Literature Review for Capstone Project

# Introduction

The literature review is about material characterization of both complex electric permittivity and magnetic permeability. This is a part of ECE 412-412 Capstone Project at PSU.

From Microwave Electronics Measurement and Materials Characterization, there are three main categories of material characterization: resonance, transmission line, and free space. Very accurate parameters can be obtained by resonators and cavities, but these resonant methods are only valid for discrete frequencies. Rectangular waveguide [1] [2], and NRL arch [3] [4] are therefore, our choice to do the measurement.

Rectangular waveguide technique has higher dynamic range because the wave is confined inside the waveguide. However, this method usually requires high precision contact between samples and sample holders. This is hard to obtain especially at high frequency. NRL arch (free space) is an industrial standard for absorption coefficient measurement.

The review is divided into sub-section: calibration, sample size, extraction. These are information required to build our test setup.

# Calibration technique

[1] HP waveguide calibration kit (HP Production Note 8510-3). Including a impedance terminator, and two short standards (1/8 lambda and 3/8 lambda long, at geometry mean frequency).

[2] Doesn’t mention

[3] Flat metal plate as ref signal

[4] Reflection from aluminum alloy plate as ref signal

# Recommended sample size and frequency range

[1] 2 to 3 GHz. 2-mm thick. About 90 mm by 45 mm. Waveguide: WR340

[2] 750 to 1120 MHz. 15-cm thick. About 25cm by 12.5cm. Waveguide: WR875

[3] 8 to 12.5 GHz. 5cm thick. About 17 cm by 17 cm.

[4] 50 to 75 GHz. 1mm thick. About 170mm by 25 mm.

# Equation for extraction

[1] An error equation is defined. Newton-Raphson iterative method then can be used to minimized the error term. The iterative algorithm use real and imaginary part of electric permittivity as two variables, and the procedure is repeated until convergence is acquired.

[2] Nicholson Ross Weir

[3] Multiple reflection model. At each frequency, complex value of permittivity is calculated to minimize the error function (from multiple reflection model)

[4] Same as [1]

# Control Sample

[1] PVC and GML-MC5 (a dielectric material)

[2] Concrete

[3] PVC

[4] Commercial fabric glass epoxy composite

# References

[1] J. M. Catala-Civera, A. J. Canos, F. L. Penaranda-Foix, and E. de los R. Davo, “Accurate determination of the complex permittivity of materials with transmission reflection measurements in partially filled rectangular waveguides,” *IEEE Trans. Microw. Theory Tech.*, vol. 51, no. 1, pp. 16–24, Jan. 2003.

[2] D. Micheli *et al.*, “Electromagnetic characterization and shielding effectiveness of concrete composite reinforced with carbon nanotubes in the mobile phones frequency band,” *Mater. Sci. Eng. B*, vol. 188, pp. 119–129, Oct. 2014.

[3] F. Sagnard and G. El Zein, “Characterization of building materials for propagation modelling: frequency and time responses,” *Aeu-Int. J. Electron. Commun.*, vol. 59, no. 6, pp. 337–347, 2005.

[4] K. Naito, Y. Kagawa, and K. Kurihara, “Dielectric properties and noncontact damage detection of plain-woven fabric glass fiber reinforced epoxy matrix composites using millimeter wavelength microwave,” *Compos. Struct.*, vol. 94, no. 2, pp. 695–701, Jan. 2012.