Development of a Lossy Flange Cover for Microwave Materials Characterization

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Objective: To improve the accuracy of the open-ended rectangular waveguide (OERW) method on electrically thin structures.

Microwave NDT Approach

- Rectangular waveguide materials characterization (Fig. 1) allows for simultaneous estimation of thickness and electrical properties of layers within a structure-under test (SUT).

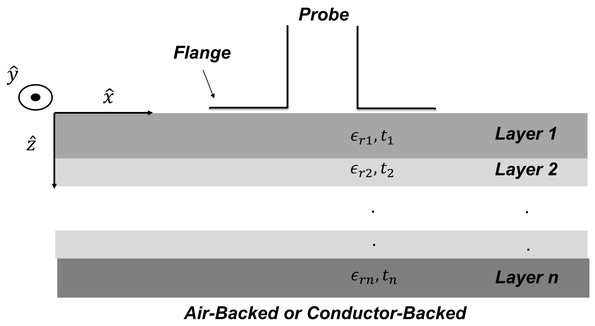

Figure 1: Depiction of a multi-layer SUT.

Flange Error

- Previous work has designed an engineered flange (Fig. 5c), to minimize finite flange error (E_{ff}):

$$E_{ff} = \left\| \Gamma^{inf} - \Gamma^{fin} \right\|_2$$

  - Finite flange error is primarily a function of the SUT loss tangent, but other SUT parameters interact and can also effect the error (Fig. 3-4).
  - Reflections generated from the flange edges, sample edges, or other discontinuities contributes to finite flange error (Fig 6).
  - Small finite flange error can create significant error in material property estimation.

Flange Error Simulation Results

- Conducted in CST Microwave Studio ®.

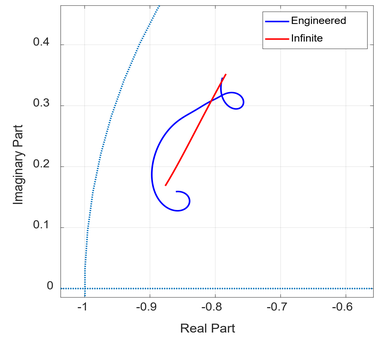

Figure 2: Simulated reflection coefficients at X-band (8.2-12.4 GHz) for an infinite sample measured with an engineered flange.

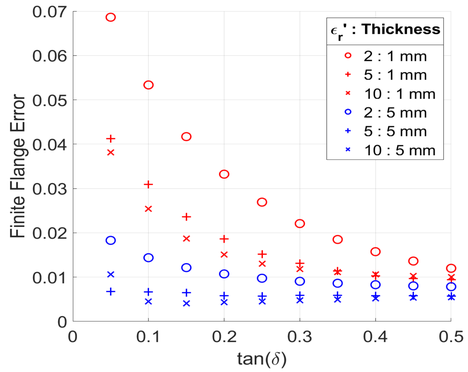

Figure 3: Error for several dielectric constant and thickness values.

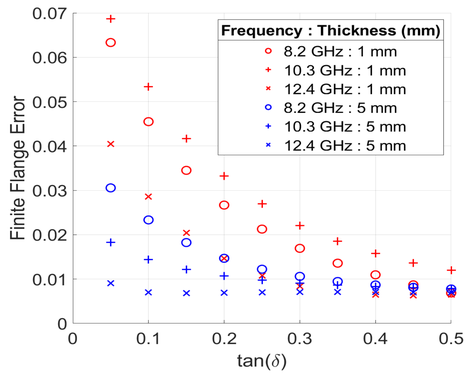

Figure 4: Error for several frequencies and thickness values.

Utility of a Lossy Flange Cover

- Lossy materials may decrease finite flange error but may also decrease measurement sensitivity.
- Lossy applicator and flange cover were 3D printed using a carbon-fill PLA filament ($\epsilon_r = 11.5 - j14.1$).

(a) (b) (c)

Figure 5: Aluminum engineered flange (a) with lossy applicator (b) and with lossy flange cover (c).

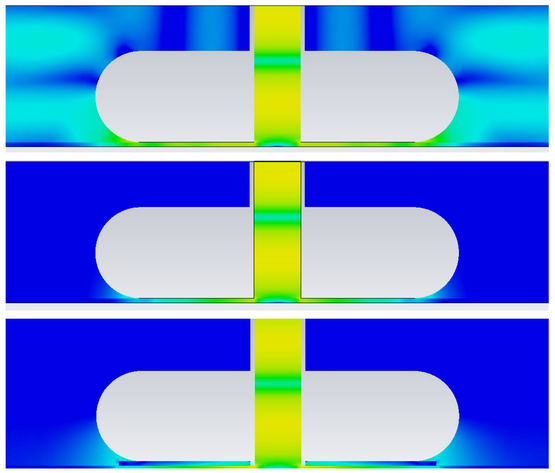

Figure 6: Simulated electric field in the E-plane for the engineered flange (top), lossy applicator (middle), and lossy flange cover (bottom) for a 1 mm conductor-backed dielectric (ϵ_r =2-j0.1).

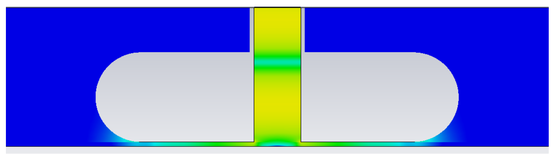

Figure 7: Simulated electric field in the E-plane for the engineered flange for the SUT of Fig.6 with increased loss factor (ϵ_r =2-j1).

Measured Results

- Flanges shown in Fig. 5 were used to measure thin and conductor-backed fiberglass (ϵ_r =4.6-j0.07).
- The lossy flange cover reduces undesired measurement variability with similar measurement sensitivity with respect to changes in thickness (Fig. 7-8).

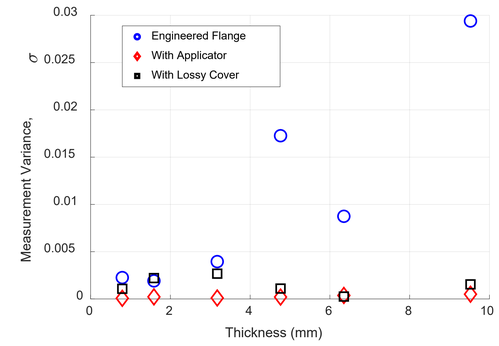

Figure 7: Measurement variance for SUT with varying thickness.

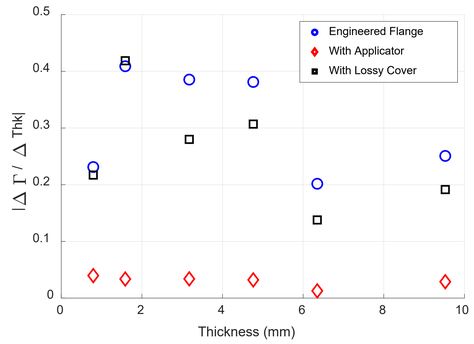

Figure 8: Measurement sensitivity for SUT with varying thickness.

Conclusion

These preliminary results clearly indicate the potential efficacy of a lossy dielectric cover for microwave materials characterization. Current work is focused on modifying the EM model for processing these measurement data.

Acknowledgements - Anna Case is the recipient of the O.D. & O.U. Trapp Graduate Fellowship in CNDE, and wishes to express her gratitude for the opportunity facilitated by this fellowship to perform research in the NDE field.