Agilent 85071E
Materials Measurement Software

Technical Overview

Features of 85071E

- Software automates complex permittivity and permeability measurements.
- Results can be charted in a variety of formats (ε_r', ε_r'', tan δ, μ_r', μ_r'', tan δ_m and Cole-Cole)
- Data is easily shared with other Windows-based programs or through the user programmable Component Object Model (COM) interface.
- A variety of measurement methods and mathematical models are provided to meet most application needs
- **New!** Choose Resonant Cavity Software for the highet loss tangent resolution

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www.agilent.com/find/materials

Agilent Technologies

Automate complex permittivity and permeability measurements with Agilent's 85071E materials measurement software

Measure ε_r* and μ_r* over a wide frequency range

The Agilent Technologies 85071E materials measurement software determines the intrinsic electromagnetic properties of many dielectric and magnetic materials. The complete system is based on a versatile Agilent network analyzer which measures the material's response to RF or microwave energy.

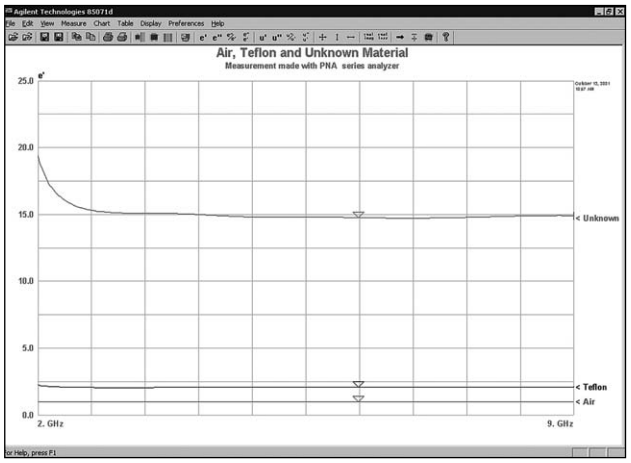

Figure 1. Examine the properties of materials across the RF and microwave frequency spectrum.

The 85071E software controls the network analyzer and calculates the complex permittivity ε_r* (or dielectric constant) and permeability μ_r*, including the loss factor or loss tangent. Results are displayed as a function of frequency, with 1 to 2% accuracy (typical). Depending on the Agilent network analyzer and fixture used, frequencies can extend to 325 GHz.

Display Data to Aid Analysis

The split screen window and markers aid in data analysis. Simply click on a point in the chart or table to activate and move the marker. Charts can be generated in a variety of formats: ε_r', ε_r", tan δ, μ_r', μ_r", tan δ_m, and Cole-Cole.

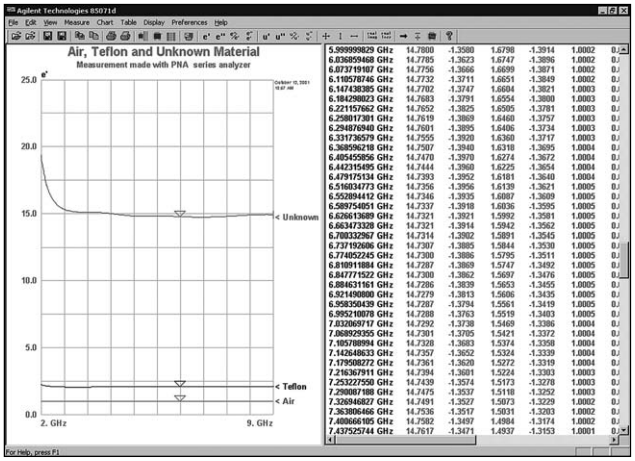

Figure 2. Display data in chart form, table form, or both!

Connect to other programs

Data charts and tables can easily be copied and pasted into any Windows-based application for further analysis or report generation.

The component object model (COM) interface allows the measurement to be setup, triggered and read from a user written program. This is particularly valuable for analyzing material changes over time. Example Visual Basic® and C++ projects are included to aid program development.

Measurement Methods

Transmission Line Method

Coaxial airlines or rectangular waveguide transmission lines are used as sample holders. The transmission line method works best for materials that can be precisely machined to fit inside the sample holder. The 85071E features an algorithm that corrects for the effects of air gap between the sample and holder, considerably reducing the largest source of error with the transmission line technique.

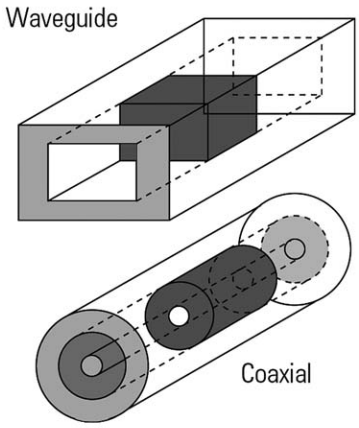

Figure 3. Simple coaxial or waveguide transmission lines hold the samples of material under test.

Free Space Method

In this method, materials are placed between antennas for a non-contacting measurement. The free space method works best for large flat solid materials, but granular and powdered materials can also be measured in a fixture. It is very useful for many applications such as non-destructive testing, measuring materials that must be heated to very high temperatures, or measuring a large area of material that is non-uniform such as honeycomb or a composite. Calibration and gating techniques performed in the network analyzer can be used to reduce measurement errors.

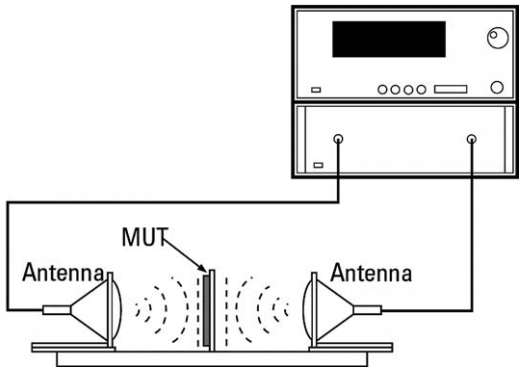

Figure 4. Antennas direct beams of microwave energy at or through a material, without enclosing it in a fixture.

Free Space Calibration (Option 100)[1]

The Free Space Calibration Option increases ease of use and reduces the costs associated with TRM and TRL calibration methods. The Gated Reflect Line (GRL) calibration technique converts a coaxial/waveguide 2-port calibration into a full 2-port freespace calibration. Use of this option requires an 8510 or a PNA Series network analyzer with the time domain option, an appropriate freespace fixture and a metal calibration plate. This option also includes a gated isolation/response calibration, which reduces errors from diffraction effects at the sample edges, and multiple residual reflections between the antennas.

Accurate free space measurements are now possible without expensive spot focusing antennas, micro positioning fixturing or direct receiver access. The software automatically sets up all the free space calibration definitions and network analyzer parameters, saving engineering time. In the PNA, additional ease and timesaving is provided with the use of ECal, electronic calibration, which features a guided calibration wizard that steps you through a fast and easy calibration process.

1. Requires Agilent 8510C, PNA or PNA-L series network analyzer with Time Domain (Option 010) installed.

Mathematical Models

The 85071E has six different algorithms to choose from, each with specific benefits:

The traditional method, as described by Nicolson and Ross, is best for magnetic materials such as ferrites and absorbers. It calculates both ε_r^* and μ_r^* (including loss) from a two-port measurement of a single sample, producing results quickly and easily.

The 85071E also includes two additional two-port algorithms for non-magnetic materials ($\mu_r^*=1$). These models do not suffer from discontinuities at frequencies where the sample length is a multiple of half-wavelengths and are best for long, low-loss materials.

While the two-port algorithms are best for most solid materials, one-port algorithms provide a simple calibration and measurement and are better suited to measurements of liquids and powders. For example, a shorted waveguide can be turned on end and filled with a material for a one-port measurement. One-port fixtures are also better suited for high-temperature measurements where one end of the fixture can be heated, while cooling mechanisms at the other end protect the network analyzer.

Although one-port fixtures are usually terminated with a short circuit, the 85071E also accommodates an arbitrary termination which produces more reliable results for thin samples.

Software models

Model name	Measured S-parameters	Number of samples	Optimum sample thickness[1]	Results	Comments
Refl/Tran μ **&** ε (Nicolson-Ross)	S_{11}, S_{21}, S_{12}, S_{22} (or S_{11}, S_{21})	1	$\lambda_g/4$	ε_r^* & μ_r^*	Fast, but has $n\lambda/2$ discontinuities. Best for magnetic, short or lossy MUTs
Refl/Tran ε (NIST Precision)	S_{11}, S_{21}, S_{12}, S_{22}	1	$n\lambda_g/2$	ε_r^*	Accurate, no discontinuities. Best for long, low-loss MUTs
Refl/Tran ε (Fast)	S_{21}, S_{12}, (or S_{21})	1	$n\lambda_g/2$	ε_r^*	Similar to precision but faster and better for lossy MUTs Best for long, low-loss MUTs
Refl ε (Short-backed)	S_{11}	1	$\lambda_g/2$	ε_r^*	Best for liquids or powders
Refl ε (Arbitrary-backed)	S_{11}	1	$\lambda_g/2$	ε_r^*	Best for thin films
Refl μ_r & ε_r (Single/Double)	S_{11}	1[2]	$\lambda_g/4$[3]	$\varepsilon_r^*$and μ_r^*	Best for liquids or powders

1. Where: $1g = \frac{1}{\sqrt{\frac{\varepsilon_r'\mu_r'}{\lambda_o} - \frac{1}{\lambda_c}}}$ λ_c = cutoff frequency (omit for coaxial) and λ_o = frequency (in GHz)

2. This model requires two measurements of one sample in different positions backed by a short, or two samples backed by a short, each measured once.
3. $\lambda g/2$ for lower loss materials

Performance Characteristics

Specifications describe the warranted performance over the temperature range 0 to 55 °C. Supplemental characteristics are intended to provide information useful in applying the instrument, by giving typical but non-warranted performance parameters. These are denoted as “typical,” “nominal,” or “approximate.”

Frequency range (typical)

100 MHz to 325 GHz depending on network analyzer, fixture and material.[1]

Accuracy (typical)

1 to 2 percent

Transmission line fixtures

Coaxial fixtures (beadless airlines) are broadband but require a sample shaped into a flat-faced torus. Waveguide fixtures are band-limited but operate at higher frequencies and accept a simpler rectangular shape.

Samples must completely fill the cross section of the transmission line without gaps at the fixture walls. Faces at either end must be flat, smooth and perpendicular to the long axis.

Free space systems

Large, flat, thin, parallel-faced samples are placed between antennas and measured under free space conditions. Antennas should maintain a planar “far-field” wavefront to the sample.[2]

Material under test assumptions

Material is homogeneous (uniform composition) with no layers.[3] Non-isotropic (uniform orientation) materials can be measured in waveguide.

Software Menu Items

File

Save or recall measurement setups or previous measurement results. Print copies of the measurement results in a tabular or graphical format.

Edit

Copy the measurement results to the clipboard. Either graph or the tabular listing can be copied. This allows your measurements results to be pasted into other applications.

View

Select what you want to view. Selections include the toolbar, status bar, table of the measurement data and chart of the measurement data.

Measure

Trigger a measurement; recalculate without re-measuring the MUT; set measurement model; define sample holder; set measurement attributes and perform a GRL calibration.

Chart

Select the format to be displayed on the chart. Choices include ε_r', ε_r'',tan δ, μ_r', μ_r'', tan δ_m and Cole-Cole. Set scale factors or “autoscale.” Select from linear, semi-log, or log-log representations.

Table

Choose between a tabular formatting of real and imaginary or real and tan δ.

Display

Display current measurement data; save/display up to 3 memory traces; compare data to reference trace with trace math. Turn the marker on or off.

Preferences

Select your preferences of fonts, colors, and annotations used to plot and list the measurement data.

Help

On line help including the product manual.

ToolBar

Provides single click access to the most important menu items.

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1. Minimum frequency is set by the maximum practical sample length (L): f (in GHz) > $\frac{1}{\sqrt{\varepsilon_r'\mu_r'}} \frac{30\text{ cm}}{L(\text{in cm})} \frac{20}{360}$
2. Antenna should be placed $\approx 2d^2/\lambda$ from the sample, where d is the larger of the antenna or sample diameter.
3. If the material is not homogeneous through the length of the sample (i.e., layers), the reflection from the front (S_{11}) and back (S_{22}) face will be different and will lead to a potentially erroneous result. If the material is not homogeneous across the face of the sample, the result is an average value over the cross section that is exposed to the EM field (weighted by the intensity).

Additional Measurement Methods

NRL Arch Free Space Method

First developed by the U.S. Naval Research Lab, the NRL arch measurement method is a useful technique to test angular dependent absorptive characteristics of a material. The typical setup involves a network analyzer connected to two horn antennas fixed to an arch armature above (or below) a flat piece of the material under test. One antenna operates as the transmitting antenna while the second one receives the reflected signal to complete a one-port measurement. Sample should be in "far field."

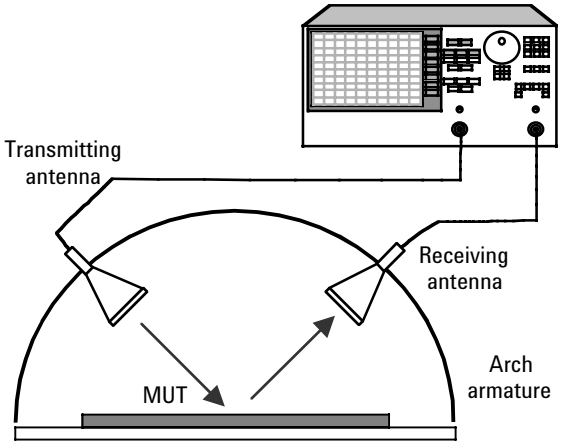

Figure 5. In the NRL arch method, one antenna transmits energy onto the MUT and the second antenna receives the reflected portion.

Arch Reflectivity Software[1] (Option 200)

Now you can automate your NRL arch measurements with the new Arch Reflectivity Software addition.

Option 200 provides a separate software program that automates NRL arch measurements. The program guides you through the complete process of setup, calibration and measurement of material absorption in dB[2]. Measurements are displayed in both a graphical and tabular form – with up to four measurements displayed simultaneously for comparison. The software includes markers to aid in measurement analysis, and complete measurement results and setup can be saved and recalled. Also, data can be saved in a spreadsheet compatible file format or copied into other applications for further analysis.

Agilent's Arch Reflectivity Software makes it possible to instantly update any NRL arch system to state-of-the-art hardware and measurement techniques.

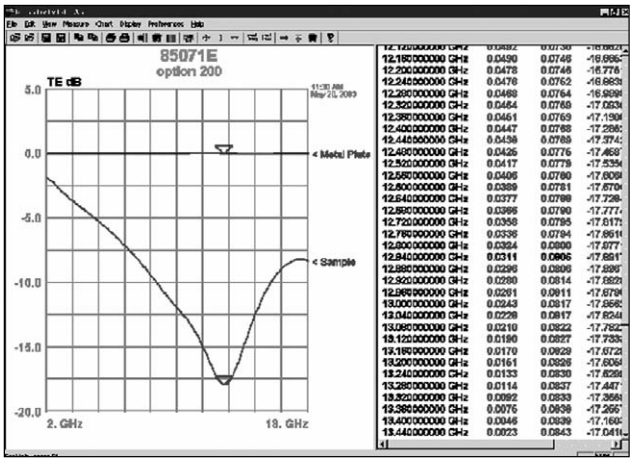

Figure 6. Example of arch reflectivity measurement results.

1. Requires Agilent 8510C, PNA or PNA-L series network analyzer with Time Domain (Option 010) installed.
2. This software program does not calculate permittivity.

Additional Measurement Methods *continued...*

Resonant Cavity Method

Choose the Resonant Cavity method, for thin films, substrate materials, and other low loss materials. The resonant cavity method uses a network analyzer to measures resonant frequency and Q of a resonant cavity fixture, first empty and then loaded with the sample under test. Permittivity can then be calculated from these measurements, knowing the volume of the sample, and some other parameters about the resonant cavity. Because it is a resonant method, only one frequency point is reported. However, it is much more sensitive and has better resolution than the other techniques. Typical resolution for this method is 10^{-5} where the broadband methods is 10^{-2}

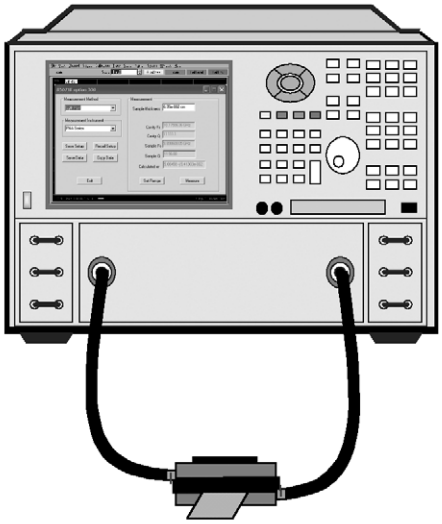

Figure 7. Resonant Cavity connected between ports.

New! Resonant Cavity Software[1] (Option 300)

Agilent's new Resonant Cavity software controls an Agilent vector network analyzer to measure the resonant frequency of the loaded and unloaded resonant cavity. A least squares circle fitting technique is used to calculate Q, which uses both magnitude and phase information and is more repeatable than other Q calculation methods. The software then calculates ε_r', ε_r'' and loss tangent and displays them in it's easy to use interface.

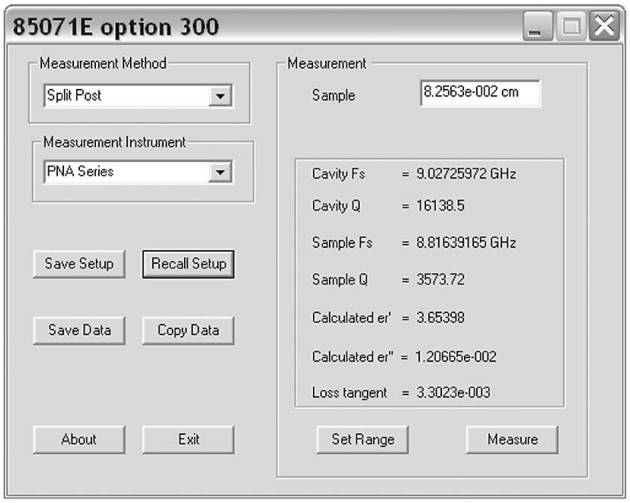

Figure 8. Resonant Cavity Software User Interface

Resonant Cavity Software has a COM applications interface, allowing users to automate measurements easily.

Resonant Cavity Software supports Split Post Dielectric Resonators from QWED. These resonators are high quality and are available in frequencies from 1 GHz to 20 GHz. For more information, please email **info@qwed.com.pl** or visit **http://www.qwed.com.pl/hardware.html**

Resonant Cavity Software also supports ASTM D2520 standard resonators.

1. Requires Agilent PNA or PNA-L series network analyzer.

Ordering Information

85071E
Materials Measurement Software

Required, but not included:
- Network analyzer (see compatible network analyzers)
- PC (see PC requirements)
- Appropriate fixture for chosen measurement method

Required Security Key (User must choose one):
- Option UL7 Parallel Software Security Key
- Option UL8 USB Software Security Key

Option 100
Free Space Calibration Option: Provides Gated Reflect Line calibration technique for free space measurement method. Only compatible with Agilent 8510C, PNA and PNA-L Series network analyzers with Time Domain Option installed.

Option 200
Arch Reflectivity Software: Provides a separate software program that automates the use of any NRL Arch measurements. Only compatible with Agilent 8510C, PNA and PNA-L Series network analyzers with Time Domain Option installed.

Option 300
Resonant Cavity Software: Provides a separate software program that automates the resonant cavity measurement technique. Only compatible with Agilent PNA and PNA-L network analyzers.

Upgrades

85071EU-071
Upgrade from any older version of 85071 software

85071EU-100
Add Free Space calibration option to existing software

85071EU-200
Add Arch Reflectivity option to existing software

85071EU-300
Add Resonant Cavity option to existing software

Compatible Network Analyzers

All PNAand PNA-L Series network analyzers [1,2,3]
All ENA Series network analyzers
8753ET/ES
8719ET/ES
8720ET/ES
8722ET/ES
8712ET/ES
8714ET/ES
8510C[1,2]

Older Agilent network analyzers may also be compatible. Please download a free trial demo from **www.agilent.com/find/materials** to determine compatibility.

PC Requirements

- Windows® 98, 2000, ME, XP, or Windows NT® 4.0[4]
- CD drive to load software
- Software can run directly on PNA series network analyzers or interfaced over LAN. All other network analyzers require a GPIB interface card with compatible driver (Agilent SICL or National Instruments 488.2M)

1. Required for Option 100, Free Space Calibration.
2. Required for Option 200, Arch Reflectivity Software.
3. Required for Option 300, Resonant Cavity Software.
4. Windows NT 4.0 requires Option UL7 Parallel Security Key.

Ordering Information *continued...*

Transmission Line Method Sample Holders

Waveguide

Agilent 11644A Series waveguide calibration kits contain a 1/4 wavelength line and a straight section which can be used as sample holders. There are many third-party suppliers as well. Contact Agilent for information on choosing appropriate waveguide sample holders.

Coaxial

Agilent 8505x Series verification kits contain airlines that can be used as sample holders. There are many third party suppliers as well. Contact Agilent for information on choosing appropriate coax sample holders.

Antennas and Fixtures for Free Space and NRL Arch Methods

Contact Agilent for information on third-party suppliers of free space antennas and fixtures.

Cables and Adapters

Cables and adapters may also be needed to attach sample holders or antennas to the network analyzer. Agilent offers a wide variety of cables and adapters. For more information, visit:
www.agilent.com/find/accessories

Calibration Kits

Electronic Calibration (ECal) modules are highly recommended, especially for the PNA Series network analyzer with the 85071E-100 Free Space Calibration Option. For more information about ECal, visit **www.agilent.com/find/ecal**. Agilent also offers a wide variety of mechanical coax and waveguide calibration kits. Contact Agilent for more information and assistance to choose an appropriate calibration technique.

Free Trial Demo

Evaluate a demo version of 85071E Materials Measurement Software for up to two weeks. Visit the Agilent Technologies Web site at **www.agilent.com/find/materials** to download this demo program.

For more information on materials measurement products such as our Dielectric Probe kit, visit us at **www.agilent.com/find/materials**

Key Web Resources

Materials measurements:
www.agilent.com/find/materials

Network analyzers:
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Electronic Calibration (ECal):
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Agilent Technologies' Test and Measurement Support, Services, and Assistance
Agilent Technologies aims to maximize the value you receive, while minimizing your risk and problems. We strive to ensure that you get the test and measurement capabilities you paid for and obtain the support you need. Our extensive support resources and services can help you choose the right Agilent products for your applications and apply them successfully. Every instrument and system we sell has a global warranty. Two concepts underlie Agilent's overall support policy: "Our Promise" and "Your Advantage."

Our Promise
Our Promise means your Agilent test and measurement equipment will meet its advertised performance and functionality. When you are choosing new equipment, we will help you with product information, including realistic performance specifications and practical recommendations from experienced test engineers. When you receive your new Agilent equipment, we can help verify that it works properly and help with initial product operation.

Your Advantage
Your Advantage means that Agilent offers a wide range of additional expert test and measurement services, which you can purchase according to your unique technical and business needs. Solve problems efficiently and gain a competitive edge by contracting with us for calibration, extra-cost upgrades, out-of-warranty repairs, and onsite education and training, as well as design, system integration, project management, and other professional engineering services. Experienced Agilent engineers and technicians worldwide can help you maximize your productivity, optimize the return on investment of your Agilent instruments and systems, and obtain dependable measurement accuracy for the life of those products.

Agilent Open

www.agilent.com/find/open
Agilent Open simplifies the process of connecting and programming test systems to help engineers design, validate and manufacture electronic products. Agilent offers open connectivity for a broad range of system-ready instruments, open industry software, PC-standard I/O and global support, which are combined to more easily integrate test system development.

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