



ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES®

3000 Lakeside Drive
Bannockburn, IL 60015-1249

IPC-TM-650 TEST METHODS MANUAL

1 Scope This method describes the nondestructive measurement of the relative permittivity and loss tangent of unclad dielectric substrates at microwave frequencies using a split-cylinder resonator (see Figure 1).

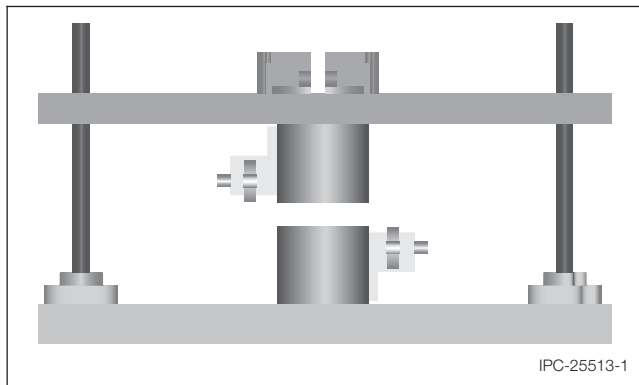


Figure 1 Split-Cylinder Resonator

This test method is directly applicable for measuring the in-plane (the plane parallel to the surface of the specimen) permittivity of the specimen because the electric field is in-plane. The permittivity of isotropic dielectrics can also be measured with this method.

Note: This measurement method does not measure the out-of-plane (direction normal to the surface of the specimen) permittivity of the specimen. However, for most printed boards the measurement uncertainties associated with this method are typically less than the difference between in-plane and out-of-plane permittivity values. Furthermore, comparison with methods measuring the out-of-plane permittivity is difficult because those methods typically do not provide measurement confidence intervals.

2 Applicable Documents See 6.2.

3 Test Specimen The test specimen is an unclad dielectric substrate. The substrate geometry can be either square or circular as long as the substrate extends beyond the diameter $2a$ of the two cylindrical cavity sections as shown in Figure 2. In particular, for the 10 GHz split-cylinder resonator discussed in this method, the dimensions of the substrate should be at least 50.0 mm [1.97 in] in diameter for circular samples or 50.0 mm [1.97 in] on a side for square samples.

Number 2.5.5.13	
Subject Relative Permittivity and Loss Tangent Using a Split-Cylinder Resonator	
Date 01/07	Revision
Originating Task Group High Frequency Resonator Test Method Task Group (D-24c)	

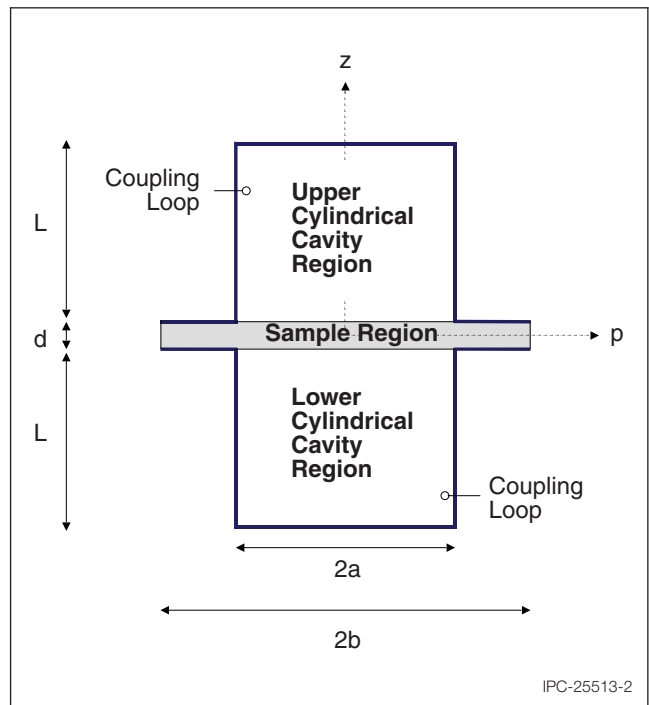


Figure 2 Split-Cylinder Resonator Diagram

Although the dielectric substrate thickness can vary from 0.05 mm to 5.0 mm [0.0020 in to 0.20 in], thin substrates may lead to larger measurement uncertainties, while the dielectric losses in thicker substrates may prevent the split-cylinder fixture from resonating properly. A substrate thickness on the order of 1.0 mm [0.040 in] is typical.

The measurement theory assumes the dielectric substrate has a uniform thickness. Therefore, to reduce the measurement uncertainty, variation and uncertainty in substrate thickness should be minimized. A typical uncertainty in thickness should be no more than 0.02 mm [0.00079 in]. In general, warped samples should also be avoided as these can lead to biases in the calculated values of the relative permittivity and loss tangent.

For the split-cylinder resonator described here, the measurement frequency of the split-cylinder resonator is a function of the relative permittivity and thickness of the substrate. Thicker substrates and higher values of relative permittivity drive the resonant frequency lower, as shown in Figure 6.



IPC-TM-650		
Number 2.5.5.13	Subject Relative Permittivity and Loss Tangent Using a Split-Cylinder Resonator	Date 01/07
Revision		

4 Measurement Apparatus

4.1 Split-Cylinder Resonator The method employs a split-cylinder resonator, which is a cylindrical cavity separated into two halves of equal length, with a dielectric substrate placed in the gap between the two cavity sections. The split-cylinder resonator must be constructed to allow an adjustable, variable gap between the two cavity sections for introduction of the dielectric substrate. Additional details about the construction of a split-post resonator are given in the references described in 6.2. Over the years there have been commercial manufacturers of this fixture.

In order to excite and detect the desired fundamental TE₀₁₁ resonant mode in the split-cylinder resonator, a coupling loop is introduced, through a small hole in the cavity wall, in each of the two cavity regions. The plane of the coupling loop should be parallel to the plane of the sample, in order to allow maximum interaction with the vertical component of the magnetic field. Each of the coupling loops is connected to a coaxial transmission line that is connected to the input port of a network analyzer. To minimize the effect of coupling losses, the distance to which the loops extend radially into each of the cavity sections must also be adjustable. In addition to the fundamental TE₀₁₁ mode, higher modes can be used to extend the measurement frequency. Typical measurements on fused silica with higher mode measurements are shown in Figures 3 and 4.

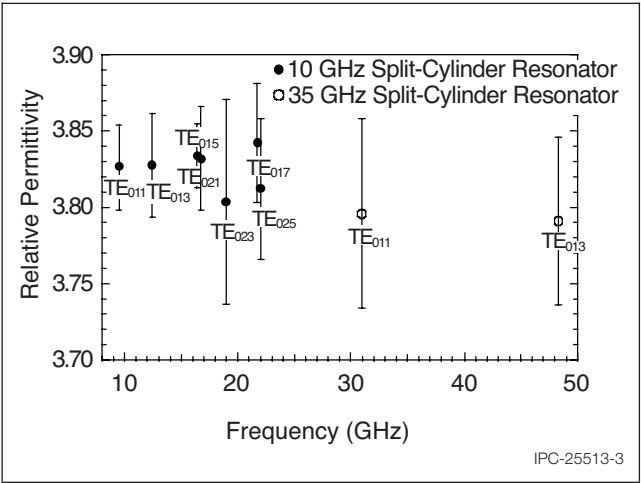


Figure 3 Typical Measurements of the Real Part of the Permittivity using 10 GHz and 35 GHz Split-cylinder Resonators including Measurements with Higher Modes

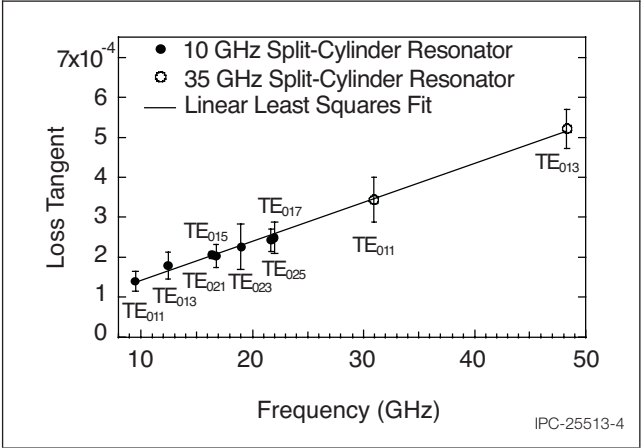


Figure 4 Typical Measurements of the Loss-tangent using 10 GHz and 35 GHz Split-cylinder Resonators including Measurements with Higher Modes

4.2 Network Analyzer A scalar or vector network analyzer is necessary to perform the measurement with the split-cylinder resonator. Commercially available network analyzers operate over various frequency ranges, so care is needed to ensure that the network analyzer covers the necessary frequency range for the particular split-cylinder resonator used.

4.3 Digital Micrometer The dielectric substrate thickness can be measured with a digital micrometer with a minimal resolution of 0.001 mm [0.000039 in].

5 Procedure

- 5.1** Turn on the network analyzer and allow the unit to warm-up and stabilize according to the manufacturer's instructions.
- 5.2** Connect the network analyzer's two input ports to the split-cylinder resonator's coupling loops using coaxial transmission lines.
- 5.3** Measure the thickness of the substrate over several locations using a digital micrometer, and compute the mean substrate thickness.
- 5.4** Determine split-cylinder resonator properties. The length, radius and conductivity of the split-cylinder resonator must be known before the substrate relative permittivity and loss tangent can be calculated. If these variables have not been already determined, the following procedure can be used: