KEYSIGHT TECHNOLOGIES

# Models in the N1500A and 85071E Materials Measurement Software

| N1500A-001 or 85071E Name | Alternate Name(s) | S-parameters measured | Result | Description | References |
|---|---|---|---|---|---|
| **Reflection / Transmission Mu and Epsilon** | Nicholson-Ross -Weir, NRW | S11, S21, S12, S22 | $\varepsilon_r$, $\mu_r$ | 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 > ½ wavelength. | 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.<br>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, S12, S22 | $\varepsilon_r$ | Developed by NIST to calculate permittivity from transmission and reflection coefficients. | 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 |

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| **Transmission Epsilon Fast** | Fast Transmission | S21, S12 | $\varepsilon_r$ | 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. | Not Published |
| **Reflection / Transmission Mu and Epsilon Polynomial Fit** | Poly Fit, Bartley | S11, S21, S12, S22 | $\varepsilon_r$, $\mu_r$ | Uses an iterative technique to fit material properties to a polynomial, incrementing the order of the polynomial until the difference between S-parameters calculated from the polynomial and the measured S-parameters is less than the expected system performance, or the maximum order specified by the user is reached. 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. |

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| **Transmission Epsilon Polynomial Fit** | Poly Fit, Bartley-Begley, BB | S21, S12 | $\varepsilon_r$ | Similar to Reflection / Transmission Mu and Epsilon Polynomial Fit. Uses an iterative technique to fit material properties to a polynomial, incrementing the order of the polynomial until the difference between S-parameters calculated from the polynomial and the measured S-parameters is less than the expected system performance, or the maximum order specified by the user is reached. For non-magnetic materials. 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. |
| **Stack Transmission Mu and Epsilon** | Stack Two Transmission | S21, S12 (2 samples) | $\varepsilon_r$, $\mu_r$ | 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 |

| N1500A-001 or 85071E Name | Alternate Name(s) | S-parameters measured | Result | Description | References |
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| **Reflection Only Epsilon Short-Backed** | Short Backed | S11 | $\varepsilon_r$ | 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 | $\varepsilon_r$ | 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 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) |

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| **Reflection Only Mu and Epsilon Single/Double Thickness** | Single/Double Thickness | S11 (2 samples) | $\varepsilon_r$, $\mu_r$ | 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 as the original. After doing so the Nicolson Ross model is used to determine the material properties. | Not Published |