Modelisation of a reverberation chamber using current image method

Maxime Spirlet[1], Valéry Broun[2], Philippe Camus[2], Véronique Beauvois[3]

1 CECOTEPE, Quai Gloesener 6, 4020 Liège, Belgium,
2 HEPL, Engineering Department, Electronics Service, Quai Gloesener 6, 4020 Liège, Belgium,
3 ULG, Applied & Computational Electromagnetics, B28 Institut Montefiore, 4000 Liège, Belgium

> Introduction & Purposes

The numeric tool we are developing aims to allow analysis and display time propagation patterns inside a reverberation chamber. The current image theory is used to reproduce the reflections on the cavity walls [1].

> Methods

Current Images Method

Image theory uses a geometrical (or optical) model where conductors are considered as mirrors [Fig. 1].

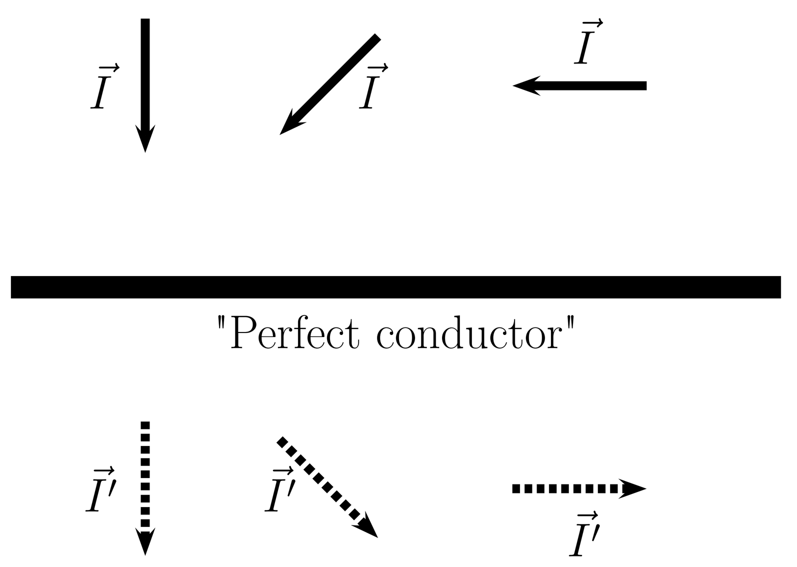


Figure 1: Illustration of the images from a current near a ground plane.

Cavity model using Current Images Method

If we consider a current inside a cavity, each wall will create its own image. Therefore, reflections are modeled by creating images of these images [Fig. 2]. We define the order of a cavity image as the number of reflections that is needed to create it.

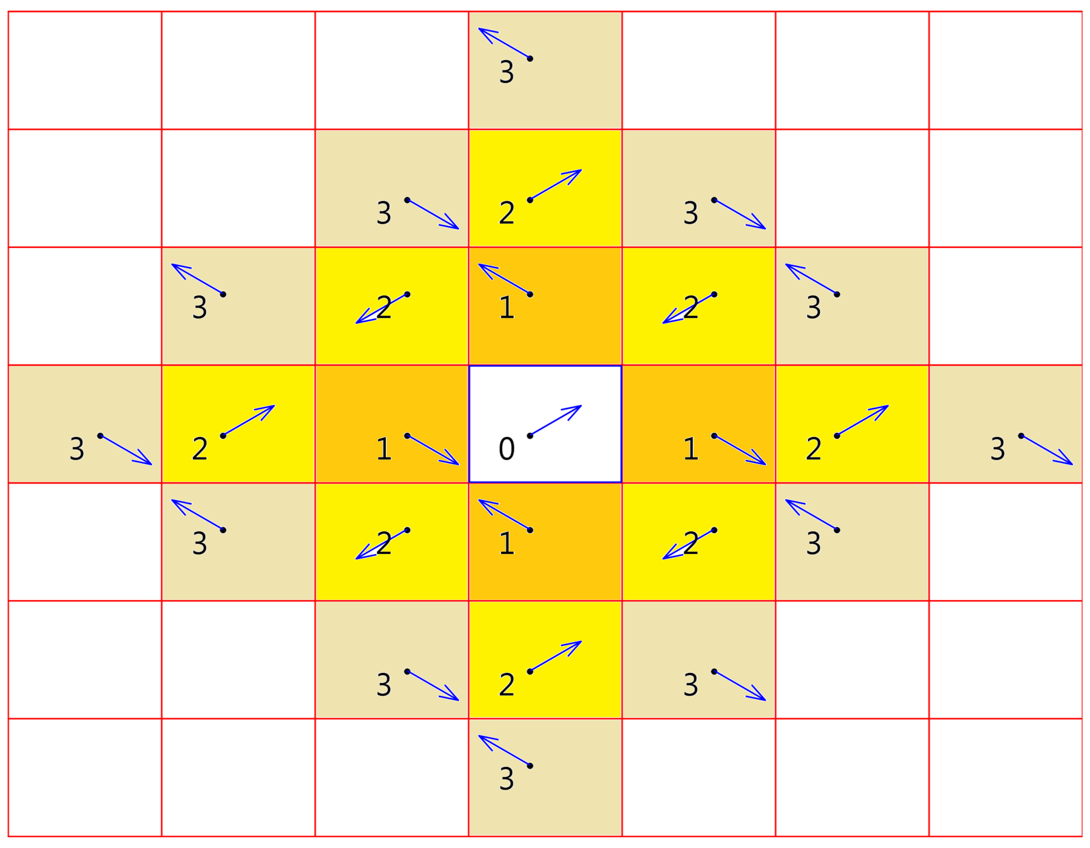


Figure 2: Locations and directions of the generated current images up to third order.

Cavity Losses

A reflection coefficient R has been defined to model cavity wall losses. Each reflection causes the reflected signal amplitude to be reduced. If n is the reflection order, the corresponding current is defined by

$$I_n = I_0 R^n \quad 0 < R < 1 \tag{1}$$

where I_0 is the source current. The value of R is determined experimentally in a reverberation chamber by calculating the time constant τ of the cavity and then applying :

$$R \approx e^{-\frac{L}{2c\tau}} \tag{2}$$

where c is the speed of the propagation and L represents the mean time between 2 reflections.

Cavity Impulse Response

The cavity impulse response h at a particular point is obtained by summing all the sources images contributions for that point. We assume that the current images are generated through synchronous impulses. To propagate the the source impulse inside the cavity, we use a dipole that is virtually set wideband (in 2D, the dipole is layed in the 2D plane). The equations of the dipole are used to evaluate each contribution of the image source (far-field). Each contribution needs to be expressed in the zero order cavity using the appropriate coordinate change. An example of the obtained cavity impulse response is given in [Fig. 3].

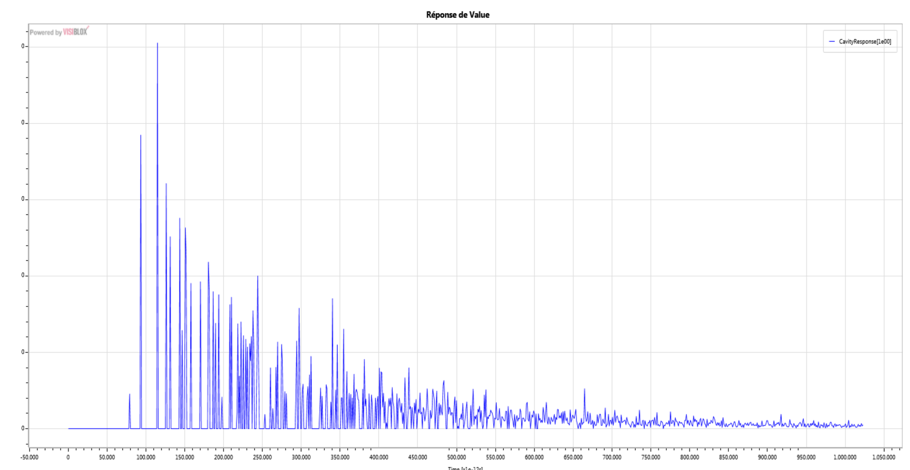


Figure 3: Simulation of a cavity impulse response at a particular point ($h(t)$).

Arbitrary source signal injected in the cavity

Any signal response y at a point of the cavity can then be obtained by simply convolving the source signal s with the cavity impulse response at the same point :

$$y(t) = s(t) \star h(t) \tag{3}$$
$$Y(f) = S(f)\,H(f) \tag{4}$$

An example of a signal response is given in [Fig. 4].

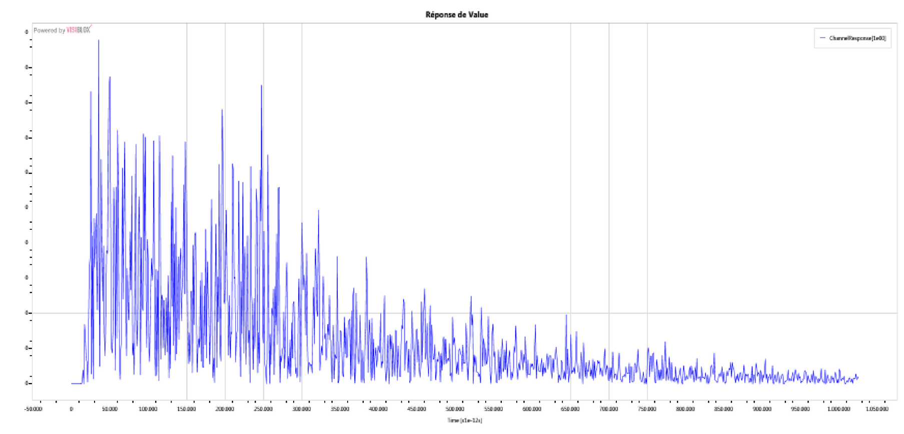


Figure 4: Simulation of a signal response at a particular point for a 2ns sinusoidal signal at 5GHz ($y(t)$).

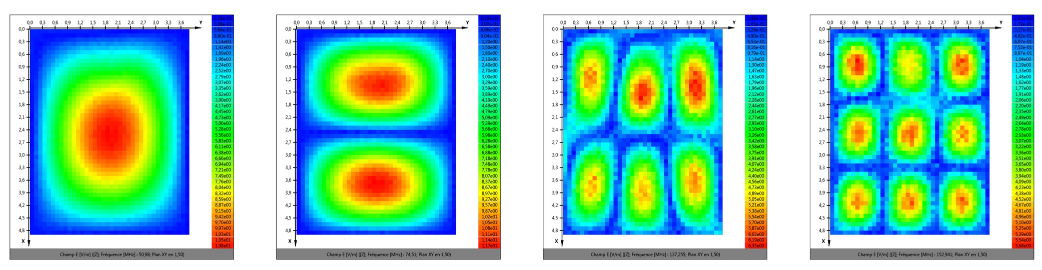
> Results

Cavity Modes Simulation

Cavity modes can be obtained using Fourier Transform on the point impulse response at each discretised point of the cavity. Different frequency patterns are represented in [Fig. 5]. This method uses a 3 dimensional current images model. The dimensions of the cavity fit those from the Mode Stirred Reverberation Chamber of the University of Liège.

Three Dipoles Simulation

We have simulated the propagation of three radiating layed dipoles inside a cavity (using a 2D image current model). In order to match our model hypothesis we have made the same simulation with an electromagnetic solver using Discontinuous Galerkin method to validate our results (this software is developed by the ULG's Applied & Computational Electromagnetics research unit). The propagation inside the cavity has been represented at different times in [Fig. 6].



(a) 51MHz (b) 75MHz (c) 137MHz (d) 152MHz

Figure 5: Evolution of the resonance modes simulated by the 3D current image method. Plane XY at Z=1.5m.

> Discussions

As expected, the cavity modes simulated don't match with those from the real reverberation chamber of the University of Liège ($4.84 \times 3.72 \times 3.11$ [m^3]). Indeed, the real cavity embeds a stirrer that modifies the impulse response of the chamber. But the correspondence between the simulated modes and the theoretical formula is however quite good as the theoretical formula does not take a stirrer into account:

$$f_{mnp} = \frac{c}{2}\sqrt{\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2 + \left(\frac{p}{H}\right)^2} \tag{5}$$

where H, L, P are the cavity dimensions and m, n, p are integers (with 2 of them different from zero). The corresponding modes for the pictures in [Fig. 5] are :

51 MHz (1/1/0)	136 MHz (3/2/0)
74 MHz (1/2/0)	152 MHz (3/3/0)

which match well the frequency observed during simulation.

The 2D simulation of the three dipole propagation with the second simulation method (Discontinuous Galerkin) produces the same patterns (when the propagation can be considered in far field) and moreover our method is quite faster as it only requires a few seconds to get the results.

> Conclusions

We are developing a software that allows us to simulate the propagation of waves inside a cavity using the current image method. This method is fast but an external electromagnetic solver is needed to simulate antenna behavior. A possible optimization would be to integrate the use of antenna models created in electromagnetic solvers to simulate different kind of antennas (in emission and in reception). Then the next step would be to develop a 3D version of the software to try to match more realistic reverberation chambers behaviours.

> References

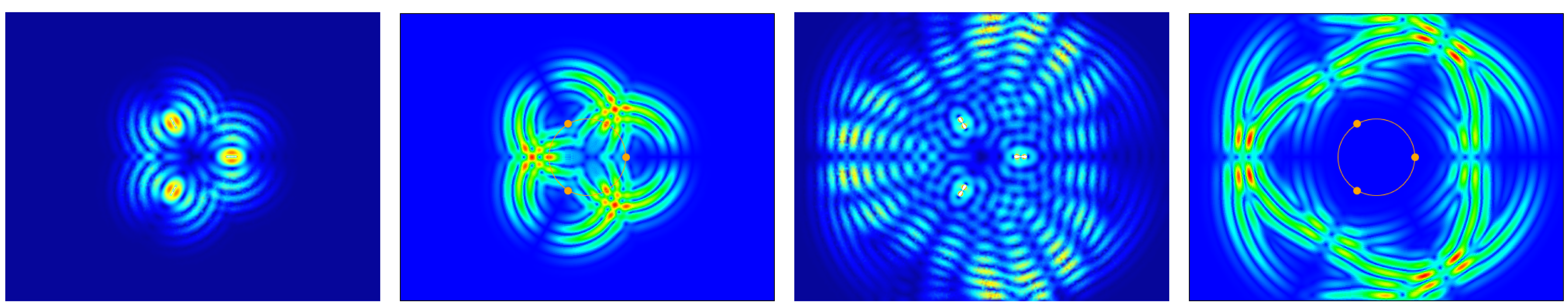
[1] Emmanuel Amador. "Modèles de compréhension par la théorie des images des phénomènes transitoires et du régime permanent en chambre réverbérante électromagnétique". Français. D11-23. THESE. INSA de Rennes, Oct. 2011.

> Contacts

Ing. Maxime SPIRLET, CECOTEPE ASBL,
Quai Gloesener 6, 4020 Liège, Belgium,
maxime.spirlet@hepl.be

> Acknowledgments

This research was funded by a FIRST grant of the Walloon Region (DGO6).



(a) Discontinuous Galerkin - 4.1ns (b) Current Image - 4.1ns (c) Discontinuous Galerkin - 7.1ns (d) Current Image - 7.1ns

Figure 6: Comparison between propagation simulation using current image method and discontinuous Galerkin method at different times.