Vehicular Roof Antenna Cavity for Coverage at Low Elevation Angles

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***Abstract*—Chassis cavities have recently been proposed as a new mounting position for vehicular antennas. Cavities can be concealed and potentially offer more space for antennas than shark-fin modules mounted on top of the roof. An antenna cavity for the front or rear edge of the vehicle roof is designed, manufactured and measured for 5.9 GHz. The cavity offers increased radiation in the horizontal plane and to angles below horizon, compared to cavities located in the roof center.**

I. Introduction

Shark-fin antenna modules mounted on the car roof contain a large number of antennas [1]. It is expected that these modules can not significantly grow in size, as they influence the aesthetic design and drag coefficient of vehicles. Recently cavities manufactured as part of the vehicle chassis were proposed, which are large enough to house a plurality of antennas [2]. In [3] it is shown by measurement, that chassis cavities are suitable for automotive antennas and can be used in a large frequency range up to $8\,\mathrm{GHz}$. This principle can be seen as a generalization of previously proposed smaller vehicular cavities for SDARS and GPS [4], and LTE [5] that are inserted into the vehicle roof. A cavity-backed spiral antenna conformally built into the trunk lid is presented in [6]. A pattern reconfigurable antenna inside a chassis cavity is presented in [7]. Near-omnidirectional radiation in the horizontal plane is possible, but antenna gain is decreased for angels below horizon because the roof acts as a large antenna ground plane. A solution is to place such cavities at the front and/or rear roof edge of a vehicle. Gain in horizontal plane is then increased in that direction, because the ground plane is shorter. From the roof edge radiation towards angles below the roof is possible, which improves car-to-car communication with smaller vehicles and enables wireless communication with vulnerable road users such as bicycles and pedestrians.

II. Chassis Antenna Cavity for the Roof Edge

The antenna cavity is manufactured as part of a $580 \times 1000\,\mathrm{mm}^2$ carbon fiber reinforced polymer (CFRP) sheet. The $40\,\mathrm{mm}$ deep antenna cavity has inclined walls, it has a size of $150 \times 500\,\mathrm{mm}^2$ on its floor and $190 \times 570\,\mathrm{mm}$ at the sheet. In commercial integration the geometry of the cavity opening towards $\varphi = 0^\circ$ will be vehicle specific. The glass of the window and the implementation of the roof-glass transition are expected to have an influence on antenna performance, as simulations for roof-mounted antenna modules in [8] show. Vehicle specific features such as roof curvature, the windshield below the cavity opening and a protective cover, are not included to increase reproducibility and the cavity is cut open vertically. The antenna cavity inside an anechoic chamber is depicted in Fig. 1. A monopole antenna for $5.9\,\mathrm{GHz}$ car-to-car communication is measured inside the cavity to quantify the improvement over a cavity in the roof center. As a reference the antenna is measured on a small $150 \times 150\,\mathrm{mm}^2$ ground plane.

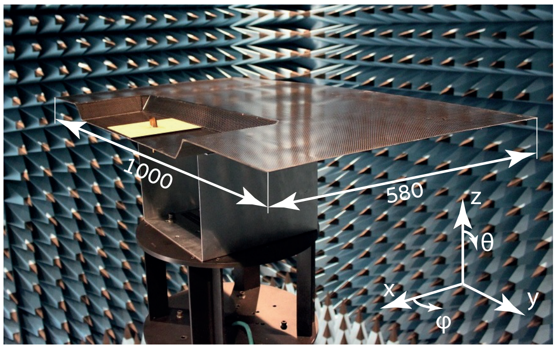

Fig. 1. The antenna cavity manufactured as part of a CFRP sheet. For placement at the roof edge, the cavity is open towards $\varphi = 0^\circ$. A monopole antenna for $5.9\,\mathrm{GHz}$ is placed in the center of the cavity.

III. Measurements and Results

When placed in the cavity, the antenna has a return loss of about $8\,\mathrm{dB}$. The vertical cuts of the measured gain patterns are compared in Fig. 2. The improvement of placing the antenna cavity at the roof edge is immediately apparent. In direction of the opening ($\varphi = 0^\circ$) the gain in horizontal plane is increased. Radiation towards angles below horizon is possible, as it would be the case on the small ground plane; gain is increased by $10\,\mathrm{dB}$ over a cavity located in the roof center. Towards the back the gain pattern resembles that of an antenna cavity in the roof center, as was expected.

Towards the sides the gain pattern in the cavity at the roof edge behaves like a cavity placed in the roof center (Fig. 3), as their geometries in these directions are identical.

The horizontal cut of the gain pattern is depicted in Fig. 4. Gain towards the front is increased to the $0\,\mathrm{dBi}$ achieved on

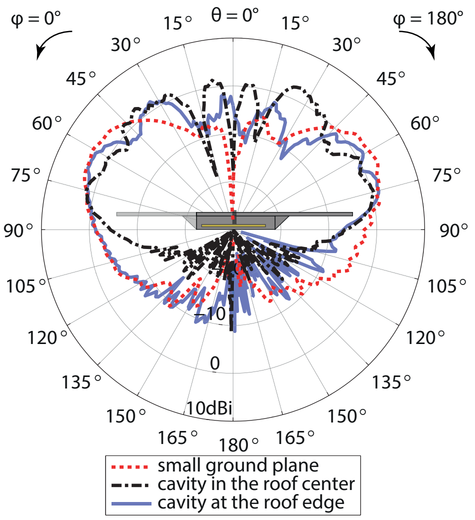

Fig. 2. Measured gain patterns, vertical cuts for $\varphi = 0^\circ$ at 5.9 GHz. Towards the front radiation is increased compared to cavities located in the roof center.

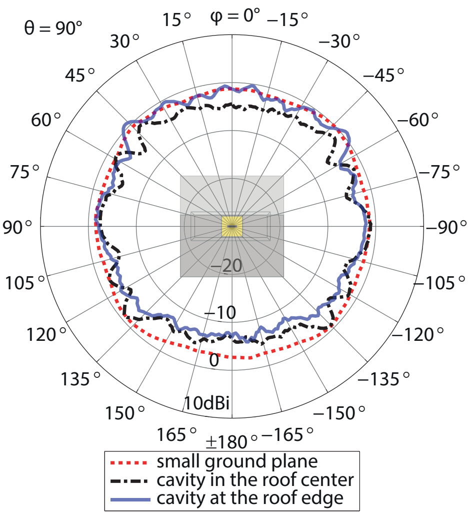

Fig. 4. Measured gain patterns, horizontal cuts for $\theta = 90^\circ$ at 5.9 GHz. Radiation towards the front is increased in a wide angular range.

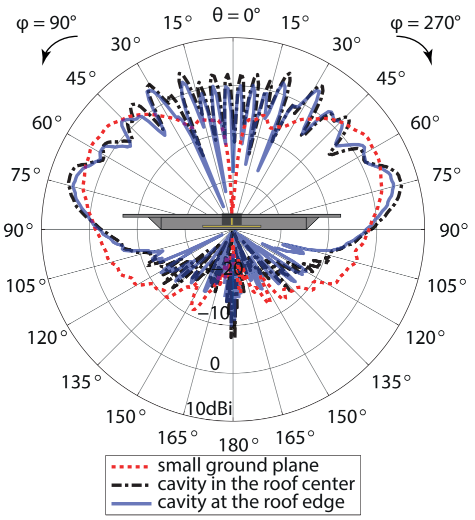

Fig. 3. Measured gain patterns, vertical cuts for $\varphi = 90^\circ$ at 5.9 GHz. Towards the sides the cavity behaves like a cavity placed in the roof center.

a small ground plane. Increased radiation towards the front is achieved in a large angular range ($-45^\circ \leq \varphi \leq 45^\circ$), which significantly improves communication with vehicles in the front.

IV. Conclusion

A prototype of a chassis cavity for the roof edge is designed and manufactured from carbon fiber reinforced polymer (CFRP). Improved radiation characteristics are shown with measurements of a laser direct structured monopole antenna for car-to-car communication at 5.9 GHz. The increase in radiation towards the front is a property of the antenna's position at the roof edge inside a cavity, not of an optimized antenna design. The presented cavity is concealable, offers more volume than roof-mounted antenna modules and is not affected by shadowing due to the roof's curvature like shark-fin modules located at the rear end of the roof are. Combination of two such cavities, placed at both the front and rear roof edges, offers increased radiation towards the front and back of the vehicle and spatial diversity for multiple-input multiple-output (MIMO) communication.

Acknowledgement

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