

Electromagnetic Modeling of a Millimeter-Wavelength Resonant Cavity

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Abstract

INTRODUCTION

Dielectric constant of a material is the physical parameter that fully accounts for its interactions with electromagnetic fields (for nonmagnetic materials). Knowledge of the dielectric constant can quantify reflectance in imaging systems that use long wavelength, nonvisible waves. Measurement of dielectric constant needs to be at the frequency related to its application because it is frequency dependent. For millimeter waves, this means measurements must be made at frequencies on the order of 20 GHz or greater. A resonant cavity for the precision measurement of the complex dielectric constant was designed using a section of WR51 waveguide and a plastic fixture to hold samples inside the cavity [1]. The assembled experimental system is shown in Figure 1.

USE OF COMSOL SOFTWARE

In measurement, a network analyzer collects the S11 parameter as a function of frequency through a coupling iris in the cavity end wall. In order to determine the dielectric constant of the sample, we use COMSOL Multiphysics® software simulation and the RF Module to solve for the field inside the cavity, the coupling iris, and an input waveguide, as shown in Figure 2. The connection between experiment and simulation must take into account the calibration plane in the case of the experiment, and the placement of the measurement port in the simulation. The simulation uses an internal waveguide port backed by a PML layer to determine S11. In the experiment, however, the calibration plane is at the coupling iris, beyond the waveguide. We tried two methods to simulate the experimental measurement: first, we applied an instrument-like calibration for the port using simulated short, offset short, and empty terminations; second, we used Poynting's theorem for harmonic fields [2] to compute the input impedance at the iris by integrating the field solutions inside the iris and the cavity.

RESULTS

A comparison of the reflection coefficients, one derived from the input impedance computed from the volume fields, and the second corresponding to the simulated S11 detected in a virtual port in a lossless input-waveguide, shows that the same result is obtained. The simulation results are overlaid with the experimental data in Figure 3 (the offset of the experimental data can be disregarded).

CONCLUSION

Frequency domain computer modeling is used to accomplish dielectric measurement in a resonant cavity: the real part of the dielectric constant is varied in the simulation to match the resonant frequency, and the imaginary part of the dielectric constant is varied to match the frequency width.

Reference

[1] J.C. Weatherall, J. Barber, B.T. Smith, Resonant System and Method of Determining a Dielectric Constant of a Sample, U.S. Patent Application 14/943,362 (2015).

[2] J.D. Jackson, Classical Electrodynamics, 3rd edition, sec. 6.9, New York: Wiley (1999).

Figures used in the abstract



Figure 1: WR51 Resonator measurement system.

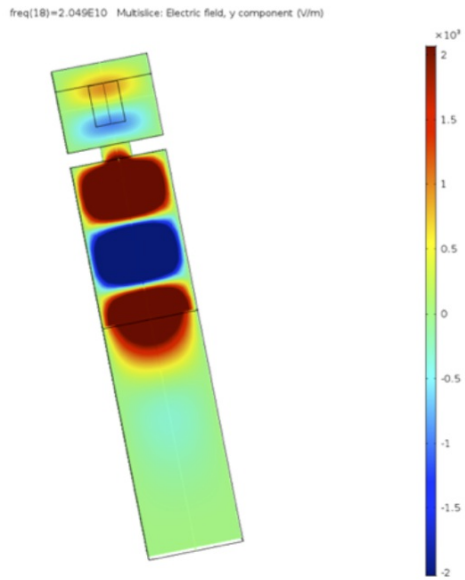


Figure 2: Simulation, Ey-field component.

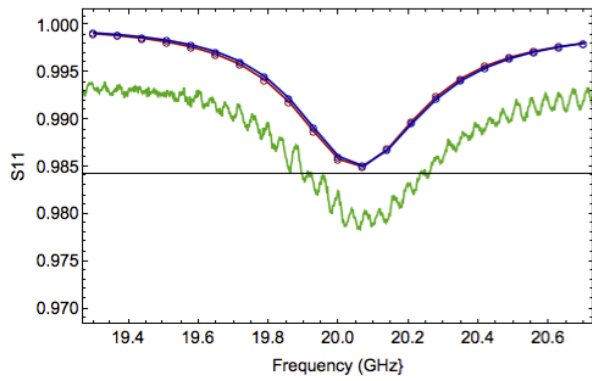


Figure 3: S11 (red), reflection coefficient (dark blue), and experiment (green).