APPLICATION NOTE

Anritsu

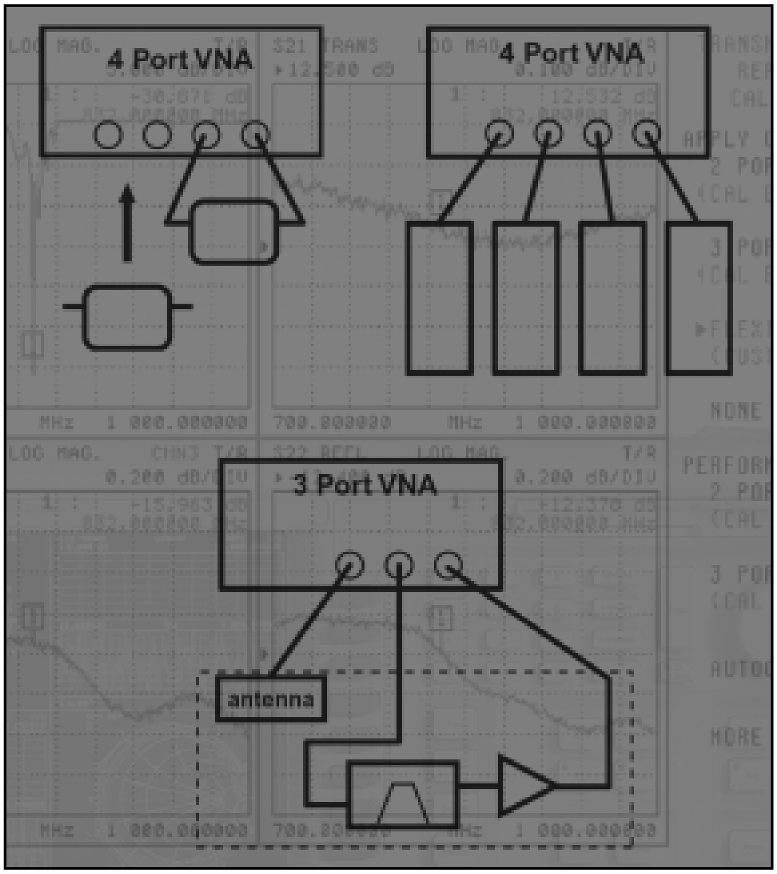
Faster Measurements Using Flexible Cal™

Scorpion®

Introduction

When Vector Network Analyzer (VNA) measurements were limited to straightforward 1-, 2- and 3-port devices, the application of a calibration was fairly simple: do a 1-, 2- or 3-port cal as appropriate and measure. In the interests of efficiency, some test methods have become compound: measure two 2-port devices in parallel or measure one while a handler is positioning another. Also more DUTs have become compound: two 2-port devices in a package or a 1-port and a 3-port in a package, etc. Applying the calibrations can be inconvenient in some of these scenarios. Either a larger cal than required is used to measure the needed parameters or multiple calibration files were sequentially recalled as needed. Both of these arrangements consume excess time and reduce test throughput.

An approach to help this situation is to let a calibration be quickly subdivided so only the required portions (and hence required measurements) are used at any given time. An implementation of this concept in the MS462XX series of instruments (firmware v. 1.16 and above) is termed Flexible Cal™. This mode allows an existing 2-, 3-, or 4-port calibration to be quickly subdivided so that only the required measurements are taken. This configuration can be changed by a simple command string so that no setups need to be recalled from memory or disk thus allowing a faster changeover between measurements. This document is intended to explain how Flexible Cal might be used and how it can improve measurement throughput in some situations.



Key Concept

One key principle behind Flexible Cal is that the saving and recalling of VNA setups can be more time consuming than the measurements themselves. This is even true for recalls from memory but becomes even more obvious when recalling from disk. If multiple setups can be enabled without a recall (such that error coefficients need not be reloaded), overall throughput can be improved. This can be accomplished by having all error coefficients available but just enabling those that are needed. An additional benefit is that with the use of an automatic calibration technique, there is no substantial difference in calibration time between these approaches.

The second key concept is that there are a number of test scenarios when a full 3- or 4-port cal is not needed for every measurement but, overall, all ports are needed at some point. This occurs with DUTs that are only partially connected, meaning all ports are not linked by low insertion loss paths so that every port does not affect every measurement (a counter example would be a power divider, this type of DUT does not benefit from Flexible Cal). The result is that unnecessary measurements are performed a good portion of the time.

Measurement Examples

To see this, consider the following situations:

Example 1

- A 4-port VNA is used to measure a pair of 2-port DUTs. While one is being measured, the next is being loaded in the other position and vice-versa. The user has two options:
  - Use two 2-port calibrations and recall a setup between each measurement subgroup. If the handler is roughly as fast as the measurement, this results in lost time since the second device is ready to be measured except its calibration has yet to be recalled.
  - The second option is to use a 4-port calibration but now 16 parameters must be measured each time when only 4 are needed. This also results in lost time.

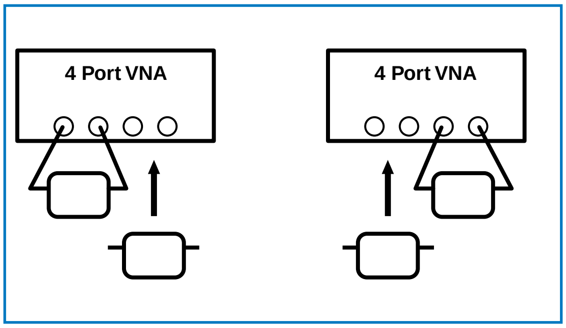


Figure 1. The first example measurement is shown here. One 2-port DUT is being measured while a second is being moved into position (by a robotic handler for example). If the handling time is not large relative to the measurement time, the application of the calibration can drastically affect throughput.

Example 2

- A 4-port VNA is used to measure four 1-port antennae. These may be four separate DUTs tested two at a time (analogous to the above two device problem) or four devices that should be measured together for reasons of comparison. In the first case, the reasoning of example 1 applies: time is lost recalling calibrations between swaps or excess measurements are taken. This time the penalty is worse since only one parameter is required per DUT. Even in the second case time is lost since only four one-port calibrations are needed (4 measurements as opposed to 16).

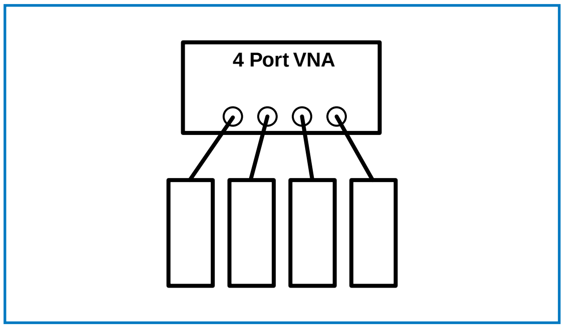


Figure 2. A second example measurement is shown here. Four 1-port devices are to be tested (antennas or resonators for example). They may either be rapidly moved in and out (four measurements in parallel for speed) in which case the reasoning of example 1 is just multiplied. Alternatively, this could represent multiple 1-ports that must be tested together for comparison purposes. In either case, significant time savings are possible through careful cal application.

Example 3

- A three port device consists of a 1-port resonator/antenna and a 2-port sub-DUT. If leakage is not of interest, then one would really like to measure only five parameters, not nine. Again, the idea is to avoid measuring more than is needed.

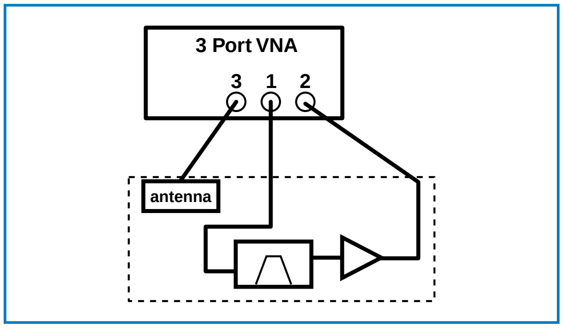


Figure 3. A third example measurement is shown here. The DUT consists of a 1-port sub-device (an antenna for example) and a two-port sub-device. These ports external to the DUT may be available for connecting an external filter. Since only five of nine S-parameters are needed (and only that many needed for correction), a careful use of the calibration can save time again.

Using Flexible Cal

The operation requires that a single N-port cal be performed (2-, 3- or 4-port) possibly with an automatic calibrator for additional time savings (see application notes 11410-00258 AutoCal or 11410-00298 4-port AutoCal for more information). Then when a given measurement is to be performed, the user or the controlling ATE program informs the instrument what portion of the cal is to be used. The simplest case is when a full M-port calibration is enabled (M≤N). In example 1, one might do a full 4-port cal to start and then enable a 2-port calibration for each of the measurement groups. In example 2, a full 4-port calibration would probably be done and then a series of 1-port calibration subsets would be used.

Main Menu

The base menu (within the calibration system) is shown in figure 4. Once the parent calibration has been performed, this menu can be used to select the appropriate subset (remote commands can of course be sent via GPIB or Ethernet). The three choices are:

- Full term cals (if the parent calibration is a 4-port, one would use this to select a full 2- or 3-port calibration or to re-enable the full 4-port calibration; if the parent calibration is a 3-port, one would use this to select any 2-port calibration or reselect the 3-port calibration).
- Reflection only (one would use this to select one to four reflection-only 1-port calibrations).
- Customize cal (used to select combinations other than full term or 1-port calibrations).

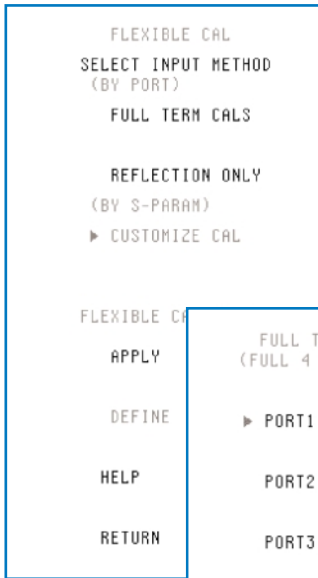


Figure 4. The main Flexible Cal menu showing the three types of sub-calibrations that can be accessed is presented here. Once a selection is made and defined (see later figures), APPLY is used to activate the Flexible Cal.

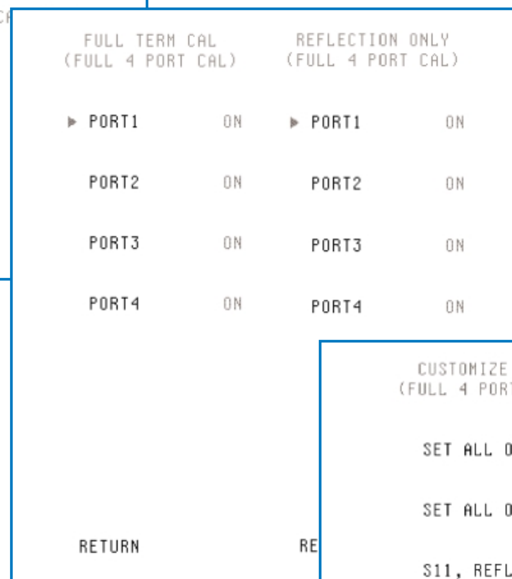


Figure 5. The submenus for a Flexible Cal composed of a full term cal or a reflection only cal are shown here.

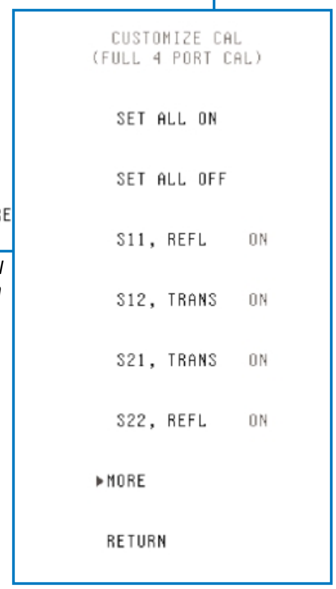


Figure 6. The submenu for customized Flexible Cal is shown here. Any or all of the S-parameters covered by the parent cal can be selected on this screen or the remaining similar ones connected by the MORE soft key.

Submenus

The submenus for full term calibrations and reflection-only (1-port) calibrations are shown in figure 5. Although the menus look the same, their functionality is quite different. When multiple ports are selected on the reflection-only submenu, 1-port calibrations at each of those ports is activated. When multiple ports are selected on the full term calibrations submenu, a full term calibration encompassing all selected ports is activated.

Customize Cal Submenu

Using the customize-cal submenu, the most flexibility is offered to individually specify which parameters are of interest. This submenu is shown in figure 6 and any or all of the N^2 S-parameters can be selected. In the case of example 3, one might perform a 3-port cal and then select parameters S11, S12, S21, S22, and S33 only (note port numbering in figure 3).

As an example, suppose the parent calibration is a 4-port, referring to the following table, observe the different VNA responses to a variety of selections.

Menu	Calibration Selections	VNA Response
Reflection only	1-port calibration at ports 1, 2, and 4	System will measure S11, S22, and S44 and correct them
Full Term Cal	3-port calibrations using ports 1, 2, and 4	System will measure S11, S12, S14, S21, S22, S24, S41, S42, and S44 and correct them
Customize Cal	Select parameters S11, S12, S21, S22, and S33	System will measure these terms and correct them; effectivity a 2-port and a reflection cal

Intelligent Flexible Cal Algorithm

An important point is that the system will automatically determine which error terms must be included to perform the correction as best as possible within the constraints supplied. The rules for the systems decisions are described in table 1.

Calibration Selections	VNA Response
Reflection term is activated (S_{ii})	Activate all reflectometer coefficients for that port. If isolated, this works like a 1-port reflection-only calibration.
Transmission term is activated (S_{ij})	Activate the transmission tracking term. If done alone, this works like a normalization calibration.
Transmission term is activated along with matching reflection terms (e.g. S12, S11, and S22)	Activate appropriate load match terms.

Table 1. An overview of the Calibration Selections and subsequent VNA response is shown here.

The net effect is if the user specifies all four parameters associated with a 2-port, a full 2-port correction will be enabled. If only S_{ii} and S_{ji} are activated, then a 1 path-2 port cal will effectively be enabled. Note that although the system can be fairly intelligent in which terms it uses, it knows little about the DUT. The user can help by specifying not only the measurements needed but also ones that are critical. The term "critical" refers to those paths tightly connected to the desired measurements but not on the measurements list. Consider if example 3 was actually a 4-port DUT (and a 4-port VNA was available) and where the fourth port was connected by a low insertion loss path to the amplifier output. It may be necessary to include S44, S42, and S24 in the customization if a high degree of accuracy is needed on S21 or S22 and it was not possible to separately terminate port 4. Situations like these are rare and usually obvious; the factory can be consulted if there are questions.

Other application notes (e.g., 11410-00279 Three and Four Port S-parameter Measurements) can be consulted for more information on the various types of calibrations possible.

Accuracy Example

To help illustrate this process, we will look at example 3. A 3-port DUT has an integrated antenna to be treated as a 1-port and an amplifier path to be treated as a 2-port. While the potential time savings are covered in the next section, the following will illustrate that in partially connected DUTs such as this, there is no accuracy penalty in using Flexible Cal.

A full three port cal was performed over 700 – 1000 MHz and measurements performed with both the full three port calibration and with the Flexible Cal defined as a Custom Cal using S11, S12, S21, S22 and S33. The results are compared, in an overlay, in figure 7. As expected, there is no difference but only five parameters were measured per cycle instead of nine. As stated before, this works for partially connected DUTs such as those discussed previously.

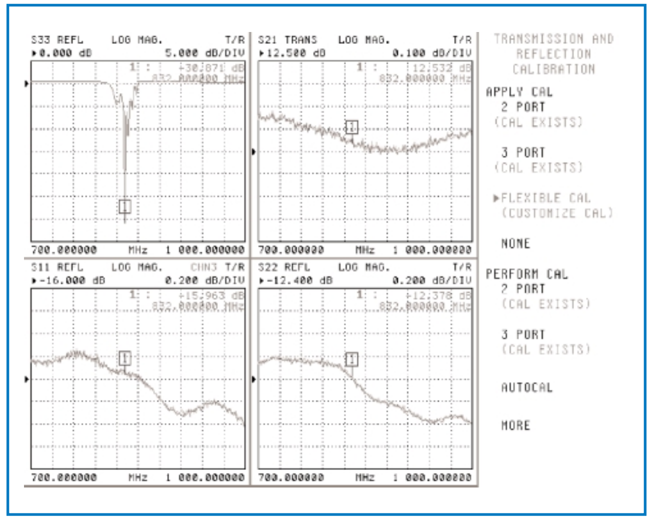


Figure 7. Example comparing Flexible Cal results with full 3 port calibration results on a DUT like example 3. The light trace is the full calibration result while the dark trace uses Flexible Cal. Aside from some minor differences due to trace noise (measurement done in a very wide IFBW with no averaging for speed), the traces overlay completely

Time Savings Examples

The amount of time saved by using Flexible Cal is largely determined by the number of unnecessary measurements that are avoided. If the IFBW is very high, there is some unavoidable overhead but we will neglect that in this analysis (i.e., in the realm where measurement time limits throughput). Initially it will be assumed that the ***old method*** choice refers to using a full N port cal.

Example 1: Measurements reduced by 50% over a full cal with no loss in accuracy assuming all four S-parameters are needed per 2-port sub-DUT. If the test device was two DUTs in a package, this would also be the time reduction. If the 2 DUTs are switched as in figure 1, then the time savings is dependent on handler speed. Suppose the measurement time per parameter is 15 ms and the handler time is 60 ms. The Flexible Cal cycle time is then 15*4*2=120 ms while the old method cycle time would be 15*16+60= 300 ms. If the handler time is 120 ms, then the Flexible Cal cycle time is 60+(120-60)+60+(120-60)=240 ms while the old method cycle time would be 15*16+120= 360 ms (still a 33% savings).

Example 2: Measurements reduced by 75% over a full cal with no loss in accuracy. If DUTs are tested four at a time, this would also be the time reduction in a measurement time-limited scenario. If, for example, 2 DUTs are changed while 2 are being measured, then the time savings is dependent on handler speed. Suppose the measurement time per parameter is 15 ms and the handler time is 30 ms. Ignoring other overhead, the Flexible Cal total cycle time would be 30 + 30= 60 ms whereas the old method cycle time (not handler limited) was 16*15 + 30= 270 ms. If the handler time was 100 ms, the Flexible Cal cycle time (handler limited) would be 30+(100 – 30)+30+(100-30)= 200 ms and the old method cycle time would be 340 ms (still a 41% savings).

Example 3: Measurements reduced by 44% over a full cal with no loss in accuracy. This would also be the time reduction in a measurement time-limited scenario. If a recall cycle was used instead of full N-port, the time differential would be tied to the recall time. In many instruments, this time exceeds 200 ms (even more if recalling from disk). To reprocess example 1 with the first handler speed, the Flexible Cal approach would lead to a cycle time of 120 ms while a recall-approach would take at least 320 ms.

As might be expected, the actual time savings is a strong function of the measurement (number of points, averaging, IFBW, etc.), the recall methods if used (from memory, hard disk or network, how large a setup file, etc.), and any handling variables. The factory can assist in any analysis if desired.

Conclusions

A new somewhat more versatile VNA calibration utility has been presented that can save time by doing only those measurements that are required without having to recall different setups. The prime benefits are for test systems trying to test multiple DUTs at a time and for multiport devices where not every path in the device is of interest. Both of these situations are of increasing importance in the more integrated and hybridized RF arena.

SALES CENTERS:

United States (800) ANRITSU
Canada (800) ANRITSU
South America 55 (21) 2527-6922

Europe 44 (0) 1582-433433
Japan 81 (46) 223-1111
Asia-Pacific (65) 6282 2400

Microwave Measurements Division
490 Jarvis Drive, Morgan Hill, CA 95037-2809
http://www.us.anritsu.com