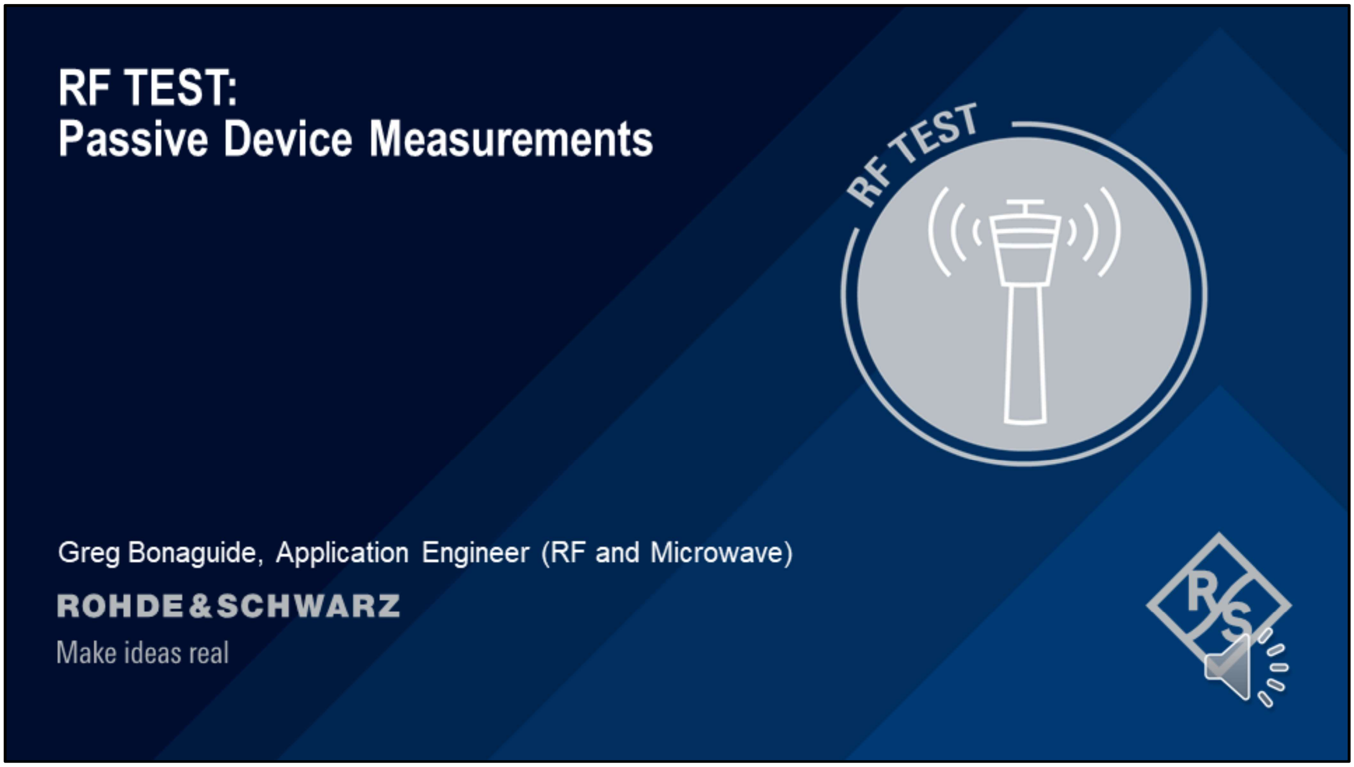
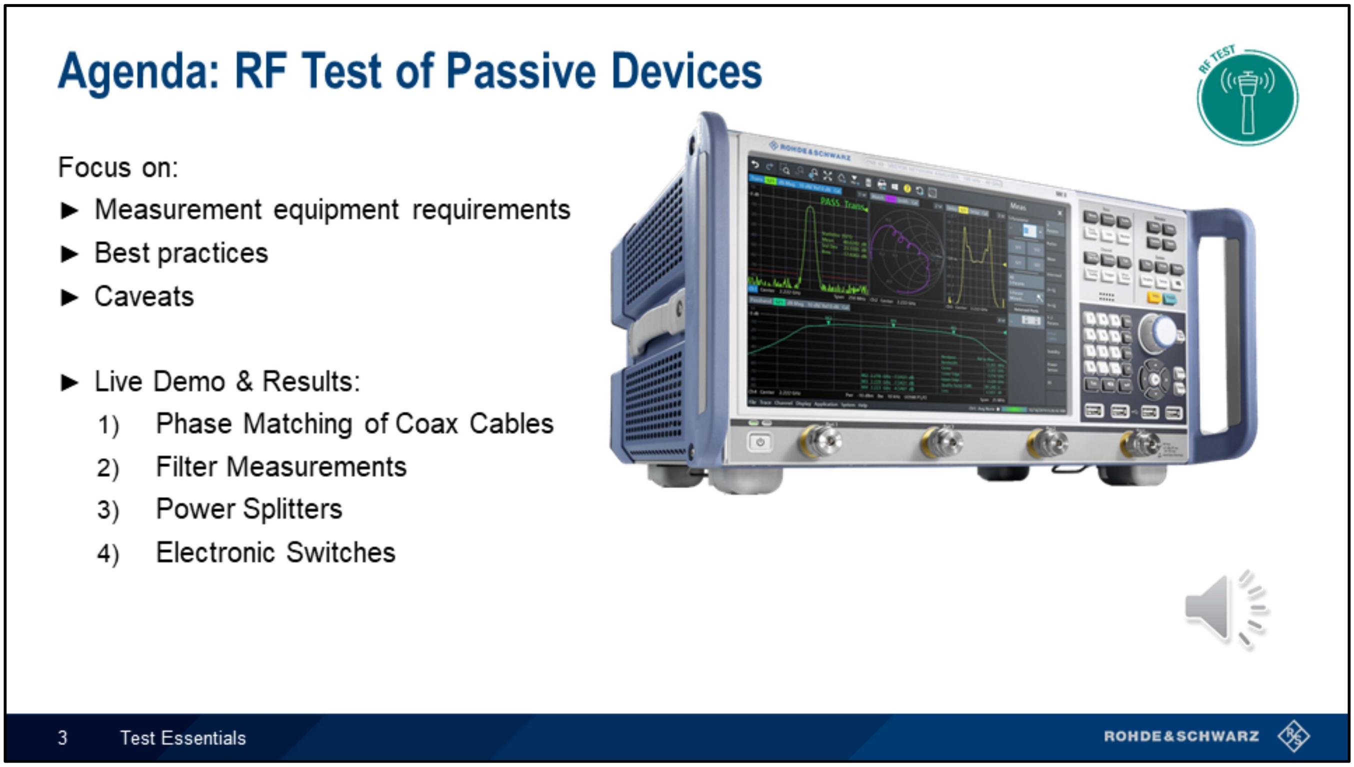

Measurement
Techniques
Design
Verification
&
Evaluation
EVERYTHING TEST
Instrument
Selection
&
Optimization

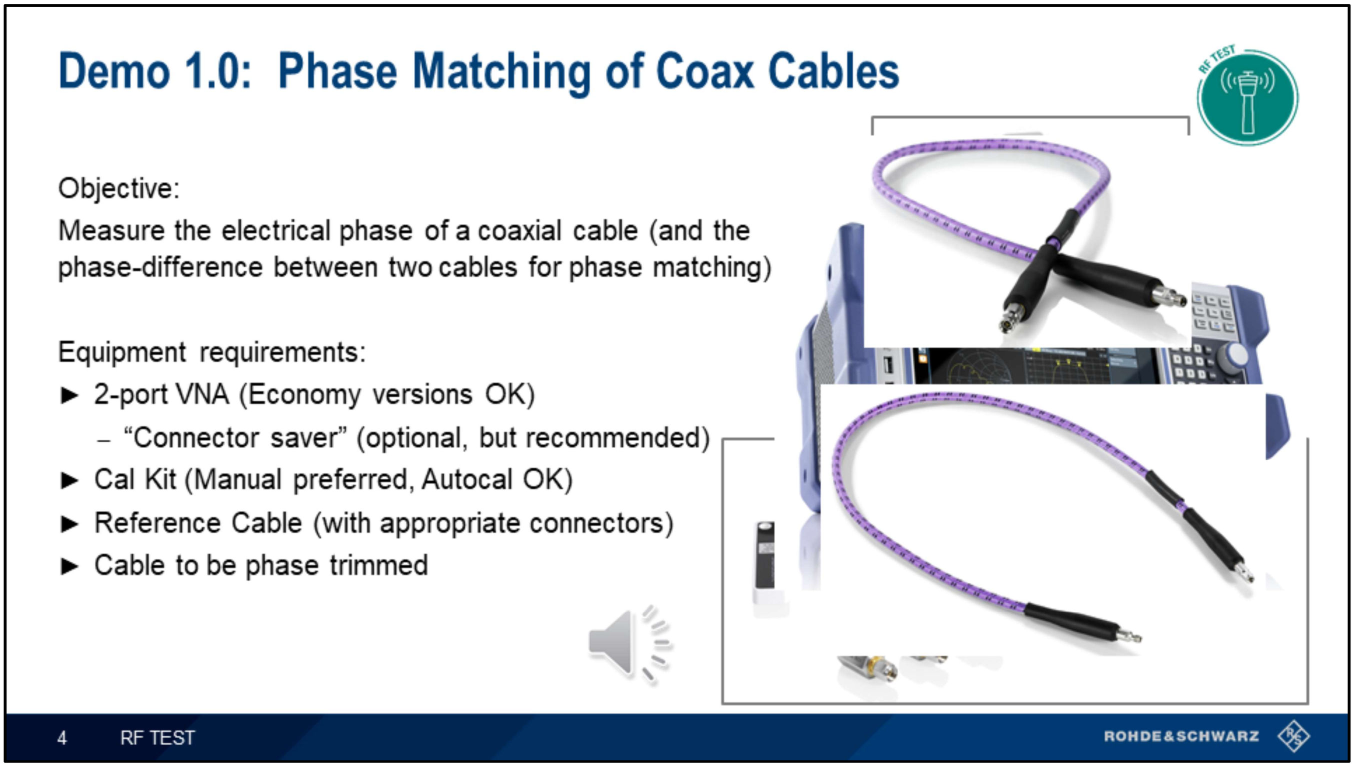


Hello and welcome to the Rohde & Schwarz RF TEST webinar. I'm Greg Bonaguide, an applications engineer specializing in RF and Microwave measurements, and I'll be hosting today's webinar focusing on Passive Device Measurements. Let's get started.



In this webinar, we'll be [1] focusing on several common and important passive device measurement applications, and discussing [2] measurement equipment requirements, [3] best practices, and [4] measurement caveats.

We'll be performing [5] live demonstrations and presenting results for four different applications. For the first application, we'll show how to use a VNA to [6] measure the phase of a cable and, by extension, show how to phase-match coaxial cables. Next, we'll tackle [7] the challenge of optimizing filter measurements for speed and dynamic range. We'll then examine [8] how to measure power-splitters and determine both amplitude and phase balance, and finally we'll look at [9] measuring the frequency-domain performance of a RF switch as well as it's time-domain transient response.

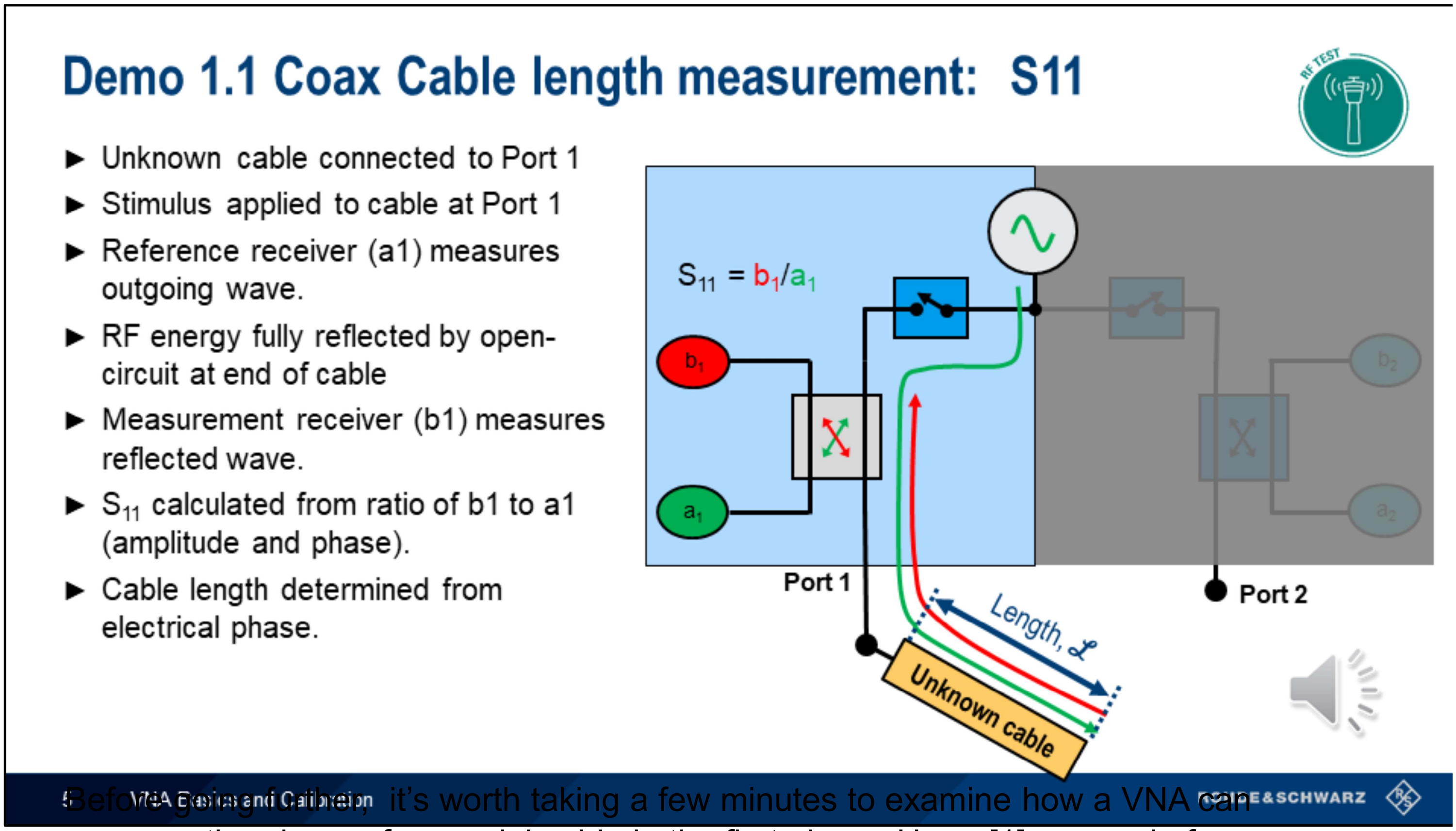


Our first measurement challenge is to [1] measure the electrical phase difference between two coaxial cables. Once we have this information, we can adjust their lengths to obtain a desired phase relationship. Often, we want them to have the same length as in the case of phase-matched cables.

This application [2] requires a [3] 2-port VNA as a minimum. Fortunately, no special options are needed, and an Economy VNA will suffice, provided it covers the desired frequency range.

As we will see, [4] connector savers may be a good investment, particularly if many cables are going to be measured. This will save wear-and-tear on test equipment and costly VNA test cables.

We wll also need to perform s-parameter system error correction, so a [5] Cal kit is required. A Manual cal kit is preferred, but [6] an autocal may also be used. Typically, a [7] reference cable is used to establish the desired or reference phase length. Then, various [8] unknown cables are measured against this reference cable, and trimmed as necessary to obtain the desired phase relationship.

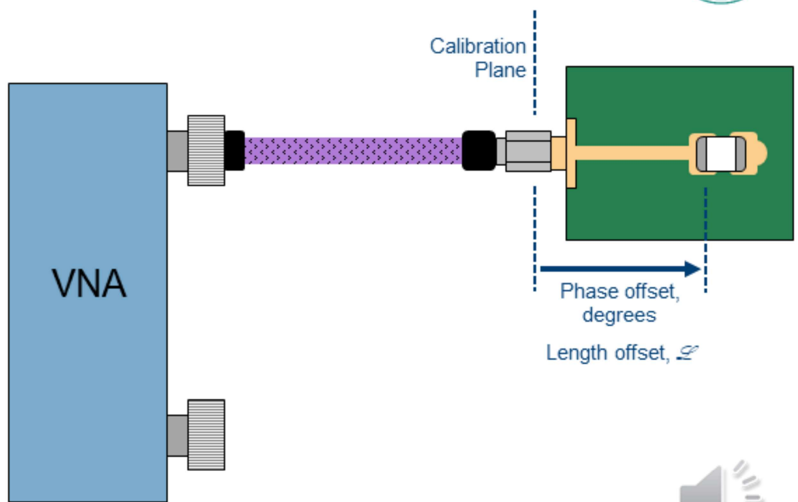


Before going further, it's worth taking a few minutes to examine how a VNA can measure the phase of a coaxial cable in the first place. Here, [1] one end of an unknown-length cable is connected to port 1 of the VNA and the other end is left unconnected. An S11 measurement is configured, which [2] injects RF energy into the cable, and [3] samples the forward-going wave via the port 1 reference receiver. This energy travels to the end of the cable and [4] is completely reflected by the open-circuit condition at the unterminated end. The reflected power [5] returns to the VNA where it is detected by the measurement receiver. The VNA [6] calculates S11 by comparing the amplitude and phase of the returning RF energy to the outgoing energy. The length [7] of the cable is determined from the measured electrical phase.

This length measurement, based on the use of simple s-parameters, is one of those rare occasions in the test and measurement world where an easy approach also happens to be a very good approach.

Electrical Offset: Typical Application

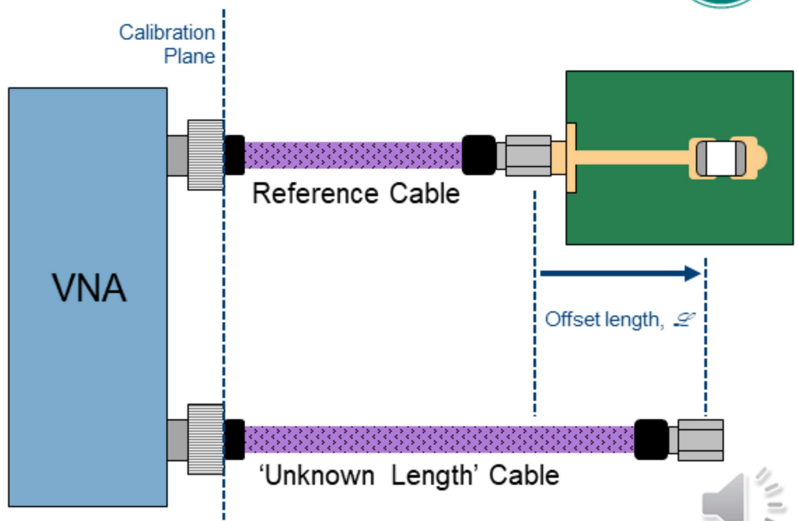
- ► Calibration performed at end of VNA Test Cable
- ► Want to measure DUT on test fixture
- ► Calibration Plane extended to DUT pad
- ► Eliminates "phase rotation" errors (on Smith Chart)



But there's more to this cable-length measurement application. We still need an easy way to calculate length differences. For this application we'll be using the electrical offset function. This function is typically used with test fixtures, as illustrated here. [1] First, a calibration is performed at the end of a VNA Test cable. Then we [2] attach a test fixture, with the ultimate goal of measuring a component mounted on this test fixture. But we don't want to include the phase rotation effects of the line between the calibration plane and the DUT. So we [3] use the Electrical Offset function to extend the calibration plane to the DUT pad, which effectively [4] eliminates the "phase rotation" errors.

Electrical Offset: Cable Phase-Matching

- Calibration performed at VNA Ports
- Want to measure electrical phase/length difference between cables
- Calibration Plane extended to end of test cable
- Directly read length difference.



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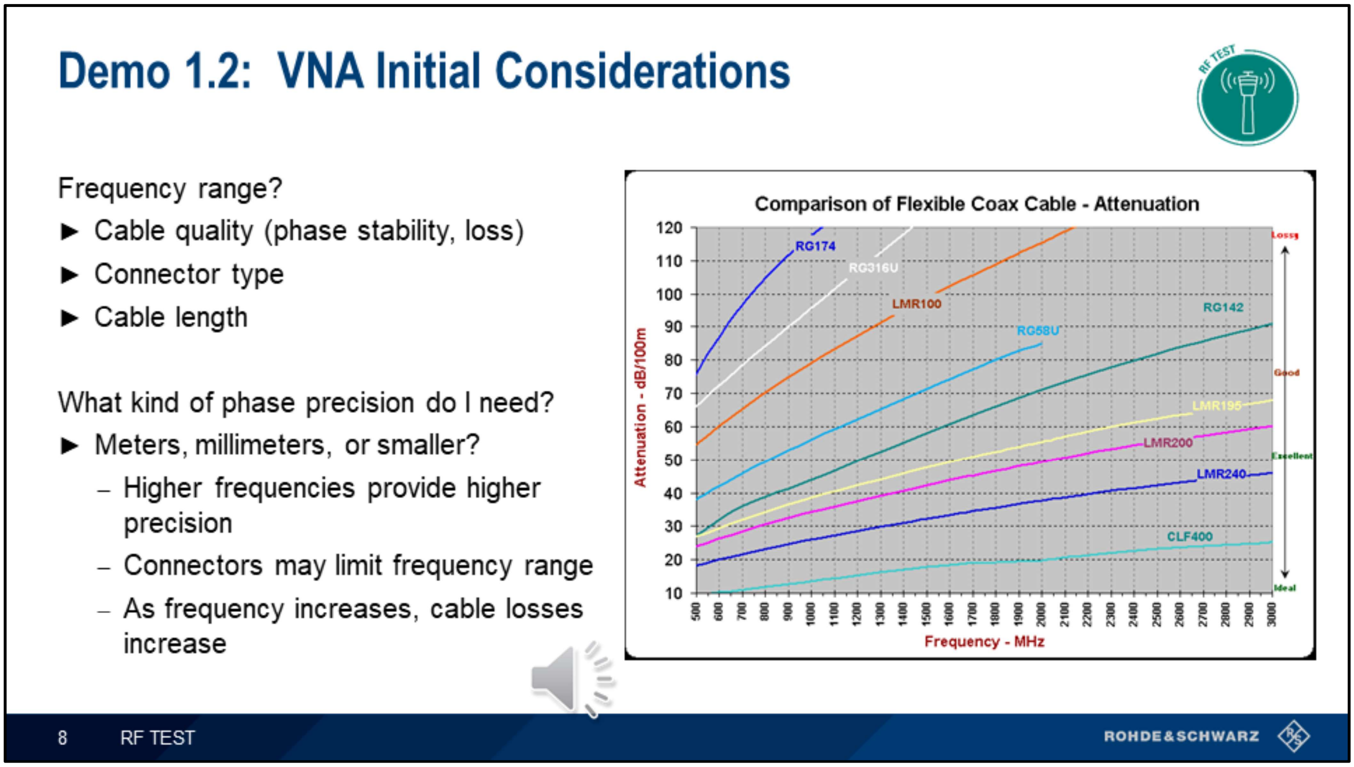
For phase matching cables, we use a variation of this procedure. We first [1] calibrate right at the VNA ports, so when we attach a Reference cable and an [2] unknown cable, we measure their full electrical length, and then use Trace Math to view the electrical phase difference, We then apply the [3] electrical offset function on the unknown cable to match its phase response to the reference cable. Depending on the unknown cable's length, this electrical offset can be either positive, indicating that it is longer than the reference cable, or negative, indicating that it is shorter. Ultimately, after equating the phase responses, we will be able to [4] directly read the difference in cable lengths.



So much for the theory. In practice, we need to understand our measurement's [1] frequency range, which may be influenced by [2] the cable quality, which in turn affects phase stability and loss characteristics, [3] connector type, or [4] even the cable length. An associated consideration is [5] what kind of phase precision do I need? [6] Do I need measurements in terms of Meters of accuracy? Or do I need sub-millimeter precision for determining electrical length at microwave frequencies? Generally, [7] higher frequencies allow phase to be determined with higher precision. But there are limits. For example, the [8] coaxial connectors or the cable dimensions may limit the maximum operating frequency. And [9] cable loss increases with frequency, sometimes quite steeply.

Once we determine our frequency range, we can set up our VNA. As mentioned a few slides ago, phase matching of Coaxial Cables is performed right at the VNA ports. This position provides the greatest phase stability (since no external VNA cables are involved during the calibration process) and it also promotes calibration stability, since the calibration will not be influenced by such external factors as subsequent VNA test cable movement or thermal effects. However, connecting cables right to the VNA ports is not ideal for large-scale testing, because it will lead to accelerated wear on the VNA port connectors. For this reason, [1] high-quality connector savers, such as the 3.5mm female to 3.5mm male adapter shown here, are recommended for installation on the VNA ports. This way, only the adapters will wear out after hundreds or thousands of mate/de-mate cycles, and can be replaced easily.

For our application, [2] 1-port OSM calibrations will be performed right at the VNA ports using a [3] Manual cal kit such as the one shown here. Why? Primarily because the cal kit standards are small and light weight and can easily be attached directly at the VNA ports. In this short video we show the process for setting up the manual calibration, with one-port OSM calibrations performed at each port. We start from a PRESET, and then set our stop frequency to 26.5 GHz, because the cables we're going to be testing are high-quality cables with 3.5mm connectors. We set our step size to 10 MHz. All other default settings are used. Then, in the cal menu, I click on the "Start Cal" tab, and then "Configure/Start Calibration…." This dialog allows me to select the ports I want to calibrate (in this case ports 1 and 2), and also choose my calibration method, which is “reflect OSM”. I then follow the prompts to attach each cal standard, the OPEN, SHORT and MATCH. At the conclusion of the calibration, I click Apply and am ready to make measurements.

Demo 1.3a: Calibration (Manual Cal Kit)

Two 1-port OSM calibrations (since cal is performed right at the VNA ports)

Demo 1.3b: Calibration (Autocal Unit)

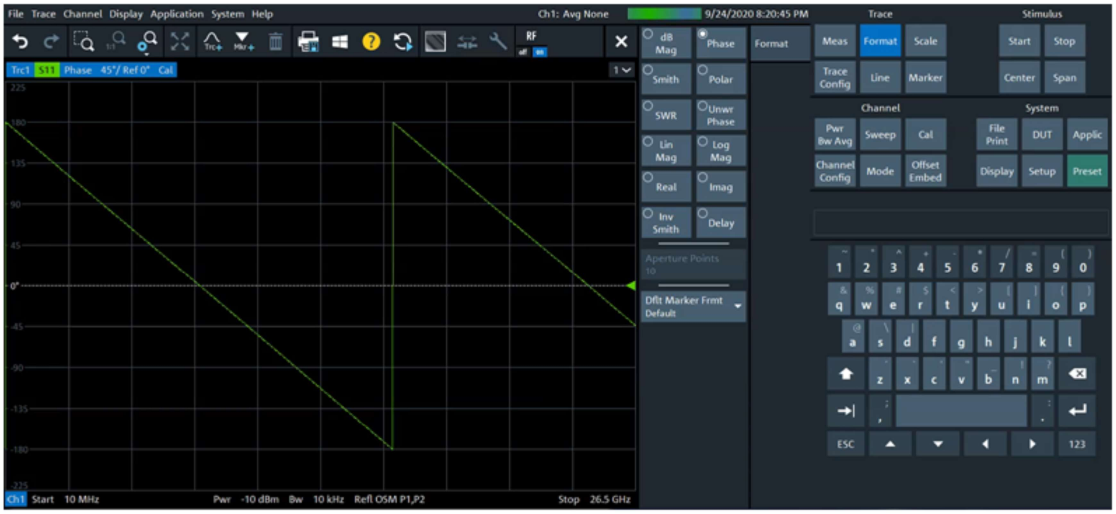
Two 1-port OSM calibrations (since cal is performed right at the VNA ports)

Sometimes, the only calibration kit available is [1] an autocal unit, such as the ZN-Z54 shown here. The autocal is much larger and heavier than the individual calibration standards available from a manual cal kit, so greater precaution is needed to account for this extra bulk when connecting directly to a VNA port. The other challenge with an Autocal unit is that these are primarily designed to simplify two-port calibrations. As a result, when you press "go" it assumes it's attached to two test cables and will try to calibrate both ports. Since we can only attach one port at a time, we have to modify the operation of the autocal unit accordingly.

Here, we again start from a PRESET condition, set our stop frequency to 26.5 GHz, and set our step size to 10 MHz. When we connect an autocal unit via a USB connector, the Rohde & Schwarz ZNA recognizes it after a few seconds and transfers the appropriate calibration information automatically. We press the CAL button and Configure/Start calibration… We then select the OSM method, and add a second calibration step that also uses the OSM method. We direct the instrument to calibrate port 1 in the first calibration step, and port 2 in the second step. In-between these steps, the cal routine stops, allowing me to physically move the cal unit from port 1 to port 2. Notice that this calibration is performed using port 1 of the cal unit at both VNA ports. I can select 'Detect Port Assignment" to verify I've got the correct autocal port connected to the correct VNA port. At the conclusion of these calibrations, I select Cal > Use Cal > Cal Manager… and transfer the current cal to the calibration pool, giving it the name “OSM Autocal”.

Demo 1.3b: Calibration (Autocal Unit)

Two 1-port OSM calibrations (since cal is performed right at the VNA ports)



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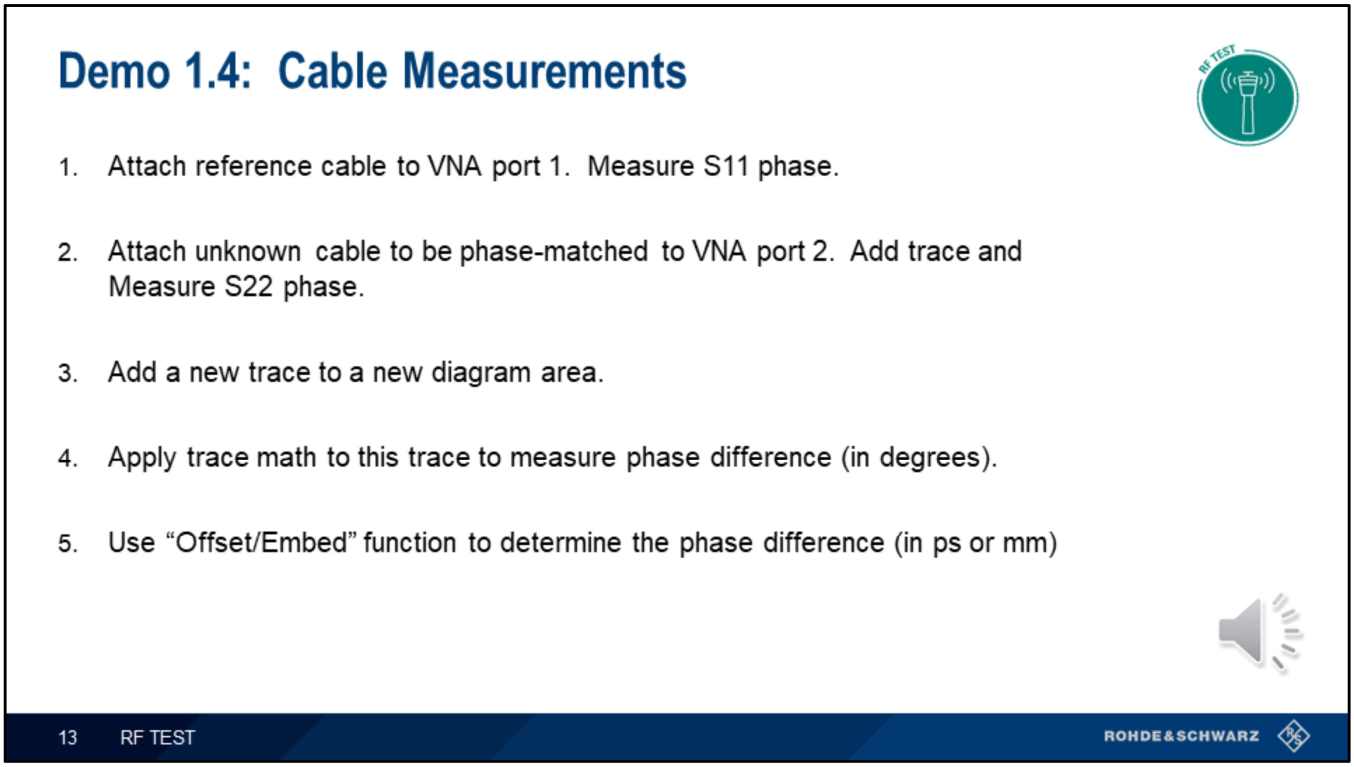

We're now ready to perform cable measurements. The first step is to [1] Attach our reference cable to VNA port 1 and configure the trace for a S11 phase measurement.

Next, we [2] attach the unknown cable to VNA port 2. We add a second trace to the VNA display and set it to measure S22 phase.

We then [3] add a third trace in a new diagram area. We let this trace be S11, but it doesn't matter, because we'll use this trace to display the results of our trace math formula. In the next step, we [4] configure the trace math formula and apply it to the 3rd trace. We also set the measurement format to phase, to allow phase difference to be displayed directly in degrees.

The final step is to [5] use the Offset/Embed function to display the phase difference in terms of physical or electrical length.

Demo 1.4: Cable Measurement

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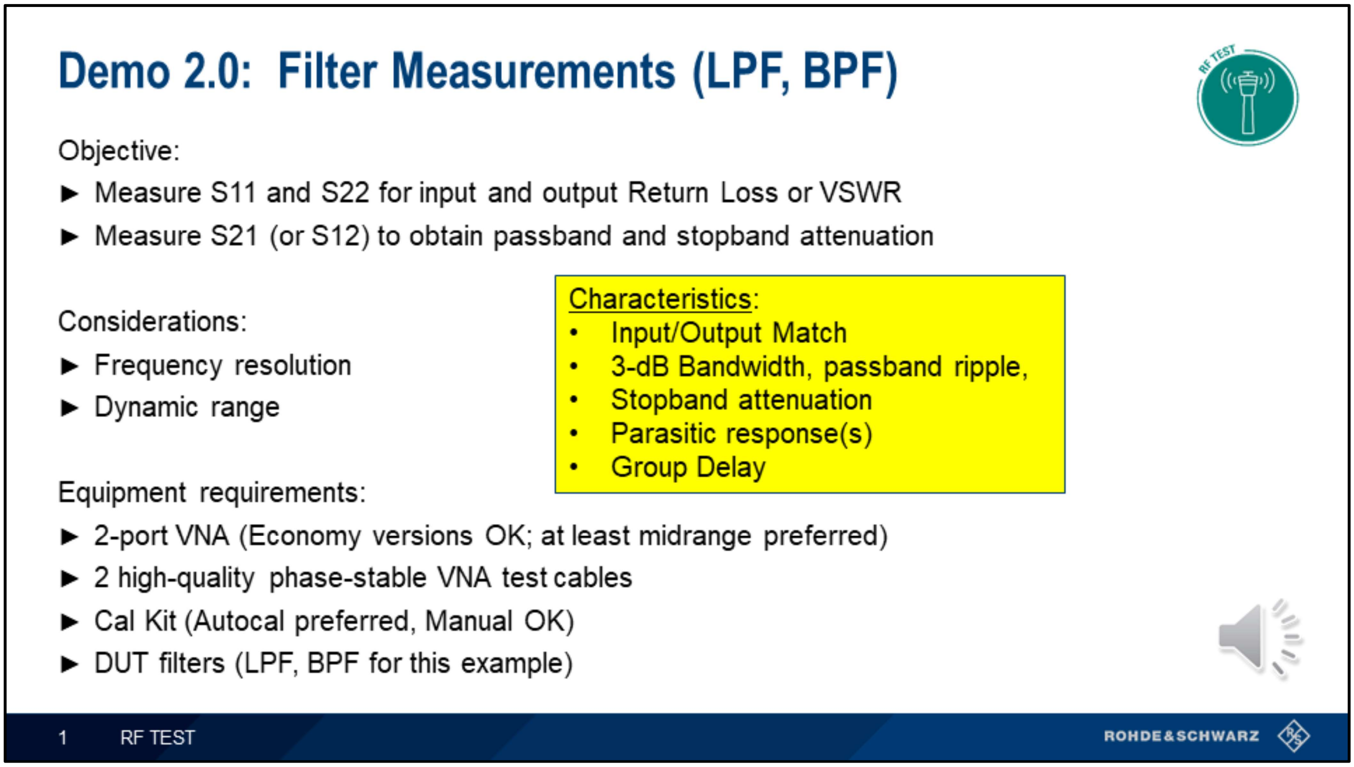

Our second measurement application focuses on RF filters. The electrical parameters of filters are typically determined through the use of s-parameters, so a two-port VNA is perfect for this task. [1] S11 and S22 provide the input and output match by measuring VSWR or return loss. [2] S21 and S12 provide the filter loss in the passband, the filter rejection or attenuation in the stopband, and the steepness of the transition between these ranges. But filter measurements require [3] special care to ensure [4] sufficient frequency resolution in these different regions to satisfy requirements. Additionally, high-performance filters can be challenging because they can have [5] stopband rejection greater than 120 dB, which is a difficult dynamic range to realize with default instrument settings, and may be impossible or impractical to achieve with an economy VNA.

The [6] equipment required for filter measurements includes:

[7] a 2-port VNA with sufficient dynamic range for the measurement. We'll talk about this in greater detail.

We'll also need [8] two high-quality VNA test cables, and

[9] a Calibration Kit. Either a manual cal kit or autocal may be used. It is important that both the test cables and the cal kit have connectors that mate with the filter connectors. Between-series adapters should be avoided whenever possible, because they introduce additional reflections, loss, and measurement uncertainty. Beyond this,

adapters have the habit of becoming loose, compromising measurement results.

[10] The final item is the DUT. In this case, we'll assume we know nothing about our filter, and [11] determine the important DUT characteristics, including:

[12] input and output return loss (and VSWR),

[13] 3-dB bandwidth and passband ripple,

[14] stopband attenuation

[15] out-of-band parasitic response, and

[16] group delay

We'll also consider ways to optimize speed and dynamic range, and make note of possible measurement pitfalls to avoid.

Demo 2.1a: Preset and "Ballpark" Measurements (LPF)

Since we know nothing about our first filter, we'll simply start from a preset and attach the filter to determine ballpark characteristics. We can clearly see this filter has a low-pass response, with a well-defined passband extending down to our lowest measurement frequencies, and a stopband with high-attenuation. We note the transition band between these two ranges, and can also see some additional frequencies where the attenuation is sharply increased. Finally, we can see that beyond a certain frequency, the lowpass filter ceases to provide good stopband attenuation. All these characteristics are quite common in RF filters, and will vary depending on the filter architecture. So now that we know this is a fairly low-frequency filter, we can set our start and stop frequencies appropriately. We'll use 10 MHz as our start frequency, because that's the lowest frequency of our ZNA analyzer, and 7 GHz as our stop frequency, so that we can capture some of the parasitic response as well.

Demo 2.1b: Cal and Initial Measurements

Now I'll attach an autocal unit and perform a 2-port UOSM calibration over this frequency range. I'm using 5 MHz steps, to give good resolution of the filter characteristics within the passband. After completing the cal, I re-connect the filter. This is a moderate-performance filter, as I'm able to capture the entire filter response with default instrument settings. How do I know I'm capturing the entire filter response? Because the stopband response is quite clean. If it were noisy, I would know that I needed to refine my measurement settings to adequately measure the filter performance.

Demo 2.1c: Filter Passband Measurements (Bandwidth)

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To determine the bandwidth, I need to find the cutoff frequency, which is defined as the frequency at which the filter insertion loss is equal to 3 dB. I turn on the REFerence marker, and use the Marker Search function to find the maximum value. I then activate Marker 1 and use the Target Search function to find the frequency at which the filter response is down 3 dB from the maximum. This frequency is 1.2 GHz. The operating frequency range is sometimes defined as 0.9 times the cutoff frequency, which in this case would be 1 GHz.

Demo 2.1d: Filter Stopband Measurements

I take a second marker and place it in the stopband. The stopband may be specified as the region in which the filter attenuation is greater than 20 dB, 40 dB, or some other value. Here, I can establish a limit line and better see this range. I click LINE, then define limit line starting a 10 MHz and stopping at 7 GHz. I leave the default as an upper limit, and establish the response value as -40 dB across this entire frequency range. I then close the dialog, click “show limit line” and “Limit Check” and can instantly see the range over which this filter meets the 40-dB rejection criteria.

Demo 2.1e: Filter Return Loss/VSWR Measurements

I'll bring down a trace and place it in a new diagram area, select S11 and use this to measure input return loss. I'll bring another trace in this diagram area, and select S22 to use it to measure the output return loss. I'm primarily interested in the input and output return loss up to the 3-dB frequency, So, I'll couple the markers from the first diagram area so they appear here. I do this by right-clicking on the trace name and opening the trace manager, and then coupling trace 3 to trace 2. Assuming the return loss requirement is 12 dB, I'll create a limit line for S11 by highlighting this trace to make it active, press LINES, click "Define Limit Line..." and set the value to -12 dB from 10 MHz to 1.2 GHz. I then click "show limit line" and "limit check." I repeat this for the S22 trace. If I were interested in displaying VSWR rather than return loss, I could simply change the format to VSWR. Since the traces are coupled, they will both be changed to VSWR. But the limit lines must be re-defined. I'll click "Clear Test" for each trace and redefine them in terms of VSWR. This time, after defining a S11 limit line for a VSWR of 1.666 (which is equivalent to a return loss of 12 dB), I'll save it and then simply recall it when defining a limit line for S22.

Demo 2.1f: Filter Group Delay Measurements

The final measurement is group delay, which is the amount of time it takes for a signal to pass through a filter. Group delay shows the time on the vertical scale and frequency on the horizontal. In an ideal filter, all frequency components would have the same value across the passband. Typically, the group delay changes at the edges of the passband. Here, I create another S21 trace and display it in it's own diagram area. Since I'm only interested in examining the group delay across the passband, I'll create a new channel for this trace by clicking Trace Config and Trace Manager, and creating a new channel. This new channel inherits all the settings from channel 1, so the calibration is still valid. Now, I simply change the stop frequency to 1.2 GHz, and can see that the group delay is 9 GHz. I can apply trace statisitcs by clicking Trace Config > Trace Statistics and observing the min, max, and pk to pk values with the range from 10 MHz to 1.2 GHz. If I want to limit this range to 1 GHz, I can click “Evaluation Range...” set Range 1 from 10 MHz to 1 GHz, turned Range Limit Lines On, and clicked close. This completes measurements of our first filter.

Demo 2.2a: Preset and “Ballpark” Measurements (BPF)

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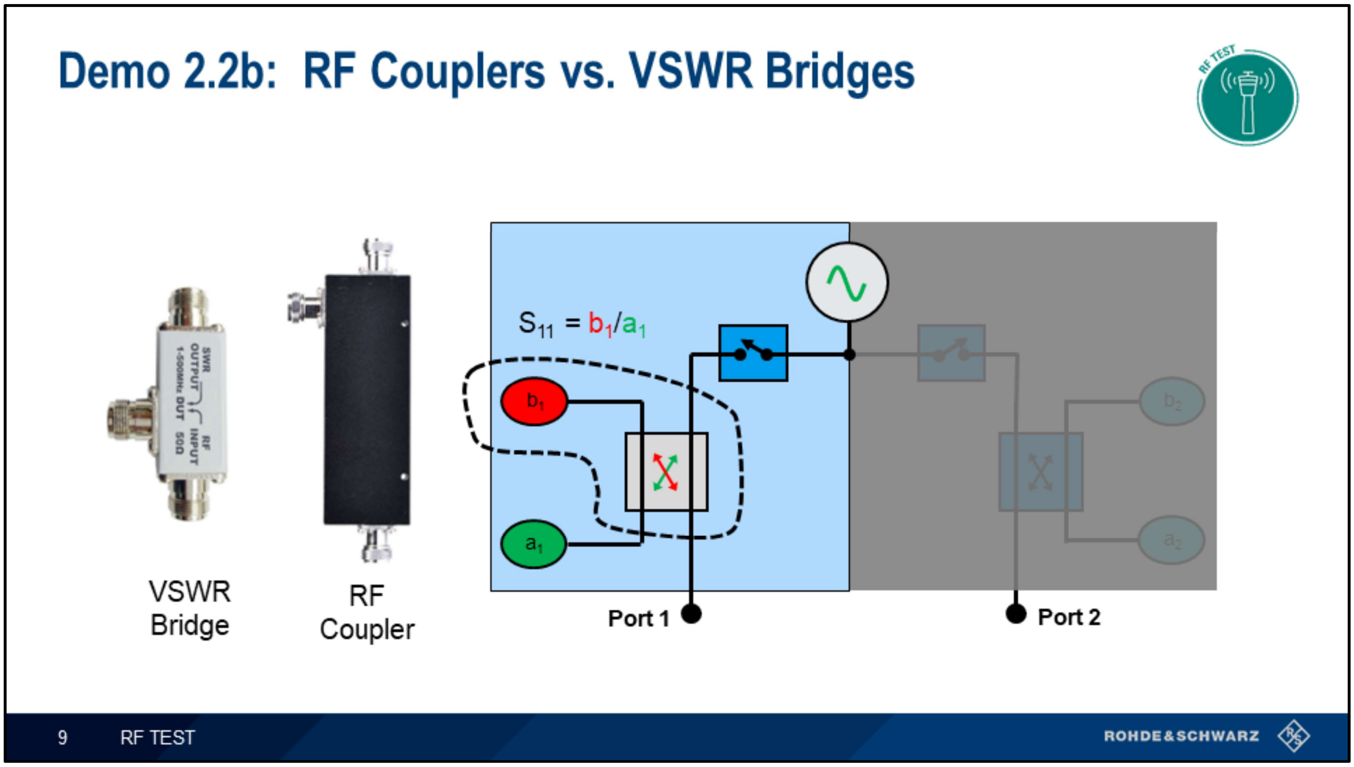
For our second filter, we again assume we know nothing about the filter, so we start from a preset and attach the filter to determine ballpark characteristics. We can clearly see that this filter is a bandpass filter, with rejection regions on either side of a broad, flat passband. If we use markers, we can determine approximate bandpass lower and upper edge frequencies. We also can see an undesired parasitic response that begins at roughly twice the passband frequency. This undesired response is a common artifact of RF filters, and its characteristics are dependent of the selected filter architecture. Here it is sufficient to make a note of where it occurs – 28 GHz.



We can also see a rise in the noise at the far left of the screen. Let's examine this a bit closer, by changing our stop frequency to 1 GHz. If I remove one of the cables and terminate it, we can see that it doesn't affect this noise at all, so we know it's not due to the filter. As we discussed earlier, [1] VNA's use [2] directional components for separating the forward-going from the reflected waves. High-frequency VNA's use [3] directional couplers which are optimized for very broadband operation across a wide swath of microwave frequencies. The drawback is that these couplers lose performance at lower frequencies, where they lack sensitivity. In general, a microwave instrument *can* be used for measuring filters in the HF, VHF, or UHF range, depending on the filter's performance level. For high-performance filters below about 500 MHz, we would actually benefit by switching to a lower-frequency analyzer. This is because lower frequency VNAs use [4] VSWR bridges which perform much better than RF directional couplers for separating the forward from the reverse waves at low-frequencies. Conversely, VSWR bridges perform poorly at high frequencies, whereas directional couplers excel. For our current application, it's clear that we need to test a microwave filter, so an instrument optimized for microwave measurements is appropriate.

Demo 2.2c: Calibration

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Demo 2.2c Calibration

So now we're ready to set up our measurement. We'll again start with a PRESET, and set the lower frequency to 1 GHz and the upper frequency to 30 GHz. We'll use 10 MHz frequency steps, which gives us 2901 measurement points. We'll then calibrate using an autocal with it's default UOSM method, and we're ready to make measurements.

Demo 2.2d: Sufficient Number of Measurement Points?

Now that we're ready to make filter measurements, the first thing to check is that we're using a sufficient number of measurement points to characterize the passband. I'll place a marker in the passband and turn on the bandpass measurement function. It shows the 3-dB bandwidth as xxx MHz. If I were to use only the default number of measurement points (which is 201), the frequency step size increases to yyy, and the 3-dB bandwidth changes to zzz, because the analyzer is applying a linear approximation to the response between each measurement point. So we need to increase the number of frequency points until the measured bandwidth no longer changes.

Demo 2.2e: Sufficient Dynamic Range (DR) for Stopband Measurements?

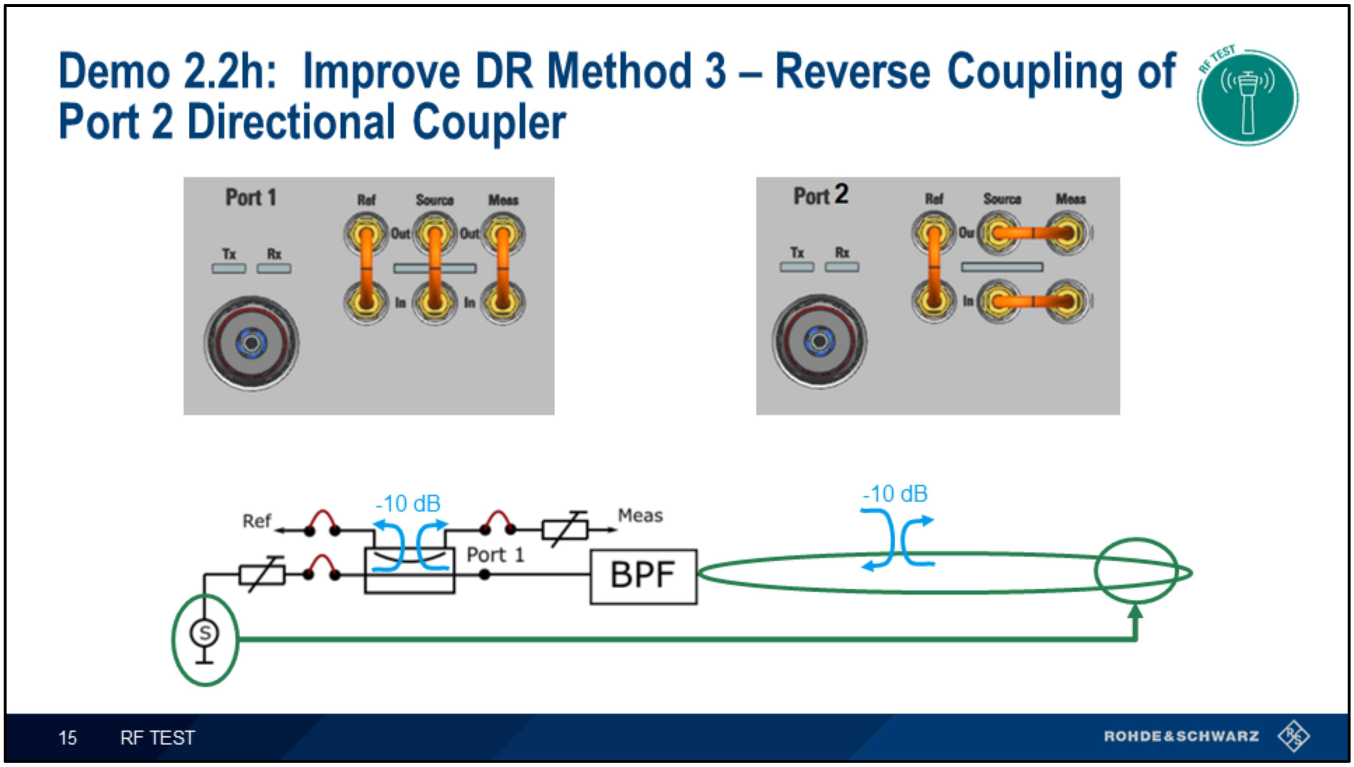
Now, let's turn our attention to the stopband. We want to accurately measure the filter response in this region. We can see this response looks noisy, so right off the bat we have to make sure we're measuring the filter performance and not being limited by the noise floor of our VNA. Let's readjust the scaling, choosing 20-dB steps, and place the reference line at the top of the screen, setting it's value to 0 dB. I'm also going to apply 1% smoothing to make the relative noise level easier to see. Now, how can we improve our dynamic range? Well, we have several options: On most VNA's we can reduce the IF BW or increase power. But High-performance analyzers may also have built-in receiver attenuators available that can be switched out of circuit to further increase the dynamic range, and other tricks to extend dynamic range even further.

Demo 2.2f: Improve DR Method 1 – Increase Power

We'll eventually examine all these methods, but let's start with the power. The default value is -10 dBm. I'll save a memory trace to record our starting point, and show what happens with a power increase. When I increase the power by 10dB, my noise floor drops by 10 dB. The source is now at 0 dBm. If I increase it by another 10 dB, to 10 dBm, the noise floor drops by another 10 dB. With smoothing turned OFF the response in the stopband is still very noisy, so we can tell that our filter actually has better than 100 dB dynamic range. Can we continue increasing source power? Eventually, we'll reach the power limit of the internal generator. But there are other concerns. Watch what happens when we increase our power by another 10 dB. While the noise floor drops, the amplitude in the passband also changes, because the reference receiver is undergoing compression, leading to an invalid amplitude measurement. We want to make sure both receivers are operating in their linear range.

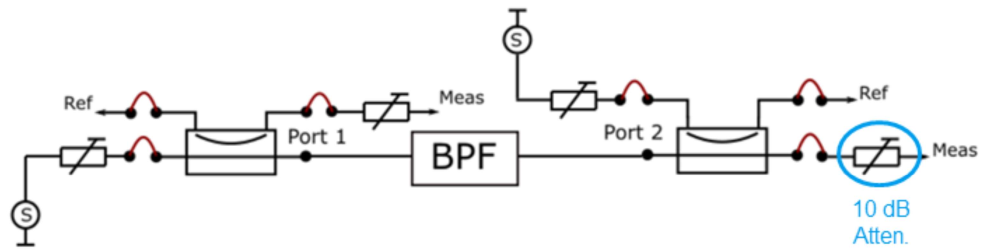
Demo 2.2g: Improve DR Method 2 – Decrease IF BW

So let's set the power back to +10 dBm (where the receivers are not compressing) and start reducing bandwidth. We'll use decade steps. As I reduce the bandwidth of the IF filters, they capture less noise, so the noise floor drops. When I reduce the IF bandwidth from the default value of 10 kHz to 1 kHz, the noise floor drops 10 dB. But notice that the sweep time increases. If I drop the BW from 1 kHz to 100 Hz, we see that the lower bandwidth requires more measurement time for each measurement point, but we can't reduce the number of measurement points too far or else we'll no longer be able to adequately characterize the filter passband. And we can't increase the IF bandwidth to speed up the sweeps without reducing the dynamic range within our stopband. We see that the 100 Hz BW does lower our noise floor, but is it worth the sweep-time penalty?



Now would be a good time to determine the noise floor of the instrument, so we can tell if we're actually able to measure the stopband of this high-performance filter. Here, I've attached 50-ohm loads to the end of both VNA cables, and performed a sweep using a 10 Hz BW. I'm just showing the result, because this measurement took 9 and a half minutes with our current nnnn-point sweep settings. Then, I reconnect the filter and repeat the measurement. As you can see, there are only a very few places where you can discern a difference in the noise floor, so this is telling us that we're still being limited by the noise floor of the VNA. We can do two additional tricks: First, we re-configure the ports to use "reverse-coupling" which eliminates the 10-dB (or so) coupler loss. In [1] this block diagram, Port 1 of the VNA is connected to the filter in the conventional fashion, where the forward and reflected waves are coupled off of the directional coupler, so we [2] see the usual coupling loss of 10 dB. The coupling cables [3] on the front of the instrument remain in their default position. However, at port 2, [4] we re-configure the analyzer so that the weak stopband signal coming out of the filter is directly applied to the measurement receiver, with no coupling loss. Instead the port 2 generator is connected [5] through the coupler, so it is attenuated by 10dB. But we don't care about this loss, since we're using [6] the port 1 generator for our stopband measurement. This coupling trick is achieved [7] by reconfiguring the port 2 coupling cables on the front of the VNA as shown here.

Demo 2.2i: Improve DR Method 4 – Remove Port 2 Meas Receiver Attenuator (10 dB)



The final trick [1] involves eliminating the standard 10-dB attenuator [2] in front of the b2 measurement receiver. This should reduce our noise floor an additional 10 dB.

Now, when we re-connect the filter, we can clearly see the noise floor of the instrument with terminated cables is below the filter response. This tells us that we're now confidently able to measure the stopband performance of the filter, and are no longer limited by the dynamic range of the VNA. Otherwise, if the instrument noise floor trace and the filter trace showed the same level, we would only be able to say that the filter rejection is “greater than the noise floor trace”, but we couldn't tell by how much.

Demo 2.2j: Using Segmented Sweep to improve Sweep Time

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While we've taken great pains to measure this filter's performance, it clearly takes a long time for a measurement sweep. While we need a large number of points to give good resolution within the passband (and into the transition region), the note that the attenuation provided by the filter is very low here and dynamic range is not an issue. Conversely, in the stopband, dynamic range is very important for measuring high filter rejection, but we generally need only a relatively few measurements in this range to assure ourselves of the filter's stopband performance. We could create two different channels, where we set up one channel to measure the filter passband and another to examine the stopband, but there's a better alternative called the segmented sweep. Here, we can break a sweep up into segments, where we have complete control over power levels, attenuator settings, filter bandwidths, and number of points in each segment. We generate a total of 6 segments to examine the lower stopband, lower transition region, passband, upper transition region, stopband region, and parasitic response region.

Now, we can perform a single segmented sweep and obtain the same information that took 9 and a half minutes with a conventional sweep takes less than 18 seconds with a segmented sweep. That is a significant time savings!

Measuring return loss and group delay is the same as for the low-pass filter, so we won't repeat those measurements here. Our chief objective was to show the challenge of measuring a high-performance filter, and how this can be achieved using a suitably-equipped high-performance VNA.

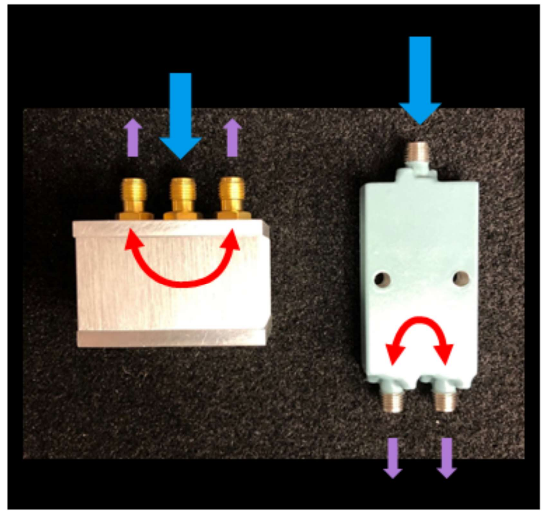
Demo 3.0: Power Splitter Measurements

Device Characteristics:

- 3-terminal devices (one port is common)
- Resistive & Wilkinson Dividers, Directional Couplers, Quadrature Hybrids
- Common goal: Split or Re-combine RF energy

Device Specifications:

- Amplitude Balance
- Amplitude Ripple
- Phase Balance
- Phase Ripple
- Insertion Loss = Loss beyond nominal splitting value
- Isolation (between divider arms)
- Return Loss



For our third and final application, we'll turn our attention to [1] power dividers, also called power splitters. Typically, these are [2] three-port devices with a [3] common port and [4] two 'arms.' There are a number of different architectures used for splitting power, including [5] Resistive Dividers, Wilkinson Dividers, Directional Couplers, and Quadrature Hybrids. But all have a [6] common goal: to split or recombine electromagnetic energy. The most frequent application calls for equal splitting, where the resulting output from each arm is identical in amplitude. This represents an amplitude ratio of 0 dB. So the challenge is to measure how well the power divider [7] meets this objective, using a specification called [8] Amplitude Balance. A companion specification is [9] amplitude ripple, which is a measure of how well the divider maintains the desired amplitude ratio over a specified bandwidth. Ideally the divider would maintain the desired amplitude radio with no ripple.

Similar to amplitude balance, power dividers are expected to maintain [10] phase balance, which is a measure of the phase shift between the two output arms. Also, [11] phase ripple measures how well the divider maintains its output phase relationship across frequency. All power divider specifications tend to get more difficult to achieve at higher frequencies.

It's important to note that [12] Insertion Loss for power dividers and couplers refers to the *__additional__* loss above the nominal loss due to splitting. So a measurement of the loss from the common port to either arm of 3 dB splitter might be 3.5 dB, but the insertion loss would be stated as 0.5 dB.

An ideal Power Divider exhibits complete [13] isolation between the arms. This means that a signal introduced into [14] one arm would not show up at the other arm. In reality, isolation is not ideal, and must be measured. Again, the higher the frequency and wider the operating bandwidth, the more difficult it is to attain good isolation.

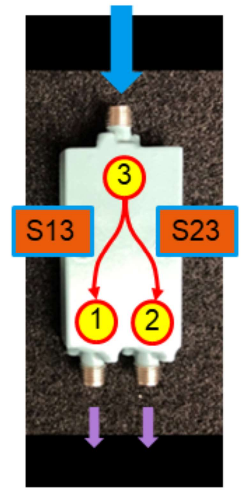
The final figure of merit is [15] return loss, measured at all three ports.

Each power divider architecture has different strengths and weaknesses regarding all these important characteristics. Our task here is simply to measure them.

Demo 3.0: Power Splitter Measurements

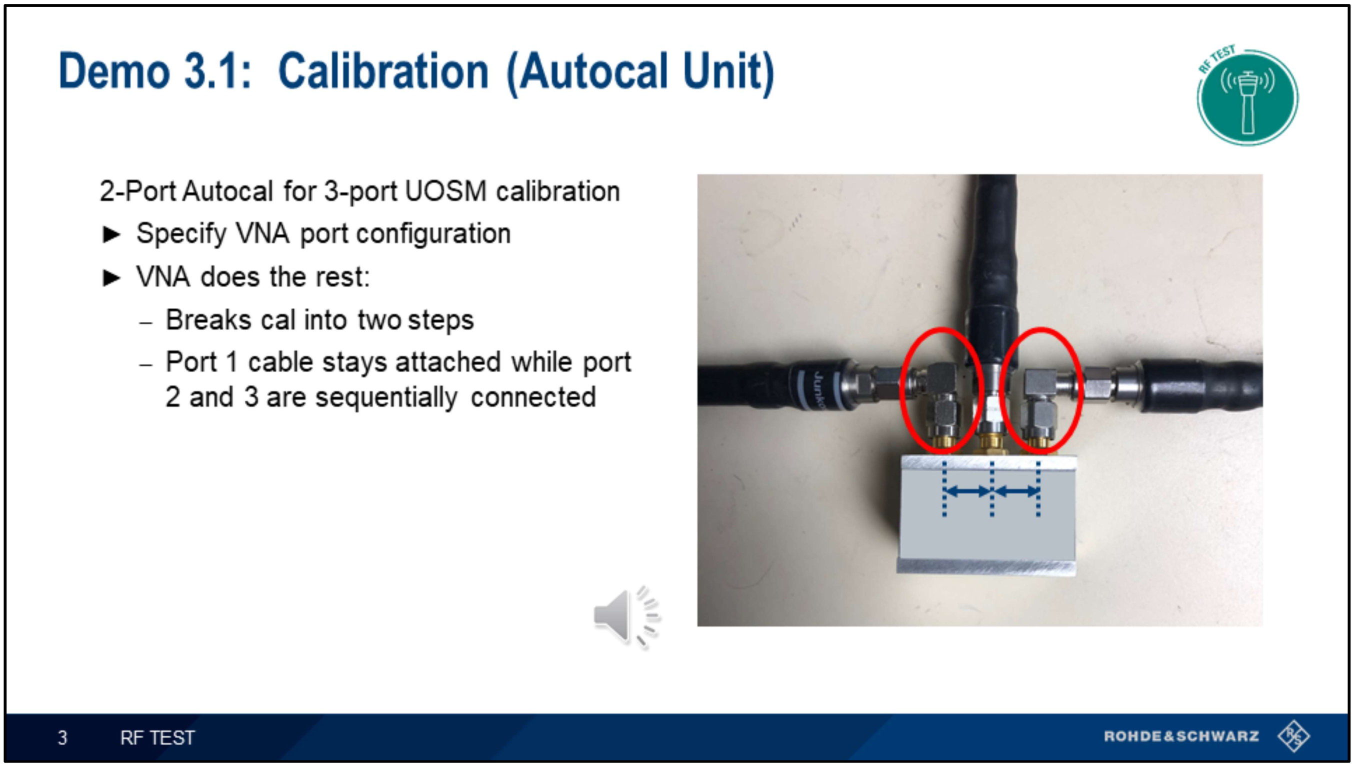
Device Characteristics:

- ► 3-terminal devices (one port is common)
- ► Resistive & Wilkinson Dividers, Directional Couplers, Quadrature Hybrids
- ► Common goal: Split or Re-combine RF energy



Device Specifications:

- ► Amplitude Balance
- ► Amplitude Ripple
- ► Phase Balance
- ► Phase Ripple
- ► Insertion Loss = Loss beyond nominal splitting value
- ► Isolation (between divider arms)
- ► Return Loss



Our first power splitter has a specified measurement range of 2 to 18 GHz. We'll extend this range to 1 to 20 GHz so we can observe how the divider characteristics diverge at the frequency end points. We'll be using [1] a 2-port autocal unit for this 3-port UOSM calibration. How? We simply need to tell the VNA the [2] port configuration we'll be using, and the instrument [3] will take care of the rest. Specifically, it [4] breaks the calibration into two steps, where [5] the port 1 cable stays attached while the port 2 and 3 cables are sequentially connected. Please note [6]: depending on the [7] spacing between your power divider ports, you may need [8] adapters, such as these 90-degree adapters to allow the VNA test cables to be connected. These should be connected to the ends of the VNA cables **before the calibration is performed** so that their influence is removed by the calibration process.

[Live Demo]

Start from preset

Select Measure > Port Config 3 single-ended ports

Sweep 1 GHz 20 GHz

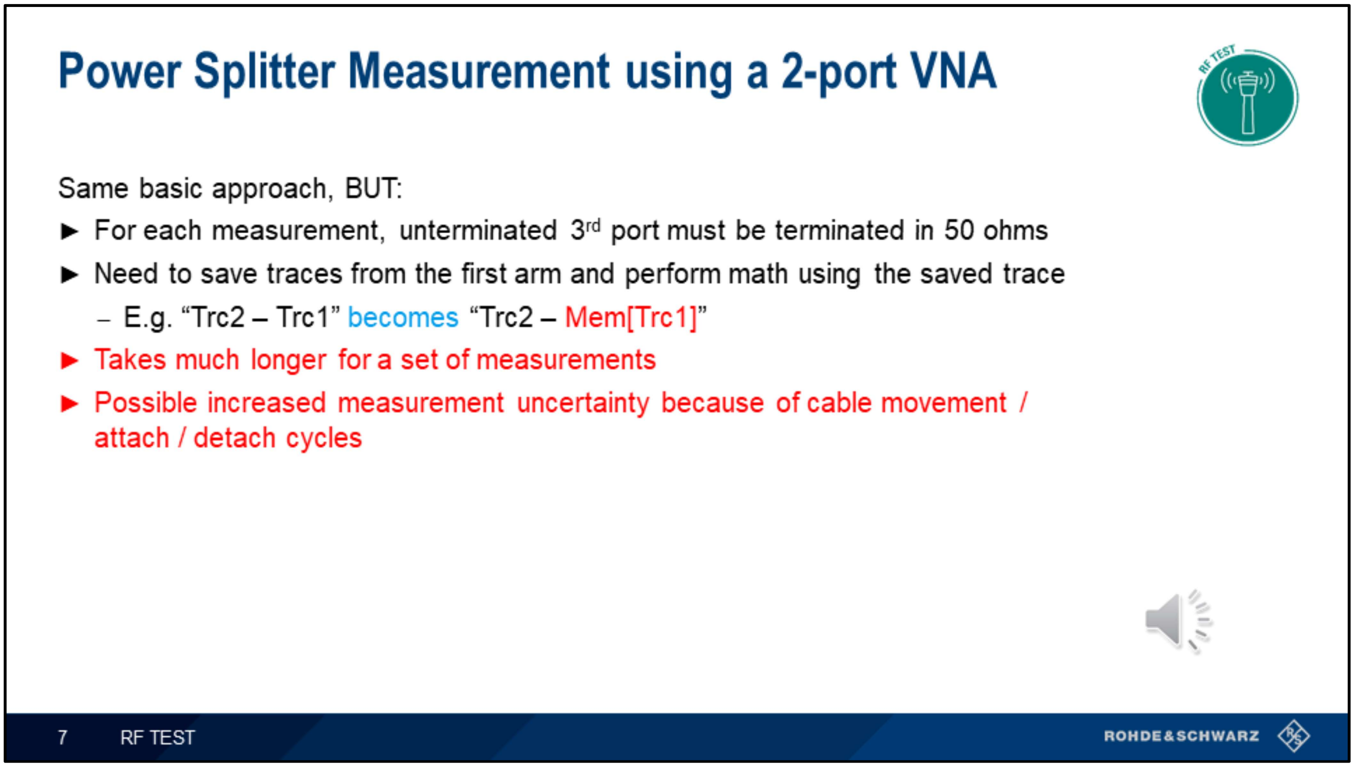
10 MHz steps

Done.

Demo 3.2a: Power Splitter Measurement – Amplitude Balance

Demo 3.2b: Power Splitter Measurement – Phase Balance

Demo 3.2c: Power Splitter Measurement – Isolation and Return Loss

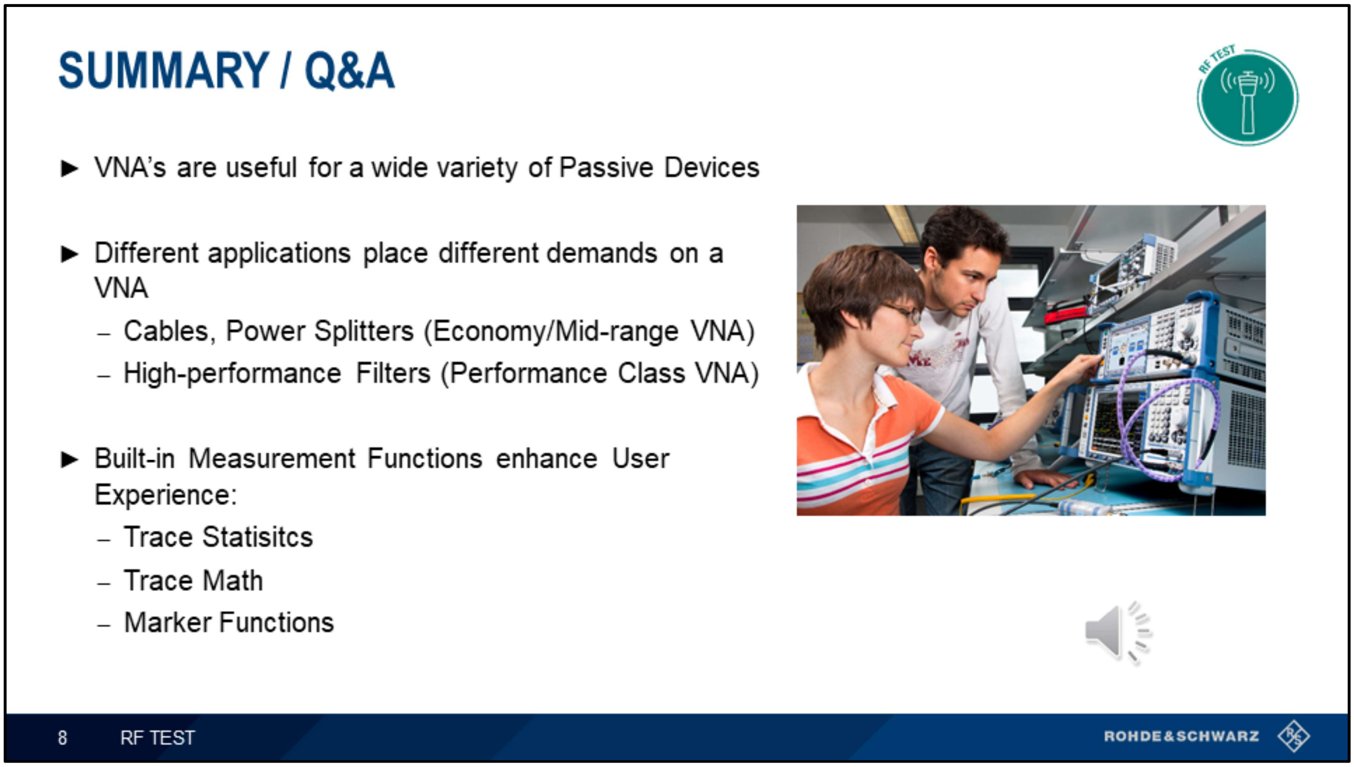


If you only have a two-port VNA available, you can [1] still make measurements on a 3-port power divider, but the unterminated port must [2] always be terminated in a good 50 ohm load.

In addition, after measuring an arm, you'll have to [3] save that trace as a memory trace before measuring the second arm, and then [4] defining the math functions using this memory trace.

As you can imagine, this process [5] is much more operator intensive and takes much longer to complete a set of power divider measurements.

In addition, this can lead to [6] increased measurement uncertainty because of cable movement and multiple attach detach cycles.



In this RF Test webinar, we have seen that [1] VNAs are useful for evaluating a wide variety of Passive Devices.

We've demonstrated that [2] different applications place different demands on a VNA. For instance, [3] cables and power splitters can be easily measured by even moderate-performance analyzers, but [4] high-performance filters pose significant challenges in terms of dynamic range and measurement speed.

Finally, we've shown a number of [5] built-in measurement functions, like [6] Trace Statistics, [7] Trace Math, and [8] Marker Functions that simplify otherwise tedious measurement tasks and enhance the user experience.

I hope you've enjoyed this tour, and wish you the very best success in your passive device measurement applications.


Measurement
Techniques
Design
Verification
&
Evaluation
EVERYTHING TEST
Instrument
Selection
&
Optimization