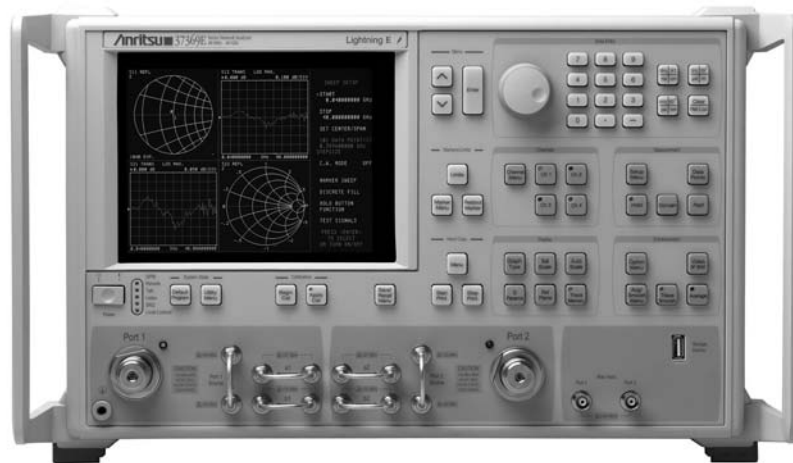


Dual Device VNA Testing

Utilizing Option 15 on the Lightning™ VNA
 37000E Series
 Vector Network Analyzer



37369E Lightning E Vector Network Analyzer

Introduction

The Lightning 37000E VNA with the flexible test set option (Option 15) provides front panel loops for direct access to the four samplers and the two source outputs. Consequently, Option 15 can be modified for a large number configurations and applications. Understanding the measurement architecture will help the user become more efficient in performing specialized measurements. One such example is using the direct access ports to perform simultaneous S21 measurements on two devices. This is an application that can be useful for matching cables, amplifiers, filters, etc.

Lightning 37000E Architecture

In order to effectively execute direct access type measurements, it is helpful to understand S-parameters and how the Vector Network Analyzer makes standard measurements. S-parameters (Scattering Parameters) describe the response of a 1 or 2 port device as a ratio of an incident signal and response of the DUT. Figure 1 shows a diagram of a 2 port network with the incident signals a1 and a2, and the response signals b1 and b2.

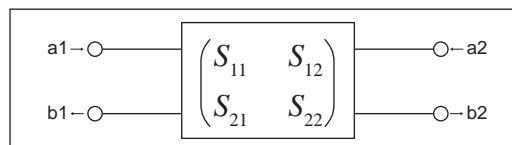


Figure 1: 2-Port Network with S-parameters.

The Equations for calculating each S-parameter are:

$$S_{11} = b_1/a_1$$

$$S_{12} = b_1/a_2$$

$$S_{21} = b_2/a_1$$

$$S_{22} = b_2/a_2$$

The Lightning VNA uses 4 samplers to measure a_1 , a_2 , b_1 and b_2 . The ratios for each of the S-parameters are calculated using the data measured at each sampler. Because S-parameters are ratios, it is not necessary for the samplers to measure absolute values. For example, when measuring S_{11} , it is only necessary to know the level at b_1 relative to a_1 . Figure 2 shows the block diagram for a 37000E. Under normal test conditions, the input of the DUT would be attached to Port 1 and output of the DUT to Port 2 of the 37000E.

From the block diagram you can see that the a_1 and a_2 samplers measure the power from the source via a power splitter. The b_1 and b_2 samplers measure the response at port 1 and port 2 via couplers at the respective ports. A normal calibration would correct for the input and output couplers and any external cabling associated with a measurement set-up.

Option 15 allows the user to disconnect the samplers from the standard configuration in order to access them directly. The block diagram shows the location of the front panel loops.

Custom Configuration

With Option 15 the connections to the samplers can be customized. There are many reasons why a user may want to do this, such as increasing dynamic range by bypassing the output coupler, connecting a 4 port test set, etc. This application note addresses the case of measuring S_{21} in two channels simultaneously. The objective is to bypass the input and output couplers on b_1 and b_2 in order to use them as port 2 connections for 2 devices. Figure 3 shows the configuration with the DUTs in place.

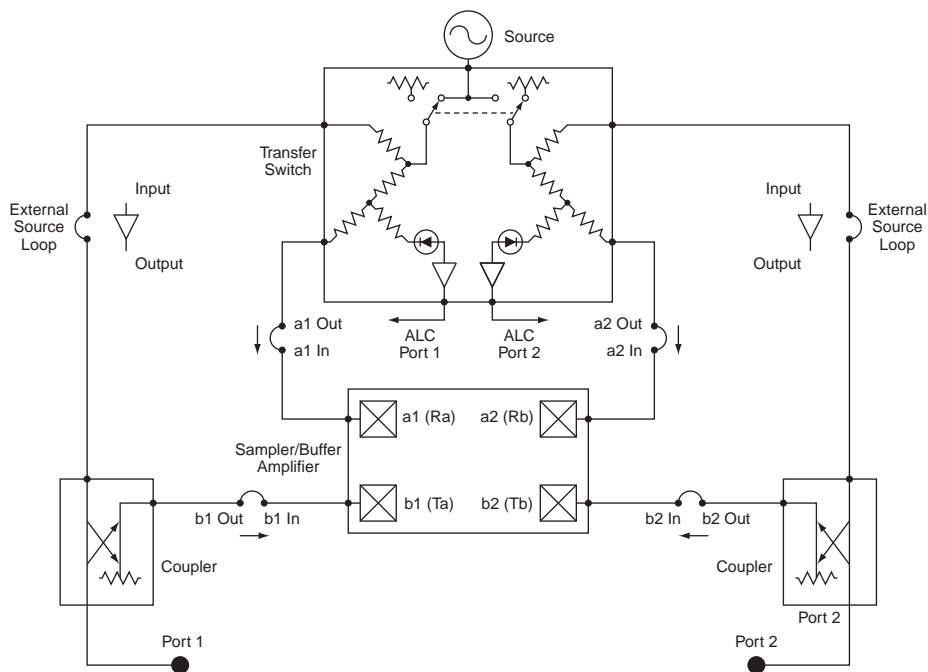


Figure 2: 37000E Block Diagram

Option 15 allows the user to disconnect the samplers from the standard configuration in order to access them directly. The block diagram shows the location of the front panel loops.

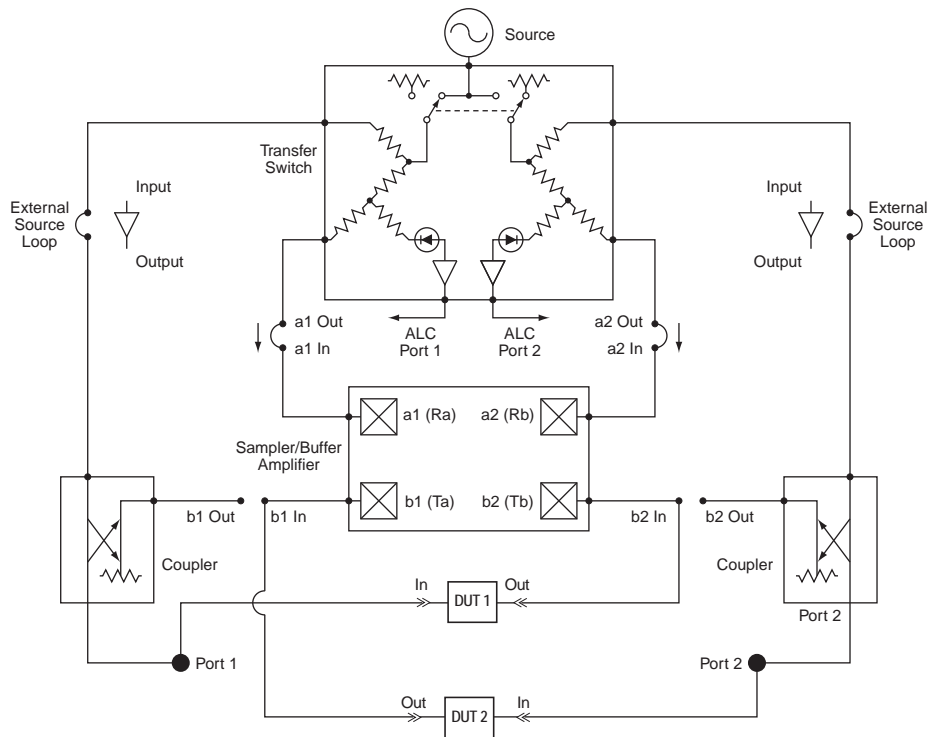


Figure 3: Test Configuration for 2 channel testing.

Configuration Set-up and Calibration

As with any test set up it is important to understand the power level limitations of the test equipment. Because the output of the DUT is being connected directly to the input of the sampler, the loss of the coupler is no longer in series. Special consideration must be given for gain devices. The damage levels for the sampler ports are printed on the front of the instrument and must be adhered to.

Additionally, the compression point for the samplers is much lower than the damage level. In order to guarantee an accurate measurement, the power level to the samplers needs to be below the compression point. If the sampler's compression point is exceeded, a message will be displayed on the Lightning display. The typical compression point for the b samplers is shown in Table 1.

To understand the sampler coupler power better, it is helpful to keep in mind that in the standard configuration Port 1 and Port 2 couplers contribute 15 to 17 dB of loss in front of the sampler. When setting power levels, this loss must be compensated for. There are two ways this can be done. Either 1) lowering the Port Power below -16 dBm, or 2) placing 16 dB of attenuation on the b1 and b2 samplers. Each method has its advantages.

1. Lowering the source power: This method will give maximum dynamic range, especially where high loss devices are concerned. The VNA can be calibrated at a lower source power, then the power can be increased during the measurement of the high loss device. Also, additional components are not necessary.
2. Placing 16 dB of attenuation in series with the b1 and b2 sampler ports: This method will allow the user to operate the VNA at nominal power levels. The advantage is that the user does not need to keep track of the power into the samplers during calibration. This method is more appropriate where gain or low loss devices are being tested. Refer to Table 1 to avoid compressing the sampler when testing gain devices.

Model	Frequency (GHz)	Power into b1 or b2 Ports at 0.2 dB Compression (dBm)
372xxE	0.04	-12
	2	-10
	20	-7
	40	-8
	50	-3
	65	-3
373xxE	0.04	-12
	2	-9
	20	-6
	40	-6
	50	0
	65	0

Table 1: Typical Compression for b Samplers

Figure 4 shows the set up for system calibration. Include any cabling and attenuation to be used during measurement in the calibration. Port 1 will attach to the b2 sampler port and Port 2 will attach to the b1 sampler port.

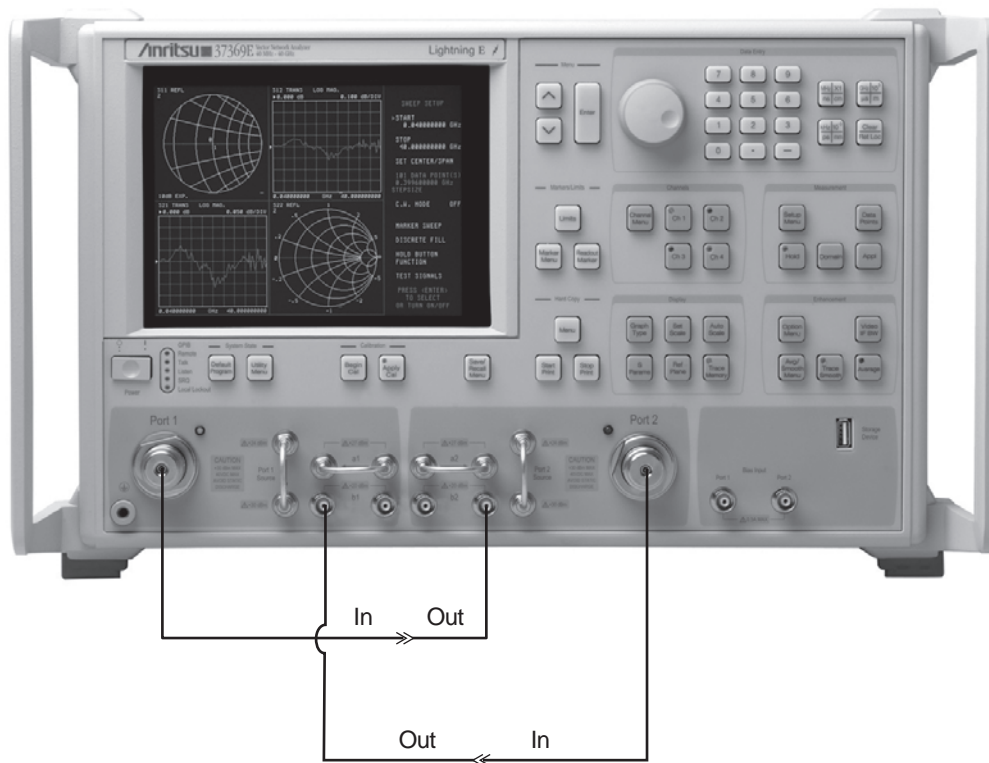


Figure 4: Calibration set-up

The following are the calibration steps for a thru calibration once the system has been set up per Figure 4.

- Step 1 Press the **Begin Cal** Key
- Step 2 Select **CHANGE CAL METHOD AND LINE TYPE**.
- Step 3 When menu C11A appears, move the cursor to the following:
- SOLT** (STANDARD), then press the **Enter** key. This selects Standard (SOLT) as the calibration method.
 - Select **COAXIAL**, then press the **Enter** key. This selects coaxial transmission line media.
 - Select **NEXT CAL STEP**, then press the **Enter** key. This causes the main cal menu to return to the screen.
- Step 4. When the main cal menu reappears, confirm that the **SOLT** calibration method and **COAXIAL** line type have been selected. Select **NEXT CAL STEP** and press the **Enter** key to proceed. This brings up menu C5.
- Step 5. Menu C5 lets you select the type of calibration. For this measurement, move the cursor to **TRANSMISSION FREQUENCY RESPONSE** and press the **Enter** key. This selection calibrates for S21 and S12.
- Step 6. Menu C5B lets you choose the Frequency Response Calibration Type. Move the cursor to **BOTH PATHS** (S21, S12) and press the **Enter** key.

MENU C11A	MENU C5	MENU C5B	MENU C5D
CHANGE CAL METHOD AND LINE TYPE	CALIBRATION TYPE	SELECT TRANSMISSION FREQ RESPONSE CALIBRATION TYPE	SELECT USE OF ISOLATION IN CALIBRATION
NEXT CAL STEP	FULL 12-TERM	FORWARD PATH (S21)	INCLUDE ISOLATION (STANDARD)
CAL METHOD	1 PATH 2 PORT	REVERSE PATH (S12)	EXCLUDE ISOLATION
SOLT (STANDARD)	TRANSMISSION FREQUENCY RESPONSE	BOTH PATHS (S21, S12)	PRESS <ENTER> TO SELECT
SSLT (DOUBLE OFFSET SHORT WITH LOAD)	REFLECTION ONLY	PRESS <ENTER> TO SELECT	
SSST (TRIPLE OFFSET SHORT)			
LRL/LRM			
TRM			
TRANSMISSION LINE TYPE			
COAXIAL			
WAVEGUIDE			
MICROSTRIP			
PRESS <ENTER> TO SELECT			

- Step 7. The next menu C5D lets you choose whether to include or exclude the error terms associated with leakage between measurement channels. For a normal calibration, you would choose to include these error terms. For this measurement they will not be included. Move the cursor to **EXCLUDE ISOLATION** and press the **Enter** key.
- Step 8 Next, menu C1 appears. It lets you select the number of frequency points at which calibration data is to be taken. Move the cursor to **NORMAL** (1601 POINTS MAXIMUM), and press the **Enter** key.
- Step 9 The next menu, C2, lets you set the start and stop frequencies. Move the cursor to **START** and enter the desired start frequency using the number pad and appropriate units button. Then move the cursor to **STOP** and set the desired frequency. Select the desired number of data points by moving the cursor and pressing the **Enter** key. After setting the frequencies select **NEXT CAL STEP** and press the **Enter** key.

- Step 10. When menu C3 appears the parameters can be changed by placing the cursor on the parameter and pressing the **Enter** key. Place the cursor on **TEST SIGNALS** and press the **Enter** key.
- Step 11. On menu **CAL_SU2** the source power can be set. Place the cursor on **POWER CONTROL** and enter the desired power level using the numeric pad and units buttons. It is important that the power level be set such that the b1 and b2 samplers are not compressed. If using series attenuators (16 dB) at the b1 and b2 sampler ports, then the power level can be set to nominal values per the 37000E (0 dBm). If the power level is too high, then the message “**5210 REF B CHAN RF OVERLOAD**” will be displayed.
- Step 12 Place the cursor on **EXIT APPLICATION** (or **RESUME CAL**) and press the **Enter** key. Menu C3 will be displayed. Place the cursor on **START CAL** and press the **Enter** key to begin the calibration procedure. Continue the calibration sequence by following the prompts as they appear.

MENU C1
SELECT CALIBRATION DATA POINTS
NORMAL (1601) POINTS MAXIMUM)
C.W. (1 POINT)
N-DISCRETE FREQUENCIES (2 TO 1601 POINTS)
TIME DOMAIN (HARMONIC)
PRESS <ENTER> TO SELECT

MENU C1
FREQ RANGE OF CALIBRATION
START 0.0400000000 GHz
STOP 20.000000000 GHz
201 DATA PTS 0.099800000 GHz
MAXIMUM NUMBER OF DATA POINTS 1601 MAX PTS 801 MAX PTS 401 MAX PTS 201 MAX PTS 101 MAX PTS 51 MAX PTS
NEXT CAL STEP
PRESS <ENTER> TO SELECT

MENU C3
CONFIRM CALIBRATION PARAMETERS
THROUGHFARE PARAMETERS
REFERENCE IMPEDANCE
TEST SIGNALS
START CAL
PRESS <ENTER> TO SELECT OR CHANGE

MENU SU2, SU2a, CAL_SU2
TEST SIGNALS
POWER CONTROL XX.X dB (0 TO -20 dB)
PORT 1 ATTN 0 dB (0-70)
PORT 1 POWER -XX.XX dBm
PORT 2 ATTN XX.X dB (0-X0)
CALIBRATE FOR FLATNESS (CAL EXISTS)
FLATNESS ON/OFF CORRECTION AT XX.X dBm
SOURCE 2 PWR XX.X dBm
EXIT APPLICATION*
PRESS <ENTER> TO SELECT

Measurement

The system is now calibrated and ready to test the DUTs. Hook up the DUTs per Figure 5.

Now you are ready to measure S_{21} for two devices simultaneously. There are a few things to remember.

1. Only the forward response is being tested. It is not possible to see S_{11} , S_{22} , or S_{12} in this configuration.
2. The path from Port 2 to b1 will show up as S_{12} . The user must remember that this port is being used in reverse to test S_{21} .
3. For gain devices, it is important to plan ahead with power levels in order to not saturate or damage the samplers.

The display can be configured to show both channels simultaneously.

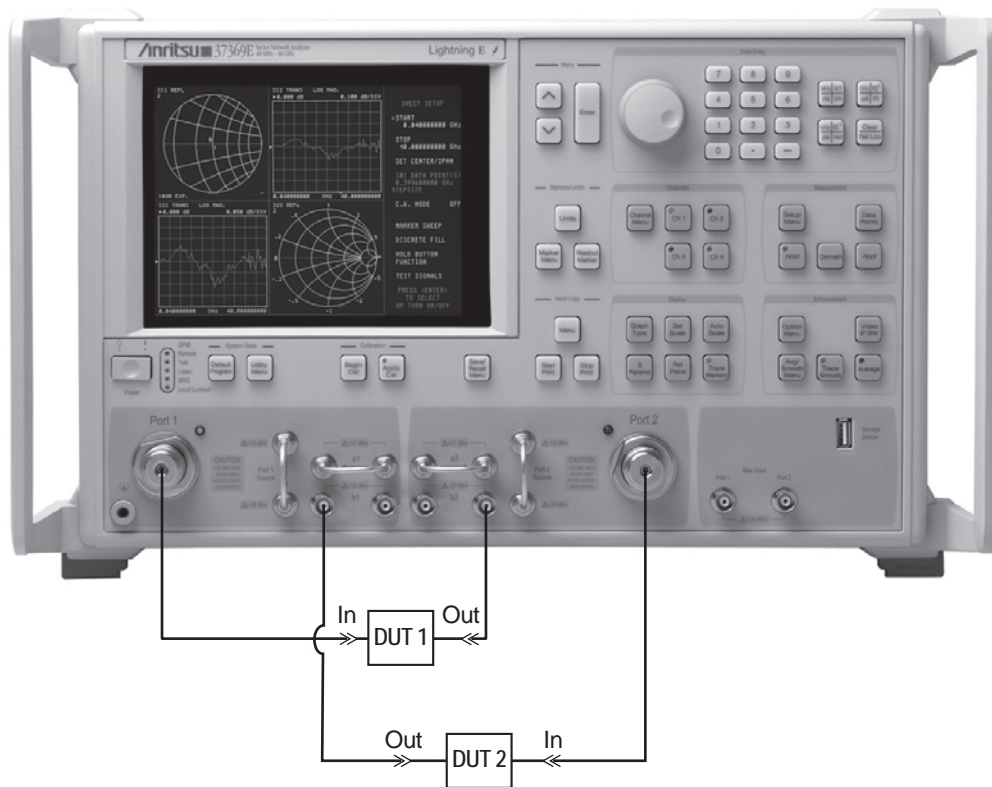


Figure 5: Measurement Set-up

Several different measurements can be made in this configuration. The user can look at absolute phase, Figure 6, Magnitude, Figure 7, Group Delay, Figure 8.

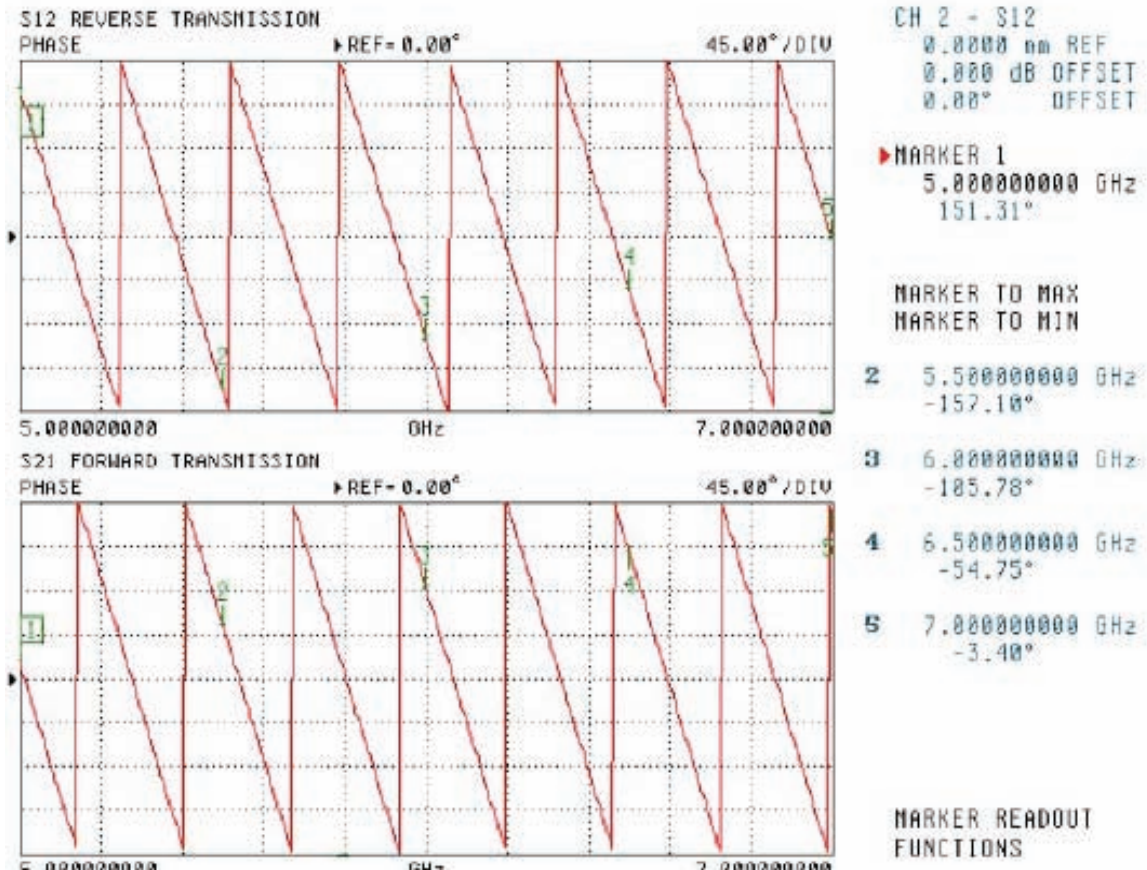


Figure 6: Absolute Phase

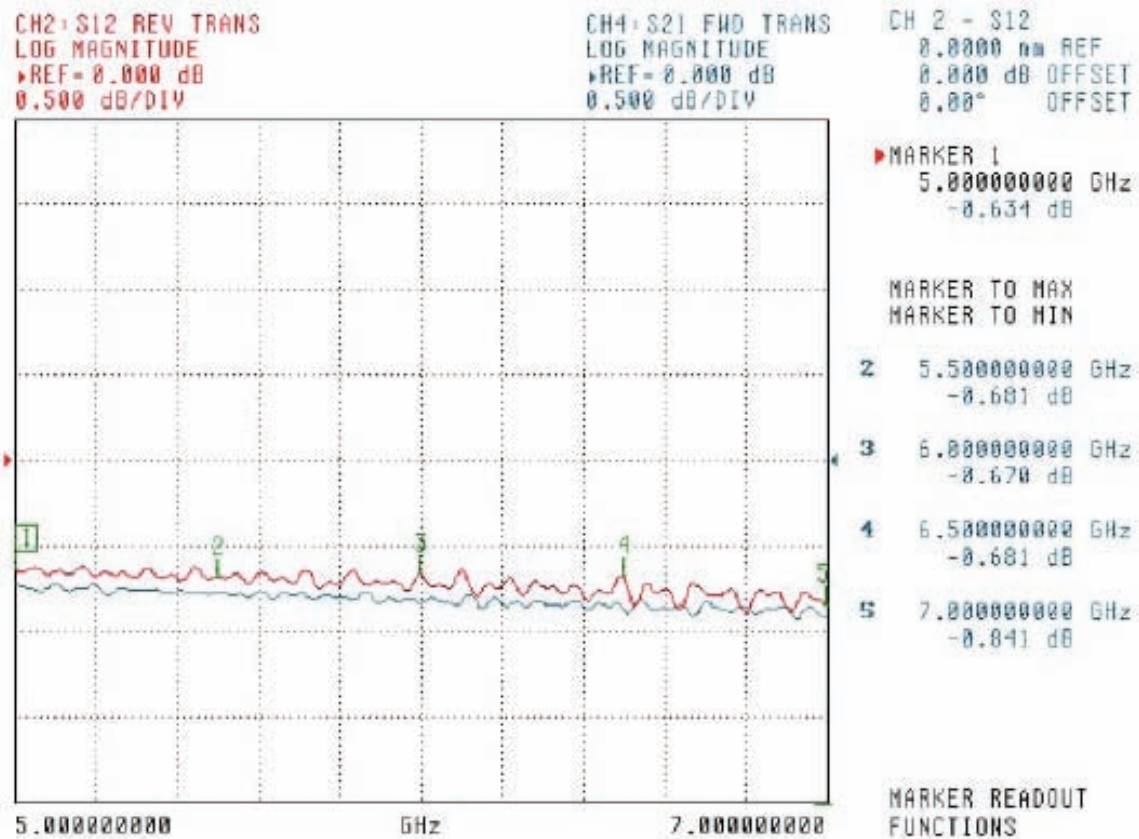


Figure 7: Magnitude

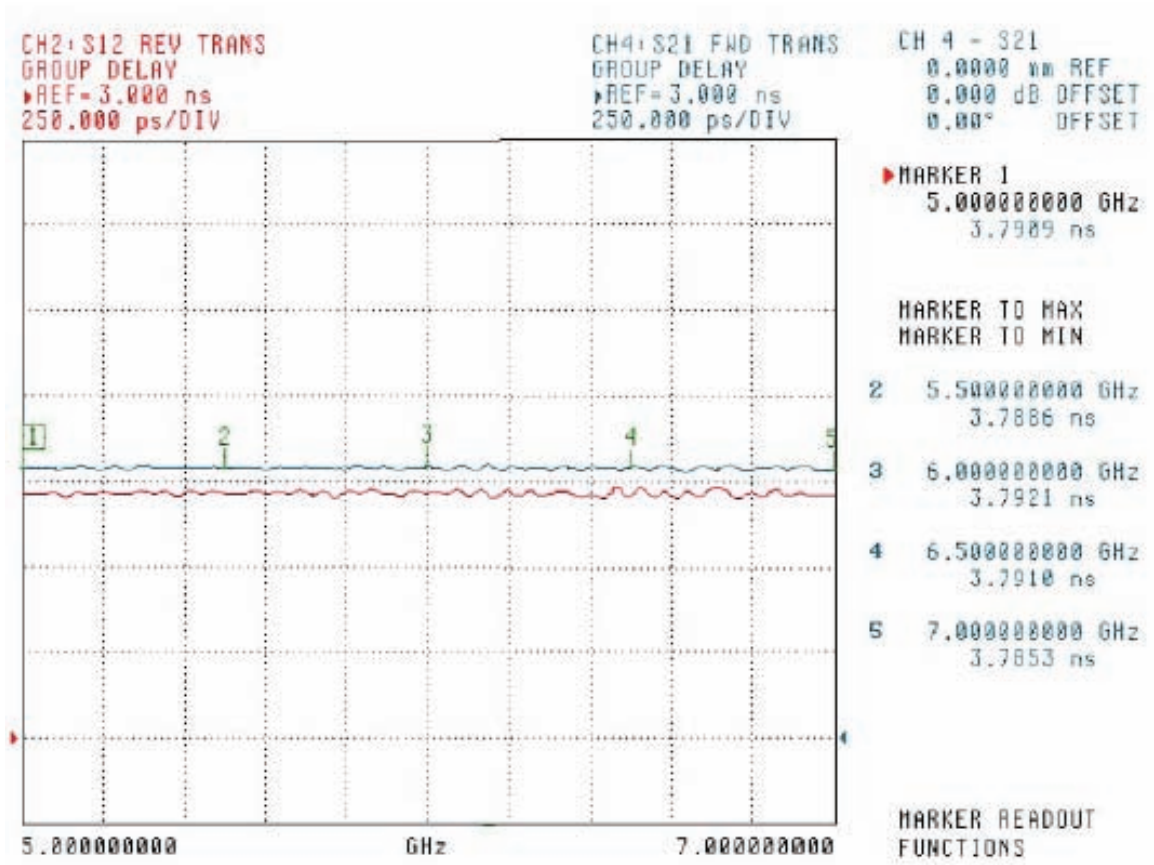


Figure 8: Group Delay

An additional measurement that can be made is relative phase between the two channels. This is achieved by using trace math. The following are the steps to set up this measurement.

Step 1: Press the **Channel Menu** Key. Move the cursor to **SINGLE CHANNEL** and press the **Enter** Key

Step 2: Press the **Graph Type** Key. Move the cursor to **PHASE** and press the **Enter** key.

Step 3: Press the **S Params** Key. Move the cursor to S12 and press the **Enter** key.

Step 4: Press the **Trace Memory** Key. Move the cursor to **STORE DATA TO MEMORY** and press the **Enter** key.

Step 5: Move the cursor to **VIEW DATA (/) BY MEMORY** and press the **Enter** key.

Step 6: Press the **S Params** Key. Move the cursor to S21 and press the **Enter** key.

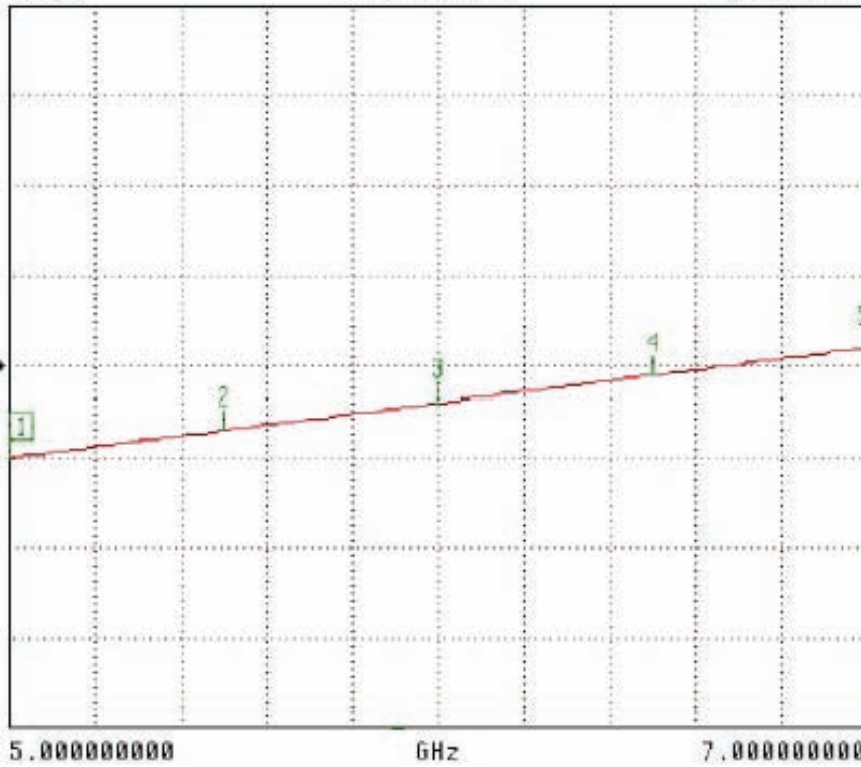
You should now be looking at the relative phase difference between DUT 1 and DUT 2. Figure 9 shows a plot of the phase difference between two cables with a 2.2 mm delta. This can be particularly useful for phase tuning to a “golden standard,” or matching two DUTs.

S12 REVERSE TRANSMISSION

PHASE

REF = 100.00°

45.00°/DIV



CH 2 - S12
0.0000 mm REF
0.000 dB OFFSET
0.00° OFFSET

MARKER 1
5.000000000 GHz
134.62°

MARKER TO MAX
MARKER TO MIN

2 5.500000000 GHz
148.21°

3 6.000000000 GHz
161.67°

4 6.500000000 GHz
174.94°

5 7.000000000 GHz
188.19°

MARKER READOUT
FUNCTIONS

Figure 9: Phase delta of 2 cables.

Summary

A technique for comparing to DUTs transmission characteristics has been presented along with the steps for performing the measurements. With an understanding of the sampler configuration and the direct access feature (Option 15) it is possible to perform these and other specialized measurements.

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