SIMULATING INSTALLED ANTENNA PERFORMANCE FOR AUTOMOTIVE RADAR APPLICATIONS

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KEYWORDS – installed antenna performance, radiation pattern, automotive radar, finite element boundary integral method (FEBI)

ABSTRACT
Radar technologies play and will continue to play an ever increasing role in the present and future of automotive industry. Especially with the advent of assisted and autonomous driving technologies, acquisition of radar data from the surroundings of a vehicle and fusion with other sensor data becomes indispensable. Radar antennas in cars are frequently placed behind front and/or rear bumpers to protect their sensitive components. Although the bumper material is dielectric, which permits the transmission of radio waves through it, its dielectric properties are different from air. Therefore, the characteristics of the radar antenna are different when it radiates behind the bumper than in free space. For a successful antenna design, a simulation of the performance of the antenna when it radiates in its proper environment (i.e. behind the bumper) is needed. In this paper we will show with the help of a generic example, how an electromagnetic solver that uses the hybrid finite element – boundary integral method (FEBI) can tackle this problem with the help of the ANSA preprocessor for generating the mesh. To this effect, first an antenna array of four patches was simulated in free space, and afterwards behind a generic car bumper. The radiation pattern was calculated in each case and compared subsequently, in order to show how the presence of the bumper alters the radiation characteristics of the antenna.

TECHNICAL PAPER -

1. INTRODUCTION

Radar technology has been an integral component of automotive technology over the past years. With the advent of assisted, automated and autonomous driving technologies, radar has become an even more indispensable part of the modern car. One major challenge for HF (high-frequency) engineers is to design antennas that will comply with requirements from other fields (aerodynamics, structural dynamics, design specifications etc.) without compromising the required EM (electromagnetic) performance of the antenna. Thus, the field of installed antenna performance (i.e. how an antenna performs when installed on a larger platform) has an increased significance in the automotive industry.

In order to demonstrate the importance of taking the larger antenna environment into account, as well as the simulation difficulties that accompany this task, we have simulated a generic scenario, where a simple array of patch antennas is placed behind the dielectric (i.e. poorly conducting or non-conducting) bumper of a car, and we compare its radiation pattern when installed behind the bumper with the pattern in free space.

2. MODEL DESCRIPTION

The antenna that was chosen to be simulated is a linear array antenna of four elements (see Figure 1). Each element is a simple patch antenna excited at 24 GHz (a typical frequency for automotive radar applications). The patches are printed/etched on a Teflon substrate with dielectric constant of ε_r=2.2-j6.353e-3. The distance between the elements is half a wavelength in free space (6.2mm) and they were excited with the same phase. The antenna surface was meshed with 21616 triangles and the antenna substrate with 34343 tetrahedrons. The mean edge length was 9.4 times smaller than the wavelength in the substrate.

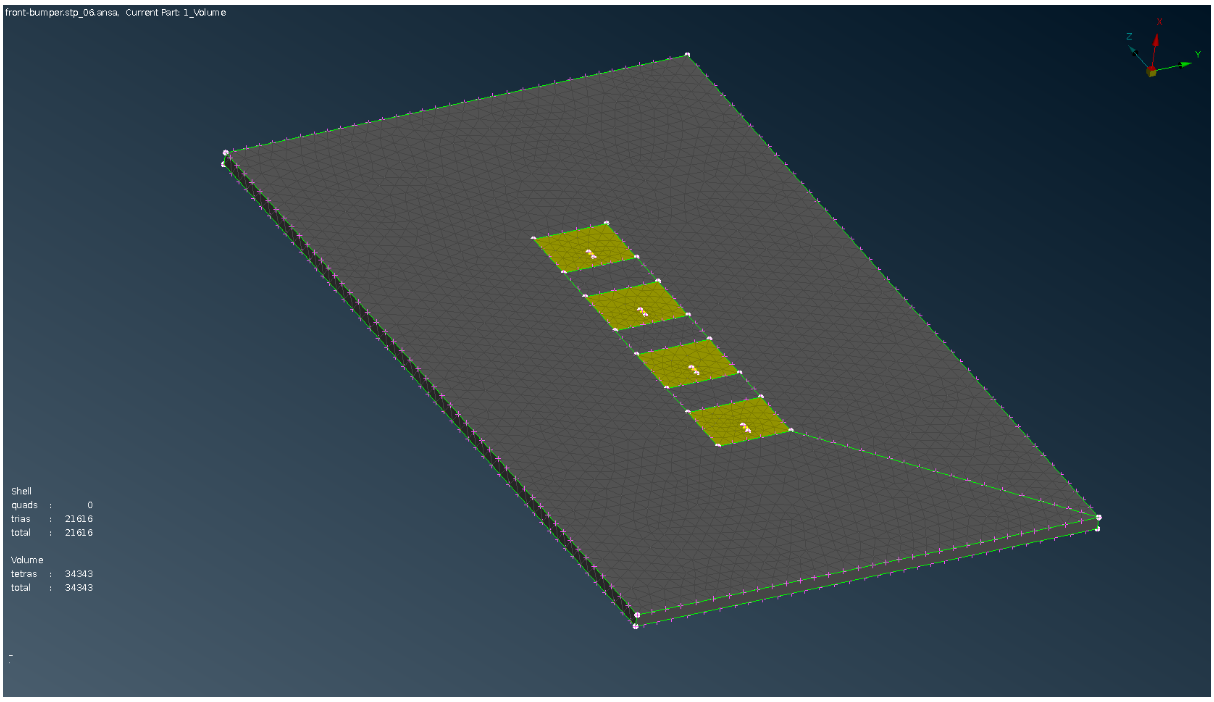

Figure 1: Meshed CAD model of the patch array

The array was placed 75.3mm behind a bumper made of a dielectric material of dielectric constant ε_r=2.5-j0.01. In order to save simulation time and memory, only half of the bumper was simulated (see Figure 2).

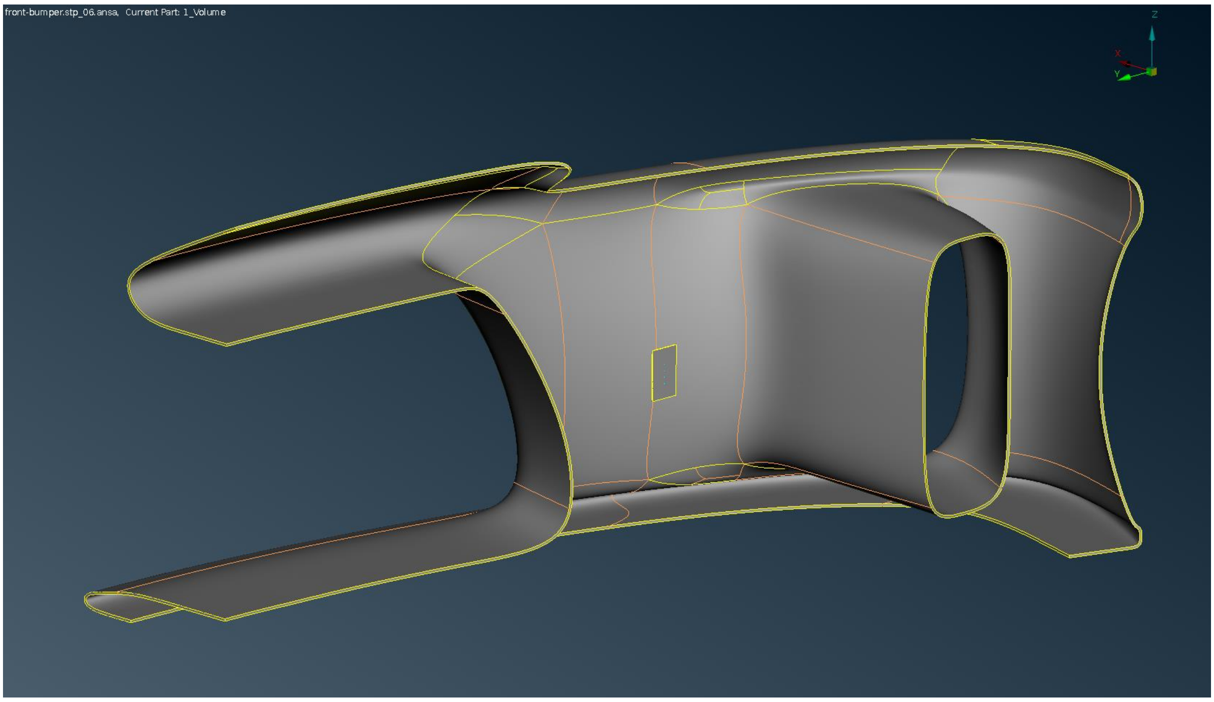

Figure 2: Bumper CAD model (rear view) with patch antenna placed behind it

The bumper volume was meshed with ~26.7 million tetrahedrons and the surface was discretized with ~4.3 million triangular elements (see Figure 3). The mean edge length was 9 times smaller than the wavelength inside the bumper and 14.2 times smaller than the wavelength in free space. All meshes were created by ANSA software.

The wave propagation inside the bumper and antenna substrate volume was simulated with the Finite Element Method (FEM) with Nédélec edge elements (1). The wave radiation from the surface of the antenna and bumper was simulated with the Boundary Integral Method (BIM) with Rao-Wilton-Glisson (RWG) basis functions (2). Hence, we used a hybrid Finite Element – Boundary Integral (FE-BI) method (see (3), Chapter 10).

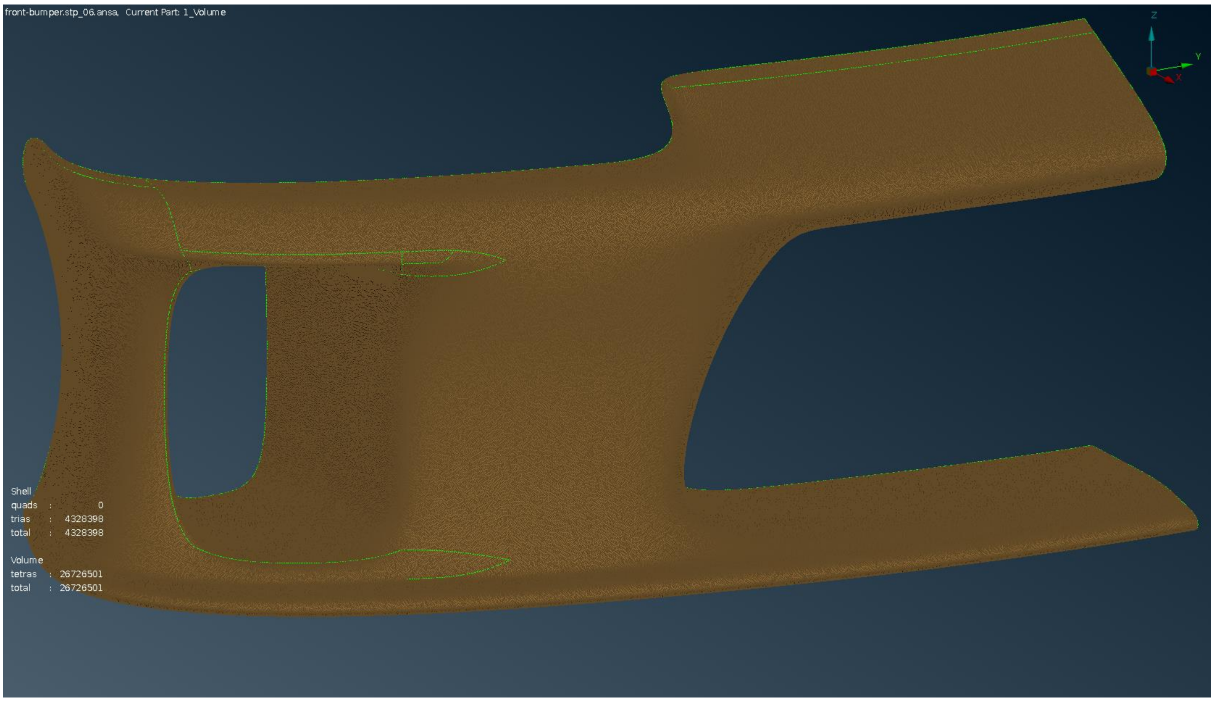

Figure 3: Meshed bumper CAD model (front view)

3. RESULTS

The 3D radiation pattern of the antenna was calculated for both cases, i.e. for the antenna in free space and behind the bumper. The calculation time for the antenna in free space was ca. 5 min, whereas for the antenna behind the bumper it was ca. 28 days (single-core).

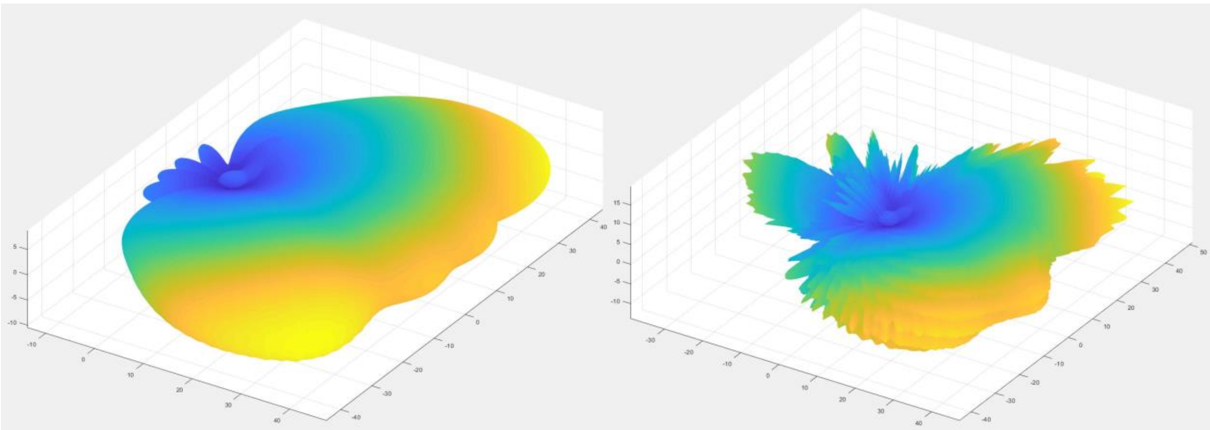

Figure 4: 3D radiation pattern of the antenna in free space (left) and behind the bumper (right)

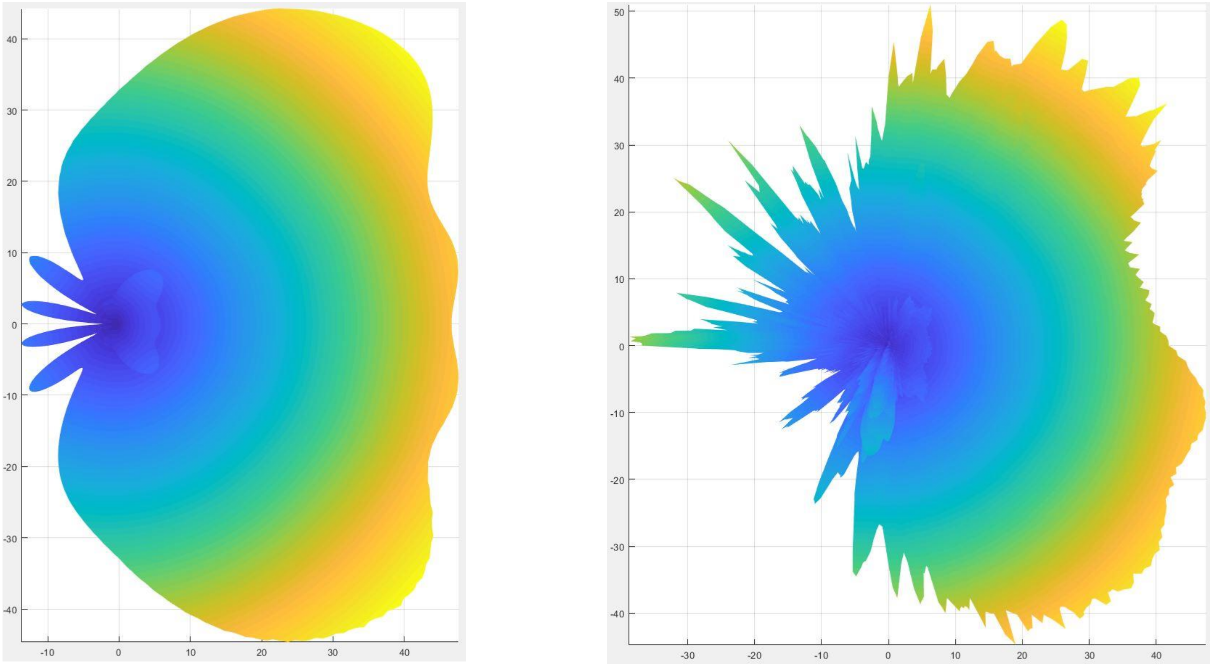

Figure 5: Top view (in azimuth plane) of the 3D radiation pattern of the antenna in free space (left) and behind the bumper (right)

The results of the simulation can be seen in Figure 4 for both the free space and the installed case. A better comparison can be drawn by looking at the radiation patterns on the azimuthal plane in Figure 5. From these figures we can see that the radiation pattern of the antenna is significantly distorted, when the antenna is installed behind the bumper of the car. The symmetry of the main lobe is broken, there is a depression of power in some forward looking directions, and the side lobe level has significantly increased.

4. CONCLUSIONS

The purpose of this paper was to show, that the performance of an antenna can significantly change when installed on a platform, so that it makes no sense designing the antenna in free space but only in its final environment. Therefore, it is the task of the antenna engineer to take the complicated environment of the antenna into account, in order to optimize the antenna's characteristics when installed in its proper place. Further possibilities for optimizing the radiation pattern can be to alter the shape, material and thickness of the bumper, in order to arrive at the desired radiation pattern.

Finally we have to remark on the long computation time for the full-wave simulation in the presence of the bumper. In order to assist in the design process, the simulation time should be drastically reduced. Some steps to be taken into this direction could be modelling an even smaller part of the bumper, using a pure surface integral method, parallelizing the solver, and using higher-order basis functions.

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