Slot Antenna Design with Optimized On-Body Pattern for Eyewear Applications

Lukas Berkelmann, Dirk Manteuffel
Institute of Microwave and Wireless Systems
Leibniz University Hannover
Hannover, Germany
berkelmann@hft.uni-hannover.de

***Abstract*—In this contribution we describe the development of an antenna concept for the 2.4-GHz ISM-band for eyewear applications. Main focus in the design process is drawn on an optimized radiation behaviour for the case of on-body communication. Therefore the antenna is designed to have a downward directed radiation characteristic with a normal polarization with respect to the body surface. This property is optimized by means of the TM component of the so called on-body directivity. It is shown that this way the on-body path-loss can be reduced by up to 10 dB compared to other recently published eyewear antenna concepts through an increased excitation of surface wave components on the body.**

I. Introduction

Wearable electronic systems have already been established in many areas. Devices such as smart watches have arrived in everyday use and the number of applications in medical technology is also growing. The wireless systems required for these are still a challenge due to the high level of integration and the influence of the lossy body tissue. This is in particular important due to the fact that there is no generally established design process that takes into account the special characteristics of wave propagation at the body. In the context of this paper an antenna system for the integration into an eyewear application or smart glasses is designed. In particular, the behavior of the transmission along the body is optimized.

Devices on the market often use simple antennas such as monopols where only impedance matching is optimized without forming the radiation characteristic in a favorable pattern. A relatively new approach is to use the glass area with transparent antenna designs [1], however again only simple monopol type antennas were designed. In [2] a dual antenna design was presented, which aims to optimize the previously ignored radiation characteristics of the antenna. The design enhances the radiation characteristic in useful directions to the front and side of the eyewear as well as in the downward direction to communicate with e.g. a smartphone in the pocket of the user. What has not been considered in this design either is the special behavior of the physical communication channel along the surface of the body. This paper aims to further improve the link from the eyewear device to devices placed at the body (on-body) through exciting a higher amount of surface wave components which propagate on the outer body contour.

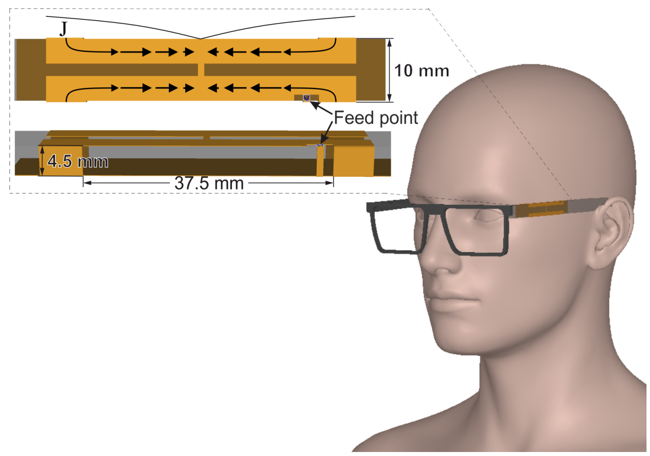

Fig. 1. Developed antenna system integrated into glasses frame, upper part depicts only the antenna structure with the current distribution

II. Antenna Design

On-body antenna concepts which aim to excite surface waves require a normal polarization with respect to the body surface. Usually, a major design criterion is also a small geometrical height. Thus, a common solution is to use e.g inverted-F antenna concepts [3], [4]. We utilized a concept of a wide slot whose aperture plane is perpendicular to the body as also a downward directed pattern would be beneficial for the on-body performance of head-worn devices. A comparable concept was presented in [5]. The antenna was designed to be folded around a plastic substrate, in our calculations we assumed a PC/ABS material (relative permittivity of $\epsilon_r = 2.8$ and loss tangent of tan$\delta = 0.078$). As can be seen in figure 1 mainly the currents in the short branches, perpendicular with respect to the body surface, can be expected to radiate since these have no mirror currents on the ground plane which can cancel their fields. The resulting radiation pattern reveals a broadside pattern, see figure 2, as a consequence of the main in-phase currents on the short branches with an effective distance close to half of a wavelength. Figure 2 depicts the on-body radiation pattern calculated according to [6], which is composed of directivities for TM (on-body) and TE (off-body) components in a plane parallel to the body

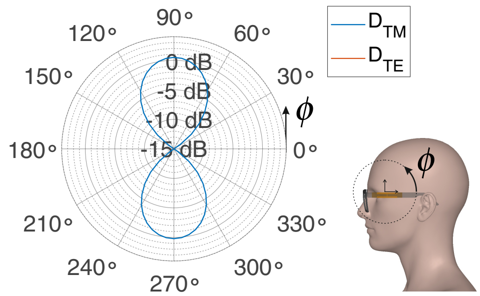

Fig. 2. On-body pattern of the proposed antenna according to [6]

surface. As can be seen, the TE component is negligible small and the designed antenna reveals a down and upward directed TM pattern. The antenna is fed near one end through an additional branch perpendicular to the body surface. To lower the input impedance of the structure a second slot was put on the opposite side of the frame and both parts were connected in the middle of the structure to ensure only a mode with currents in phase on both sections can be excited. Figure 3 shows the simulated input return loss, it can be seen that the antenna is well matched in the desired band.

III. Analysis of the On-Body Performance

To analyze the performance of the designed antenna for an on-body link we performed simulations with the antenna located in the position as shown in figure 1. For the body phantom we assumed a homogeneous tissue with a relative permittivity of $\epsilon_r = 39.2$ and a conductivity $\sigma = 1.8$ S/m. As a baseline we performed the same simulations with the dual antenna system as described in [2]. It is composed of a loop antenna and a monopol. The loop antenna is located at the front of the frame in a similar position as our antenne, ref. figure 1, while the monopol sits at the other end of the glasses frame behind the ear. We evaluated the resulting electric field distribution on a surface with constant distant of $d = 10$ mm above the surface of the body phantom. Figure 4 depicts the relative path gain on this surface, calculated as:

$$G_{\text{path, r}} = 20 \cdot \log\left(\frac{|E_{\text{AUT}}|}{|E_{\text{ref}}|}\right). \quad (1)$$

E_{AUT} represents the electric field strength calculated for the proposed antenna design, E_{ref} is the field strength calculated

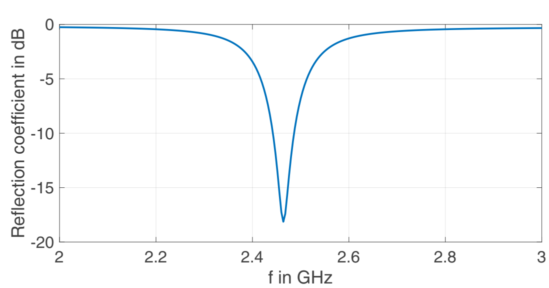

Fig. 3. Simulated input matching of the designed antenna

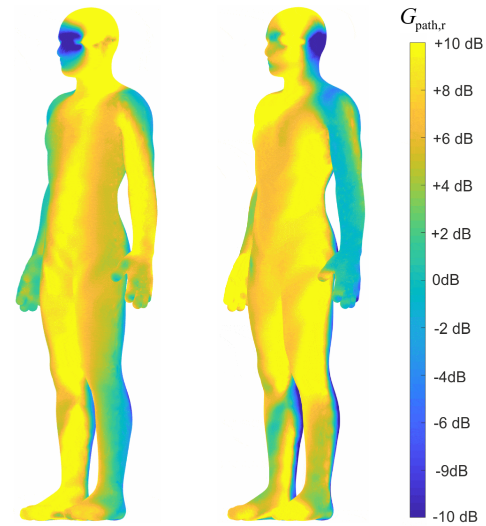

Fig. 4. Relative path gain of the designed antenna at $d = 10$ mm above the body phantom surface, reference antennas according to design in [2], left graph: loop antenna, right graph : monopol

with the antennas used as reference from [2]. The radiated power in all simulations was normalized to $P_{\text{rad}} = 1$ W. Thus, using the proposed antenna system the path loss of an on-body link, e.g. to the pockets, can be expected to be decreased by the same amount. It can be seen that the designed antenna outperforms the antennas used as baseline in the on-body scenario for large regions on the front of the body by more than 10 dB in the relative path gain.

IV. Conclusion

We designed an antenna system for an eyewear application with a downward directed on-body pattern that excites a high amount of surface wave components. The analysis of the on-body performance of the designed antenna shows that adapting the antenna design process for the special needs of the on-body channel can significantly improve the path loss to devices worn at the body, e.g. in the pockets.

References

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