Broadband Antenna FDTD Modeling for EMC Test

R. Jauregui, M. A. Heras and F. Silva

Grup de Compatibilitat Electromagnètica (GCEM),Departament d'Enginyeria Electrònica (DEE), Universitat Politècnica de Catalunya (UPC)

Barcelona, Spain

ricardojt@eel.upc.edu; ferran.silva@upc.edu; mdeheras@gmail.com

***Abstract*— This paper describes the modeling and analysis to modeling EMC immunity test by means of computer simulation with Finite Difference Time Domain (FDTD) method. To ensure the integrity of the results the log-periodic antenna was simulated separately and then included in a more complex model. Despite the many limitations of both the numerical models and the measurements, the models provide a satisfactory representation of the electrical field radiated by the antenna.**

I. Introduction

The traditional result of test-based methods for validating vehicle electromagnetic compatibility (EMC) performance are becoming inadequate and excessively time consuming. More mature engineering disciplines make greater use of simulation supported by better targeted testing [1]. Computational electromagnetism has had a great development thanks to the computational systems speed increase and their cost reduction [2]. With those improvements the mathematical algorithms are able to work properly with more practical EMC issues.

In the near future, numerical simulation is expected to play a major role in increasing the cost effectiveness of Electromagnetic Compatibility (EMC) testing within the vehicle design cycle [3,4]. Modeling EMC immunity test setups using simulation is a particularly challenging activity. In those tests the disturbance is usually applied in a near-field situation, not only because of the size of the object under test, but also because of the need to measure with broadband antennas placed in very close proximity (≈1m) to the equipment under test (EUT). The use of idealized plane waves and simple antennas to excite the model do not address correctly the problem. By this reason, to obtain successful simulation results, it is required not only to simulate the object under test but also to include in the simulation the antenna used.

In this paper, Finite Difference Time Domain (FDTD) is used to model and validate a log-periodic antenna. Finally, an application on an automobile is shown, studying the electrical field in different locations of the car frame.

II. Antenna Modeling

The need to include the antenna as part of the problem of simulation leads multiple complications with meshing and time of simulation, leading to errors and misinterpretation of reality. It is therefore essential to make a validation step with the antenna alone to ensure the integrity of the results. This ensures that the electromagnetic field will not be hindered by a nearby object.

A. *Experimental measurement*

A log-periodic antenna model LPA-30 (Figure 1) is used. The antenna is constructed of thirty-four element of aluminium and phenolic with a type N connector. The antenna is a linearly polarized broadband antenna designed to operate from 200 to 1000 MHz.

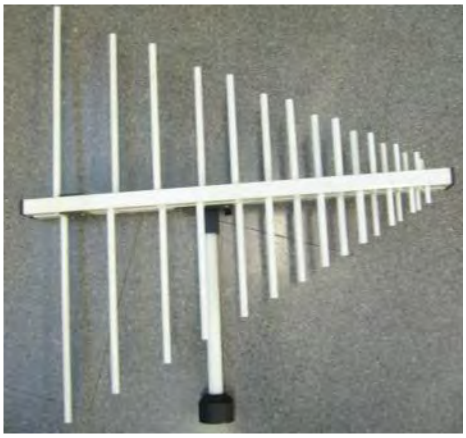


Fig. 1: Log-periodic antenna (LPA-30).

B. *Numerical model*

The numerical model is developed to be included in a Final Difference Time Domain (FDTD) simulation. Time-domain methods are particularly suitable for EMC applications because of the need for broadband results and for this reason the FDTD method is an ideal method for this study. However, this method has serious limitations with curved objects causing significant increases in meshing [5]. It is therefore important to minimize the number of meshes needed to simulate the antenna, since this model will be included in a complex model and the total meshes could be important.

The first step to reduce the mesh is modeling as cubes all cylindrical elements of the antenna (Fig 2); this reduces the number of meshes in more than 50%. To reduce further the number of mesh is used the sub-mesh technique that consists in perform a fine-meshes in the critical areas ($Cell_{min}$) and increasing the cells size gradually reached a maximum size ($Cell_{max}$).

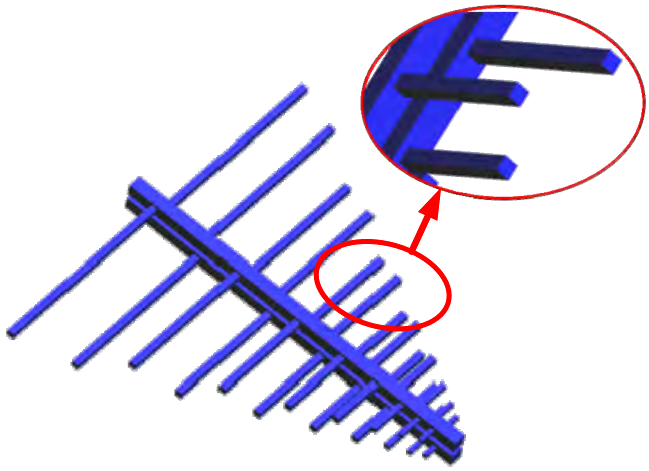


Fig.2: Numerical antenna model.

The program used is SEMCAD [6] and the numerical model developed is shown in fig. 2. The minimum size of the mesh used to model the element of the antenna is $Cell_{min}$=0.5 mm and the maximum is $Cell_{max}$=20 mm. With this meshing configuration a total of 11 MCells were generated. A Pentium CoreTM 2 Duo 2.66 GB processor with 8-Gbyte RAM has been used for the calculation.

III. VALIDATION RESULTS

To validate the antenna model, the real antenna was placed inside of a fully anechoic chamber (4.6x3.5x2.2 m), 1 m above the floor, thereby reducing potential interference and reflections. With this setup, a set of ten electric field measurements were made around the antenna with a field probe model FL7006 StarProbe. The locations of the measuring points are depicted in Fig. 3. The RF generator is HM8134 which, together with the amplifier B1080M-10, produces electric field levels around 20 V/m at 1m in front of the antenna in all the frequency range considered (200-1000 MHz).

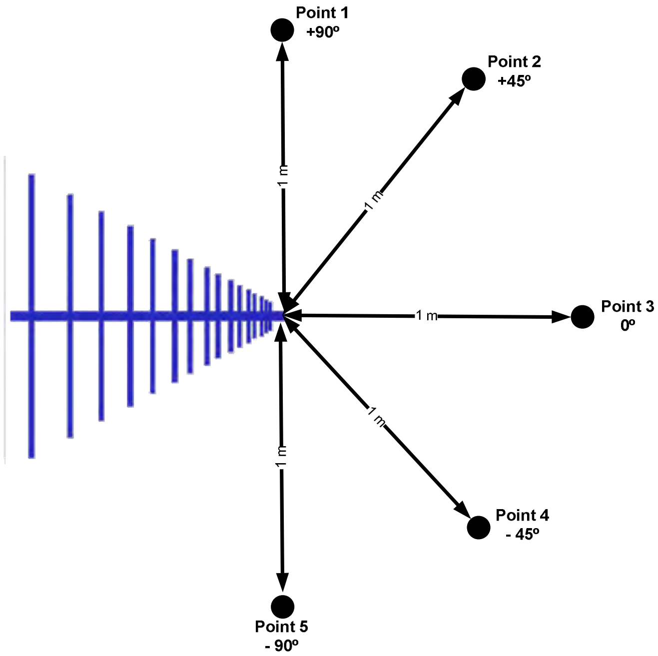
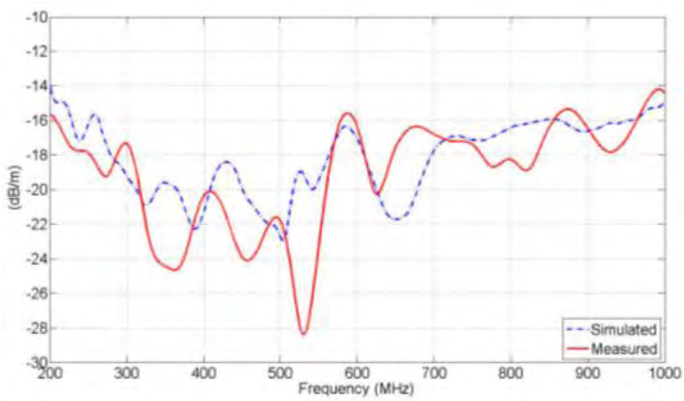
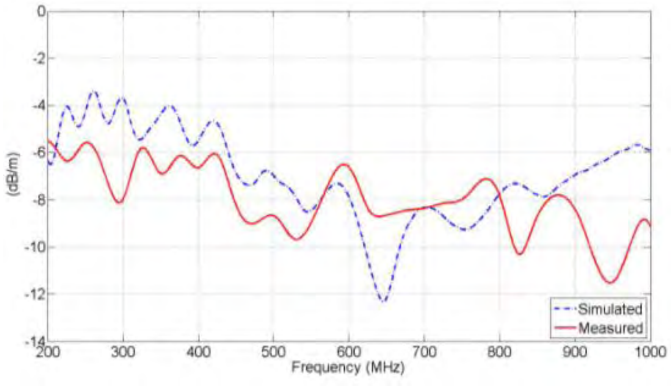


Fig.3: Experimental measuring localizations.

The simulation reproduces the same conditions stated in the measure. To facilitate the comparison between the measurement and simulation was divided the electric field between the source voltages. In this way we are able to compare the simulation and measurement levels of dB/m generated in each of the selected points over the entire frequency spectrum range. Fig. 4 shows an example of these results in a point located 1 m in front of the antenna.



(a)



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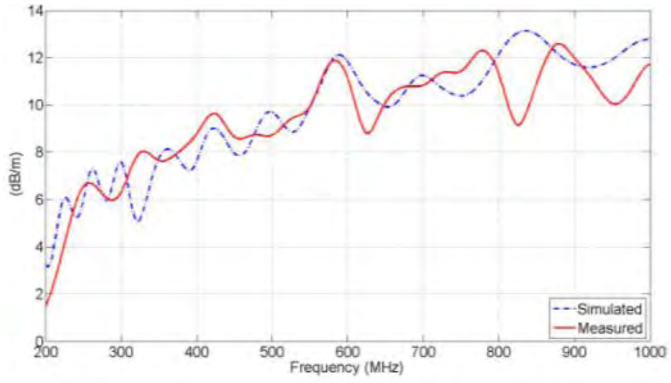

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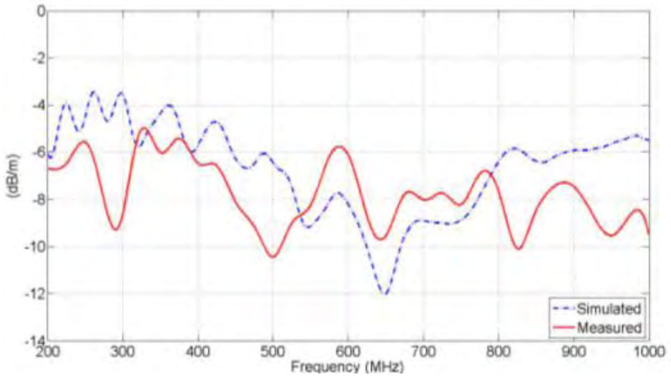

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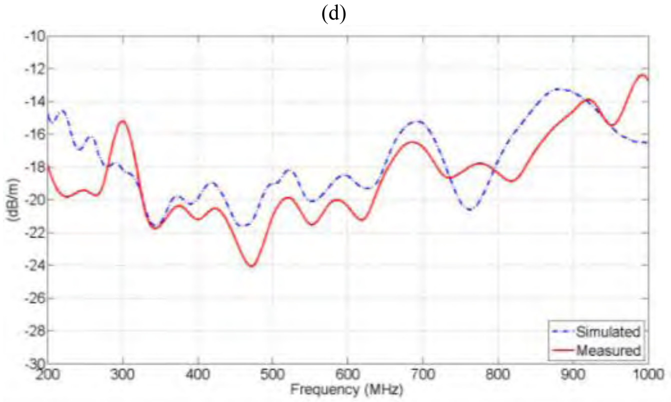
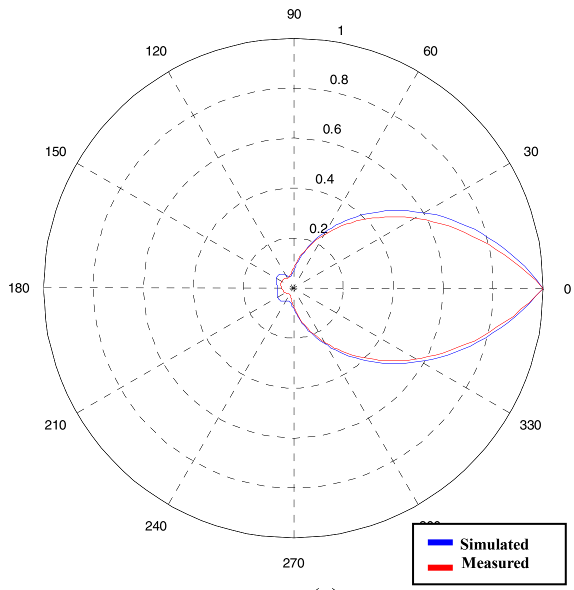


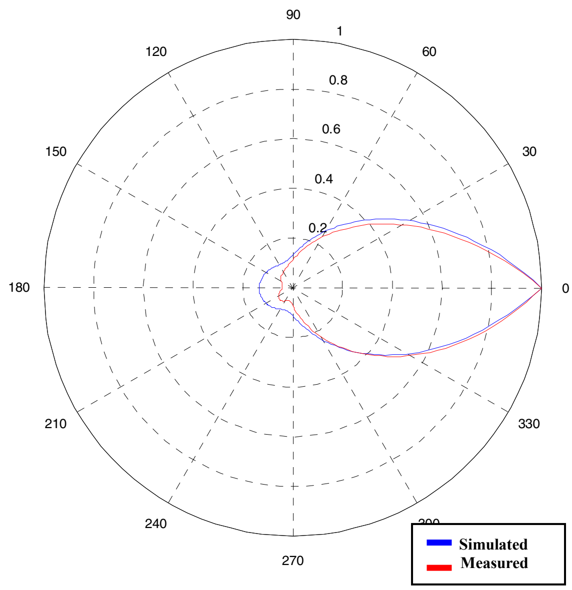
(e)

Fig.4: Measured (solid line) and simulated (dashed line) electrical field levels to the different places. (a) +90º, (b) +45º, (c) 0º, (e) -45º, (e) -90º.

Another important point to be studied is the properties of radiation in different directions of log-periodic antenna. To find the radiation diagram was measured and simulate the electric field around the antenna at a distance of 1 m, assuming the antenna in the origin, then was calculate the radiation diagram for different points (fig 5).



(a)



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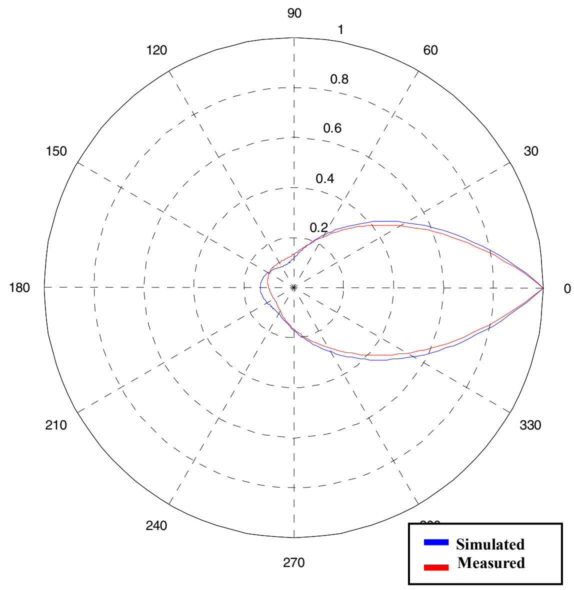


(c)

Fig 5: Radiation diagram measured and simulated in spherical coordinates for different frequencies: (a) 400, (b) 600, (c) 900 MHz.

Analysing with more detail the last figures (Fig. 4&5), it is observed that the values for the simulated and measured signals are similar. These values are regarded as satisfactory of the antenna model. But it is important take into account that the difference increases as it moves away from 0.

Once we have compared and quantify the behaviour of the antenna in free space it is possible to perform numerical simulations of radiated immunity EMC testing for any purpose, such as a car.

IV. APPLICATION

A complete vehicle was illuminated from side using the LPA-30 antenna (Fig. 6). The antenna was positioned at a distance of 0.6 m from the edge of the vehicle and at a height of 1 m. Fig 6 shows the antenna location and the selected points in the different vehicle areas.

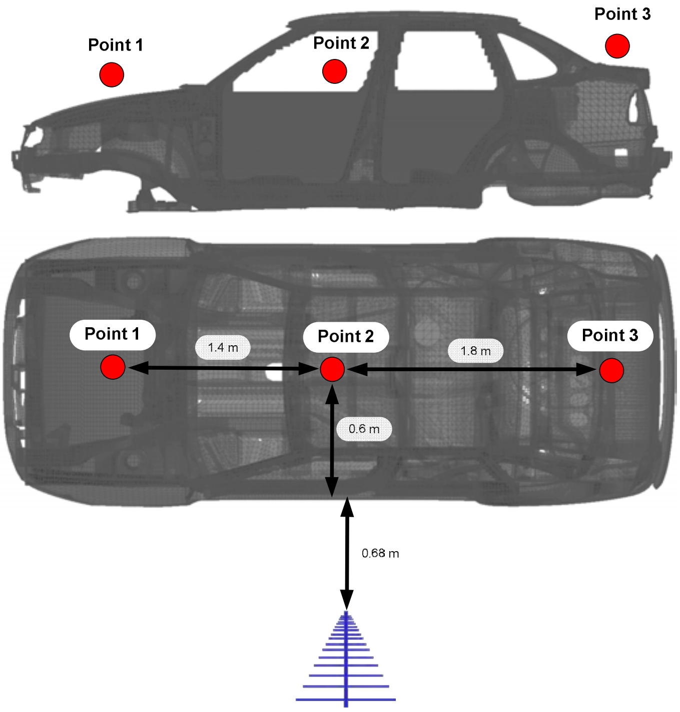


Fig.6: Location of log-periodic antenna and selected.

A. Experimental measurement

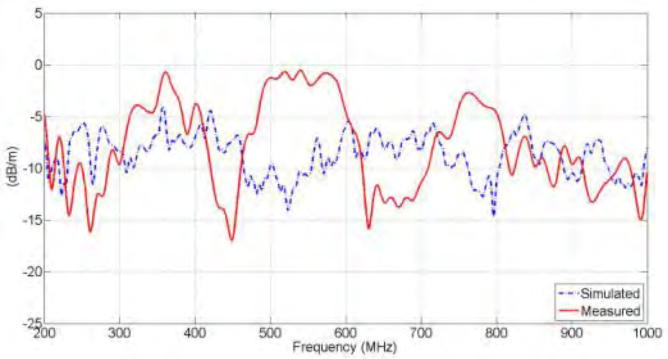
The system was excited by an RF generator model HM8134 which, together with the amplifier B1080M-10 produces electric field levels around 10 V/m. The field measurements were made with a field probe model FL7006 StarProbe.

B. Numerical model

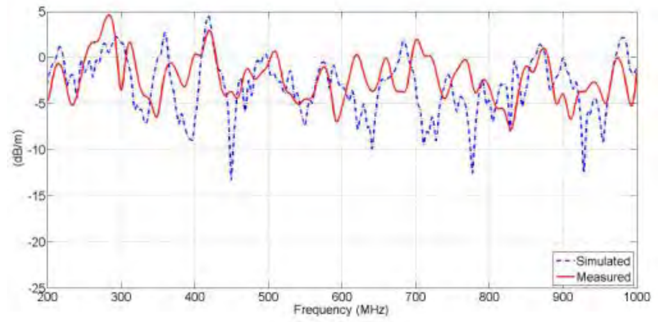
In complex structures is very important to take into account meshing methods, because the mesh sizes could exceed the available computational resources making the problem impossible to solve. Again the sub-meshing technique was used to minimize the simulation domain. The minimum size of the mesh used was $Cell_{min}$=0.5 mm and the maximum was $Cell_{max}$=50 mm, with this meshing configuration a total of 38 MCells were generated. A Pentium CoreTM 2 Duo 2.66 GB processor with 8-Gbyte RAM has been used for the calculation.

C. Validation Results

To verify the quality of the numerical simulations results obtained, we compare the electric field levels with measurements performed by isotropic field probes at these locations in a real car frame (Fig. 7). Again, the comparison between measurement and simulation was presented in dB/m and in the antenna broadband (200 to 1000 MHz).



(a)



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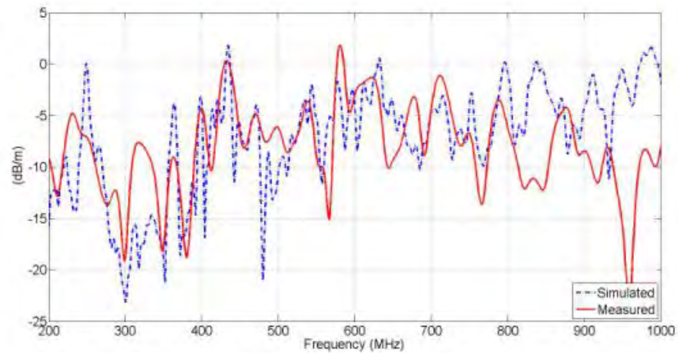

(c)

Fig.7: Measured (solid line) and simulated (dashed line) electrical field levels to the different places in the car. (a) point 1, (b) point 2, (c) point 3.

Despite the many approximations and limitations of the simulation and measurement, we could see (Fig. 7) that the simulated and measured signals have a very similar trend.

The results vary in detail depending on the exact location of the point under consideration. In general, the results show that it is possible to successfully predict the electrical field generated by the antenna on a complex structure. The differences of the average error are generally no more than ± 6 dB at all points.

Analyzing with more detail figures 7b it is observed that the values of amplitude for the simulated and measured signals are very similar along of the frequency spectrum. On the other hand the worst results are obtained for the farthest point (points 1&3). This deterioration is not only due to the effect of structure on the point but also the difficulty of measuring electric field levels.

ACKNOWLEDGMENT

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V. CONCLUSIONS

In this paper, was carried out electromagnetic modeling and characterization of a log-periodic antenna using FDTD simulations. The simulations were validated comparing with real measurement in the antenna model, obtaining excellent results that demonstrated the usefulness of the numerical model. After validated the model this was introduced in a real situation, analysing and verifying that the electric field strength varies greatly depending on the measuring point and the structures surroundings.

The results achieved in this investigation show that it is possible to calculate with enough reliability the behaviour of the realistic EMC test. Whether it will ever be possible to substitute EMC measurements by numerical computations is outside the scope of this paper. However we have shown that it is possible to obtain sensible results with reasonable computation means and those results can be applied in the early phases of design to help addressing EMC problems in the automotive environment.

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