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Microwave Materials Characterization Using a Waveguide Iris

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Objective

This work aims to use a waveguide iris for reducing finite flange error when estimating structure properties of thin, conductor-backed samples with finite extent.

Background

- Open-ended waveguide measurements are used for materials characterization, in which intrinsic electrical properties are related to other physical or chemical properties of interest.

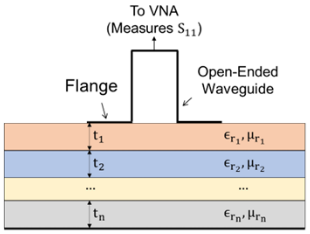


Figure 1: Schematic of a open-ended waveguide measurements.

- Finite flange error, which is created by waveguide flange and sample edges, can lead to subsequent property estimation error.
- A waveguide iris can be used to selectively change the wave incident upon a structure-under test through changes in the iris size, location, and thickness.

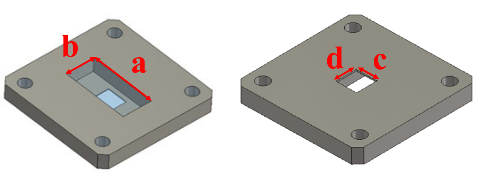
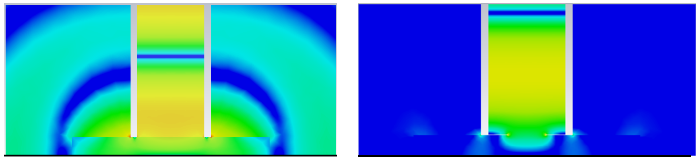


Figure 2: Schematic of a waveguide iris.

Approach

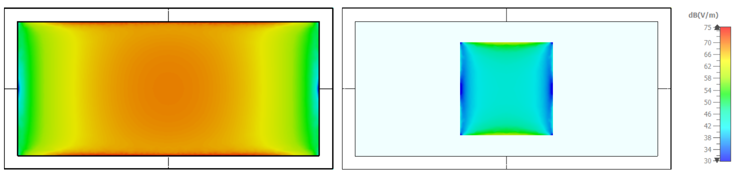
- CST Microwave Studio® is used to simulate X-band (8.2-12.4 GHz) rectangular waveguide probes inspecting a thin (3.175 mm) and conductor-backed rubber ($\epsilon_r = 4.8 - j0.17$) coating.
- This probe is highly sensitive to flange and sample edges when inspecting *thin* and conductor-backed structures.
- The use of a 7 mm-square and 0.1 mm thick iris limits sensitivity towards the flange and sample edges but limits depth of penetration of the signal as well.



(a) (b)

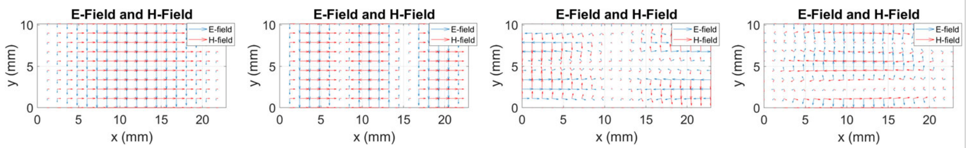
Figure 3: Cross-sectional view of the electric field distribution in the E-plane at 10.3 GHz on a finite 3.175 mm thick conductor-backed rubber coating using: (a) standard waveguide, and (b) 7 mm-square iris.

- The total electric field present at the waveguide aperture is complex due to interactions with the structure-under-test and the iris dimensions, location, and thickness.
- The electric field on the aperture is modelled as a weighted summation of the dominant mode and higher-order waveguide modes (i.e., TE_{mn} and TM_{mn} modes) using Fourier analysis.



(a) (b)

Figure 4: Electric field distribution at 10.3 GHz in the aperture plane of the probe on a finite 3.175 mm thick conductor-backed rubber coating using: (a) standard waveguide, and (b) 7 mm-square iris.



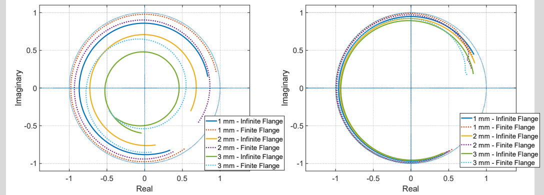
(a) (b) (c) (d)

Figure 5: Rectangular waveguide modes for the: (a) dominant TE_{10} mode, and next three higher-order modes: (b) TE_{30}, (c) TE_{12}, and (d) TM_{12}.

Simulated Results

- Reflection coefficient, Γ, is measured as a function of frequency and finite flange error is computed:

$$E(f) = \left\| \Gamma^{infinite} - \Gamma^{finite} \right\|_2$$



(a) (b)

Figure 6: Reflection coefficient in the complex plane, as a function of frequency, inspecting conductor-backed rubber coatings of varying thickness using: (a) standard waveguide, and (b) 7 mm-square iris.

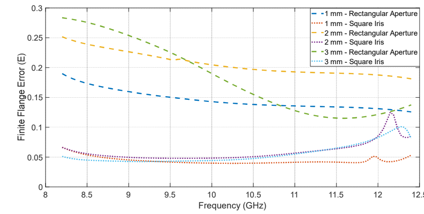


Figure 7: Finite flange error as a function of frequency for reflection coefficients inspecting conductor-backed rubber coatings of varying thickness using: (a) standard waveguide, and (b) 7 mm-square iris.

- Sensitivity of the reflection coefficient with respect to changes in rubber thickness is higher for the rectangular waveguide probe as is the finite flange error. Iris dimensions should be optimized to maximize reflection coefficient sensitivity and minimize finite flange error.

Conclusion

This work has shown the potential efficacy for a waveguide iris probe to reduce finite flange error when inspecting a thin, conductor-backed structure.

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