2021 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (APS/URSI)

Integration of a 28 GHz Beamforming Module into a Handset Device Using LDS-MID Technology

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***Abstract*—In this paper a concept for integration of a 28-GHz beamforming antenna system into a 5G smartphone is shown. The antenna array consists of slot antenna elements in the metal bezel of the smartphone chassis. Beamforming is achieved by a 4-port 5G beamforming chip. In order to attach the beamforming module firmly to the slots in a way suitable for mass production assembly of the smartphone a MID (Molded Interconnect Device) is designed. The MID module carries all millimeter wave components and enables accurate and reliable aperture coupling to the slot antenna elements.**

I. Introduction

The fifth generation (5G) of wireless communication systems is about to be introduced. To cope with the demand for enhanced mobile broadband millimeter wave (mmWave) bands, e.g. around 28 GHz, will be used because of higher available bandwidths. This frequency range will not only be used for the wireless backhaul communication, but shall also be used to enable enhanced data mode for smartphones in small cells. Integration of a 28-GHz antenna array into a smartphone chassis is difficult for different reasons. Firstly, the attenuation of the smartphone chassis is high at mmWave frequencies. Secondly, usual interconnects between a mmWave front end and the antennas are bulky and expensive. The possibility of integrating beamforming functionality into cellular handset devices has been actively researched in recent years, e.g. in [1]. In this paper we introduce a concept for integration of such a mmWave beamforming antenna system that addresses both challenges mentioned above with a focus on a suitable assembly for mass production.

II. Antenna system integration concept

Current 4G smartphone devices operate in sub 6-GHz frequency bands. Their antenna functionality is basically based on utilizing the entire chassis as a radiating element. Coupling elements, typically realized out of different parts of the metal bezel excite those chassis modes. Due to the relatively low frequency bands below 6 GHz rather simple and cheap interconnects between the front end and the coupling element can be used. Most of the sub 6-GHz bands will be continued for 5G devices and as a consequence their coupling elements in the bezel are likely to remain. The bezel itself does already contain gaps for the separation of the coupling elements and holes for acoustic outlets. With respect to mmWave antennas it may also be used as carrier for a slot antenna array as it is usually a precisely manufactured metal structure of excellent connectivity. A prospective configuration is illustrated in Fig. 1. It consists of four slot antennas integrated into the metal bezel of the chassis and a module inside the chassis containing a beamforming chip and all other mmWave components. The module is designed as an MID using the LDS (Laser Direct Structuring) technology. Fig. 2 shows only the mmWave section of the metallized MID together with the beamforming IC and a cooling pad for simplicity. The mechanical design flexibility of LDS-MID enables 3D shapes as well as its mechanical accuracy allows for accurate and easy assembly that also allows to integrate a mmWave transition between the front end module and the antennas. The MID module consists of an injection molded 3D-shaped plastic part that is intended to snap into the metal bezel to guarantee exact positioning. It contains all mmWave components of the front end, but can be designed to contain peripheral electronics as well. Microstrip lines (see Fig. 2a) placed on the MID plastic part using LDS technology are used to feed the slots

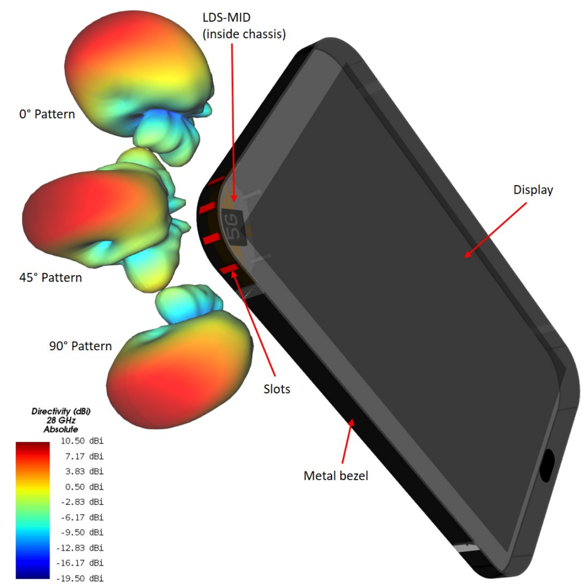
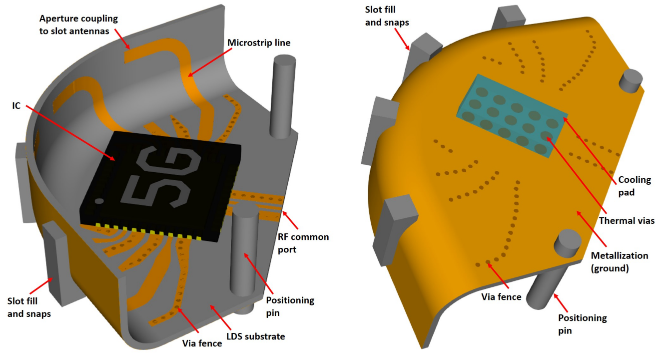


Fig. 1: Smartphone chassis with four-slot-array realized in the upper-left corner of the metal bezel and examplary radiation patterns achieved by different settings of the beamformer



(a) Front (b) Back

Fig. 2: LDS-MID with beamforming IC and cooling pad

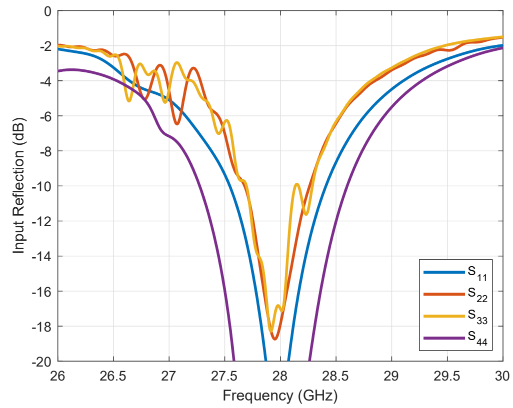


Fig. 3: Input reflection coefficients at microstrip feed lines inside metal smartphone chassis

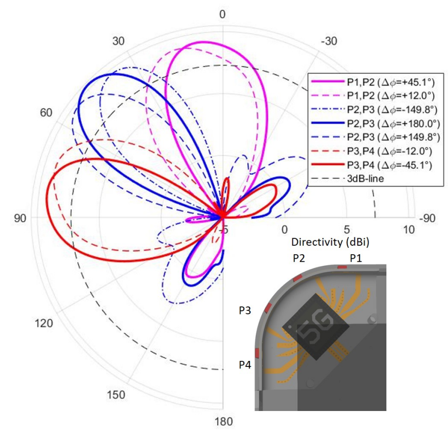


Fig. 4: Beam steering pattern with labeling of active ports (P1,P2,P3,P4) and phase difference $\Delta\phi$ between ports

by aperture coupling. The microstrip lines are connected to the beamforming IC, which is an AWMF-0108 in a QFN-package by Anokiwave [2] in this concept. This IC has a size of 6 mm x 6 mm and a height of 0.85 mm. The IC is soldered onto the MID in a central position to keep the microstrip lines as short as possible for low signal attenuation. To avoid coupling of the mmWave signals to neighboured lines the microstrip lines are enclosed by via-fences (via diameter of 0.2 mm) in the plane part of the MID, as can be seen from Fig. 2. Next to the beamforming IC there is space for peripheral components as for example for a transceiver IC. The backside (see Fig. 2b) of the plastic MID is completely metallized, except for the four slots at the frame, and can be used as a ground plane for the microstrip lines. The plastic MID substrate is a polyether ether ketone (PEEK) based compound that is suitable for laser activation in the LDS process. It has a relative permittivity of 3.59 and a loss tangent of lower than 0.002, as we measured in preliminary studies for this frequency range. The thickness of the plastic MID part is 0.3 mm, the thickness of the metallization is 10 μm on both sides (lines and ground). The tolerances in the injection molding of the MID and in the LDS process slightly depend on the used material. For the PEEK material we measured tolerances comparable to standard RF substrates in our preliminary studies [3]. Underneath the QFN packaged beamforming IC there is a ground pad for heat dissipation. This pad is soldered onto a metallized plane containing thermal vias with a diameter of 0.6 mm connected to the metallized backside of the MID, which can then be connected by a cooling pad (e.g. graphite pad) to the bottom metal smarthphone chassis.

III. Simulation results

The structure consisting of the integrated LDS-MID and the complete smartphone chassis was simulated using EmpireXPU EM software. Fig. 3 shows the input reflection at the four microstrip feed lines inside the metal smartphone chassis. Fig. 4 shows exemplary directivity patterns and the associated active ports together with the phase difference between the signals at the input ports. To get a wide beam steering range of more than 90° (3-dB steering angle) the ports are grouped into three sub-arrays (P1+P2, P2+P3 and P3+P4) of two neighboured ports each. For the fine resolution beam steering the phase difference between the two ports of a sub-array is tuned, as can be seen from the dashed lines in Fig. 4.

IV. Conclusion

A concept for integration of a 28-GHz beamforming antenna system into a smartphone using LDS-MID technology was shown. Beamforming performance for the integrated MID using realistic material and geometry parameters was simulated to compare to a prototype that is in progress. The concept focusses on an easy and reliable assembly for mass production.

References

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