Primary Standards Laboratory

Metrology Program

Fact Sheet

Microwave

Primary Standards Laboratory (PSL) microwave standards capabilities include power (both CW and pulse), group delay, and scattering parameters (which include attenuation and reflection coefficients or voltage standing-wave ratio [VSWR]).

All the primary microwave standards are directly traceable to the National Institute of Standards and Technology (NIST). The primary standards include 50 ohm terminations, various coaxial air lines, and coaxial and waveguide thermistor mounts. These standards support a variety of measurement systems, including four Vector Network Analyzers (VNAs), a power standard calibration system and a power meter calibration system.

Capabilities

Below is a representative sample of our uncertainties. We are accredited under Lab Code 105002-0 by the National Institute of Standards and Technology/ National Voluntary Laboratory Accreditation Program (NIST/NVLAP). For details, see **http://ts.nist.gov/Standards/scopes/1050020.pdf**

Quantity	Uncertainties
•S-PARAMETERS [0.3 MHz TO 18 GHz]	
Magnitude $\|S_{ij}\|$, i≠j	
0 to 60 dB	± 0.018 dB/10 dB
Phase - Arg (S_{ij}), i≠j	
0° to 360°	± 0.2° to 4°
Magnitude $\|S_{ii}\|$	
0 to 1	± 0.001 to 0.05
Phase - Arg (S_{ii})	
0° to 360°	± 0.01° to 180°
•CW POWER	
0.1 nW to 200W	
10 MHz to 18 GHz	± 1.7% to 10%
•THERMISTOR MOUNTS	
1 mW to 10 mW	
1 MHz to 18 GHz	± 0.3% to 1.1 %
•PULSE POWER	
10 mW to 100 mW	
Pulse Width 0.2 to 0.5 µs	
2 GHz to 18 GHz	± 7% to 10%

•GROUP DELAY	
5 to 500 ns for $\|S_{ij}\|$, ≤ 10 dB	
50 MHz to 50 GHz	± 0.02 ns to 1 ns

Low-Band Vector Network Analyzer

Major Resources

- Scattering (S) parameters of an n-port device (for n up to 4) characterize how the device interacts with signals presented to its various ports. Since the S parameters are dimensionless ratios (i.e. reflection and attenuation coefficients), a reference impedance must be specified. A 50Ω impedance level is used for virtually all microwave devices calibrated. Four vector network analyzers (VNAs) are used to make low-uncertainty S-parameter measurements very rapidly at many frequencies.

- Thermistor mounts provide the basis for all microwave power measurements. The effective efficiency and/or calibration factor of an unknown thermistor mount is determined by comparison with a NIST-calibrated coaxial or wave-guide thermistor mount. Calibrations are performed on a system which combines power-ratio and reflection measurements to eliminate all mismatch uncertainties.

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Microwave Power Calibration

- All power meter calibrations are performed on the system shown in the figure above. Every calibration is based on the Brammall technique, or a variation thereof, wherein each calibration power level is referenced to a NIST calibrated thermistor mount by means of power ratio measurements. Pulse power meter calibrations also employ notch-wattmeter techniques.
- Group Delay is the ratio of the change in transmission phase shift through a two-port device to the change in its radian frequency of excitation that caused the change in phase shift. The measurement of the transmission phase shift is referenced to the electrical length of a NIST-calibrated air line, whereas the change in the frequency of excitation is measured relative to NIST-traceable GPS-derived frequencies.

Special Capabilities

•Dielectric Material Properties Measurements

Dielectric material properties can be measured on the VNAs at frequencies in the 0.03 to 18 GHz band using resonant cavity and/or transmission-line techniques. Cavity techniques provide high accuracy at the relatively few frequencies where resonant cavities are available, while transmission techniques cover many frequencies but at lower accuracies. Parameter range capabilities are 1 to 10 for real part of dielectric constant and 0.0001 to 0.1 for loss tangent.

• Certification of HP Network Analyzer Uncertainties

Tables of uncertainties for scattering parameter measurements made by many HP/Agilent VNAs and PNAs are readily generated using the CERTVANA and CertPNA certification procedures, respectively. Typically the uncertainties for a given scattering parameter measurement are tabulated as a function of frequency and measurand magnitude. The uncertainties are deduced from network error models for the particular VNA system and scattering parameter. For reflection scattering parameters, the Thru-Reflect-Line (TRL) and Thru-Match-Short techniques are used to deduce the parameters of the error model. A standard attenuator and a bootstrap technique are used to establish |Sij| uncertainties. Finally, Arg(Sij) uncertainties are determined from measurements on air lines of certified electrical length.

•Certification of Passive Three or Four-Port Networks

Accurate calibrations of multi-port devices (like directional couplers, hybrid junctions, reflectometers, power splitters, and power dividers) can be performed using a VNA. Virtually any combination of popular microwave connector types may appear at the device ports. During calibration measurements between each 2-port pair on the device, the effects of the terminations on the remaining ports are rigorously accounted for. The device may be unilateral or bilateral. One can certify either scalar or vector values of the S-parameters of the device. Additionally, the effective source reflection coefficient of a three-port network may be certified. Finally, a certificate can tabulate the worst-case uncertainties of a four-port network when used as a scalar reflectometer.

•Check Standard Software

Verification of the proper operation of a measurement system is critical to providing accurate measurements of customer's devices. We developed a check standard measurement and database program to provide assurance to the user of the accurate operation of the measurement system. Current check standard measurements are plotted along with the means and standard deviations of prior measurements to indicate the measurement system's present state of statistical control.

Three versions of the software are available: One version automatically acquires data from either an HP/Agilent 8510 or 8753 VNA; the second version is more general and allows data entry by keyboard, file input, or directly from instruments via user-prepared data-acquisition subprograms. The software can present either parameter-dependent (e.g. frequency-dependent) and/or the familiar time/event-dependent displays. Both versions run under HP Basic or HT Basic. The third version was written in

Visual Basic.NET and works with Microsoft SQL Server 2000 Desktop Engine (MSDE 2000) to acquire, store and plot current PNA check standard data with respect to limits based on historical PNA check standard data. Such software verifies statistical control of the measurement system allowing for high-quality measurements acquired in a time-efficient manner.

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