# Measuring Dielectric Properties using Agilent's Materials Measurement Solutions

A wide variety of industries need a better understanding of the materials they are working with to shorten design cycles, process monitoring, and quality assurance. Every material has a unique set of electrical characteristics that are dependent on its dielectric properties. Accurate measurements of these properties can provide scientists and engineers with valuable information to properly incorporate the material into its intended application. A dielectric materials measurement can provide critical design parameter information for many electronics applications. For example, the loss of a cable insulator, the impedance of a substrate, or the frequency of a dielectric resonator can be related to its dielectric properties. More recent applications in the area of aerospace, automotive, food and medical industries have also been found to benefit from knowledge of dielectric properties.

The material evaluation systems that generate these measurements must combine precise measurement instruments, test fixtures that hold the material under test (MUT), and software that calculate and display material parameters. Agilent offers you fast, accurate and often non-destructive solutions.

The measurement instruments, such as network analyzers, impedance analyzers and LCR meters provide accurate measurement results with wide frequency range up to 1.1 THz. Fixtures are available

that are based on coaxial probe, parallel plate, coaxial/waveguide transmission lines, free space and resonant cavity methods. The easy-to-use materials measurement software streamlines the process of measuring complex permittivity and permeability. The table below shows product examples that can be measured by Agilent's material test solutions.

- **Fast, accurate and non-destructive solutions**
- **Wide frequency coverage, up to 1.1 THz**
- **A variety of measurement methods supported**

| Industry | Application/products |
|---|---|
| Electronics | Capacitor, substrates, PCB, PCB antenna, ferrites, absorbers, SAR phantom materials |
| Aerospace/defense | Stealth, RAM (radiation absorbing materials), radomes |
| Industrial materials | Ceramics & composites: A/D and automotive components, coatings<br>Polymers & plastics: fibers, films, insulation materials<br>Hydrogel: disposable diaper, soft contact lens<br>Liquid crystal: displays<br>Other products containing these materials: tires, paint, adhesives, etc. |
| Food & agriculture | Food preservation (spoilage) research, food development for microwave, packaging, moisture measurements |
| Forestry & mining | Moisture measurements in wood or paper, oil content analysis |
| Pharmaceutical & medical | Drug research and manufacturing, bio-implants, human tissue characterization, biomass, fermentation |

## Measurement techniques

There are several measurement techniques that exist for measuring dielectric properties of materials. Users need to verify which technique is appropriate for their MUT. Agilent solutions cover all the measurement techniques.

### Coaxial probe method

The coaxial probe method is best for liquids and semi-solid (powder) materials. The method is simple, convenient, non-destructive and with one measurement. A typical measurement system consists of a network analyzer or impedance analyzer, a coaxial probe and software. Both the software and the probe are included in the Agilent 85070E dielectric probe kit. Depending on the analyzer and probe used, we can measure from 10 MHz to 50 GHz.

The high temperature probe (a) withstands a wide –40 to +200°C temperature range. The large flange allows measurements of flat surfaced solid materials, in addition to liquids and semi-solids. The slim probe (b) allows it to fit easily in fermentation tanks, chemical reaction chambers, or other equipment with small apertures. The performance probe (c) combines rugged, high temperature and frequency performance in a slim design. The probe can be autoclaved, so it is perfect for applications in the food, medical, and chemical industries where sterilization is a must.

### Transmission line method

The transmission line method is a broadband technique for machine-able solids. It puts the MUT inside a portion of an enclosed transmission line.

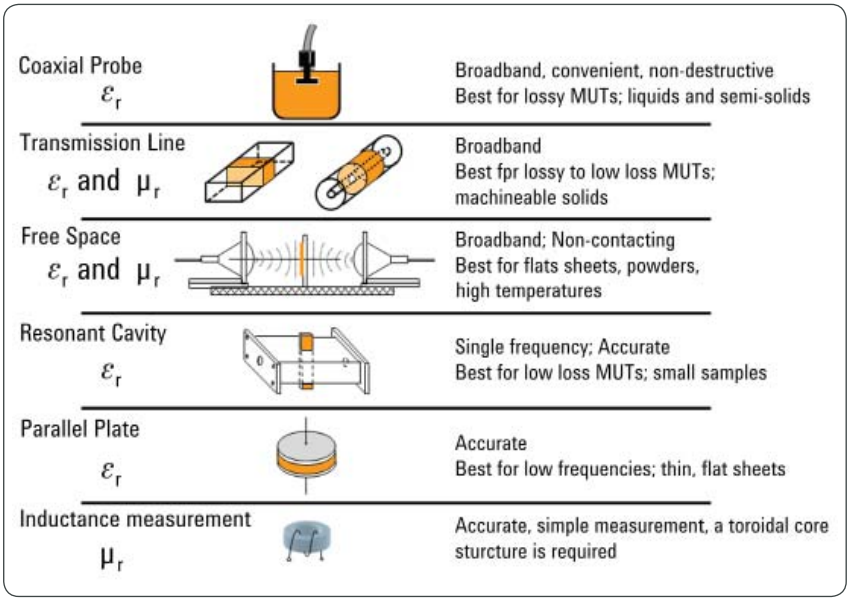



*Figure 1. Materials measurement techniques*

### Free space method

Free space methods use antennas to focus microwave energy at or through a slab of material. This method is non-contacting and can be applied under high temperatures. It is especially useful at mm-wave frequencies.

### Resonant cavity method

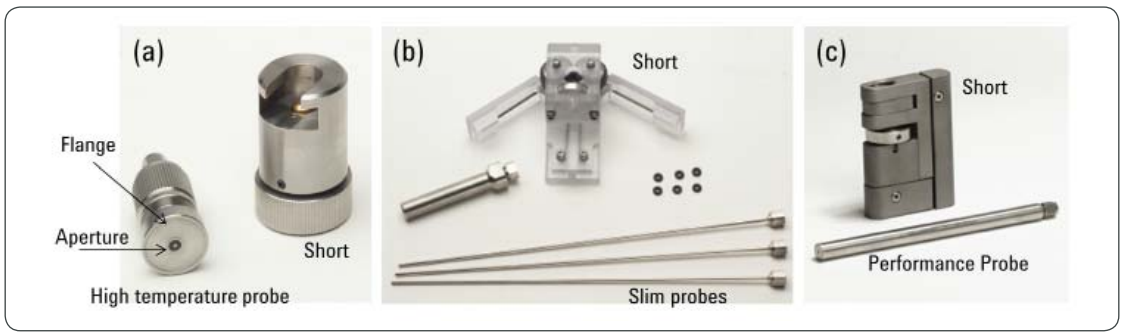
Resonant cavities are high Q structures that resonate at certain frequencies. A sample of the material affects the center frequency and Q factor of the cavity. The permittivity can be calculated from these parameters. Agilent offers 85072A 10 GHz split cylinder resonator, as well as Split post dielectric resonators (SPDR).

### Parallel plate capacitor method

The parallel plate capacitor method involves sandwiching a thin sheet of material between two electrodes to form a capacitor. The method works best for accurate, low frequency measurements of thin sheets or liquids. A typical measurement system using the parallel plate method consists of an LCR meter or impedance analyzer. Agilent offers several test fixtures such as 16451B, 16452A and 16543A depending on material types and applied frequency ranges that can cover up to 1 GHz.

### Inductance measurement method

This method derives the permeability by measuring the inductance of the material (toroidal core). The concept is to wind some wire around MUT and evaluate the inductance with respect to the ends of the wire. The Agilent 16454A magnetic material test fixture provides an ideal structure for single-turn inductor, with no flux leakage when a toroidal core is inserted in it.




*Agilent 85070E dielectric probe kit*

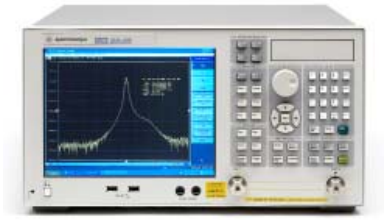
## Measurement systems

Agilent offers a variety of fixtures and measurement instruments that covers many material types. The software is also provided depending on required measurement techniques or instruments. See related literature for more information.

**Test fixtures and instruments**
The lineup of Agilent test fixtures is summarized in Figure 2. See Table 1 for available measurement instruments.

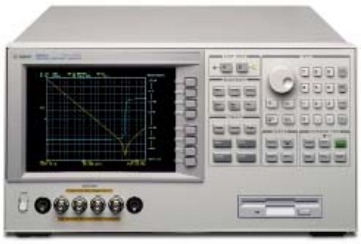
**Agilent network analyzers, up to 1.1 THz**

*PNA family network analyzers*



*ENA series network analyzers*

**4294A precision impedance analyzer, 40 Hz to 110 MHz**



**E4991A impedance/material analyzer, 1 MHz to 3 GHz**

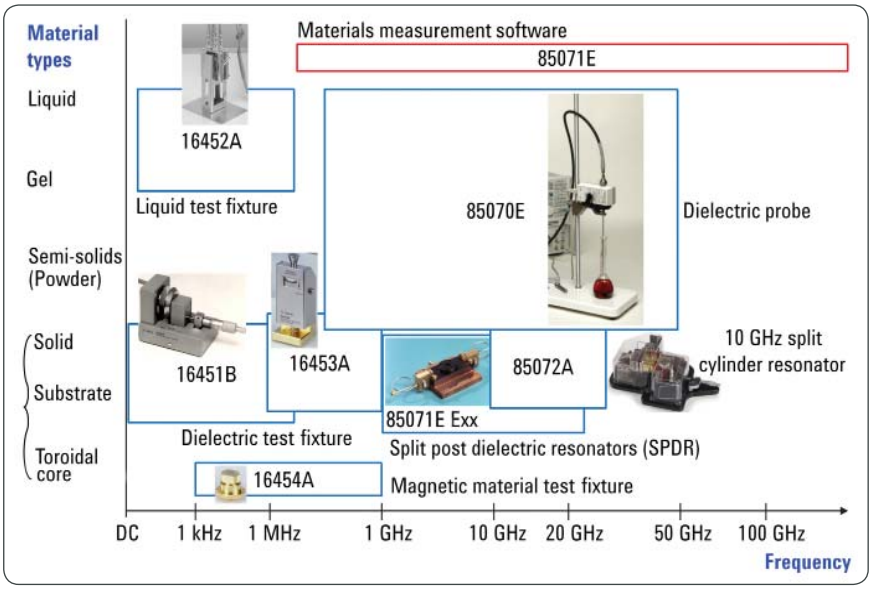



*Figure 2. Agilent materials measurement fixtures*

*Table 1. Agilent test fixtures and instruments*

| | | PNA | ENA | FieldFox | E4991A | 4294A | E4980A | 4285A | |
|---|---|---|---|---|---|---|---|---|---|
| 85070E | Dielectric probe kit | • | • | • | • | | | | Coaxial probe |
| 85071E Exx | Split post dielectric resonators (SPDR) | • | • | • | | | | | Resonant cavity |
| 85072A | 10 GHz split cylinder resonator | • | | | | | | | Resonant cavity |
| 16451B | Dielectric material test fixture | | | | | • | • | • | Parallel plate |
| 16452A | Liquid test fixture | | | | | • | • | • | Parallel plate |
| 16453A | Dielectric material test fixture | | | | • | | | | Parallel plate |
| 16454A | Magnetic material test fixture | | | | • | • | | | Inductance |

**Software**
The Agilent 85071E materials measurement software streamlines the process of measuring complex permittivity and permeability with a network analyzer. The easy-to-use software guides the user through setup and measurement, instantly converting S-parameter network analyzer data into the data format of your choice and displaying the results within seconds. Results can be charted in a variety of formats: $\varepsilon_{r'}$, $\varepsilon_{r''}$, tan δ, $\mu_{r'}$, $\mu_{r''}$, tan $\delta_m$ and Cole-Cole.

A variety of measurement methods and mathematical models are provided to meet most application needs. The free space calibration option provides Agilent's exclusive gated reflect line (GRL) calibration for measuring materials in free space. Arch reflectivity option automates popular NRL arch method for measuring reflections off the surface of a sample. Resonant cavity option offers the highest loss tangent accuracy and resolution.

## Related Literature

*Basics of Measuring the Dielectric Properties of Materials, Application note,* Literature number 5989-2589EN

*Solutions for Measuring Permittivity and Permeability with LCR Meters and Impedance Analyzers, Application note,* Literature number 5980-2862EN

*Split Post Dielectric Resonators for Dielectric Measurements of Substrates, Application note,* Literature number 5989-5384EN

*Agilent 85070E Dielectric Probe Kit, Technical overview,* Literature number 5989-0222EN

*Agilent 85071E Materials Measurement Software, Technical overview,* Literature number 5988-9472EN

*Agilent 85072A 10-GHz Split Cylinder Resonator, Technical overview,* Literature number 5989-6182EN

*Agilent LCR Meters, Impedance Analyzers and Test Fixtures, Selection guide,* Literature number 5952-1430E

## Web Resources

Visit our websites for additional product information.

Materials Test Equipment:
**www.agilent.com/find/materials**

Network Analyzers:
**www.agilent.com/find/na**

Impedance Analyzers and LCR Meters:
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