ADAS Simulation Under Severe Vibrations

Introduction

Automotive radars are becoming standard equipment on vehicles. Their purpose is to adjust the distance between vehicles and/or alert the driver when dangerous situations arise.

Since 2010, the safety functions became more and more important and included in the last automotive standards (ex: EURONCAP) for 5 stars' level. Automotive OEM's are now moving to include several safety systems covered by several sensors to reach the 5 stars' level safety standards.

Several antenna architectures are used to cover the different safety functions in complex bumper/car chassis environment where the side effects become more and more significant on the radar performances. Hence, automotive radar integration process becomes a very important topic. Weak radar integration will generate gain loss, high side lobes levels and angular errors. Those degradations will impact the radar range, the main radar axis (BSE) and the radar detection quality (resolution, ambiguity, discrimination ...).

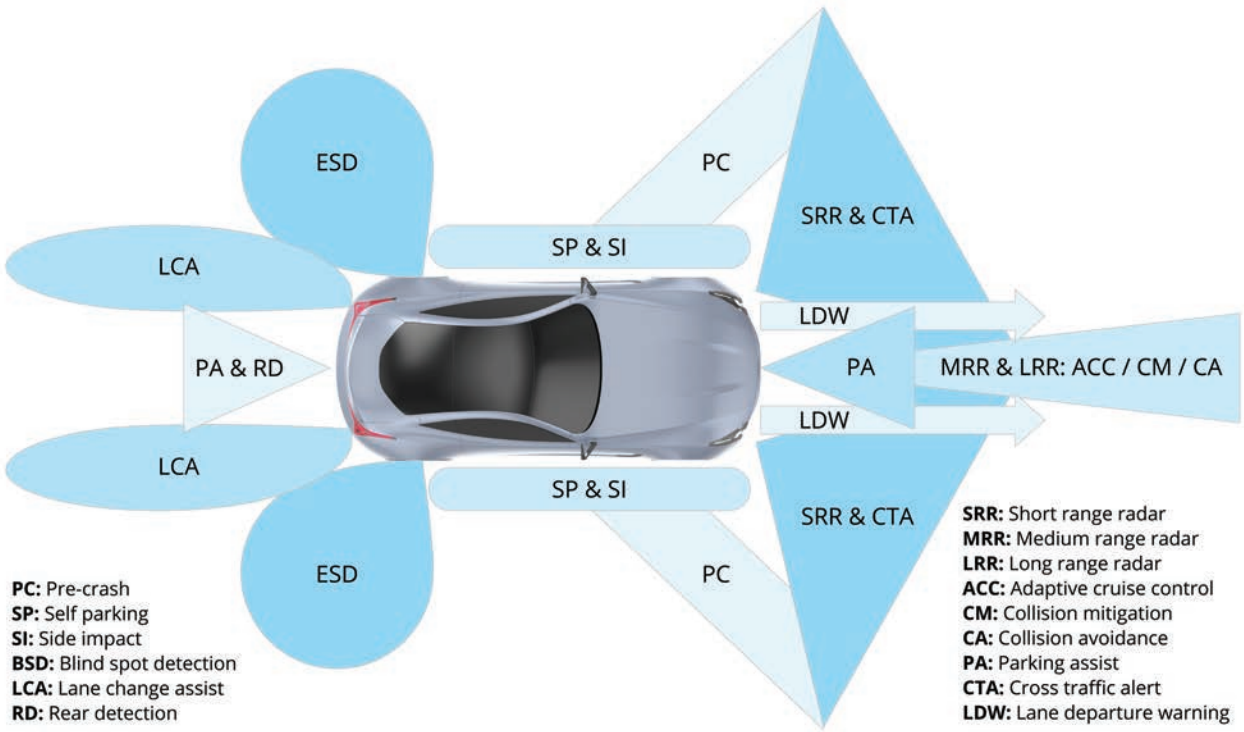

Figure 1: Sensor coverage

In addition, vibrations during situations such as hard maneuvers or bumps on roads may significantly modify the position of the radar with respect to the rest of the structure, mainly the bumper, causing some responses changes which must be taken into account. The purpose of this paper is to show how vibration effects can be calculated with Altair's HyperWorks solver suite.

The car model is a multibody model where the bumper is modelled as a flexible body, using OptiStruct®. The global movement of the vehicle is calculated using MotionSolve®. Critical times are identified based on the maximum and minimum distance between the radar and the bumper and the deformed geometry at those times is exported to FEKO. A calculation of the phase error and the radar pattern is then performed and compared to the "nominal situation".

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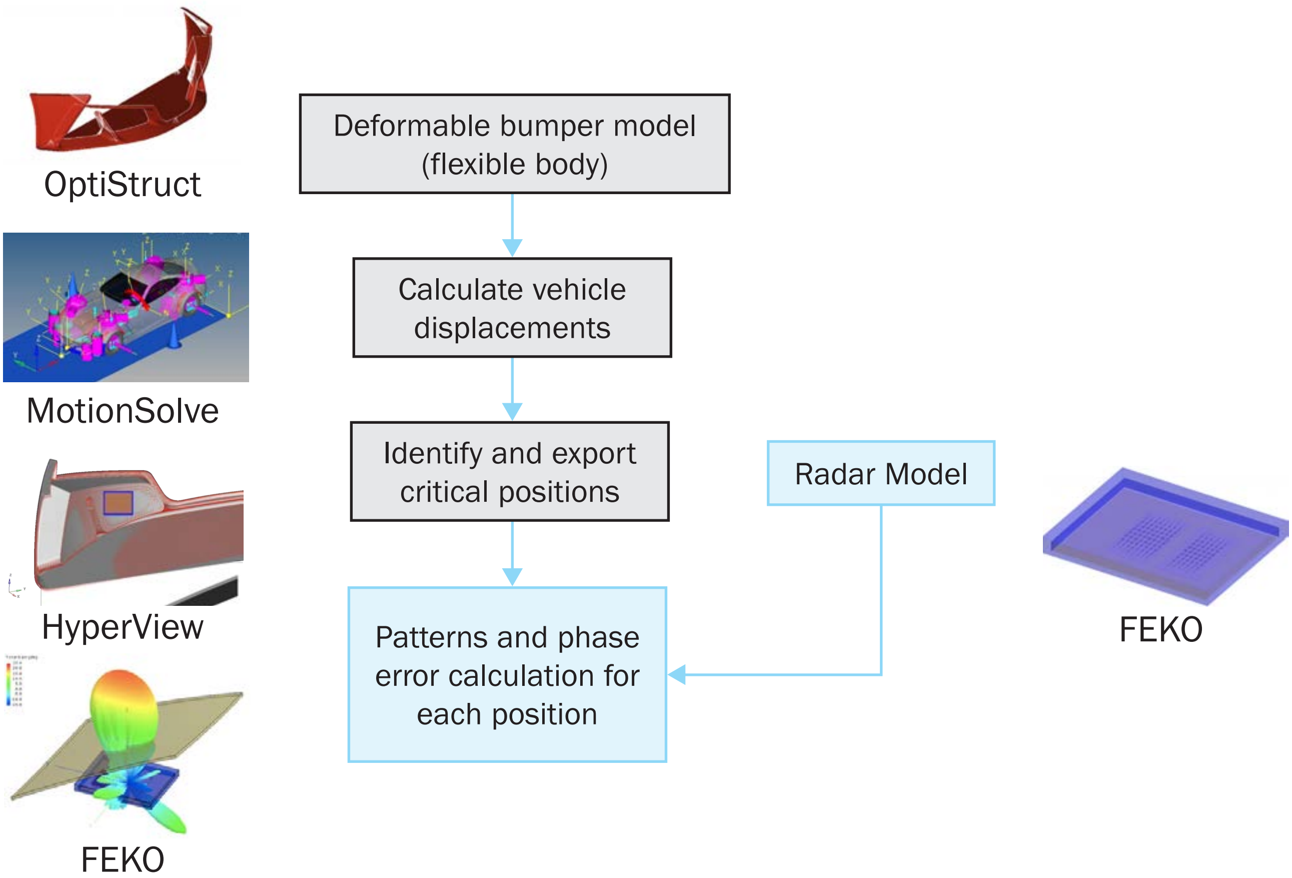

Figure 2: Process description

Radar Model

The antenna design is related to the radar architecture and the functions covered by this sensor. The most common radar architectures are based on amplitude or phase monostatic / multistatic architectures. The low-cost architectures based on planar multistatic (digital beam forming) antenna are more and more privileged to cover one or several functions in the same sensor. Thus, one or several Tx / Rx channels (Figure 3) linked to several antenna arrays are mainly used for the automotive radars with different antenna beams depending from the radar range and application. Microstrip or slotted arrays are the most common technologies for planar antenna design.

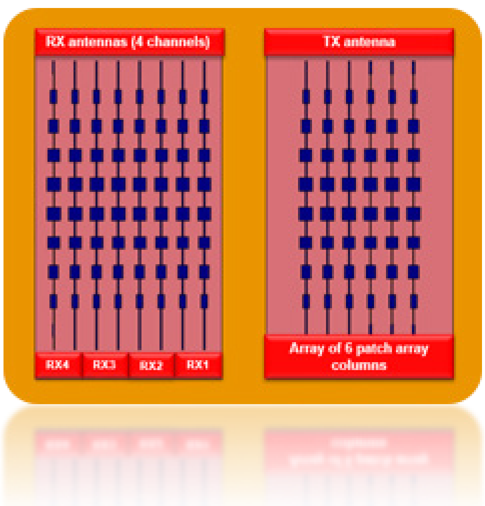

Figure 3: Medium / Short range radar made of 2 Tx and 8 Rx channels (Patch technology)

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In this paper, we consider a medium range ACC radar used for Front Detection or Lane Change Assist Function in city or highway driving. Its specifications are given in figure 4. Calculations are performed in a Front Detection context. The architecture of the radar is as follows :

- The antenna designed is based on Digital Beamforming (DBF) radar architecture for Medium range detection (1TX + 4RX's)
- The TX antenna is made of 6 patch columns. Each column is made of a 10 patchs array
- The RX antenna contains 4 RX channels. Each channel is made of 2 patch columns
- Same columns are used for TX and RX antennas

Parameters	Medium Range ACC Radar
Frequency Band Operation	76-77 GHz
Distance Detection Range	0.5 à 120m
Radar Azimuth Field Of View FOV (Tx+Rx)	50°
Radar Elevation Field Of View FOV (Tx+Rx)	10°
Sensor architecture	Digital Beamforming (1Tx channel and 4 Rx channels)
Azimuth pointing direction	0°
Targets	(Trucks, Cars, Motorcycles; Bicycles and Pedestrians)
Detection objects	Trucks@ 120m; Cars @100m; Motorcycles @50m and other obstacles <20m
Side lobes rejection in Elevation plan (one way channel)	SL≥20dB
Side lobes rejection in azimuth plan (Tx)	SL≥30dB
Side lobes rejection in azimuth plan (Rx's)	-----------
Azimuth Tx Beam width (@-3dB)	20°<θ°<22°
Azimuth Rx Beam width (@-3dB)	55°<θ°<65°
Elevation Beam width for Tx and Rx's (@-3dB)	<10°

Figure 4: radar properties

Radar Model Without Bumper

Full wave methods are used for radar simulations and some surroundings parts. When the electrical structure size become heavy, the radar is replaced by an equivalent model (fields, dipole array, spherical modes…) to reduce computational costs. In this project, an equivalent electric or magnetic dipole array method was used: each patch/slot is replaced by an equivalent electric or magnetic dipole excited by an optimized amplitude and phase to match the original antenna pattern.

The radome (front housing, Figure 5) is also taken into account as a dielectric membrane. Important parameters are dielectric material properties, thickness.

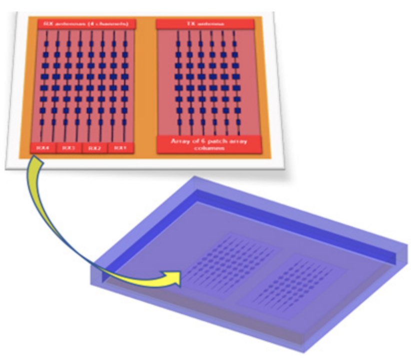

Figure 5: radar housing

The following results are analyzed:

- Radar Field of view (gain > -20 dB)
- Amplitude patterns
- Phase patterns and phase differences between channels

Some results are presented in the figures 6 to 8:

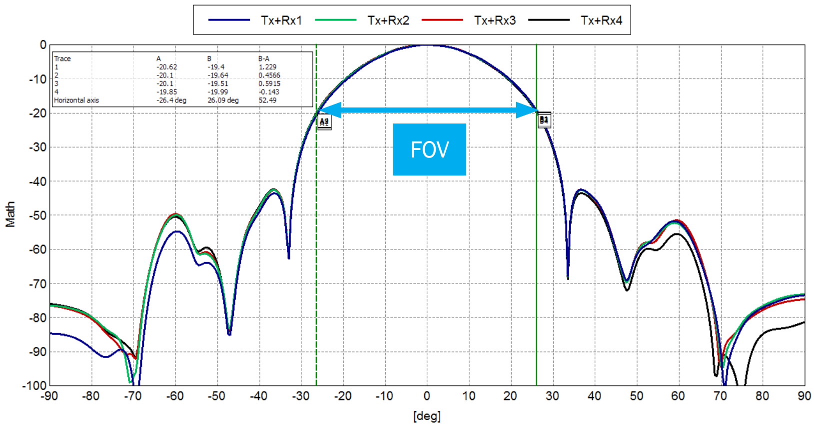

Figure 6: Amplitude patterns in Azimuth + Radar Field Of View

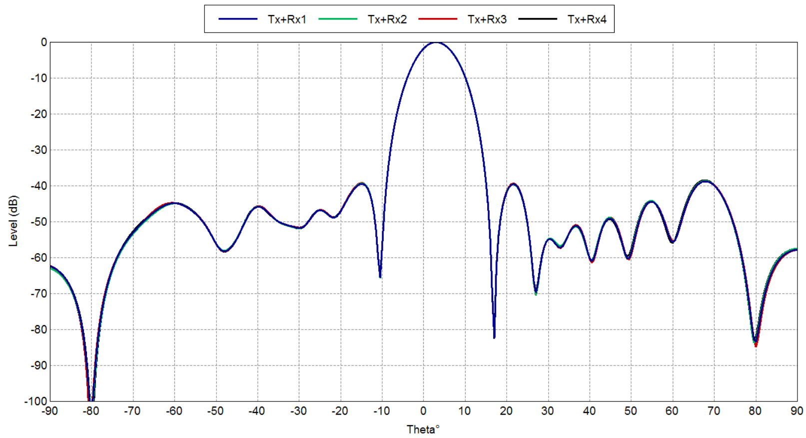

Figure 7: Amplitude patterns in Elevation

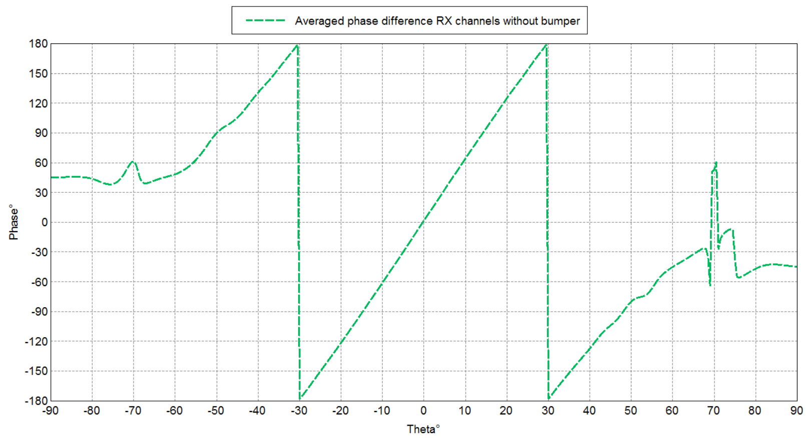

Figure 8: Phase difference in Azimuth

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Effect on the bumper

The bumper is shadowing the radar antennae, with consequences on the radar performances depending on thicknesses, dielectric properties of the material, shape and angle of incidence between the radar and the bumper.

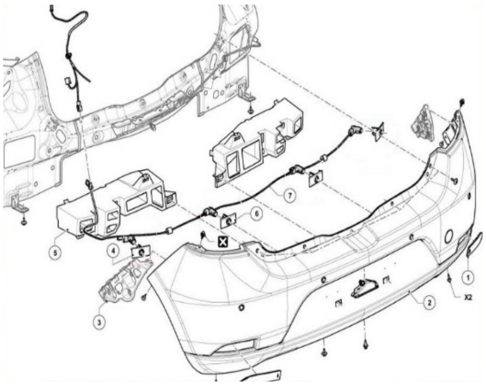

Figure 9: BSD sensor integration (front)

The bumper induces several types of errors, mainly:

- BoreSight Error (BSE) : If the peak of the main lobe level is deviated from the reference data, the obstacles are detected out of the main radar axis, thus creating an angle difference between the target's actual position and the radar indicated position

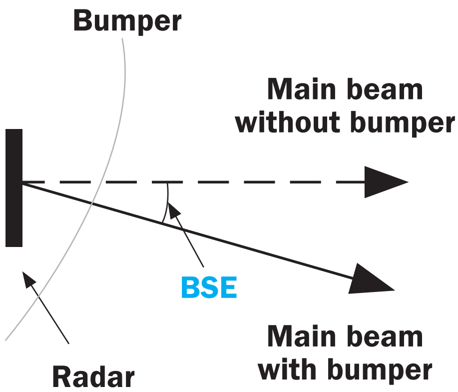

Figure 10: BSE representation

- The phase error is the result of bumper shape and wave front distortion and is responsible for erroneous object displacements.

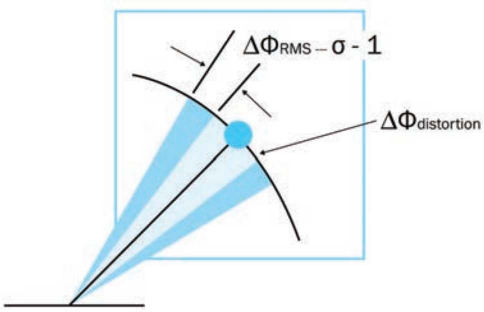

Figure 11: Phase error representation

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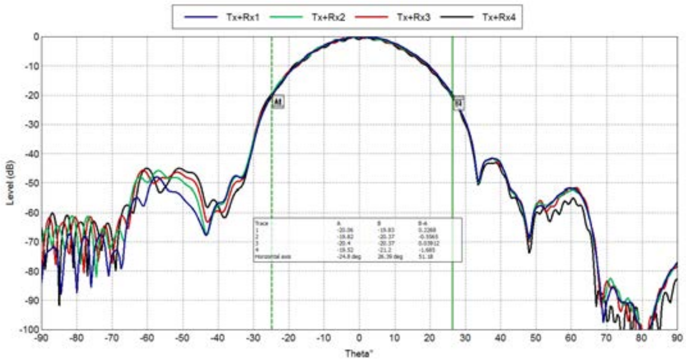
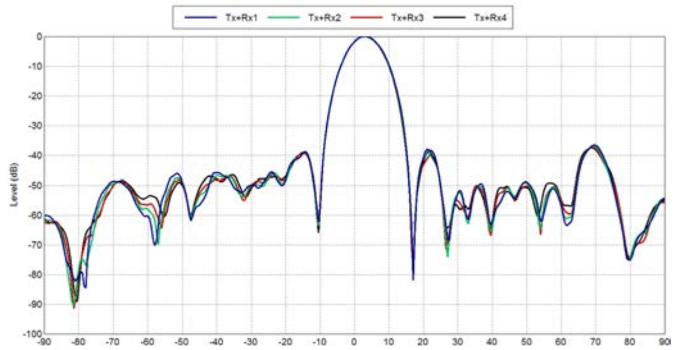
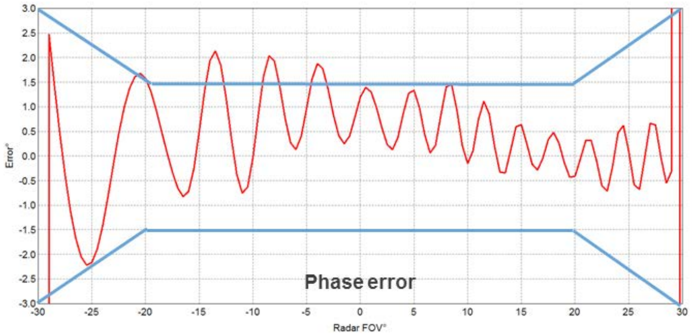
Like the radome, the bumper is modelled using a dielectric membrane. The results are as follows:



Amplitude pattern in azimuth for each TX+RX couple



Amplitude pattern in elevation for each TX+RX couple



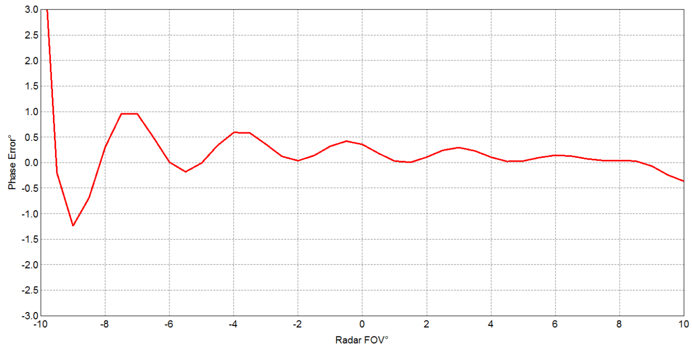


Figure 12: Effect of the bumper on Radar pattern at nominal position

The phase error is representative of the performance decrease created by the bumper. In this case, the deviation stays between the acceptable corridors most of the time, so the integration of the radar is acceptable

Structural Model

In this project the bumper is deformable. The bumper will be modeled as a flexible body in the multibody car model to take into account its deformations under severe road movements (hard bumps, hard lane changes …). A generic bumper has been considered. 12 modes, between 10 and 120 Hz were retained. The calculation was performed using Optistruct, based on a FE model.

Figure 13: FE model of the bumper

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Multibody dynamic model

To calculate the constrains applied on the bumper during the trajectory of the car while retaining acceptable computation times a multibody dynamic model of the car is used.

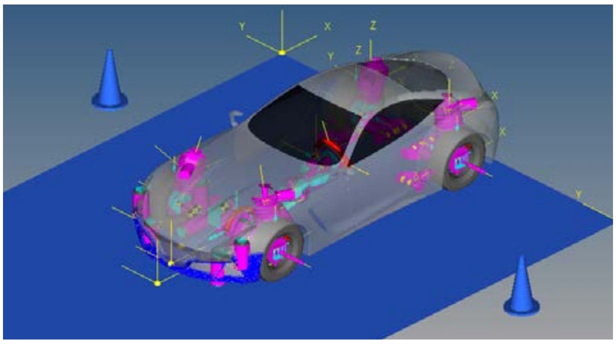

Figure 14: Multibody model of the car

The event retained is a double lane change event

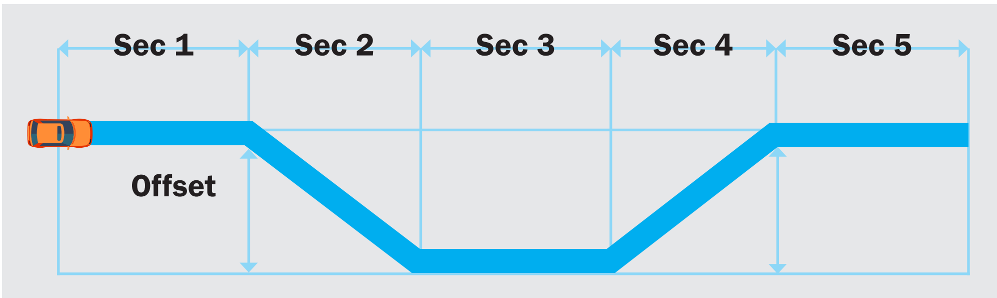

Figure 15: Double lane change event

Calculation is performed using MotionSolve. The results of interest are mainly the displacements and deformations of the bumper with respect to the car chassis, where the radar is fixed.

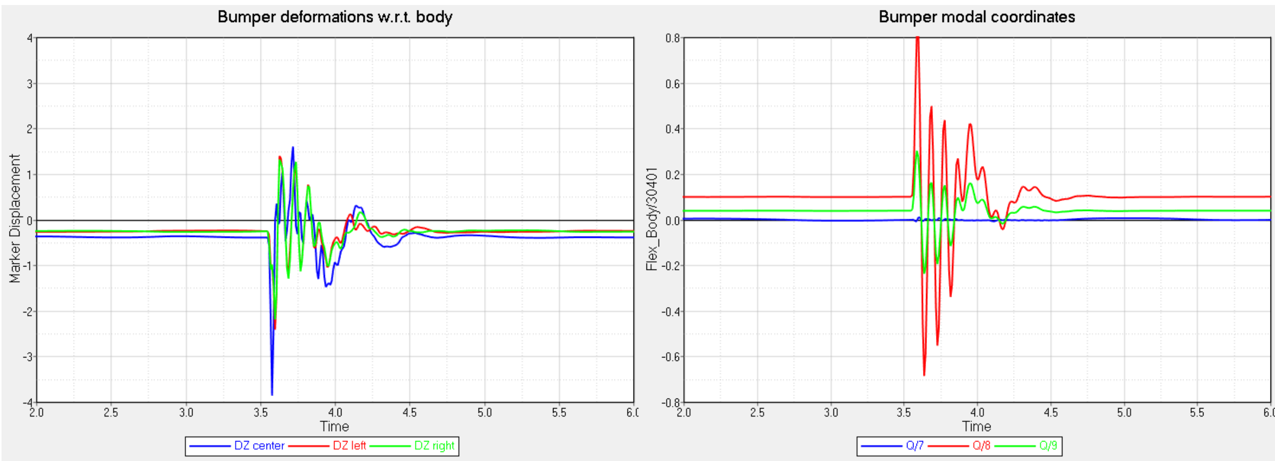

Figure 16: Bumper deformations and modal coordinates during the double lane change event

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Radar response at critical time

The radar response needs to be calculated only at the most critical times. They are determined by checking the relative translational and angular displacements and retaining only the maximum values.

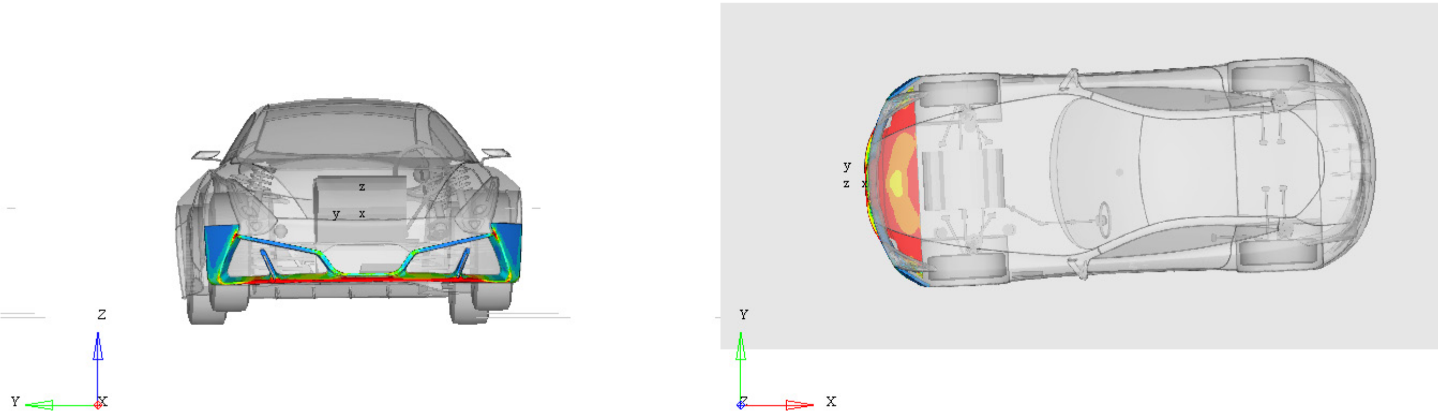

Figure 17: car position and bumper deformations at t=3.64 s

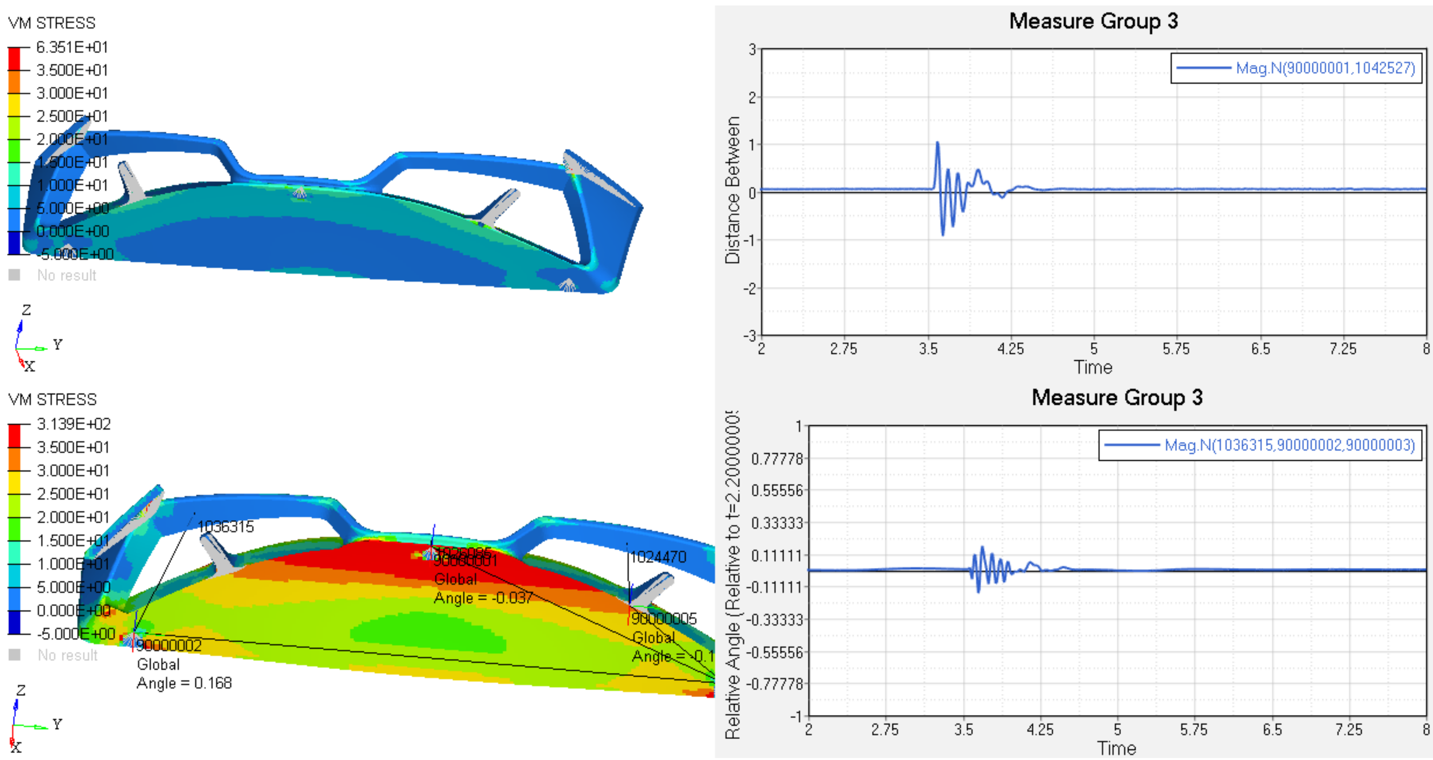

Figure 18: maximum relative displacements occurs at times 3.60 and 3.64 s

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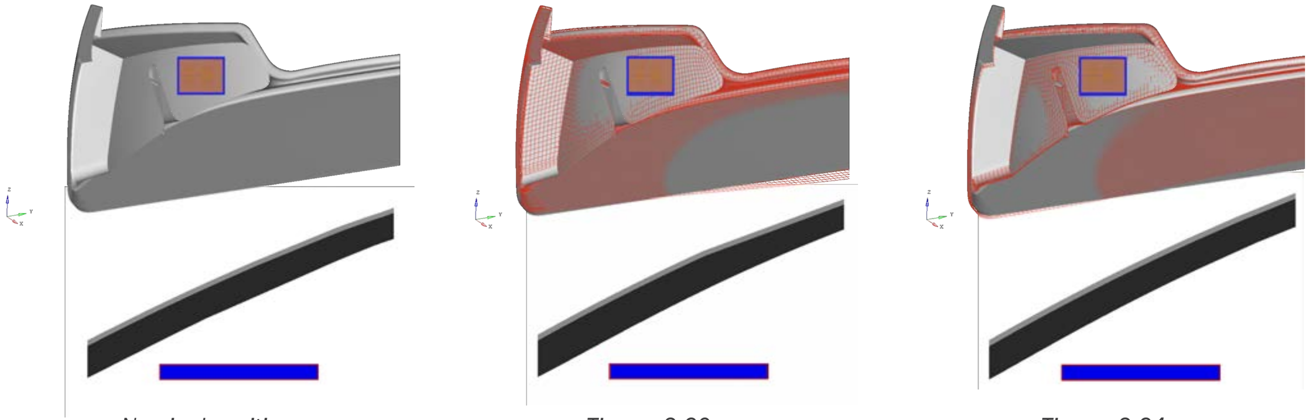

Nominal position *Time = 3.60 s* *Time = 3.64 s*

Figure 19: Deformation of the bumper at nominal position and critical times

The deformed geometry of the bumper is saved in HyperView® and imported to FEKO. New calculations are performed using the deformed geometries using a process similar to Section 2.3. The results for each Tx and Rx are then compared.

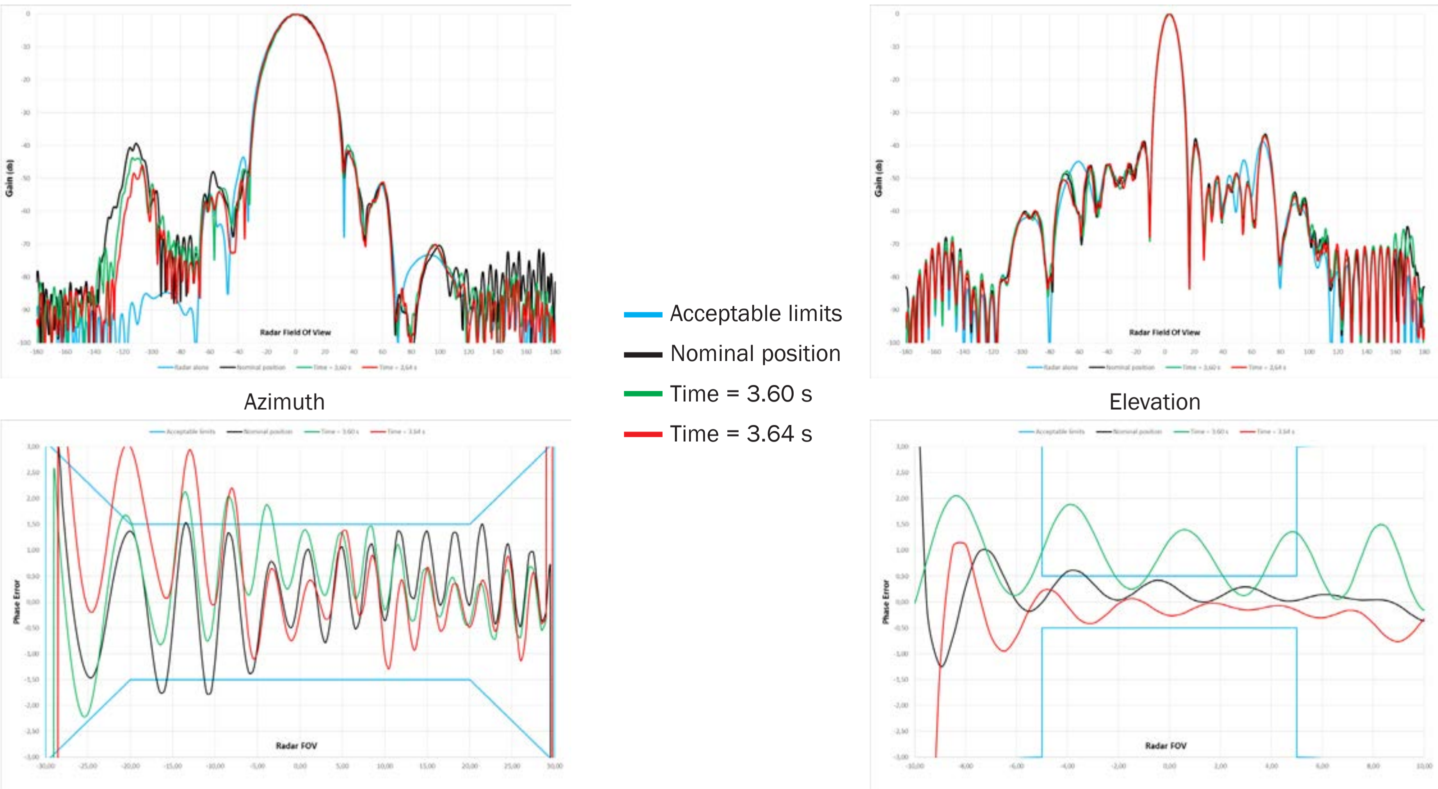

Figure 20: Amplitude patterns and phase error at critical times (3.60 and 3.64 s)

It can be seen that the phase error, either in azimuth or elevation are clearly out of the corridor. In this case, a new placement of the radar would be required.

The radar FOV changes and gain loss are shown figure 21:

Scenario	Gain loss	Radar FOV Az (@-20dB)
Radar alone	0 dB (normalized level)	52.6°
Bumper nominal position	-0.88 dB	51.04°
Bumper maximum middle position	-0.64 dB	51.2°
Bumper minimum middle position	-0.57 dB	51,36°
Bumper minimum left position	-1.11 dB	50,89°

Figure 21: Response modifications

Conclusion

The placement of the radar must take into account the vibrations of the car that may occur during harsh maneuvers. The consequences of those events can be calculated using HyperWorks, opening the possibility of optimizing its placement to minimize the degradation of the response.

Hyperworks suite is highly suited to this type of applications as global vehicle movement, vibrations and high frequency Electromagnetic simulations can be calculated in the Hyperworks environment (using MotionSolve, OptiStruct and FEKO respectively) creating a global process. Moreover, HyperStudy can help the design engineers by providing a multi-disciplinary optimized solution taking into account both electro-magnetic and structural requirements, even though they may conflict.

More generally, this methodology demonstrated here can be generalized in any situation where possible deformations and vibrations of the radar environment may affect its performances, such as drones and other vehicles.