



LA19-13-04A 6 GHz Vector Network Analyser

Users Manual



LA Techniques Ltd

Chancerygate Business Centre, Unit 5
Red Lion Road, Surrey KT6 7RA, UK

VAT no GB 689 4720 79
Registered in England No 3356289 Registered Office as above

Tel: 0208 3973150
Fax: 0208 3975372

E-mail: info@latechniques.com
Web site: www.latechniques.com

Notice

The information contained in this document is provided “as is” and may be subject to change without notice in future editions. In addition, to the full extent permitted by applicable law, LA Techniques Ltd disclaims all warranties, either express or implied, with regard to this document and any information contained herein, including but not limited to the implied quality and fitness for a particular purpose.

LA Techniques Ltd shall not be liable for mistakes or consequential or incidental damages in connection with the use or accuracy of this document or of any information contained herein.

Contents

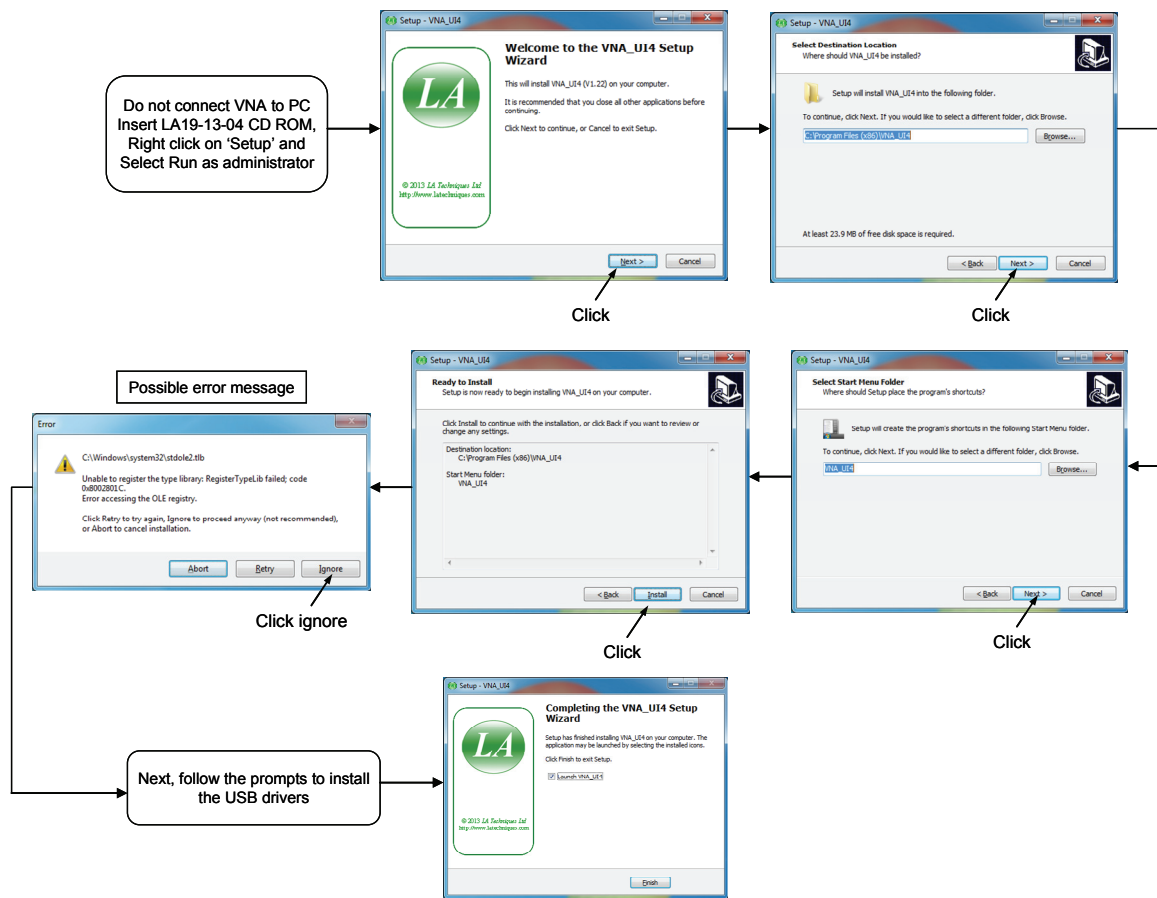
1	Quick Start Guide	5
2	Description	9
3	Safety	11
4	Vector Network Analyser Basics	12
4.1	Introduction	12
4.2	Structure of the VNA.....	12
4.3	Measurement	12
4.4	S-parameters	13
4.5	Displaying Measurements	15
4.6	Calibration and Error Correction.....	16
4.7	Other Measurements.....	16
5	Getting Started.....	25
5.1	Minimum Requirements	25
5.2	User Interface Software Installation	26
5.3	Switching on the VNA	27
5.4	Calibration Kit.....	27
5.4.1	Using a matched termination with poor return loss or un-modelled Short and Open	30
6	Operation	32
6.1	The User Interface Window	32
6.1.1	Display set up	32
6.1.2	Data markers.....	35
6.1.3	Measurement enhancement	37
6.1.4	Memory facility	41
6.1.5	Limit Lines facility	42
6.1.6	Status panel.....	44
6.1.7	Triggered sweep	44
6.1.8	Sweep trigger output.....	45
6.1.9	Measurement Start / Stop.....	45
6.1.10	PC data link interruption.....	46
6.2	Calibration.....	46
6.2.1	Changing the Frequency Sweep Settings without Re-Calibrating.....	50
6.2.2	Calibration steps for S11 measurements.....	50
6.2.3	Calibration steps for S21 measurements.....	51
6.2.4	Calibration steps for S11 and S21 measurements.....	51
6.2.5	Calibration steps for all s-parameters measurements (insertable DUT)	52
6.2.6	Calibration steps for all s-parameters measurements (non-insertable DUT)	52
6.2.7	Calibration for best dynamic range – minimising the effect of crosstalk	53
6.3	Measurements.....	55
6.3.1	Return loss.....	55
6.3.2	Insertion loss / gain.....	55
6.3.3	Complete 2-port measurement.....	56
6.3.4	Group delay	56
6.3.5	Time domain measurements	57
6.3.6	Reverse measurements on two port devices	62
6.3.7	Powering active devices using the built-in bias-Ts	62
6.3.8	Mixer measurements.....	63
Figure 6.29a	Typical mixer measurement set up	63
6.4	Reference Plane Extension and De-Embedding	66
6.5	Saving Data	69
6.6	Loading Data	70
6.7	Plotting Graphics	70
6.8	Saving Graphics.....	71
6.9	Signal Generator Utility.....	71
6.10	Output Power at the 1 dB Gain Compression Point Utility.....	72
6.11	AM to PM Conversion Utility	74
6.12	Compare Data Utility.....	76
6.13	Closing Down the User Interface Window.....	78
7	Performance verification and maintenance	79
7.1	Measurement Uncertainty.....	80

7.2	Routine Maintenance.....	81
8	Performance Specification.....	82
9	Troubleshooting Guide.....	87
10	Warranty.....	89
11	EC Declaration of Conformity	90

1 QUICK START GUIDE

Install the software

Before connecting the instrument to the PC, install the software on the PC. The typical procedure for Windows 7 is shown in the diagram below. The procedure is similar for Windows XP and Windows 10.



Installation sequence for the user interface software on the host PC.

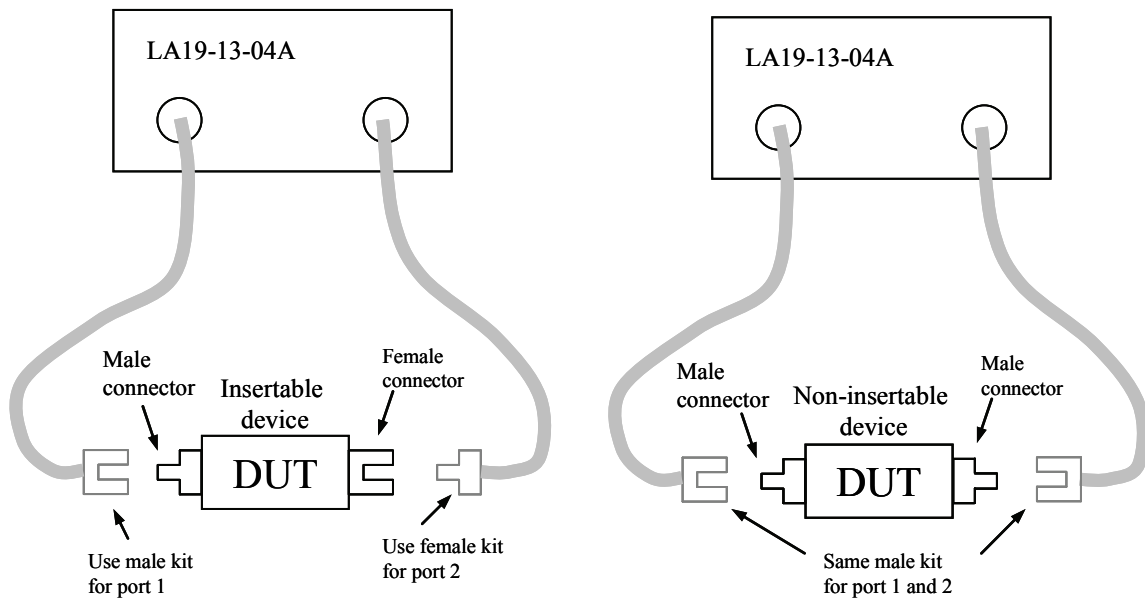
Load the calibration kit(s)

If the device to be tested is 'insertable' (one female and one male connector) then two kits are required. Otherwise a single kit is required. See diagram below

- Load the calibration kit(s) to be used:

Menu item: Tools > Calibration kit > Load P1 kit > Apply

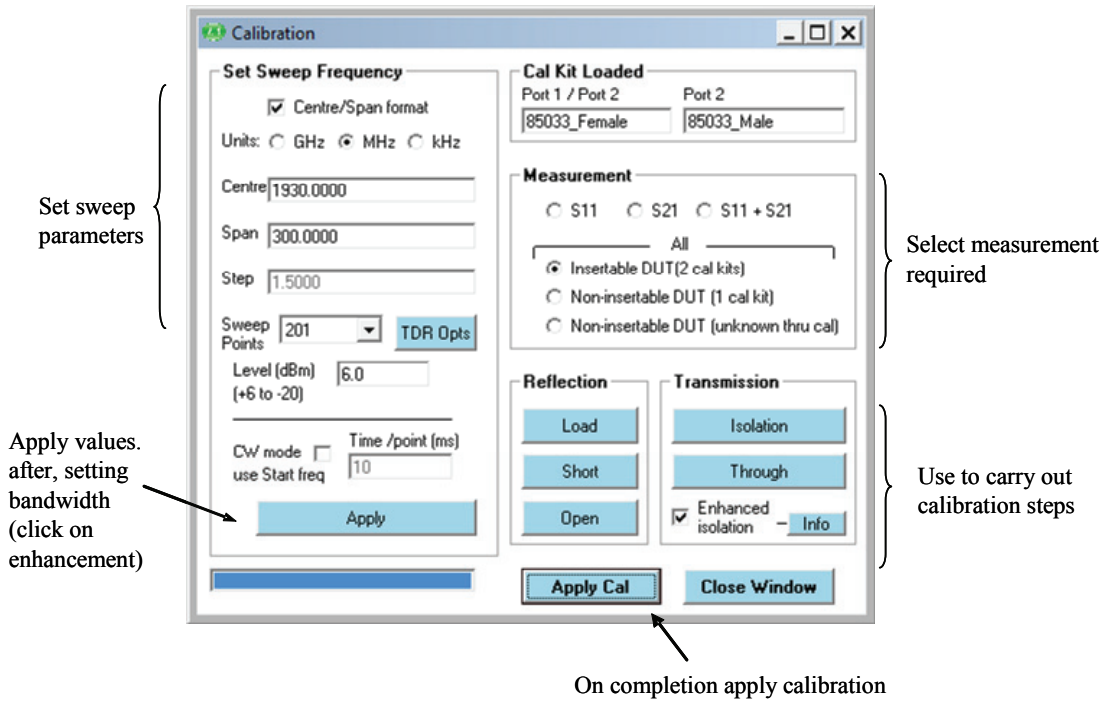
Load P2 kit > Apply



Select the calibration kit(s) required depending on the device to be tested. Note, if testing a non-insertable DUT with, for example, female connectors then a single female kit is used for ports 1 and 2.

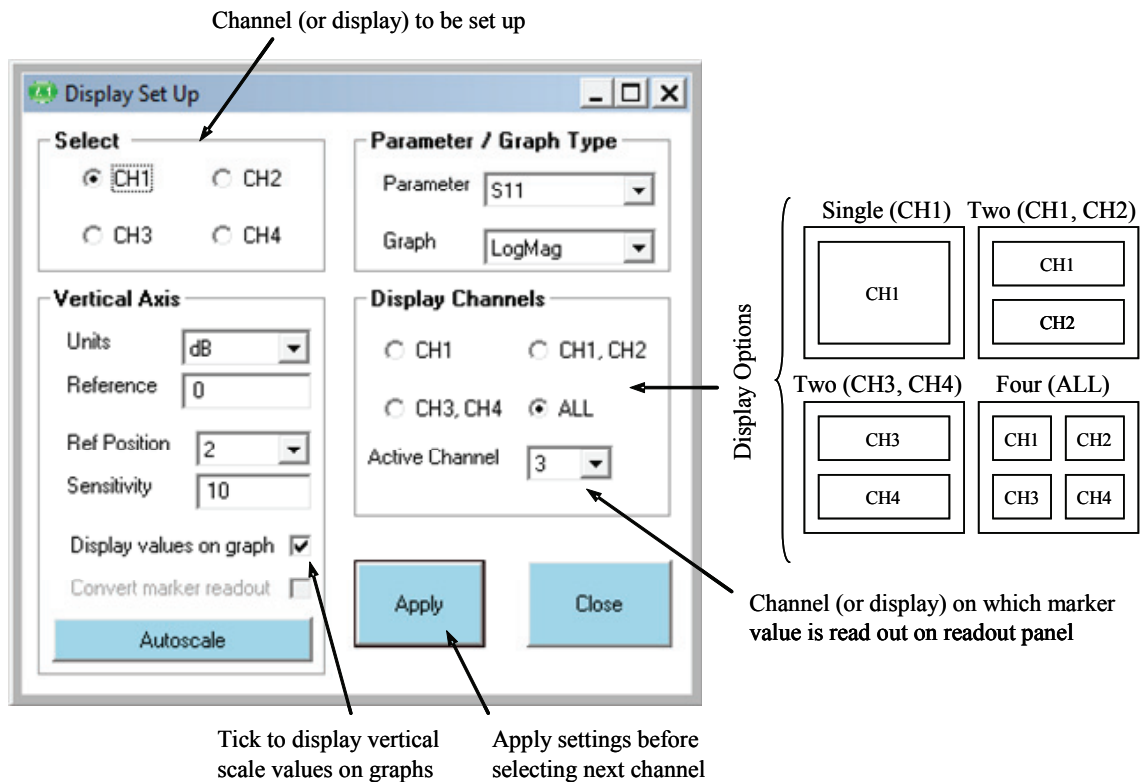
Set the calibration parameters and calibrate

Click on the ‘Calibration’ button to bring up the calibration window



Set up the display parameters

(see section 6.1.1 for details on using the mouse to set values)



Click on the ‘Display’ button to bring up the setup window. Once done click on the ‘Start’ button on the main window to begin measurements

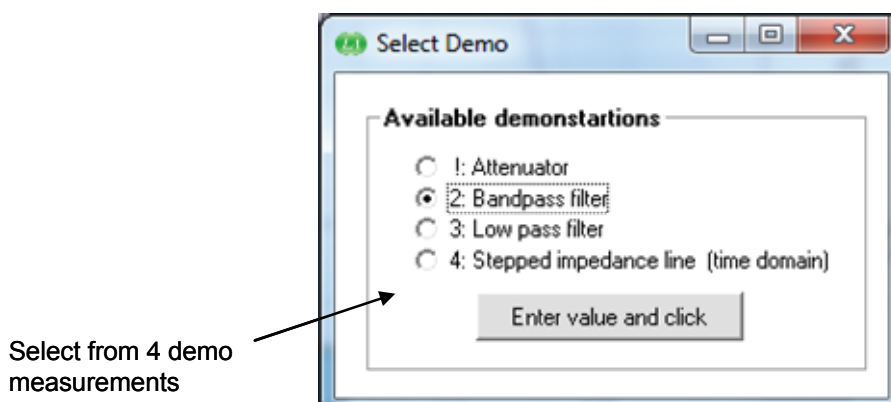
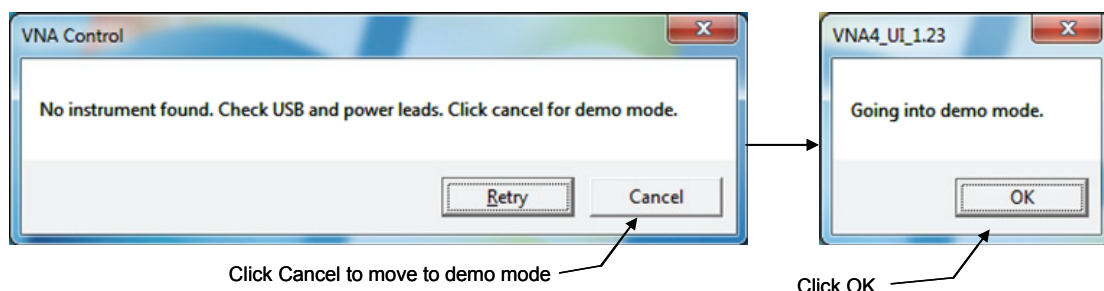
Calibration tips

The bandwidth setting used during calibration largely determines the available dynamic range during the measurement. The table below shows suggested bandwidth and power settings to use during calibration depending on the type of measurement to be undertaken.

Measurement	Calibration Bandwidth	Calibration Averaging	Calibration Power	Comments
Fastest speed	10 kHz	None	+0 dBm	Set bandwidth to 140 kHz during measurement
Best accuracy and ~100dB dynamic range	100 Hz	None	-3 dBm	Leave bandwidth set to 100 Hz during measurement
General use, fast speed, ~90 dB dynamic range	1 kHz	None	+0 dBm	Leave bandwidth set to 1 kHz during measurement
Best dynamic range	10 Hz	None	+6 dBm	Leave bandwidth set to 10 Hz during measurement. Refer to section 6.2.7 “Calibration for best dynamic range – minimising the effect of crosstalk”

Running in demo mode

The demo mode allows the user to explore the user interface software without the need to have an instrument running. In order to run the software in demo mode, follow the following steps after running the software without an instrument connected.



2 DESCRIPTION

The LA19-13-04A is a personal computer-driven Vector Network Analyser capable of operation over the range of 300 kHz to 6 GHz. It can perform direct measurements of forward and reverse parameters with up to 118 dB of dynamic range. The test frequency can be set with a resolution of 10 Hz or less. A simplified block diagram of the instrument is shown below in Fig. 2.1.

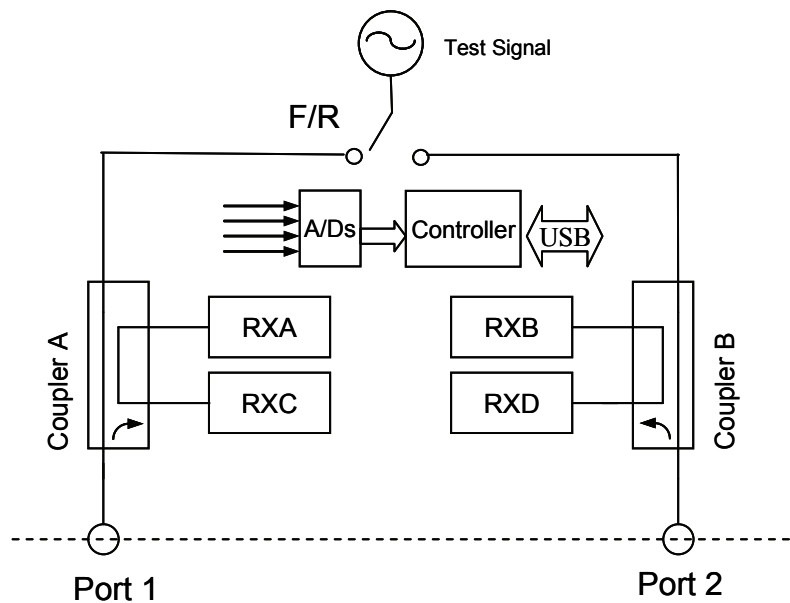


Figure 2.1 Simplified block diagram of the LA19-13-04A

The architecture is based on a four receivers arrangement using a bandwidth of up to 140 kHz. Couplers A and B are wide band RF bridge components which provide the necessary directivity in both directions. Signal detection is by means of analogue to digital converters used to sample the IF signal. The sample data is processed by the embedded controller to yield the I and Q components. The detection system operates with an IF of 1.3MHz and employs a patented circuit technique to yield fast speeds with very low trace noise.

The instrument's User Interface (UI) software runs on a personal computer and communication with the instrument is through the USB interface. The UI carries out the mathematical processing and allows the display of measured parameters in many forms, including: frequency domain, time domain and utilities to de-embed measurements, measure output power at the 1dB gain compression point and AM to PM conversion.

Figures 2.2 and 2.3 below show the front and back panels of the instrument.

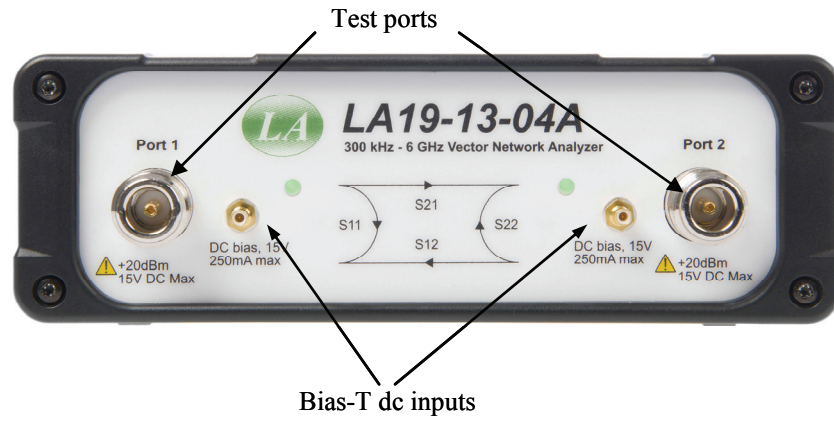


Figure 2.2 Front panel of the LA19-13-04A

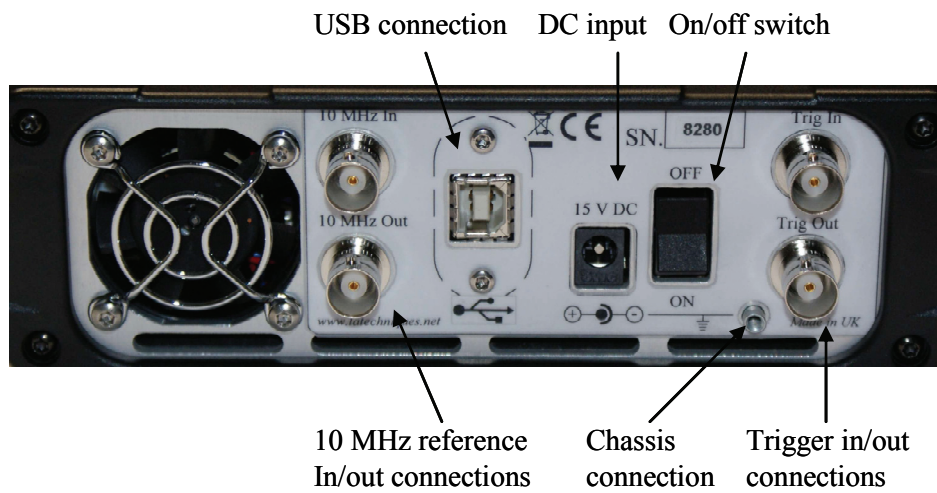


Figure 2.3 Back panel of the LA19-13-04A

3 SAFETY

This instrument has been designed to meet the requirements of EN61010-1 (Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use) and is intended only for indoor use in a Pollution Degree 1 environment (no pollution, or only dry non-conductive pollution) in the temperature range 15 °C to 35 °C, 20 % - 80 % relative humidity (non-condensing).

Use of the instrument in a manner not specified by these instructions may impair the safety protection provided. Do not operate the instrument outside its rated supply voltages or environmental range.

It is recommended that any adjustment, maintenance and repair shall be carried out only by a skilled person who is aware of the possible hazards involved.

Do not block the ventilation ports on the instrument. Do not wet the instrument.

The symbols used in this manual and on the labelling of the instrument are as follows:



Refers to the Manual if the instrument is marked with this symbol



Alternating current



Direct current



On (Supply)



Off (Supply)



A chassis terminal; a connection to the instrument's chassis, which includes all exposed metal structure.

4 VECTOR NETWORK ANALYSER BASICS

4.1 Introduction

A vector network analyser is used to measure the performance of circuits or networks such as amplifiers, filters, attenuators, cables and antennas. It does this by applying a test signal to the network to be tested, measuring the reflected and transmitted signals and comparing them to the reference signal. The vector network analyser measures both the magnitude and phase of these signals.

4.2 Structure of the VNA

The VNA (Fig. 4.1) consists of a tuneable RF source the output of which is split into two paths. One signal is used as the reference and is measured by the R (Reference) receiver, the other is used for the test stimulus for the DUT (Device Under Test). In the forward mode, the test signal is passed through a directional coupler or directional bridge before being applied to the DUT. The directional output of the coupler, which selects only signals reflected from the input of the DUT, is connected to receiver A where the signal's magnitude and phase are measured. The rest of the signal, the portion that is not reflected from the input, passes through the DUT to receiver B where its magnitude and phase are measured. The measurements at receivers A and B are referenced to the measurement made by receiver R so that any variations due to the source are removed. The reference receiver R also provides a reference for the measurement of phase.

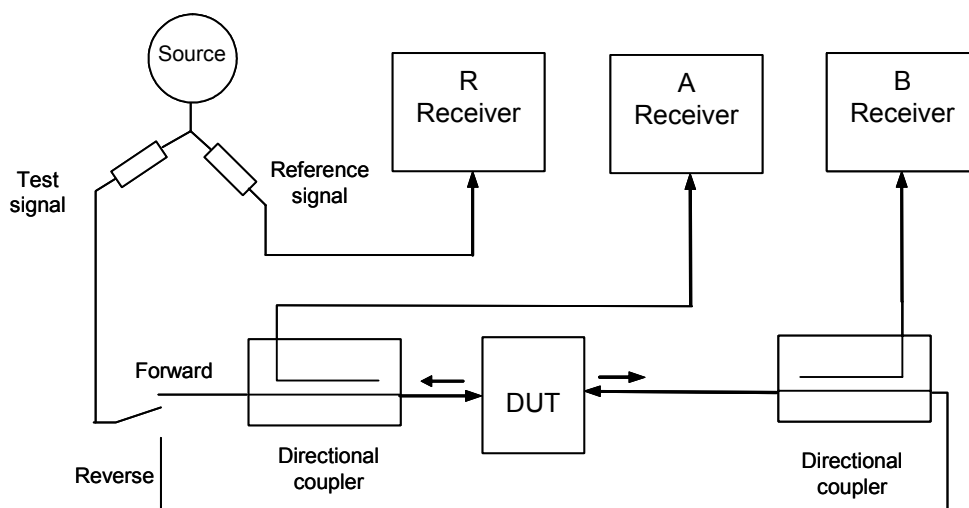


Fig. 4.1 Simplified Vector Network Analyser block diagram

In the reverse mode, the test signal is applied to the output of the DUT, and receiver B is used to measure the reflection from the output port of the DUT whilst receiver A is measures the reverse transmission through the DUT.

4.3 Measurement

Vector network analysers have the capability to measure phase as well as magnitude. This is important for fully characterising a device or network either for verifying the performance or for generating models for design and simulation. Knowledge of the phase of the reflection coefficient is particularly important for matching systems for

maximum power transfer. For complex impedances the maximum power is transferred when the load impedance is the complex conjugate of the source impedance (Fig. 4.2).

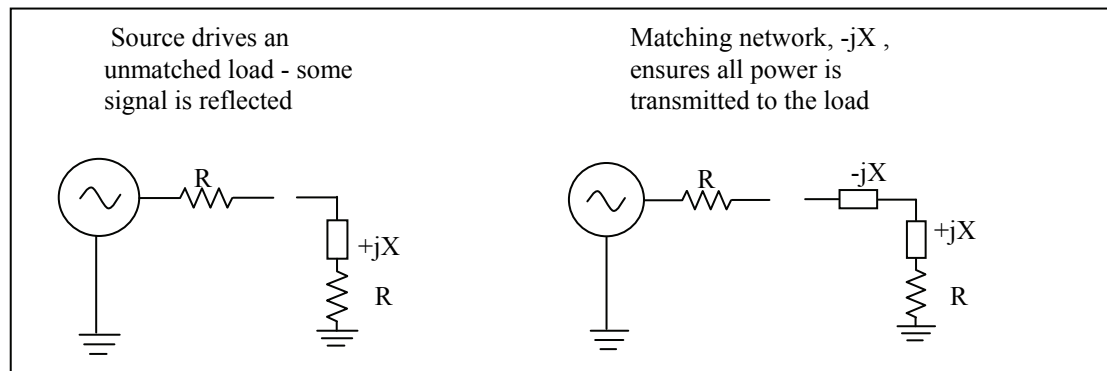


Fig.4.2 Matching a load for maximum power transfer

Measurement of phase in resonators and other components is important in designing oscillators. In feedback oscillators, oscillation occurs when the phase shift round the loop is a multiple of 360° and the gain is unity. It is important that these loop conditions are met as close as possible to the centre frequency of the resonant element to ensure stable oscillation and good phase noise performance.

The ability to measure phase is also important for determining phase distortion in a network. Phase distortion can be important in both analogue and digital systems. In digital transmission systems, where the constellation depends on both amplitude and phase, any distortion of phase can have serious effects on the errors detected.

4.4 S-parameters

The basic measurements made by the Vector Network Analyser are S (Scattering) parameters. Other parameters such as H, Y and Z parameters may all be deduced from the S-parameters if required. The reason for measuring S-parameters is that they are made under conditions that are easy to produce at RF. Other parameters require the measurement of currents and voltages, which is difficult at high frequencies. They may also require open circuits or short circuits that can be difficult to achieve at high frequencies, and may also be damaging to the device under test or may cause oscillation.

Forward S-parameters are determined by measuring the magnitude and phase of the incident, reflected and transmitted signals with the output terminated with a load that is equal to the characteristic impedance of the test system (Fig. 4.3).

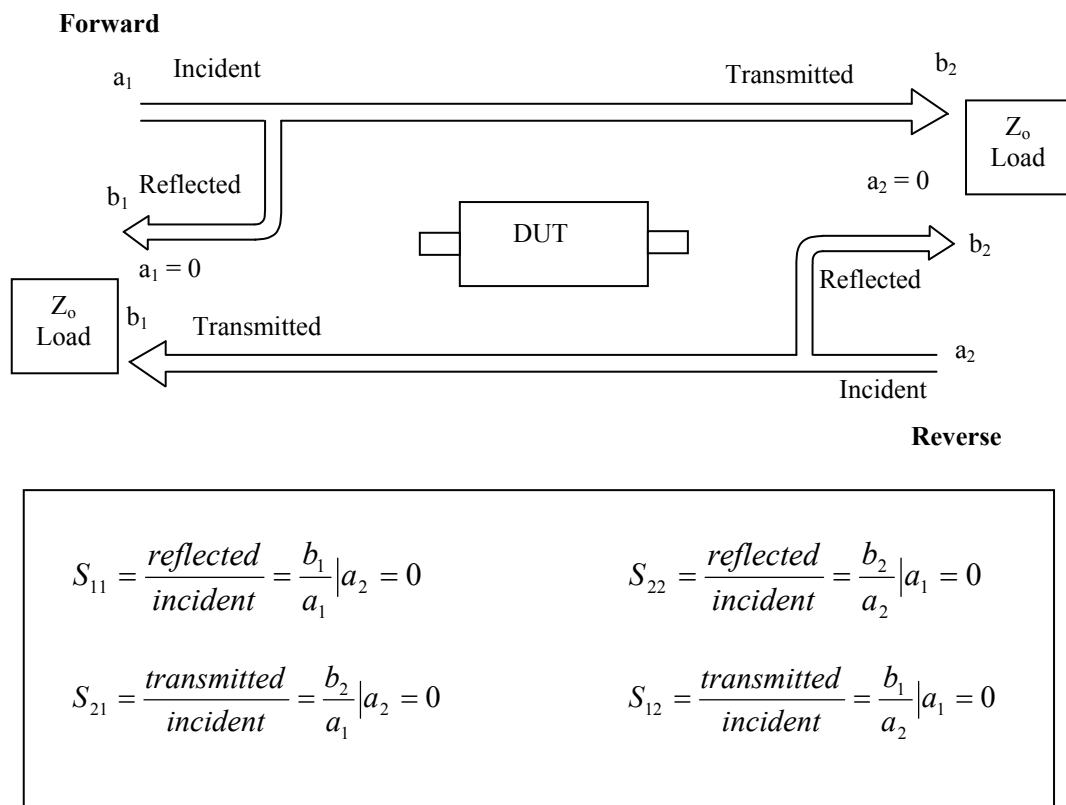


Fig. 4.3 S-Parameters definition

The measured parameters are presented in a file similar to the one overleaf. It will usually start with a header section that may give some general information such as time and date. The header lines start with an exclamation mark (!). There will also be a line that starts with a # symbol. This line gives information about the format of the data. The first field gives the frequency units, in this case MHz, the second indicates the parameters measured, in this case S-parameters, the third indicates the format of the measurement, in this case “Magnitude and Angle”. If this had been RI instead of MA it would have indicated the format was “Real and Imaginary”. The number of columns of data depends on the parameters that have been measured. A 1 Port measurement measures the reflected signal from the device under test and will usually produce three columns. If the format is MA (magnitude and angle) then the first column is the measurement frequency, the second is the Magnitude of S_{11} and the third is the Angle of S_{11} . If the format is RI then the second column is the Real part of S_{11} and the third column is the Imaginary part of S_{11} . When a reflection and transmission measurement is made there will be five columns of data. Column 1 will be the measurement frequency, Column 2 and 3 will contain S_{11} magnitude and angle or real and imaginary data, and Columns 4 and 5 will contain S_{21} magnitude and angle or real and imaginary data. If a full 2 Port measurement is made, there will be nine columns of data. Column 1 contains frequency information, Columns 2 and 3 S_{11} data, 4 and 5 S_{21} data, 6 and 7 S_{12} data, and 8 and 9 S_{22} data.

The LA19-13-04A VNA can generate full set of 2 port parameters but the user can chose to export either 1 port or full 2 port S-parameter files to suit most RF / microwave circuit simulators.

Part of a typical 2 Port S-parameter file is shown below. The header shows that the frequency units are MHz, the data format is Magnitude and Angle and the system impedance is 50 Ω. Column 1 shows frequency, 2 and 3 S₁₁, 4 and 5 S₂₁, 6 and 7 S₁₂, and 8 and 9 S₂₂.

```

! 06/09/2005 15:47:34
! Ref Plane: 0.000 mm
# MHZ S MA R 50
!
3          0.00776 16.96      0.99337 -3.56      0.99324 -3.53      0.00768 12.97
17.985    0.01447 19.99      0.9892  -20.80     0.98985 -20.72     0.01519 15.23
32.97     0.01595 20.45      0.98614 -37.96     0.98657 -37.95     0.01704  6.40
47.955    0.01955 28.95      0.98309 -55.15     0.98337 -55.10     0.018   1.75
62.94     0.02775 24.98      0.98058 -72.29     0.98096 -72.29     0.0199  -6.07
77.925    0.03666 11.76      0.97874 -89.46     0.9803  -89.45     0.02169 -23.06
92.91     0.04159 -6.32       0.97748 -106.62  0.9786  -106.62    0.01981 -48.43
107.895   0.0426  -24.79     0.97492 -123.77  0.97579 -123.89    0.01424 -87.79
122.88    0.0396  -41.35     0.97265 -141.25  0.97269 -141.30    0.00997 -166.81
137.865   0.03451 -52.96     0.96988 -158.65  0.96994 -158.76    0.01877 113.15
152.85    0.03134 -56.07     0.96825 -176.27  0.96858 -176.28    0.03353  69.81
167.835   0.03451 -57.72     0.96686 166.10   0.96612 165.99    0.04901  34.83
182.82    0.04435 -67.59     0.9639  148.18   0.96361 148.21    0.06131  1.42
197.805   0.05636 -86.28     0.96186 130.15   0.96153 130.06    0.07102 -33.33
212.79    0.06878 -110.45  0.95978 111.82   0.95996 111.90    0.07736 -69.57
227.775   0.08035 -136.14  0.9557  93.50   0.9568  93.41     0.08303 -107.21
242.76    0.09099 -161.24  0.95229 74.84   0.95274 74.89     0.08943 -144.34
257.745   0.10183 175.34   0.94707 56.03   0.94755 55.95     0.09906 -179.63
    
```

4.5 Displaying Measurements

Input and output parameters, S₁₁ and S₂₂, are often displayed on a polar plot or a Smith chart. The polar plot shows the result in terms of the complex reflection coefficient, however impedance cannot be directly read off the chart. The Smith chart maps the complex impedance plane onto a polar plot. All values of reactance and all positive values of resistance, from 0 to ∞, fall within the outer circle. This has the advantage that impedance values can be read directly from the chart.

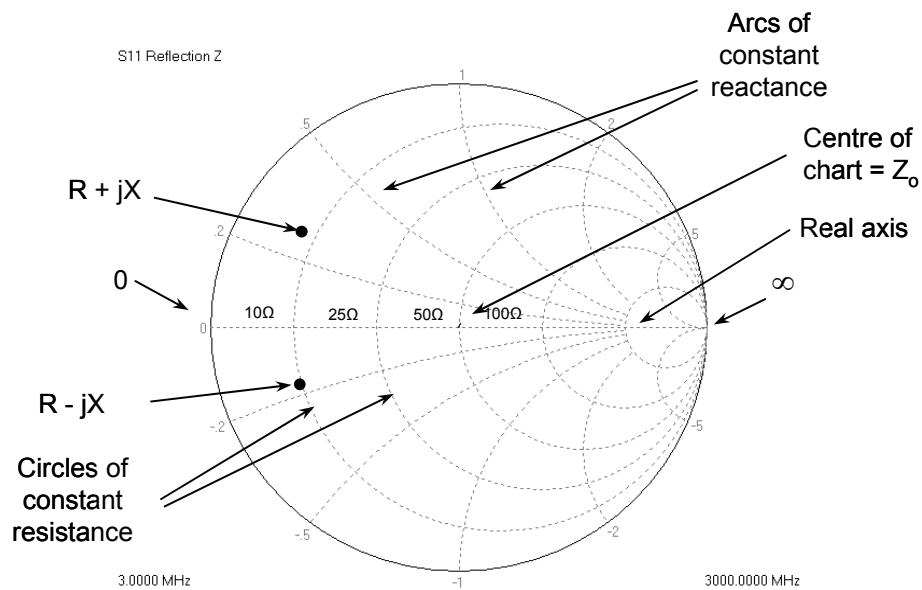


Fig. 4.4 The Smith Chart

4.6 Calibration and Error Correction

Before accurate measurements can be made the network analyser needs to be calibrated. In the calibration process well-defined standards are measured and the results of these measurements are used to correct for imperfections in the hardware. The most common calibration method SOLT (Short, Open, Load, Through), uses four known standards, a short circuit, an open circuit, a load of the same value as the system impedance, and a through line. These standards are usually contained in a calibration kit and their characteristics are stored in the analyser in a Cal Kit definition file. For analysers that have a full S-parameter test set (such as the LA19-13-04), 12 systematic error terms are measured and can be corrected.

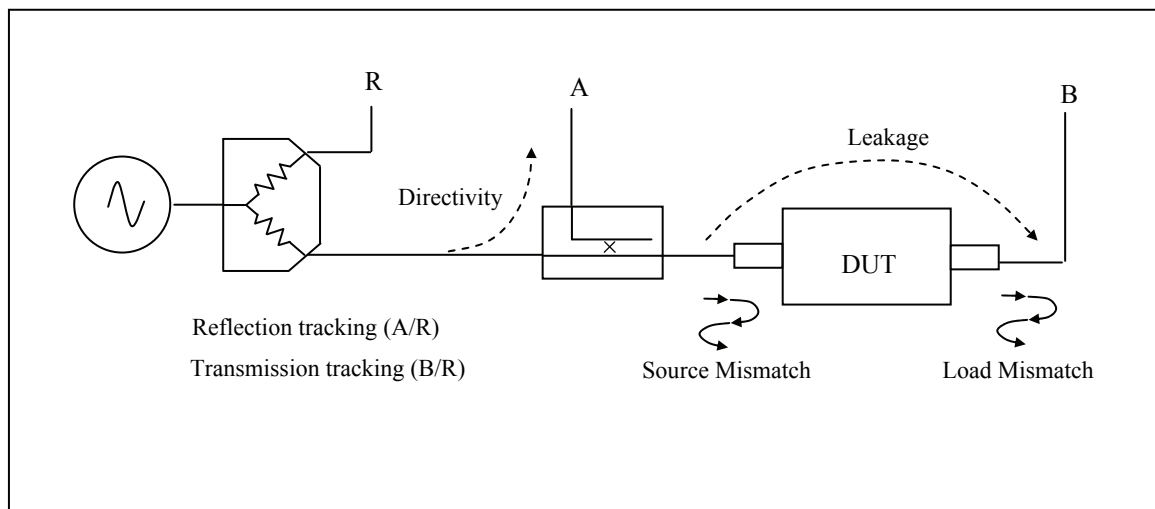


Fig. 4.5 Key sources of errors (forward measurement)

4.7 Other Measurements

Whilst the fundamental measurement performed by the Network analyser is S-parameters, many other parameters may be derived from the S-parameters. H, Y and Z parameters can all be calculated from the S-parameters.

Reflection parameters

The input reflection coefficient Γ , can be obtained directly from S_{11} .

The complex reflection coefficient Γ is given by

$$\Gamma = \frac{V_{reflected}}{V_{incident}} = S_{11} = \rho \angle \phi$$

ρ is the magnitude of the reflection coefficient i.e. the magnitude of S_{11} .

$$\rho = |\Gamma|$$

Sometimes ρ is expressed in logarithmic term as Return Loss

$$return_loss = -20\log(\rho)$$

VSWR can also be derived

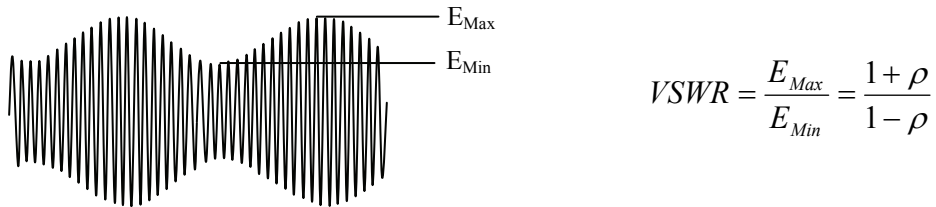


Fig. 4.6 VSWR definition

Transmission parameters

Transmission coefficient T , is defined as the transmitted voltage divided by the incident voltage. This is the same as S_{21} .

$$T = \frac{V_{transmitted}}{V_{incident}} = S_{21} = \tau \angle \phi$$

If T is less than 1 there is loss in the DUT which is usually referred to as Insertion Loss and is usually expressed in decibels. A negative sign is included in the equation so that the insertion loss is quoted as a positive value:

$$Insertion_loss(dB) = -20\log\left|\frac{V_{trans}}{V_{incident}}\right| = -20\log\tau$$

If T is greater than 1 the DUT has gain which is also normally expressed in decibels:

$$Insertion_gain(dB) = 20\log\left|\frac{V_{trans}}{V_{incident}}\right| = 20\log\tau$$

Phase

The phase behaviour of networks can be very important, especially in digital transmission systems. The raw phase measurement is not always easy to interpret as it has a linear phase increment superimposed on it due to the electrical length of the DUT. Using the reference plane function the electrical length of the DUT can be removed leaving the residual phase characteristics of the device (Fig. 3.7).

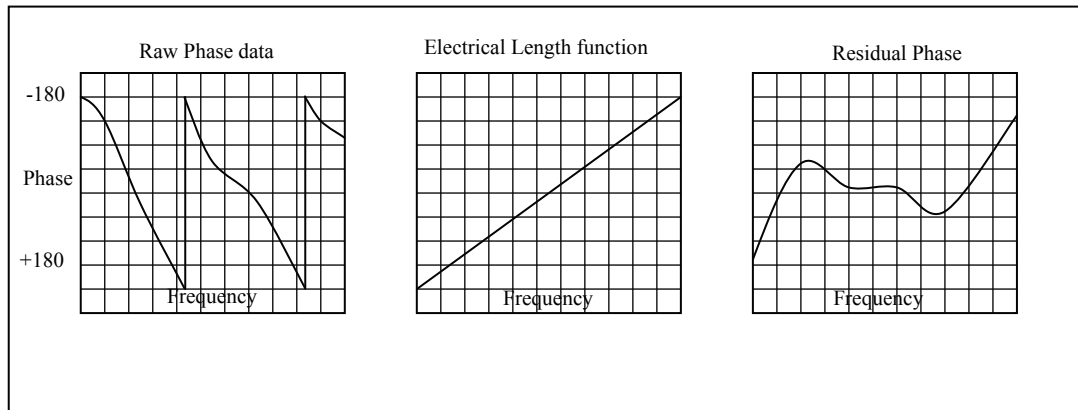


Fig. 4.7 Operation on phase data to yield underlying characteristics

Group delay

Another useful measurement of phase is group delay. Group delay is a measure of the time it takes a signal to pass through a network versus frequency. It is calculated by differentiating the phase response of the device with respect to frequency, i.e. the rate of change of phase with frequency:

$$\text{Group_delay} = -\frac{d\phi}{df}$$

The linear portion of phase is converted to a constant value typically, though not always, representing the average time for a signal to transit the device. Differences from the constant value represent deviations from linear phase. Variations in group delay will cause phase distortion as a signal passes through the circuit.

When measuring group delay the aperture must be specified. Aperture is the frequency step size used in the differentiation. A small aperture will give more resolution but the displayed trace will be noisy. A larger aperture effectively averages the noise but reduces the resolution.

Gain compression

The 1 dB gain compression point of amplifiers and other active devices can be measured using the power sweep. The small signal gain of the amplifier is determined at low input power, then the power is increased and the point at which the gain has fallen by 1 dB is noted (Fig. 4.8).

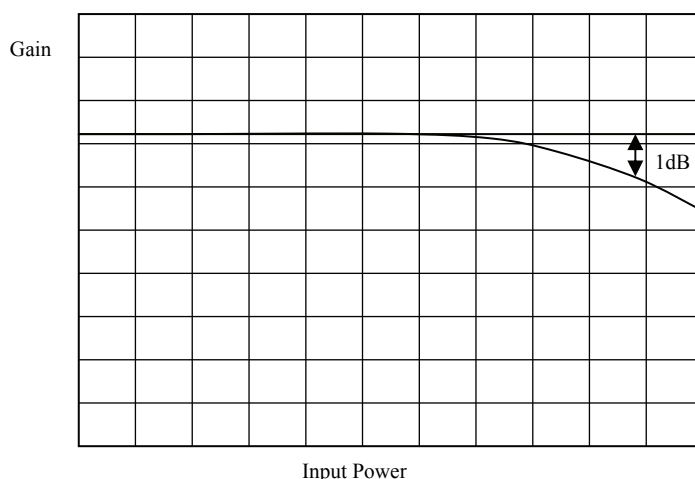


Fig. 4.8 The 1 dB gain compression is often used to quote output power capability

AM to PM conversion

Another parameter that can be measured with the VNA is AM to PM conversion. This is a form of signal distortion where fluctuations in the amplitude of a signal produce corresponding fluctuations in the phase of the signal. This type of distortion can have serious effects in digital modulation schemes where both amplitude and phase accuracy are important. Errors in either phase or amplitude cause errors in the constellation diagram.

Time domain reflectometry

Time domain reflectometry is a useful technique for measuring the impedance of transmission lines and for determining the position of any discontinuities due to connectors or damage. The network analyser can determine the time domain response to a step input from a broad band frequency sweep at harmonically related frequencies. An inverse Fourier Transform is performed on the reflected frequency data (S_{11}) to give the impulse response in the time domain. The impulse response is then integrated to give the step response. Reflected components of the step excitation show the type of discontinuity and the distance from the calibration plane.

A similar technique is used to derive a TDT (Time Domain Transmission) signal from the transmitted signal data (S_{21}). This can be used to measure the rise time of amplifiers, filters and other networks. The following provides a more detailed treatment of TDR and TDT.

Traditional time domain reflectometry (TDR)

The traditional TDR consists of a step source and sampling oscilloscope (Fig.4.9). A step signal is generated and applied to a load. Depending on the value of the load, some of the signal may be reflected back to the source. The signals are measured in the time domain by the sampling scope. By measuring the ratio of the input voltage to the reflected voltage the impedance of the load can be determined. Also by observing the position in time when the reflections arrive, it is possible to determine the distance to impedance discontinuities.

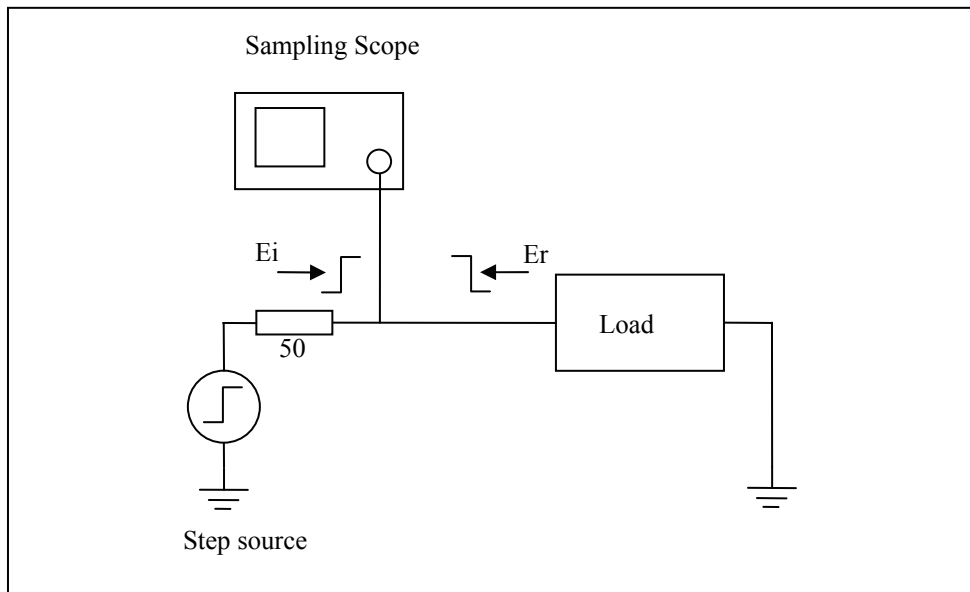


Figure 4.9 Traditional TDR set up.

TDR examples

1. Shorted $50\ \Omega$ transmission line:

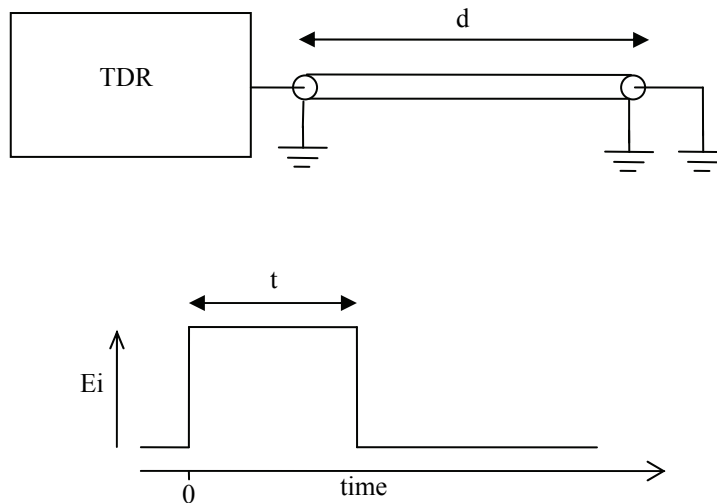


Figure 4.10 Simplified representation of the response of a shorted line.

For a transmission line with a short circuit (Fig. 4.10) the incident signal sees the characteristic impedance of the line so the scope measures E_i . The incident signal travels along the line to the short circuit where it is reflected back 180° out of phase. This reflected wave travels back along the line cancelling out the incident wave until it is terminated by the impedance of the source. When the reflected signal reaches the Scope the signal measured by the Scope, goes to zero as the incident wave has been cancelled by the reflection. The result measured by the Scope is a pulse of magnitude E_i and duration that corresponds to the time it takes the signal to pass down the line to the short and back again. If the velocity of the signal is known the length of the line can be calculated.

$$d = \frac{tv}{2}$$

Where v is the velocity of the signal in the transmission line, t is the measured pulse width and d is the length of the transmission line.

2. Open circuit 50 Ω transmission line:

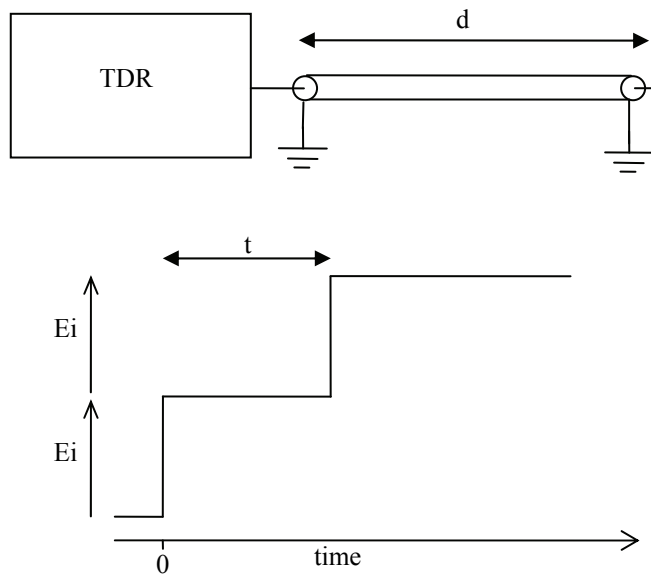


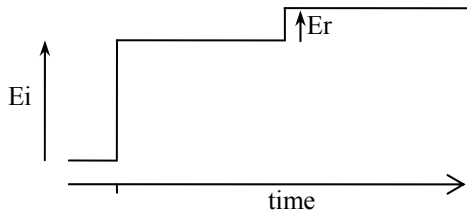
Figure 4.11 Simplified representation of the response of an open line

In the case of the open circuit transmission line (Fig. 4.11) the reflected signal is in phase with the incident signal, so the reflected signal combines with the incident signal to produce an output at the scope that is twice the incident signal. Again, the distance d can be calculated if the velocity of the signal is known.

3. Resistive termination of 50 Ω transmission line:

$$\rho = \frac{E_r}{E_i} = \frac{R-50}{R+50}$$

R > 50



R < 50

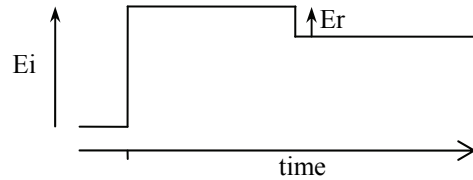


Figure 4.12 Simplified representation of the response of a resistively terminated line

4. Reactive terminations and discontinuities:

Reactive elements can also be determined by their response. Inductive terminations produce a positive pulse. Capacitive terminations produce a negative pulse.

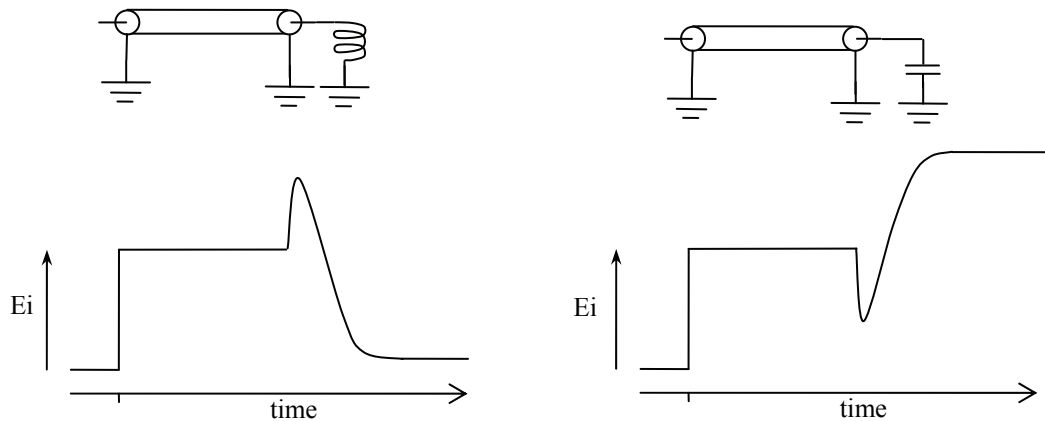


Figure 4.13 Simplified representation of the response of a reactively terminated line

Similarly, the position and type of discontinuity in a cable, due to connectors or damage, can be determined. A positive pulse indicates a connector that is inductive or damage to a cable, such as a removal of part of the outer screen. A negative going pulse indicates a connector with too much capacitance or damage to the cable, such as being crushed.

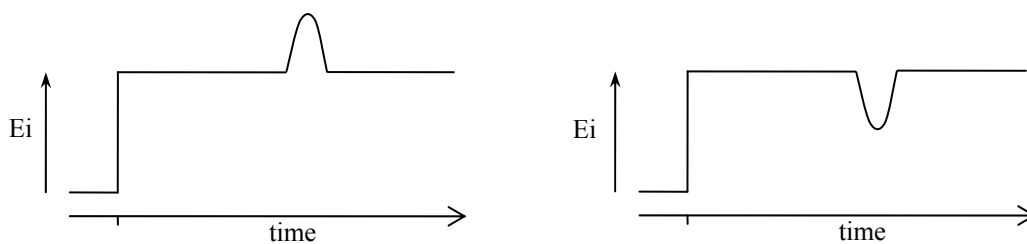


Figure 4.14 Simplified representation of the response of a line discontinuity

Time domain from the frequency domain

An alternative to traditional TDR is where the time domain response is determined from the frequency domain using an Inverse Fast Fourier Transform (IFFT). Several methods are available for extracting time domain information from the frequency domain. The main methods are Low Pass and Band Pass.

The Low Pass method can produce results that are similar to the traditional TDR measurements made with a Time Domain Reflectometer using a step signal, and can also compute the response to an impulse. It provides both magnitude and phase information and gives the best time resolution. However it requires that the circuit is dc coupled. This is the method supported by the LA19-13-04A VNA.

The Band Pass method provides only magnitude information so it is not possible to distinguish between inductive and capacitive reactances. Also, the time resolution is only half as good as in the Low Pass mode. However, the method can be used for circuits where there is no DC path and hence is suitable for AC coupled circuits such as band pass filters. This method is not currently supported in the LA19-13-04A VNA.

Low Pass method

The Low Pass method uses an Inverse Fourier Transform to determine the impulse response in the time domain from the reflection coefficient measured in the frequency domain. The DC component is extrapolated from the low frequency data to provide a phase reference. Alternatively, if the DC termination is known it can be entered manually. Once the impulse response is computed, the step response may be determined from the time integral of the impulse response. In the step response mode the trace is similar to that of a TDR, except that there is no step at $t = 0$. When the time domain response is derived from the frequency information the value at $t = 0$ is the impedance of the transmission line or load immediately following the calibration plane. The value is referenced to 50Ω , the characteristic impedance of the system. For example an open circuit would appear as a value of +1 unit relative to the reference value and a short circuit would appear as a value of -1 unit relative to the reference value (see example plots in section 5.3.4).

In order to facilitate the use of the Inverse Fourier Transform to compute the time domain response, the samples in the frequency domain must be harmonically related and consist of 2^n points. For this reason, in order to use the TDR facility in the LA19-

13-04A VNA makes available special 512, 1024, 2048 or 4096 frequency point calibrations, each having a stop frequency of up to 6000 MHz. The resulting alias free range is a function of the number of frequency points (N) and the total frequency span. It is given by the expression:

$$R = \frac{N - 1}{FreqSpan}$$

So, the available ranges on the LA19-13-04A are approximately 100ns, 171ns, 341ns and 683ns.

Now, the transform returns twice the number of points of the calibration in the time domain thus the above ranges provide a time resolution of approximately between 98ps and 84ps.

Windowing

The bandwidth of the network analyser is limited by the frequency range, therefore the frequency domain data will be truncated at the bandwidth of the analyser. Also the analyser gathers data at discrete frequencies. The result of the sampled nature of the data and the truncation in the frequency domain is to produce a $\sin(x)/x$ response when transformed to the time domain. This appears as ringing on both the displayed impulse response and the step response. To overcome this problem, a technique known as windowing can be applied to the frequency domain data before implementing the Inverse Fourier Transform. The windowing function progressively reduces the data values to zero as the edge of the frequency band is approached, thus minimising the effect of the discontinuities. When the modified data is transformed, the ringing is reduced or removed depending on the selected windowing function. However, the windowing function reduces the bandwidth and so increases the width of the pulse in impulse response mode and slows the edge in step response mode. A balance must be made between the width of the pulse, or speed of the edge, and the amount of ringing to be able to determine closely spaced discontinuities. The LA19-13-04A VNA allows one to choose a rectangular window (no bandwidth reduction), a Hanning window (raised cosine), or a Kaiser Bessel window. The order of the Kaiser Bessel window can be set by the user.

Aliasing

The sampled nature of the data means it is subject to the effects of aliasing. The result is repetition of time domain response at the effective sampling rate in the frequency domain. This limits the maximum time delay and hence maximum cable length that can be observed. In the LA19-13-04A VNA this is 683 ns (approximately 138 m cable).

5 GETTING STARTED

The following sequence diagram (Fig. 5.1) illustrates the steps necessary to install the operating software of the instrument.

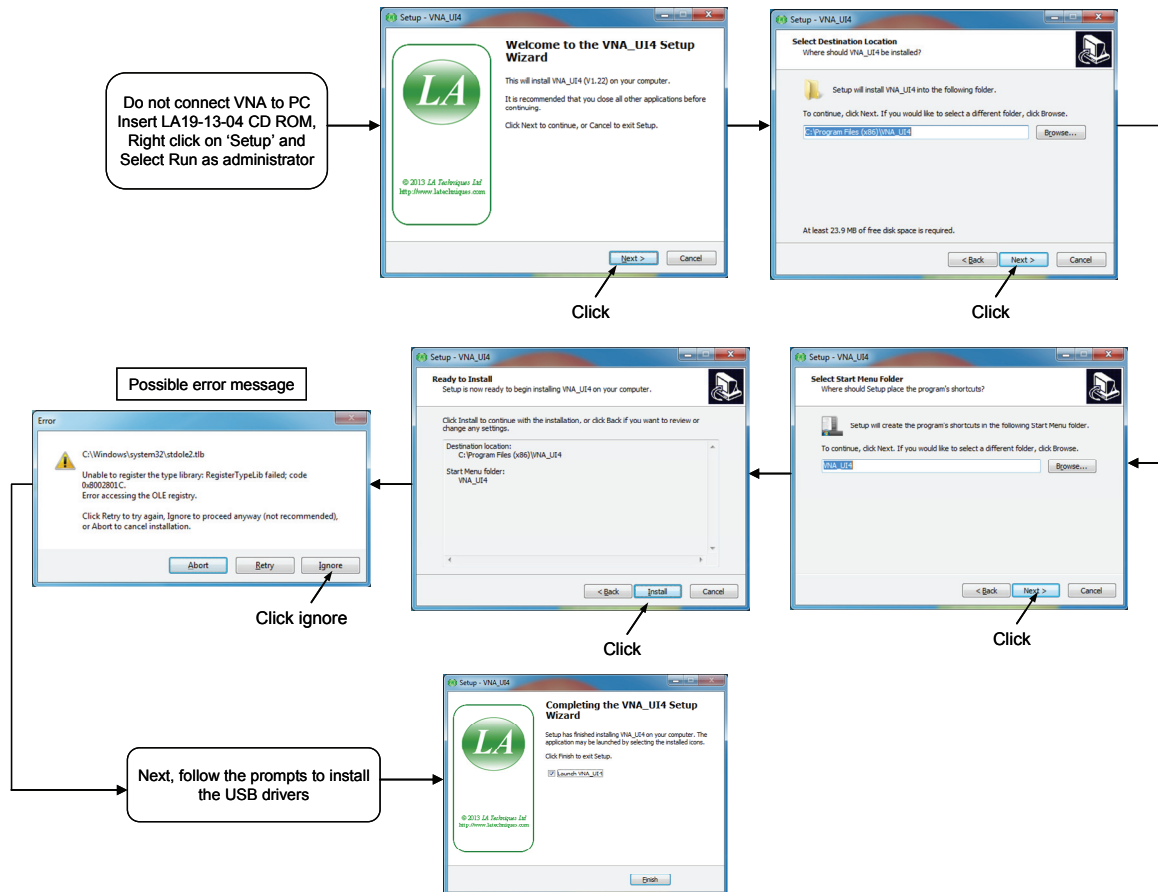


Fig. 5.1 Initial setting up of the VNA software. Run setup.exe as administrator if using Windows 7 or higher.

5.1 Minimum Requirements

The recommended minimum requirements to operate the VNA are as follows.

- PC or portable PC
- Pentium 4 (2 GHz) or equivalent
- 2 GB of RAM
- 200 MB of hard disk storage available on the C: partition
- Windows XP or Windows 7
- USB port

The performance of the User Interface software will be influenced by the performance of the PC and video adaptor installed in it. It is important that an adaptor with good graphics performance is used. As a general guide, it is recommended that an adaptor with at least 64 MB of memory is used.

5.2 User Interface Software Installation

Follow the instructions written on the CD provided to install the user interface software CD Rom (see Fig. 5.1). The procedure will copy the necessary files from the CD ROM to the PC's hard disk, install the executable file and install the USB driver.

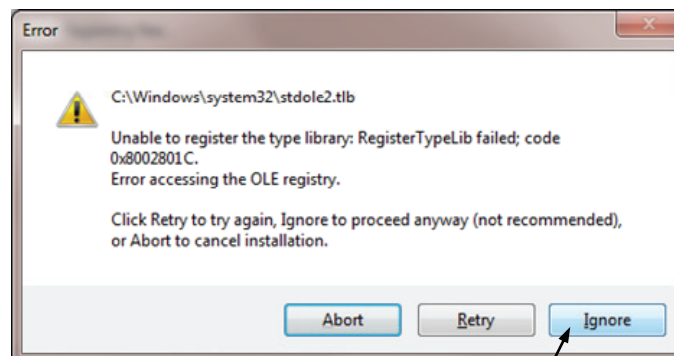
If the host PC is running Windows 7, then ensure the user has administrative privileges. Also, run the Setup.exe file as administrator.

During installation, a support directory "C:\User\Public\Documents\LA19-13-04A" is created. This directory will contain the following files.

- xxx-log.txt > This is the status log file. 'xxxx' is the serial number
- DefCal.cal > Default calibration data (last used calibration)
- DefUnc.dat > Default measurement uncertainty values
- \cal kits*.kit > Calibration kit files (if supplied)
- \cal kits*.dat > Load calibration data for the cal kit (if supplied)
- UsersManual.pdf
- \Support > Folder with data files to support the software

Typical Error Messages

On Windows 7 machines it is common to see the following error message:



Click on ignore to continue

5.3 Switching on the VNA

When power is applied to the VNA, the front panel channel activity indicators will flash to indicate that the controller has started correctly.

5.4 Calibration Kit

The minimum requirements to carry out a 12-term calibration (full error correction) depend on the device to be tested. For example, the most accurate calibration is for 'insertable' devices which requires a total of 6 Standards. An 'insertable' device is one which has connectors of different sex at its ports. On the other hand, a calibration for a non-insertable device can be carried out using only 3 Standards by using the "unknown through" calibration method.

Insertable DUT

- Open circuit (2 pieces, one male and one female)
- Short circuit (2 pieces, one male and one female)
- Matched termination (2 pieces, one male and one female)
- Through connection test cable(s)

Non-Insertable DUT

- Open circuit (1 piece)
- Short circuit (1 piece)
- Matched termination (1 piece)
- Either a characterised through connection adaptor (1 piece) or any uncharacterised reciprocal* adaptor
- Through connection test cable(s)

* **The 'unknown thru' calibration method only requires that the 'thru' adaptor be reciprocal, that is, have $S_{21} = S_{12}$.**

So, for insertable DUTs the requirement is for two calibration kits, one of each sex. Generally, it is required that the matched termination should be of good quality and, as a guide, should have a return loss of better than 40 dB. However, the LA19-13-04A allows terminations with relatively poor return loss values to be used and still maintain good accuracy. This is discussed in section 5.7.1.

For non-insertable DUTs only a single calibration kit is required. In addition, a reciprocal, but otherwise unknown through adaptor, or a fully characterised through adaptor is required. These are supplied with all of LA Techniques Ltd economy kits.

The calibration kits parameters can be inspected using the window (see Fig. 5.4) found under the 'Tools' menu. From this the kit editor can be launched to modify and create new kits as discussed later in the section.

Open circuit model

The open circuit capacitance model used is described by the equation below, where *Freq* is the operating frequency. Generally, with typical Open Circuit Standards, the effect is small, amounting to no more than a few degrees of phase shift at 6 GHz

$$C_{open} = C_o + C_1Freq + C_2Freq^2 + C_3Freq^3$$

In addition, an offset length (sometimes referred to as offset delay) can be entered as well as the loss of the offset line.

Short circuit model

The Short circuit inductance is modelled by an inductance component and in addition, a non-zero offset length can be entered together with the loss of the offset line.

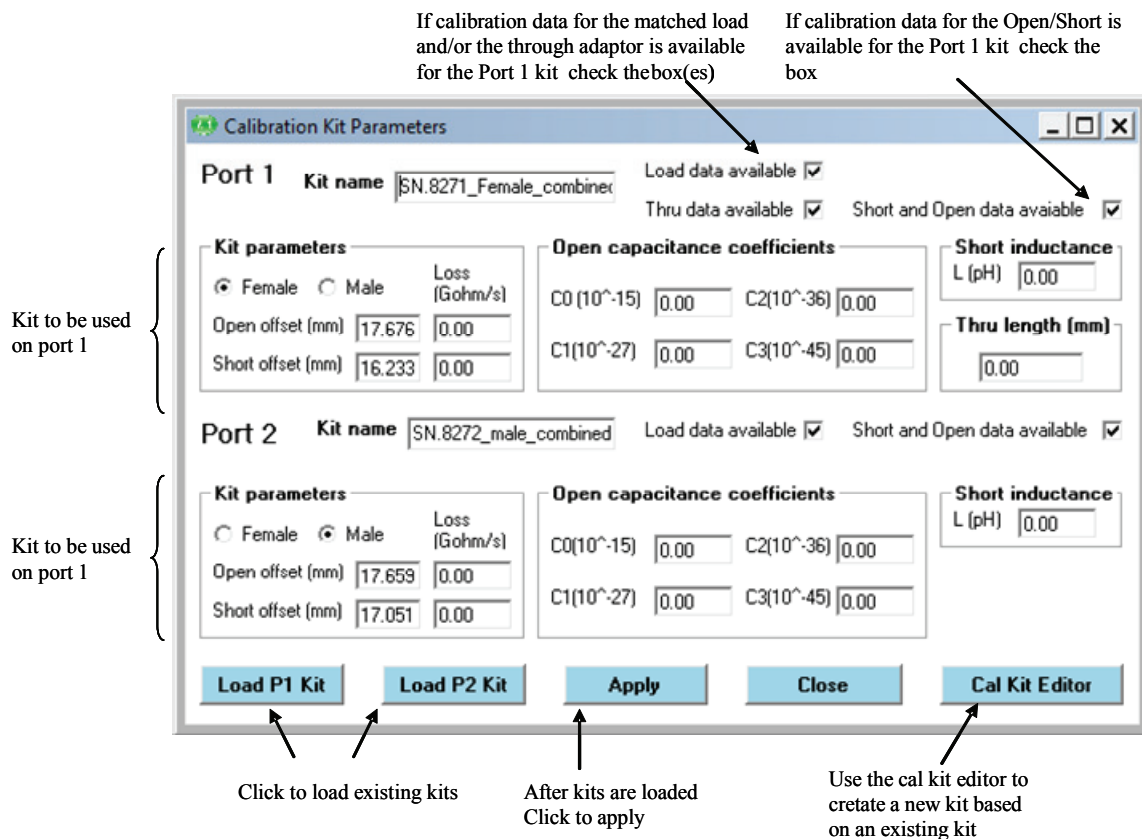


Figure 5.4 Calibration Kit window. The Short/Open offsets are in mm in air

Short and Open without models

The LA19-13-04A supports Short and Open Standard defined by data. In this case the data is supplied in the form of a 201 frequency points table. Each point has three

comma separated entries, frequency (in MHz), real part of the reflection coefficient and the imaginary part of the reflection coefficient.

Calibration kit editor

As already mentioned, the calibration kit editor can be used to create or edit an existing calibration kit. Fig. 5.5 shows the editor window. A typical example is to create a new kit using an existing kit as a template to speed things. So, we would first load the existing calibration kit. Then, type the new kit name in the name box and modify the parameters as needed. Finally, click Save Kit to save the kit with a new name.

In the above example, if the existing kit loaded had load data and or through data and it is required to replace this with new data, then uncheck the appropriate box and then re-check it.

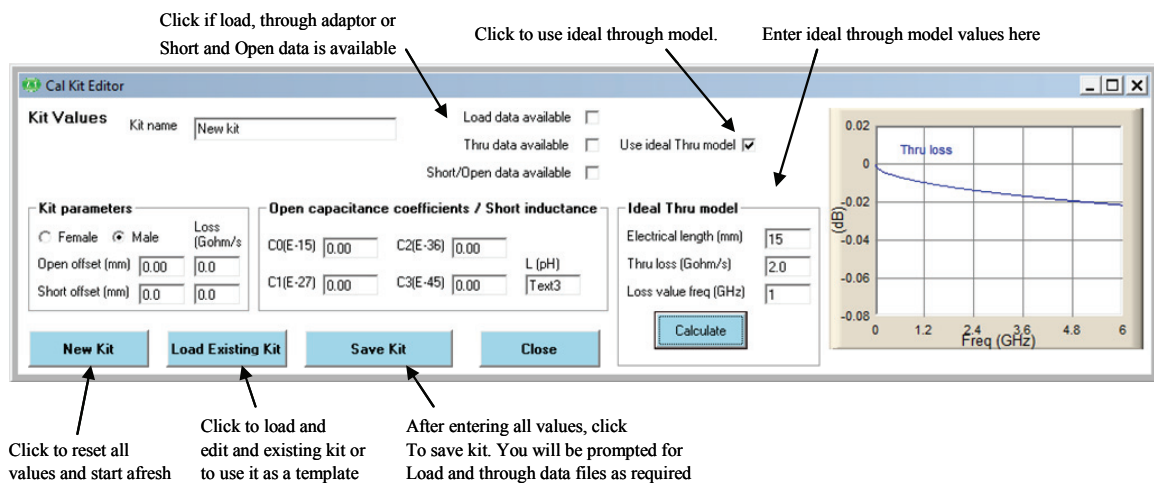


Figure 5.5 Calibration Kit Editor

The calibration kits optionally supplied with the LA19-13-04A provide an economical solution whilst retaining good measurement accuracy. They are supplied with precision 3.5mm (SMA compatible) connectors and the available kits are as follows.



Optional Calibration kits available for the LA19-13-04A

Table 5.1 Optional economy calibration kits

Female Cal Kit (DW97157)	Male Cal Kit (DW97158)
1 x 3.5mm Female Matched load	1 x 3.5mm Male Matched load
1 x 3.5mm Female Short circuit	1 x 3.5mm Male Short circuit
1 x 3.5mm Female Open circuit	1 x 3.5mm Male Open circuit
1 x 3.5mm Female to female Through adaptor	1 x 3.5mm Male to male Through adaptor
1 x Matched load data	1 x Matched load data
1 x Through adaptor data	1 x Through adaptor data
1 x Short circuit data	1 x Short circuit data
1 x Open circuit data	1 x Open circuit data

5.4.1 Using a matched termination with poor return loss or un-modelled Short and Open

A successful calibration can be carried out without the need for a good quality matched load. In order to retain accuracy, it is necessary to provide the instrument with accurate performance data of the matched load to be used. The data needs to be in a fixed format as shown in Fig. 5.6a.

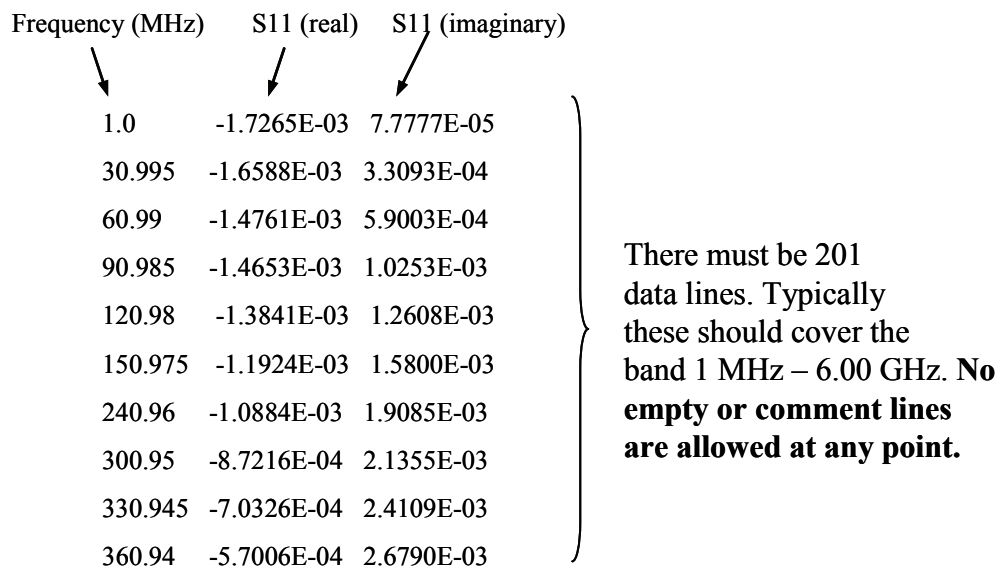


Figure 5.6a Characteristics of matched load must be in this format

In the case when the model for the Open and Short are not known, it is possible to enter measured data in the same format as shown in Fig.5.6a. This approach can give good results if the Open and Short can be measured accurately, particularly at the higher frequencies where it is usually difficult to model components accurately.

When supplied, the data for the through connection adaptor must be in the format shown below in Fig. 5.6b. The data must be a full set of S-parameters with no empty or comment lines. It is recommended that the data spans as much of the full frequency range as possible, say 1 MHz to 6000MHz.

Freq (MHz)	S11r	S11i	S21r	S21i	S12r	S12i	S22r	S22i
0.3	1.1450E-04	-1.0852E-04	9.9965E-01	-1.0394E-03	9.9947E-01	-7.4717E-04	1.0723E-04	4.9711E-05
40.3	2.9307E-04	1.9923E-04	9.9973E-01	-1.0241E-02	9.9934E-01	-1.0505E-02	2.0715E-04	2.0814E-04
80.3	4.1774E-04	4.3168E-04	9.9922E-01	-1.9672E-02	9.9927E-01	-1.9668E-02	2.8195E-04	2.8897E-04
120.3	5.3415E-04	5.7609E-04	9.9898E-01	-2.9165E-02	9.9855E-01	-2.8852E-02	4.0525E-04	2.8043E-04
160.3	7.1924E-04	6.4942E-04	9.9883E-01	-3.8214E-02	9.9846E-01	-3.8128E-02	4.0646E-04	2.8133E-04
200.3	7.8941E-04	7.5903E-04	9.9834E-01	-4.7690E-02	9.9807E-01	-4.7805E-02	5.4323E-04	2.2344E-04
240.3	9.9069E-04	7.8126E-04	9.9792E-01	-5.7033E-02	9.9758E-01	-5.7198E-02	5.7273E-04	2.9411E-04
280.3	1.0791E-03	8.0397E-04	9.9715E-01	-6.6419E-02	9.9699E-01	-6.5967E-02	5.7191E-04	2.6551E-04
320.3	1.2779E-03	8.5429E-04	9.9648E-01	-7.5557E-02	9.9625E-01	-7.5449E-02	6.3081E-04	2.9580E-04

201 frequency points

Figure 5.6b Characteristics of the through connector must be a full set of S-parameters (real and imaginary) in this format.

In order to add matched load, Short and Open, or through adaptor data to a calibration kit, follow the steps below:

- Load kit using the Kit Editor (see Fig. 5.5)
- Check the 'Load Data Available' and similarly the boxes for the Thru' and Short and Open circuits boxes on the Kit Editor parameters window.
- If existing kit already has load, Short and Open or through data, then un-check and re-check the appropriate box. **If this is not done the existing data will be kept and copied to the new kit.**
- If needed, manually enter the rest of the kit parameters. Ensure the correct offset is entered.
- Click the 'Save Kit' button
- When prompted, select the data file containing the matched load and or the through adaptor data in the format shown in Fig. 5.6
- Save the kit for future use by clicking the 'Save Kit' button (Fig. 5.5).

Note: When a kit is loaded, any available matched load or through adaptor data that is associated with the kit will be automatically loaded.

The economy calibration kits optionally supplied with the LA19-13-04A come complete with matched load, Short and Open, and through adaptor data in a CD ROM. The files should be copied to the PC's hard disk for easy access. It is critically important that the correct kit data (check serial number) is loaded.

6 OPERATION

Operation of the instrument is carried out through the User Interface (UI) window. This allows programming of the measurement parameters and plots the measurement results in real time. The UI window includes a status panel. This displays information that includes calibration status, frequency sweep step size and sweep status. Note that a copy of this manual is provided in the ‘Help’ drop down menu.

6.1 The User Interface Window

The main User Interface window is shown in Figure 6.1. This is dominated by a large graphics area where the measurement results are plotted together with the readout of the markers. A maximum of four plots can be displayed simultaneously. Each plot can be programmed to display the desired measurement.

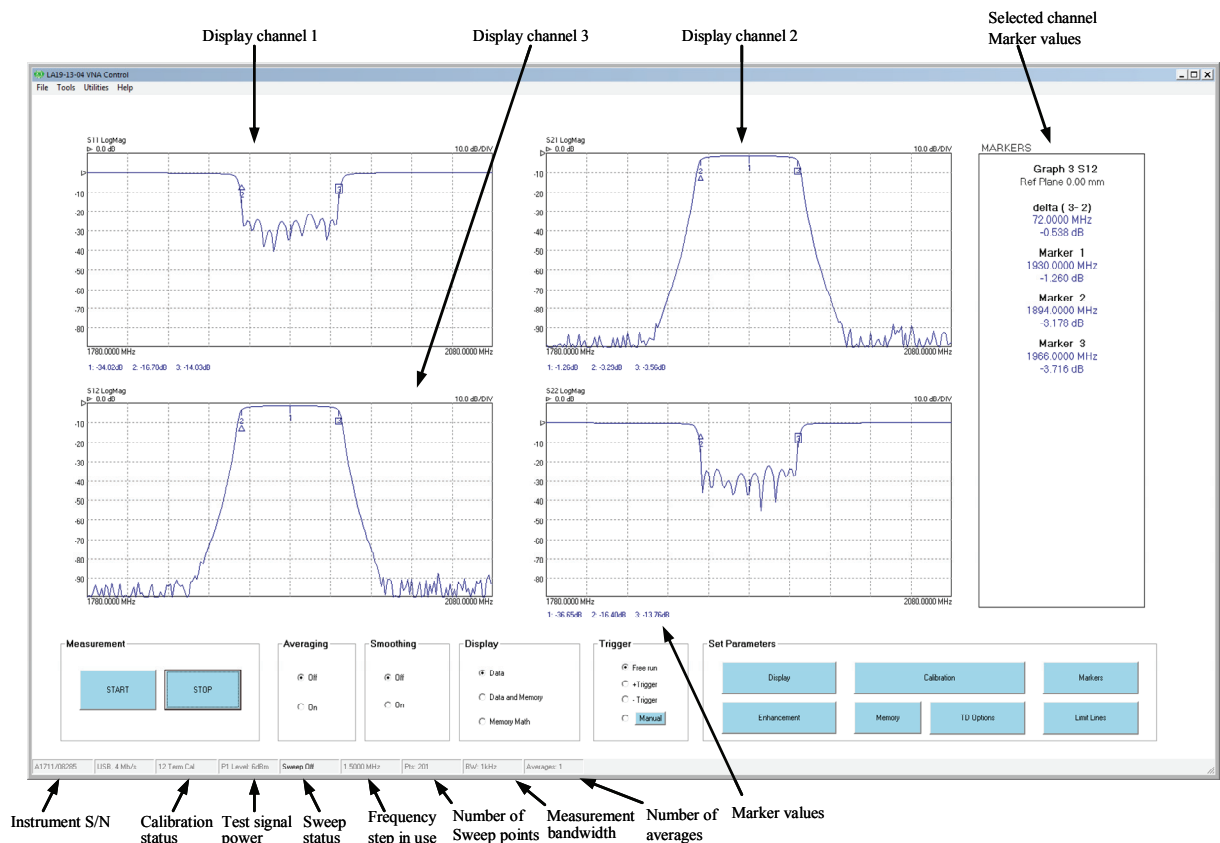


Figure 6.1 User interface window

6.1.1 Display set up

Setting up the display is carried out through the Display Set Up window which is called up from the main UI window by clicking on the Display button. The window is shown in Fig. 6.2. The typical sequence to set up the display is as follows:

- Set the number of channels to be displayed by clicking on the appropriate radio button under 'Display Channels'
- Select the desired active channel from the drop down list (can also be selected by left clicking on a marker on the desired display channel)
- Select the channel to set up by clicking on the appropriate radio button under 'Select'
- Choose the desired parameter to display on this channel from the drop down list under 'Parameter / Graph Type'
- Choose the desired graph type from the drop down list under 'Parameter / Graph Type'
- Select the vertical axis values from the 'Vertical Axis' section. If desired, the Autoscale button can be clicked to automatically set the sensitivity and reference values. Note that reference position 1 is at the top (Fig. 6.3).
- Click the Apply button to apply the selected values
- Repeat the above steps for each display needed

Note: The Active Channel selection must be one of the channels to be displayed.

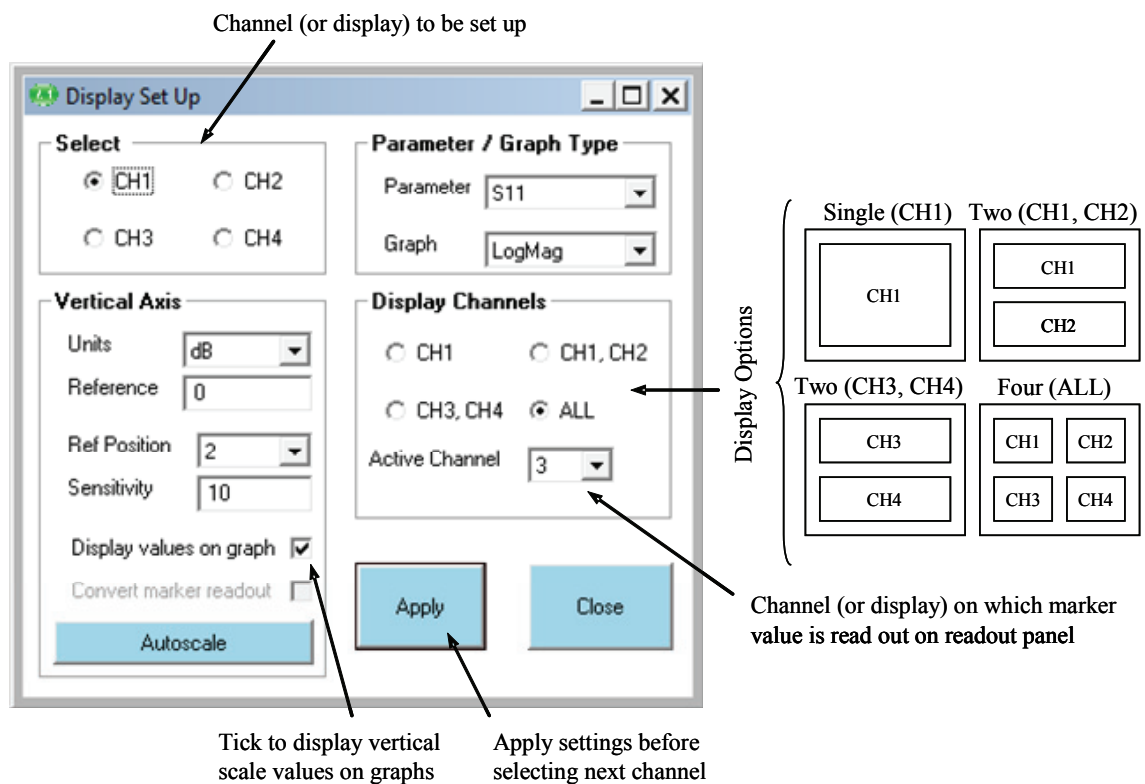


Figure 6.2 The Display Set Up window is used to set up the measurements display

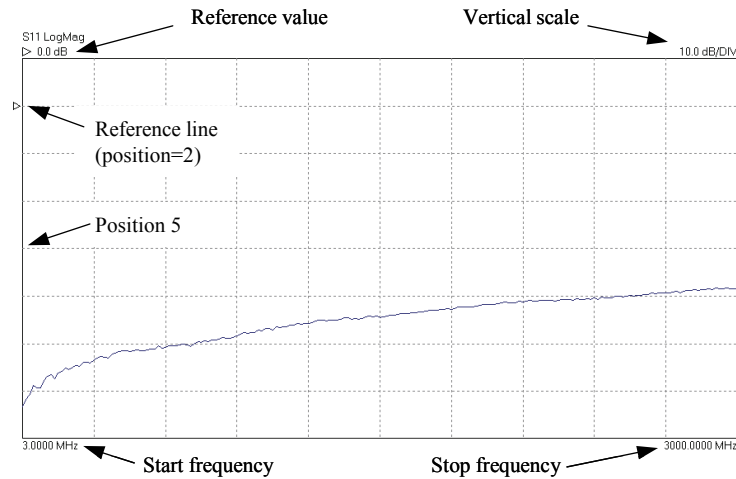


Figure 6.3 Display graph parameters

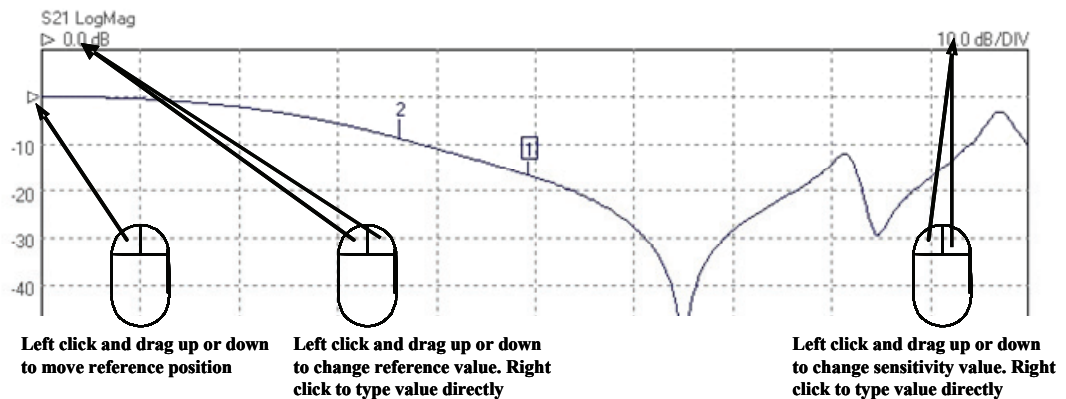


Figure 6.3a Editing graph parameters using the mouse

Figure 6.3a shows how the mouse can be used to quickly adjust the graph parameters: Reference position, reference value and vertical scale sensitivity.

The **colours** of the main graphics display as well as the command buttons can be changed to suit individual preferences. This can be done by selecting the 'Colour Scheme' item from the 'Tools' drop down menu. To set a colour, click on the preview box next to the item name. Almost all item colours can be modified, including the command buttons and its colour when in active state (Highlight Button).

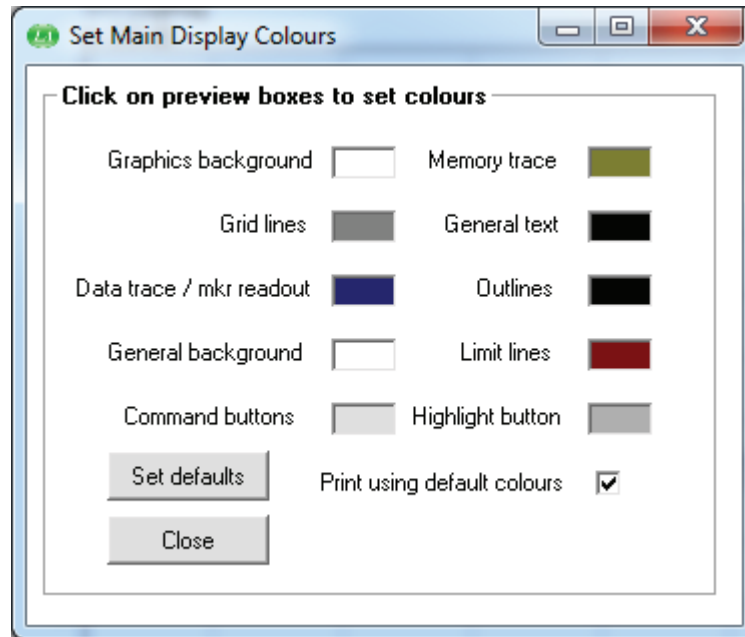


Figure 6.3b The colour scheme adjustment tool is in the Tools drop down menu

6.1.2 Data markers

It is possible to display up to 8 markers on each display. They are set up by clicking on the 'Markers' button (Fig. 6.4). There are four possible marker modes as follows.

Active marker: The active marker is the marker used for comparison when the delta marker mode (switched on by selecting a reference marker) is on. One of the displayed markers must be chosen as the active marker.

Reference marker: The reference marker causes the delta marker mode to be switched on. The value difference between the active marker and the reference markers is shown on the right hand marker display panel.

Fixed marker: A fixed marker cannot be moved and its position is not updated with subsequent measurement values. It provide a fixed reference point. Only a reference marker can be made a fixed marker. Once a marker is fixed, it cannot be moved until it is unfixed.

Normal marker: The value of a normal marker is displayed on the right-hand marker readout panel.

Any marker (except a fixed marker) can be moved to a new position by left clicking on it (on any displayed channel) and dragging it to a new position.

The markers set up form provides a **Peak / Minimum Search** facility. This places marker 1 at either the peak or minimum value on the displayed trace on the active channel when the corresponding Find button is pressed.

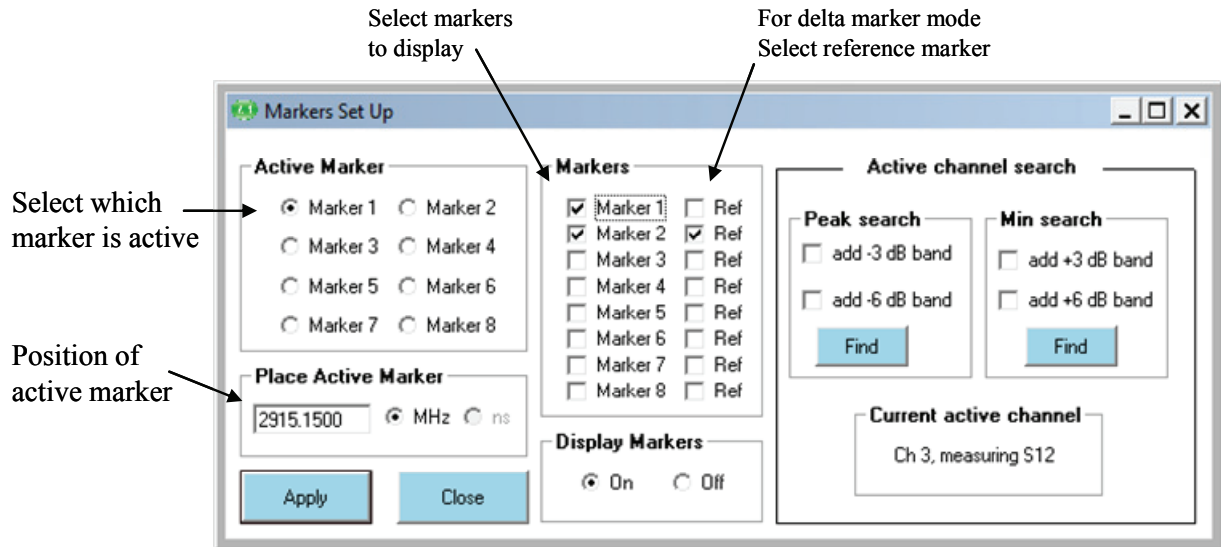


Figure 6.4 The Markers Set Up form is used to display measurement markers

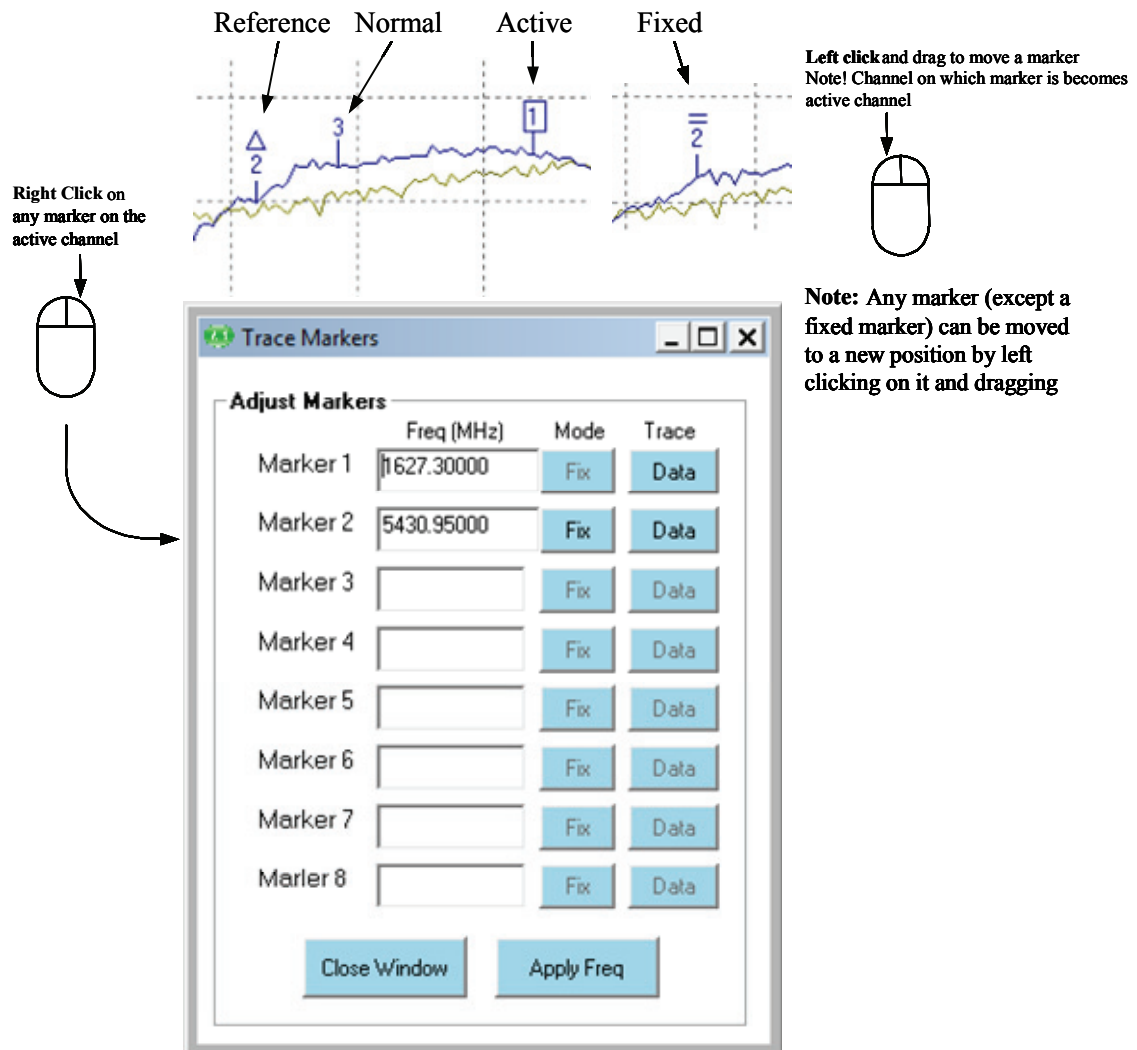


Figure 6.5 The marker type can be changed by right clicking on any marker on the active channel. Note that only the reference marker can be fixed

The peak / minimum search facility provides a means of placing additional markers to indicate the **3 or 6 dB bandwidth**. If either the 3 dB or 6 dB band box are selected, then clicking the Find button will place markers 2 and 3 on the frequency points either side of marker 1 which are 3 dB or 6 dB relative to it. Note that for best accuracy a sufficient number of sweep points should be used. This will ensure a fine enough resolution to allow accurate determination of the band points.

6.1.3 Measurement enhancement

The measurement enhancement options are displayed (Fig. 6.6) by clicking on the 'Enhancement' button on the main UI window. The options available are as follows.

- Averages (1 to 255, on a point by point basis)
- Trace Smoothing (0 to 10%)
- Bandwidth (140KHz to 10Hz)
- Port 1 Level (+6 dBm to -20 dBm, 0.1 dB resolution)
- CW sweep time per point (500 to 65,000 μ s/point)
- Reference Plane Extension (manual entry or automatic)

- Effective dielectric constant of device under test (manual entry to correct plane extension values)
- De-embedding (specify embedding networks at ports 1 and or 2)
- Impedance conversion for devices which are not 50Ω

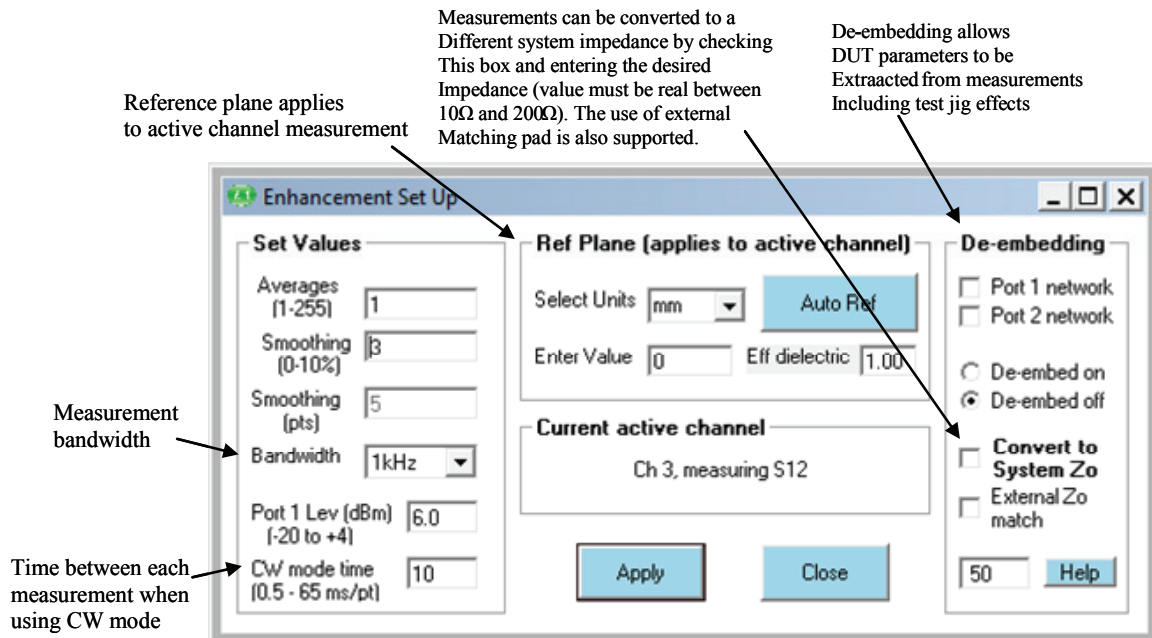


Figure 6.6 The measurement enhancement window

The **Bandwidth** setting refers to the receiver bandwidth. Maximum sweep speed is achieved with the highest (140kHz) setting. On the other hand, the widest dynamic range (lowest noise floor) is achieved with the lowest value, 10 Hz. Note that the bandwidth setting used during calibration determines the maximum dynamic range achievable during measurements. So, consider this when carrying out a calibration. For example, if you need to carry out measurement over more than, say 90 dB dynamic range, then use a 500Hz or less bandwidth setting when calibrating.

The **Port 1 Level** sets the test signal level. The default value is -3 dBm as this gives best overall measurement accuracy. However, it may be necessary, particularly when measuring active devices (e.g. amplifiers) to reduce the test level. For maximum dynamic range, then use the highest power setting. For best measurement accuracy it is recommended that the calibration is carried out at the same test level as it is intended to use for the measurement. Whenever the test level is different to that used for the calibration, a '?' will be added to the calibration status indicator on the Status Panel (Fig. 6.1)

The **Reference Plane** facility allows the reference plane of each parameter measurement to be arbitrarily moved away from the calibration plane. The value entered applies to the measurement parameter (S11, S21, S12 or S22) displayed on the active channel. Note that the same plane value will be used for all other measurements on that same parameter regardless if they are on the active channel or not.

The **Auto Reference** automatically moves the reference plane. It uses the measurement on the active channel. This feature is particularly useful, for example, when measuring microstrip devices and it is necessary to remove the effect of the connecting input and output lines. It takes the effective dielectric constant value entered to correct the displayed value. Refer to Section 6.4 for more details.

Note: The reference plane must be at 0 mm for the Auto Ref function to work correctly. Also, Enhancement window changes only take place when the instrument is sweeping.

The **Effective Dielectric** of the device under test can be entered so that the displayed Reference Plane extension values (shown on the Enhancement Window) are corrected accordingly when the Auto Ref button is clicked. The default value is 1.0 and the maximum value allowed is 50.0.

Note: The reference plane extension value shown on the main display window (see Fig. 6.1) on the markers display panel on the right, is the reference plane extension as shown on the Enhancement window.

The **de-embedding** facility is explained in detail in section 6.4.

The **System Zo Conversion** facility allows measurements, which are always taken in 50Ω , to be converted to another impedance selected by the user. This feature can be useful, for example, for measuring 75Ω devices. The value of Z_o entered must be real (purely resistive) and must be within the range of 10Ω to 200Ω . Whenever this facility is selected, an indicator is displayed on the top right corner of the graphics display as shown in Fig. 6.6b. **Note** that when requested, impedance conversion will be performed on the **live measurement** and any stored **memory trace**.

There are two possible ways of using the **System Zo Conversion** facility. For example, 75Ω devices can be measured using the techniques illustrated in Fig.6.6a.

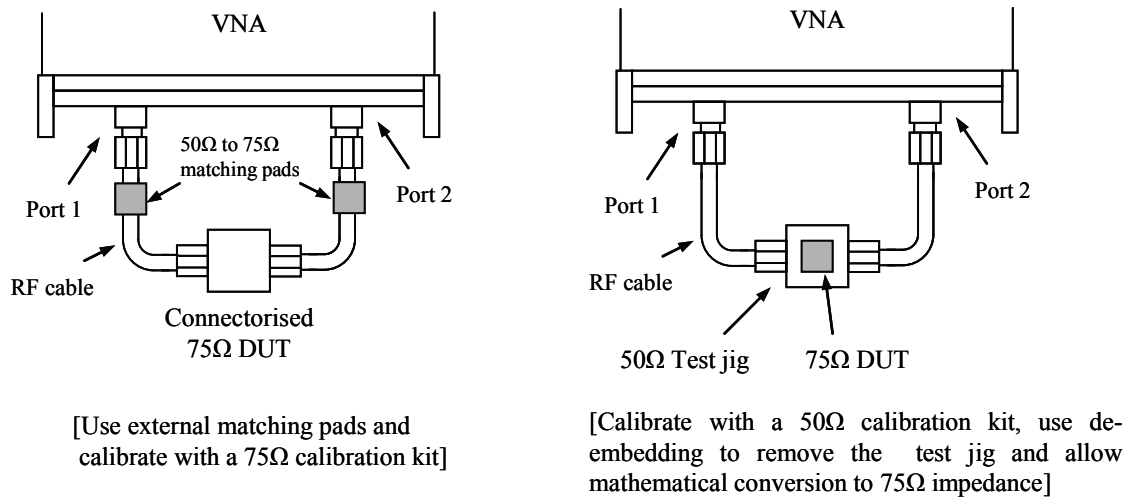


Figure 6.6a Possible techniques for measuring 75 Ω devices. Impedance matching pads can be used to measure a connectorised device. A discrete device mounted on a 50Ω test jig is somewhat simpler to measure.

The steps necessary for each of the two techniques illustrated in Fig. 6.6a, are as follows:

75Ω Device with Connectors

- (i) Connect **50Ω to 75Ω impedance matching networks** (e.g. matching pads) at the ends of the cables connected to ports 1 and 2.
- (ii) In the Enhancement window, **check** the box 'Convert System Zo'
- (iii) Check **External Zo match** to indicate external matching networks in use
- (iv) Enter **75** in the Convert System Zo value box and click **Apply**
- (v) Proceed to calibrate using a **75Ω calibration kit**
- (vi) Connect the DUT and **start the measurement**

75Ω Device mounted on 50Ω Test Jig

- (i) In the Enhancement window, **uncheck** the box 'Convert System Zo'
- (ii) Calibrate at the ends of the test cables using a **50Ω calibration kit**
- (iii) **Apply de-embedding** to remove test jig effects. See section 5.4 for some suggestions.
- (iv) In the Enhancement window, **check** the box 'Convert System Zo'
- (v) **Uncheck External Zo match** box (in this case mathematical impedance conversion is done by the software)
- (vi) Enter **75** in the Convert System Zo value box and click **Apply**
- (vii) Connect the DUT and **start the measurement**

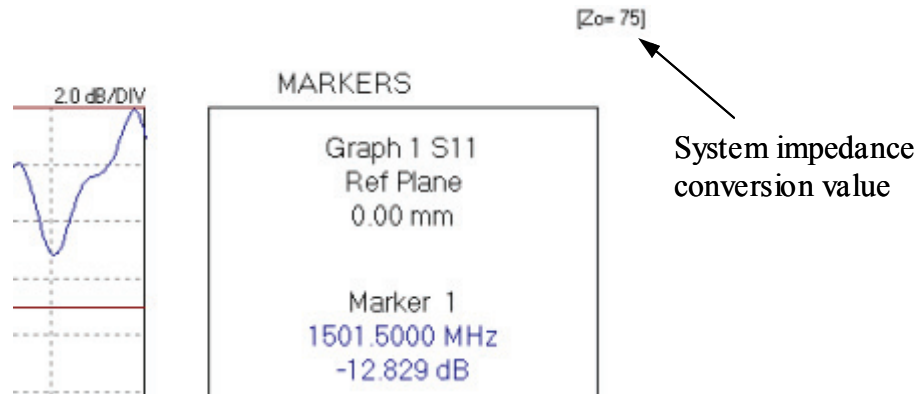


Figure 6.6b System impedance chosen is displayed on the top right corner

Note: S-parameters are inter-related, so, when using the Z_o conversion facility (and no external impedance matching networks) without a full set of S-parameters available (e.g. only an S11 calibration) the program will assume values for the unavailable parameters as shown in Table 5.1. A warning will be displayed in such cases

Table 6.1. Values assumed for parameters not available during Z_o conversion

S11	S12	S21	S22
$10^{-6}, j0.0$	$10^{-6}, j0.0$	$10^{-6}, j0.0$	$10^{-6}, j0.0$

6.1.4 Memory facility

The current displayed data on each channel can be stored in memory. Also, each channel can be stored independently of all others. The Memory Set Up window is used to store the data and this window can be displayed by clicking on the ‘Memory’ button on the main window.

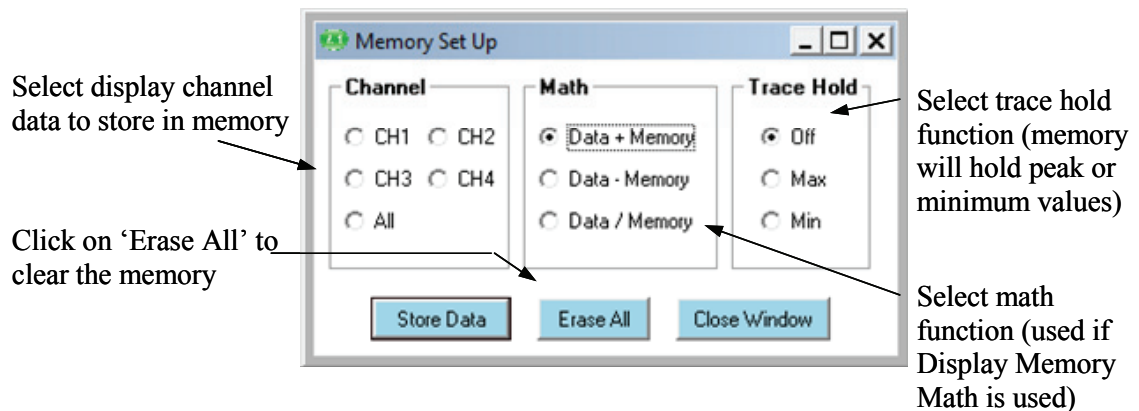


Figure 6.7 The Memory Set Up window is used to store data into memory

Once the data is stored, it can be displayed by clicking on the ‘Display Data and Memory’ radio button on the main User Interface window.

There are three vector math functions available: sum, subtraction and division. The selected function is used when the user selects the 'Display Memory Math' function on the main window.

The trace hold is used to store the maximum or minimum values on the memory trace. Trace hold is **not** available when group delay is displayed.

6.1.5 Limit Lines facility

The Limit Lines facility allows six segments to be defined for each displayed graph. By taking advantage of the overlapping capability (see below) a maximum of 11 segments can be created. The set up window, shown in Fig. 5.8, is displayed by clicking on the 'Limit Lines' button on the main window.

Overlapping Segments

All valid segments entered are loaded in sequence (i.e. segment 1 first) with the each segment loaded having priority over the previous segment. This feature allows overlapping segments to be loaded. For example, if segment 1 is specified to cover, say, 400 to 800 MHz, then a second segment can be specified to a section of this band, for example, 500 to 600 MHz. This would result in a total of three segments even though only two were specified. That is, 400 to 500, 500 to 600 and 600 to 800 MHz. An example of a complex, 11 segments template is shown in Fig. 5.8a.

Alarm

An alarm facility is provided with the limit lines. This provides audible warning during a sweep if any measurement exceeds the limits set. A visible indication of the last measurement and measurement channel in error is provided on the status panel where normally the calibration type is displayed. In addition a symbol is drawn on the trace indicating the last error point detected as shown in Fig. 6.8b. The alarm is available for all graph types except Smith plots.

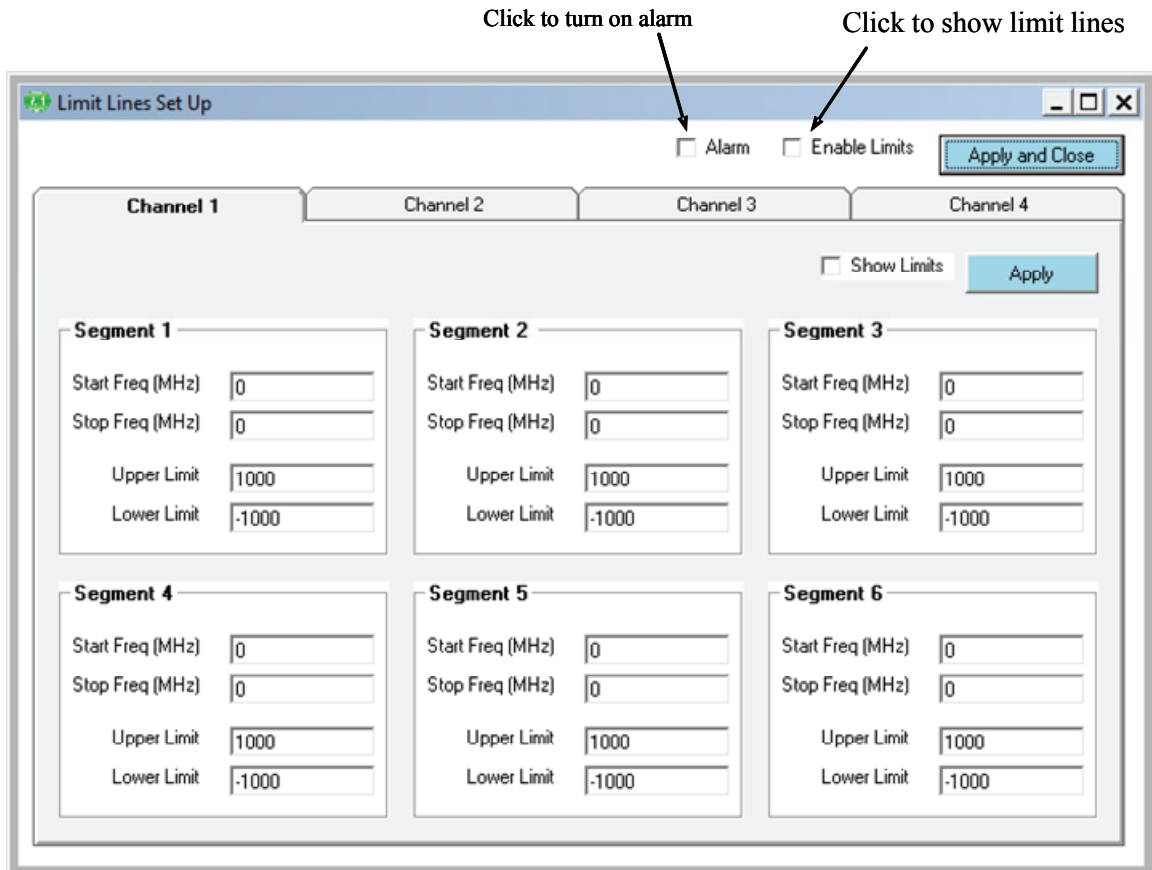


Figure 6.8 The Limit Lines Set Up allows at least six segments per graph

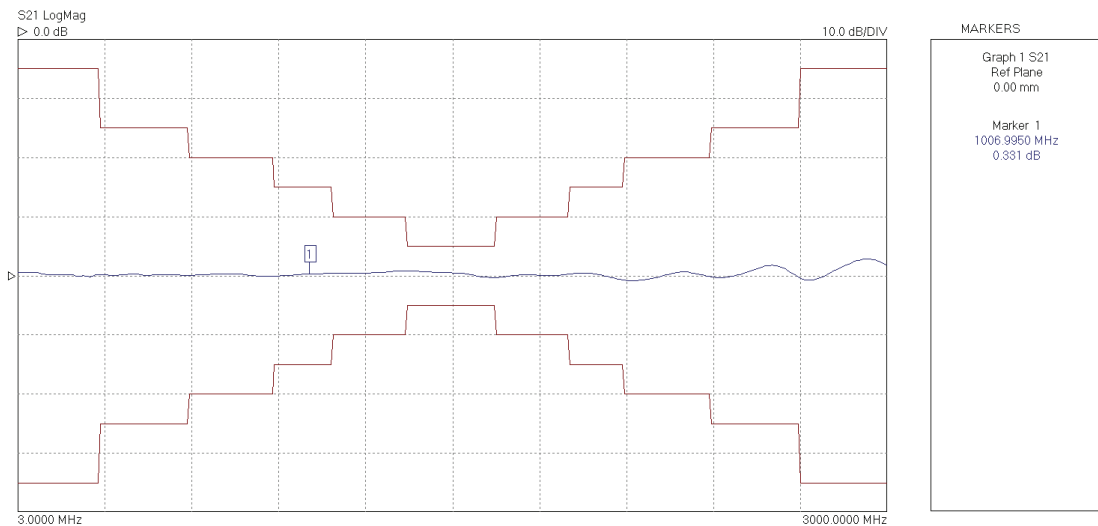


Figure 6.8a Complex Limit Lines templates are possible by overlapping segments

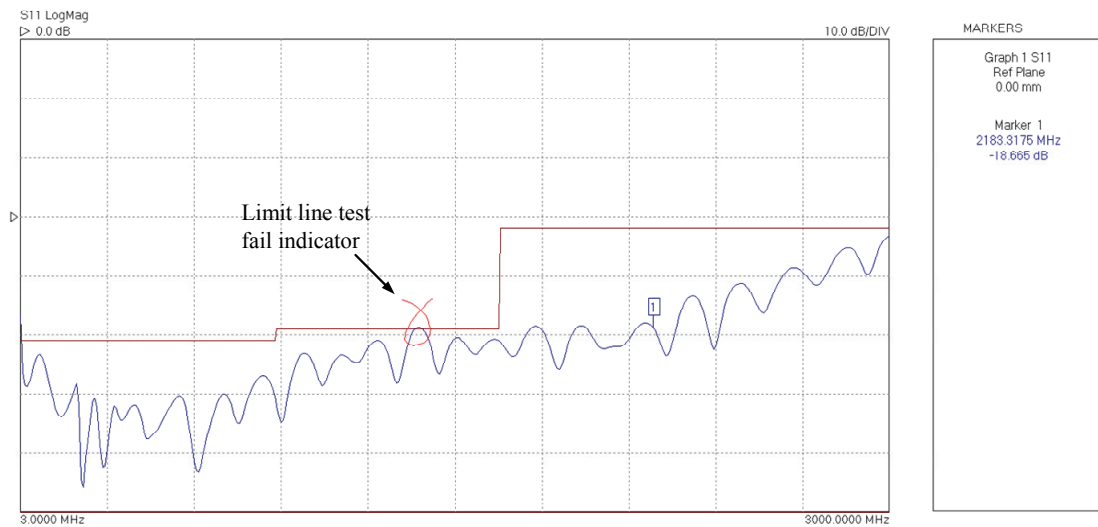


Figure 6.8b Limit Lines failure graphical visual indicator

6.1.6 Status panel

The status panel on the main window, see Fig. 6.1, provides useful information to the user. The information is as follows:

- **Instrument serial number**
- **Calibration status** (S11, S21, S11 + S21, 12 terms or U/T). A question mark indicates that the test power has been changed from that used for calibration
- **Test signal power.** This is the Port 1 signal level
- **Sweep status.** Indicates whether instrument is sweeping
- **Frequency step.** Step size of sweep
- **Sweep points.** Number of points in programmed sweep
- **Limit Lines alarm** if any measurement exceed the set limits (temporarily replaces Calibration Status)
- **Internal temperature.**

6.1.7 Triggered sweep

It is possible to synchronise each measurement sweep to an external trigger. Simply select the appropriate radio button on the main panel (See Fig. 6.9) and ensure a trigger signal is connected to the instrument's rear panel Trigger terminal.

The instrument supports either positive or negative edge trigger depending on the radio button selected on the main panel. The input resistance is 10 k Ω .

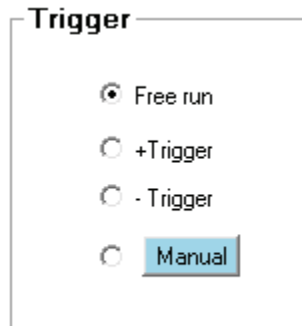


Figure 6.9 Trigger selection radio button on main panel

When the 'manual' trigger option is selected, the instrument will wait until the button 'Manual' is pressed before carrying out a sweep.

6.1.8 Sweep trigger output

The rear panel Trigger output terminal provides a 3V logic output with the rising edge synchronised to the start of the measurement sweep. The signal goes to 0V at the end of the sweep. The output resistance of this is approximately 500 Ω .

6.1.9 Measurement Start / Stop

The measurement Start / Stop buttons (see Fig.6.9a) are used to start or stop the instrument's sweep mode (measurement mode). This is necessary as functions which require re-programming the instrument can only take place when the instrument is idling. The instrument status is shown in the Status Panel as described in the previous section.

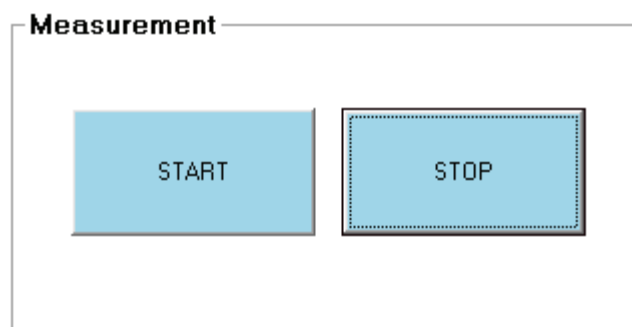


Figure 6.9a The Start / Stop Measurement buttons control the sweep status

Note that when the sweep is stopped, the test signal frequency will be held at the frequency point at the time the stop command is received by the instrument. In the case of triggered sweep, by default, at the end of the sweep, the frequency is held at the last frequency point until the next sweep trigger event is received. This can be changed using the menu found in Tools > Diagnostics.

6.1.10 PC data link interruption

It may be possible that the data flow between the VNA and its controlling PC is interrupted by external factors. In this case, if the UI software cannot restore the link, a message similar to that shown in Fig. 6.10 will be displayed. In such a case, the UI software should be re-started using the selection in the drop-down menu under 'Tools' and the the VNA should be reset (use button on the back panel) when prompted to do so. Wait until the front panel lights have stopped flashing before clicking OK to complete the software re-start. The instrument should be re-calibrated.



If the data link is interrupted reset the VNA (red button on rear panel) and re-start the UI software ('Tools' menu)

Figure 6.10 Warning message when the link with the PC is interrupted

A 'No Response' message should rarely be encountered. If it happens often, check that the PC is not running other applications or that the VNA software is running as a background task when the sweep is on.

6.2 Calibration

The instrument must be calibrated before any measurements can be carried out. This is done by loading a previous calibration (see File menu) or carrying a fresh calibration by clicking on the Calibration button on the main window, which brings up the Calibration window shown in Fig. 6.11.

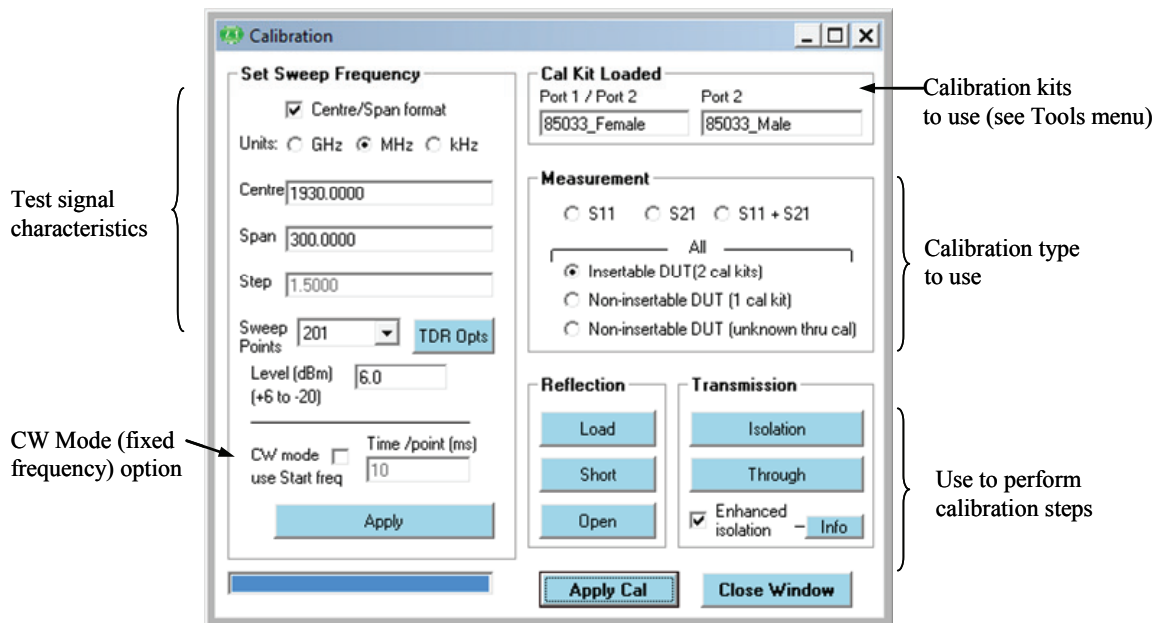


Figure 6.11 Instrument calibration is carried out through the Calibration window. Before starting calibration select the preferred enhancement settings (bandwidth and averages)

Note: The frequency sweep is set by entering the start, stop and selecting the number of sweep points. Alternatively, by entering the centre frequency and span after clicking on the Centre/Span format option box.

Table 6.1 summarises the calibration types available together with the Standards required to complete the calibration. For best overall accuracy, particularly when measuring low isolation devices with poor Return loss values, a 12-term calibration should be performed.

Table 6.1 Calibration types supported

	S11	S21	S11 + S21	12 Terms (insertable DUT)	12 Terms or 8 Terms (non-insertable DUT)
Minimum calibration Standards required	<ul style="list-style-type: none"> Matched load Open Short 	<ul style="list-style-type: none"> Through connection Termination (see text) 	<ul style="list-style-type: none"> Matched load Open Short Through connection 	<ul style="list-style-type: none"> Matched load (x 2) Open (x 2) Short (x 2) Through cable 	<ul style="list-style-type: none"> Matched load (x 1) Open (x 1) Short (x 1) Through adaptor* (x 1) Through cable
Measurement capability	<ul style="list-style-type: none"> S11 using 3-term error correction 	<ul style="list-style-type: none"> Frequency response with isolation correction 	<ul style="list-style-type: none"> S11 using 3-term error correction Frequency response with isolation and source match correction 	<ul style="list-style-type: none"> S11, S21, S12, S22 using 12-term error correction 	<ul style="list-style-type: none"> S11, S21, S12, S22 using 12-term error correction

*The unknown through calibration (8 error terms) requires only a reciprocal through adaptor

The basic calibration sequence is shown as a flowchart in Fig. 5.12.

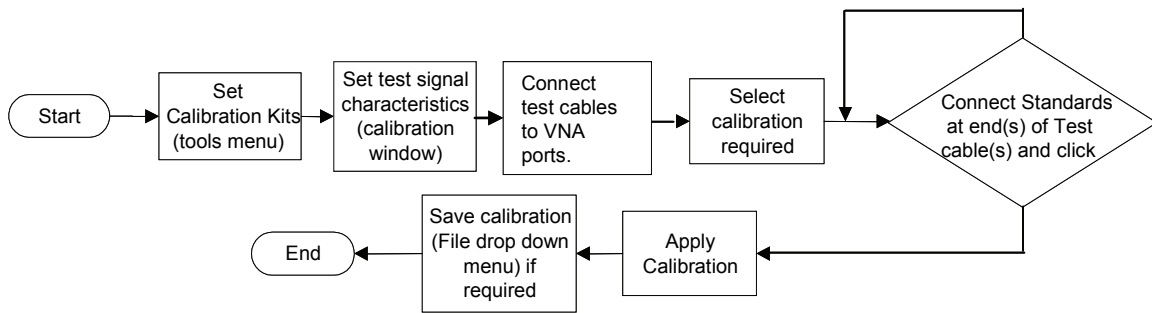


Figure 6.12 Instrument calibration sequence

The calibration process involves connecting each Standard in turn and clicking. An asterisk will appear once it has been measured so that the next Standard can be done.

Note: For best results, ensure that the instrument is fully warmed up before carrying out a calibration.

Calibration for Measuring Non-Insertable Devices

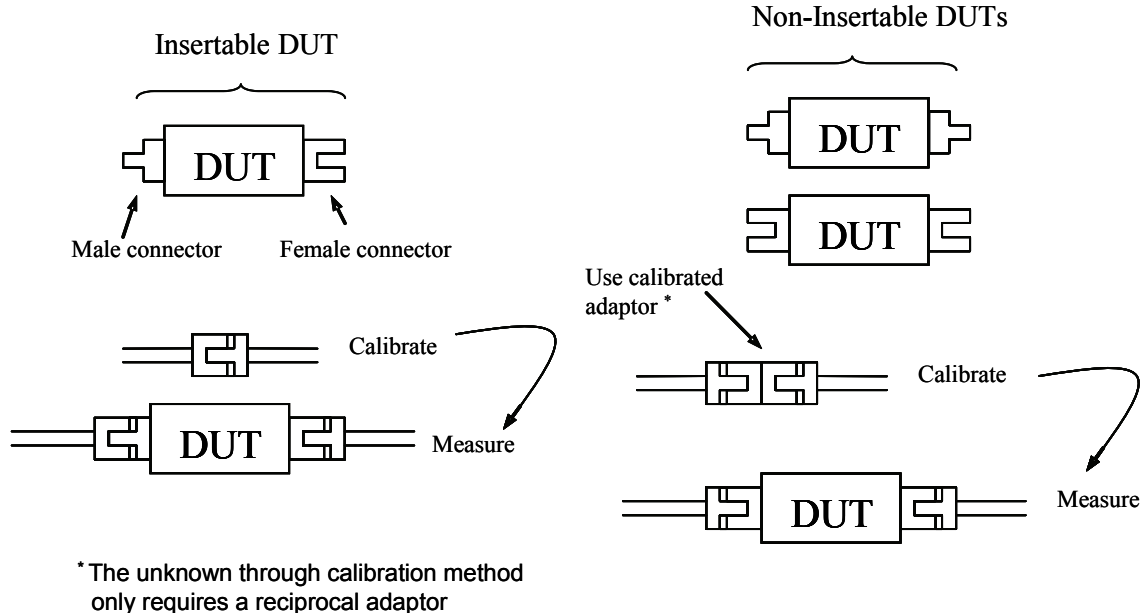


Figure 6.13 Insertable and non-insertable DUTs

It is important to be aware of the difference between ‘insertable’ and ‘non-insertable’ devices and the impact on measurement and calibration technique. Figure 6.13 illustrates the difference between an insertable device and non-insertable devices. The key issue is that with non-insertable devices an adaptor may be required during the measurement as shown. In order to obtain accurate measurement data, the effect of

the adaptor needs to be removed from the measurements. Some of the possible ways of doing this with the LA19-13-04A VNA are as follows:

Table 6.2: Techniques for dealing with non-insertable DUTs

Calibration Used	Adaptor Removal Method	Comments
(A) 12-Term (non-insertable DUT)	Calibration removes adaptor effect	Accurate but requires kit with through adaptor Standard. Only one calibration kit is required.
(B) 8-Term (unknown through method)	Calibration automatically removes adaptor effect	Accurate and easiest method as it does not require a characterised thru' Standard
(C) Any except 12-Term or 8-Term	De-embedding	Accurate but requires prior knowledge of adaptor characteristics
(D) Any except 12-Term or 8-Term	Reference plane extension	Quick and easy but errors due to loss of adaptor remain

The preferred method is method (B) shown in Table 6.2. This requires only a reciprocal through adaptor. **Note** that with this method the **isolation calibration** is done automatically by the software using measurements taken during the Short, Open and Load steps.

Note that only the 12-term non-insertable DUT calibration and 8-term unknown thru' methods support a non-zero length through connection. All other calibrations (S21 or S11+S21 or full 12-term insertable DUT) require a through connection of zero length. In effect, this means that the calibration port terminals should be of opposite sexes. In other words, it should be possible to connect the terminals together without the use of an adaptor. Consequently, the DUT must be an **insertable** device. If this is not the case, an adaptor will be needed during the measurement and its effect will need to be removed by either moving the reference plane or by using the de-embedding facility as indicated in Table 6.2.

When performing just an S21 calibration it is possible to complete the calibration without doing the Isolation calibration. Simply click on the 'Apply Cal' button after performing the 'Through' calibration. The isolation calibration corrects errors due to crosstalk (see section 4.6) and should be carried out when measuring insertion loss values less than, say 40 dB. The terminations to use during the isolation calibration can, as a guide, be 50 Ω loads. In some circumstances, such as when testing a highly reactive device (e.g. filter beyond cut-off), a short or an open circuit may be more appropriate or for best results two actual DUTs with 50 Ω loads at their unused ports.

6.2.1 Changing the Frequency Sweep Settings without Re-Calibrating

If the start or stop frequency or number of sweep points is changed when the instrument has a valid calibration, the user is given the choice to either keep or delete the existing calibration. If the user chooses to keep the calibration, a new set of calibration error terms will be automatically generated by **interpolation** to fit in with the new sweep parameters. In this case, a “?” is added to the calibration status bar to indicate that operating parameters have changed from those used in calibration.

If it is required to change the frequency sweep parameters without re-calibrating, then simply enter the new values (see Set Sweep Frequency values in Fig. 6.11) and click Apply. Once the new values are sent to the instrument, just close the window (Close Window in Fig. 6.11) to exit. Note that this process will **delete all memory traces** and the display data may be invalid until a fresh measurement sweep is performed.

Some care needs to be exercised when using interpolation, particularly at low frequencies, say below 20MHz. For example, if starting with a wide band sweep with large frequency steps, say 500kHz or larger, then interpolating down to a narrow band of, for example, 1 MHz to 10 MHz may lead to larger than expected errors.

6.2.2 Calibration steps for S11 measurements

The calibration for S11 measurements performs a three term error correction calibration. Note that if the device to be tested has a female connector, then a female calibration kit should be used for best results. The typical steps are as follows:

1. Select the calibration kit (Tools > Calibration kit > Load P1 kit > Apply)
2. Set the bandwidth and test power (Enhancement button)
3. Set the frequency range and measurement steps (Calibration button)
4. Select S11 calibration (in Calibration window)
5. Connect adaptor and test cable to port 1 of the instrument
6. Connect each Standard in turn and click on appropriate Standard button (in Calibration window)
7. When all 3 Standards are done click on the Apply button (in Calibration window)
8. If desired, for later use, save calibration (File > save cal)
9. Connect device to be tested and click on the Start button

Tips:

- For best linearity and dynamic range combination use a test power level of 0dBm
- For best accuracy calibrate using the same bandwidth you intend to use for your measurements
- You can re-measure any Standard at any stage before completing the calibration, just re-connect the Standard and click again on the appropriate Standard button prior to completing the calibration

6.2.3 Calibration steps for S21 measurements

The simple S21 calibration is a frequency response calibration. Sometimes it is referred to as normalisation and only corrects for response characteristics of instrument and external connections. The typical steps are as follows:

1. Set the bandwidth and test power (Enhancement button)
2. Set the frequency range and measurement steps (Calibration button)
3. Select S21 calibration (in Calibration window)
4. Connect adaptors and test cable2 to port 1 of the instrument
5. Connect ends of test cable together (the 'through' connection) and select Through (in Calibration window)
6. Connect 50 Ω load to the ends of test cables (to perform the isolation step) and select Isolation (in Calibration window)
7. Click on the Apply button (in Calibration window)
8. If desired, for later use, save calibration (File > save cal)
9. Connect device to be tested and click on the Start button

Tips:

- For best dynamic range use a test power level of +6dBm and calibrate using the same bandwidth you intend to use for your measurements
- For best accuracy (linearity) use a test power level of -3dBm and calibrate using the same bandwidth you intend to use for your measurements

6.2.4 Calibration steps for S11 and S21 measurements

The 'S11 + S21' calibration provides three term error correction for S11 measurements and Source match correction for S21 measurements. The typical steps are as follows:

1. Select the calibration kit (Tools > Calibration kit > Load P1 kit > Apply)
2. Set the bandwidth and test power (Enhancement button)
3. Set the frequency range and measurement steps (Calibration button)
4. Select 'S11 + S21' calibration (in Calibration window)
5. Connect each Standard (Short, Open and Load) in turn and click on appropriate Standard button (in Calibration window)
6. Connect ends of test cables together and click on 'Through'
7. Connect 50 Ω load to the ends of test cables (to perform the isolation step) and select Isolation (in Calibration window)
8. Click on the Apply button (in Calibration window)
9. If desired, for later use, save calibration (File > save cal)
10. Connect device to be tested and click on the Start button

Tips:

- For best linearity and dynamic range combination use a test power level of 0dBm
- For best dynamic range use a test power level of +6dBm and calibrate using the same bandwidth you intend to use for your measurements – particularly at the Isolation calibration step

6.2.5 Calibration steps for all s-parameters measurements (insertable DUT)

This calibration provides full error correction for all S-parameters. Typical steps are as follows:

1. Select the calibration kits (Tools > Calibration kits > Load P1 Kit > Load P2 Kit >Apply)
2. Set the bandwidth and test power (Enhancement button)
3. Set the frequency range and measurement steps (Calibration button)
4. Select 'All –Insertable DUT' calibration (in Calibration window)
5. Connect each Standard (Short, Open and Load) in turn and click on appropriate Standard button (in Calibration window)
6. Click on Isolation and select the first method on the left (isolation is measured with 50Ω loads on each calibration port which is the same as the Load step in 5 above)
7. Connect ends of test cables together and click on 'Through'
8. Click on the Apply button (in Calibration window)
9. If desired, for later use, save calibration (File > save cal)
10. Connect device to be tested and click on the Start button

Tips:

- (i) For best linearity and dynamic range combination use a test power level of +0dBm. Use the same bandwidth as you will use during measurements
- (ii) For best dynamic range use a test power level of +6dBm and calibrate using the same bandwidth you intend to use for your measurements

6.2.6 Calibration steps for all s-parameters measurements (non-insertable DUT)

This calibration provides full error correction for all S-parameters. It requires a calibration kit with a characterised through connection. Typical steps are as follows:

11. Select the calibration kit (Tools > Calibration kits > Load P1 Kit > Apply)
12. Set the bandwidth and test power (Enhancement button)
13. Set the frequency range and measurement steps (Calibration button)
14. Select 'All – Non-insertable DUT' calibration (in Calibration window)

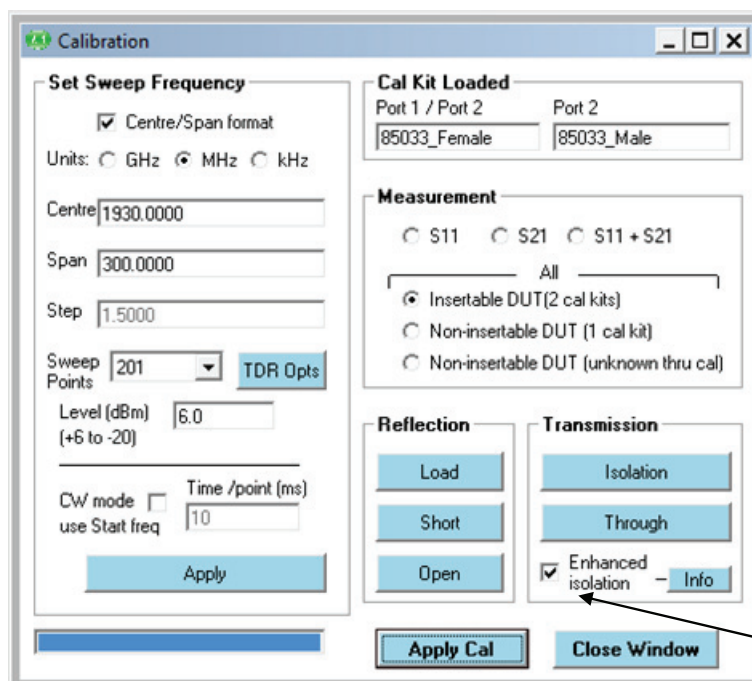
15. Connect each reflection Standard (Short/Open) in turn and click on appropriate Standard button (in Calibration window)
16. Click on Load to measure the Load Standard (in Calibration window)
17. Connect ends of test cables together using the characterised through included in the calibration kit and click on 'Through'
18. Click on the Apply button (in Calibration window)
19. If desired, for later use, save calibration (File > save cal)
20. Connect device to be tested and click on the Start button

6.2.7 Calibration for best dynamic range – minimising the effect of crosstalk

Instrument crosstalk is a limiting factor when making large dynamic range measurement. This is particularly the case at higher frequencies, say above 4 GHz. The reason is that some of the crosstalk is dependent on the loading at the test ports. Therefore, the isolation calibration process can only compensate it fully when the terminations are left unchanged from that used at the isolation calibration step.

Enhanced isolation calibration

The LA19-13-04A provides an enhanced isolation calibration option. This method makes crosstalk measurements at the Short, Open and Load calibration steps. In this way it attempts to more closely model the effect of port termination on the internal crosstalk components of the instrument.



The enhanced isolation Calibration option

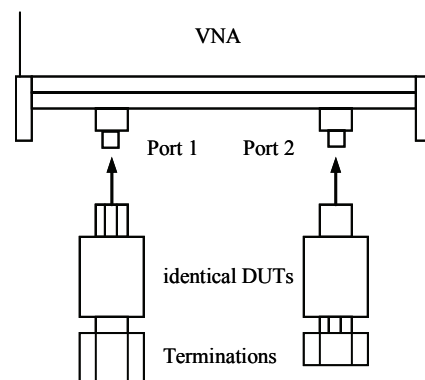
Figure 6.14 The enhanced isolation calibration helps to model the crosstalk more accurately

It is important to note that for best dynamic range, when using the enhanced isolation calibration method, each of the Short, Open and Load steps need to be made at the same or lower resolution bandwidth that will be used for the measurement. So, for the

ultimate range, each calibration step will need to be done using 10 Hz bandwidth. This is the downside of the enhanced isolation calibration (slower overall calibration process) compared to traditional isolation calibration, where only the isolation step need be taken at the lowest bandwidth setting.

Achieving the ultimate dynamic range using conventional isolation calibration

In cases when two identical DUTs are available, the ultimate dynamic range can be achieved using a conventional crosstalk (isolation) calibration step as shown in Fig. 6.15. In this approach the correct termination is presented at each port during the crosstalk calibration step. In this way its effect can be removed accurately over the entire measurement band. Note that when using this technique, only the isolation step need to be performed at the lowest resolution bandwidth. The other calibration steps can be performed at higher bandwidth settings to speed up the process.



Note: connecting cables not shown

Figure 6.15 If two identical DUTs are available, a conventional isolation calibration step can be carried out as shown

6.3 Measurements

6.3.1 Return loss

In order to carry out return loss measurements (S_{11}) the VNA must be calibrated as described before, either S_{11} calibration only, both S_{11} and S_{21} or 12-term. The device to be tested (DUT) is then connected to Port 1 of the VNA as indicated in Fig. 6.16. If the DUT can only be connected to the VNA using a cable, then the VNA should be calibrated at the end of the cable for best results.

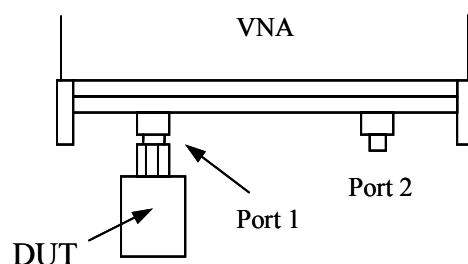


Figure 6.16 Connect device under test to Port 1 to carry out S_{11} measurements.
Note: any test cable used is not shown

Displaying the results

The measurement result can be displayed by selecting the S_{11} parameter and an appropriate display graph as described in Section 6.1.1. Note that the measured phase is relative to the calibration reference plane as discussed in Section 6.4. The reference plane can be shifted at any time from the 'Enhancement' window. Note that changes to the reference plane only take place when the instrument is sweeping.

6.3.2 Insertion loss / gain

To carry out insertion loss measurements (S_{21}) the VNA must be calibrated with the test cables in place, either S_{21} calibration only, both S_{11} and S_{21} or full 12-term. The device to be tested (DUT) is then connected between Ports 1 and 2 of the VNA as indicated in Fig. 6.17.

For best results, the arrangement shown on the right hand side of Fig. 6.17 should be used whenever possible. When using an $S_{11}+S_{21}$ calibration this will minimise errors introduced by the load return loss. On the other hand, when using a 12-term calibration, this will minimise repeatability / cable flexing errors associated with the connecting cables.

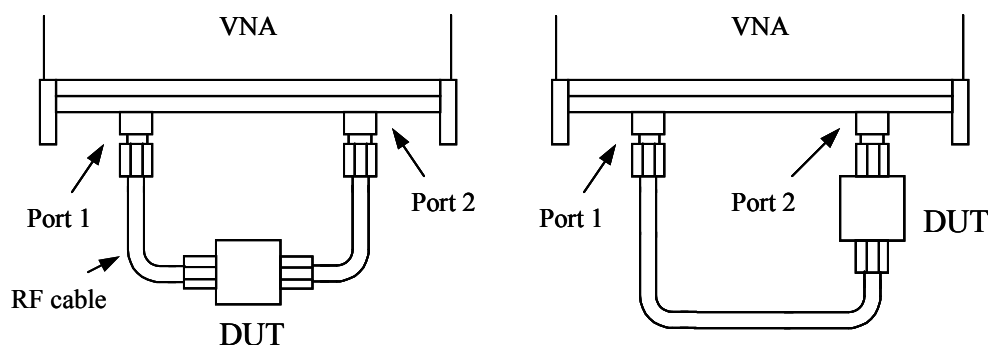


Figure 6.17 Connect DUT between Ports 1 and 2 to carry out S21 measurements. For best results use the arrangement shown on the right.

Displaying the results

The measurement result can be displayed by selecting the S21 parameter and an appropriate display graph and described in Section 6.1.1. Note that the measured phase is relative to the calibration reference plane as discussed in Section 6.4. The reference plane can be shifted at any time from the ‘Enhancement’ window. Note that changes to the reference plane only take place when the instrument is sweeping.

6.3.3 Complete 2-port measurement

In order to measure all four s-parameters a 12-term calibration needs to be completed. The arrangement shown on the right hand side of Fig. 6.17 is likely to yield best results in terms of repeatability by virtue of using only one test cable, reduces the effects of cable flexing.

Displaying the results

The measurement result can be displayed by selecting a different parameter for each of the possible four display graphs, as described in Section 6.1.1. Note that the measured phase is relative to the calibration reference plane as discussed in Section 6.4. The reference plane can be shifted (independently for each parameter) at any time from the ‘Enhancement’ window. Note that changes to the reference plane only take place when the instrument is sweeping.

Maximising dynamic range

Refer to section 6.2.7 “Calibration for best dynamic range – minimising the effect of crosstalk” for guidance on achieving the largest dynamic range.

6.3.4 Group delay

Group delay is defined as the rate of change of phase with frequency. In relatively non-dispersive components such as transmission lines, group delay is the transit time through the line. However, some components such as filters can exhibit negative group delays so care is needed when attaching an interpretation to group delay.

$$GroupDelay = \frac{\partial \phi}{\partial \omega}$$

The LA19-13-04A calculates the group delay by dividing the phase change between adjacent sweep points and dividing by the size of the sweep step. It is usual to apply some degree of trace smoothing to remove very rapidly changing perturbations from the trace. Care should be exercised to ensure that genuine sharp group delay variations are not masked by the smoothing.

Displaying the results

Group Delay of any S-parameter can be measured. The result can be displayed by selecting the required parameter and group delay graph from the 'Display' window as described in Section 6.1.1.

6.3.5 Time domain measurements

The time domain facility allows the display of the time domain response of a network under test. For example, time domain reflectometry (TDR) measurements can be made by first carrying out an S11 calibration using 1024 sweep points. Similarly, Time domain transmission (TDT) measurements can be made by first completing an S21 calibration using 1024 sweep points. The steps necessary are shown in the flowcharts in Figs. 6.18 and 6.19.

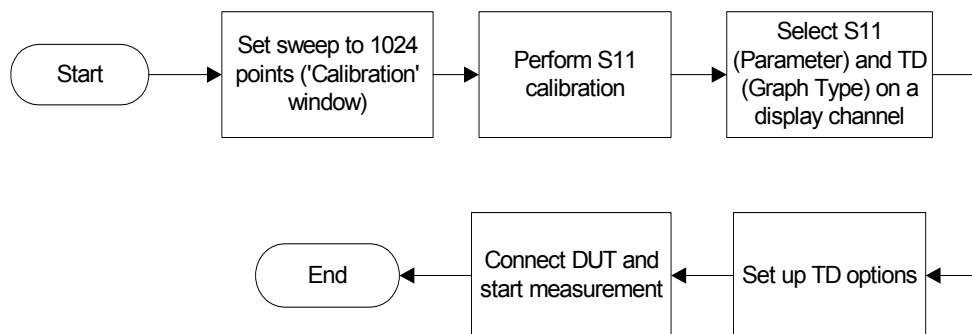


Figure 6.18 Performing a TDR measurement

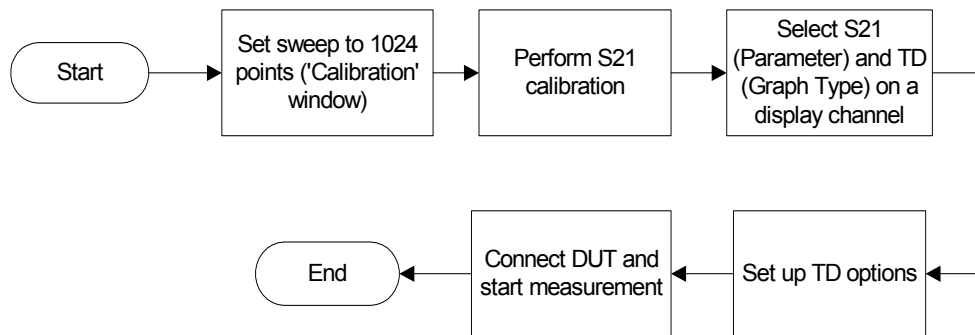


Figure 6.19 Performing a TDT measurement

Note that carrying out time domain measurements requires a lot of mathematical processing and therefore each sweep will be noticeably slower when displaying time domain.

Examples of TDR measurements using the LA19-13-04A VNA

The trace below shows the time domain response of a 50 cm, 50 Ω coaxial cable with an open circuit termination. The trace goes to +1 relative to the reference indicating a reflection coefficient of +1 for an open circuit. The window used is rectangular.

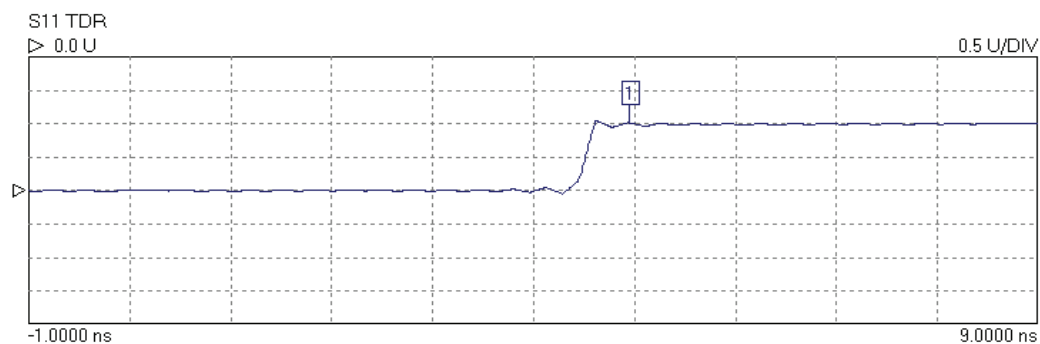


Figure 6.20 Measured 50cm line terminated in an open circuit.

The trace below is the same as above except that the ringing either side of the transition has been reduced by the use of a fifth order Kaiser Bessel window. This reduces the ringing but also slows the rise time.

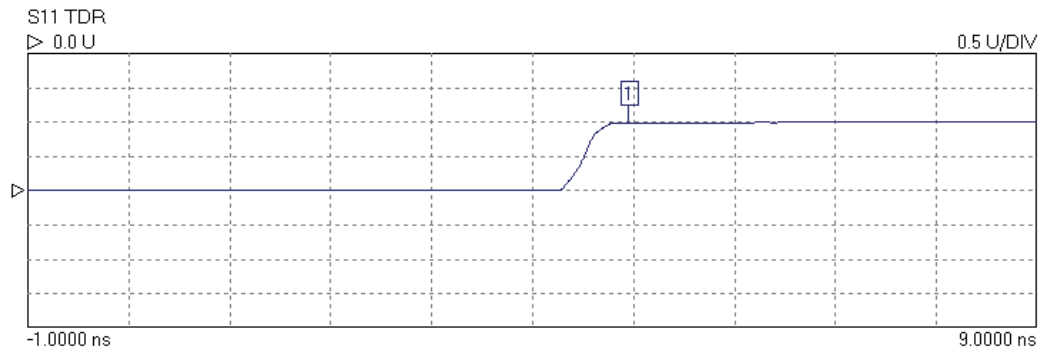


Figure 6.21 Same as shown in Fig. 5.15 but using the Kaiser Bessel window.

The type of window, the order of the Kaiser Bessel window, and the time span over which the signal is displayed can be selected in the TDR options window, shown below.

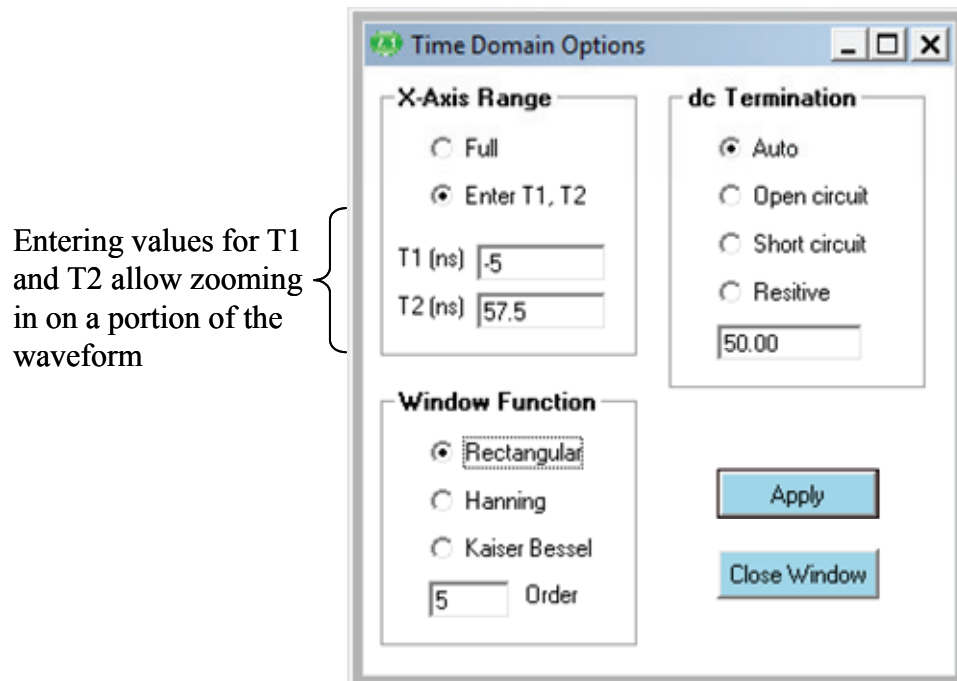


Figure 6.22 Time Domain Options window allows measurement set up

Note: To set a time range either starting or ending beyond 161.66 ns, use the ‘Enter T1, T2’ facility. However, the displayed total time span must be less than 166.66 ns.

The plot below shows the same cable terminated with a short circuit. The window is fifth order Kaiser Bessel. This time the trace goes to -1 relative to the reference, indicating a reflection coefficient of -1 for the short circuit.

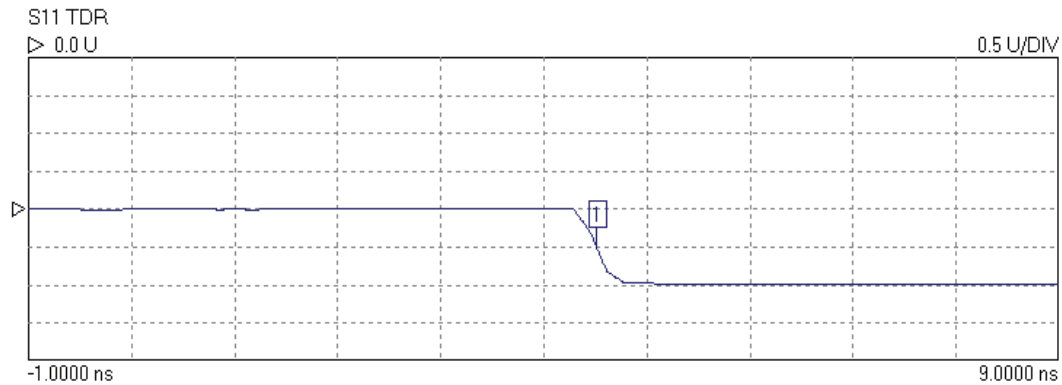


Figure 6.23 Measured response of 50 cm shorted cable using Kaiser Bessel fifth order window

The trace below shows the effect of increasing the order of the Kaiser Bessel window to 10. The ripple has been completely removed but the slope of the edge has been further reduced.

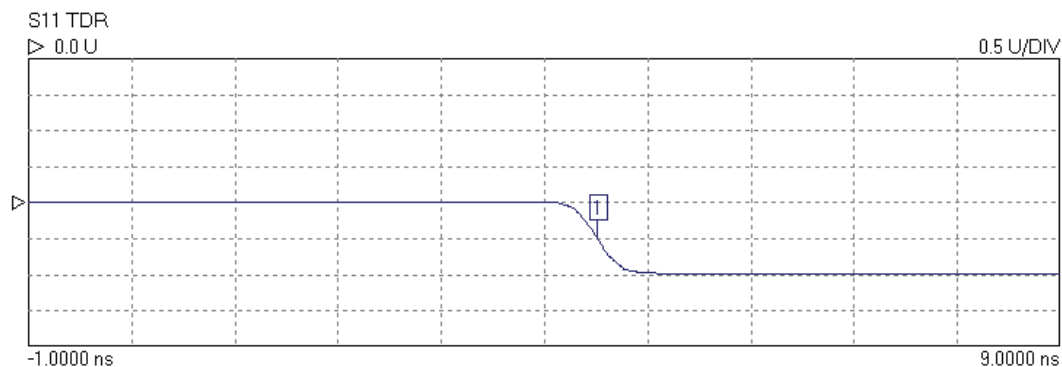


Figure 6.24 Measured response of 50 cm shorted cable using tenth order Kaiser Bessel window.

A more complicated example:

The trace below shows the response of a 30 cm, 50 Ω line followed by 30 cm of 25 Ω line terminated in a short circuit. The window is third order Kaiser Bessel. The trace shows the multiple reflections from the discontinuity of impedance at the connection between the lines and the short circuit termination.

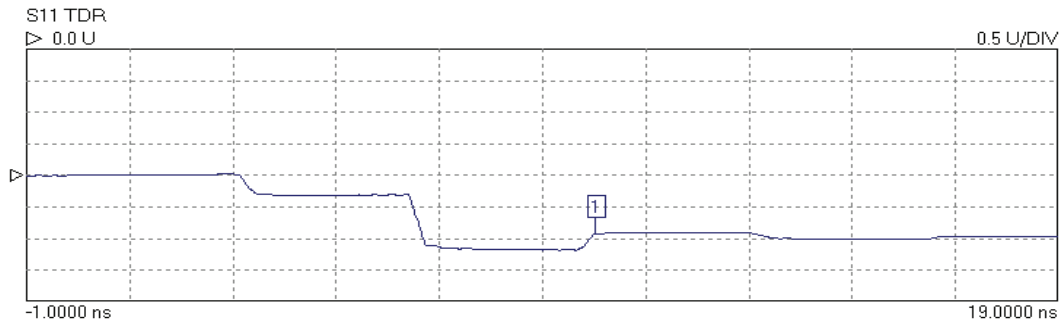


Figure 6.25 Measured response of multiple reflections. See text for details.

The last example is the same $50 \Omega / 25 \Omega$ cable combination but this time the termination is an open circuit. The response is also displayed over a longer period.

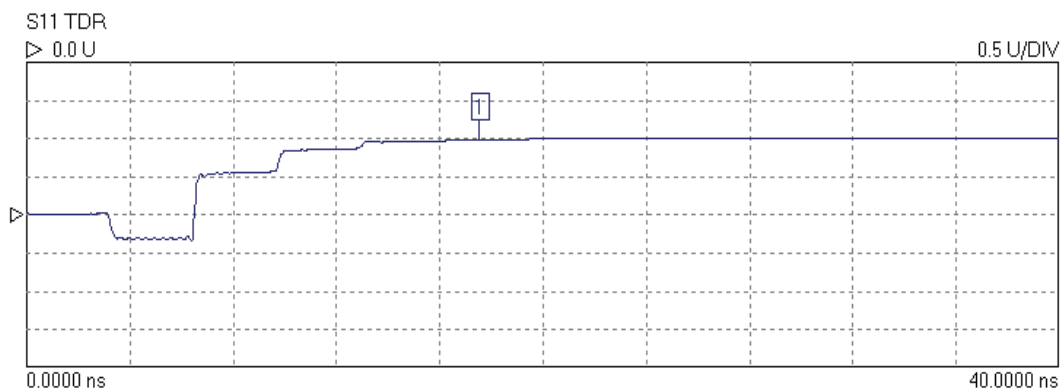


Figure 6.26 Measured response of multiple reflections, see text for details

Time domain transmission

Time domain transmission (TDT) is similar to the TDR technique except that the transmitted signal is observed. Traditionally, this is accomplished using a step source and a sampling scope, as with the TDR, but the transmitted signal at the output of the network is observed rather than the reflected signal at the input to the network. This technique is useful for measuring the step response or rise time of amplifiers, filters and other networks.

Examples:

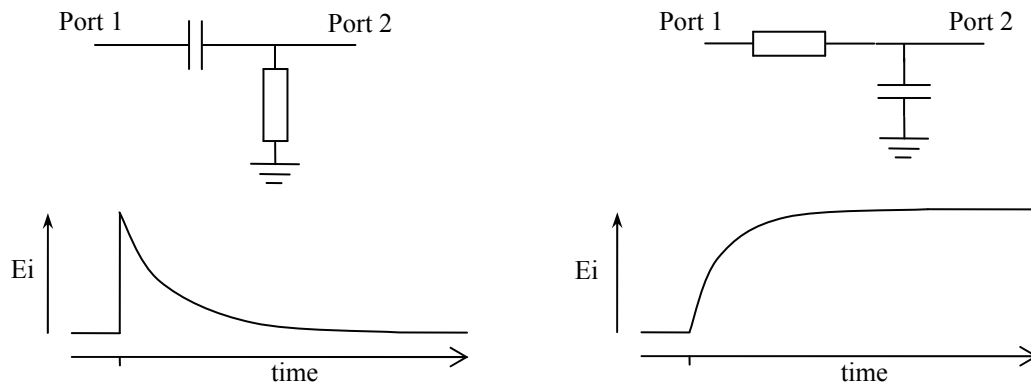


Figure 6.27 Expected responses from simple RC networks

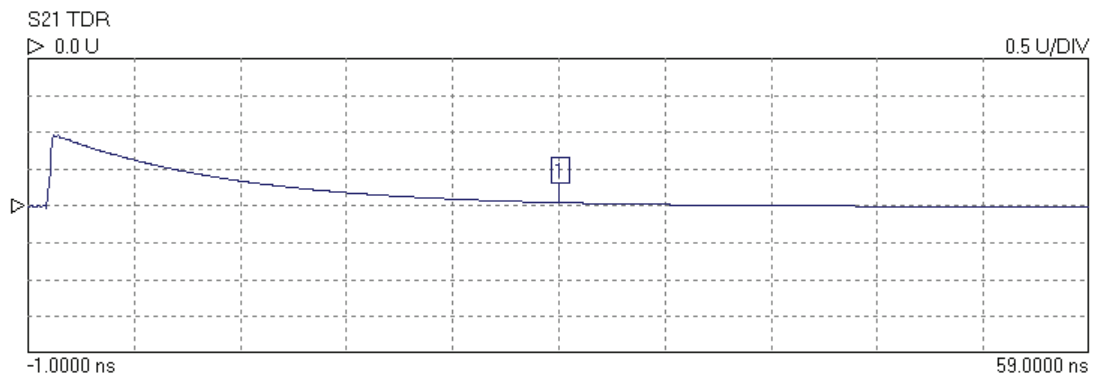


Figure 6.28 Measured TDT for 100 pF series capacitor

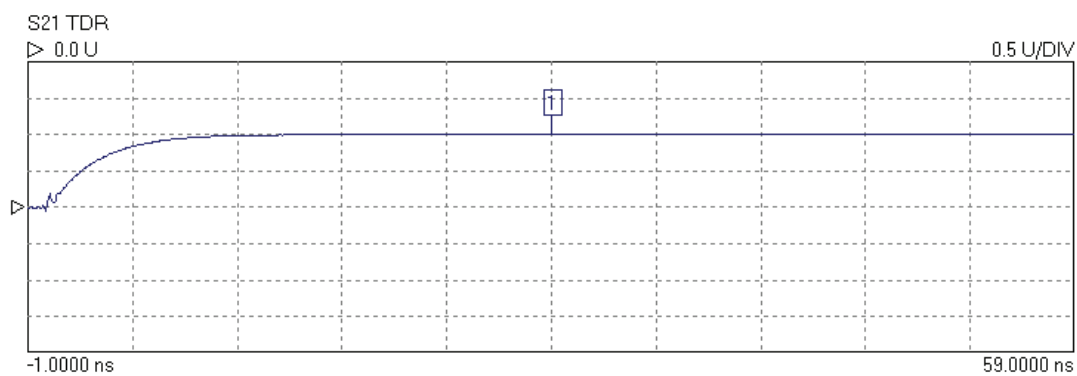


Figure 6.29 Measured TDT for 100 pF shunt capacitor

6.3.6 Reverse measurements on two port devices

In order to measure the reverse parameters (S12 and S22), it is necessary to complete a 12-term or 8-term calibration first (select 'insertable' or 'non-insertable' DUT on calibration window as shown in Fig. 6.11). The other calibration options measure only forward parameters. After the calibration is completed, simply select the reverse parameter(s) to be required on any displayed channel and start the measurement.

6.3.7 Powering active devices using the built-in bias-Ts

The LA19-13-04A VNA includes two bias-Ts which can be used to provide dc bias to the measurement ports 1 and 2. The bias-Ts are rated at 250 mA and can support dc voltages up to 15V. The dc injection terminals are type BNC, female. They are located on the back panel. This facility can be used, for example, to provide dc bias to an active device being measured.



Warning: Exceeding the voltage rating may cause permanent damage to the internal biasing circuit

6.3.8 Mixer measurements

The LA19-13-04A VNA can perform measurements on mixers (frequency conversion devices) with the use of an external LO source. The user interface software provides support for some commercially available instruments as well as power sensors (power meters) needed to carry out signal level calibration for improved measurement accuracy.

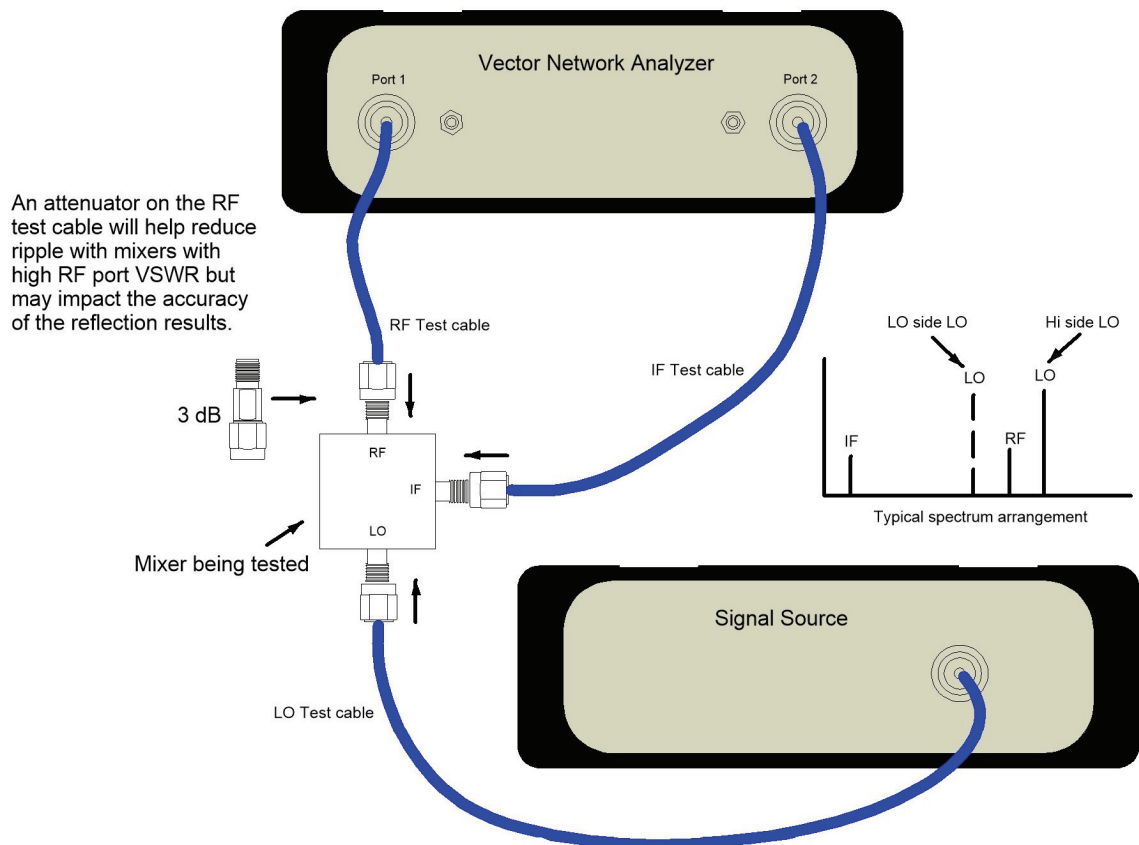


Figure 6.29a Typical mixer measurement set up

Measurement Selection

The appropriate mixer measurement form is launched from the Utilities drop down menu as shown below in Fing.6.39b.

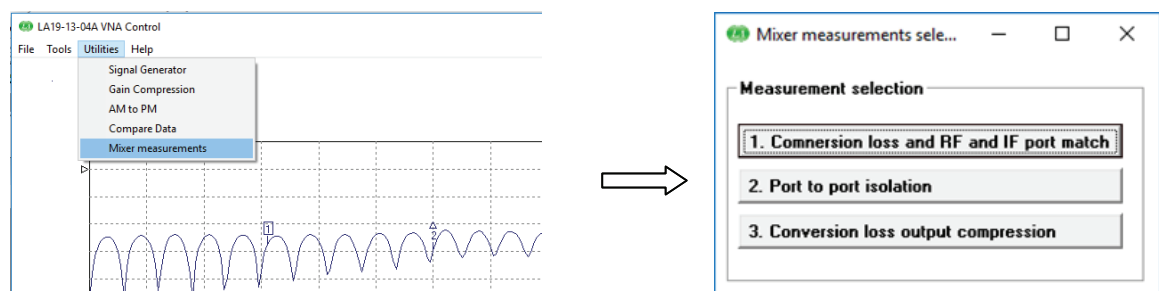


Figure 6.29b Mixer measurement selection

External instrument selection

Before the measurement parameters are set, the user should select the source of the LO signal and the means for calibrating the power level. This is done from the Instruments drop down menu as shown below in Fig. 6.29c. Contact the factory if your preferred instrument(s) is not on the list in case support may be added at a later date.

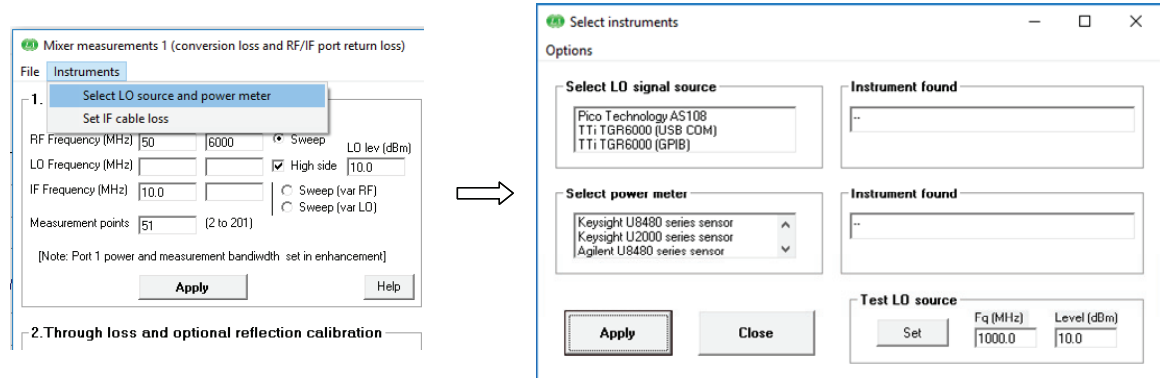


Figure 6.29c External instrument (LO source and power meter) selection

Conversion loss and return loss

This measurement is set up using the dialog form shown in Fig. 6.29c. It allows the frequency ranges to be set up as well as the LO power level.

The user can chose whether or not to measure return loss by means of the selection tick box ‘Ignore’ under the Reflection calibration buttons. If the button is left un-ticked the instrument will perform a standard SOLT calibration to allow corrected return loss values to be displayed.

The return loss of either the RF port or the IF port will be measured and displayed. If the IF frequency is swept, then the IF port return loss is measured otherwise the RF port return loss is measured and displayed.

One important advantage of return loss calibration is that the measured conversion loss will corrected for the effects, for example, of poor mixer return loss. This is sometimes referred to as VSWR correction and is illustrated in Fig. 6.29d.

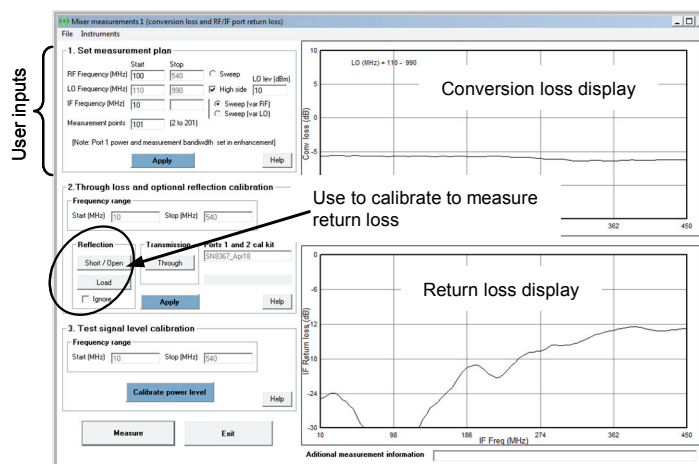


Figure 6.29c Mixer measurement set up dialog

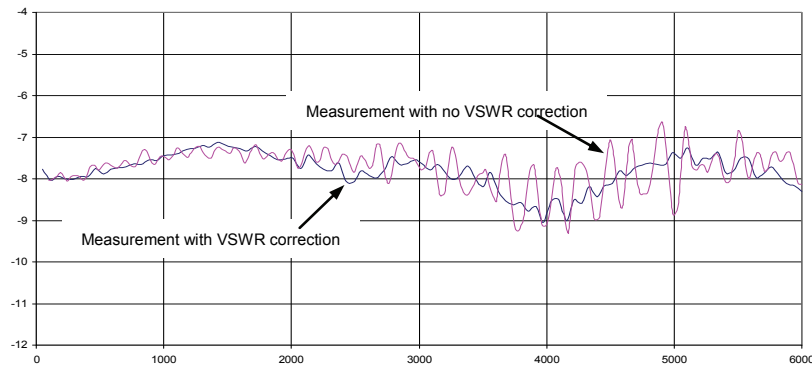


Figure 6.29d VSWR Correction can significantly improve conversion loss uncertainty

Isolation and conversion loss compression

The other main measurement options are port to port isolation and conversion loss compression as shown in Fig. 6.29b. Setting each of these up will require selection of the external instruments as described above (Fig. 6.29c). The corresponding form for each of these set of measurements provide graphical indication of the calibration steps.

Figure 6.29e shows the conversion loss compression set up form. As indicated, the need for an external power meter can be bypassed albeit at the risk of reduced measurement accuracy. On completion of the measurement the variation of conversion loss with RF port power level and the 0.1 dB and 1 dB compression points are displayed.

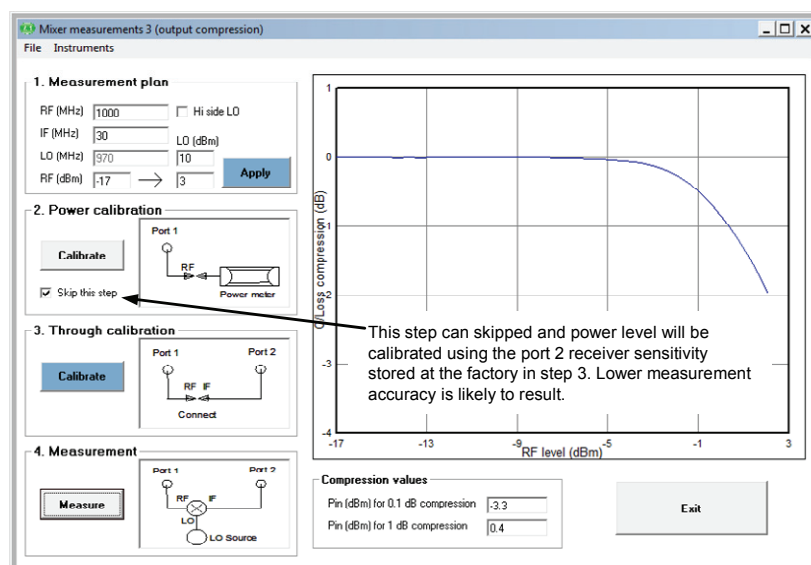


Figure 6.29e Conversion loss compression measurement form

6.4 Reference Plane Extension and De-Embedding

The Reference Plane extension facility on the LA19-13-04A allows the user to shift the measurement reference plane away from the value set during calibration. This can be useful in removing the effect of interconnecting cables or microstrip lines from measurements. The instrument allows independent reference plane extensions on each of the measurement parameters (S11, S22, S12 or S21).

An example of an application requiring the use of reference plane extension is shown in Fig. 6.30. In this, it is desired to measure the S11 of a device mounted on a microstrip test jig with SMA connectors. In order to remove the effect of the interconnecting line to the input of the device, the following procedure may be followed:

- Perform an S11 calibration at the end of the N to SMA adaptor on Port 1
- Connect the test jig **without** the DUT mounted on it
- Display the phase of the S11 on active display channel
- Click on the ‘Auto Ref’ button on the Enhancement window (Fig. 6.6)
- Click on the ‘Apply’ button on the Enhancement window

The above steps will move the reference plane to the end of the microstrip line. This can be verified by noting that the displayed phase is close to 0° over the entire measurement band. Imperfections associated with the microstrip line and coaxial connector (loss, dispersion, etc) will mean that some residual phase will remain. However, with careful design and employing good RF practice for the construction of the jig, this error should remain small.

After the above steps are completed, the DUT can be mounted on the jig and its S11 parameter measured.

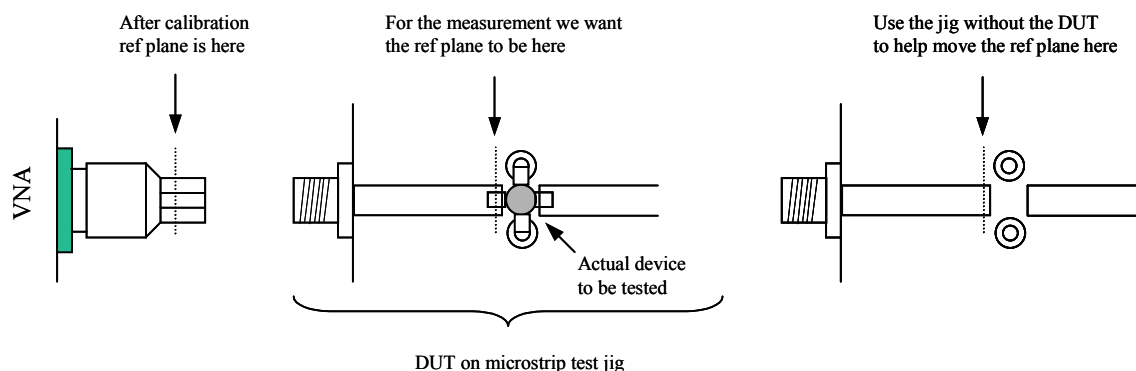


Figure 6.30 Example of S11 measurement requiring reference plane extension

Note: The Reference Plane extension moves the reference plane for each parameter measurement independently. So, if required for example, different values can be used for S11 and S21. A reference plane extension value entered, applies to the active channel measurement parameter (either reflection or transmission).

In the example above, correction was applied to the S11 phase but not S21. An often-used way to correct the S21 phase is by using a calibration jig with length of microstrip line equal to the sum of the two sections of line used either side of the DUT jig (Fig. 6.31). Proceed as follows to make S11 and S21 measurements of the DUT.

Reference plane extension for S11 correction

- Perform a 12 term calibration (exclude test jig). Ensure that the test cable has connectors of different sex at each end. Adaptors may be needed to connect the DUT.
- Connect the input port of the test jig **without** the DUT mounted on it to Port 1
- Display the phase of the S11 on the **active** display channel
- Click on the 'Auto Ref' button on the Enhancement window
- Click on the 'Apply' button on the Enhancement window

Normalization for S21 correction

- Connect the through microstrip test line between Ports 1 and 2 of the VNA
- Display the phase of S21 on a non-active channel (keep active channel for S11)
- Start the measurement and store data on the S21 channel only to memory (use the memory window)
- Select 'Data / Memory' for the math function on the Memory window
- Select the display 'Memory Math' radio button on the main window

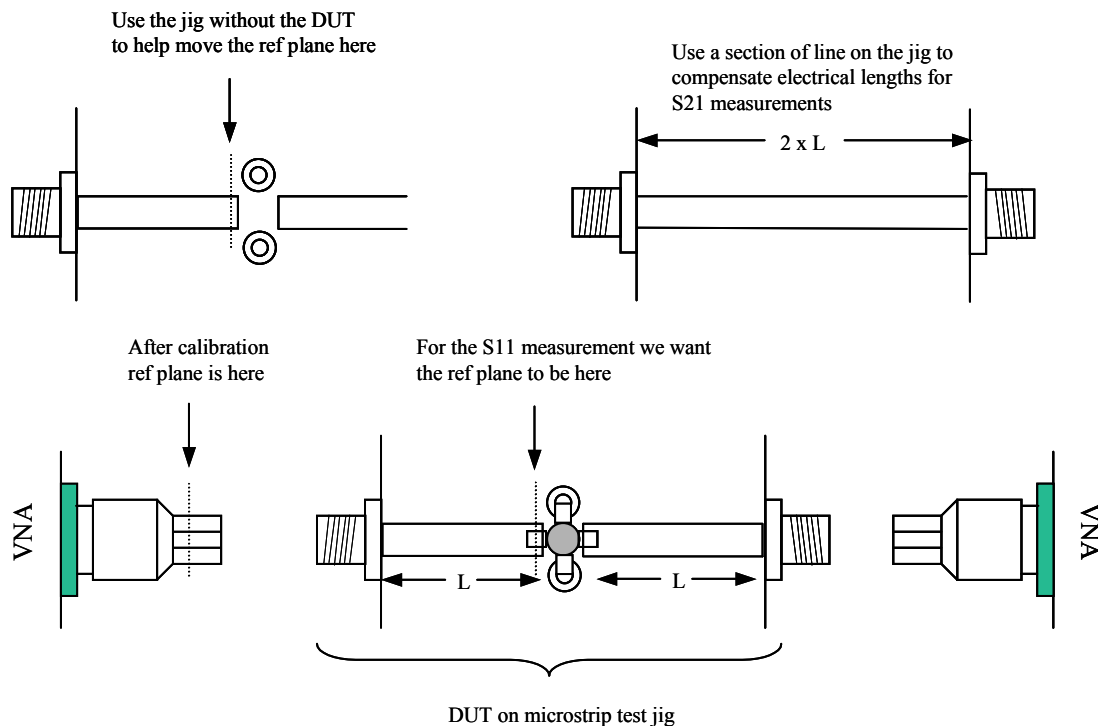


Figure 6.31 Correcting S21 and S11 phase measurements. Reference plane extension corrects S11 measurements and normalisation to a test line corrects S21

The above steps will allow the DUT's S_{11} and S_{21} (or S_{22} and S_{12}) parameters to be measured with the right phase correction. In addition, the loss of the microstrip line will be accounted for. The same approach can be used to measure S_{12} and S_{22} . Note, however, that there will be an error on both measurements due to the imperfections of the microstrip line and connector interface. With careful design of the jig these can be kept acceptably small but further accuracy can be achieved by making use of the de-embedding facility described below.

De-Embedding Facility

A typical measurement jig, as shown in Fig.6.29, includes input and output networks which introduce errors to the measured values of the device under test (DUT). For best measurement accuracy, these networks can be specified (in the form of 2 port s-parameters files) and then used to extrapolate the DUT's characteristics.

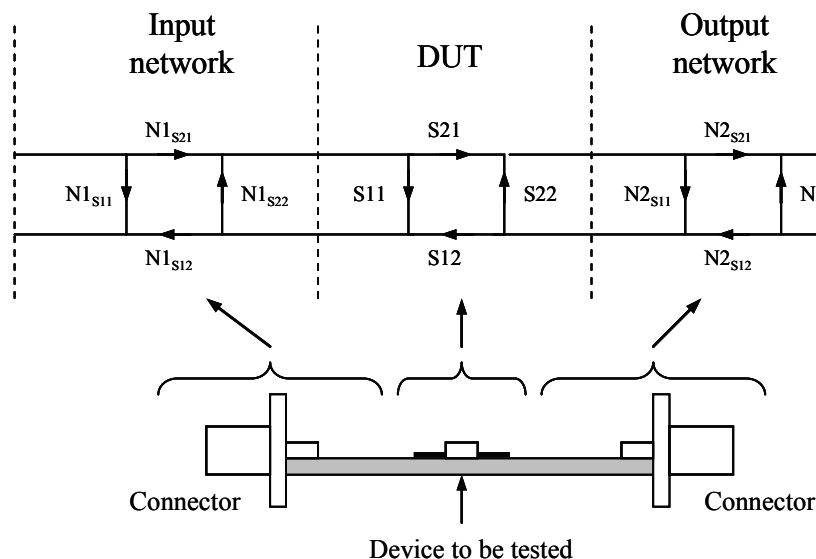


Figure 6.32 De-embedding allows the effects of the test jig's input and output networks to be removed.

The LA19-13-04A allows the user to specify s-parameter files (must be full 2 port data) for the input and output networks as shown in Fig. 6.32 so that the de-embedding takes place automatically as the instrument measures the test jig. After first calibrating as usual, follow the steps below to enable de-embedding.

1. Select the s-parameter file(s) that represent the embedding network(s) by clicking on the embedding network check box(es) as shown in Fig. 6.6. Check box 'Port 1 Network' represents the input network as shown in Fig. 6.32, and 'Port 2 Network' represents the output network. The files selected must be full 2-port s-parameters files in Touchstone® format.
2. Click on the radio button to enable de-embedding (Fig. 6.6).

Once the above steps are completed, starting the measurement will display de-embedded results.

The de-embedding facility relies on s-parameter data for the input **and / or** output networks being available. This data must be in the form of 2-port s-parameter files in Touchstone® format.

6.5 Saving Data

Measured data can be saved to a file by selecting 'Save Measurements' from the drop down menu under 'File' on the main window. Various formats are available as shown. In all cases, frequency is saved in megahertz. **Note that only the Touchstone® format can later be read back into the instrument's memory trace.**

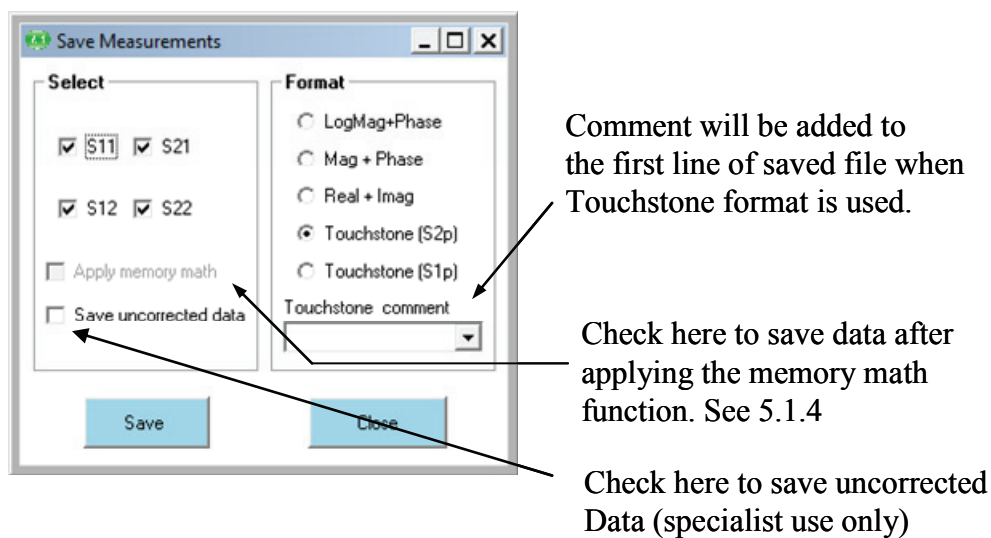


Figure 6.33 The Save Measurements window is used to save data

Note: For true compatibility with the Touchstone® format, only 1-port or full 2-port S-parameters should be saved. For example, selecting S11 and S21 (but not S12 and S22) is not Touchstone® compliant.

If required, the data can be saved with the memory math function applied as described earlier in section 6.1.4. In order to do this, check the box 'Apply Memory Math'. Note that the memory math display function on the main window (see Fig. 4.1) must be set otherwise the 'Apply Memory Math' check box will be disabled.

When saving data in Touchstone® format, ensure that you provide the file name extension when entering the file name. Typically, for 1-port networks, the extension ".s1p" is used and ".s2p" for 2-port networks. This will help when reading back the data files since, by default, only files with these extensions will be displayed.

Note: Data will be saved with any System Zo conversion applied

6.6 Loading Data

Measured data (or data from a circuit simulator) can be read into the instrument's memory trace(s). This can be done by selecting the 'Load Measurement', from the drop down menu under 'File' on the main window. The file containing the data (in Touchstone®) format is selected by clicking on the 'Select Data File' button.

The data will be read from the file and copied to the appropriate display channel(s). So, for example, assume the user reads a data file holding full 2-port data. Further, the user has only two channels on display showing, say, S11 and S21, so only the S11 and S21 data from the data file read will be copied to the memory traces of the displayed channels. **Note:** system impedance conversion will apply if turned on (see Fig. 6.6).

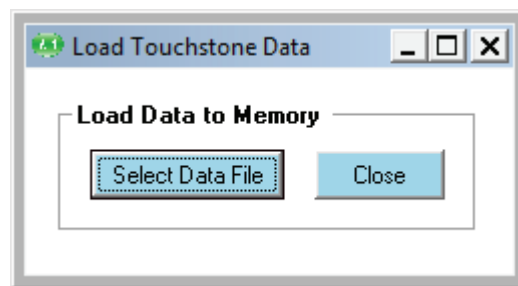


Figure 6.34 Loading data is done from the 'Load Measurement' under the 'File' menu

6.7 Plotting Graphics

Plotting the graphics displayed on the main window can be done from the drop down menu under 'File' near the top left corner of the main window. A printer set-up window will appear from which the desired printer can be chosen and its properties set. If required, a label can be added to the plotted graphics. This can be done by clicking on the 'Print / Save Graphics Label' item from the 'File' drop-down.

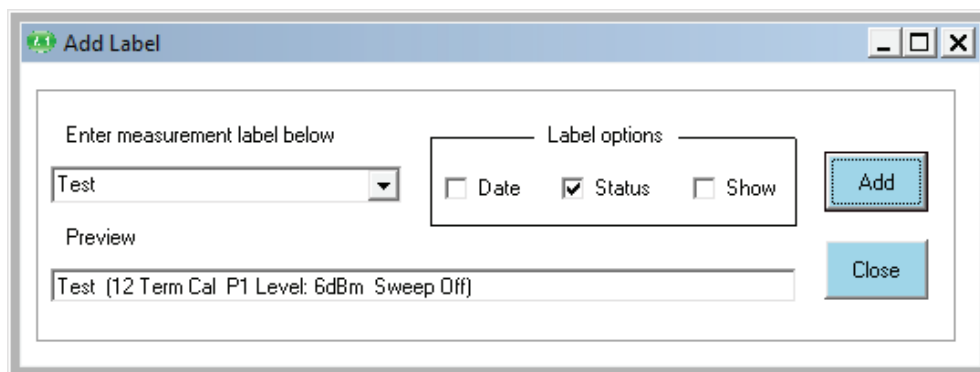


Figure 6.35 A label can be added when plotting or saving graphics

A similar plotting facility exists on the P_{1dB} and AM to PM utilities control windows as shown in Figs. 5.34 and 5.35.

6.8 Saving Graphics

The graphics shown on the main window (Fig. 5.1) can be saved in .bmp, .png, .gif, .tif or .jpg formats. This allows measurement results to be directly pasted into most electronic documents. The facility to save the graphics can be found on the drop down menu under 'File' near the top left corner of the main window. After clicking, a dialogue box will appear allowing the user to select the name of the file, its location and format from a drop-down box. As described in the previous section, a label can be added by clicking on 'Print / Save Graphics Label' item from the 'File' drop-down.

The save graphics facility is not available on the P_{1dB} and AM to PM utilities. Instead, the graphics on these can be captured by pressing the 'ALT' and 'Print Screen' buttons. The image can then be pasted to the chosen document from the 'Edit' menu.

6.9 Signal Generator Utility

This utility allows the instrument to act as a simple signal generator with variable output power. The VNA measurement sweep must be stopped first and the control window, shown in Fig. 6.36, called from the 'Utilities' menu.

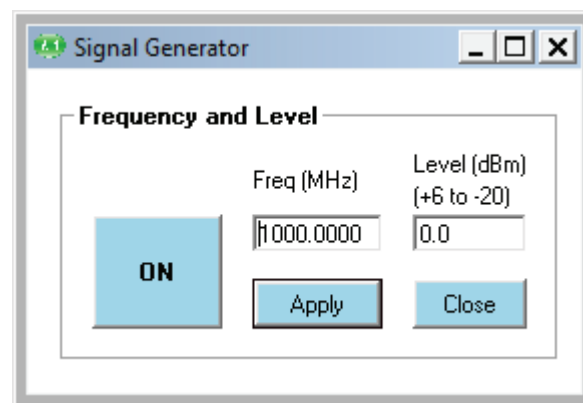


Figure 6.36 The Signal Generator utility control window

6.10 Output Power at the 1 dB Gain Compression Point Utility

This utility allows the measurement of the power output at the 1 dB gain compression point of active devices such as amplifiers. The measurement can be done at a single frequency or over the entire frequency plan specified at the last S-parameter measurement calibration. The utility is started up by going to the drop down menu under ‘Utilities’ near the top left corner of the main window.

The P1dB utility only works for devices connected between ports 1 and 2 and with the factory fitted front panel bypass links in place. Devices connected in any other way will yield incorrect results.

P_{1dB} calibration

Calibration minimises errors by removing small variations associated with the instrument’s hardware. The procedure is simple, as shown below.

- Ensure that an S21 (or S11 + S21, or 12-term) calibration has been carried out
- Connect Port 1 to Port 2 as shown on the left-hand side of Fig. 6.34
- Enter Input and Output attenuation values (or select ‘Read from file’)
- Enter the test frequency (or select ‘Use sweep plan’) and press the ‘Calibrate’ button

P_{1dB} test

The basic connection arrangement is shown on the right hand side of Fig. 6.34. Note that the input and output attenuators should be carefully selected to ensure that the DUT compresses whilst preventing the power at Port 2 of the instrument exceeding the nominal limit of +6 dBm. It is recommended that the following guidelines are used to estimate the value of the input and output attenuators needed.

$$P_{1dB(DUT)} - G_{(DUT)} - 1 + A_{tt1} = -5 \pm 2 \text{ dBm}$$

$$P_{1dB(DUT)} - A_{tt2} + 5 < 6 \text{ dBm}$$

where;

P_{1dB(DUT)} = Output power of DUT at the 1 dB gain compression point
 G_(DUT) = Linear Gain of DUT
 A_{tt1}, A_{tt2} = Input and output attenuators

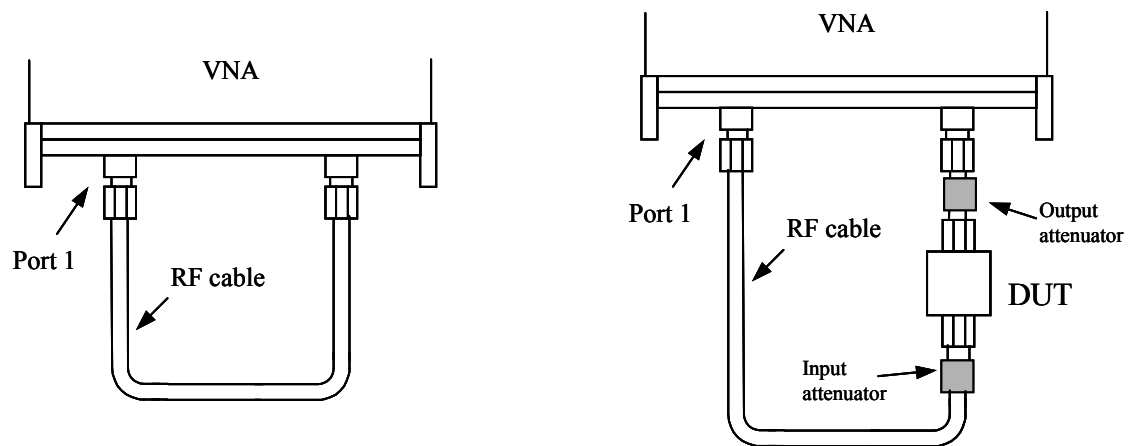


Figure 6.37 Basic connection guide for P_{1dB} measurements. Calibration connection is shown on the left

The instrument makes the measurement by setting the signal source (Port 1) frequency to the chosen value and then stepping its power from -20 to 0 dBm in 1 dB steps. The gain at each power setting is recorded. On completion of the power sweep, a second order curve is fitted over a narrow section centred on the point closest to the 1 dB gain compression point. The coefficients of this curve allow the actual P_{1dB} point to be calculated.

Note: Choose the input attenuator with care. Ensure that there is no gain compression at the start of the power sweep (-20 dBm at Port 1) and that at least 0.7 dB of gain compression is reached at the end of the sweep (0 dBm at Port 1). A '?' will be displayed if insufficient compression has been achieved.

After the attenuator values have been established and the DUT is in place (and powered up as appropriate), enter the values into the P_{1dB} control window (Fig. 6.34). Note that the output attenuation value impacts directly on the P_{1dB} value, it is important to enter an accurate value that takes into account all losses in the output path, including any connecting cable that may have been used.

Pressing the 'Start' button will perform the test, plot the gain and output power curves, and compute the P_{1dB} . This, together with the linear gain, will be displayed in the text boxes to the right of the 'Start' button. The results can then be printed (the window as displayed will be printed) or saved as a text file by clicking on the 'Print' or 'Save' button.

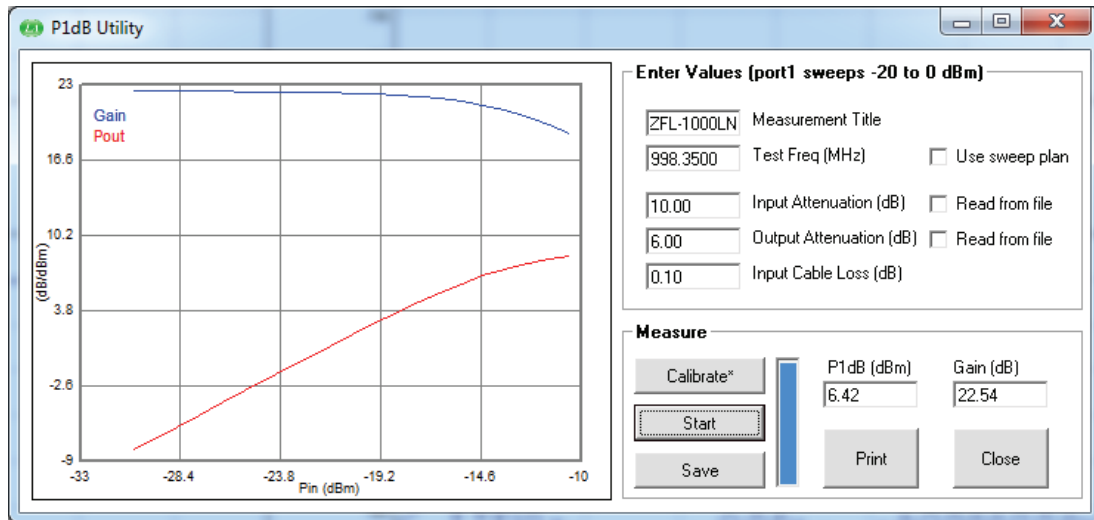


Figure 6.38 The P_{1dB} measurement utility control window

Attenuation Values from file

When measuring P_{1dB} using the frequency sweep plan, it is possible to read the input and output attenuation values from a file. The data is held in a simple text file with one line for each frequency point. The format must be as follows.

Frequency (MHz), magnitude (dB), phase (degrees)

Note: The number of lines in the file must match the number of sweep points in the sweep plan.

6.11 AM to PM Conversion Utility

This utility allows the measurement of the AM to PM conversion factor of a DUT. Generally it is used for evaluating the linearity of active devices such as amplifiers. The utility is started up by going to the drop down menu under 'Utilities' near the top left corner of the main window. It is shown in Fig. 6.37.

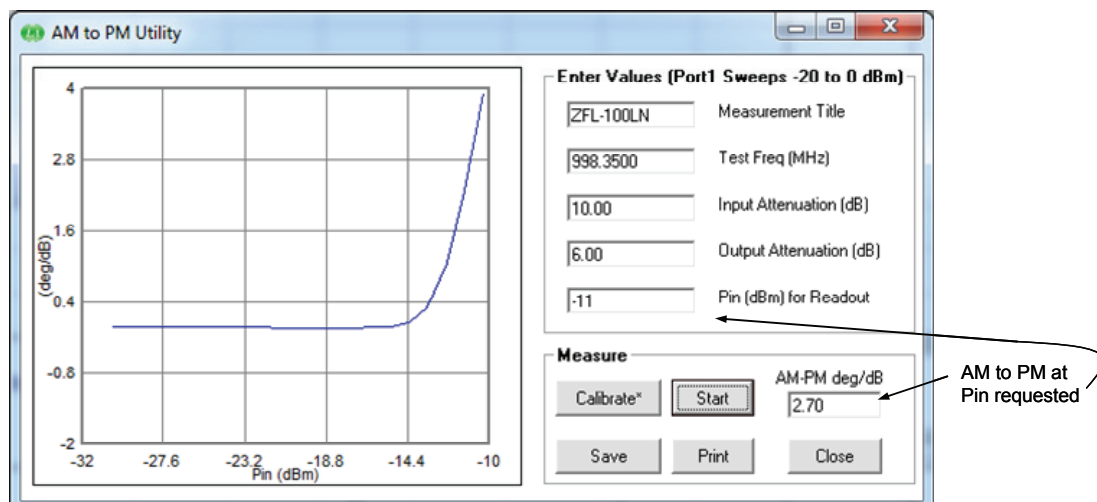


Figure 6.39 The AM to PM measurement utility control window

In order to use this facility an S21 calibration (or S11+S21, or 12-term) must have been carried out. For best results, some averaging (e.g. 16) should be used. Further, a second through calibration is suggested to remove residual phase variations. The steps are summarised as follows.

AM to PM utility (calibration)

- Perform a normal S21 calibration (or S11+S21, or 12-term), see left hand side of Fig. 5.37
- Call up AM to PM Utility (window shown in Fig. 6.37)
- Enter frequency required (Test Freq) in megahertz
- Click on Calibrate button (connection as on left-hand side of Fig. 6.38)

AM to PM utility (test)

- Connect DUT with attenuators as shown on right hand side of Fig. 6.38
- Enter attenuator values, input power at which result is required and measurement title
- Power up DUT if necessary
- Click the Start button

On completion of the AM to PM test, a graph of AM to PM as a function of input power at the DUT input will be plotted. In addition, the AM to PM factor at the specified input power entered will be displayed in the text box in the Measure section of the window.

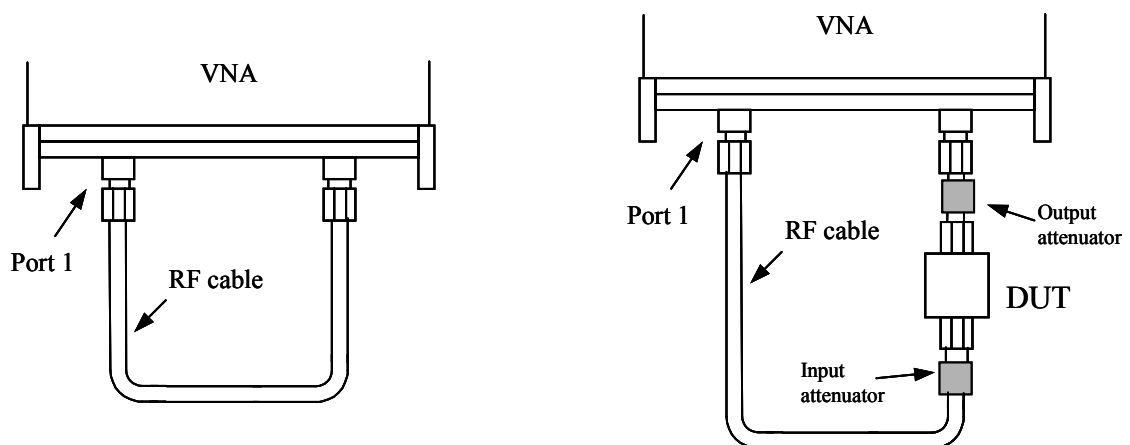


Figure 6.40 Calibration (left) and test connections for AM to PM test

Note: For best AM-PM results apply some averaging (e.g. 16) and carry out an AM-PM calibration (left hand side of Fig. 6.40). A '?' will displayed if the requested Pin for readout is outside the available range.

6.12 Compare Data Utility

The compare data utility provides a quick and simple way to compare two sets of full S-parameter measurements taking into account the instrument’s measurement uncertainty and optionally, the uncertainty associated with the reference measurement. Typically this facility can be used to measure a verification (reference) DUT and compare the measurement values produced by the LA19-13-04A VNA with those supplied with the verification DUT. This is a simple and quick way of determining the adequacy of the calibration and calibration kit to be used.

The compare data utility can be found in the utility drop-down menu. This brings up the form shown in Fig. 6.41.

In order for the compare utility to work the user needs to follow the following steps.

- Perform a full S-parameter calibration
- Set display graph 1 to S11, 2 to S21, 3 to S12 and 4 to S22
- Measure the reference DUT
- Load the reference measurement of the DUT (supplied with the DUT) using Load Measurement (this must be a full s-parameter measurement)
- Launch the compare data utility
- Load the LA19-13-04A VNA uncertainty file (usually in the file DefUnc.dat)
- Load the reference measurement uncertainty file (this may be ignored in most cases where reference measurements are believed to be highly accurate)
- Click on the ‘Compare’ button to perform the comparison and display the results

Measurement uncertainties are set here

S11 Measurement													
Freq (MHz)	S11 Mg	S11 ph	Ref S11 Mg	Ref S11 ph	Delta Mg	Delta ph	U(Mg)	U(ph)	Ref U(Mg)	Ref U(ph)	Total U(Mg)	Total U(ph)	Pass/Fail
10	-29.00	177.61	-28.98	177.94	-.02	-.33	2.50	15.0	0.00	0.0	2.50	15.0	Pass
33.95	-34.40	-27.73	-34.37	-28.98	-.03	1.25	200.00	360.0	0.00	0.0	200.00	360.0	Pass
68.9	-31.52	41.62	-31.54	40.70	.02	.92	200.00	360.0	0.00	0.0	200.00	360.0	Pass
99.05	-31.99	109.87	-32.05	109.00	.06	.87	200.00	360.0	0.00	0.0	200.00	360.0	Pass
129.8	-31.28	-167.18	-31.34	-167.79	.07	.61	200.00	360.0	0.00	0.0	200.00	360.0	Pass
159.75	-30.26	-100.26	-30.29	-100.79	.04	.53	200.00	360.0	0.00	0.0	200.00	360.0	Pass
189.7	-29.56	-24.60	-29.59	-25.25	.04	.65	2.50	15.0	0.00	0.0	2.50	15.0	Pass
219.65	-27.29	34.26	-27.33	33.74	.05	.52	2.50	15.0	0.00	0.0	2.50	15.0	Pass
249.6	-28.38	74.59	-28.35	74.55	-.03	.04	2.50	15.0	0.00	0.0	2.50	15.0	Pass
279.55	-34.08	172.61	-34.15	171.29	.06	1.32	200.00	360.0	0.00	0.0	200.00	360.0	Pass
309.5	-31.36	-108.03	-31.63	-108.62	.05	.59	200.00	360.0	0.00	0.0	200.00	360.0	Pass
339.45	-30.64	-33.43	-30.66	-34.11	.03	.68	200.00	360.0	0.00	0.0	200.00	360.0	Pass
369.4	-29.12	21.49	-29.16	20.96	.05	.53	2.50	15.0	0.00	0.0	2.50	15.0	Pass
399.35	-33.74	70.06	-33.69	69.27	-.05	.79	200.00	360.0	0.00	0.0	200.00	360.0	Pass
429.3	-38.15	-176.27	-38.36	-177.75	.21	1.38	200.00	360.0	0.00	0.0	200.00	360.0	Pass
459.25	-34.66	-79.23	-34.77	-79.56	.11	.33	200.00	360.0	0.00	0.0	200.00	360.0	Pass
489.2	-31.23	-6.90	-31.30	-7.29	.07	.39	200.00	360.0	0.00	0.0	200.00	360.0	Pass
519.15	-30.22	48.96	-30.27	48.50	.05	.36	200.00	360.0	0.00	0.0	200.00	360.0	Pass
549.1	-32.15	124.27	-32.20	123.81	.05	.46	200.00	360.0	0.00	0.0	200.00	360.0	Pass
579.05	-31.17	-159.52	-31.21	-159.90	.05	.38	200.00	360.0	0.00	0.0	200.00	360.0	Pass
609	-30.04	-79.43	-30.08	-79.75	.04	.32	200.00	360.0	0.00	0.0	200.00	360.0	Pass
638.95	-27.67	-12.91	-27.71	-13.34	.04	.43	2.50	15.0	0.00	0.0	2.50	15.0	Pass
668.9	-27.65	45.35	-27.68	44.93	.03	.42	2.50	15.0	0.00	0.0	2.50	15.0	Pass
698.85	-28.28	120.32	-28.32	119.87	.04	.45	2.50	15.0	0.00	0.0	2.50	15.0	Pass
728.8	-27.66	-175.14	-27.70	-175.45	.04	.31	2.50	15.0	0.00	0.0	2.50	15.0	Pass

Figure 6.41 Data comparison dialogue form

Defining uncertainties

Measurement uncertainty is defined by means of text file as illustrated in Fig. 6.42. The definition is made up of several segments. Each segment refers to reflection [REFLECTION] or transmission [TRANSMISSION] with an entry for the applicable range in dB followed by the frequency range (in MHz). After the frequency range entry, the magnitude uncertainty in dB is specified followed by the corresponding phase uncertainty in degrees.

One segment of the uncertainty definition

```
[Default uncertainty for LA19-13-04 6GHZ VNA. Apr 2017]
[REFLECTION]
[RANGEDB]
-15, 0
[FREQ]
0, 1.99999
[MAGDB]
0.7
[PHASE]
8
[REFLECTION]
[RANGEDB]
-15, 0
[FREQ]
2, 6100
[MAGDB]
0.5
[PHASE]
4
[REFLECTION]
[RANGEDB]
```

Figure 6.42 The uncertainty definition is made up of several reflection and transmission segments. A reflection segment is highlighted above.

It is possible to define the uncertainty by a polynomial. To do this, follow the [MAGDB] keyword with the keyword [POLY]. Then, the uncertainty can be define by means of 3 coefficients, say, K_0 , K_1 , and K_2 . The uncertainty for given measured absolute magnitude value in dB, M , is given by:

$$U_p = K_0 + K_1M + K_2M^2$$

The same approach can be used to defining the phase uncertainty. That is, add the keyword [POLY] after the [PHASE] keyword.

The data compare utility resolves the total combined uncertainty as follows:

$$U_c = \sqrt{U_I^2 + U_R^2}$$

In the above, U_I is the uncertainty associated with the LA19-13-04A VNA and U_R is that provided with the reference DUT.

6.13 Closing Down the User Interface Window

It is recommended that a formal shut down of the user interface window is carried out before the VNA is to be switched off. This allows the calibration and status to be saved (so that it is restored next time the software runs) and the instrument's log file to be updated. The sequence is shown below in Fig. 6.41.

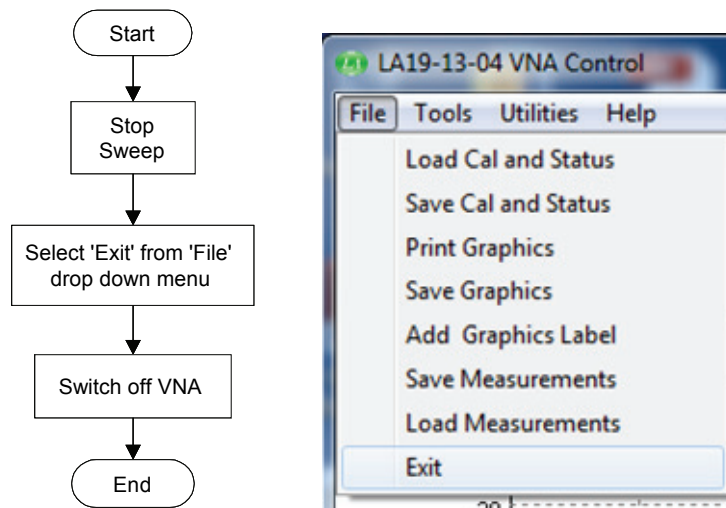


Figure 6.41 Formally closing down the software

Closing the program by clicking on the top right hand X will end the program without saving anything. A warning will be issued.

7 PERFORMANCE VERIFICATION AND MAINTENANCE

It is recommended that the instrument is checked periodically for safety (chassis grounding, fan operation, clear ventilation grilles and operator markings) and compliance with the stated electrical specification. Table 7.1 shows a possible suggestion of the parameters that should be checked as part of the calibration process. Note that the ventilation inlets / outlets should be checked as described later.

Table 7.1 Suggested annual instrument verification / calibration schedule

Measurement	DUT	Conditions	Calibration Type
S21 and S12, magnitude and phase	20 dB Attenuator	51 points sweep, 0.3-6000 MHz, 1kHz BW, -3 dBm test level.	12 term
S11 and S22, magnitude and phase	A known mismatch at ports 1 and 2 (-16dB or worse return loss)	51 points sweep, 0.3-6000 MHz, 1kHz BW, -3 dBm test level.	12 term
Or			
S11, S21, S22 and S12, magnitude and phase	Mismatched attenuator (> 10 dB attenuation and -16dB or worse return loss)	51 points sweep, 0.3-6000 MHz, 1kHz BW, -3 dBm test level.	12 term

It is recommended that the measured results should be compared with the values provided with the standards and be within the combined instrument uncertainty and provided reference measurements' uncertainty. The frequency values should be set to agree with those available for the standard(s) used. The recommended test arrangement is shown in Fig. 7.1. The results should be within the instrument's quoted uncertainty as detailed in the following section. Allowance should also be made for the uncertainty of the Standard reference values.

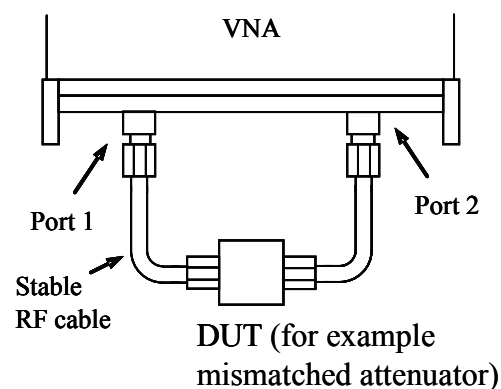


Fig. 7.1 Performance verification arrangement.

Tip: A data compare utility is provided in the user interface software that can be used to compare the measurements taking into account the uncertainty of the instrument.

7.1 Measurement Uncertainty

The measurement uncertainty figures below are based on calibration (12 term, insertable device, with -3 dBm test power and using 10Hz bandwidth) using 3.5mm calibration kits optionally supplied with the instrument. The plots for S21/S12 assume the DUT has a value of S11 and S22 of less than 0.2. Similarly, the plots for S11/S22 assume the DUT has a value of S21/S12 of less than 0.2. Other external factors such as connector and cables effects are excluded.

Table 7.2 Reflection (S11, S22) measurement uncertainty

Range	Magnitude	Phase
-15 dB to 0 dB		
Freq < 2MHz	0.7	8°
Freq > 2MHz	0.5	4°
-25 dB to -15 dB		
Freq < 2MHz	0.8	10°
Freq > 2MHz	1.0	6°
-30 dB to -25 dB		
Freq < 2MHz	3.0	20°
Freq > 2MHz	2.5	15°

Table 7.3 Transmission (S21, S12) measurement uncertainty

Range	Magnitude	Phase
+0 dBm to +6 dBm		
Freq < 2MHz	0.4	6°
Freq > 2MHz	0.2	2°
-40 dBm to 0 dBm		
Freq < 2MHz	0.3	2°
Freq > 2MHz	0.1	1°
-60 dBm to -40 dBm		
Freq < 2MHz	0.5	8°
Freq > 2MHz	0.3	4°
-80 dBm to -60 dBm		
Freq < 2MHz	2.0	15°
Freq > 2MHz	1.5	12°

7.2 Routine Maintenance

Electrical safety

The safety ground should be checked regularly in accordance with best practice. This should include a resistance test and a visual inspection of the mains connector and lead.

Ventilation grilles

Check that all ventilation grilles are clear of any debris, dust or any other material that may impede the flow of air. Particularly, check the vents in the bottom panel of the instrument. It is advisable to brush these to remove any gradual build up of dust.

Failure to clean the ventilation grilles may lead to overheating and eventual failure of the instrument.

Front panel connectors

The Port 1 and Port 2 N-type connectors should be inspected routinely for signs of damage or dirt. It is recommended that adaptors are used whenever possible to prevent damage or wear to the fixed connectors.

8 PERFORMANCE SPECIFICATION

The instrument's performance specification is given below. Unless otherwise stated, the figures apply with 10Hz resolution bandwidth, at -3dBm test power, 12-term calibration (for insertable DUT) using the enhanced isolation option, at an ambient temperature of $23 \pm 1^\circ\text{C}$ and 60 minutes after power up.

Specifications	
Measuring Functions	
Measuring parameters	S11,S21,S22, S12 Mixer conversion loss, return loss, compression and port isolation P1dB (Power at 1dB gain compression) AM-PM conversion factor
Error correction	12 term, 8 term (unknown through calibration), S11 (1 port correction) S21 (normalise, normalise + isolation) S21 (source match correction + normalise + isolation) averaging, smoothing, Hanning and Kaiser Bessel filtering on time domain measurements, electrical length compensation (manual), electrical length compensation (auto), de-embed (2 embedding networks may be specified), impedance conversion
Display channels	4 channels (CH1, CH2, CH3, CH4)
Traces	2 traces / channel
Display formats	Amplitude (logarithmic and linear) Phase, Group Delay, VSWR, Real, Imaginary, Smith Chart, Polar, Time Domain
Memory trace	one per channel
Limit lines	6 segments per channel (overlap allowed)
Markers	8 markers
Marker functions	Normal, Δ marker, fixed marker, peak / min, 3 dB and 6 dB bandwidth

Specifications	
Signal Source Characteristics	
Frequency range	300 kHz to 6.020 GHz
Frequency setting resolution	10 Hz
Frequency accuracy	± 10 ppm ($23 \pm 3^\circ\text{C}$)
Frequency temperature stability	± 0.5 ppm/ $^\circ\text{C}$ (15 to 35°C)
Harmonics (-3 dBm output level)	-20 dBc
Non-harmonic spurious (typical)	-40 dBc
Phase noise (10 kHz)	-90 dBc/Hz (0.3 MHz to 1000 MHz) -80 dBc/Hz (1000 MHz to 4000 MHz) -76 dBc/Hz (>400 MHz)
Output power	+6 to -20 dBm (+3 to -20 dBm for $F > 4\text{GHz}$)
Power setting resolution	0.1 dB (nominal)
Output power accuracy	± 2.0 dB
Reference input frequency	10 MHz ± 6 ppm
Reference input level	0 ± 3 dBm
Reference output level	0 ± 3 dBm

Specifications	
Sweep Functions	
Sweep type	Linear sweep, CW sweep (timed sweep) Power sweep (P_{1dB} utility)
Trigger modes	Free run Positive trigger Negative trigger Manual trigger
Sweep times (full 2 port calibration) Bandwidth set to 140kHz, no averaging	201 points : 37 ms (Freq > 5 MHz)
Number of points	51, 101, 201, 401, 801, 1001, 1024, 2001, 4001, 9001, 10001

Specifications			
Receiver Characteristics			
Resolution bandwidth (Hz)	140 k, 70 k, 35 k, 15 k, 10 k, 5 k, 1 k, 500, 100, 50, 10		
Averaged displayed noise floor (dB) S21 calibration, BW set to 10Hz , test ports terminated as per during isolation calibration step	Band	Typ	Max
	0.3MHz-10MHz	-110	-100
	10 MHz-4 GHz	-118	-108
	4 GHz – 6 GHz	-110	-100
Dynamic range (dB) BW set to 10Hz, test ports terminated in 50 ohm load.	See Fig. 8.1		
Temperature stability (typical)	0.02 dB/°C for frequency < 4 GHz 0.04 dB/°C for frequency \geq 4 GHz		
Trace noise (mdBrms) Full band, test level set to 0 dBm, 201 point sweep	Bandwidth	Typ	Max
	10KHz	0.8	2
	70KHz	3	5
	140KHz	5	10

Specifications			
Test Port Characteristics			
Load match (uncorrected)	16 dB typ		
Source match	16 dB typ (uncorrected) 40 dB min (48 dB typical)		
Directivity (corrected, using 3.5mm cal kit)	40 dB min (47 dB typical)		
Crosstalk (dB, corrected) Test ports terminated with short circuits, value is average displayed noise level.	Band	Typ	Max
	0.3 kHz – 2 MHz	-100	-90
	2 MHz – 4 GHz	-110	-90
	4 GHz – 6 GHz	-100	-90
Main test ports maximum input level (1 dB compression)	+10 dBm		
Main test ports maximum input level (no damage)	+20 dBm		
Main test ports connectors	Type N (female)		
Bias-T maximum current	250 mA		
Bias-T maximum dc voltage	+25 V		
Bias-T current protection	Built-in resettable fuse		
Bias-T dc port connectors	SMB (female on front panel)		
Sweep trigger input voltage	Low: -0.1 to +1.0V High: +2.0 to +4V		

Specifications	
Mixer measurements	
Frequency range	0.3 to 6020 MHz
Input power sweep range	-17 to 6 dBm (3 dBm for F > 4 GHz)
Input power sweep step	0.5 dB (nominal)
LO Source	External, required
Power level calibration	External power sensor supported with option to use internal receivers with reduced accuracy
Measurements	Conversion loss, return loss, isolation and compression
Accuracy (conversion loss with return loss correction applied)	0.2 dB (typical)
Display format	Graphical, conversion loss, return loss, isolation and compression

Specifications	
P1dB Utility	
Frequency range	0.3 to 6020 MHz
Input power sweep range	-20 to 3 dBm
Input power sweep step	1 dB (nominal)
P1dB calculation method	2 nd order curve fit
Display format	Graphical, gain and output power
Accuracy	0.5 dB (typical)

Specifications	
AM to PM Utility	
Frequency Range	0.3 to 6020 MHz
Input power sweep range	-20 to 0 dBm
Input power sweep step	1 dB (nominal)
AM to PM point calculation method	2 nd order curve fit
Display format	Graphical, phase conversion (deg / dB)
Accuracy (Port 2 power +5 to -20 dBm)	1° (typical)

Specifications	
Signal Generator Utility	
Frequency range	0.3 to 6020 MHz
Output power	-20 to +3 dBm
Setting resolution	0.1 dB
Output power accuracy	±2.0 dB max

Specifications	
Group Delay	
Range (180° maximum phase shift per frequency step)	$\tau = \frac{0.5}{\Delta f}$ where Δf is the aperture frequency
Aperture frequency	Frequency sweep step size
Accuracy	$\Delta \tau = \frac{\text{PhaseError}}{360 \cdot \Delta f}$

Specifications	
Data Handling	
Calibration data	Store / Recall on hard disk / floppy disk
Calibration kit data	Store / Recall on hard disk / floppy disk
Print measured data (graphics)	To any printer installed on host PC
Save measured data (graphics)	To hard disk / floppy disk
Measured data	Store on hard disk / floppy disk
Measured data (Touchstone® format)	Store on hard disk / floppy disk
Measured data (Touchstone® format)	Recall to memory trace from hard disk / floppy

[Touchstone® is a Trade Mark of Keysight Technologies]

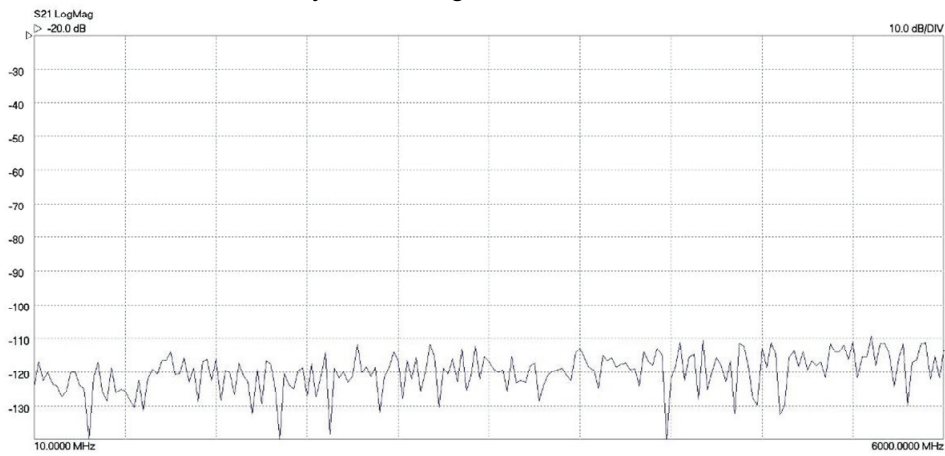
Specifications	
Accessories	
Calibration kit (3.5mm*, male) Model DW97158	Matched load, short, open, male to male adaptor
Calibration kit (3.5mm*, female) Model DW97157	Matched load, short, open, female to female adaptor
Mismatched line (3.5mm female connector on port 1, 3.5mm male connector on port 2)	Insertable 25 Ω transmission line, nominal electrical delay of 470 ps

* SMA compatible connector

Specifications	
Miscellaneous	
Controlling PC data interface	USB
Controlling PC minimum requirements	Pentium 4 (3 GHz) or equivalent 1GB RAM 200 MB Hard disk storage on C: partition Windows© XP or higher
External dimensions (L x W x H)	286 x 174 x 61 mm
Weight	2.1 kg
Temperature range (operating)	15°C to 35°C
Temperature range (storage)	-20°C to 50°C
Humidity	80% max (non-condensing)
Power source	DC, 12 – 15V, 1.6A max

Windows is a Trade Mark of Microsoft Corporation

Dynamic range 10 MHz to 6 GHz



Dynamic range 0.3 MHz to 10 MHz

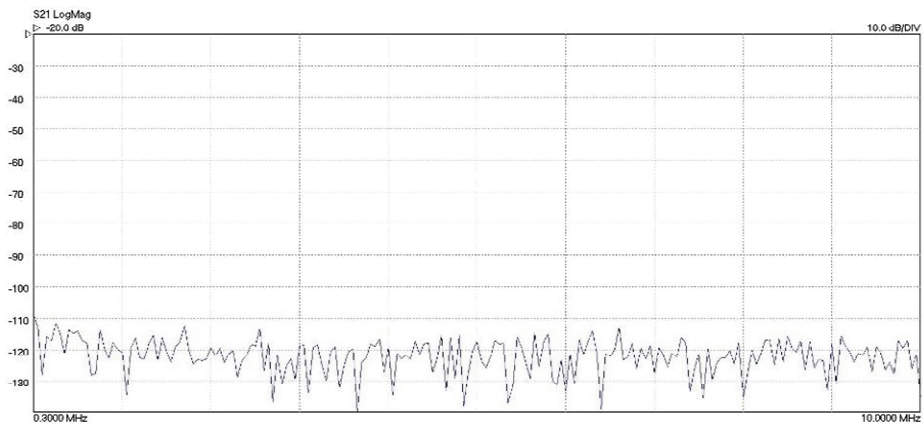


Figure 8.1: Typical system dynamic range ($P_{\text{test}} = +6\text{dBm}$, $\text{BW} = 10\text{Hz}$)

9 TROUBLESHOOTING GUIDE

WARNING! No user serviceable parts in this instrument. Refer servicing and repairs to a trained person.

Symptom	Possible Cause	Possible solution
Instrument does not power up	<ul style="list-style-type: none"> Power not applied Incorrect supply 	<ul style="list-style-type: none"> Check dc connection Check external supply
UI software unable to communicate with the instrument	<ul style="list-style-type: none"> Driver not installed Link interrupted 	<ul style="list-style-type: none"> See Section 5.3 Re-start instrument and UI software
Instrument sweeping but display not refreshing	<ul style="list-style-type: none"> Data link interrupted 	<ul style="list-style-type: none"> Re-start instrument and UI software
Display freezes	<ul style="list-style-type: none"> PC crash 	<ul style="list-style-type: none"> Ensure PC's video driver is the latest version (consult your PC supplier)
'Last Calibration not found' message on power up	<ul style="list-style-type: none"> 'C:\users\public\public documents\LA19-13-04A' directory deleted or corrupted 	<ul style="list-style-type: none"> Restore folder. Set up display and calibrate. Exit the software using File/Exit item from the drop down menu. This will save the current calibration in a file named defcal.cal.
Diagnostics Tests (under 'Tools' menu) fail	<ul style="list-style-type: none"> Data corruption 	<ul style="list-style-type: none"> Re-start instrument and re-start UI software. Ensure test cable used is in good condition.
Error reading data files	<ul style="list-style-type: none"> Invalid format Too many lines Leading space(s) 	<ul style="list-style-type: none"> Check for correct format / '#' line Number of lines must be < 1000 Remove leading spaces from data lines

Diagnostics tests

It is possible to run self-check tests on the instrument. This facility (Diagnostic Tests) is available from the 'Tools' menu as shown in Fig. 9.1. In order to complete the tests a low loss cable is required to link Port 1 to Port 2. The tests carry out the following checks.

- Synthesisers: test that they remain in lock over the frequency range
- Test signal: test the level range and step size
- Receiver levels: test that the receiver is operating at normal signal levels
- Receiver crosstalk: test that raw crosstalk remains below limit

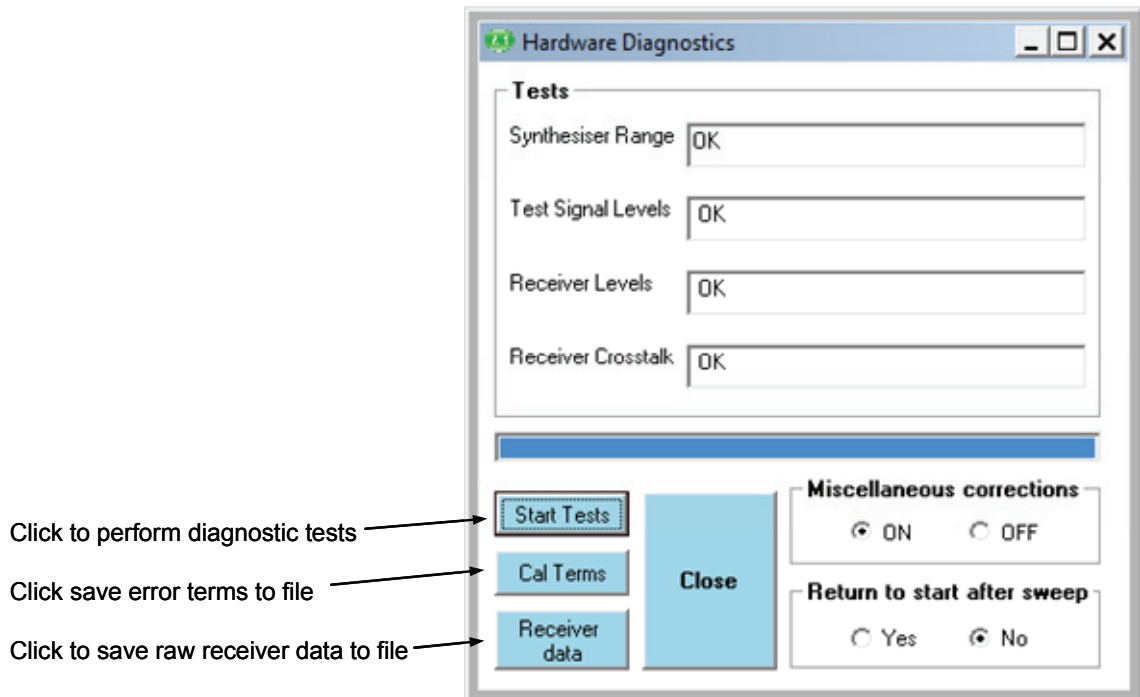


Figure 9.1 The Diagnostics Tests perform internal checks on key components

If any of the tests returns an error, check connectors and linking cable. If this does not resolve it, re-start the instrument and UI program. Wait until the front panel channel activity indicators have stopped flashing after pressing reset to continue with the tests.

Calibration error terms and raw receiver data

The diagnostics tests dialog form (Fig.9.1) also provides the facility for retrieving the calibration error terms and raw receiver data. The latter can be helpful for users wishing to carry out their own calibration procedure.

10 WARRANTY

This instrument is warranted against any defects of material or workmanship within a period of three years following the date of delivery. Any instrument claimed to be defective during the warranty period should be returned to LA Techniques Ltd at the owner's risk and expense. Prior to return, LA Techniques or its representative must be contacted to obtain a Returns Material Authorisation. For your local representative, contact LA Techniques or visit its web site at <http://www.latechniques.net>

LA Techniques Ltd does not guarantee that the operation of the instrument, software or firmware will be error-free or uninterrupted.

The warranty above shall not apply to defects caused by improper or inadequate maintenance by the user, user-supplied software, user modifications or misuse, operation outside the stated environmental specification.

11 EC DECLARATION OF CONFORMITY

We, LA Techniques Ltd, Unit 5, Red Lion Road, Surbiton, Surrey KT6 7RA, UK declare that the instrument model number meets the intent of the EMC Directive 2004/108/EC and the Low Voltage Directive 2006/95/EC.

EMC

Emissions: EN61326-1 (2006) Radiated, Class B
EN61326-1 (2006) Conducted, Class B
EN61326-1 (2006) Harmonics

Immunity: EN61326-1 (2006) Immunity Table 1 referring to:

EN61000-4-6 (2007) Conducted RF
EN61000-4-5 (2006) Surges
EN61000-4-4 (2004) Transient immunity
EN61000-4-3 (2006) Radiated immunity
EN61000-4-2 (1995) Electrostatic discharge
EN61000-4-11 (2004) Dips and interruption

Safety

EN61010-1 (2001) Safety requirements for electrical equipment for measurement or control in laboratory use.

Compliance with the requirements of the EMC Directive 2004/108/EC was demonstrated by achieving the test limits of the following standards:

Emissions:

EN61326-1 (2006) EMC product standard for electrical equipment for measurement, control and laboratory use:

- (i) Radiated: Class B
- (ii) Conducted: Class B
- (iii) Harmonics: Class A

Immunity

EN61326-1 (2006) EMC product standard for electrical equipment for measurement, control and laboratory use:

- (i) EN61000-4-2 (1995) Electrostatic discharge: 4kV air, 4kV contact; test result A (requirement B)
- (ii) EN61000-4-3 (2006) RF immunity: 80% AM at 1KHz, 80MHz to 2.7GHz band, 3V/m and 1GHz to 3GHz, 6V/m (voluntary); test result A (requirement A)

(iii) EN61000-4-11 (2004) Dips and interrupts: 100% for 10ms and 60% for 100ms; test result A (requirement B). 60% for 200ms, 30% for 500ms, 30% for 1000ms; test result A (requirement B). 100% for 5000ms; test result C (requirement C)

(iv) EN61000-4-4 (2004) Fast Transient Immunity: ± 0.5 and ± 1 kV peak into AC line; test result A (requirement B). ± 0.5 and ± 1 kV peak into control cable; test result A (requirement B)

(v) EN61000-4-5 (2006) Surges: ± 0.5 kV, ± 1 kV and ± 2 kV, line to earth and line to line; test result A (requirement B)

(vi) EN6100-4-6 (2007) Conducted RF immunity: 3V and 6V (voluntary), 80%AM at 1kHz, 150kHz to 80MHz, AC line and control; test result A (requirement B)

For guidance, performance criteria are as follows:

Performance criterion A: *The equipment shall continue to operate as intended without operator intervention. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer when the equipment is used as intended. The performance level may be replaced by a permissible loss of performance. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, then either of these may be derived from the product description and documentation, and by what the user may reasonably expect from the equipment if used as intended.*

Performance criterion B: *After the test, the equipment shall continue to operate as intended without operator intervention. No degradation of performance or loss of function is allowed, after the application of the phenomena below a performance level specified by the manufacturer, when the equipment is used as intended. The performance level may be replaced by a permissible loss of performance. During the test, degradation of performance is allowed. However, no change of operating state or stored data is allowed to persist after the test. If the minimum performance level (or the permissible performance loss) is not specified by the manufacturer, then either of these may be derived from the product description and documentation, and by what the user may reasonably expect from the equipment if used as intended.*

Performance criterion C: *Loss of function is allowed, provided the function is self-recoverable, or can be restored by the operation of the controls by the user in accordance with the manufacturer's instructions. Functions, and/or information stored in non-volatile memory, or protected by a battery backup, shall not be lost.*

N Nazoa
LA Techniques Ltd
23 Apr 2019

Index

- activity indicators, 27
- Aliasing**, 24
- AM to PM conversion**, 19
 - Utility, 74
- Averages, 37
- Back Panel, 10
- Calibration, 46
- Calibration Kit, 27
- Closing Down, 78
- Compare data, 76
- Crosstalk, 83
- Data
 - loading, 70
 - saving, 69
- Data Link Interruption, 46
- Diagnostics Tests**, 87
- Directivity, 83
- Display Set Up, 32
- Dwell Time, 37, 38
- Electrical Safety**, 81
- Enhancement, 37
- Front Panel, 10
- Front Panel Connectors**, 81
- Gain compression**, 18
 - Utility, 72
- Graphics
 - plotting, 70
 - saving, 71
- Group delay**, 18, 56
- Insertion Loss, 55
- Level, 37
- Limit Lines, 42
- Load Match, 83
- Marker, 35
 - Active, 35
 - Fixed, 35
 - Normal, 35
 - Reference, 35
 - Set Up, 36
- Measurement Uncertainty, 80
- Memory, 41
- Normalization**, 67
- Operation, 32
- PC, 25
- Performance verification, 79
- Phase**, 17
- Raw receiver data**, 88
- Reference Plane Extension, 37, 66
- Reflection parameters**, 16
- Resolution Bandwidth, 83
- Return Loss, 55
- Reverse Measurements, 62
- Routine Maintenance, 81
- Safety, 11
- Saving current calibration, 78
- Signal Generator, 71
- single conversion, 9
- Smith Chart, 15
- Smoothing, 37
- SOLT, 16
- Source Match, 83
- S-parameters, 13
- Specification, 82
- Start / Stop, 45
- Status Panel, 44
- Switching on, 27
- Time Domain**, 19, 57
 - Options, 59
 - Transmission, 61
- Trace Smoothing, 37
- Transmission parameters**, 17
- Troubleshooting, 87
- Ventilation Grilles**, 81
- Warranty, 89
- Windowing**, 24