New Look of the Mysteries of the Characteristic Modes

T. Bernabeu-Jiménez[(1)], A. Valero-Nogueira[(1)] F. Vico-Bondia[(1)], A. A. Kishk [(2)]
(1) Universitat Politècnica de València, Valencia, Spain,
(2) Concordia University, Montreal, Canada

The theory of characteristic modes is being widely used for designing antennas (Y. Chang, and R. F. Harrington, 1977, *Antennas and Propagation, IEEE Transactions* on, 25(6), 789-795). Regarding to the design of dielectric objects there are still unknown aspects in the interpretation of their solutions. Previous works about characteristic Modes are published for conducting bodies and dielectric Bodies, but a difficulty to understand the solution using the surface integral equations based on Poggio-Miller-Chang-Harrington-Wu-Tsai (PMCHWT) formulation appears. It is also found that analyzing a dielectric body using different formulations, different results are obtained as the PMCHWT formulation provides more modes than those obtained using the Volume Integral Equation (VIE). What is observed is that the characteristic eigenvalues obtained with VIE are contained in the PMCHWT solution, resulting in the latter more solutions than in VIE. The observed difference is that PMCHWT provides two eigenvalues for each mode.

In this paper, we show that these two solutions are converging to each other in the complex frequency plane. In order to show this, we must look at the Complex Natural Resonances (CNR) (C. C. Chen, 1998, *Antennas and Propagation, IEEE Transactions* on, 46(7), 1074-1083). The CNR are obtained when the determinant of the method of moment matrix Z, which is complex, vanishes. The CNR are unique and provides us information about the resonances and the damping factor that is related to the quality factor of the object. It should be pointed out that although the object materials are lossless, the CNR are complex as the real part is presenting the radiation losses or the leackage losses for the particular mode. Finally, this paper concludes by explaining the relationship between CNR and Characteristic Modes Resonances (CMR).