Forum for Electromagnetic Research Methods and Application Technologies (FERMAT)

Antenna Design Using Characteristic Modes and Related Techniques.

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Response to "Comments and Questions on the EuCAP presentation on, "Scattering Analysis for Arbitrarily Shaped bodies using Characteristic Modes," by Y. Chen in the EuCAP'16 Special Session on Theory and Application of Characteristic Modes, convened on Monday, April 11, 2016".

Thanks a lot for your interests in my paper as well as your valuable comments! Some mentioned issues really confused many researchers interested in modal analysis methods. I felt this author raises critical comments for the CM theory, including the CM theory of PEC proposed by Prof Harrington, et. al. in 1965, 1971, which is widely used in various designs. I would also like to sincerely invite any other interesting CM researchers to contribute positive replies. It is helpful for us to reach a common understanding or standardize the definition of the "true modes". My personal replies are presented in the following.

1. I have given the discussion to explain why the old CM formulation failed in providing correct resonant frequency. It failed because the imaginary parts of the <J, ZJ> in the old formulation does not represent the stored energy in a dielectric system.

   How do you think the CM's predict resonance? We know quite well that the CM's are derived from the eigenvalue equation:

   $[X]\,\{J_n\} = \lambda_n\,[R]\,\{J_n\}$

   where R and X are the real and imaginary parts of the MoM matrix Z, appropriately derived for the object under investigation, be it PEC or dielectric. We use this equation to compute the J_n's and associated λ_n's and order them. For a given excitation, and operating frequency, the mode with the smallest λ_n is the one which is excited most strongly. As we change the operating frequency, the dominant mode (one with the smallest eigenvalue) will change in general. The mode with the smallest λ_n is often referred to as the resonant mode, because of it similarity with closed cavity modes. Note however, that for an ideal lossless cavity the eigenvalue goes to 0, exactly at the resonant frequency, but it can never do that for open region problems, PEC or dielectric, i.e., the λ_n's are always non-zero for open region problems.

The questions I have for you are:

1. What is your definition of resonance, which, according to the assertion you made in your EuCAP presentation, the conventional formulation presented above failed to “predict” and to yield “reasonable modal currents and fields,” as you put it?
2. Did you solve the above eigenvalue equation with the conventional Z, as opposed to Z_e, which you introduced in your paper for dielectric objects?
3. Did it not give you the usual eigenvalues and eigenvectors? If not why not?
4. If it did, why do you say the conventional approach failed for dielectric objects until you switched from Z to Z_e

Please provide evidence that the conventional approach didn’t work, until you used a totally different formulation of the eigenvalue problem (see below), based on energy storage and radiated, which is the main argument of your paper.

$$\mathcal{X}^{\mathcal{E}} \boldsymbol{J}_n = \lambda_n \mathcal{R}^{\mathcal{E}} \boldsymbol{J}_n$$

$$f(\boldsymbol{J}_n) = \frac{P_{store}}{P_{radiation}} = \frac{< \boldsymbol{J}_n^*, \mathcal{X}^{\mathcal{E}} \boldsymbol{J}_n >}{< \boldsymbol{J}_n^*, \mathcal{R}^{\mathcal{E}} \boldsymbol{J}_n >}$$

I submit that you could do everything you want to do by following the conventional approach and expressing the current induced on the scatterer by a given incident field in terms of the conventional CMs. If not, please explain why not?

It would also help if you provide your definition and understanding of “resonance” in terms of the eigenvalues of the defining equation for CMs, given above, which you have chosen to use in your work, and explain how does it (i.e., the resonance) relate to the radiated power? Note that the resonant frequency is usually defined as that for which the electric and magnetic “stored” energies are balanced, and the radiate power is not directly into the picture.

In any case, I argue that if your goal is to solve a scattering problem involving either PEC or dielectric objects, you could do everything you are doing in your approach by using the conventional CMs. I suggest that you try that and also refer to many published works in the literature on the *Singularity Expansion Method* introduced by C.E. Baum, where this has been well demonstrated.