

Dielectric Property Characterization Using Thru-Reflect Calibration in Focused Free-Space Measurements Across Broadband Frequency Range

Shaikha AlDhaheri, Papa Ousmane Leye, Stanislav Bobrovskiy, Islem Yahia, and Felix Vega
Directed Energy Research Centre, Technology Innovation Institute, Abu Dhabi, United Arab
Emirates (shaikha.aldhaheri@tii.ae)

This study investigates the dielectric properties of materials using a free-space measurement system calibrated with the Thru-Reflect Calibration (TRC) method. This technique uses an empty space (thru) measurement for transmission (S_{21} or S_{12}) and a metal plate (reflect) for reflection (S_{11} or S_{22}) to normalize system response and eliminate systematic errors caused by equipment imperfections, environmental reflections, and wavefront distortions. Accurate extraction of complex permittivity (ϵ_r) and loss tangent ($\tan\delta$) is essential for applications in electromagnetic material characterization, including antenna design, radar systems, microwave absorbers, stealth technology, and advanced telecommunications.

The calibration process involves measuring the reflection and transmission coefficients of the system with and without the sample in place. The metal plate serves as a reference for reflection, providing a known reflection coefficient of (-1) , while the empty space measurement establishes the baseline for transmission. The normalized S-parameters are used to extract the material's dielectric properties via the Nicolson-Ross-Weir (NRW) method. Validation is performed using standard dielectric materials, such as Teflon and acrylic, to assess the accuracy, repeatability, and robustness of the method.

This study demonstrates the TRC method's efficiency and versatility for non-destructive dielectric property characterization. It provides insights into optimizing free-space systems for consistent and reliable material analysis, ensuring accurate characterization for applications in diverse electromagnetic technologies.