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See How This New VNA Stacks Up

Earlier this year, Tektronix introduced its new TTR500 Series. In this article, a bandpass filter measurement example is presented to demonstrate what this new VNA can do.

In past years, the oscilloscope was likely the first instrument that came to mind when thinking of Tektronix (www.tek.com). This thinking was certainly justified, as the company's history with oscilloscopes dates back many years. However, while Tektronix is clearly still at the forefront of this area, the company now offers a wide range of other test-and-measurement instrumentation. These instruments include spectrum analyzers, vector signal generators (VSGs), arbitrary waveform generators (AWGs), and more.

However, one critical test instrument still had not been offered by Tektronix: the vector network analyzer (VNA). That finally changed earlier this year when the company released its new TTR500 Series of USB-based VNAs.This article takes a firsthand look at a TTR500 Series VNA thanks to a demo kit the company provided. For purposes of the demonstration, a bandpass filter measurement is described here. While measuring a bandpass filter with a VNA may seem like something pretty basic to some engineers, the example presented is intended to illustrate how the TTR500 Series has a rightful place in the VNA arena.

1. Shown is a photo of the actual VNA used to perform the measurements described throughout this article.

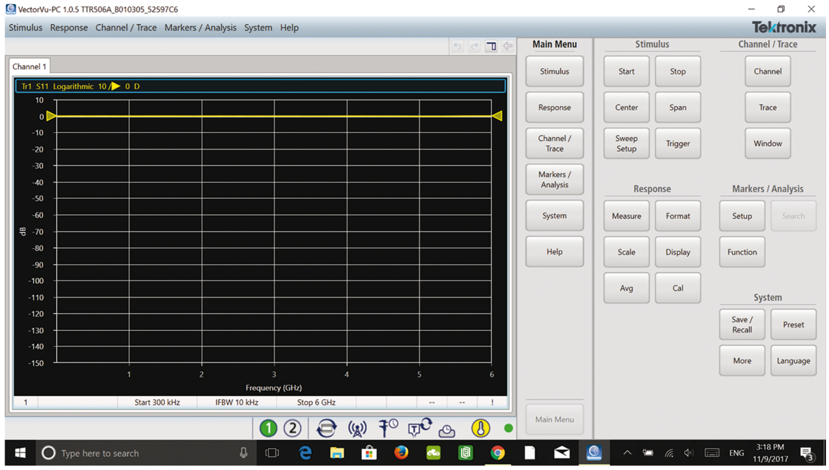
GETTING STARTED

The TTR500 Series consists of two models: the TTR503A and the TTR506A. The TTR503A covers a frequency range of 100 kHz to 3 GHz, while the TTR506A covers a frequency range of 100 kHz to 6 GHz. A TTR506A VNA was used to perform the measurements that are discussed later in this article *(Fig. 1)*.

The TTR500 VNAs connect to a laptop or desktop computer via a USB cable. This connection allows measurement acquisition to be separated from analysis. The end result is a VNA that can easily be carried from one location to another.

To operate the TTR500 VNAs, one must download Tektronix's VectorVu-PC software. In a sense, VectorVu-PC is the VNA equivalent of Tektronix's SignalVu-PC software, which is used with the company's spectrum analyzers. *Figure 2* shows the VectorVu-PC software when first starting the program with the TTR506A VNA connected to the computer. Typical VNA functions can be seen.

The device-under-test (DUT) in the measurement example that follows is Mini-Circuits' (www.minicircuits.com) NBP-1560+ bandpass filter *(Fig. 3)*. This filter has a passband from 1,500 to 1,620 MHz. It is built with a type-N male connector on one side and a type-N female connector on the other.



2. The VectorVu-PC software is used in conjunction with the TTR500 Series VNAs.

TWO-PORT CALIBRATION

Of course, calibration is critical for making VNA measurements. For this example, calibration was performed over a frequency range of 600 MHz to 2.7 GHz. One can perform calibration by clicking the *Cal* button in the *Response* section of the VectorVu-PC user interface. Selecting *Cal Kit* then allows users to select from several built-in calibration kits. For this example, the BN533844 calibration kit from SPINNER (www.spinner-group.com) was used *(Fig. 4)*.

Next, by selecting *Calibrate*, users can choose from different calibration options. For this example, *2-port SOLT* was selected. *Figure 5* shows the user interface after clicking *2-port SOLT*.

The calibration procedure was then carried out in order. After directly connecting the *OPEN* port of the BN533844 calibration kit to *Port 1* of the VNA, the *Open* button was clicked. *Port 1 Short* and *Load* calibration steps were then performed by the same process of connecting the BN533844 *SHORT* and *LOAD* ports, respectively, to *Port 1* of the VNA.

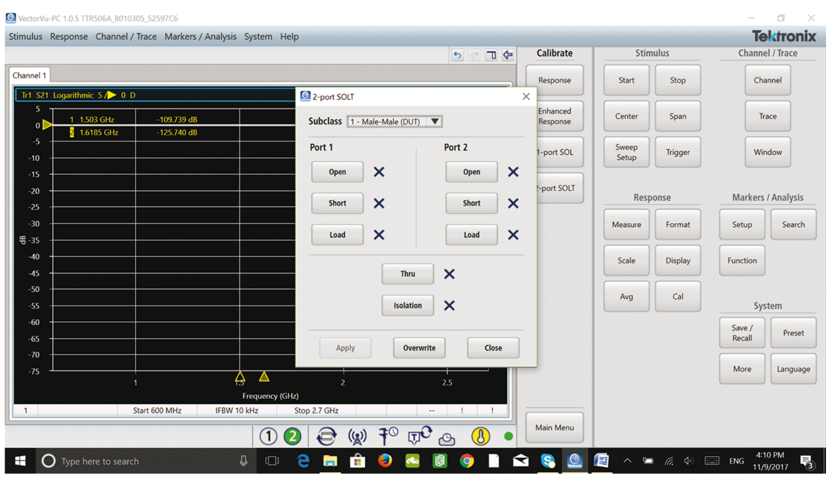
The same process was carried out for the *Port 2* calibration steps. The only difference is that a cable with type-N male connectors on both ends was actually connected to *Port 2* of the VNA. This cable was required to actually measure the filter. Thus, the calibration kit ports were not connected directly to *Port 2* of the VNA, but rather the end of the cable that was connected to *Port 2*.

After completing the *Port 2 Open*, *Short*, and *Load* calibration steps, a *Thru* calibration was carried out. Performing a *Thru* calibration required one of the *THROUGH* ports of the calibration kit to be connected to *Port 1* of the VNA while the other *THROUGH* port was connected to the cable connected to *Port 2 (Fig. 6)*. Once a calibration procedure is complete, users can save the calibration file by first clicking the *Save/Recall* button in the *System* section and then selecting *Save*.

3. Shown is the actual bandpass filter that was used as the DUT.

It also should be noted that an additional calibration step was needed to compensate for the connection change between the calibration and measurement setups. When performing the *Port 2* calibration steps, an adaptor with a type-N female connector on both sides was used in order to connect the end

4. This figure shows the calibration kit used to calibrate the VNA.

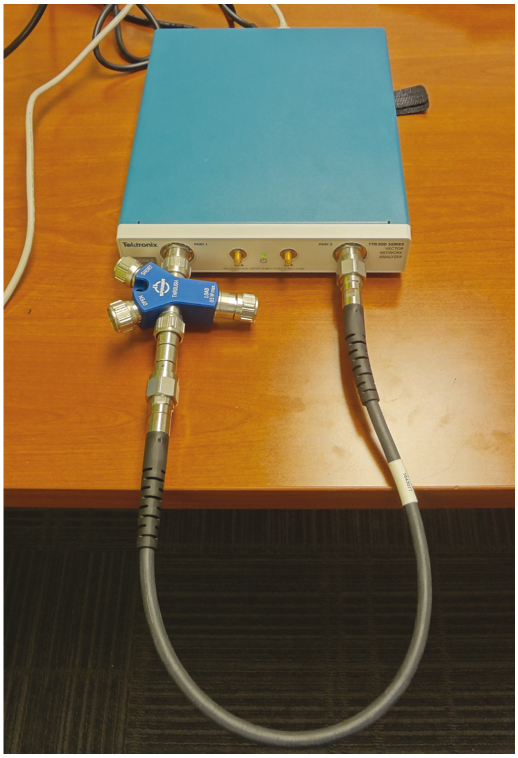


5. Users will see this interface upon selecting 2-port SOLT calibration.

of the cable to the calibration kit ports. However, that adaptor was not actually used in the measurement setup.

For the measurement setup, an adaptor with a type-N male connector on one side and a type-N female connector on the other side was used. This adaptor was placed between the end of the cable connected to *Port 2* and one side of the bandpass filter. *Figure 7* shows both adaptors (For the description that follows, the adaptor with a type-N male connector on one side and a type-N female connector on the other side is referred to as the "measurement adaptor.")

Because the two adaptors have different electrical lengths, an additional calibration step was needed. This additional step, known as *Port Extension*, was carried out by connecting one side of the measurement adaptor to *Port 1* of the VNA and the other side to the end of the cable connected to *Port 2*. After clicking *Cal*, the *Port Extension* button was selected. A delay time of 25 ps was entered, as this value is the approximate delay time that must be compensated for in this example.



6. This photo shows the test setup when performing a Thru calibration.

MEASURING THE FILTER

Next, the filter was connected *(Fig. 8)*. Before discussing the actual filter measurements, it is helpful to first discuss some of the options that users can choose from when using VectorVu-PC. For one, clicking the *Format* button in the *Response* section subsequently displays a number of format types. These formats are *Log Mag*, *Phase (Deg)*, *Phase (Rad)*, *Group Delay*, *Lin Mag*, *SWR*, and *Real*. In addition, selecting the *More* button displays these additional formats: *Imaginary*, *Phase Units*, *Expanded Phase*, *Positive Phase*, *Smith*, and *Polar*.

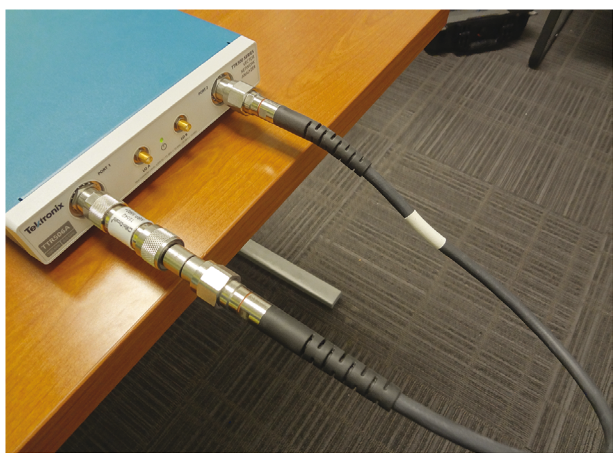
Also, clicking on the *Measure* button in the *Response* section subsequently displays *S11*, *S21*, *S12*, *S22*, and *Absolute*. *Figure 9* shows an *S21* measurement in *Log Mag* format of the bandpass filter over the calibrated frequency range.

A couple of additional points should be noted. First, while Fig. 9 shows one trace being displayed, users have the option of displaying multiple traces by clicking the *Trace* button in the *Channel/Trace* section. One would then select *Num Traces* to specify the number of trace displays.

Furthermore, clicking the *Trace Layout* button subsequently allows users to select from a number of trace layout options. *Figure 10* shows four traces being displayed using the *D12_34* trace layout option. As can be seen, these settings can allow four S-parameter measurements to be viewed simultaneously.

Another notable point is the *Bandwidth* feature, which could be very useful when measuring filters. This feature can be accessed by first clicking the *Search* button in the *Marker/Analysis* section and then by clicking the *Bandwidth* button. Utilizing this feature displays a DUT's bandwidth, center frequency, low and high frequencies, and Q-factor. *Figure 11* shows the *S21* measurement of the filter with the *Bandwidth*

7. Shown are the adaptors used to perform calibration and measurements, respectively.



8. This photo shows the DUT connected to the VNA.

function turned on. While Fig. 11 displays a measurement with the *Bandwidth Value* option set to 3 dB, users can enter any desired bandwidth.

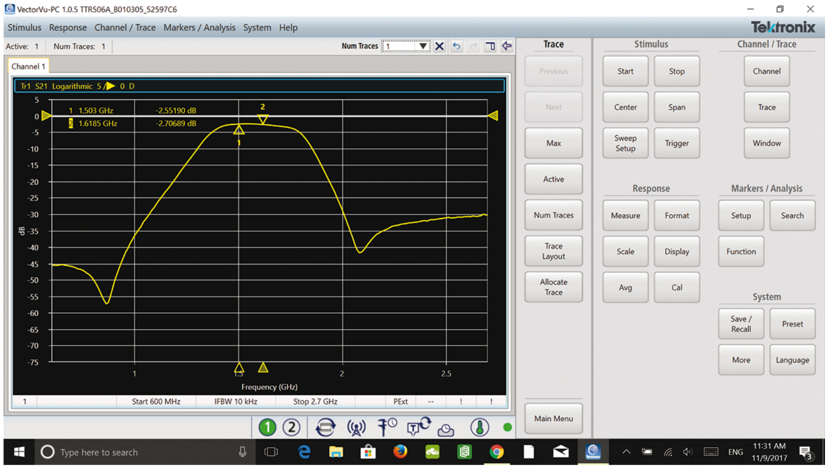
Of course, phase response is also significant in terms of VNA measurements. As stated earlier, *Phase (Deg)*, *Phase (Rad)*, and *Group Delay* measurements are made possible by clicking the *Format* button. Selecting *Phase (Deg)* displays a phase measurement in degrees that is bounded by ±180 deg. Alternatively, selecting *Expanded Phase* displays a phase measurement in degrees that is not bounded by ±180 deg. *Figure 12* shows both *Phase (Deg)* and *Expanded Phase* measurements of the bandpass filter.

TOUCHSTONE FILES AND OFFLINE ANALYSIS

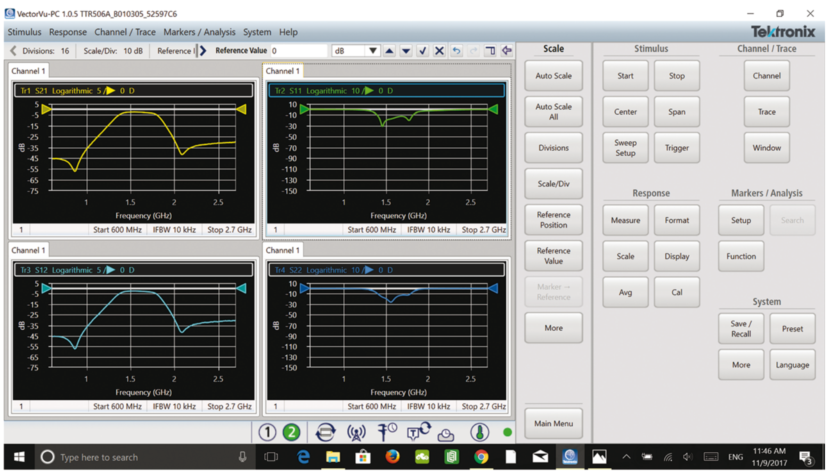
Touchstone files and offline analysis are two additional features that should be mentioned. Essentially, when measuring a DUT, such as the filter used here, the measurement data can be saved in the form of a touchstone file. To create a touchstone file, one would click *Save/Recall* in the *System* section followed by *Save SnP*. This touchstone file, which could be saved in the form of an S1P or S2P file, could then be used in a software simulation tool.

In addition, creating a touchstone file allows for offline analysis, meaning the data contained in the touchstone file can be viewed in VectorVu-PC without even being connected to an actual VNA. Offline analysis can be performed by clicking *More* in the *System* section followed by *Connections*. *Figure 13* shows the resulting interface. After connecting to the simulator, the next step would be to click *Simulator* followed by *Load SnP* to load the touchstone file.

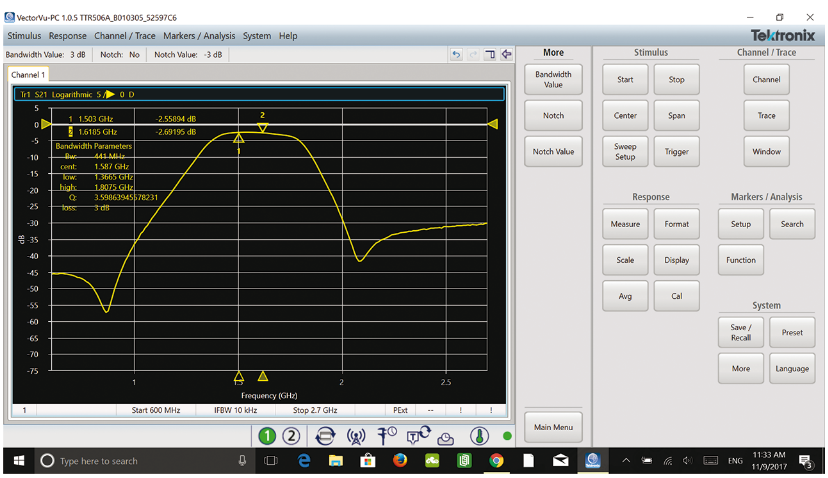
These steps enable the data contained in that touchstone file to be analyzed with VectorVu-PC—without an actual VNA being connected. *Figure 14* shows a laptop that is running VectorVu-PC with offline analysis enabled. In the figure, a touchstone file that was created when measuring the bandpass filter is being analyzed. As can be seen, the VNA is nowhere in sight.



9. This VectorVu-PC plot illustrates an S21 measurement of the DUT.



10. The software allows multiple traces to be displayed simultaneously.

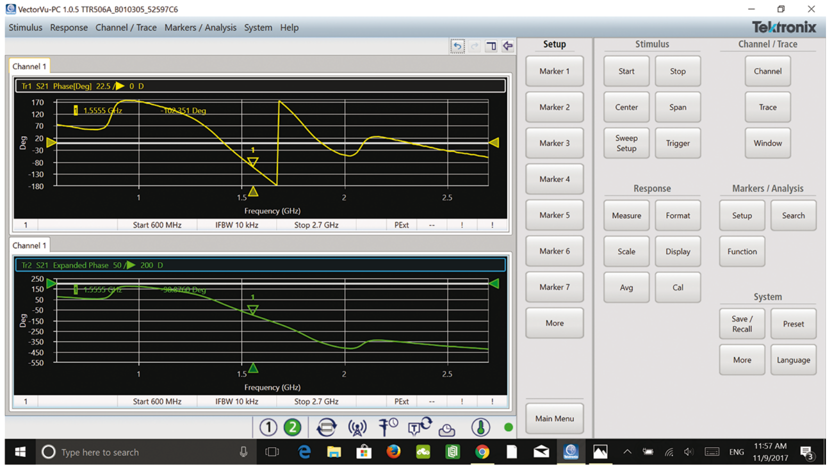


11. Shown is an S21 measurement with the Bandwidth feature turned on.

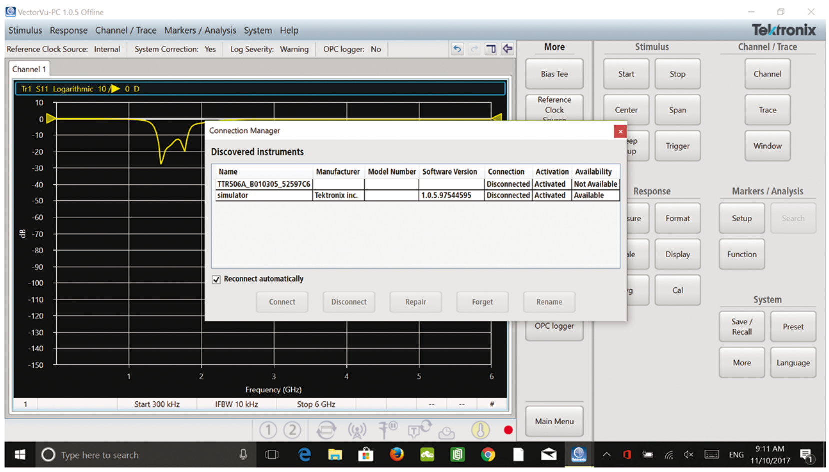
BIAS TEE AND FINAL THOUGHTS

Although not demonstrated in this article, the TTR500 also includes bias tee input ports located on the rear panel. Applying dc bias to these ports allows dc voltage to be supplied to a DUT via the inner conductor of the VNA. This feature can simplify test setups by eliminating the need for additional external hardware.

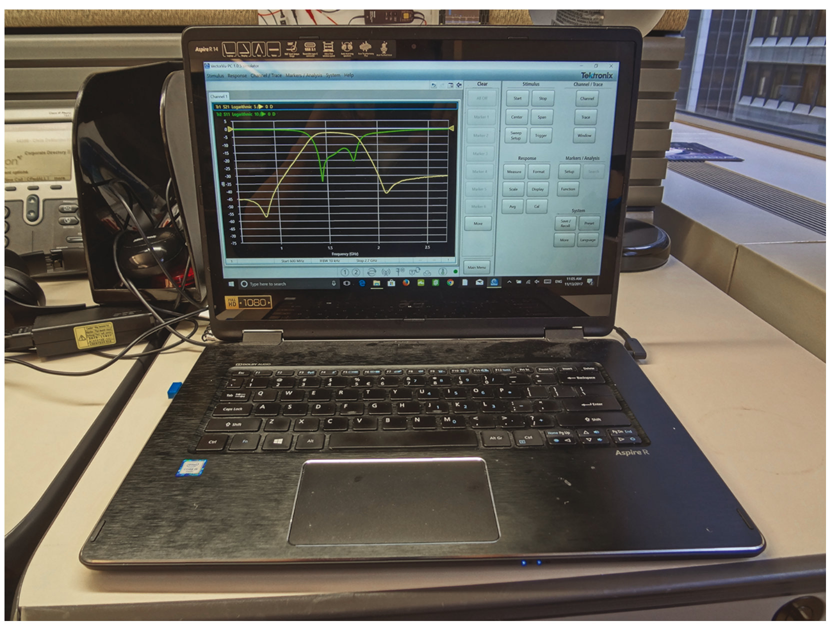
To summarize, this article demonstrated Tektronix's new VNA with a bandpass filter measurement example. Some of the features were explained in an attempt to offer a better picture of the new VNA Series for anyone who has not had the opportunity to use one. In the end, it is clear that the new TTR500 Series is a worthy product in the VNA market.



12. This image shows both Phase (Deg) and Expanded Phase plots.



13. With offline analysis, touchstone files can be analyzed in VectorVu-PC without a VNA connection.



14. Offline analysis is demonstrated in this photo, as the laptop is displaying data from a touchstone file