SEFERE

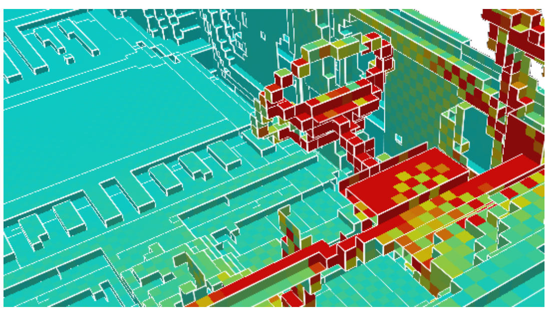
Simulation of **E**lectromagnetic **F**ield **E**xposure in **R**esonant **E**nvironments

ELECTROMAGNETIC SIMULATION

Simulation tools based on computational electromagnetics methods are now widely available and have been used extensively in the SEFERE project. There are various techniques which can be used to obtain the solution of Maxwell's equations for the electric and magnetic fields and the currents in any problem. The different methods all have their own strengths and weaknesses. They require the system to be modelled with some type of mesh, either structured (cuboidal and regular in size) or unstructured (usually tetrahedra of various sizes). In addition, the excitation of the system has to be defined, e.g. a radiating antenna or an incident plane wave, and what happens at the boundaries of the problem has to be specified.

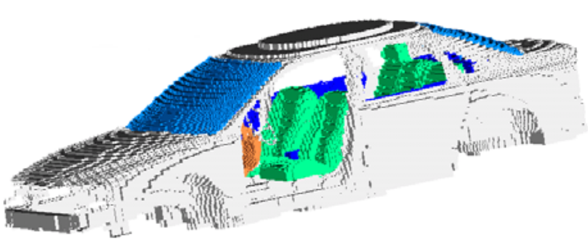
The SEFERE partners have used the following software in the project:-

- **TLM** – transmission line modelling – with the commercial code Microstripes (now available from CST). This method uses the analogy between the electromagnetic and electric circuit equations so is conditionally stable. The system must be modelled with a cuboidal mesh. It has the advantage that modules for handling small features in the structure (e.g. slots and seams) are incorporated in the code, so a high resolution mesh for these features is not needed.



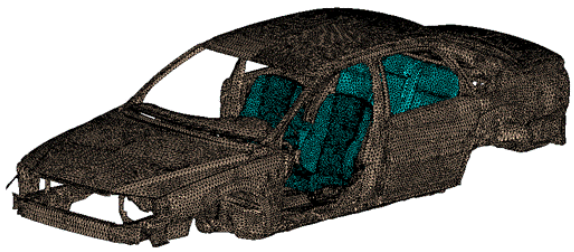
Results from TLM vehicle model, showing surface currents on steering wheel and cuboidal mesh used for modelling structure.

- The **finite integration method** (FIT) which is based on a discrete reformulation of Maxwell's equations in their integral form. The use of integrals provides stability and satisfies the conservation laws before starting the numerical analysis. The formulation normally uses an interleaved cuboidal grid and timestep for the E and H fields, like the finite difference time domain (FDTD) technique. The main commercial source of FIT software is the 'Microwave Studio' package from CST.



Vehicle meshed for CEM analysis with Finite Integration Technique

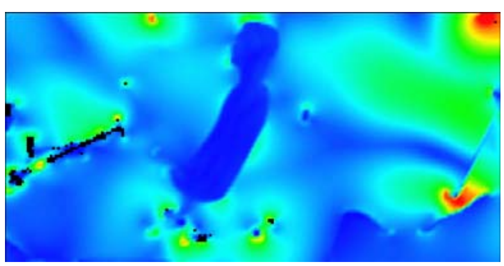
- The **boundary element method** (BEM), an integral equation approach which is excellent for solving antenna installation problems on conducting structures, and can also be used for non-conductors and for scattering problems. This method has the advantage that it is not necessary to model a region of 'white space' around the system, and that fast methods for accelerating the basic solver are available. The commercially available software package FEKO which employs the BEM method has been used in the SEFERE project.



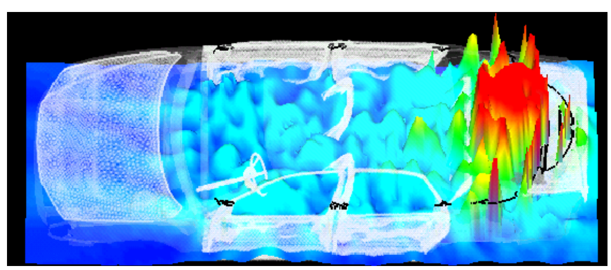
Same vehicle meshed with surface conforming triangular mesh for CEM analysis with Boundary Element Technique

- **Hybrid methods** offer scope for combining the advantages of two different modelling methods to create a better solver. This approach has been adopted in the BAE Systems solver HY3D which is a hybrid finite difference/finite element code. Finite elements, which provide geometrical flexibility, are used for modelling the system in detail while the surrounding region of white space is modelled with FDTD which employs a cuboidal meshing scheme.

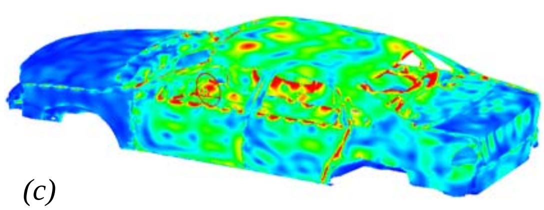
Outputs from the simulation software normally include electric and magnetic fields in all cells in the mesh and electric currents (or current density) in conducting parts of the structure. It is often possible to include circuit components in models (resistance, inductance, capacitance) and to calculate other output quantities, e.g. S parameters, antenna input impedance, power density in lossy materials.



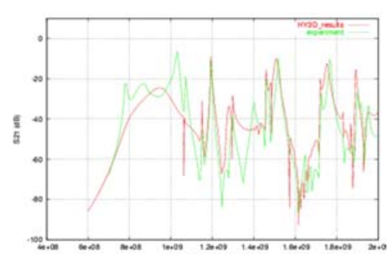
(a)



(b)



(c)



(d)

Some typical outputs from CEM codes: (a) electric field strength distribution in a car in vertical plane through the driver obtained by TLM, (b) electric field in horizontal plane using FIT, (c) surface current density on conducting car body shell with BEM, (d) S parameter predictions with hybrid FE/FD approach for air vehicle model.

The **electrical size of the problem** is very significant in electromagnetic modelling. To obtain accurate results from an electromagnetic simulation the structure needs to be meshed with a cell size of at least λ/10, where λ is the wavelength at the highest frequency modelled. For some methods, and especially in regions where fields vary rapidly, a higher mesh density is needed. Some problems include regions of geometrical complexity where meshing at a higher resolution than the λ/10 limit is needed in order to capture the structural detail. These factors mean that electromagnetic problems tend to require large numbers of cells in the mesh and hence be very demanding in terms of computational resources. Another factor impacting on problem size is the requirement, in the methods based on differential techniques, to model a region of white space around the structure. The boundary of this region needs to be at least one wavelength away from the structure at the lowest frequency of interest. This, coupled with the mesh density requirement, adds to the size of the problem. Techniques where meshing of the white space region is not required, while benefitting from a smaller number of cells, tend to be computationally intensive in terms of solution time which cancels out the size advantage.

The **choice of a suitable modelling method** for a given electromagnetic problem is a complex procedure in which many factors have to be assessed. The problem size affects both the run time and computer storage needed. Some codes operate in the time domain and some are frequency domain. Applications involving pulse propagation, such as electrostatic discharge and lightning strike, obviously need a time domain representation, while antenna radiation problems are probably better modelled in the frequency domain. If modelling of materials is required, then the relevant material parameters – conductivity, permittivity and permeability – are normally measured in the frequency domain, and conversion to a time domain representation is needed if a time domain electromagnetic code is used. This can introduce instabilities and inaccuracies if the code is effectively operating over a wider frequency range than was used for the material parameter measurements.

Computer Simulation Time: the different simulation techniques have varying degrees of complexity which also impacts on the run time. For example, the time domain finite difference technique derives directly from the Maxwell curl equations and is the simplest and fastest method. However, it is based on a cuboidal meshing scheme and lacks the geometrical flexibility to model structurally complex regions. If a finite element scheme is adopted, especially one which allows different types of elements, then a very realistic conformal model of a complex system can be built, but the mathematical overhead of the FE method will increase the run time. The code user needs to be aware of all these factors when choosing the correct method. In addition, there are practical considerations, such as the mechanics of handling the CAD in which the system is defined and post-processing of the output data. Often the CAD for the structure is not supplied in a form that is immediately usable for electromagnetic applications, particularly if CAD initially designed for other purposes is being reused. It is helpful to allocate time for CAD repair or modification before the electromagnetic model is run.

Electromagnetic Modelling Advice: experience gained by the SEFERE partners in electromagnetic modelling can be applied to other projects, either in the form of consultancy on suitable techniques and software or in terms of direct applications work for customers.