

# MIMO Antenna Concept for 4G Electronic Eyewear Devices

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**Abstract**—MIMO antenna concepts for electronic eyewear devices operating in 4G cellular standard are proposed in this paper. Coupling element type antennas and matching circuits are used to obtain a high bandwidth potential for the coverage of the 700-960MHz and 1.7-2.7GHz frequency bands. To obtain a dual-antenna MIMO configuration, two CE type antennas are placed on the two sides of the head, resulting in a very high isolation level thanks to the lossy nature of the human tissues (head). It is shown through simulated 3D radiation patterns that very low envelope correlation coefficients are obtained for this placement. Preliminary SAR simulations show values above the 1g standards.

## I. INTRODUCTION

An increasing interest has arisen for wearable technology devices like connected watches, bracelets etc... One of the hot targets of the wireless industry is the eyewear that can accept calls, take photos, help the user in navigation [1]. However the connectivity of this kind of device is currently limited to Bluetooth and Wi-Fi standards, with the antenna generally placed behind the user's ear like in wireless headsets for mobile phones. It is foreseen that these eyewear devices may even replace smartphones in the following years, needing the ability to transmit/receive in the 4G cellular communication bands.

Recently, we performed a feasibility study [2] concerning the operation of an eyewear antenna in the 4G frequencies: 700-960MHz (Low-Band, LB) and 1.7-2.7GHz (High-Band, HB). In this paper, the single-antenna concept is extended to dual-antenna for MIMO operation in 4G standards. Section II briefly presents two antenna alternatives for 4G coverage in a single antenna scenario. MIMO operation is discussed in Section III. Finally, a conclusion in Section IV ends the paper.

## II. SINGLE ANTENNA SCENARIO

To be able to cover the 4G communication bands in an eyewear application, several Coupling Element (CE) antennas with their associated matching networks (MN) were proposed in [2]. Two different antenna locations are evaluated here where the CE is placed behind the ear in Design-1 (Fig. 1) and placed at the edge of the FR4 PCB, close to the eye in Design-2 (Fig. 2). Both antennas consist of simple CEs printed on the inner side of the PCB. The ground planes are set on the other side of the FR4 PCBs which are 0.8mm thick. The MNs optimized in Optenni Lab software [3] consist of two lumped elements for Design-1 and three lumped elements in Design-2.

The simulated reflection coefficients for the two designs with their MNs are given in Fig. 3 (from Empire Xcel software[4]). The simulated radiation efficiencies are on average 9% in LB and 20% in HB for Design-1 and 14% in LB and 36% in HB for Design-2.

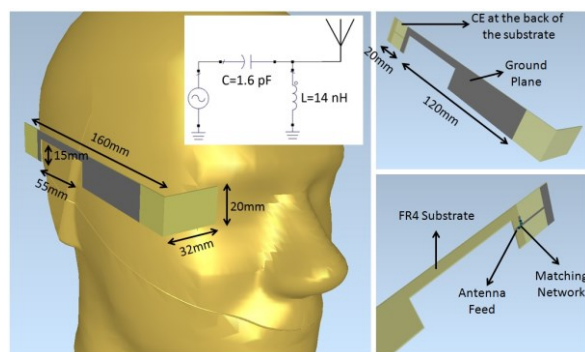


Fig. 1. Layout of Antenna Design-1 with SAM head

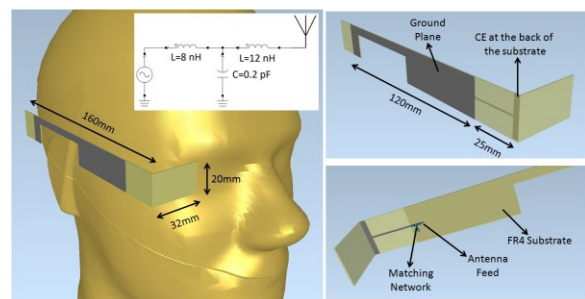


Fig. 2. Layout of Antenna Design-2 with SAM head

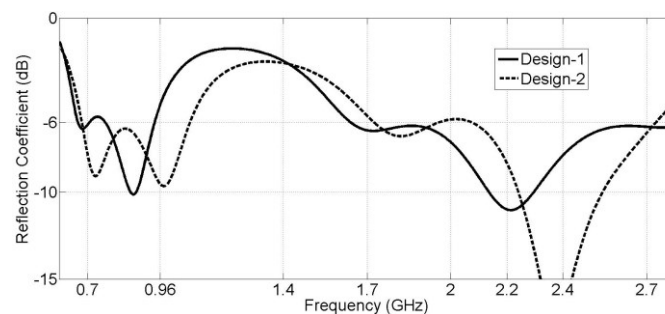


Fig. 3. Simulated Reflection Coefficient for Single Antenna Case (Design-1 and Design-2 with SAM head)

### III. MIMO SCENARIO

The two antenna designs were evaluated in a MIMO scenario () by placing a duplicate antenna/PCB on the other side of the SAM head. This simulates the case where two antennas are situated on the frames of eyewear device. As can be seen in Fig. 4 (for Design-1) and in Fig. 5 (for Design-2), a high level of isolation (40 to 60 dB) is achieved for both designs due to the lossy nature of the human head. The isolation level is lower for Design-2 (average 48 dB) than Design-1 (average 55 dB) since the CE is situated further away from the tissue in this design. This can also be seen from the higher radiation efficiency obtained with Design-2 with single antenna case. The simulated gain patterns for both designs (MIMO case) are presented in Fig. 6 and Fig. 7. For both designs, the radiation is concentrated away from the head. The patterns are more directive in the HB with an interesting dual-lobe behavior for Design-1 (Fig. 6).

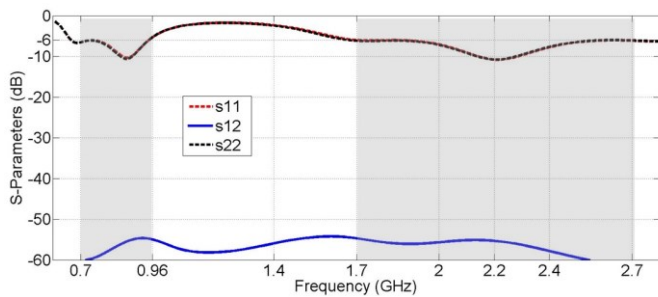


Fig. 4. Simulated S-Parameters (Design-1, MIMO Scenario)

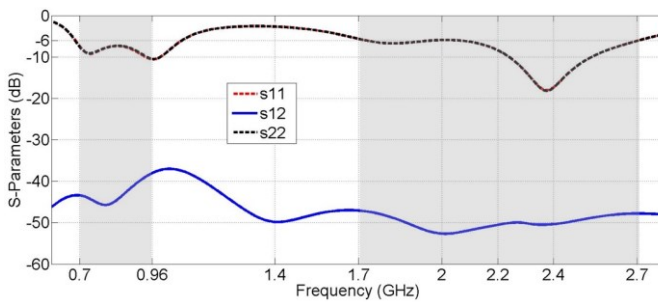


Fig. 5. Simulated S-Parameters (Design-2, MIMO Scenario)

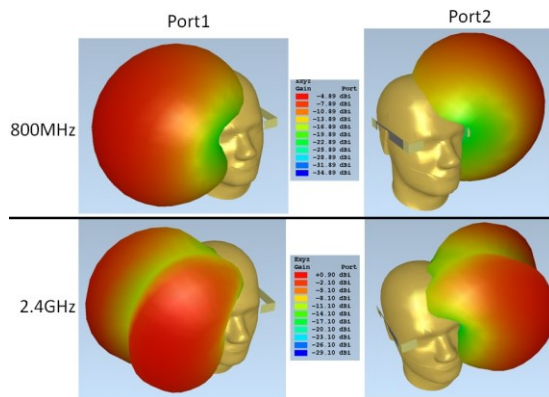


Fig. 6. 3D Gain Radiation Patterns for Design-1

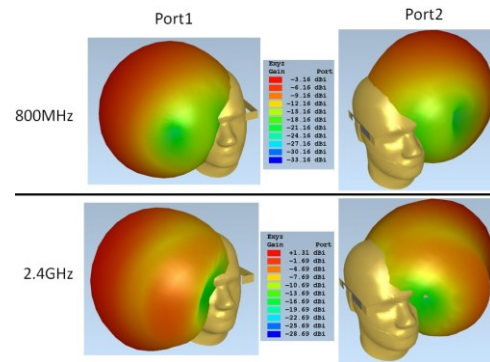


Fig. 7. 3D Gain Radiation Patterns for Design-2

The envelope correlation coefficient (ECC) calculated from the complex E-fields in a uniform multi-path environment is given in Fig. 8 for both designs. A very low ECC is seen for both designs (much lower than 0.5) since the antennas radiate in opposite directions away from the head. Preliminary SAR simulations achieved with SAM and visible human phantoms (normalized to 0.25W incident power) show values above the 1g SAR standards (1.6W/kg over 1g for 30 minutes) in all cases while the 10g SAR values are generally acceptable. Especially, the SAR values from Design-2 are lower than SAR values from Design-1 (but still above the 1g standards) as the primary excitation is further away from the head [2].

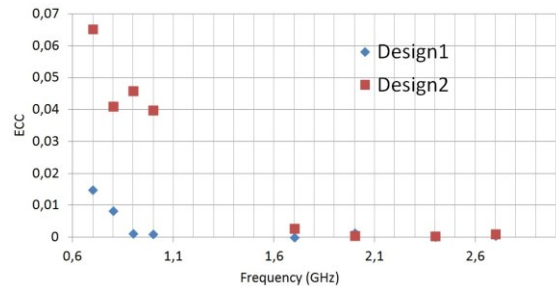


Fig. 8. ECC Computed from E-fields for both designs

### IV. CONCLUSION

With consumer interest in electronic eyewear expected to grow, eyewear provides an ideal platform for implementing on-body MIMO due to the considerable isolation provided by the user's head. The use of CE is a viable option but careful design is required to minimize SAR in the user.

### REFERENCES

- [1] "Google Glass," Information Available at: <http://www.google.com/glass/start/>
- [2] A. Cihangir, W. Whitrow, C. Panagamuwa, F. Ferrero, G. Jacquemod, F. Giancesello, C. Luxey, "Feasibility study of 4G cellular antennas for eyewear communicating devices," accepted for publication in IEEE Antennas and Wireless Propagation Letters
- [3] Optenni Lab, Information Available at: <http://www.optenni.com/optenni-lab/>
- [4] EMPIRE XCell, Information Available at: <http://www.empire.de/>