Understanding the Fundamental Radiating Properties of Antennas with Characteristic Mode Analysis

Danie Ludick, Gronum Smith
EM Software & Systems - (Pty.) Ltd.
32 Techno Avenue, Techno Park, Stellenbosch, South Africa

SUMMARY

Characteristic mode analysis (CMA) is a useful design tool that equips antenna designers with a non-brute force way of systematically extracting the radiating properties of a structure. These properties are presented by CMA in the form of eigenvalues and eigenvectors, i.e. the solution of a generalised eigenvalue equation that is formulated from the MoM impedance matrix. An important aspect to note at this stage, is that the eigenvalue equation can be solved without taking into account the effect of sources. Only the geometrical properties of the structure are considered.

One can deduce valuable information form the eigenvalues that are calculated. Reactive power is proportional to the magnitude of the eigenvalue, with modes radiating more efficiently as the eigenvalue approaches zero. In addition, the sign of the eigenvalue provides information on the type of energy being stored, i.e., in the form electric and magnetic energy. Derived quantities such as modal significance, modal weighting coefficients and modal input power also provide additional information on how external sources couple with, and excite, certain modes. The information that is obtained in this manner, aids the developer in choosing and exciting a desired behavior of the structure, something that is particularly useful in the mobile phone industry.

One particular challenge to CMA, however, is the manner in which quantities such as eigenvalues are presented as a function of frequency. At each discrete frequency sample, the eigenvalues are sorted according to modal significance, i.e., based on the efficiency with which they radiated. At higher frequencies, the ordering of modes may differ to that obtained at lower frequencies, as these higher order modes may contribute more towards the radiated or scattered power of the structure. To mitigate this problem, we have developed a tracking algorithm to keep the ordering of modes as consistent as possible over frequency.

The talk will first discuss the fundamental concepts of CMA, where the quantities such as eigenvectors, eigenvalues, modal significance, modal excitation coefficients and the modal weighting coefficients will be introduced. Thereafter, a step-by-step overview will be provided for the mode-tracking algorithm that is implemented in our solver. The efficiency of our technique will be illustrated at the hand of various practical examples.

Danie Ludick was born in the Free State, South Africa, on July 30, 1985. He received the B.Eng. degree in electrical and electronic engineering with computer science (*cum laude*) and the M.Sc.Eng. degree in electronic engineering (*cum laude*) from the University of Stellenbosch, South Africa, in 2007 and 2009, respectively. His masters thesis was based on the efficient analysis of focal plane arrays for the Square Kilometre Array (SKA) radio telescope using electromagnetic simulation techniques. He is currently part of the development team for the computational electromagnetic software package, FEKO. He is also presently pursuing a Ph.D. degree in electronic engineering at the University of Stellenbosch. His main research interests include computational electromagnetic simulation, domain decomposition techniques and antenna design.

Dr. Gronum Smith obtained his PhD from the University of Stellenbosch in 1993 and established EM Software and Systems with Dr Frans Meyer in 1994. EMSS started as a consulting company with first projects on characterisation of EM fields in the Naval environment, Bio-Electromagnetics, radiation hazards in naval and mobile phone industry, radome development and antenna placement on aircraft. These projects required good EM simulation and EMSS started cooperation with, and further development, of FEKO. From 2000 Gronum focussed on global marketing and distribution of FEKO