A Microwave Measurement System for Measurement of Dielectric Properties

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Measurement System

We present a prototype of a microwave measurement system for the estimation of dispersive dielectric properties. The measurement system consists of a metal cavity that features a measurement region in the center formed by the intersection of six rectangular waveguides. The waveguides are terminated by adapters connected to coaxial cables. We exploit the frequency band 2.7-5.1 GHz and a connected network analyzer and switch allows for automatic measurements of the 6-by-6 scattering matrix $\tilde{S}$.

Calibration Procedure

We utilize a simulated and measured scattering matrix for the empty cavity to estimate identical 2-by-2 scattering matrices $S^a$ for all adapters by solving

$$S_{11}^a + S_{22}^b \tilde{S}_0 + (S_{12}^a S_{21}^b - S_{11}^a S_{22}^b) S_0 = \tilde{S}_0$$

Any measured scattering matrix $\tilde{S}$ can then be calibrated by removing the estimated adapters. The calibrated scattering matrix $\tilde{S}$ can then be directly compared with the simulated $S$.

We find that using this calibration procedure we achieve a residual of about -30 dB between our simulated and measured results.

Optimization

Using gradients, we minimize the misfit between the simulated and calibrated scattering matrix

$$g(p) = ||S(f, p) - \tilde{S}(f)||$$

where $p$ are the parameters defining the permittivity of the material distribution.

Measurement Results

We estimate the complex effective permittivity of densely packed MCC (microcrystalline-cellulose) pellets over frequency for different moisture contents. This material is used in pharmaceutical processes.

Four different types of frequency dependent dispersive models are tested; Debye, Cole-Cole, Cole-Davidsson and piecewise-constant in small frequency intervals. All models yield similar results.

Conclusions

• A measurement system for determining dispersive dielectric properties
• The calibration procedure is important to compensate for the adapters and other effects not included in the 2D model
• Low uncertainties in the Debye parameters and consistent results for the different permittivity models as a function of frequency
• Measured permittivity can be related to moisture content