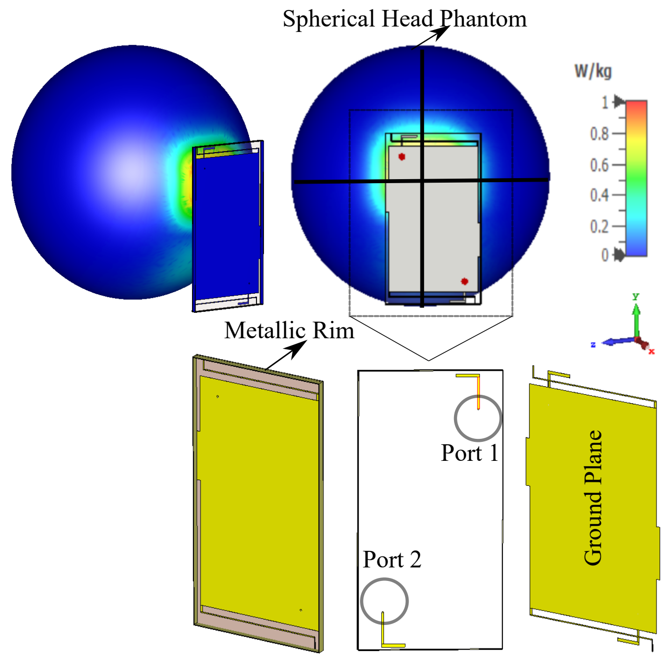

Fig. 1. Experimental setup using a 2×2 MIMO metallic rim handset antenna.

A plethora of work has been reported on estimating SAR for multiple antenna systems. Different methods to combine E fields of multiple antennas for SAR estimation are discussed in [5]. Time-averaged simultaneous peak SAR (TASPS) is employed in [6], to efficiently reduce the complexity of SAR measurements in multiple antenna handsets. In this work, we have investigated the effect of phase offset on SAR for rim-based multi-antenna mobile handsets to effectively reduce the length and complexity of MIMO-SAR measurements.

II. Experimental Setup

The use of metallic rim-based antennas has seen a sharp increase as it enhances the robustness of mobile handsets. However, the metallic frame makes use of larger number of antenna elements challenging and hence, adds to the complexity of SAR measurements [7]. The works of [8]–[10]

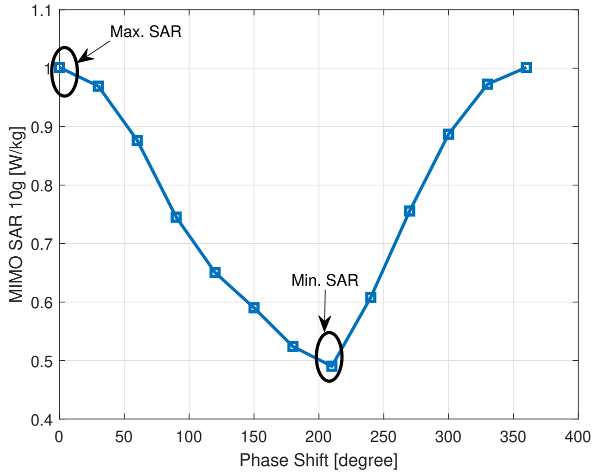

Fig. 2. Variation of SAR over different phase offset.

propose metallic rim-based MIMO antenna designs, but rely on measuring single element SAR for compliance reasons. Although, some efforts are made to simplify the SAR measurement techniques for MIMO antennas, reduction in the SAR measurement time and estimation complexity of rim-based MIMO antenna systems has not been attempted. To fill this gap, the metallic rim antenna proposed in [11] is employed to perform the SAR dependence analysis on the phase offset. A spherical phantom having ε_r of 39.9 and conductivity of 1.42 S/m is used to replicate the human head as shown in Fig. 1. The ground plane of the 2×2 MIMO rim antenna is placed tangent to the spherical head model depicting talk position scenario. The spacing between the handset and the head phantom is kept at 5 mm, adhering to industrial standards.

III. Analysis and Discussion

A 2×2 MIMO metallic rim-based antenna resonating at 2.1 GHz is used in this study (Fig. 1). Both antenna elements are symmetrical, having S_{12} well below -15 dB and the value of envelope correlation coefficient (ECC) within the MIMO limits [11]. The SAR is noted for a phase offset varied from 0° to 360°, while keeping the maximum transmit power at 0.2 Watts (i.e., maximum transmit power for LTE enabled handsets). Based on ICNIRP guidelines, the value of SAR is averaged over 10 g tissue volume [12]. As shown in Fig. 2, the SAR values are well below the regulatory limits but varies with the phase offset. The maximum value of MIMO-SAR is noted to be at 0° phase offset whereas 210° phase offset yields the minimum MIMO-SAR. The phase of the port 1 is fixed whereas the phase of port 2 is varied. It can inferred that for symmetric configurations, the phase offset of MIMO-SAR can be predicted easily. Therefore, by utilizing the dependency of SAR on phase offset, the estimation time of SAR can be significantly reduced as the SAR estimation only for 0° would suffice.

IV. Conclusion

In this paper, a phase offset analysis for SAR estimation has been carried out by using a 2×2 MIMO metallic rim-based antenna for mobile handsets. It is found that phase offset of 0° maximizes MIMO-SAR whereas 210° minimizes it. Hence, SAR analysis only at 0° phase offset would be enough to analyze the maximum exposure conditions for the MIMO handset user reducing the estimation time greatly. The analysis holds true for symmetrical antenna elements placed on opposite sides of the shorter edge and for a talk position configuration. Future work include SAR analysis for antenna elements placed at different sides of the rim and varying the transmit power levels.

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