Tektronix®

TTR500 Series
Vector Network Analyzer
Specifications and Performance Verification

Technical Reference Manual

077-1255-00

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Vector Network Analyzer
Specifications and Performance Verification

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- In North America, call 1-800-833-9200.
- Worldwide, visit www.tek.com to find contacts in your area.

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Important safety information

This manual contains information and warnings that must be followed by the user for safe operation and to keep the product in a safe condition.

To safely perform service on this product, additional information is provided at the end of this section. (See page iv, *Service safety summary*.)

General safety summary

Use the product only as specified. Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it. Carefully read all instructions. Retain these instructions for future reference.

Comply with local and national safety codes.

For correct and safe operation of the product, it is essential that you follow generally accepted safety procedures in addition to the safety precautions specified in this manual.

The product is designed to be used by trained personnel only.

Only qualified personnel who are aware of the hazards involved should remove the cover for repair, maintenance, or adjustment.

This product is not intended for detection of hazardous voltages.

While using this product, you may need to access other parts of a larger system. Read the safety sections of the other component manuals for warnings and cautions related to operating the system.

When incorporating this equipment into a system, the safety of that system is the responsibility of the assembler of the system.

To avoid fire or personal injury

Connect and disconnect properly. Do not connect or disconnect probes or test leads while they are connected to a voltage source.

Use only insulated voltage probes, test leads, and adapters supplied with the product, or indicated by Tektronix to be suitable for the product.

Observe all terminal ratings. To avoid fire or shock hazard, observe all ratings and markings on the product. Consult the product manual for further ratings information before making connections to the product.

Do not apply a potential to any terminal, including the common terminal, that exceeds the maximum rating of that terminal.

The measuring terminals on this product are not rated for connection to mains or Category II, III, or IV circuits.

Do not operate without covers. Do not operate this product with covers or panels removed, or with the case open.

Avoid exposed circuitry. Do not touch exposed connections and components when power is present.

Do not operate with suspected failures. If you suspect that there is damage to this product, have it inspected by qualified service personnel.

Disable the product if it is damaged. Do not use the product if it is damaged or operates incorrectly. If in doubt about safety of the product, turn it off and disconnect the power. Clearly mark the product to prevent its further operation.

Examine the exterior of the product before you use it. Look for cracks or missing pieces.

Use only specified replacement parts.

Do not operate in wet/damp conditions. Be aware that condensation may occur if a unit is moved from a cold to a warm environment.

Do not operate in an explosive atmosphere.

Keep product surfaces clean and dry. Remove the input signals before you clean the product.

Provide proper ventilation. Refer to the installation instructions in the manual for details on installing the product so it has proper ventilation.

Provide a safe working environment. Avoid improper or prolonged use of keyboards, pointers, and button pads. Improper or prolonged keyboard or pointer use may result in serious injury.

Be sure your work area meets applicable ergonomic standards. Consult with an ergonomics professional to avoid stress injuries.

Use only the Tektronix rackmount hardware specified for this product.

Service safety summary

The *Service safety summary* section contains additional information required to safely perform service on the product. Only qualified personnel should perform service procedures. Read this *Service safety summary* and the *General safety summary* before performing any service procedures.

To avoid electric shock. Do not touch exposed connections.

Do not service alone. Do not perform internal service or adjustments of this product unless another person capable of rendering first aid and resuscitation is present.

Disconnect power. To avoid electric shock, disconnect the USB 3.0 cable from the instrument before removing any covers or panels, or opening the case for servicing.

Use care when servicing with power on. Disconnect power, remove battery (if applicable), and disconnect test leads before removing protective panels, soldering, or replacing components.

Terms in this manual

These terms may appear in this manual:

WARNING. Warning statements identify conditions or practices that could result in injury or loss of life.

CAUTION. Caution statements identify conditions or practices that could result in damage to this product or other property.

Terms and symbols on the product

These terms may appear on the product:

- DANGER indicates an injury hazard immediately accessible as you read the marking.
- WARNING indicates an injury hazard not immediately accessible as you read the marking.
- CAUTION indicates a hazard to property including the product.

When this symbol is marked on the product, be sure to consult the manual to find out the nature of the potential hazards and any actions which have to be taken to avoid them. (This symbol may also be used to refer the user to ratings in the manual.)

The following symbol(s) may appear on the product:

Preface

Verify the software version

The VectorVu-PC software version must be version 1.0 or greater.

Purpose

This manual lists the electrical, mechanical, and environmental specifications, and the certification and compliance statements for the Tektronix TTR500 Vector Network Analyzer (VNA). Also provided are procedures for verifying the performance of the instrument.

Documentation

This table lists some of the documentation that is available for the TTR500 series products.

Product documentation

Document	Purpose	Location
Installation and Safety Instructions	Provides software and hardware installation instructions and associated safety warnings	Printed format ships with product. PDF available on the product flash drive and at www.tek.com/manuals.
Specifications and Performance Verification (this manual)	Provides specifications and performance verification procedures for checking instrument performance	PDF available at www.tek.com/manuals.
Help (User manual)	Provides operating information about the hardware and software	Available as a help file in VectorVu-PC application and in PDF at www.tek.com/manuals.
API Programmer manual	Information on commands used to control the instrument through an API	PDF available at www.tek.com/manuals.

Specifications

All specifications are guaranteed unless labeled **Typical**. Typical specifications are provided for your convenience.

NOTE. Warranted characteristics that are checked in the Performance Verification are marked with a ✓ symbol.

The performance limits in this specification are valid for the following conditions:

- The VectorVu-PC software version is 1.0 or greater.
- You operate the instrument in an environment that meets the temperature, altitude, and humidity characteristics listed in these specifications.
- You allow the instrument to warm up sufficiently (> 30 minutes). To do this, connect the instrument to a PC and start the VectorVu-PC application. The application must be continuously acquiring data for at least 30 minutes. Once the instrument has warmed up, the thermometer indicator in the instrument status bar changes from yellow to green.

NOTE. The TTR500 does not fully power on until VectorVu-PC has established communication with the TTR500 and is acquiring data.

- For small signal S-parameters, the instrument must have been calibrated using the recommended precision calibration kit at an ambient temperature within ±1°C of the current ambient temperature.
- All specifications are valid in the temperature range of 18°C to 28°C unless specified otherwise.

Frequency

Frequency range	100 kHz to 6.0 GHz

Measurement bandwidth

Effective IF bandwidth	1 Hz to 500 kHz

Sweep

Configurable sweep parameters	Sweep time, sweep delay and number of points are configurable. Sweep Delay is the time from end of last frequency point to start of first point of next sweep You can specify sweep delay sequentially—e.g. (Start, Stop, N), or (Start, Stop, Step). Sweep Delay: 0 sec (Min) to 1.0 sec (Max) Number of points: 1 to 20001 (host memory limited) Up to 16 channels Up to 16 displays Up to 16 traces, and 9 markers/trace
Sweep type	Linear Logarithmic

Test port levels

Output power settable level	-50 to 10 dBm 0.25 dB step
Maximum port output power	≥2 dBm, 300kHz to < 2 MHz ≥9 dBm, 2 MHz to < 3 GHz ≥8 dBm, 3 GHz to < 4.5 GHz ≥7 dBm, 4.5 GHz to 6.0 GHz
Output harmonics	-25 dBc, 300 kHz to < 1 MHz -30 dBc, 1 MHz to 6 GHz Output power ≤0 dBm
✓Output power level accuracy	± 2.5 dB, 300 KHz to 6 GHz -25 dBm to 3 dB below max specified output power
Output power level accuracy, typical	± 1.7 dB, 300 kHz to 6.0 GHz -25 dBm to 3 dB below the maximum specified output power.
Automatic output power calibration	You can perform automatic power calibration with an external power meter. These models are supported: ■ Tektronix USB power meters: PSM 3000, 4000, 5000 series ■ Keysight USB power meters: U848x, U2020, U2000 series ■ Rohde and Schwartz USB power meters: NRP-Z, NRP-xxS/SN power meters You can also perform receiver level calibration. This requires the completion of the output power calibration procedure.
Maximum RX input level	10 dBm operational, 100 KHz to 6 GHz
Maximum RX input power without damage	15 dBm, < 10 MHz 20 dBm, >= 10 MHz
Maximum RX input DC level without damage	+/- 30 VDC
✓Test port noise floor	< -125 dBm/Hz, 200 MHz to 6 GHz
Test port noise floor, typical	< -115 dBm/Hz, 300 kHz to < 1 MHz < -125 dBm/Hz, 1 MHz to < 200 MHz < -130 dBm/Hz, 200 MHz to 6GHz

Dynamic range

System dynamic range

The system dynamic range is measured in a 10 kHz IF bandwidth scaled to 10 Hz noise bandwidth. Measurement dynamic range may be limited at low levels by crosstalk or the noise floor.

System dynamic range	System dynamic range, typical	Frequency range
	112 dB	300 kHz to < 1 MHz
	117 dB	1 MHz to < 2 MHz
	124 dB	2 MHz to < 200 MHz
124 dB	125 dB	200 MHz to < 3 GHz
123 dB	123 dB	3 GHz to < 4.5 GHz
122 dB	122 dB	4.5 GHz to 6 GHz

Uncorrected crosstalk with load

For best isolation results, connect a DUT to each port. Measurement dynamic range may be limited on the lower end by crosstalk or the noise floor.

Uncorrected crosstalk	Frequency range
–85 dB	300 kHz to < 1 MHz
–110 dB	1 MHz to < 10 MHz
–105 dB	10 MHz to < 200 MHz
–120 dB	200 MHz to < 1 GHz
–115 dB	1 GHz to < 2 GHz
–120 dB	2 GHz to 6 GHz
10 Hz IFBW, 18°C to 28°C, within 1°C of calibration temperature	

Corrected crosstalk with load

The corrected crosstalk with load refers to the crosstalk measured after performing a full 2–port SOLT calibration with isolation using a Spinner BN533861 type-N 50Ω load.

Corrected crosstalk	Frequency range
–90 dB	300 kHz to < 1 MHz
–118 dB	1 MHz to < 10 MHz
–115 dB	10 MHz to 200 MHz
–125 dB	> 200 MHz to < 1 GHz
–125 dB	1 GHz to < 2 GHz
–120 dB	2 GHz to 6 GHz
10 Hz IFBW, both ports terminated in 50Ω	

Trace noise

Trace noise	Specification
Magnitude [1]	0.008 dB rms, 300 kHz to < 200 MHz 0.006 dB rms, 200 MHz to 6 GHz
Phase [1]	0.050 degree rms, 300 kHz to < 200 MHz 0.040 degree rms, 200 MHz to 6 GHz

1 **Determined using a thru connection with 1 kHz IFBW and +10 dBm source power**

Temperature stability

Temperature stability	Specification
Magnitude [1]	0.008 dB/°C, 300 kHz to 3 GHz 0.015 dB/°C, > 3 GHz to 6 GHz
Phase [1]	0.1 deg/°C, 300 kHz to 3 GHz 0.2 deg/°C, > 3 GHz to 6 GHz

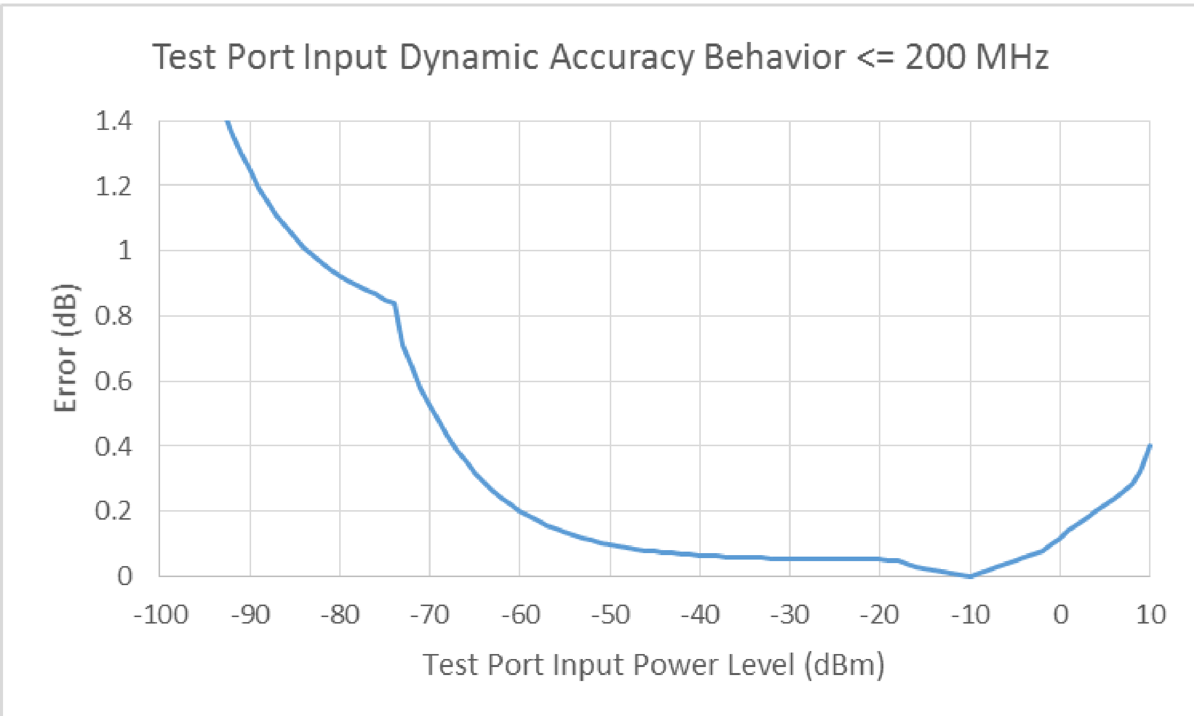
1 **Determined using a thru connection with 10 Hz IFBW and 0 dBm receiver power**

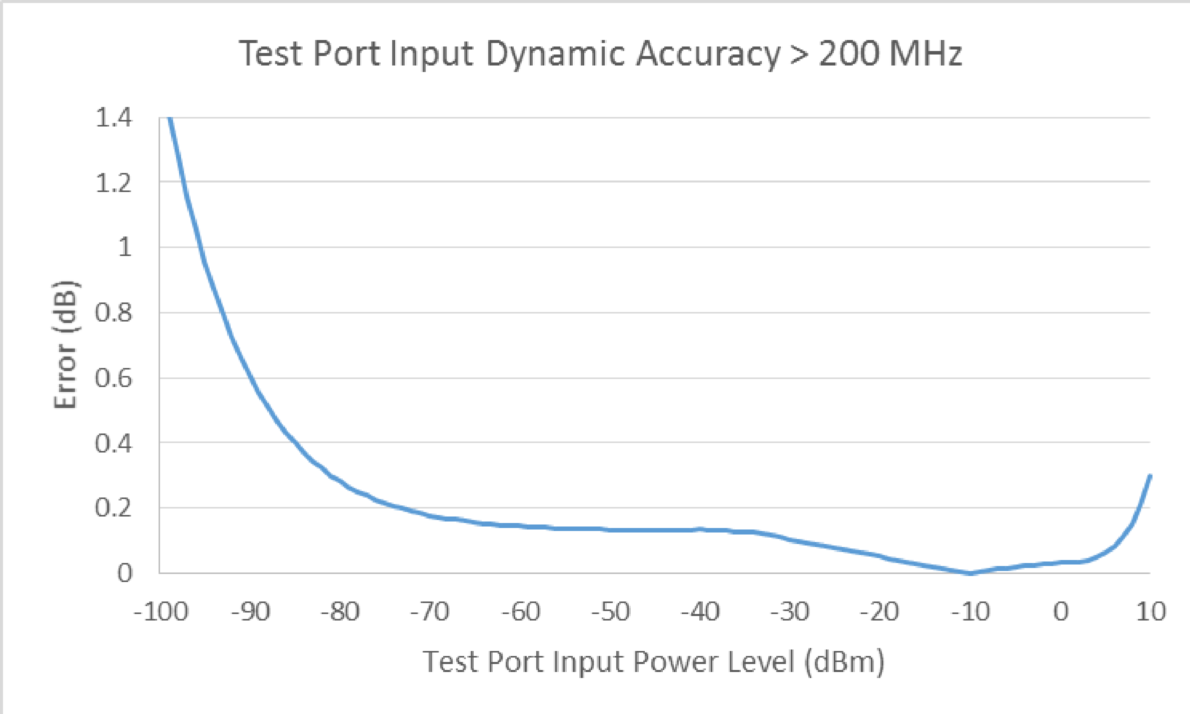
✓Dynamic accuracy

	105 MHz	2 GHz
> -60 to -50 dBm	0.55 dB	0.45 dB
> -50 to -34 dBm	0.35 dB	0.30 dB
> -34 to -20 dBm	0.25 dB	0.20 dB
> -20 to 0 dBm	0.20 dB	0.15 dB
> 0 to +5 dBm	0.35 dB	0.20 dB
> +5 to +10 dBm	0.65 dB	0.40 dB

Dynamic accuracy, typical

	Power range			
Frequency	+5 to +10 dBm	0 to +5 dBm	–30 to 0 dBm	–50 to –30 dBm
10 MHz	0.40 dB	0.25 dB	0.15 dB	0.20 dB
105 MHz	0.30 dB	0.25 dB	0.10 dB	0.15 dB
350 MHz	0.30 dB	0.10 dB	0.10 dB	0.15 dB
783.5 MHz	0.30 dB	0.10 dB	0.10 dB	0.15 dB
1.083 GHz	0.25 dB	0.10 dB	0.10 dB	0.15 dB
2 GHz	0.20 dB	0.05 dB	0.10 dB	0.15 dB
3 GHz	0.20 dB	0.05 dB	0.10 dB	0.15 dB
4 GHz	0.15 dB	0.05 dB	0.10 dB	0.15 dB
5.25 GHz	0.15 dB	0.05 dB	0.10 dB	0.15 dB
6 GHz	0.15 dB	0.05 dB	0.10 dB	0.15 dB





Test port compression at maximum input level, typical

Frequency	+10 dBm input level
10 MHz	0.40 dB
105 MHz	0.40 dB
350 MHz	0.30 dB
787.5 MHz	0.25 dB
1.083 GHz	0.25 dB
2 GHz	0.20 dB
3 GHz	0.20 dB
4 GHz	0.20 dB
5.25 GHz	0.20 dB
6 GHz	0.20 dB

Signal flow parameters

✓Uncorrected signal flow parameters

- User correction OFF
- Factory correction ON
- IF Bandwidth <= 30 kHz

Frequency	Directivity (dB)	Source match (dB)	Load match (dB)	Reflection tracking (dB)	Transmission tracking (dB)
300 kHz to < 500 kHz	–25	–25	–4.5	±1	±1
500 kHz to < 2 MHz	–25	–25	–4.5	±1	±1
2 MHz to < 10 MHz	–25	–25	–11	±1	±1
10 MHz to < 200 MHz	–25	–25	–11	±1	±1
200 MHz to < 1.50 GHz	–25	–25	–10	±1	±1
1.50 GHz to < 4.50 GHz	–25	–25	–8	±1	±1
4.50 GHz to < 5 GHz	–25	–25	–8	±1	±1
5 GHz to 6 GHz	–25	–25	–7	±1	±1

Corrected signal flow parameters, typical — using Type-N Precision mechanical calibration kit Spinner BN533861

Frequency	Directiv-ity (dB)	Source match (dB)	Load match: Insertable de-vices(dB)	Load match with M-M or F-F thru (dB)	Reflection tracking (dB)	Trans-mission tracking (dB)
300 kHz to < 1 MHz	–38	–34	–37	–35	0.08	0.05
1 MHz to < 10 MHz	–37	–34	–37	–35	0.08	0.02
10 MHz to < 100 MHz	–37	–34	–37	–35	0.08	0.01
100 MHz to < 1 GHz	–36	–34	–37	–35	0.08	0.01
1 GHz to < 3 GHz	–36	–34	–37	–35	0.08	0.02
3 GHz to 6 GHz	–36	–34	–36	–35	0.09	0.02
18°C to 28°C, within 1°C of calibration temperature and at the same ambient humidity conditions when the calibration was performed.						

Corrected signal flow parameters, typical — using 3.5mm Precision mechanical calibration kit Spinner BN533864

Frequency	Directiv-ity (dB)	Source match (dB)	Load match: Insertable de-vices(dB)	Load match with M-M or F-F thru (dB)	Reflection tracking (dB)	Trans-mission tracking (dB)
300 kHz to < 1 MHz	–36	–33	–37	–35.5	0.10	0.06
1 MHz to < 10 MHz	–35	–33	–37	–35.5	0.10	0.02
10 MHz to < 100 MHz	–35	–33	–37	–35.5	0.10	0.01
100 MHz to < 1 GHz	–35	–33	–35	–35.5	0.10	0.01
1 GHz to < 4 GHz	–35	–33	–35	–35.5	0.10	0.02
4 GHz to 6 GHz	–28	–28	–29	–29	0.22	0.03
18°C to 28°C, within 1°C of calibration temperature and at the same ambient humidity conditions when the calibration was performed.						

Corrected signal flow parameters, typical — using 4–in-1 Type-N mechanical calibration kit Spinner BN533844

Frequency	Directiv-ity (dB)	Source match (dB)	Load match: Insertable de-vices(dB)	Load match with M-M or F-F thru (dB)	Reflection tracking (dB)	Trans-mission tracking (dB)
300 kHz to < 1 MHz	–32	–31	–32	–31	0.15	0.07
1 MHz to < 10 MHz	–32	–31	–32	–31	0.15	0.03
10 MHz to < 100 MHz	–31	–31	–32	–31	0.15	0.01
100 MHz to < 1 GHz	–31	–31	–32	–31	0.15	0.01
1 GHz to < 4 GHz	–31	–31	–32	–31	0.15	0.02
4 GHz to 6 GHz	–25	–25	–26	–26	0.30	0.04
18°C to 28°C, within 1°C of calibration temperature and at the same ambient humidity conditions when the calibration was performed.						

Reference frequency

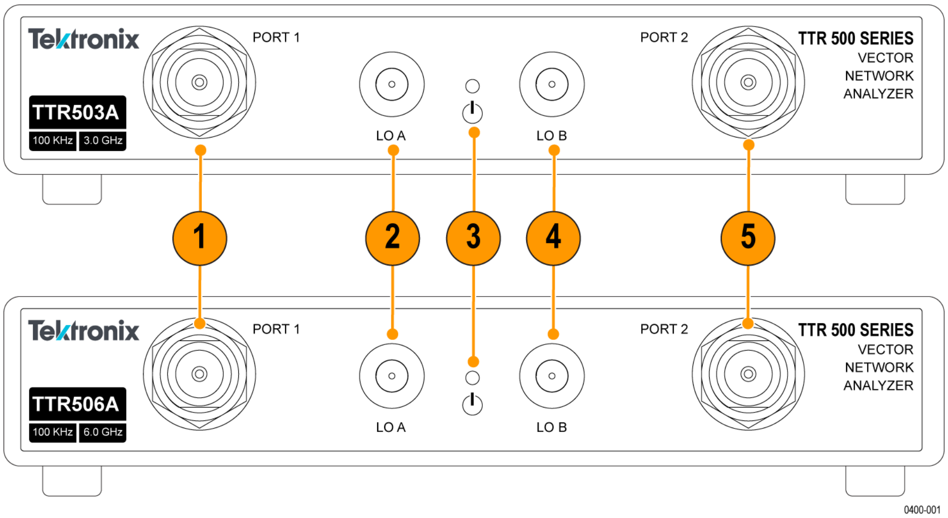
✓Initial reference frequency accuracy	±10 Hz
Temperature drift	< 1.0 PPM, 18°C to 28°C
✓Accuracy over calibration period	±60 Hz This includes initial accuracy, aging, and temperature drift over the specified calibration interval.
External frequency reference input frequency and level range	Input Frequency Range: 10 MHz ± 50 Hz Input Level Range: -5 dBm to 12 dBm sinusoid Maximum level without damage: +15 dBm. AC coupled Maximum Lock Time: 5 seconds
External frequency reference input maximum DC voltage without damage	Maximum voltage without damage: ±30 VDC
✓Frequency reference output level	>5 dBm sinusoid
Frequency reference output level, typical	+11.5 dBm

Trigger

Input trigger levels	Low threshold: < 0.70 V High threshold: > 1.7 V Operating range: 0 V to 5 V Pulse width: > 50 nsec, edge or level, positive or negative polarity

Interfaces, input, and output ports

Front panel connections



Connection	Description
1	RF Port 1
2	Aux LO A
3	LED indicator
4	Aux LO B
5	RF Port 2

RF ports

- Type N, 50 Ω, female, front panel, (2 ports)
- Torque 12 in-lbs nominal, <= 15 in-lbs (32Nm + margin)
- Type N MIL-STD-348B / MIL-C-39012 Class 2 Female
- Use connector savers or cables to extend life.

LO ports

- SMA, 50 Ω, front panel (2 ports)
- Torque <= 8 in-lbs

LO port input power level range

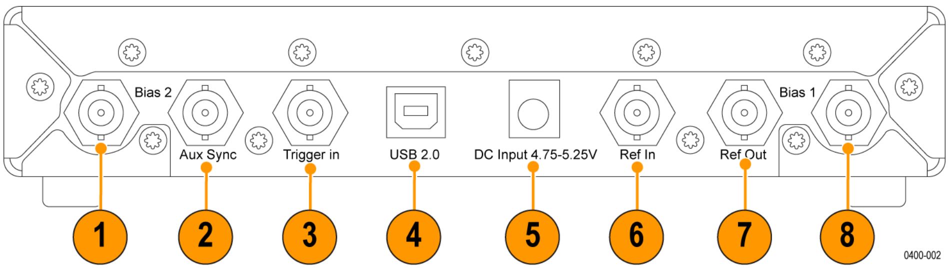
- -12 to +7 dBm
- Maximum input level without damage: 10 dBm, 30V DC

Status indicator

- LED, multicolor

LED state	Description
Red	Instrument is powered and disconnected
Green	Instrument is powered and connected

Rear panel connectors



Connection	Description	Specification
1	DC bias connection for RF Port 2	(See bias tee information below)
2	Auxiliary trigger	BNC, 50Ω, short-circuit protected, female
3	Trigger input	BNC, 1.7kΩ, female
4	USB communications port	USB 2.0 connector, Type-B jack
5	4.75V — 5.25V DC	5V DC input
6	Time base reference input	BNC, 50Ω, female
7	Time base reference output	BNC, 50Ω, female
8	DC bias connection for RF Port 1	(See bias tee information below)

Bias tee

Bias tee connectors	BNC, female, self-resetting fuse
Bias tee connector input level	±24V DC maximum, ±200mA max
Bias tee series resistance, typical	< 5Ω, measured between bias tee input and RF test port

Power supply system

Power consumption	≤ 16W Maximum from 5V DC supply, 5°C to 50°C
Power supply voltage	4.75V to 5.25V, 5°C to 50°C
Power connector	2.5mm jack, barrel type (Ault #3), center contact (+)

Host processor

System requirements	
Minimum PC requirement	Intel® Core™ i3 processor, 8 GB RAM, Windows® 7 or higher, 64-bit
To meet all performance specifications	Intel® Core™ i5 processor with 8 GB solid state drive
Best performance	Intel® Core™ i7 processor, 8 GB solid state drive,

Mechanical characteristics

Weight	3.5 lbs (1.59 kg)
Overall dimensions	Length: 11.25” (28.58 cm) Width: 8.125” (20.64 cm) Depth: 1.75” (4.45 cm)

Environmental performance

Classification	General product classification of **Portable** equipment.
Temperature	
Operating	+5°C to +50°C
Nonoperating	–40°C to +71°C
Humidity, operating	Non-condensing under steady state and transient conditions. 5% to 80±5% RH (relative humidity) in the temperature range of +10°C to 30°C (+50°F to 86°F) 5% to 75% ±5% RH from +30 °C to +40 °C (+86°F to 104°F) 5% to 45% ±5% RH in the temperature range of above +40 °C to +50 °C (+104°F to +122°F) non-condensing
Altitude	
Operating	5000 meters (16,404 feet)
Nonoperating	15,240 meters (50,000 feet)
Dynamics	
Random vibration: operating	Level (g^2/Hz): 0.0002 from 5 to 350 Hz Level Slope (dB/octave): -3 from 350 to 500 Hz Level @ 500 Hz (g^2/Hz): 0.00014 Overall GRMS reference (g): 0.31 Duration per axis (minutes) : 10
Random vibration: non-operating	Level (g^2/Hz): 0.02 from 5 to 100 Hz Level Slope (dB/octave): -3 from 100 to 200 Hz Level (g^2/Hz): 0.01 from 200 to 350 Hz Level Slope (dB/octave): -3 from 350 to 500 Hz Level @ 500 Hz (g^2/Hz): 0.007 Overall GRMS reference (g): 2.46 Duration per axis (minutes) : 10
Mechanical shock: operating	Half-sine mechanical shocks 30 g peak amplitude 11 mSec duration 3 drops in each direction of each axis, 18 total
Mechanical shock: non-operating	Half-sine mechanical shocks 40 g peak amplitude 11 mSec duration 3 drops in each direction of each axis, 18 total
Handling and transit	
Bench handling, operating	Rotational-edge-drops of appropriate edges on appropriate sides of the equipment
Transit drop, nonoperating	Transit drops onto 6 faces and 4 corners of the equipment, from a height of 30 cm for a total of 10 impacts.

Performance verification

The procedures in this section verify that your instrument meets key performance specifications. However, the performance verification procedures are not intended to calibrate the VNA. To calibrate your instrument, return it to a Tektronix service facility.

Prerequisites

For the tests in this section to confirm performance and functionality, these requirements must be satisfied:

- You must run a version of VectorVu-PC application that is 1.0.0 or higher.
- Operate the instrument in an environment that meets the temperature, altitude, and humidity characteristics listed in the specifications.
- The instrument must be completely assembled and covers installed per factory specification.
- The instrument must be operating for a warm-up period of at least for 30 minutes or until the thermometer indicator is green, whichever is longer. The warm-up period is calculated after completing these steps:
  - **a.** Connect the TTR500 instrument to a power supply.
  - **b.** Connect the TTR500 instrument to a PC.
  - **c.** Start VectorVu-PC.
  - **d.** Ensure that VectorVu-PC is continuously acquiring data.

***NOTE.** The TTR500 instrument does not fully power on until VectorVu-PC has established communication with the instrument and is acquiring data.*

- For small-signal S-parameters, the TTR500 instrument must have been calibrated using the recommended precision calibration kit at an ambient temperature within ±1 °C of the current ambient temperature.

***NOTE.** For information on calibration procedures, marker functions and other operations mentioned in these tests, click **Help** in VectorVu-PC software and refer to user documentation.*

Required equipment

The performance verification procedures use external, traceable signal sources to directly check warranted characteristics. This table lists the equipment required for these procedures.

Table 1: Test equipment required for TTR500 series

Item	Description	Qty	Model Number	Purpose
Desktop or Laptop PC	Windows® 7 or higher USB 2.0 or higher	1	Dell Optiplex 9020 MT, or equivalent	Run VectorVu-PC, USB power sensor
USB2 cable	Cable, USB 2.0 Type A Male to Type B Male, 6 ft.	1	174-6150-00 (Tekronix P/N) or equivalent	Communication with TTR500
Frequency counter	10-digits/sec RF Frequency Counter	1	Tektronix FCA3000 series Option HS OCXO or equivalent	Verify frequency accuracy. Opt. HS not required if alternative high accuracy frequency reference is available.
Frequency reference	10 MHz Frequency Standard < ±0.25 ppm error	1	Fluke 910 or high accuracy OCXO	Reference for frequency counter (if needed)
Signal generator	< 10 MHz to > 2 GHz RF Signal Generator, 15 dBm output power min.	1	Tektronix TSG4102, TSG4104, TSG4106 *Opt. M00 or E1 or equivalent	Dynamic range, external reference lock range tests. (Order with Opt. M00 or E1 if using as high accuracy frequency reference.)
Power sensor	100 kHz to 6 GHz	1	Rohde & Schwarz NRP-Z91 or Keysight U2004A or equivalent	Verify TTR500 signal amplitude
Power splitter	Two resistor type, DC – 18 GHz, N	1	Weinschel 1870A or Keysight 11667A or equivalent	Power measurement
3 dB power splitter	$f_l \leq 100$ MHz, $f_h \geq 2$ GHz, Isolation > 17 dB N connectors	1	Pulsar P2-16-411N or Mini-Circuits ZAPD-2-252-N+ or equivalent	Measure dynamic accuracy
Precision adapter N(male) to N(male)	DC -18 GHz coaxial adapter	1	Maury Microwave 8828B	Power measurements
Type N OSLT calibration kit	Type-N OSLTcalibration kit MM 9 GHz	1	Tektronix P/N 015080200(SPINNER BN 533844) or equivalent	Verify specified performance with calibration
Precision 20 dB attenuator	Type N Metrology grade 20 dB attenuator	1	Weinschel Model 44-20, Keysight 8491B-020	Measuring transmission tracking
Type N VNA verification kit	Type N 20,40 dB Attenuation, 50, 25 Ω Airline	1	Spinner BN533480	Verify specified performance
Precision Type N test cable	Cable, Phase-Stable, Type-N(M) To Type-N(F), 60CM	1	Tektronix P/N 012176500 or equivalent	Connect to calibration and verification standards

Table 1: Test equipment required for TTR500 series (cont.)

Item	Description	Qty	Model Number	Purpose
Precision Type N test cable	Cable, Phase-Stable, Type-N(M) To Type-N(M), 60CM	1	Tektronix P/N 012176800	Connect to calibration and verification standards
N(M) - N(F) adapter	Adapter, Coaxial, 50Ω Type-N (M) To Type-N (F) 18 GHz	1	Tektronix P/N 013041000 Maury CC-A-N-FF	
N(F) - N(F) adapter	Adapter, Coaxial, 50 Ω Type-N (F) To Type-N (F) 18 GHZ	1	Tektronix P/N 013041000 Maury CC-A-N-FF	
N(M) - N(M) adapter	Adapter, Coaxial, 50Ω Type-N (M) To Type-N (M) 18 GHZ	1	Tektronix P/N 013041200 Maury CC-A-N-MM	
Type N(F)-BNC(M) adapter	Adapter, Coaxial, 50Ω Type N(F) to BNC(M)	1		If using Type N cable to connect to counter, otherwise use type N(M)-BNC(M) adapter
Type N(M)-BNC(M) adapter	Adapter, Coaxial, 50 Ω Type N(M) to BNC(M)	1		If using BNC cable to connect to counter
BNC cable	BNC cable, 1 m	2		
Type N termination	50Ω, DC - 6 GHz, N-m, VSWR 1.2:1	1	Fairview Microwave STN0610	50Ω terminator for isolation test
Precision N termination	DC -18 GHz, N-m	1	Tektronix P/N 103043500 Maury Microwave 2510B6	
Gauge	Type N MIL-STD-348B / MIL-C-39012 Class 2 female (socket) contact gauge	1	Spinner BN 53 70 13 Maury A0007A	Measure connector pin depth to check for damage
Torque wrench	12 in-lb - Type N	1	Spinner BN 53 70 91 R000 Maury Microwave 2698C2	N- connector attachments

***NOTE.** Make sure that any adaptor and cable you use is specified to operate at the frequency range of the test you are performing.*

Preliminary checks

Complete these steps before starting the performance verification procedures.

Warm up the instrument

1. Connect the TTR500 USB cable to the host PC. The LED on the TTR500 should initially glow red and then turn green after a few moments.
2. Make sure that VectorVu-PC is active and connects to the TTR500 instrument.

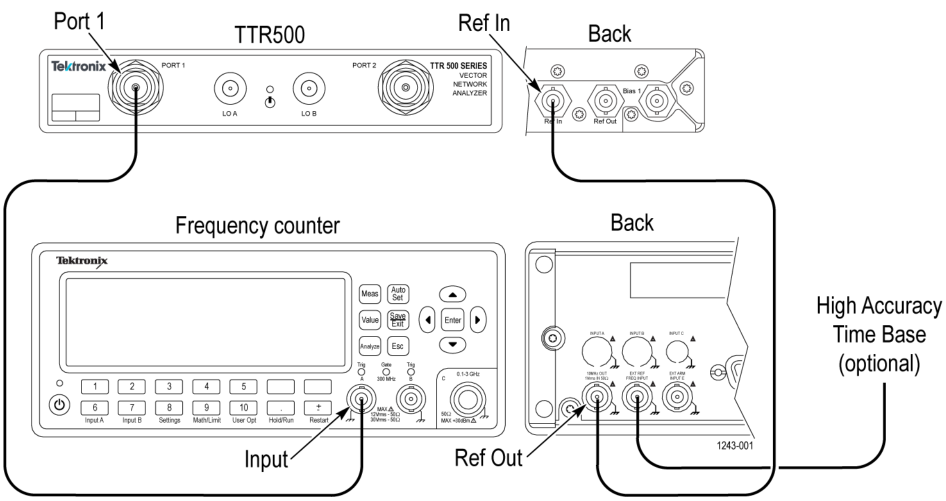
3. View the instrument status bar in the lower left corner of the VectorVu-PC display. Verify that there are no errors or messages indicating loss of data or invalid calibration data.

4. Let the application acquire data. Allow the instrument to warm up for at least 30 minutes.

Performance verification procedures

Internal reference frequency accuracy over the calibration period

Use this procedure to determine whether the internal time base is within its specified accuracy for a full calibration period.



Procedure.

1. Perform an instrument preset (**System > Preset**) on the TTR500 instrument.

2. Set these parameters:

Parameter	Soft key path	Value
Center frequency	**Stimulus > Center**	10 MHz
Span	**Stimulus > Span**	0 MHz
Sweep points	**Stimulus > Sweep Setup > Points**	1
Measurement	**Response > Measure > S21**	S_{21}
Trigger source	**Stimulus > More > Trigger Source**	Manual
Point trigger	**Stimulus > More > Point Trigger**	ON

3. Connect the input terminal of the frequency counter to port 1 of the TTR500 instrument in one of these ways:
   - Use a type N test cable with a type N-to-BNC adapter.
   - Use a BNC cable with a N-male-to-BNC adapter.

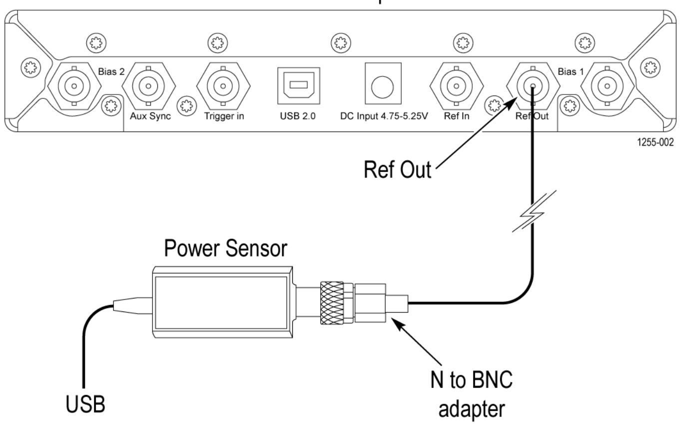
4. Set up the frequency counter to measure a 10 MHz, 0 dBm input signal. The counter resolution and averaging should be set to display frequency with 1 Hz or smaller resolution. If the frequency reference of the counter is not accurate to within 0.1 Hz/MHz then it should be locked to an accurate external frequency standard.

5. Use a BNC cable and splitter to connect the TTR external reference input to the same 10 MHz reference as the frequency counter.
6. In **System > More > Reference Clock Source**, set the TTR500 reference clock source to **External**.
7. Trigger a measurement on the TTR500. Verify that the frequency counter reads 10.000000 MHz.
8. Note the measured value in the calculations table. (See Table 2.)
9. Set the TTR500 reference clock source to **Internal**.
10. Record the frequency measured by the counter in the table for reference accuracy calculations. (See Table 2.) Enter the value under '**Measured frequency**' in the row for internal reference frequency.
11. Compare the measured value with the specification for internal frequency accuracy. Enter the results in the test record.

Table 2: Reference accuracy calculations

	Measured frequency (MHz)	Frequency error (Hz)	Specification	Hz
External reference lock check frequency			**0 (or ≤accuracy of frequency counter)**	**Hz**
	Measured frequency (Hz)	**Frequency error (Hz)**	**Specification**	**Hz**
Internal reference frequency			**± 60**	**Hz**
Ext.Ref. Pass/Fail				
Int.Ref. Pass/Fail				

Frequency reference output level



Procedure.

1. Reset the TTR500 instrument to factory default settings (**Preset > Main**).
2. Connect the power sensor to the TTR500 reference output using a BNC cable and appropriate adapters.
3. Set the frequency of the power sensor to 10 MHz.
4. Note the power sensor reading in the table for frequency reference output level. (See Table 3.) Compare the measured value with the specification for output level.

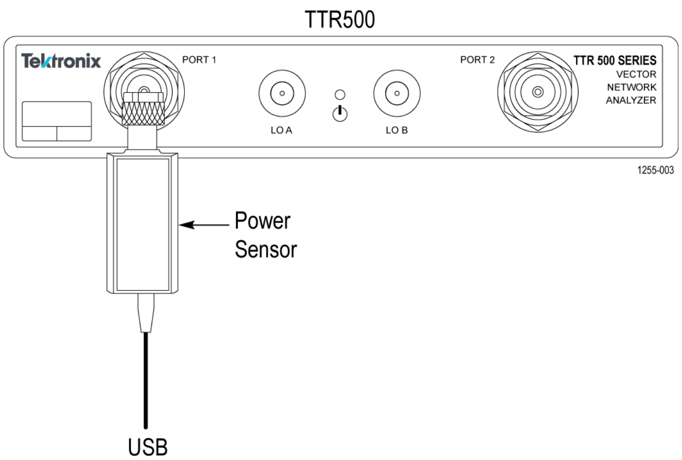
Table 3: Frequency reference output level

	Measured (dBm)	Specified (dBm)	Pass/Fail
Frequency reference output level		> 5 dBm	

Maximum output power and output power level accuracy

You test the port output power at four levels:

- At 10 dBm to measure the maximum output power
- At three lower levels to determine the output power accuracy



Procedure.

1. Power on the power meter/sensor and allow it to warm up to calibrated operating conditions. Perform a calibration and zeroing of the sensor as required by the manufacturer to meet specifications.
2. Perform an instrument preset (**System > Preset**) on the TTR500 and set these parameters:

Parameter	Soft key path	Value
Center frequency	**Stimulus > Center**	300 kHz
Span	**Stimulus > Span**	0 Hz
Sweep points	**Stimulus > Sweep Setup > Points**	1
Measurement	**Response > Measure > S12**	S_{12}
Trigger source	**Stimulus > Trigger > More > Trigger Source**	Manual
Point trigger	**Stimulus > Trigger > More > Point Trigger**	YES

3. Connect the power sensor/power meter to port 1 of the TTR500.
4. If necessary, set the sensor frequency to the same as the TTR center frequency. Some power sensors have sufficiently flat frequency response over the 300 kHz to 6 GHz range that a default frequency can be used, but this must be verified.
5. Set the TTR power level to the first of the TTR levels listed for the center frequency in the table for output power measurements for port 1. (See Table 4.)
6. Execute a manual trigger on the TTR.
7. Measure and record the power meter amplitude. (See Table 4.)
8. Set the TTR power level to the next power listed for this frequency. Execute a manual trigger and record the power meter reading.
9. Repeat until all power levels for this frequency have been recorded.

10. Set the frequency of the instrument to the next value in the table. (See Table 4.)

11. Repeat steps 5 – 10 for this frequency.

12. Complete recordings for all frequencies in the table.

13. Connect the power sensor/power meter to port 2 of the TTR500.

14. Set the center frequency to the first frequency in the table for output power measurements for port 2. (See Table 5.) Repeat steps 5 – 12 for port 2.

15. For each power setting (Max-3 dB, 0 dBm, and –25 dBm) note the largest positive and negative errors in all the reference level measurement tables. Enter these values in the summary table for output power measurements. (See Table 6.)

16. Compare the +peak and –peak errors against the specifications.

17. Enter **pass** or **fail** in the test record.

Table 4: Output power measurements — Port 1

Center/signal frequency	Max. power specification	TTR500 setting (Max-3 dB)	Power meter reading	TTR setting (0 dBm)	Power meter reading	TTR setting (–25 dBm)	Power meter reading
Hz	dBm	dBm	dBm	dBm	dBm	dBm	dBm
300 kHz	2	-1		0		-25	
1 MHz	2	-1		0		-25	
3 MHz	9	6		0		-25	
5 MHz	9	6		0		-25	
10 MHz	9	6		0		-25	
30 MHz	9	6		0		-25	
100 MHz	9	6		0		-25	
199.999 MHz	9	6		0		-25	
200.001 MHz	9	6		0		-25	
300 MHz	9	6		0		-25	
1 GHz	9	6		0		-25	
2.99 GHz	9	6		0		-25	
3 GHz	8	5		0		-25	
4.49 GHz	8	5		0		-25	
4.5 GHz	7	4		0		-25	
4.999 GHz	7	4		0		-25	
5.001 GHz	7	4		0		-25	
6 GHz	7	4		0		-25	

Table 5: Output power measurements — Port 2

Center/signal frequency	Max. power specification	TTR500 setting (Max-3 dB)	Power meter reading	TTR setting (0 dBm)	Power meter reading	TTR setting (–25 dBm)	Power meter reading
Hz	dBm	dBm	dBm	dBm	dBm	dBm	dBm
300 kHz	2	-1		0		-25	
1 MHz	2	-1		0		-25	
3 MHz	9	6		0		-25	
5 MHz	9	6		0		-25	
10 MHz	9	6		0		-25	
30 MHz	9	6		0		-25	
100 MHz	9	6		0		-25	
199.999 MHz	9	6		0		-25	
200.001 MHz	9	6		0		-25	
300 MHz	9	6		0		-25	
1 GHz	9	6		0		-25	
2.99 GHz	9	6		0		-25	
3 GHz	8	5		0		-25	
4.49 GHz	8	5		0		-25	
4.5 GHz	7	4		0		-25	
4.999 GHz	7	4		0		-25	
5.001 GHz	7	4		0		-25	
6 GHz	7	4		0		-25	

Table 6: Output power summary

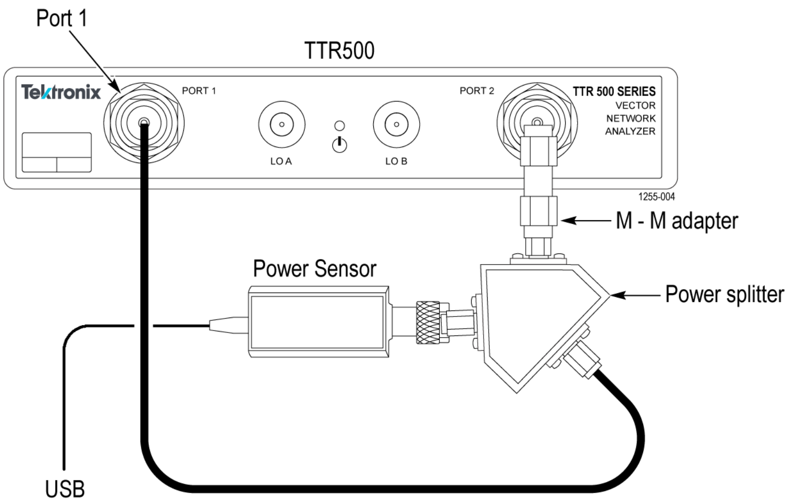
Reference level	Frequency range	Peak positive error	Peak negative error	Specifica-tion	Pass/Fail
Port 1					
Max.power-3dB					
	300 kHz to 6 GHz			±2.5 dB	
0 dBm					
	300 kHz to 6 GHz			±2.5 dB	
-25 dBm					
	300 kHz to 6GHz			±2.5 dB	
Port 2					
Max.power–3 dB					
	300 kHz to 6 GHz			±2.5 dB	
0 dBm					
	300 kHz to 6 GHz			±2.5 dB	
-25 dBm					
	300 kHz to 6 GHz			±2.5 dB	

Test port noise floor

This test measures the average internal noise level of the TTR500 instrument. The specification does not cover residual spurs which may appear depending on the frequency sweep parameters. If you notice residual spurs, turn on spur avoidance (**Stimulus > Sweep Setup > Avoid Spurious**). In addition, if the specific measurement frequency results in measuring a residual spur that is visible above the average noise level, the specification for test port noise floor applies to the noise level on either side of the spur (not to the spur itself).

Workflow.

1. Calibrate the power from the source using a power meter.
2. Use the power as a calibrated source for a receiver power calibration.
3. Correct the low level receiver gain by performing a thru calibration.
4. Switch off the source and measure the noise floor.
5. Repeat the procedure for the other port.



Procedure.

1. Connect a 50 Ω N cable between the power splitter and port 1.
2. Ensure that the power sensor is warmed up and zeroed out from the previous procedure. Connect one output of the power splitter to port 2 and the other output to the power sensor.
3. To avoid conflicts with VectorVu-PC (which controls the sensor for power calibration), you must prevent the power sensor from acquiring signals. To do this, click **Stop** in the power sensor software application.
4. Remove any cables from the bias ports as these can couple noise into the inputs, thus affecting the measurement.
5. Preset the TTR500 to factory default settings (**System > Preset > OK**).
6. Set these parameters:

Parameter	Soft key path	Value
Number of frequency points	**Stimulus > Sweep Setup > Points**	51
Sweep type	**Stimulus > Sweep Setup > Sweep Type**	Log Freq
Averaging	**Response > Avg > Averaging**	ON (use default factor of 16)
Power level	**Stimulus > Sweep Setup > Power Menu > Power Level**	-6 dBm

7. To display the absolute power level at port 2, select **Measure > Absolute > B1**.
8. Click **Cal > Power Calibration > Port 1 > Configure** to set up power calibration at port 1.
9. Set **Averaging Factor** to 4 and **Tolerance** to 10.
10. Click **Calibrate** to run power calibration.
11. Run receiver calibration at port 2. Select **Cal > More > Receiver Calibration > Calibration** and set the receiver port to port 2.
12. Click **Calibrate**.
13. Change the first trace back to B_1 (**Measure > Absolute > B1**).
14. Align the port 2 receiver by performing a thru calibration (**Cal > Calibrate > Response > Thru > S21 > Thru**).
15. Change the first trace back to B_1 (**Measure > Absolute > B1**).
16. Set these parameters:

Parameter	Soft key path	Value
Reference value	**Response > Scale > Reference Value**	-50 dBm
Scale/div	**Scale > Scale/Div**	5 dB/div
Averaging factor	**Response > Avg > Factor**	100
RF power	**Sweep Setup > Power Menu > RF Out**	No

17. For the frequency range in the table for noise floor calculations. (See Table 7.), find the maximum point on the trace using this procedure:
    a. Set up a marker (**Markers / Analysis > Setup**).
    b. In **Markers / Analysis > Search > Search Range**, select the **Search Range** option and set it to **Arbitrary range**.
    c. Enter the range values in **Start** and **Stop**.
    d. Click **Couple** and disable it.
    e. Go back a level to **Markers / Analysis > Search** and enable **Tracking**.

18. The default value of the IFBW for the TTR500 unit is 10 kHz. Therefore, you must subtract 40 dB from the measured noise value to normalize it to a 1 Hz IFBW. To do this, enter the measured value in **Level** in the table for noise floor calculations. (See Table 7.) Subtract 40 dB from this value in the next column.

19. Swap the connections between ports 1 and 2.

20. Repeat the procedure by measuring A_2 in place of B_1. Enter the measured values in the table for noise floor calculations .(See Table 7.)

21. Compare the values in **Level-40dB** with the specification limit. Record if they pass or fail.

Table 7: Noise floor calculations

Frequency range	Specification	Level	Level-40 dB (dBm/Hz)	Pass/Fail
Port 2				
200 MHz to 6 GHz	< -125 dBm/Hz			
Port 1				
200 MHz to 6 GHz	< -125 dBm/Hz			

Dynamic range

The dynamic range of the system is the difference in dB between the specified maximum RF output power and the receiver noise floor in a 10 Hz IF bandwidth. Use the test to measure the average internal noise level of the instrument.

The specification does not cover residual spurs which may appear depending on the frequency sweep parameters. If you notice any residual spurs, turn on spur avoidance (**Stimulus > Sweep Setup > Avoid Spurious**).

Workflow.

1. Calibrate the power from the source using a power meter.
2. Use the power as a calibrated source for a receiver power calibration.
3. Correct the low level receiver gain by performing a thru calibration.
4. Switch off the source and measure the noise floor.
5. Repeat the procedure for the other port.

Since you measured the receiver noise in the noise floor test with a 10 kHz IF bandwidth, the noise level measurements can be scaled by the ratio of bandwidths (10 Hz/10 kHz=0.001 or -30 dB) to compute the noise in a 10 Hz bandwidth. The dynamic range is the difference between the specified maximum RF output power and the noise power at 10 Hz bandwidth.

Procedure.

1. Copy the noise level measurements from the table for noise floor calculations (See Table 7.) to the second column in the table for dynamic range(See Table 8.)
2. Subtract 30 dB from the noise level measurements to compute the noise level in a 10 Hz bandwidth. Enter these values in the third column.
3. Subtract the noise level value in 10 Hz bandwidth from the corresponding value for maximum power. Enter this result in the column for dynamic range.
4. Compare the result with the specification for dynamic range. Note if the value passed or failed the test.

Table 8: Dynamic range

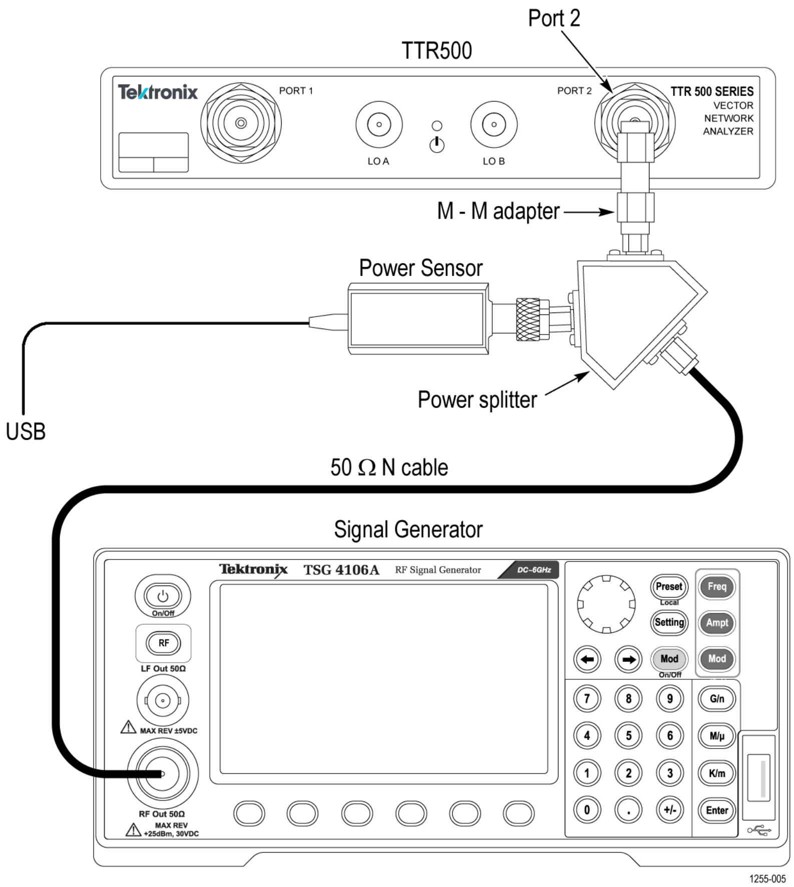
Frequency range	Noise level(See Table 7.)	10 Hz BW Noise level (Noise level -30 dB)	Max specified output power	Dynamic range (Max specified output power -10 Hz BW noise level)	Specification	Pass/Fail
	dBm	**dBm**	**dBm**	**dB**	**dB**	
Port 2						
200 MHz to 2.99 GHz			9		124	
3.00 GHz to 4.49 GHz			8		123	
4.5 GHz to 6 GHz			7		122	
Port 1						
200 MHz to 2.99 GHz			9		124	

Table 8: Dynamic range (cont.)

Frequency range	Noise level(See Table 7.)	10 Hz BW Noise level (Noise level -30 dB)	Max specified output power	Dynamic range (Max specified output power -10 Hz BW noise level)	Specification	Pass/Fail
3.00 GHz to 4.49 GHz			8		123	
4.5 GHz to 6.0 GHz			7		122	

Dynamic accuracy

Use the dynamic accuracy test to measure the power level accuracy of the receiver over its specified range relative to a measurement at –10 dBm.



Preparation.

- Power on the DUT, signal generator, and power meter. Allow them to warm up for 30 minutes.
- Perform the test without interruption.
- Perform the test in an environment with stable temperature (±1°C).

Procedure.

1. Perform a calibration and zeroing of the sensor per manufacturer specifications.
2. Turn on the signal generator and allow it to warm up per manufacturer specifications.
3. Connect a 50 Ω N cable between the output of the signal generator and the input to the 3 dB power splitter.
4. Connect one output of the 3 dB power splitter to port 2 of the TTR500 instrument using an N male-male adapter.
5. Connect the other output of the power splitter to the power sensor.

6. Connect a BNC cable between the reference output of the signal generator and the external reference input to the TTR500 instrument.
7. In **System > Preset**, perform a system preset of the TTR500 instrument to factory defaults.
8. In **System > More > Reference Clock Source**, select an external reference clock.
9. Perform a system preset of the signal generator to factory defaults.
10. Set these parameters in the signal generator:

Setting	Value
Frequency	2 GHz
Output power level	-5 dBm
RF output	ON

11. Adjust the output level of the signal generator until the power meter reads -10.00 dBm or close to it.
12. Disconnect the power splitter.
13. Swap the output connections of the power splitter and reconnect it. You do this to calibrate the port of the power splitter that is connected to the TTR500. This action takes into account any power imbalances in the power splitter.

    The port that was set to -10 dBm level will now provide that level to the input of the TTR500. The power meter reading changes by the balance error of the splitter. You will normalize this error in step 15.
14. Set up a measurement in the TTR500 with these specifications:

Specification	Soft key path	Value
Measurement	**Response > Measure > Absolute > B1**	B1
Center frequency	**Stimulus > Center**	2 GHz
Span	**Stimulus > Span**	10 Hz
Points	**Stimulus > Sweep Setup > Points**	11
Scale/Div	**Response > Scale > Scale/Div**	5 dB
Reference value	**Response > Scale > Reference Value**	0 dBm
Reference position	**Response > Scale > Reference Position**	11

15. In **Setup > Marker 1**, set marker 1 at 2 GHz.
16. Normalize the display (**Display > Memory > Normalize**).
17. Turn on averaging (**Response > Avg > Averaging**) and use the default factor of 16. The marker should read 0.00 dBm.
18. Save the power meter reading as a reference and set the meter in relative mode. The power meter should also read 0.00 dB, like the marker.
19. Decrease the power level of the signal generator in 5 dB steps. Restart averaging (**Response > Avg > Restart**) on the TTR500 after each level change.
20. Compare the power meter reading to the marker reading and note the difference.
21. Repeat steps 7 and 8.
22. Save a new reference level to normalize the power meter again.

23. Normalize the TTR500 reading as in step 15.
24. Return the signal generator to the level that exceeded the error limit. Note the difference.
25. Normalize the power meter by saving a new reference level.
26. Normalize the TTR500 as in step 15.
27. Increase the signal generator level in 5 dB steps, noting the difference between marker and power meter in the table. Repeat until you reach +20 dB on the power sensor.
28. Move the splitter connection from port 2 to port 1 of the TTR500 instrument. Adjust the signal generator level so that the relative power meter reading is 0.00 dB.
29. Set the TTR500 instrument to measure A_2 (**Measure > Absolute > A2**).
30. Normalize the display (**Display > Memory > Normalize**).
31. Restart averaging. The marker should read 0.00 dBm.
32. Perform steps 19 – 27 and note the results in the table for Port 1. (See Table 9.)

Table 9: 2 GHz Dynamic accuracy calculations

Approximate level of signal generator	Approximate test port level (See Table 7.)	Relative reading of power meter	TTR500 marker — normalized reading	Error	Specifica-tion	Pass/Fail
dBm	**dBm**	**dB**	**dBm**	**dB**	**dB**	
Port 2						
15	10				0.4	
10	5				0.4	
5	0				0.15	
0	–5				0.15	
–5	**–10**	**0.00**	**0.00**	0.00	0.15	
–10	–15				0.15	
–15	–20				0.15	
–20	–25				0.2	
–25	–30				0.2	
–30	–35				0.3	
–35	–40				0.3	
Port 1						
15	10				0.4	
10	5				0.4	
5	0				0.15	
0	-5				0.15	
–5	**–10**	**0.00**	**0.00**		0.15	
–10	–15				0.15	
–15	–20				0.15	
–20	–25				0.2	
–25	–30				0.2	
–30	–35				0.3	
–35	–40				0.3	

33. Repeat steps 7 – 32 after setting the signal generator frequency to 105 MHz. Record the results in the table below. (See Table 10.)

Table 10: 105 MHz Dynamic accuracy calculations

Approximate level of signal generator	Approximate test port level (See Table 7.)	Relative reading of Power meter	TTR500 marker — normalized reading	Error	Specifica-tion	Pass/Fail
dBm	**dBm**	**dB**	**dBm**	**dB**	**dB**	
Port 2						
15	10				0.65	
10	5				0.35	
5	0				0.2	
0	–5				0.2	
–5	**–10**	**0.00**	**0.00**		**0.2**	
–10	–15				0.2	
–15	–20				0.2	
–20	–25				0.25	
–25	–30				0.25	
–30	–35				0.35	
–35	–40				0.35	
Port 1						
15	10				0.65	
10	5				0.35	
5	0				0.2	
0	–5				0.2	
–5	**–10**	**0.00**	**0.00**		**0.2**	
–10	–15				0.2	
–15	–20				0.2	
–20	–25				0.25	
–25	–30				0.25	
–30	–35				0.35	
–35	–40				0.35	

Uncorrected signal flow parameters (User correction OFF, Factory correction ON)

Use the tests in this section to check for changes in the TTR500 hardware characteristics based on uncorrected signal flow parameters and factory calibration.

The test procedure measures or computes these errors:

- Directivity
- Source match
- Load match
- Transmission tracking
- Reflection tracking

Definitions.

- **Directivity** is a measure of forward power coupling into the reflected power receiver. From the equation below, if the load match is perfect ($\Gamma_L = 0$), the measured reflection coefficient is equal to the directivity.

  $$S_{11L} = \frac{b_0}{a_0} = E_{DIR} + \frac{\Gamma_L E_{RT}}{1-E_{SM}\Gamma_L} = E_{DIR}$$

  This is a good approximation because the match of a good calibration standard is 10-20 dB better than the directivity specification.

- **Source match** is the output impedance of port 1 or port 2 while sourcing power.

  $$E_{SM} = \frac{S_{11O}+S_{11S}-2S_{11L}}{S_{11O}-S_{11S}}$$

  Since $S_{11O}\approx 1$, $S_{11S}\approx -1$, and $S_{11O}-S_{11S}\approx 2$, the numerator is approximately equal to 2. After you apply factory correction, the sum of ($S_{11O}+S_{11S}$) is generally less than 0.03. $2S_{11L}$ is also of the same order. In the worst case, the two values are equal and in phase, resulting in twice the error.

  Doubling the worst value is canceled out by the approximate factor of 2 in the denominator. The source match is usually not lower than the worst case values of ($S_{11O}+S_{11S}$) and $2S_{11L}$.

- **Reflection tracking** refers to the magnitude response of S_{11} or S_{22} when measured with a perfect short circuit. To estimate the reflection tracking error, you measure short, open, and load calibration standards and remove the effects of directivity. Then you account for the source match error. Since $S_{11O}\approx 1$ and $S_{11S}\approx -1$,

  $$S_{11O} = \frac{b_0}{a_0} = E_{DIR} + \frac{\Gamma_0 E_{RT}}{1-E_{SM}\Gamma_0} = E_{DIR} + \frac{E_{RT}}{1-E_{SM}}$$

  $$S_{11S} = \frac{b_0}{a_0} = E_{DIR} + \frac{\Gamma_S E_{RT}}{1-E_{SM}\Gamma_S} = E_{DIR} - \frac{E_{RT}}{1+E_{SM}}$$

- **Load match** is the input impedance of port 1 or port 2 when the opposite port is sourcing power.

- **Transmission tracking** refers to the magnitude response of S_{21} or S_{12} measured with a perfect thru. Since a perfect thru line does not exist, you must determine its loss independent of other errors. Remove the loss from the measurement.

  To isolate the transmission tracking term, you must correct gain errors due to reflections from source and load. The effective source match is better than -25 dB and you can improve the load match by adding a well-matched 20 dB attenuator to port 2.

  $$S_{21T} = \frac{b_3}{a_0} = \frac{E_{TT}}{1-E_{SM}E_{LM}}$$

Procedure.

1. Power on the TTR500 instrument and allow it to warm up.
2. Restore the instrument to factory default settings (**System > Preset > OK**).

3. In **Sweep Setup > Sweep Type**, select **Log Freq** for logarithmic frequency sweep.
4. **Directivity:** Use a 50Ω metrology-grade calibration load in this procedure.
   a. Connect the 50Ω load calibration standard to port 1.
   b. Measure S_{11}.
   c. Measure the maximum value for each band in the specification. Note these values in the table for uncorrected signal flow parameters. Compare them with the specifications for each band. (See Table 11.)
   d. Note the maximum reading for each band and note if the readings passed or failed. (See Table 11.)
   e. Also note in the test record if the instrument passed this test.
   f. Repeat step 4 for port 2. Verify that the S_{22} parameter at port 2 is lower than the limit for each band in the directivity column.
5. **Source match:** You calculate the source match by measuring short, open, and load calibration standards.

   In **Response > Display > Memory**,

   a. Click **Data** →**Mem** to store the load calibration standard S_{11} to memory.
   b. Use **Data Math > Data+Memory** to add the S_{11} data trace and memory trace values.
   c. Note the maximum value for each frequency band in the specification.
   d. Connect the open calibration standard to port 1.
   e. Store the S_{11} parameter to memory using data math operations as described earlier.
   f. Connect the short calibration standard to port 1.
   g. Measure S_{11}.
   h. Note the maximum value of each frequency band in the specification. (See Table 11.)
   i. Select the worst of the two results for each frequency band. Compare them with the specification.
   j. Note pass/fail in the test record.
   k. Repeat step 5 for port 2 to measure S_{22}.

6. **Reflection tracking:**

   a. Restore the instrument to factory default settings by performing a system preset (**System > Preset > OK**).

   b. In **Sweep Setup > Sweep Type**, select **Log Freq** for logarithmic frequency sweep.

   c. Connect the 50Ω load calibration standard to port 1.

   d. Measure S11.

   e. In **Display > Memory > Data →Mem**, store the load calibration standard S_{11} to memory.

   f. Use **Data Math > Data-Memory** to subtract from the measurement and remove the directivity error.

   g. Connect the open calibration standard to port 1.

   h. Adjust **Scale > Scale/Div** as required.

   i. Note the maximum deviation from zero for each frequency band in the specification in the table for uncorrected signal flow parameters. (See Table 11.)

   j. Connect the short calibration standard to port 1.

   k. Note the maximum deviation from zero for each frequency band in the specification.

   l. Select the worst of the two results for each frequency band. Compare them with the specification.

   m. Note pass/fail in the test record.

   n. Repeat step 6 for port 2 by measuring S_{22}.

7. **Load match:** You can directly measure the load match by performing a 1–port user calibration at the end of a type-N male test cable and then measuring the other port.

   a. Restore the instrument to factory default settings by performing a system preset (System > Preset > OK).

   b. In **Sweep Setup > Sweep Type**, select **Log Freq** for logarithmic frequency sweep.

   c. Connect a test cable to port 1.

   d. Connect a type-N F-F adapter to the open end of the test cable.

   e. Use the BN533844 M-M type-N calibration kit to perform a 1-port SOL calibration referenced to the adapter.

   f. After the calibration is complete, connect the thru line of the calibration kit to the adapter.

   g. Connect the other end of the thru line to port 2 of the TTR500.

   h. Measure S_{11} (load match of port 2).

   i. Note the maximum value for each frequency band in the specification in the table for uncorrected signal flow parameters. (See Table 11.)

   j. Note pass/fail in the test record.

   k. Repeat step 7 for port 2. Perform a 1-port SOL calibration at the end of the test cable connected to port 2. Measure S_{22}.

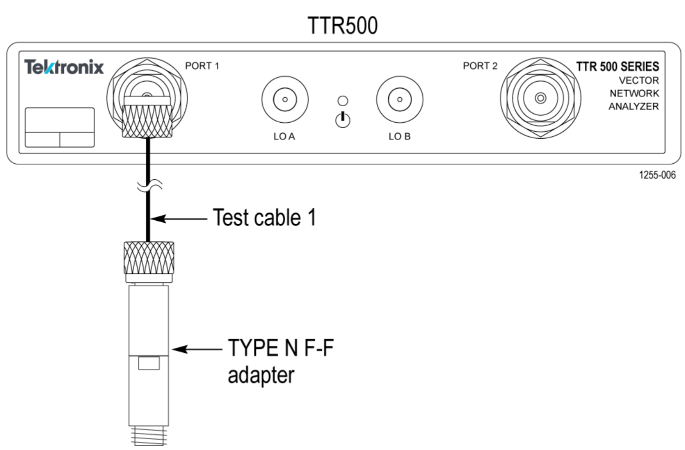
8. **Transmission tracking:** This is the gain error when measuring a perfect thru line.

   a. Restore the instrument to factory default settings by performing a system preset (**System > Preset > OK**).

   b. In **Sweep Setup > Sweep Type**, select **Log Freq** for logarithmic frequency sweep.

   c. Connect test cable 1 to port 1.

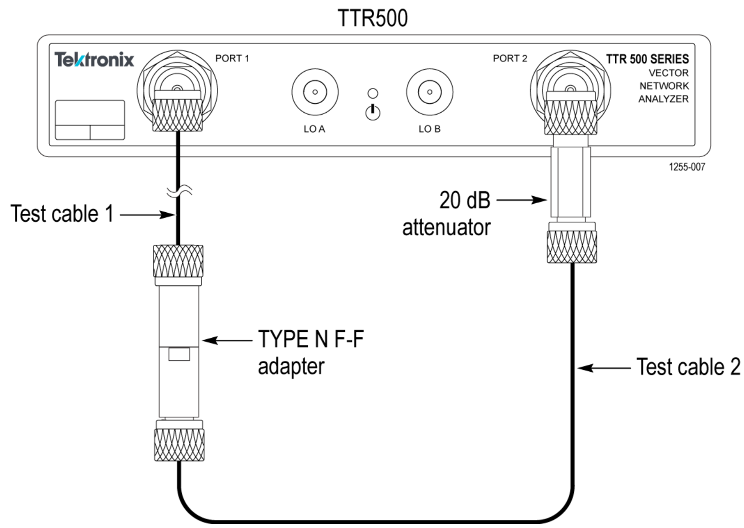
   d. Connect a type-N F-F adapter to the open end of test cable 1.



   e. Use the BN533844 M-M type-N calibration kit to perform a 2-port SOLT calibration referenced to the adapter.

   f. After completing the calibration, connect the 20 dB attenuator to port 2.

   g. Connect test cable 2 between the adapter at port 1 and the 20 dB attenuator.

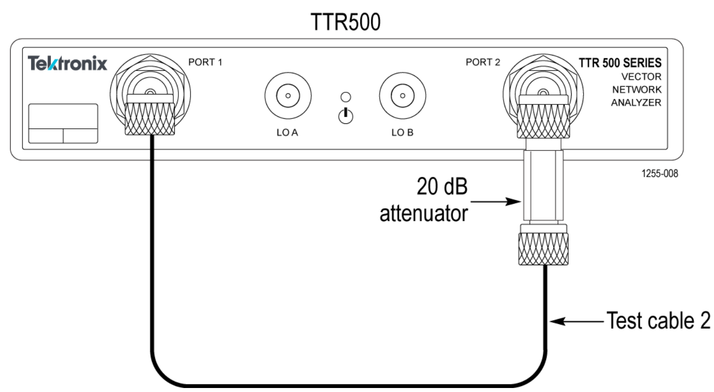


h. Measure S_{21} of the cable+attenuator combination.

i. Store the measurement to memory using **Display > Memory > Data →Mem**.

j. Remove cable 1 and the adapter from port 1.

k. Connect the open end of cable 2 to port 1 of the TTR500 unit.



l. Measure S_{21} of the cable+attenuator combination.

m. Use **Display > Memory > Data Math > Data / Mem** to divide the S_{21} value you measured with the value stored in memory.

n. Autoscale the trace (**Response > Scale > Auto Scale**), which should be approximately 0 dB.

o. Disable error correction (**Cal > Correction**). The trace now displays the approximate transmission tracking error because you removed the cable/attenuator loss and used the 20 dB attenuator to minimize the effect of source/load match.

p. Note the maximum value for each frequency band in the specification in the table for uncorrected signal flow parameters. Note if the value passed/failed. (See Table 11.)

q. Repeat step 8 for S_{12}. When you disable error correction, the displayed trace shows the approximate reverse transmission tracking error.

Table 11: Uncorrected signal flow parameters

Frequency	Specification	Port 1 measured	Port 2 measured	Pass/Fail
	Directivity (dB)			
300 kHz — 6 GHz	-25			
	Source match (dB)			
300 kHz — 6 GHz				
	Load match (dB)			
300 kHz — <2 MHz	-4.5			
2 MHz — <200 MHz	-11			
200 MHz — <1.5 GHz	-10			
1.5 GHz — <4.5 GHz	-8			
4.5 GHz — <6 GHz	-7			
	Reflection tracking (dB)			
300 kHz — 6 GHz	±1			
	Transmission tracking (dB)	**Forward**	**Reverse**	
300 kHz — 6 GHz	±1			

Test record

Record the performance test results for the TTR500 vector network analyzer in this section.

Table 12: Test record for TTR500 VNA

Instrument Serial Number:	Certificate Number:
Temperature:	RH %:
Date of Calibration:	Technician:

Instrument performance test	Pass/Fail	Notes
External frequency reference lock		
Internal reference frequency error		
Frequency reference output level		
Output power level accuracy		
Test port noise floor		
Dynamic accuracy		
Uncorrected signal flow parameters		