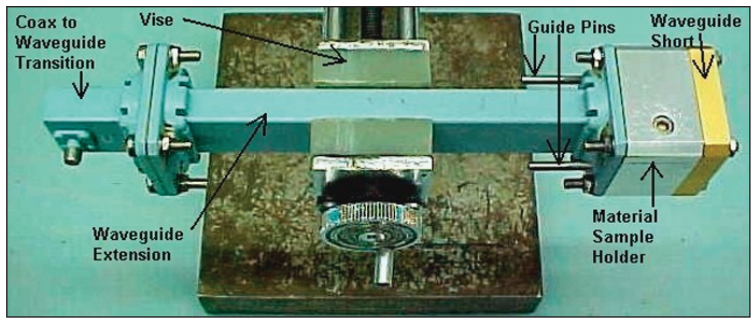
Waveguide-Based Dielectric Measurements of Solid Low and Medium Dielectric Materials

By Travis J. Mensen and Bryan L. Hauck
Rockwell Collins

This article provides an overview of a method for characterizing the real part of the dielectric constant of solids as implemented at Rockwell Collins. This method is based on the waveguide reflection method originally developed by the National Institute of Standards and Technology (NIST).

The Rockwell Collins method was developed using an Agilent 8510C for the network analyzer. The calibration kit is an X-band waveguide calibration kit from Maury Microwave. Agilent makes a software package, 85071C, that is based on algorithms designed by NIST for measuring the dielectric constant of materials in waveguide or coax. A computer with a minimum of 64 MB of RAM and a 400 MHZ processor is also used, and communication to the 8510C runs through the GPIB interface. Some of the smaller tools include a screwdriver, wrench, allen wrench (if needed), vise, scissors, copper tape, hardware and a caliber.

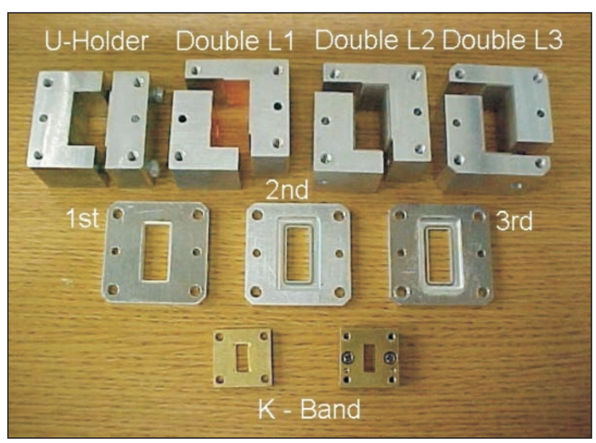


▲ **Figure 1. Complete setup of material sample holder.**

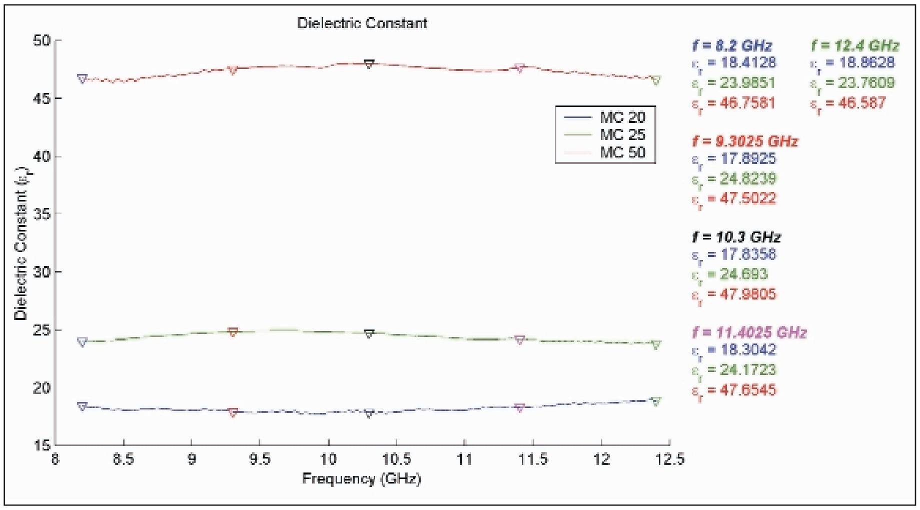
The process for measuring the dielectric constant is very delicate. The first step is to ensure that the waveguide pieces are precisely lined up using guide pins. A waveguide extension is used to prevent modal disruption. The extension is clamped into a vise for convenience and to prevent the cable from moving, which helps prevent phase changes during a measurement (Figure 1).

Starting the Agilent 85071C program loads the parameters into the Agilent 8510, which is necessary to prevent program failure when taking a measurement. The program does not load two parameters, Z_0 and waveguide delay. Z_0 should be set to 1 ohm for the waveguide method, and waveguide delay should be set for the frequency cutoff of the waveguide under the response menu of the Agilent 8510. The program and analyzer are now properly configured for calibration.

The sample holder must be included during the calibration so that it is calibrated out. As shown in Figure 2, the holder is two pieces, so a



▲ **Figure 2. Collection of material sample holders.**

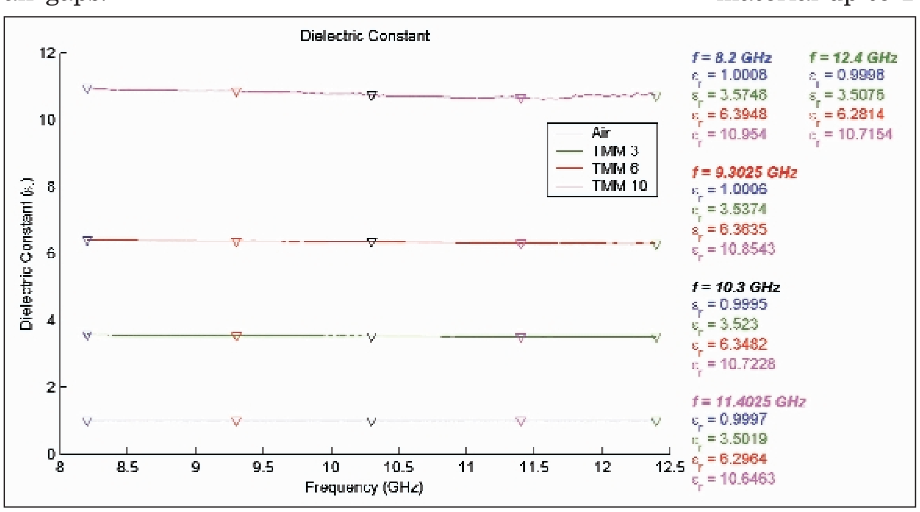


▲ **Figure 3. Measurement results of MC 20, MC 25 and MC 50.**

Material	Dielectric Constant	Frequency (GHz)
TMM 3	3.27	10
TMM 4	4.5	10
TMM 6	6	10
TMM 10	9.2	10
MC 20	19.4	10
MC 25	24.65	6
MC 50	48.13	1

▲ **Table 1. The materials, their dielectrics and the corresponding frequencies.**

small misalignment is possible between the two pieces. To help correct this problem, a copper shim tape is used between the waveguide extension and the material sample holder. The center of the shim is then cut to fit the waveguide opening. When the holder is tightened down, the copper shim conforms and fills in any cracks and/or air gaps.



▲ **Figure 4. Measurement results of air: TMM 3, TMM 6 and TMM 10.**

The materials, their dielectrics and the measurement frequencies are shown in Table 1. The results should have a smooth response within 10 percent of nominal, preferably within 5 percent.

The first material sample holder was K-band waveguide, because some of the materials used were only available in small sizes. Samples of material that have a known dielectric were used to verify that the program was meeting the required standards. The material measured in K-band was not available commercially, so the experiment was moved to X-band.

The first three material sample holders in X-band are similar in style. For the first holder, the material was about 0.0295 inches (0.75 mm) oversized on all four sides. The pieces were 0.039 inches (1 mm) thick. Measurements were not very repeatable. Air gaps were present, but the significance was not understood.

Next, a piece that was 0.2755 inches (7 mm) oversized on all sides was selected. The thickness was also 0.039 inches so that only one parameter changed at a time. The width of the material was increased to allow a cylindrical-shaped gasket to be placed against the face of the material. The gasket is shown in the second holder in Figure 2. The gasket seemed to make the results worse.

For the third fixture, the material thickness was changed to 0.125 inches to match available material. No significant difference was seen. The conclusion after these experiments was that the tiniest air gap was making a difference, so an attempt was made to build a better fixture.

The next two material sample holders are similar in style. Both are 1 inch in thickness and designed for material up to 1 inch thick. The U-holder was the first, designed 0.02 inches oversized on all sides, with the edges wrapped in copper tape. This holder showed improvement over the first three holders, with everything under a dielectric of 10 measured within tolerance, but there were still air gaps.

On the next fixture, double L1, the way that the fixture pieces were put together was changed to allow a better seal around the piece of material. The inside of the fixture was lined with copper tape, instead of the outside of the material. The results were better, but further improvement was desired.

The final two fixtures were similar

to the first double L1. Double L2 is like double L3, except that double L2 was widened by one gasket width instead of two gasket widths. Double L2 explored the gasket being protruded inside the waveguide dimensions, but reflections resulted. The gasket was conductive and 0.028 inches thick and in a sheet form to line the entire inside of the material sample holder. The double L3 inside dimensions were barely over the dimensions of the waveguide, eliminating reflections. The material was somewhat bigger than the opening so that when the fixture was tightened down. The piece pressed into the gasket making an airtight seal. The resulting measurements were reasonably accurate up to a dielectric constant of 50.

Future tests are planned, using material with a higher dielectric constant and comparing results with various material thickness. These tests have identified problems and potential solutions. ■

Author information

Travis Mensen received his associate of applied science degree in electronics and telecommunications from Indian Hills Community College, Ottumwa, Iowa, in May of 2000. He is an engineering technician in the Advanced Technology Center of Rockwell Collins, Cedar Rapids, Iowa. His area of specialty is antenna technology and antenna metrology. His areas of interest include material parameter measurements of high dielectric materials at microwave frequencies, near-field and far-field antenna measurements and general antenna metrology. He may be reached via E-mail: tjmensen@rockwellcollins.com.

Bryan L. Hauck received a bachelor of science degree and master of science degree in electrical engineering from the University of Michigan, Ann Arbor, in 1995 and 1997, respectively. He is a senior electrical engineer in the Advanced Technology Center of Rockwell Collins. His interests include advanced technology for phased array antenna applications, material parameter measurements of high dielectric materials at microwave frequencies and antenna metrology. He is a member of the IEEE Antennas and Propagation Society, the IEEE Microwave Theory and Techniques Society, the Antenna Measurement Techniques Association and Sigma Xi, The Scientific Research Society. He may be reached via E-mail: blhauck@rockwellcollins.com.