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Comprehensive Electromagnetic Solutions

Intelligent Design with Characteristic Mode Analysis

Introduction

The theory of characteristic mode analysis (CMA) [1, 2] is a well-known method that allows for the analysis of arbitrary structures. CMA gives insight into the resonating behaviour of structures such as antennas. The method solves a generalised eigenvalue equation derived from the method of moments (MoM) impedance matrix.

After running a CMA simulation the eigenvalues (EV), modal significance (MS) and characteristic angle (CA) are available for the calculated modes. A mode can be considered resonant when EV=0, MS=1 or CA=180°. Modal currents, near fields and far fields are also useful to visualise and interpret modal behaviour,and can be applied to enhance or suppress certain modes depending on the requirements [3]. If an excitation is present the modal excitation and modal weighting coefficients are calculated, giving an indication of how well the excitation will excite each mode.

The above-mentioned parameters are what make CMA such a novel alternative for design optimisation. The fundamental insight that is provided in terms of the resonant performance of the structure leads to a systematic and intelligent design approach. This in turn may lead to a significant reduction in the number of iterations required to achieve an optimised performance.

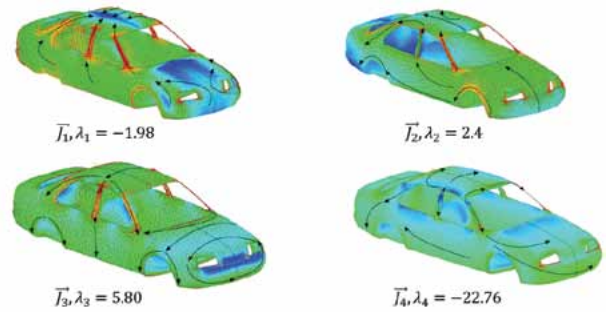
CMA for Antenna Design

CMA is widely applicable to antenna design, placement and integration. One example is illustrated in [4] where a mobile antenna is designed to operate in the LTE 1.8 GHz band. CMA is used to calculate the modal currents on a surface reserved for the antenna. A resonant path is created by etching slots into the sheet where the modal current amplitude values are low. Where the modal current amplitude levels are high, strips of metal are left on the sheet. After each modification, the modal significance is re-analysed to ensure the resonance is still at 1.8 GHz (MS=1).

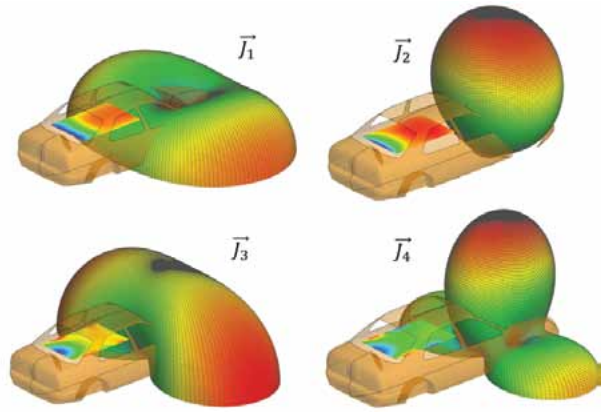
While [4] concentrates on antenna design aspects, in [5] CMA is used to facilitate the integration of a dual channel multiple-input multiple-output (MIMO) antenna into a mobile device.

The modal current distribution on the PCB at resonance is useful for various aspects during the integration process. It provides insight for optimum placement of the antenna on the PCB, for passive test cable routing, for modification of the PCB geometry and for the design of passive resonators.

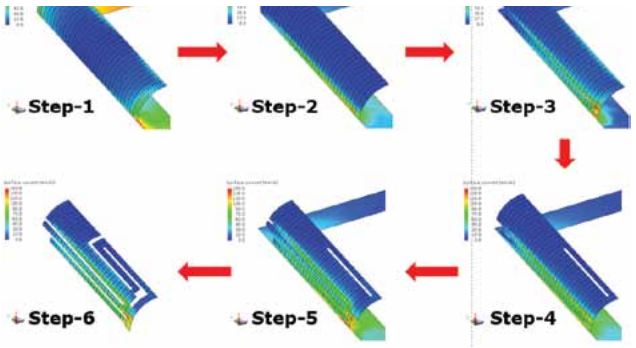
The display frame geometry and battery position are optimised with CMA to improve the overall MIMO performance. Following this approach an



Modal currents on a car chassis



Modal near field and far field patterns for a car chassis



An antenna designed by systematically modifying a metal sheet based on the sheet's modal current distribution

improvement of 5% in radiation efficiency, 5 dB reduction in coupling between elements and up to 1 dB in mean effective gain are achieved while the envelope correlation coefficient is acceptably low. The advantage that CMA offers in this study is fast simulations (in the order of a few minutes) that bring valuable insight and ultimately lead to an improved design during the integration process.

Conclusions

CMA provides a novel approach to problems ranging from antenna design and placement to EMC and coupling. This stems from the parameters that CMA calculates, which describe the fundamental resonant behaviour of a structure. When applied with the correct interpretation, the possibilities for this intelligent and systematic design approach are endless.

References

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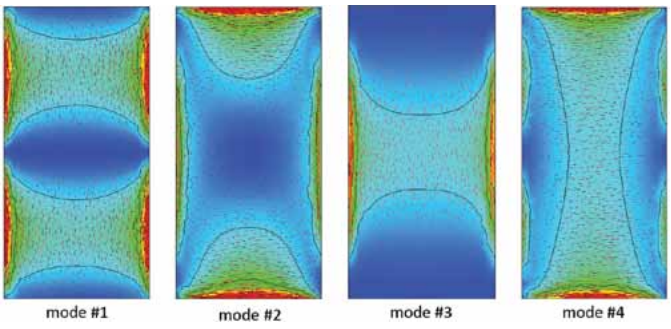
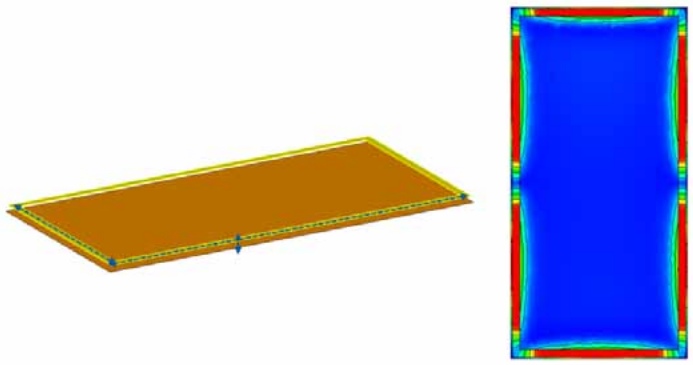
[3] M. Cabedo-Fabrés, E. Antonio-Daviu, A. Valero-Nogueira and M. F. Bataller, "The Theory of Characteristic Modes Revisited: A Contribution to the Design of Antennas for Modern Applications," IEEE Antennas and Propagation Magazine, vol. 49, no. 5, pp. 52-68, Oct. 2007.

[4] G. Gampala and C. J. Reddy, "Compact LTE Antenna Design Using the Theory of Characteristic Modes for Smart Phone Applications," Radion Science Meeting (Joint with AP-S Symposium) 2014 USNC-URSI, July 2013.

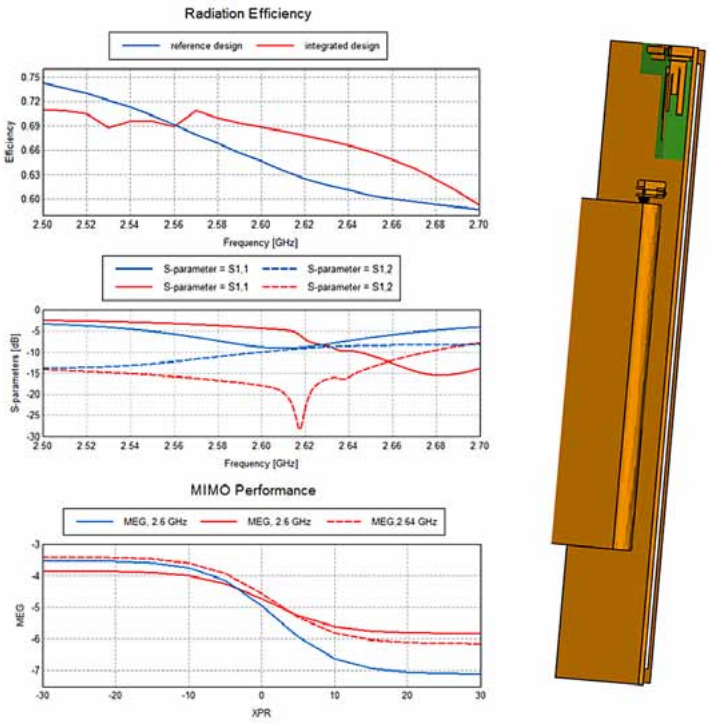
[5] P. Futter, G. Gampala and C.J. Reddy, "MIMO Antenna Integration for LTE Operation," Progress in Electromagnetics Research Symposium (PIERS), Stockholm, Sweden, August 2013



Instantaneous modal currents on a PCB at 2.6 GHz



Display frame geometry tweaked using CMA to design a passive resonator



CMA optimised performance of antenna, display frame and battery compared to the reference design

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