

N1500xA Material Measurement Software

Features



N15001A
Transmission
line and free



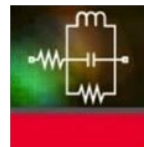
N15002A
Arch reflectivity



N15003A
Resonant cavity
for SPDR &
85072A



N15004A
Coaxial probe



N15005/6A
Parallel
Plate/Inductance



N15007A
Resonant cavity
for SCR

- The software automates complex permittivity and permeability measurements
- Runs on Windows 10 and 11
- Download a free trial from our website

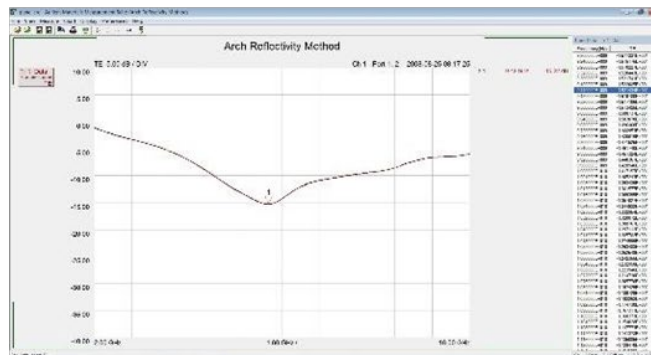
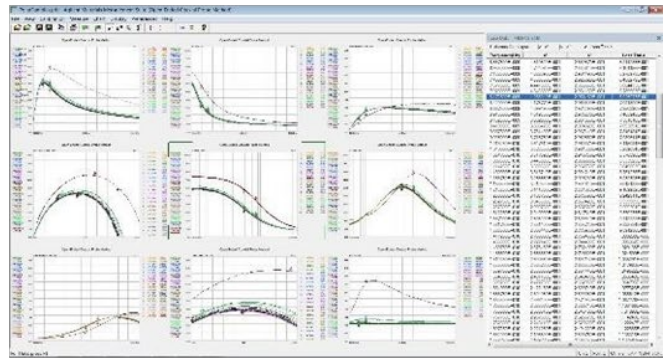


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Automate Complex Permittivity and Permeability Measurements with Keysight's Materials Measurement Software Suite

Measure ϵ_r^* and μ_r^* Over a Wide Frequency Range

With Keysight N1500A materials measurement software suite, you can determine the intrinsic electromagnetic properties of many dielectric and magnetic materials. The complete system is based on a versatile Keysight network analyzer which measures the material's response to RF or microwave energy. The N1500A software controls the network analyzer and calculates results. Depending on the Keysight network analyzer and sample holder used, frequencies can extend from the mid-MHz to the low THz.

Powerful Features

- Multiple channel and port selections provide maximum flexibility when setting up network analyzers with up to four ports.
- Multiple charts and traces aid in data analysis. Depending on method option selected, data can be displayed in a variety of formats:
 - Permittivity: ϵ_r' , ϵ_r'' , $\tan \delta$, Cole Cole
 - Permeability: μ_r' , μ_r'' , $\tan \delta \mu$
 - S-parameters: log mag, linear mag, phase, unwrapped phase, group delay, smith chart, polar chart, real, imaginary, and SWR
 - Trace math functions: +, -, *, /, mean and standard deviation
 - Trace data pane: displays the active data trace in tabular format

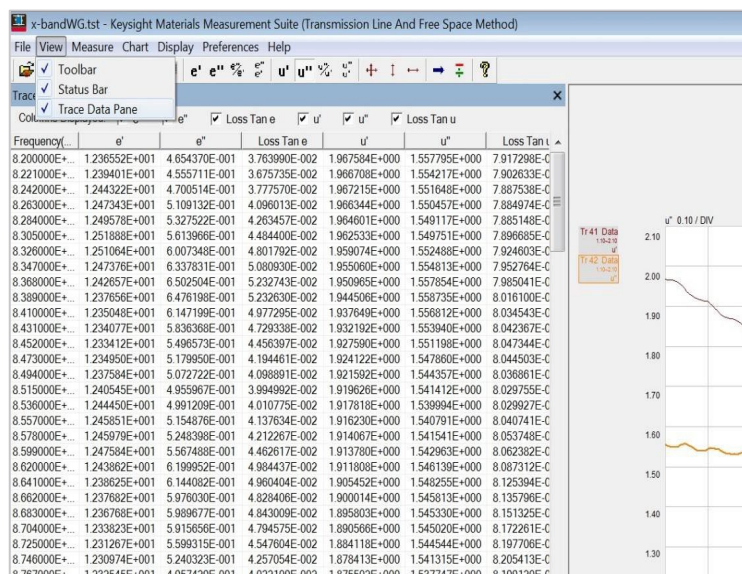


Figure 1. Configurable trace data pane allows you to choose if and where it is displayed and which data columns to include.

- Markers with reference and delta functions and rubberband zoom scaling allow close inspection of critical data.
- Offline mode allows software to run on a PC without being connected to an instrument. Free up shared network analyzer resources by taking your data analysis back to your desk, or wherever you want!
- S-parameter import and save
- Measurement report captures trace and tabular data, equipment used, sample description, user name, date and more in a professionally formatted document ready to print, save, or send electronically in an Adobe Acrobat (.pdf) file.

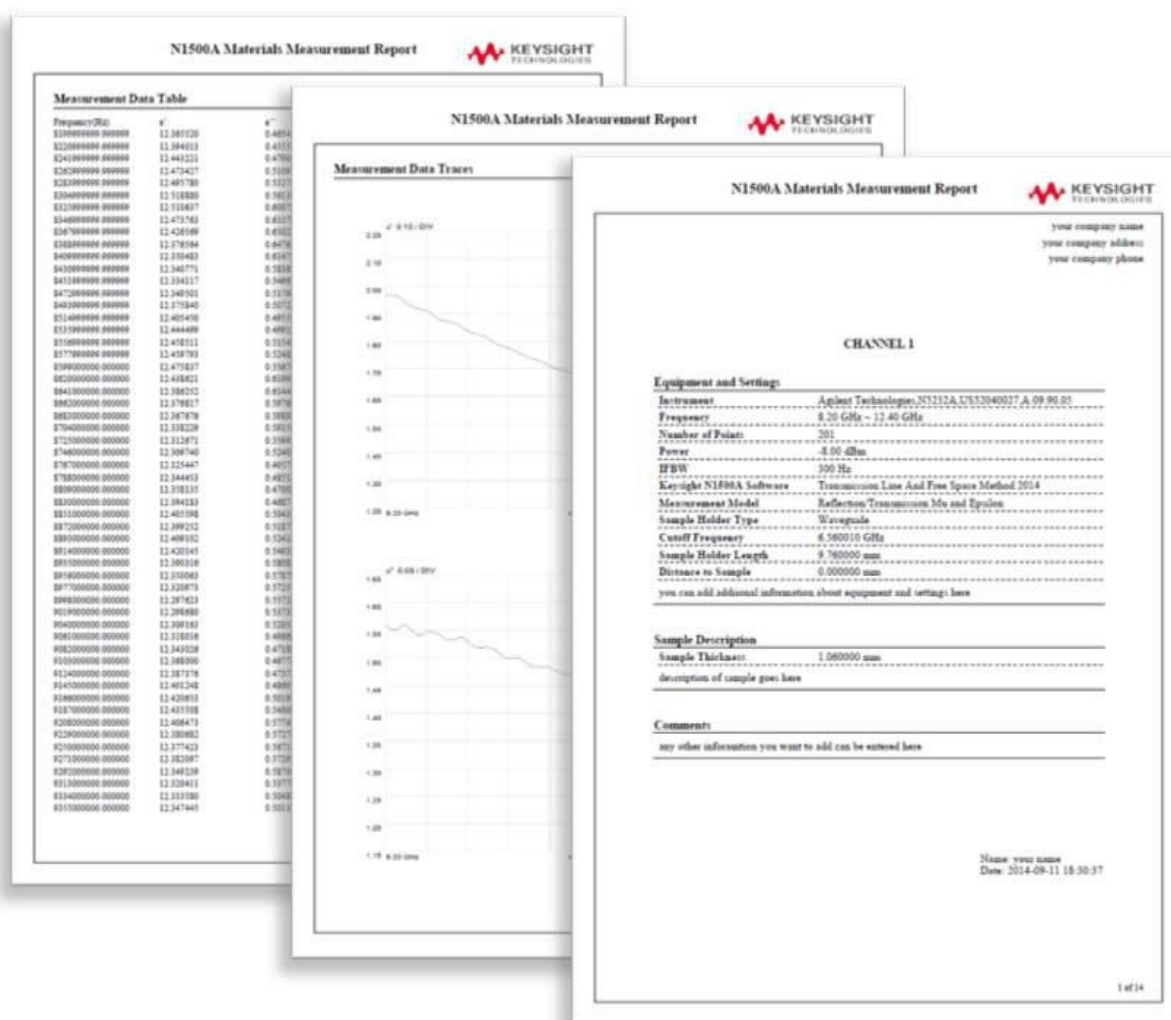


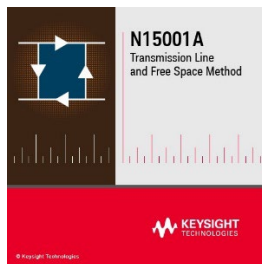
Figure 2. Measurement reports

Connect to Other Programs

Data can also be saved in a variety of formats to bring into other programs for reporting or further data analysis. An application programmable interface (API) allows the measurements to be set up, triggered and read from a user written program.

Measurement Method Software

Keysight offers a variety of measurement methods to meet the needs of most materials under test with N15001A through N15007A. Each method has its own strengths and limitations that make it more or less useful for a particular application.



N15001A Transmission Line and Free Space Method

The sample is placed in a guided transmission line such as a coaxial airline or waveguide straight section, or suspended in free space between two antennae. Several algorithms to calculate permittivity and permeability from S-parameter measurements are available to choose from.

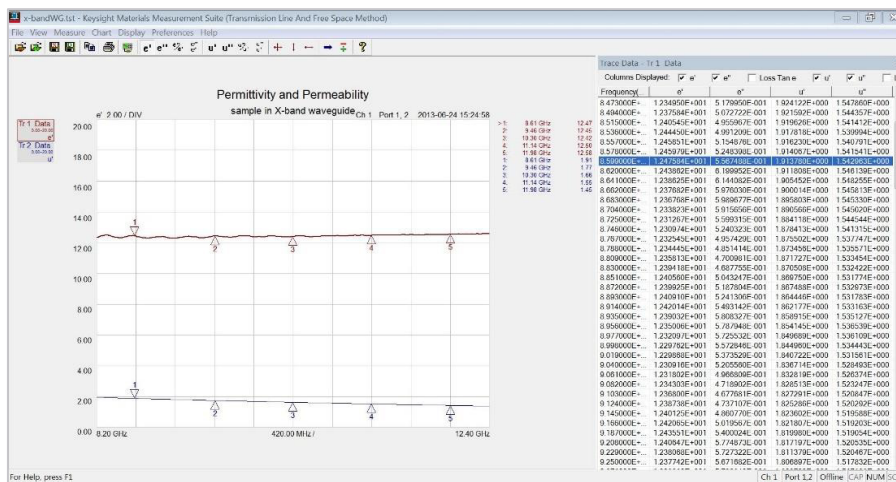


Figure 3. Example of transmission line measurement results.

Transmission Line

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 N15001A includes an algorithm that corrects for the effects of air gap between the sample and holder, reducing the largest source of error with the transmission line technique.

In addition, N15001A Transmission line offers measurement uncertainty for Nicholson-Ross-Weir (NRW) when operates with PNA/PNA-X families of VNA. The VNA requires S93015A/B Real-time S-parameter and Power Measurement Uncertainty. It supports both waveguide and coaxial type. The uncertainty computation takes into account of S-Parameter measurement uncertainty, mechanical dimension tolerances of the sample holder, and sample thickness. This feature is very important for measurement results' integrity and providing highest confident level.

Typical Transmission Line System Configuration

- Keysight network analyzer
- Waveguide or coaxial transmission line for sample holder
- Waveguide or coaxial calibration kit to match sample holder connectors
- A pair of test port cables
- Adapters as required to connect cables to network analyzer and sample holder

Free Space

In this method, materials are placed between two antennae 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 a honeycomb or a composite.

Typical Free Space System Configuration

- Keysight network analyzers
- Free space fixture consisting of a pair of horn antennae, sample holder, and metal plate for calibration.
- The antenna should be placed appropriately ($2d^2 / \lambda$) from the sample, where d is the larger antenna aperture dimension.
- Waveguide or coaxial calibration kit to match the horn antenna input connector.
- A pair of test port cables to reach from network analyzer ports to the free space fixture (not required for millimeter-wave systems where horns are usually connected to millimeter-wave frequency extender modules).
- Adapters as required to connect cables to network analyzer and sample holder.

Powerful Free Space Calibration and Gating Techniques

Gated isolation/ response calibration reduces errors from diffraction effects at the sample edges, and multiple residual reflections between the antennas. Gated reflect line (GRL) calibration makes accurately calibrating in free space fast and easy. A software wizard automatically sets up all the free space calibration definitions and network analyzer parameters, saving engineering time. It reduces costs associated with TRM and TRL calibration methods by eliminating the need for micro antennae positioners or direct receiver access.

There are now two ways to perform GRL calibration. The original 2 tier GRL calibration technique converts a previously saved full 2-port coaxial or waveguide calibration into a full 2-port free space calibration by measuring two additional standards, the empty free space fixture and a metal plate. With 1 tier GRL cal, a waveguide or coaxial cal is not required before the metal plate and empty fixture measurements. Because 1 tier GRL cal requires a longer alias free time domain span, it is best suited for set ups that don't have long cables, when the frequency span is not extremely wide, or a large number of points is not desired. GRL calibration requires a network analyzer with full S-parameter (S_{11} , S_{21} , S_{12} , S_{22}) capability and time domain option. An appropriate free space fixture with metal calibration plate is also needed.

Mathematical Models

N15001A has nine different algorithms to choose from, each with benefits for different materials and applications. The reflection transmission model 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. There are 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 like the Nicholson-Ross model and are best for long, low-loss materials. The two polynomial fit models can smooth out the effects of measurement error due to noise and mismatch but are not suitable for materials that have sharp narrow band responses.

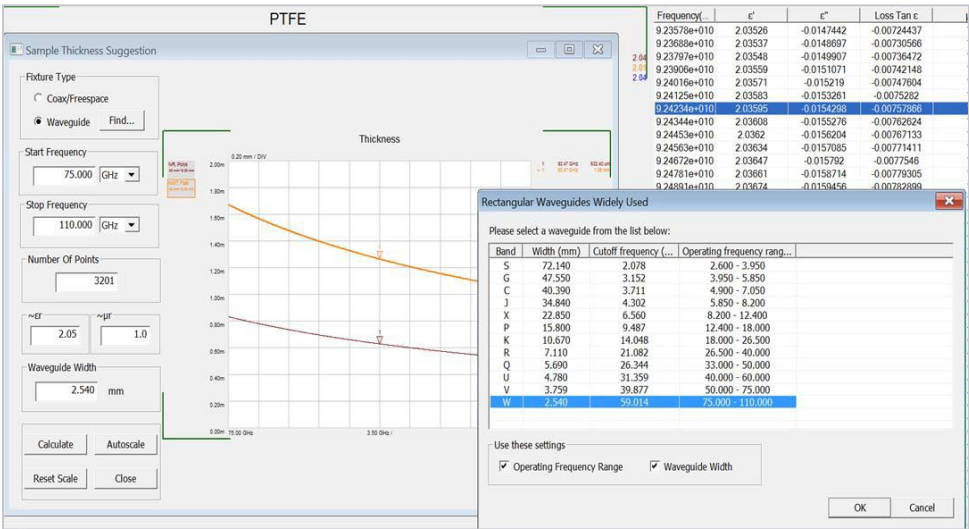
While the two-port algorithms are best for most solid materials, one-port algorithms provide a simple calibration and measurement and hence can be better suited to measurements of liquids and powders. For example, a shorted waveguide can be turned on end vertically and filled with a material for a one-port 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 N1500A-001 also accommodates an arbitrary termination which produces more reliable results for thin samples.

N15001A	Alternate	S-Parameters Measured	Result	Description	References
Reflection/ Transmission Epsilon Mu and Epsilon	Nicholson-Ross-Weir, NRW	S11, S21, S12, S22	ϵ_r, μ_r	Originally developed by Nicholson and Ross, and later adapted to automatic network analyzers by Weir to calculate permittivity and permeability from transmission and reflection coefficients. Can have discontinuities for low loss samples with thickness of $> \frac{1}{2}$ wavelength. Best for magnetic materials such as ferrites and absorbers.	AM. Nicolson and G. F. Ross, "Measurement of the intrinsic properties of materials by time domain techniques," IEEE Trans. Instrum. Meas., IM-19(4), pp. 377-382, 1970. W.W. Weir, "Automatic measurement of complex dielectric constant and permeability at microwave frequencies," Proc. IEEE vol. 62 pp.33-36, Jan 1974
Reflection/ Transmission Epsilon Precision	NIST Precision	S11, S21, S22	ϵ_r	Developed by NIST to calculate permittivity from transmission and reflection coefficients. Best for longer samples of low-loss dielectric materials.	Improved Technique for Determining Complex Permittivity with the Transmission/Reflection Method, James Baker-Jarvis et al, IEEE transactions on microwave Theory and Techniques vol 38, No. 8 August 1990.
Transmission Epsilon Fast	Fast Transmission	S21, S12	ϵ_r	An iterative technique that estimates permittivity and then minimizes the difference between the S-parameter value calculated from that permittivity and the measured values until the error is less than the expected system performance. Uses only transmission parameters S21, S12, or the average of S21 and S12. Best for longer samples of low-loss dielectric materials or systems with significant reflection error.	Not Published
Polynomial Fit Reflection/ Transmission Mu and Epsilon	Poly Fit, Bartley	S11, S21, S12, S22	ϵ_r, μ_r	Uses an iterative technique to fit measured S-parameters to a polynomial, incrementing the order of the polynomial until the error is less than the expected system performance. Best for magnetic samples. Not recommended for meta or left-handed materials.	P. G. Bartley, and S. B. Begley, "A New Technique for the Determination of the Complex Permittivity and Permeability of Materials Proc. IEEE Instrument Meas. Technol. Conf., pp. 54-57, 2010.
Polynomial Fit Transmission Epsilon	Poly Fit, Bartley	S21, S12	ϵ_r	Uses an iterative technique to fit measured S-parameters to a polynomial, incrementing the order of the polynomial until the error is less than the expected system performance. Best for magnetic samples. Not recommended for meta or left-handed materials.	P. G. Bartley, and S. B. Begley, "A New Technique for the Determination of the Complex Permittivity and Permeability of Materials Proc. IEEE Instrument Meas. Technol. Conf., pp. 54-57, 2010.

N15001A	Alternate	S-Parameters Measured	Result	Description	References
Stack Transmission Mu and Epsilon	Stack Two Transmission	S21, S12 (2 samples)	ϵ_r, μ_r	An iterative technique that uses two transmission measurements. One measurement is of the sample which optionally may be backed by a known dielectric. The second is of the sample, backing, and another known dielectric. The model is useful for free space measurements. It requires a full 2-port or a two-port transmission resp/isol cal.	Not Published
Reflection Only Epsilon Short-Backed	Short Backed	S11	ϵ_r	An iterative technique that minimizes the difference between the measured and calculated reflection coefficient of a material backed by a short. The idea of measuring a material backed by a short was published by Von Hippel. Although, Von Hippel uses tables to determine the value of permittivity instead of iteration.	A. R. Von Hippel, Ed. Dielectric Materials and Applications, John Wiley and Sons, New York, 1954)
Reflection Only Epsilon Arbitrary-Backed	Arbitrary Backed	S11	ϵ_r	An iterative technique that minimizes the difference between the measured and calculated reflection coefficient of a material backed by a separately measured backing. This model is an extension of the method proposed by Von Hippel. It is useful when the material is electrically short such that the voltage across the material is effectively zero when backed by a short.	A. R. Von Hippel, Ed. Dielectric Materials and Applications, John Wiley and Sons, New York, 1954)
Reflection Only Mu and Epsilon Single/Double Thickness	Single/Double Thickness	S11 (2 samples)	ϵ_r, μ_r	Uses two reflection coefficient measurements to calculate S11 and S21 of the material. The measurements are a sample and a sample that is twice the length of the original. After doing so the Nicolson-Ross model is used to determine the material properties.	Not Published

Sample Thickness Calculator

This utility provides you with a suggested thickness for your sample, given an estimate of the sample's electromagnetic properties and measurement frequency range. Electrical lengths of $\frac{1}{4}$ and $\frac{1}{2}$ wavelength are graphed over frequency so you can optimize for different models. Markers can be added to target specific frequencies of interest. **Figure 4.** Sample thickness calculator



Discontinuity Detector

When measuring low loss samples with a thickness of more than $\frac{1}{2}$ wavelength using the Nicholson Ross Weir model, discontinuities can appear in the trace. The discontinuity detector calculates where this will occur and highlights that portion of trace, giving you the information you need to determine whether or not a response is a true response of your material.

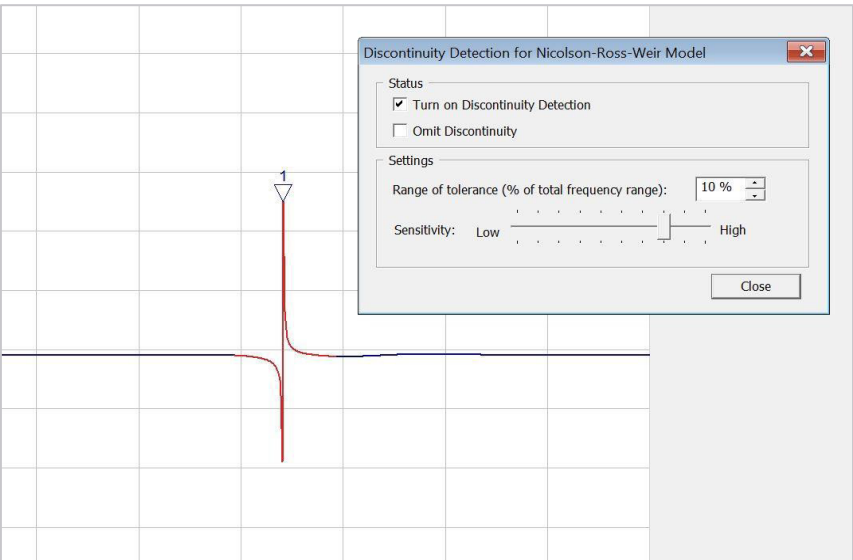


Figure 5. Sample thickness calculator

De-Embedding

The screenshot shows the 'Measurement Description' dialog box with the 'Sample Holder' tab selected. The 'Gap Correction - waveguide' sub-tab is also active. The 'Deembed' checkbox is checked. The 'Sample holder' section has 'Waveguide' selected. The diagram at the bottom illustrates the sample holder layout with four segments: 'Distance to Sample' (white), 'Port 1 Thickness' (yellow), 'Sample Thickness' (grey), and 'Port 2 Thickness' (red). The total length is labeled 'Sample holder length'.

Parameter	Value
Sample holder length	0.383
Distance to sample	0
Sample thickness	0.0375
Port 1 thickness	0
Port 2 thickness	0.06
Port 1 permittivity	1
Port 2 permittivity	4.35
Cutoff frequency	6.5600100218 GHz

Figure 6. Sample holder definition screen with de-embedding

De-embedding allows a sample to be backed with a dielectric backing on one or both sides. It mathematically removes the effects of the backing, so the electromagnetic properties of just the sample are reported. This is useful when a sample is not stiff or thick enough to stand up by itself, or it cannot be removed from a substrate. The backing must have a known permittivity and thickness. If the permittivity of the backing is not known, it can be measured separately first. The backing material cannot be magnetic and it must allow the microwave signal to transmit through it so that S21 and S12 can be measured.

De-embedding feature works with the following transmission models:

- Reflection/Transmission Mu and Epsilon
- Transmission Epsilon Fast
- Polynomial Fit

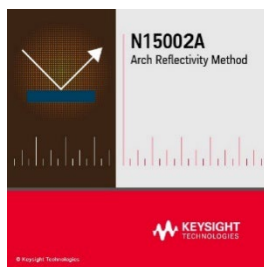
Typical Frequency Range 100 MHz ¹ to 1.1 THz

Material properties	Dielectric and magnetic Material under test is assumed to be homogeneous (uniform composition) with no layers ² Anisotropic materials can be measured in waveguide
Sample form	Most often used for solid materials The sample is assumed to have flat parallel sides
Typical accuracy	1 to 2%
Data formats	Permittivity: ϵ_r' , ϵ_r'' , $\tan \delta$, Cole Cole Permeability: μ_r' , μ_r'' , $\tan \delta\mu$ S-parameters: log mag, linear mag, phase, unwrapped phase, group delay, smith chart, polar chart, real, imaginary, and SWR Trace math functions: +, -, *, /, mean and standard deviation Data pane: view displays trace data in tabular format
File formats	Data and Setup: .tst Data: .prn, .csv Measurement report: .pdf S-parameters: .s2p, .ts
Sample holders and fixtures	For a list of recommended sample holders and fixtures, please see; https://www.keysight.com/my/en/assets/9922-02183/training-materials/N1500A-Sample-Holders.pdf?success=true

1. The minimum frequency is set by the maximum practical sample length (L):

$$f(\text{GHz}) = \frac{1}{\sqrt{\epsilon_r' \mu_r'}} \frac{30 \text{ cm}}{L(\text{cm})} \frac{20 \text{ deg}}{360 \text{ deg}}$$

2. If the material is not homogeneous through the length of the sample (i.e., layers), the reflection from the front (S11) and back (S22) faces 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).



N15002A Arch Reflectivity 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".

Typical Arch Reflectivity System Configuration

- Keysight network analyzer
- NRL arch fixture
- Cables and adapters as needed



Figure 7. In the NRL arch method, one antenna transmits energy onto the MUT and the second antenna receives the reflected portion.

N15002A automates NRL arch measurements. The program guides you through the complete process of setup, calibration and measurement of material reflectivity.

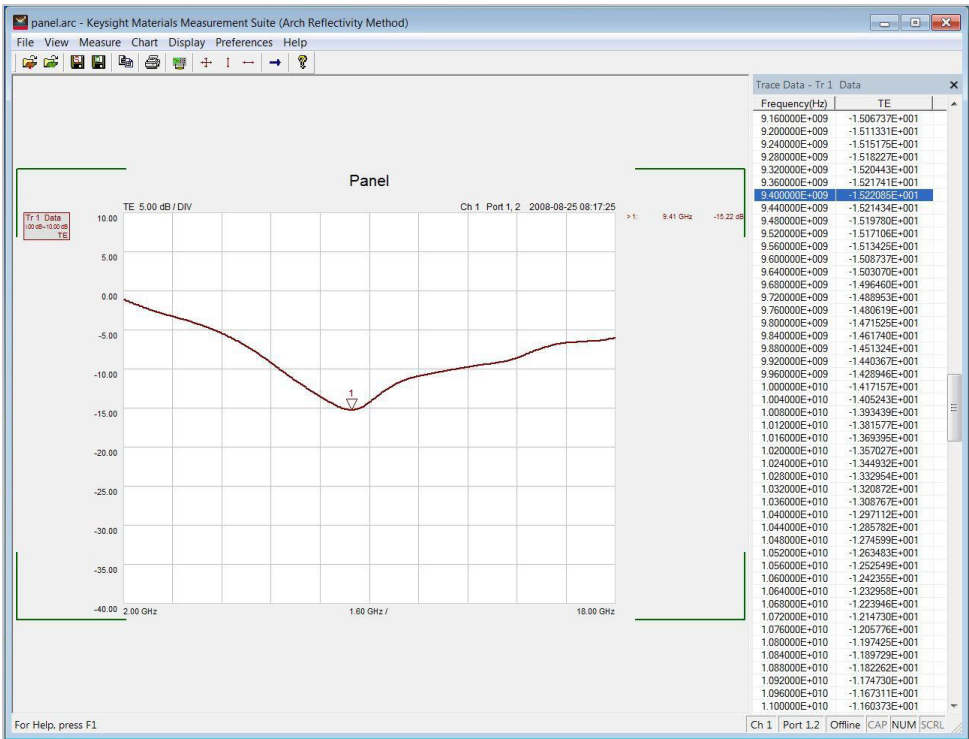
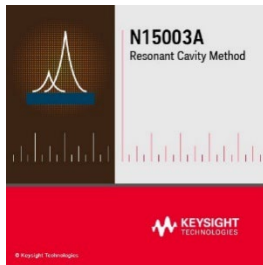


Figure 8. Example of arch reflectivity measurement results.

Typical Frequency Range	100 MHz to 1.1 THz
Material properties	Dielectric and magnetic
Sample form	Most often used for solid materials The sample is assumed to have flat parallel sides
Typical accuracy	1 to 2%
Data formats	Bi-static reflection (S21) in dB The data pane view displays trace data in tabular format
File formats	Data and Setup: .arc Data: .prn, .csv Measurement report: .pdf S-parameters: .s2p, .ts



N15003A Resonant Cavity Method for SPDR & 85072A

Choose the resonant cavity method for thin films, substrate materials, and other low loss dielectric materials. The resonant cavity method uses a network analyzer to measure 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^{-4} where the broadband method is 10^{-2} .

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 its easy to use interface.

Typical Resonant Cavity System Configuration

- Keysight network analyzer
- One or more resonant cavity fixtures:
- Split Post Dielectric Resonators (SPDR) from QWED. These resonators are high quality and are available in frequencies from 1 GHz to 15 GHz. For more information, refer to the SPDR App Note.
 - N1501AE19 SPDR 1.1 GHz
 - N1501AE03 SPDR 2.5 GHz
 - N1501AE04 SPDR 5.0 GHz
 - N1501AE10 SPDR 10.0 GHz
 - N1501AE15 SPDR 15.0 GHz
- ASTM D2520 standard waveguide resonators

A pair of test port cables

Adapters as required to connect cables to the network analyzer and resonant cavity



Figure 9. Resonant cavity system

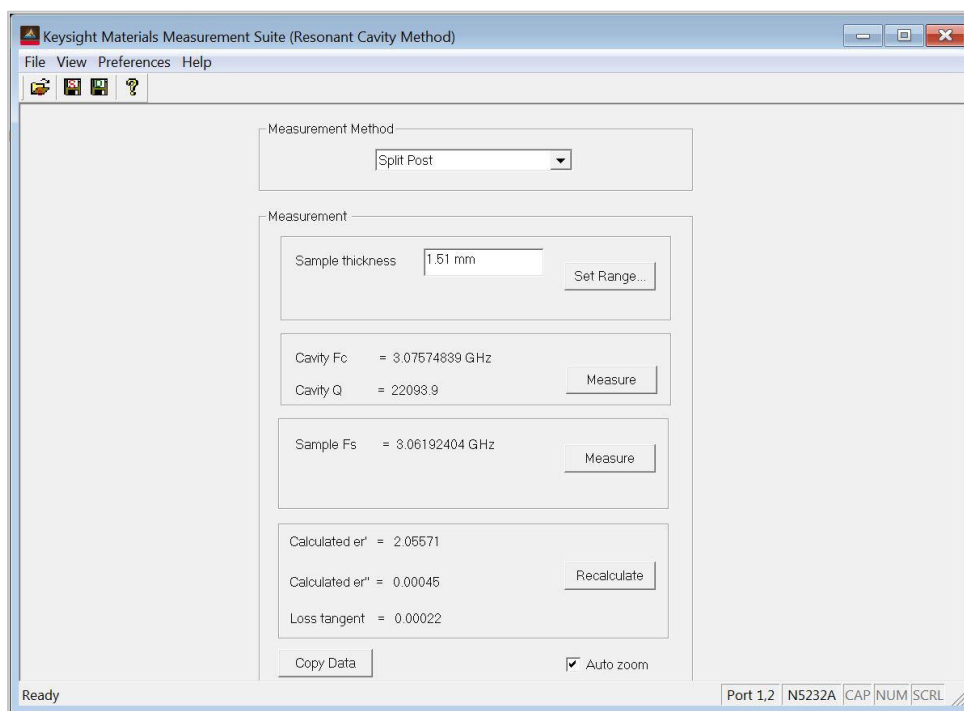
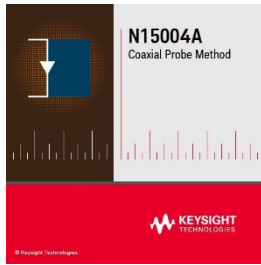


Figure 10. Resonant cavity method user interface

Typical Frequency Range 1 to 15 GHz

Material properties	Dielectric, low loss
Sample form	For the split post and split cylinder resonator, the sample is a thin sheet with flat parallel sides. For the ASTM D2520 method, the sample is a cylindrical rod shape.
Typical accuracy	1%, loss tangent resolution 1×10^{-4}
Data formats	Permittivity: ϵ_r' , ϵ_r'' , $\tan \delta$
File formats	Data and Setup: .cav Data: .prn



N15004A Coaxial probe method

The coaxial probe method works with Keysight N1501A and 85070E series dielectric probe hardware. Measurements are conveniently made by immersing the probe into liquids or semi-solids – no special fixtures or containers are required. Measurements are non-destructive and can be made in real time. These important features allow the dielectric probe kit to be used in process analytic technologies.

Typical coaxial probe system configuration

- Keysight network analyzer
- Keysight N1501A or 85070E dielectric probe kit with cable and probe stand.
- Optional Keysight Ecal module for electronic calibration refresh. Electronic calibration refresh with ECal is not compatible with FieldFox network analyzers. ECal module requires USB connection to PC or PNA and ENA series network analyzers.
- 8509xC Series
- N469x Series
- N443x Series (ports a and b only)
- N755xA Series

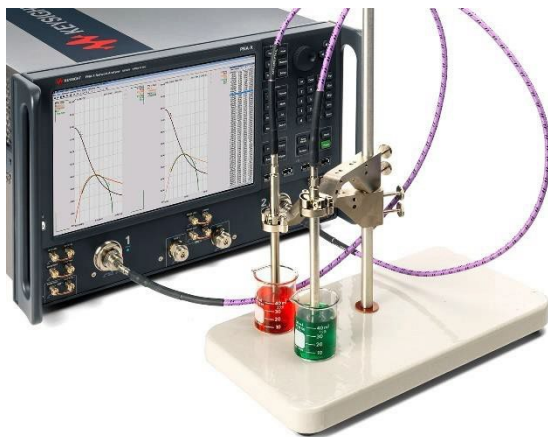


Figure 11. Coaxial probe system

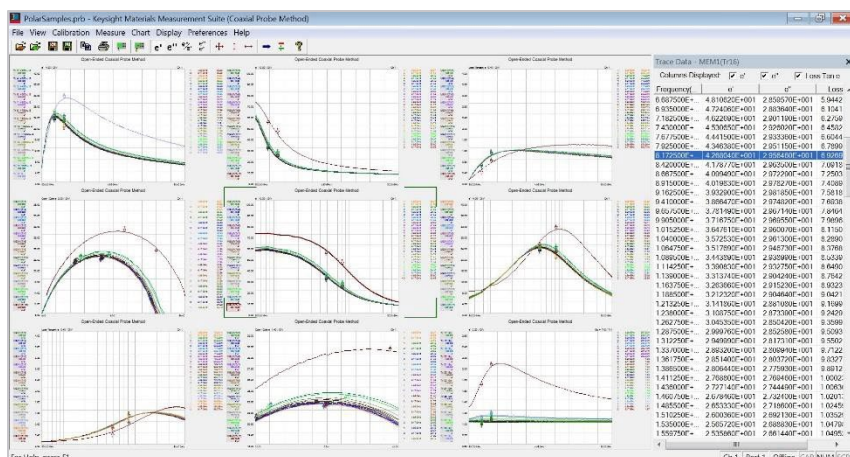


Figure 12. Example of coaxial probe measurement results.

Discontinuity Detector

The automated electronic calibration refresh feature recalibrates the system automatically, in seconds, just before each measurement is made. This virtually eliminates cable instability and system drift errors.



Figure 13. Ecal module connected in line for electronic

How it Works:

A Keysight electronic calibration module (ECal) microwave ports are connected in line between the probe and the network analyzer test port cable. The ECal module USB communication port is connected either to the PC, PNA or ENA Series network analyzer running the N1500xA software. The software guides you through a normal “three standard” calibration, (usually open, short, water), performed at the end of the probe. This calibration is then transferred to the ECal module. The ECal module remains in line and a complete ECal calibration is automatically performed before each measurement. Errors due to test port cable movement and system drift are removed by the new calibration.

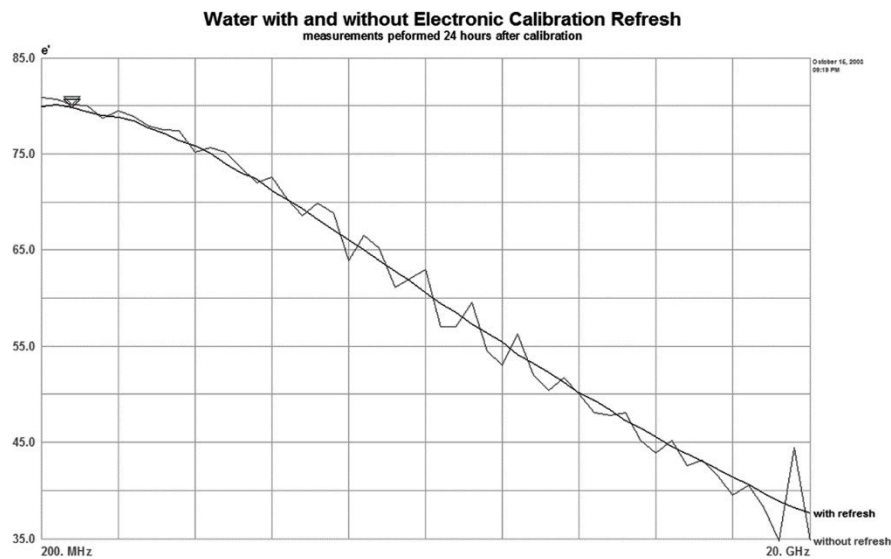


Figure 14. Water with without electronic calibration refresh

This measurement shows the effects of system drift and cable instability on a dielectric measurement of water and the improvement with electronic calibration refresh. Both measurements were made 24 hours after the original calibration. The lighter colored, noisier, trace was made before the electronic calibration refresh was turned on. The darker, smoother, trace shows the improvement made after the electronic calibration refresh was turned on.

For systems without an ECal module, a simpler, “one standard” refresh calibration feature is also available, which can reduce the effects of system drift over time or temperature. After the initial “three standard” probe calibration is performed, the calibration can be refreshed at any time with the connection of a single standard. Any one of the three calibration standards can be defined as the refresh standard.

Multiple Measurements Utility

The multiple measurements utility automates multiple measurements over time. Enter the desired number of measurements and the time between the measurements and the utility will calculate the total time required. You can choose to have your measurements displayed or saved in .prn format data files. Click the Start Measurements button and let the software do the rest.

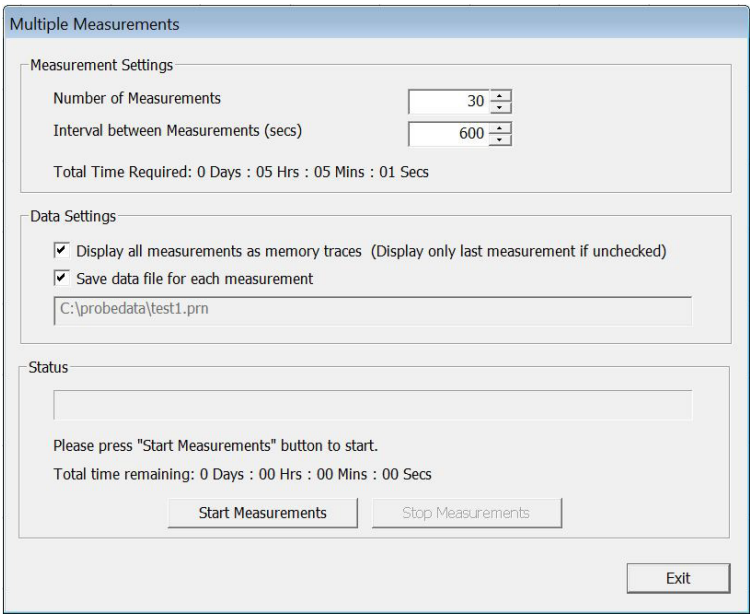
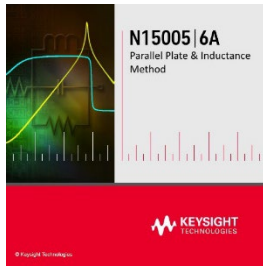


Figure 15. Multiple measurements utility

Suggested Frequency Range	200 MHz to 50 GHz with the Network Analyzer 10 MHz to 3 GHz with E4991A/B Impedance Analyzer
Material properties	Dielectric only (non-magnetic)
Sample form	Best used for liquids or soft conformable solids
Typical accuracy	5-10%
Data formats	Permittivity: ϵ_r' , ϵ_r'' , $\tan \delta$ S-parameters: log mag, linear mag, phase, unwrapped phase, group delay, smith chart, polar chart, real, imaginary, and SWR. Trace math functions: +, -, *, /, mean and standard deviation. Data pane view: displays trace data in tabular format.
File formats	Data and Setup: .prb, .tst Data: .prn, .csv Measurement report: .pdf S-parameters: .s1p, .ts



N15005A/6A Parallel Plate/Inductance Method

N15005A up to 1 GHz

N15006A up to 120 MHz

Parallel Plate

The parallel plate method, also called the three terminals method in ASTM standard D15012, involves sandwiching a thin sheet of material or liquid between two electrodes to form a capacitor. The measured capacitance is then used to calculate permittivity. In an actual test setup, two electrodes are configured with a test fixture sandwiching dielectric material. The impedance-measuring instrument would measure vector components of Capacitance (C) and Dissipation (D) and a software program would calculate permittivity and loss tangent. 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 impedance analyzer or LCR meter and a fixture such as the 16451B and 16453A dielectric test fixture, which operates up to 1 GHz. The 16452A*1 test fixture is offered for measuring liquids. More information about the parallel plate method and other Keysight low-frequency materials measurement solutions are available in Application Note 1369-1 (P/N 5980-2862EN)¹ and 380-111.

*1: 16452A Liquid test fixture was discontinued.

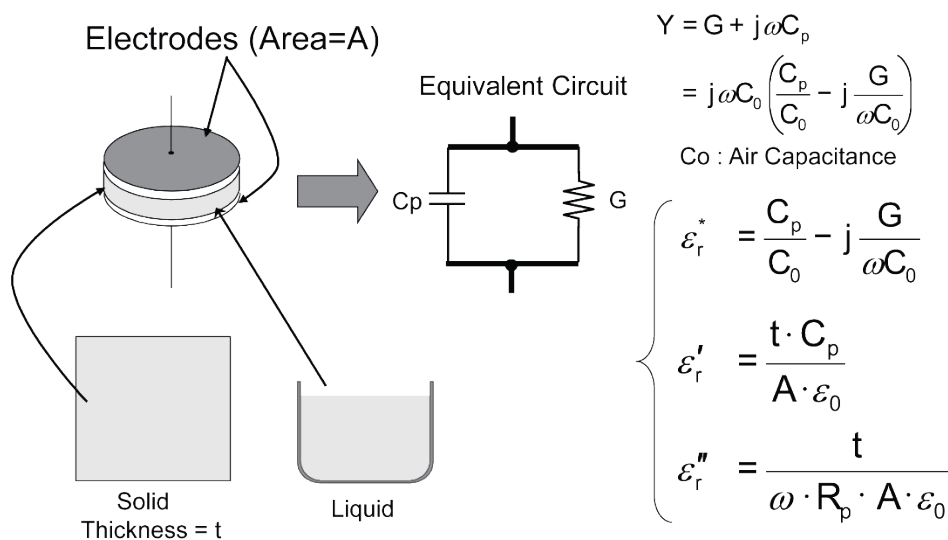


Figure 16. Parallel plate method

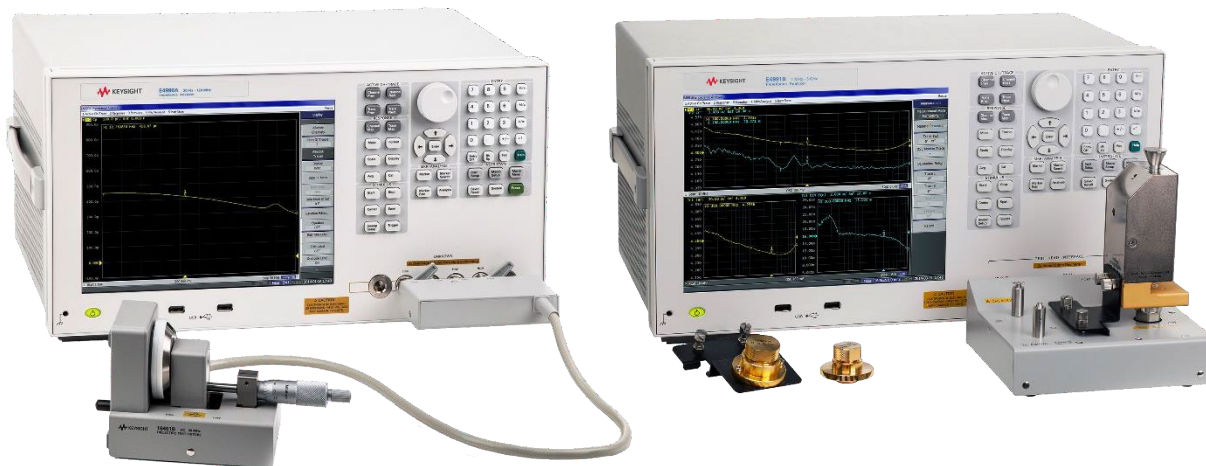


Figure 17. Keysight 16451B and 16453A dielectric test fixture with impedance

Inductance Measurement Method

The relative permeability of magnetic material derived from the self-inductance of a cored inductor that has a closed loop (such as the toroidal core) is often called effective permeability. The conventional method of measuring effective permeability is to wind some wire around the core and evaluate the inductance with respect to the ends of the wire. This type of measurement is usually performed with an impedance analyzer. Effective permeability is derived from the inductance measurement result. The Keysight 16454A magnetic material test fixture provides an ideal structure for a single-turn inductor, with no flux leakage when a toroidal core is inserted in it. More information about the inductance measurement method is available in Application Note 1369-1 (P/N [5980-2862EN](#)).

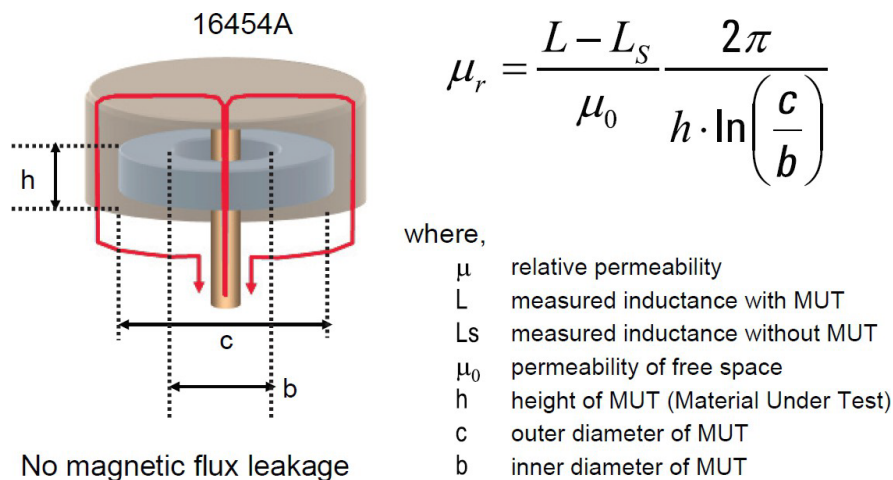
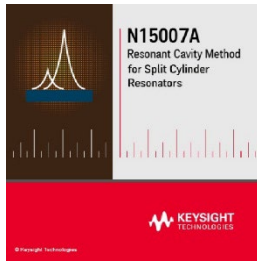


Figure 18. Inductance measurement method



N15007A Resonant Cavity Method for N1501AKEAD-10/20/24/28/35/40/50/60/80

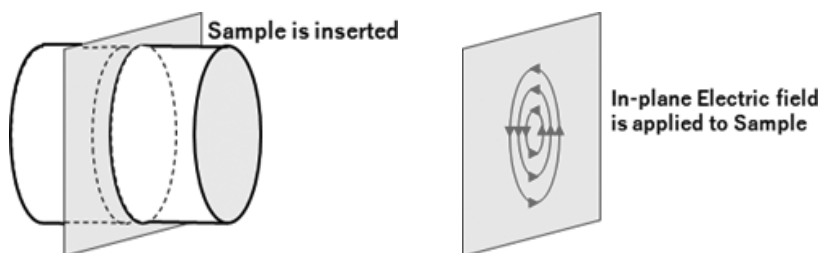
- Very high Q resonators enable low-loss material tests in mmWave frequency applications up to 80 GHz
- Easy operation for excellent repeatability and test efficiency regardless of operator skills
- Complies with IPC test method TM-650 2.5.5.13

The Split Cylinder Resonator consists of two halves of a cylindrical cavity that face each other to form one complete cylindrical cavity resonator. One measures the permittivity just as in the other cases, simply inserting a sample into the narrow slit between the two halves of the cavity. The sample must be held securely to avoid air gaps that can affect the accuracy of the measurement.

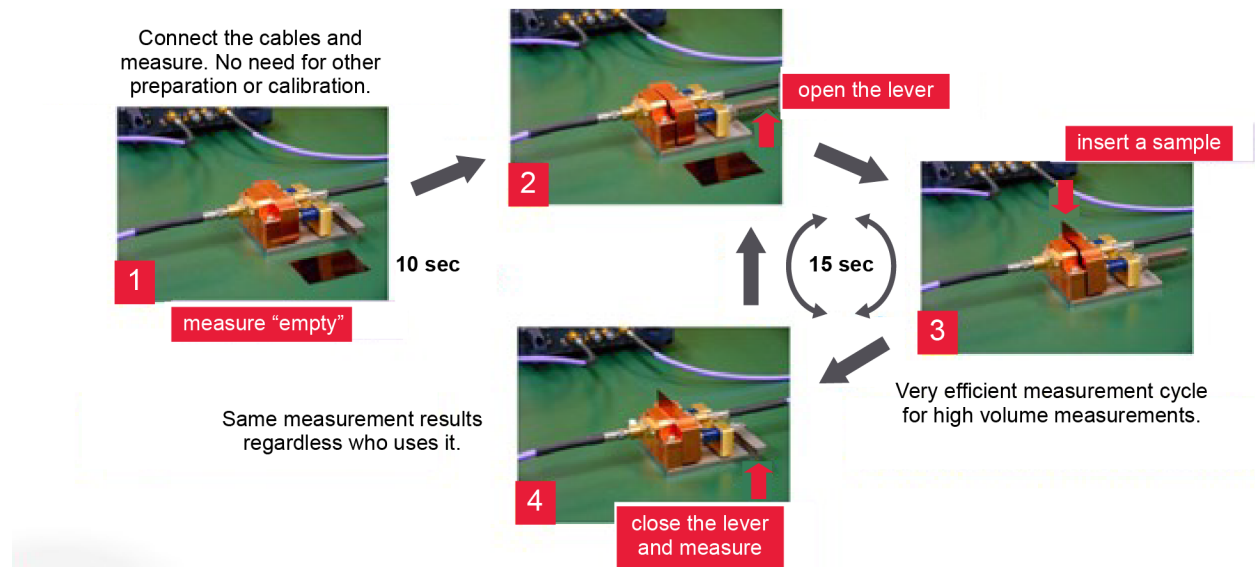
SCRs use the TE₀₁₁ mode resonance to measure permittivity. In many instantiations, the TE₀₁₁ mode resonance generates a circular electric field in parallel with the sample plane, therefore, interacts with the permittivity in the plane of the sample. The electric current also flows in the circular direction, **which keeps the TE₀₁₁ resonance intact even when the two halves of the cylinder do not touch electrically.**

There are a few limitations to this technique. The sample dimensions simply need to be known and sufficient to fill the active region of the resonator. This requirement places limits on the loss tangent and permittivity to values typically less than 30 and 0.01, respectively. The loss tangent also cannot be too large because the resonance amplitude becomes too low to be under the noise floor of the measurement instrument.

501AKEAD-710/20/24/28/35/40/50/60/80 fixturing issues, making the cavities far more reproducible and user-friendly. One example had an easy operation for excellent repeatability and test efficiency regardless of operator skills. The repeatability of the real part of the permittivity was 0.0003 and 0.000003 for the loss tangent.



Schematic diagram of a split cylinder resonator. The split cylinder resonator is simply two metal cylinders (grey) cut in the middle to allow for a sample (green).



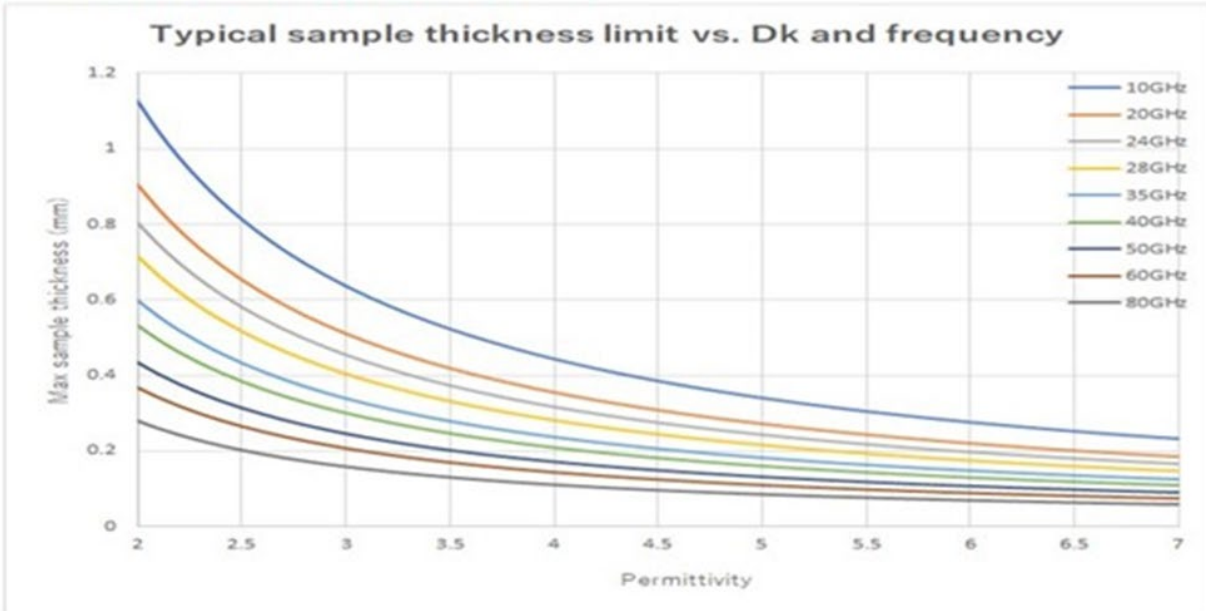
Test Sample Requirements

A thin flat plate sample is required for Split Cylinder measurements. Size recommendation for accurate measurement and easy handling:

10 GHz: 62 mm x 75 mm, Others: 34 x 45 mm

Thickness recommends ~ 100 μm . The typical maximum thickness is shown in the chart below. In the case of relatively high-loss materials, $D_f > 0.01$ for example, a sample may need to be significantly thinner than the limit in the chart.

Sample Thickness – SCR



Excellent Repeatability Up to 80 GHz!

Repeat 8 measurements: removing/inserting the sample every time

	ϵ			$\tan\delta$		
	28GHz	40GHz	80GHz	28GHz	40GHz	80GHz
1	3.5513135	3.5461616	3.5316448	0.0014638	0.0014985	0.0026641
2	3.5573029	3.5513652	3.5259343	0.0014652	0.0015015	0.0027728
3	3.5373529	3.5454758	3.5286601	0.0014661	0.0015031	0.0027724
4	3.5475343	3.5451975	3.5406693	0.0014636	0.0015016	0.0026712
5	3.5462314	3.5571790	3.5343098	0.0014635	0.0015048	0.0027275
6	3.5546762	3.5534020	3.5418378	0.0014570	0.0015082	0.0026762
7	3.5535140	3.5450251	3.5301140	0.0014585	0.0015111	0.0027662
8	3.5463382	3.5533046	3.5460484	0.0014584	0.0015120	0.0026603
Avg	3.5492829	3.5496389	3.5349023	0.0014620	0.0015051	0.0027138
S. Dev	0.0063110	0.0047489	0.0071602	0.0000035	0.0000049	0.0000513
S. Dev	0.0063110	0.0047489	0.0071602	0.0000035	0.0000049	0.0000513

For ordering configuration, please refer to the product brochure.

<https://www.keysight.com/my/en/assets/7018-06384/brochures/5992-3438.pdf>

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License Term	Description
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Subscription	Licenses can be used through the term of the subscription (3 to 36 months)

License type

License Type	Description
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Transportable	License can be used on one instrument/computer at a time but may be transferred to another using Keysight Software Manager (internet connection required).
USB portable	License can be used on one instrument/computer at a time but can be transferred to another using a certified USB dongle (available for additional purchase, Keysight part number SW1000-D10).
Floating (Networking)	Networked instruments/computers can access a license from a server one at a time. Multiple licenses may be purchased for concurrent usage. Three types of floating license are available: Single Site: 1-mile radius from the server Single Region ¹ : Americas, Europe, Asia Worldwide (export restriction identified in End User License Agreement (EULA))

1. Americas (North, Central, and South America, Canada); Europe (European Continent, Middle Eastern Europe, Africa, India); Asia (North and South Asia Pacific Countries, China, Taiwan, Japan).

KeysightCare Software Support Subscription Provides Peace of Mind Amid Evolving Technologies

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- Gain additional insight into your measurement problems with live access to our team of technical experts.
- Stay on schedule with fast turnaround times and priority escalations when you need support.

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KeysightCare software support	Perpetual licenses are sold with a 12 (default), 24, 36, or 60-month software support subscription. Support subscriptions may be renewed for a fee after that. Software subscription licenses include a software support subscription through the term of the license.

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- Step 1. Choose your software product.
- Step 2. Choose your license term: perpetual or subscription.
- Step 3. Choose your license type: node-locked, transportable, USB portable, or floating.
- Step 4. Depending on the license term, choose your subscription or support duration.

License Term				
Product	License Type	Perpetual		Subscription
N1500xA		License	+	Support
	Node-locked (fixed)	SW1000-LIC-01	+	SW1000-SUP-01
	Transportable			
	USB portable ¹			
	Floating (single site)			
	Floating (single region)			
	Floating (worldwide)			
		License Type attributes	+	Durations attributes (Duration or start/stop dates, 12 – 60 months)
				License Type and Durations attributes (Subscription Duration or start/stop dates, 3 – 36 months)

1. USB portable license requires a certified USB dongle (available for additional purchase, Keysight part number E8900-D10).

License Term			
Product	License Type	Perpetual	Subscription
	Node-locked (fixed)	SW1000-SUP-01	
	Transportable		
	USB portable ¹		
	Floating (single site)		
	Floating (single region)		
	Floating (worldwide)		
		License Type attributes (1 month – 60 months)	License Type attributes (Start/stop dates (1 – 36 months))

1. USB portable license requires a certified USB dongle (available for additional purchase, Keysight part number E8900-D10).

Upgrade Information

Purchasing N1500xA software is the migration path who owns 85070E, 85071E, or N1500A-001/002/003/004/005/006/007 license. For more detail, please contact to the Keysight sales representative or the nearest Keysight office.

Current Software	Description	New Software
85071E, N1500A-001	Transmission Line and Free Space Method	N15001A
85071E-100, N1500A-001		
85071A/B/C/D, N1500A-001		
85071E-200, N1500A-002	Arch Reflectivity Method	N15002A
85071E-300, N1500A-003	Resonant Cavity Method	N15003A
85070E, N1500A-004	Coaxial Probe Method	N15004A
85070A/B/C/D, N1500A-004		
N1500A-005	Parallel Plate/Inductance Method up to 1 GHz	N15005A
N1500A-006	Parallel Plate/Inductance Method up to 120 MHz	N15006A
N1501AKEAD-ST1, N1500A-007	Resonant Cavity Method for Split Cylinder Resonators	N15007A

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