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Wideband Absorber Characterization Using Coaxial Airline and Electromagnetic Simulation

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Introduction

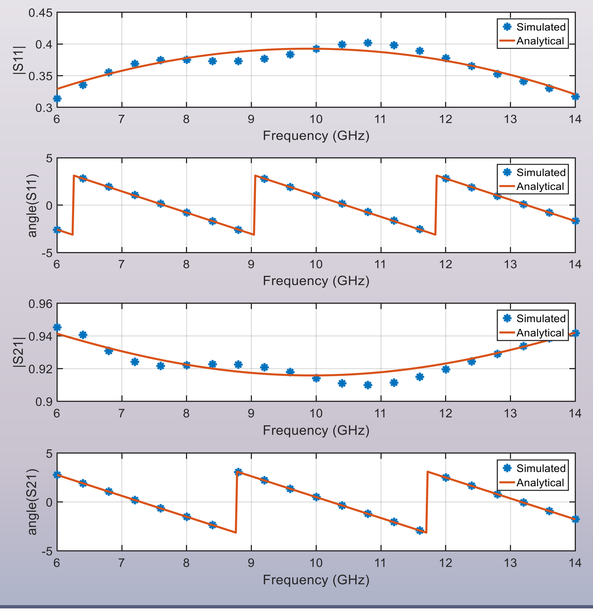
In this study, we focused on developing a procedure to parameterize material electromagnetic properties. We first extract material properties by placing samples inside an airline and taking measurements of scattering parameters matrix [S] with a vector network analyzer (VNA). Extraction process is verified with a full-wave electromagnetic (EM) solver.

With the extracted material properties, we then simulate absorber performance by mimicking the naval research laboratory arch setup. Radar cross section is used instead of a full -D model to reduce complexity and computing resources. Finally, the reflectivity measurement the absorber is performed and compared with simulation results.

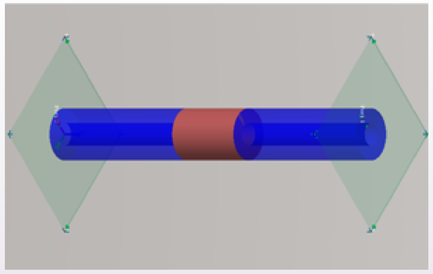
EM simulation of airline

Since the coaxial airline outer diameter and inner diameter is 7 mm and 3.04 mm respectively, sample preparation process was difficult. To make sure that extraction process works for all condition of complex permittivity and complex permeability, HFSS was use to generate test [S].

Transmission and reflection model of TEM transmission line with a sample in between was established in the classical Nicolson Ross Weird algorithm [1]. The two graphs below compare the analytical solution from [1] with our simulated results. The sample was 5mm HDPE in 10cm airline.



Electromagnetic properties extraction



First, we use simulated [S] from HFSS, the expected should be e_c = 2.3-1i*0.005*2.3

f (GHz)	6	7	8	9	10	11	12	13	14
Re{e}	2.245	2.297	2.291	2.295	2.355	2.337	2.315	2.304	2.251
Im{e}	0.008	0.008	0.009	0.009	0.009	0.010	0.010	0.010	0.011

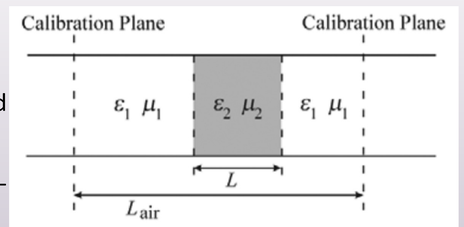
After knowing that measurement and extraction both works. We apply the process to comercialy avaialble absorber form MAST, MR21 80 mil. Sample is extremely hard to prep, expect high variance of epsilon and mu.

f (GHz)	6	7	8	9	10	11	12	13	14
Re{e}	10.63	10.32	9.266	8.769	8.803	7.897	7.865	8.100	8.576
Im{e}	0.776	1.236	1.364	0.794	0.597	0.350	0.002	0.164	0.240
Re{u}	1.884	1.884	1.737	1.403	1.286	1.233	1.117	1.070	1
Im{u}	1.596	1.630	1.804	1.964	1.953	2.204	2.305	2.155	1.921

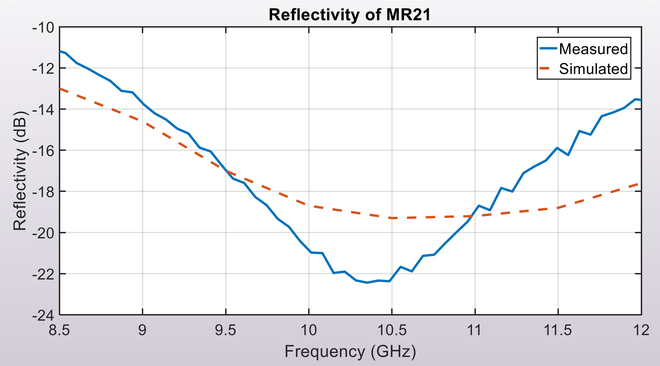
Reference Plane Invariant Method [2]

We adopted the Reference-Plane Invariant (RPI) method to extract the microwave properties of the materials. Our own Matlab code is created following the RPI algorithm described in [2]. The schematic model of a RPI measurement is demonstrate in the figure below. The measurement and extraction process includes 5 steps:

- Step 1: Calibrate VNA and coaxial cables
- Step 2: Measure empty airline, take phase to find L_air (using eq.10 [2])
- Step 3: Calculate Reflection coefficient (R) and-Transmission coefficient (T) from measured [S]
- Step 4: Find index of refractio n, then find er and ur. Note that the fact that e_r > u_r was used to check which gamma satisfies them (below equation 27)



Reflectivity simulation and measurement



Accomplishments

♦ EM Simulation

- ♦Setup airline simulation using HFSS and generate [S] to verify the measurement and extraction code.
- ♦Radar cross session simulation for the reflectivity measurement.

♦ EM properties measurement and extraction

- ♦Performed Airline measurement
- ♦Extracted both complex $\boldsymbol{\varepsilon}$ and $\boldsymbol{\mu}$ using RPI algorithm.

Future Work

- ♦ Refine the extraction algorithm
- ♦ Measure and extract different types of materials
- ♦ Compare the RCS simulation with reflectivity measurement for wideband frequency sweep

Reference

[1] W. B. Weir, “Automatic measurement of complex dielectric constant and permeability at microwave frequencies”, Proc. IEEE, vol. 62, no. 1, pp. 33–36, Jan. 1974.

[2] K. Chalapat, K. Sarvala, J. Li, G. S. Paraoanu, "Wideband reference-plane invariant method for measuring electromagnetic parameters of materials", IEEE Trans. Microw. Theory Techn., vol. 57, no. 9, pp. 2257-2267, Sep. 2009.

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