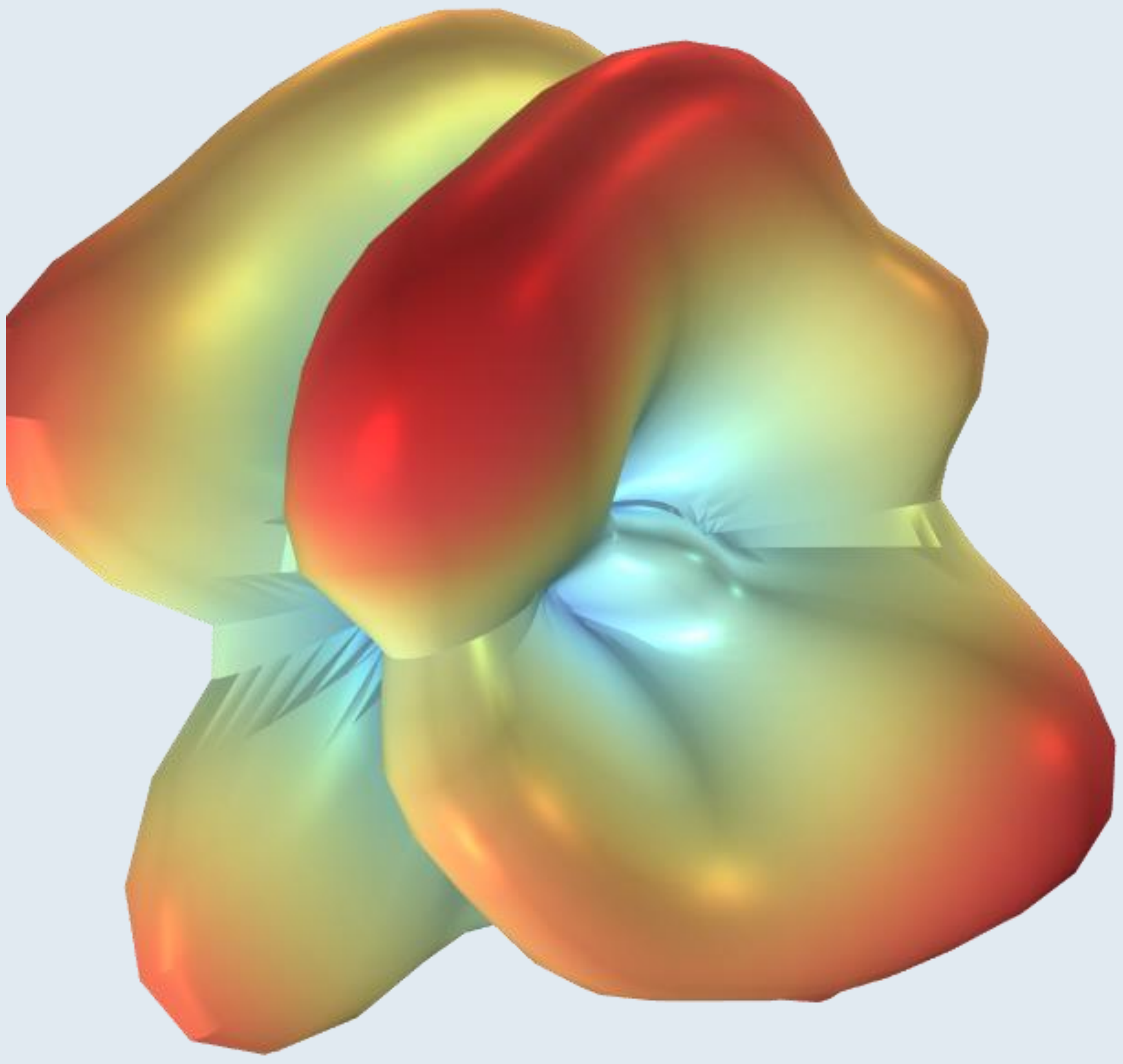

Improved Techniques for Microwave Dielectric Characterization

The study demonstrates that the perturbative technique can measure dielectric permittivity, bypassing inaccuracies from hypothesis limitations.

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Abstract

The electromagnetic study for the design of microwave ovens requires knowledge of the electric permittivity of materials within the chamber. In some cases, data can be easily obtained from the literature, as with PTFE, Mica, and borosilicate glass. However, for more advanced composite materials, ad-hoc measurements become necessary. This study investigates the measurement of the dielectric constant using the perturbative method, leveraging a numerical model to overcome certain restrictive limitations associated with the small perturbation hypotheses. Specifically, the model enables optimization of the resonant chamber geometry for accurate measurement, the appropriate selection of the base dielectric material, and crucially, it accounts for the actual launcher within the chamber. By addressing these factors, the study enhances the precision and reliability of dielectric constant measurements, providing a comprehensive approach to improve experimental setups and results in this domain.

Hypothesis

1) The disturbed fields $\vec{E}, \vec{H}$ in the presence of the dielectric to be measured are not too different from those of the cavity with only the base dielectric $\vec{E_0}, \vec{H_0}$ respectively
2) The resonance frequency f must not deviate too much from f_0 after the insertion of the dielectric to be measured.

Exact formulation (not experimentally usable)

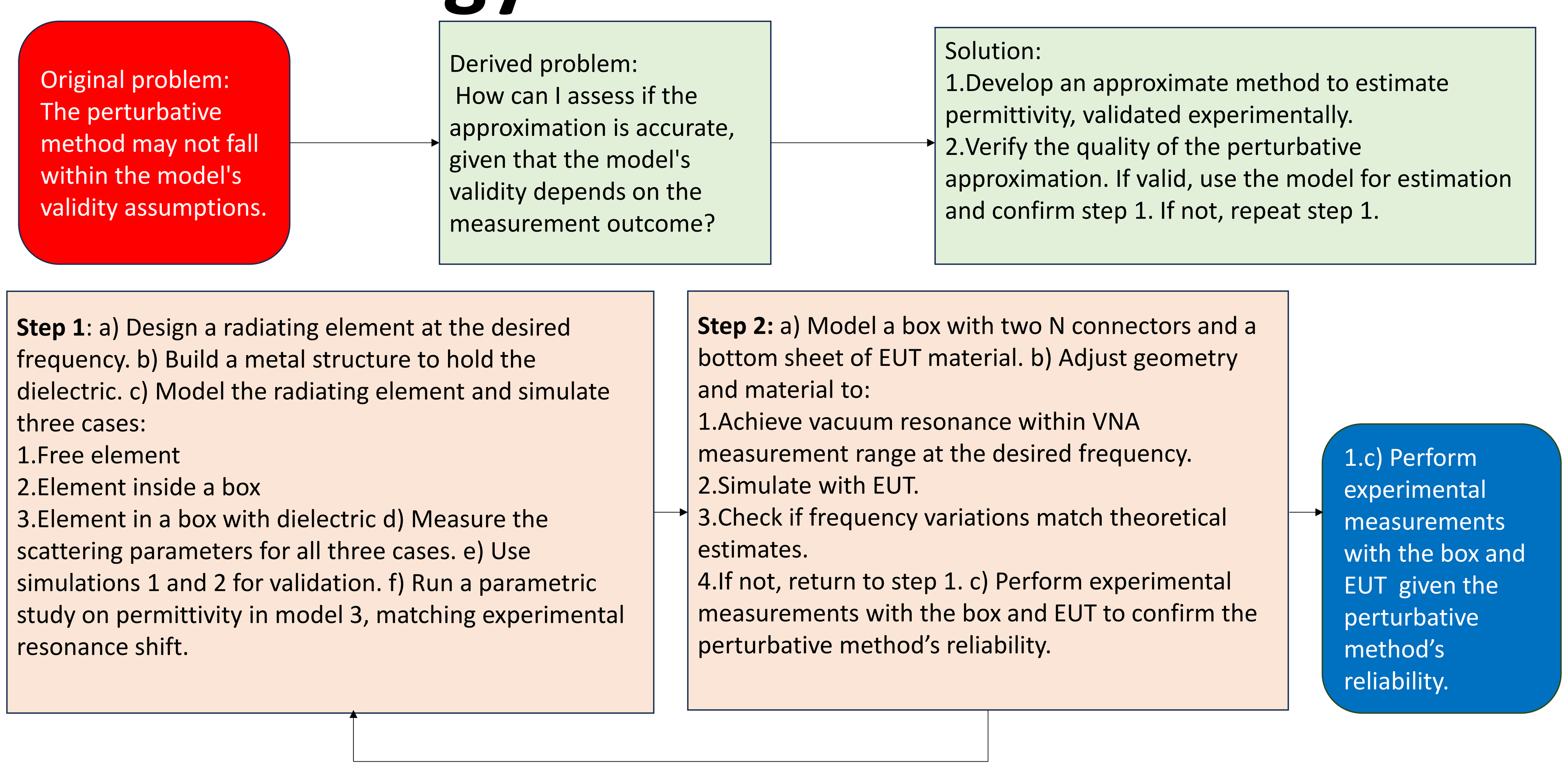
$$\frac{\omega - \omega_0}{\omega} = \frac{-\int_{V_0}\left(\Delta\epsilon\,\vec{E}\cdot\vec{E_0^*} + \Delta\mu\,\vec{H}\cdot\vec{H_0^*}\right)dV}{\int_{V_0}\left(\epsilon_r\,\vec{E}\cdot\vec{E_0^*} + \mu_{r\,base}\,\vec{H}\cdot\vec{H_0^*}\right)dV} \qquad f_{101} = \frac{c}{2\pi\sqrt{\epsilon_{r\,base}}}\sqrt{\left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{d}\right)^2}$$

Aproximate formulation (experimentally usable)

$$\frac{\omega - \omega_0}{\omega_0} = \frac{-(\epsilon_r - \epsilon_{r\,base})t}{2b\,\epsilon_{r\,base}} \qquad \epsilon_r = \epsilon_{r\,base}\left[1 + \left(\frac{2b}{t}\right)\left(\frac{\omega_0 - \omega}{\omega_0}\right)\right]$$

FIGURE 1. Perturbative method, basic theory and general formulation of the problem

Methodology



Results

It has been proven that the technique is capable to provide higher accuracy for the dielectric measurement. With this method, the box used to perform the measurement is designed specifically to satisfy the requirements of the model. The main consequence is that it is possible to perform the measurement with less expensive equipment. Moreover, this technique is highly performing even with solid materials, which is a typical limitation of other traditional techniques based on coaxial probes.

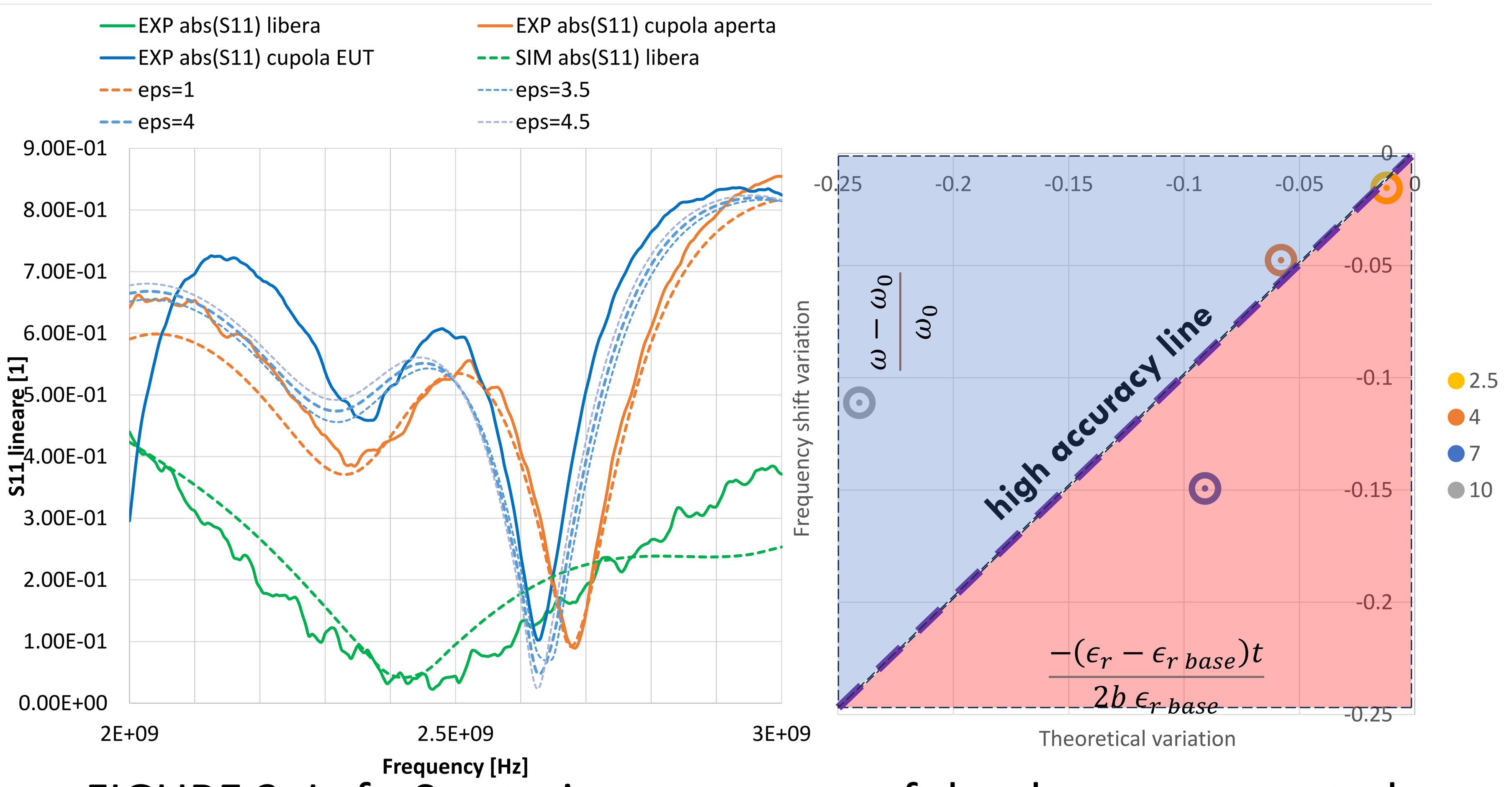


FIGURE 2. Left, Scattering parameter of the three cases tested at step 1. Right, assessment of the mismatch between theoretical and actual frequency shift variation.

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