Waveguide Measurement of Materials
Paul Deffenbaugh, Dr. Kenneth Church, Dr. Raymond Rumpf

**CAPABILITY**
Measurement of dielectric constant
- R-band: 1.72-2.6 GHz (109 x 54 x 35 mm)
- X-band: 8.2-12.4 GHz (22 x 10 x 7 mm)

Knowledge of dielectric constant is critical for EM design

Using new materials such as 3D printed materials in EM work requires measurement of dielectric constant

**DESIGN FOR LOW ERROR**
- Avoid sample electrical lengths of $\lambda/2$ because 100% trn / 0% ref condition magnifies errors
- Loss cannot be measured accurately using NRW, use a resonant method

**REFERENCE:**

**PROCESS**
1. Fab material to waveguide holder dimensions (no air gaps!)
2. Calibrate network analyzer using TRL calibration
3. Measure s-parameters using network analyzer
4. Run Nicholson-Ross-Wier math for each frequency point

**NICHOLSON-ROSS-WEIR**
Based on the reflection and transmission coefficients of a wave through an air-material-air interface. From the coefficients, one may find the complex permittivity and permeability.

Specifics of derivation are complex and are described elsewhere.

Essentially converts measured s-parameters to dielectric constant.

**NICHOLSON-ROSS-WEIR MATH**

Reference:

**W.M. Keck Center**
FOR 3D INNOVATION

**Pioneering 21st Century**
Electromagnetics and Photonics