

Automotive Radars – Antenna Design, Integration and Channel Modelling

Meeting the Challenges

One of the key enabling technologies in the development of autonomous vehicles is driving aid radar systems. Although the applications will mostly focus on road safety, radars are also used in parking assist functions. Meeting the gain, beam width and side lobe level specifications for the radar antennas can be challenging, but these specifications must also be maintained during integration of the antenna into the vehicle. For example, the effect of the radome and bumper must be carefully quantified. Furthermore, the radar channel interactions with its environment need to be understood for system level design.

This paper will touch on some of the typical challenges experienced during the design and integration of automotive radars, while highlighting the applicable numerical solutions that FEKO offers. Radar channel modelling with WinProp is also presented.

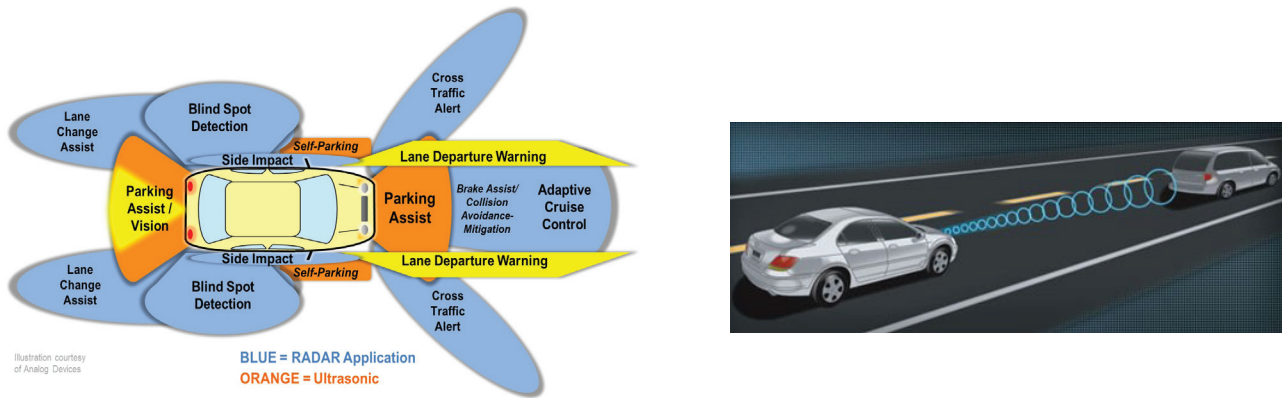


Figure 1: Automotive radar systems [www.eetimes.com] like anti-collision detection are set to make our roads safer.

The Antenna Design

Operating at 77 GHz, long range automatic cruise control (ACC) radar systems are used to maintain the cruising distance between the vehicles. Typically, multiple receiver and transmitter chains are co-located on the same antenna. Co-site interference between antenna chains must be minimized to ensure optimum radar performance.

FEKO offers powerful solvers combined with automated optimization to assist in the design of these antennas. Initially, the MoM or MLFMM methods can be used (with planar Green's function for printed antennas) for fast, multi-goal optimization of the single antenna chain performance. Once the specifications have been met, the array spacing of the chains can be determined in a second step taking advantage of FEKO's finite array tools. The FDTD solver can be used to calculate S-parameters for the full radar system efficiently, especially when combined with GPU acceleration.

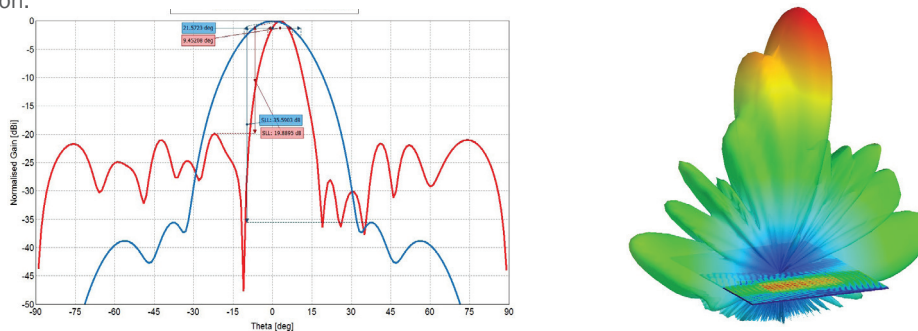


Figure 2: Example of an optimized TX chain for ACC: the normalized azimuth and elevation cuts are shown along with the 3D gain pattern.

Integration into the Vehicle

Once a suitable antenna has been designed, the effects of integrating the antenna into the vehicle need to be quantified. The high operating frequency of ACC radar means that the vehicle is electrically extremely large (thousands of wavelengths). It is not possible to simulate the full vehicle geometry with the solvers that were mentioned in the previous section and only the relevant parts should be considered.

Radome Design and Integration:

FEKO offers ideal tools for characterization of the different radome materials. These include thin layers of paint, polish, primer and even a layer of water from rain. These layers can be considered efficiently using the multi-layer planar Green's function.

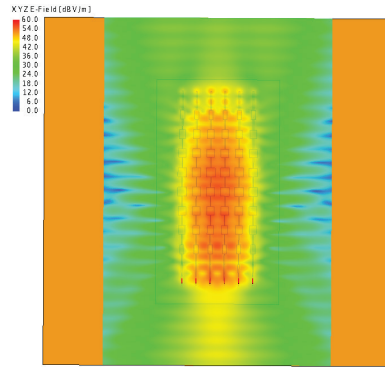


Figure 3: Near field aperture representation to be used for the simulation of the radome.

Due to the size and complexity of the radar antenna, it might be computationally more efficient to solve this problem using a two-step model decomposition approach (Figure 4). An equivalent (near field, far field or spherical mode) representation is determined (by simulation or measurement) for the antenna, and then used to excite the radome geometry.

If single material radomes are considered (or effective material parameters are used), the FDTD method can be applied to simulate the full radar and radome directly (model decomposition not necessary). The advantage of this approach is that coupling between chains is inherently taken into account.

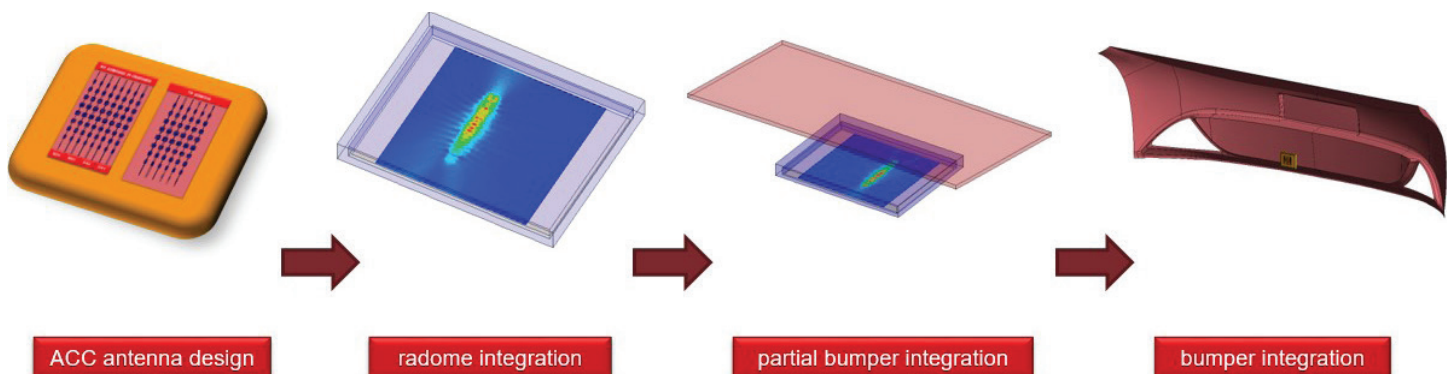


Figure 4: Typical simulation model decomposition workflow from antenna design to integration with radome and bumper.

Including the Bumper Effects:

The electrical size of the bumper means that an asymptotic method like RL-GO must be used to solve the problem in order to quantify the effects of the bumper and determine the optimum antenna location. Once again, a model decomposition approach is applied. An equivalent representation of the antenna (this time a far field source) is used to excite the radome and bumper (Figure 4). Figure 5 shows some results for the full integration of an ACC radar including radome and bumper.

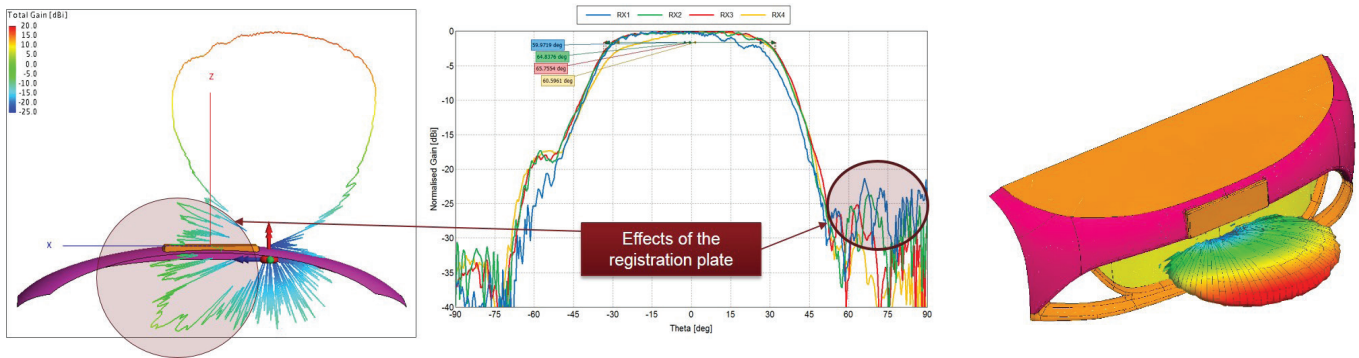


Figure 5: Effect of the bumper and registration plate on the radar performance can be seen in the side lobes. When considering a different location further from the registration plate the effect is smaller.

The Radar Channel

The development of automotive radar systems (e.g. for ACC) relies on an in-depth understanding of the radar channel between the car and its environment. Using WinProp’s sophisticated ray tracing models, simulations of the radio channel helps to improve the algorithms for angle and distance estimation. For this purpose, time-variant objects (e.g. moving cars) as well as stationary objects (guard railings, buildings, etc.) can be defined and considered in WinProp.

Propagation scenarios include collision avoidance with oncoming traffic, field strength with respect to Doppler shift and delay, analysis of received ACC signal and detection of approaching vehicles. The 3D antenna pattern of the integrated radar sensor can be considered in WinProp.

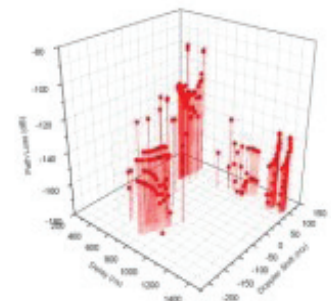
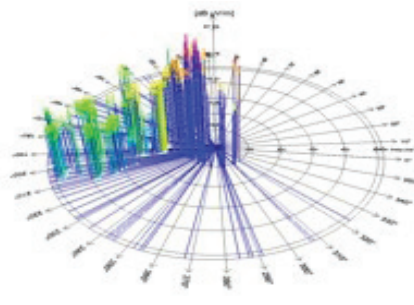
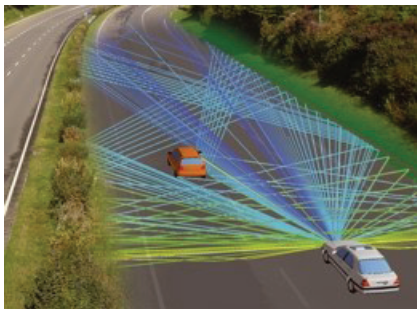


Figure 6: Computed propagation paths in an ACC scenario (left), spatial channel impulse response (CIR) and path loss, delays and Doppler shifts for several snapshots (right).

Conclusions

The challenges in designing automotive radar systems make it an intricate process. The combination of FEKO’s powerful 3D and asymptotic solvers can be applied at various stages of the design and integration process to achieve accurate and efficient solutions to these challenges. Furthermore, antenna performance results computed with FEKO can be used in WinProp for accurate characterization of the channel model for system level design.