From Radar Waves to Road Safety

Automotive Sensors: Background

From the moment radar had been invented, it proved its value in collision avoidance - first at sea, then in the air and later on the road.

During the 1950's, microwave labs were planning to introduce radars mounted on cars. There were two reasons that delayed this initiative. The first one was that, since the radar antenna depends on the wavelength and the gain needed to do long range detection, the size of radars at X band was too big to fit on regular cars. Only with the introduction of the new microwave technology in K band and then in W band, it was possible to built radars that had acceptable dimensions to be mounted on vehicles. The second factor that delayed the development of automotive radars was the price of the RF front end. The high frequency technology was simply too expensive for a civil application intended for mass production. The first generation of radars was able to detect several cars on the road in a limited antenna beam, with the collision alert related to the car-to-car distance. Then more intelligent sensors were developed. With these it was possible to include braking assistance, safe distance keeping and collision avoidance for long and medium range detections.

At the same time, conventional Cruise Control (CC) systems, maintaining a pre-set vehicle speed and improving the comfort for the driver were under development. These systems struggle to maintain fixed speed and comfort options when traffic conditions are complex and chaotic. An entirely new idea was then developed - an autonomous intelligent cruise control (AICC) system, using automotive radar combined with the cruise control system. By detecting the cars in front and acting on the braking system with a cruise control function, the new combined structure could now automatically adapt the car's speed to the traffic flow. This function completed the ACC functions and led to the Stop & Go function for the third generation of sensors. With these, the automotive system migrated to multiple sensors coupling: radars, cameras, lidar, etc.

Advanced Driver Assistance Systems (ADAS)

Since 2010, safety functions became increasingly important and have been included in the latest automotive standards (ex: EURONCAP) for a 5 stars' level. Automotive OEMs are now moving towards the inclusion of several safety systems, which are covered by several sensors, to reach the 5 stars' level. Many new functions have been considered to assist the driver avoiding accidents that might be caused by different road scenarios. The new ADAS systems are mainly: lane change assistants (LCA), blind spot detection (BSD), pedestrian recognition, collision avoidance and pre-crash functions, cross traffic alerts and parking assistance (fig.1)

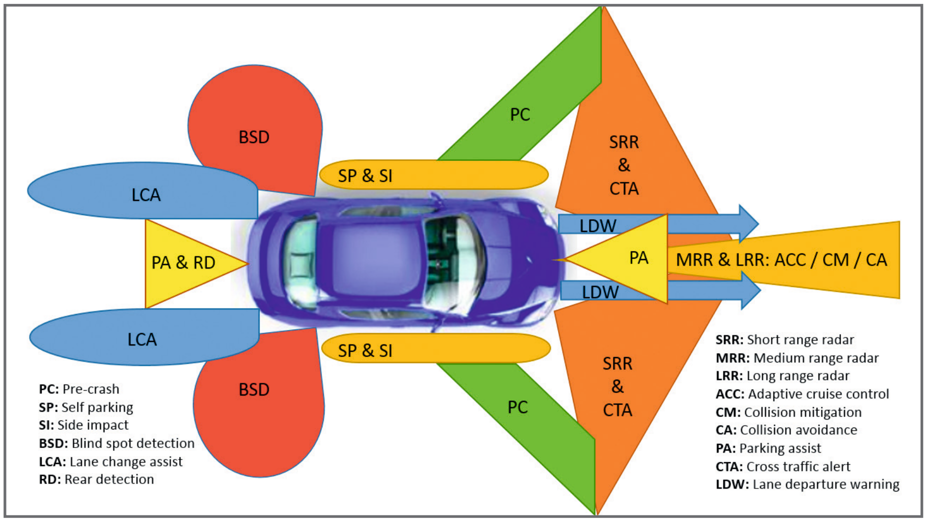

Figure 1: Safety and assistance sensors functions

In automotive sensors two frequency bands are mainly used – one frequency band around 24GHz and another around 79GHz. Long and medium range radars require less distance accuracy than other sensor systems, in which distance is a key parameter to have more precision for short distance detection and to separate between obstacles (bicycles, pedestrians,...). Since the distance accuracy is in inverse proportion to the frequency band, meaning, the wider this band is, the smaller the distance between obstacles. Long and medium range radars are mainly based on narrow frequency band sensors; while short range radars, used for high accuracy detection, especially in urban scenarios, are based on a wide frequency band architecture. Because the 22-29GHz band had been dedicated to another, non automotive related, application, radar manufacturers migrated to the 76-81GHz band and only a few medium range radars are still working on narrow frequency bands of around 24GHz.

Meeting the Challenges

Today radar design and integration (fig. 2) has become increasingly more challenging with regards to very high frequency bands, where the wavelength is around 4mm. As a result electromagnetic simulation is now more often applied in this area. In this use case EM simulation helps to avoid time consuming and expensive prototyping cycles for the radar manufacturer and a complex radar integration behind a car's bumper for automotive OEMs. Radar integration becomes a very important topic in this development process, since the antenna radome and the car bumper are also playing an important role. If those parts are not considered right from the beginning of the integration process, gain loss, high side lobes levels and angular errors will significantly degrade the radar's performance. Those degradations have an impact on the radar range, on the main radar axis (boresight error), and on the radar detection quality (resolution, ambiguity, discrimination ...). The radome / bumper material characteristics, shape and layers thickness are the key parameters and must therefore be considered during the radar integration process.

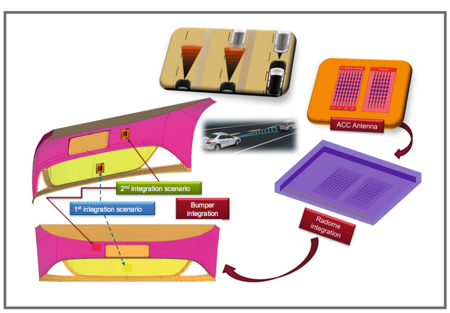

Figure 2: From antenna design to radar integration and function validation

The complex and large structures used in electromagnetic analysis (radome, car parts), have long simulation run times and require a high memory. To study several cases and to optimize the final integration scenario, "light" and fast simulations are needed.

From Antenna Design to Radar Integration – HyperWorks in the Development Process

Antenna design and packaging are the main steps for sensor engineers to reach several functions of a sensor: blind spot detection, lane change assistance, pedestrian detection, etc. The aim is to end up with a compact and low cost sensor that at the same time also fulfils all challenging safety requirements. FEKO, Altair's solution for EM simulation within the company's HyperWorks CAE Suite, contains several methods to design and optimize antennas with adapted fast tools, using modern simulation platforms.

Another important development step is the integration of the antenna sensor behind a front housing called radome, which has to respect compactness and radar performance. Fast tools and methods are available and frequently used to optimize the radome thickness and the final housing shape. Additional constraints (vibrations, shocks,...) can be addressed with other tools within Altair's HyperWorks suite. With these tools it is possible to consider the mechanical aspects of the entire system to reach a good trade-off between compactness, weight and strength.

With efficient sensors available off the shelf, automotive OEMs will face yet another challenge – the integration of the on-board radars. As mentioned above, the sensor's environment affects the antenna patterns and the radar's performance. In addition, the car's look and style becomes increasingly important in the overall design of a new vehicle. Since bumpers and other car chassis parts are considered under the style aspects, attractive and complex shapes are expected. On the other hand, the car's parts stylishness which may include sharp angles and thick materials, often conflicts with the sensors' performance. Furthermore, new painting classes are employed with a very wide spectrum of colours with different electromagnetic characteristics. Thus a good compromise between bumper shape, main materials, layer thickness and painting classes, becomes increasingly more difficult to find. Materials characterization tests linked to FEKO tools, can be used to classify and score bumper constituents and painting classes. Then very fast techniques based on MoM Green's Functions and Periodic Boundaries can be applied to optimize the bumper's layers, including paintings, and to perform sensitivity stack studies for the considered materials. New and innovative matching layer methods are under development to reach bumper transparency over the wide frequency and the angle of incidence ranges.

The last challenging step in this development process is to simulate the sensor behind the bumper and car chassis parts to validate the final and complex integration scenario. For this CAD data analysis and cleaning are required to receive a valid 3D model. The meshing process is then launched to receive an appropriately meshed model for the electromagnetic simulation. HyperWorks offers a large variety of products that help the user to deal with very complex shapes and meshing steps. In addition, the CADFEKO interface contains useful and powerful options from CAD cleaning and fixing, to the meshing procedure itself.

Finally a last simulation procedure is required to validate the system, using several numerical methods adapted to several integration scenarios. To handle this simulation FEKO contains single and hybridized methods that are very flexible and offer consistent results that match with the measured patterns. The aim is to match the appropriate method to the complexity and the electrical size of the structure. To investigate the integration patterns, one can use mathematical tools/scripts integrated in the POSTFEKO interface as well as HyperWorks products to perform radar key parameters analysis such as: ambiguity, angular error, resolution, discrimination, etc.

To complete the automotive sensors studies, also Radiation Hazard aspects can be considered with different numerical techniques. For these two scenarios it is possible to calculate the field level around the sensor or the specific absorption rate of the human body. The aim is to respect the exposure levels given by the different dedicated standards.

For more information, please visit: altairhyperworks.com

Altair Engineering, Inc., World Headquarters: 1820 E. Big Beaver Rd., Troy, MI 48083-2031 USA
Phone: +1.248.614.2400 • Fax: +1.248.614.2411 • www.altair.com • info@altair.com