# RF and MICROWAVE TEST SETS

# 6200B SERIES



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# CONTENTS

# PREFACE

## About this manual

The purpose of this manual is to show how the 6200B Series of RF and Microwave Test Sets (MTS) can be used for common microwave measurements. It serves to demonstrate many of the features and capabilities of the MTS in actual measurement situations. By following the example measurement procedures provided in this guide you will soon become familiar with the basic controls and capabilities of the instrument, and will see how quickly and easily accurate measurements can be made.

This chapter provides an overview of front panel operation and then presents a general procedure for making microwave measurements. The same procedure is followed throughout the examples in Chapter 2.

Chapter 2 illustrates the MTS at work making some typical measurements. The examples provided illustrate many of the instrument's features and their ease of implementation. A basic insertion loss measurement is covered first, with subsequent examples generally becoming more complex. The chapter concludes with an example showing how vector and time domain measurements can be made when a 6210 Reflection Analyzer is connected to the MTS.

When you are familiar with the basic operation of the MTS, you can then make fullest use of the more detailed information contained in the MTS Operating Manual, which includes detailed descriptions of all the soft key menus. GPIB operation is not covered in this manual; this information can be found in the GPIB Operating Manual.

WARNING

**Observe the warnings given in the 'Precautions' section of the Operating Manual for the 6200B Series RF and Microwave Test Sets.**

## Conventions

The following conventions are used in this manual:

| | |
|---|---|
| CAPS | Capitals are used to identify names of controls and panel markings, or system functions where no direct reference to an associated key is intended. |
| [CAPS] | Capitals in square brackets indicate hard key titles. |
| *[Italics]* | Italics in square brackets indicate soft key titles. |
| *[Averaging ●]* | A '●' after a soft key title indicates that the key has a toggle action, and that the function is enabled. |
| *[Averaging ○]* | A '○' after a soft key title indicates that the key has a toggle action, and that the function is disabled. |

# Chapter 1
# INTRODUCTION

## Controls overview

The front panel of the MTS has been designed to simplify operation and provide a logical approach to making measurements. It is assumed that you are familiar with the basic concepts of the MTS user interface; this is covered in detail at the front of Chapter 3 of the MTS Operating Manual. A brief outline of the functions of the front panel hard keys is given below:

### The Function keys

These give access to the main operational aspects of the MTS, and provide a logical approach to making measurements. Soft keys and menus are used for further selection. The keys in this group are:

**[SOURCE]** Provides control of the synthesized sweep generator and the programmable voltage/current source.

**[MEASURE]** Provides menus allowing the measurement to be set up and defined, and to apply various functions to aid examination and interpretation of the measurement results.

**[CAL]** Enables system errors to be removed prior to a measurement, detectors/sensors to be zeroed and sensors to be calibrated.

**[FORMAT]** Enables selection of the units in which scalar measurements are displayed. For reflection analyzer measurements, this key enables selection of the display format in which the information is presented.

**[SCALING]** Enables the size and placement of the trace on the graticule to be adjusted.

**[MARKERS]** Provides access to various marker functions, which allow the measurement to be examined in greater detail.

### The System keys

These provide access to various system functions:

**[COPY]** Accesses the hard copy capabilities of the MTS. Hard copies off all measurements can easily be obtained, either on a suitable parallel printer or a GPIB plotter with HPGL language. Recommended printers/plotters are listed in 'Associated Equipment' in Chapter 1 of the MTS Operating Manual.

| | |
|---|---|
| **[SAVE/RECALL]** | Enables instrument settings and measurement traces to be saved or recalled. Memory cards can be used to extend the number of stores available. Facilities are also provided to make measurements relative to a previously stored measurement. |
| **[MACRO]** | Enables a sequence of key presses and on-screen operator prompts to be stored and later recalled to simplify and automate complex measurement tasks. |
| **[UTILITY]** | Provides access to instrument setup, service and diagnostics functions. |
| **[HOLD]** | Used to hold (freeze) the display of a measurement. |
| **[LOCAL]** | Used to return the instrument to local (front panel) operation after being put into the remote (GPIB controlled) mode. It will also terminate a macro. |
| **[PRESET]** | Returns the instrument to its default set-up conditions. Alternatively, it can be set to the conditions defined by settings store 10, or a macro can be run to define the startup conditions. |

## The Display keys

These are used to specify the number of channels and measurements that are to be displayed, which of these is active, and enables the channel mode to be defined (i.e. scalar, readout, fault location or reflection analyzer).

| | |
|---|---|
| **[SELECT MEAS]** | Cycles around all the displayed measurements, making each active in turn. |
| **[MEAS 1 ON/OFF]** | Toggles measurement 1 on or off within the active channel |
| **[MEAS 2 ON/OFF]** | Toggles measurement 2 on or off within the active channel |
| **[SWITCH CHANNEL]** | Switches to the other channel, making it active. |
| **[CHANNEL MODE]** | Determines the type of measurement that the channel displays (scalar, readout, fault location or reflection analyzer). |

## General measurement sequence

Below is a summary of the general measurement procedure that is used in the example measurements presented in Chapter 2. The sequence shown provides a systematic approach to making microwave measurements. Some steps may not be relevant to a particular measurement, for example, format and scaling do not apply to frequency readout measurements.

- Use [PRESET] to put the instrument into a known state.
- Use [MEAS 1 ON/OFF], [MEAS 2 ON/OFF], [SWITCH CHANNEL] to define the display configuration.
- Use [SOURCE] to define the stimulus to be applied during the measurement.
- Use [MEASURE] to define the measurements to be made.
- Use [CAL] to calibrate out any systematic errors in the measurement path, to zero detectors/sensors, and to calibrate sensors.
- Use [FORMAT] to select the units for each measurement response.
- Use [SCALING] to select the appropriate scale and position for each measurement trace.
- Use [MARKERS] and other MTS features to examine the measurement in detail.
- Use [COPY] to create a permanent record of the measurement results.
- Use [SAVE/RECALL] to save the instrument or measurement traces for future use, and to specify measurements relative to memory.

In the example measurements of Chapter 2, the actual keys to be pressed are shown in the left hand column of the page. In the right hand column an explanation of the effect of the keys is given.

# Precautions

## Microwave connectors

Care should be taken when using microwave connectors, both on the MTS and any accessories that are used, such as cables, adapters, attenuators, etc. Complying with the following precautionary notes will ensure longer component life time and less equipment downtime due to connector or component failure. These measures will also help to ensure that the components will operate within specification and give repeatable results.

- The precision connectors fitted to the MTS, and its accessories may be damaged by mating with a non-precision type. Damage to these and other connectors may occur if the connector interface parameters are not within specification. This should be checked with the appropriate gauging tool. It is strongly recommended that every connector be gauged prior to its first use and regularly thereafter, e.g. every 20 connections.
- The precise geometry of the connectors can be easily degraded by dirt and other contamination adhering to connector interfaces. Alcohol is the recommended cleaning agent, and a clean, damp cotton swab is the recommended applicator. When not in use, keep the connectors covered with the protective caps provided.
- Always use the correct mating techniques. In particular, the two connectors to be mated should be pressed together such that the pin penetrates the collet prior to the nut being tightened. Never rotate one connector body relative to the other because this wears out the mating interfaces, thus reducing connector lifetime.
- Avoid over-torquing connectors during mating, because it may damage the connector centre pin or may cause the connector body to turn in its housing.
- Avoid mechanical shock by dropping or otherwise roughly handling microwave components.

## Calibration kit handling precautions

The calibration kit used for reflection analyzer measurements requires special handling precautions to be observed. Refer to Appendix E in the MTS Operating Manual for full details.

## Excessive detector input power

The 6230A/L Series EEPROM scalar detectors that are used with the 6200B Series MTS utilise zero-biassed Schottky diodes. These are of a physically small geometry and consequently can be damaged under high power conditions. **It is strongly recommended that care is taken to avoid exceeding an input power of +20 dBm for 'A' versions and +26 dBm for 'L' versions during normal operation.**

# Chapter 2
# EXAMPLE MEASUREMENTS

## Example 1: Insertion loss measurement of a band-pass filter

In the first example measurement, we will measure the insertion loss response of a 9 GHz band-pass filter. This will be a narrowband measurement so that the passband response can be examined in detail. The measurement system is shown below:

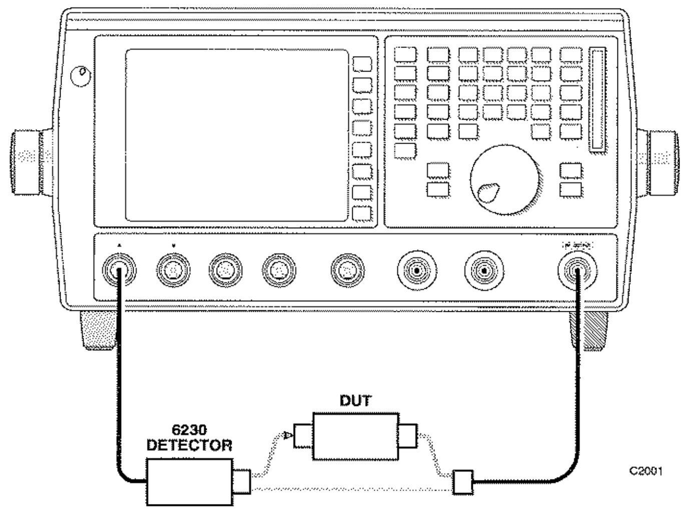



*Fig. 2-1 Setup for single channel insertion loss measurement*

Although a ratio system involving a reference detector and a power splitter could be used to improve mismatch uncertainty, the source match of the synthesized sweep generator within the MTS is sufficiently good to make it unnecessary in the majority of measurement situations. (Example 5 provides an example of a ratioed measurement.)

Connect the detector as shown in Fig. 2-1. The 6230 detector contains a self-identification mechanism which results in the appropriate linearity correction data being applied automatically.

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]**<br>***[Default Settings]*** | Pressing these keys will result in the instrument being preset to its default state, as defined in Appendix A of the Operating Manual. The Channel Mode menu will be displayed along with a single scalar channel measurement of input A (Fig. 2-2). |

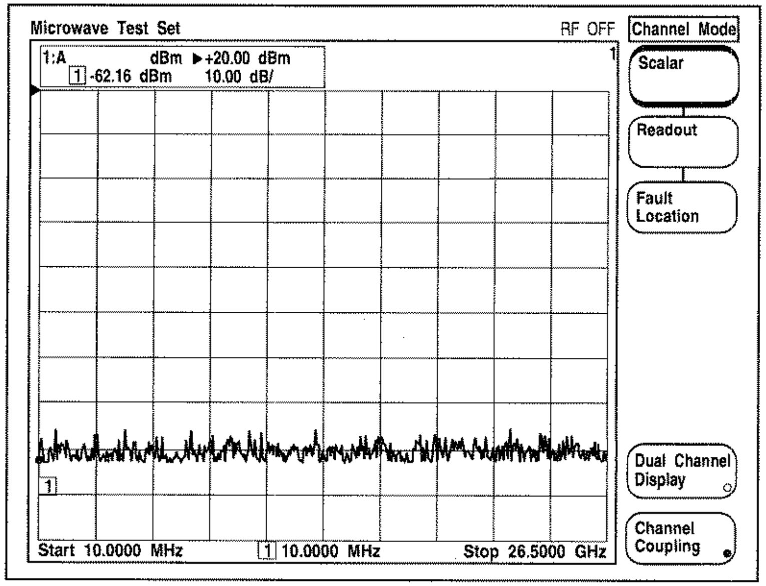



*Fig. 2-2 Single channel display*

## Step 2 - Define the display configuration

Measurement 1 of channel 1 will be used to display the insertion loss of the filter. Since the default state of the instrument is a single scalar channel displaying measurement 1, we can proceed immediately to Step 3.

## Step 3 - Define the source conditions

Following the pressing of the [PRESET] key in Step 1, all the source parameters have been set to their default values. A complete list of the default conditions may be found in Appendix A, but the major ones are shown below:

| | |
|---|---|
| Start Frequency | 10 MHz ($F_{min}$) |
| Stop Frequency | Maximum available ($F_{max}$) |
| Output Power | 0 dBm |
| Number of Points | 401 |
| Sweep Time | Auto |
| RF | Off |
| Source Mode | Start & Stop Frequency Sweep |
| Channel Coupling | On |

Since the passband of the filter we wish to measure is centred at 9 GHz, it is necessary to change the start and stop frequency values. The output power level, number of measurement points and sweep time can remain at their default settings.

| | |
|---|---|
| **[SOURCE]** *[Set Start Frequency]* | This results in a dialogue box being displayed which shows the existing value of the parameter and prompts you to enter a new value. Whilst such a dialogue box is displayed the rotary control and step keys may be used to change the value; alternatively the numeric keys may be used to enter a specific value. |
| **[8] [$G_n$]** | Once entered, the graticule annotation will reflect the change in start frequency value. |
| *[Set Stop Frequency]* **[1] [0] [$G_n$]** | Sets the stop frequency to 10 GHz. |
| **[ENTRY OFF]** | The dialogue box is removed by pressing this key. |
| *[RF ●]* | RF power is toggled on and off by pressing this soft key. The indicator in the bottom right hand corner of the soft key box is illuminated and the **RF ON** symbol is displayed in the instrument status information field (at the top of the display) in red. An indicator above the RF OUTPUT connector is also illuminated when the RF power is turned on. |

## Step 4 - Define the measurements

From Fig. 2-1 we see that the insertion loss is measured by a scalar detector connected to input A of the MTS. Again, no changes need to be made since all measurements default to input A following PRESET.

At this stage, the decision to use either AC or DC detection should be made. When making swept measurements, AC detection mode will tend to give you better low level measurements than DC detection. The reason is that in AC detection mode, the RF output is chopped, and the analyzer constantly compares the RF ON level to the RF OFF level. Because the analyzer is always measuring the RF OFF level, the effects of zero drift are effectively cancelled. In the DC detection mode, an unmodulated RF signal is used and the detector simply converts the incident RF to an equivalent DC output. This mode will have to be used, for example, when measuring amplifiers with automatic gain control that cannot handle AC modulation.

It should be noted that the detection mode is not affected by an instrument preset; it is the same as the detection mode that existed when the instrument was last powered down. In this example, the DC detection mode will be used, and is set as follows:

| | |
|---|---|
| **[MEASURE]** *[General Set-up]* *[DC Detection]* | If the *[DC Detection]* soft key label is not highlighted, press it to select DC detection mode. |

It is worth noting that by default, i.e. following the use of the [PRESET] key, **detector autozeroing** is enabled. This is indicated by the **AZ** indicator in the General Information Area. When it is on, detector zeroing will be performed as a background task in the inter-sweep period. The RF is turned off automatically whilst the zero takes place. This process removes any drift in the zero level of the data acquisition system. If you change the detector connected to a particular input, you should perform a manual detector zero by selecting [CAL] *[Det/Sensor Zero] [Zero Detectors]*.

## Step 5 - Calibrate the measurement system

Before making any measurements on the filter the measurement system must be calibrated.

Although the synthesized sweep generator produces a levelled output signal there are still some residual errors resulting in a source power flatness accuracy of ±1 dB. Also, any components such as cables and adapters placed between the source's RF output and the DUT will have a frequency response. In addition, the scalar detector or autotester being used to make the measurement also has a power variation with frequency. All of these power variations with frequency will affect the accuracy of the measurement and should therefore be removed. Since they are systematic variations their effect can be removed by performing a 'Path Calibration', i.e. by calibrating out the variations in the measurement path.

| | |
|---|---|
| **[CAL]** *[Through Cal]* | Presents a text box informing you that you are about to perform a through path cal and that the path cal store to be used is store 1. The message also prompts you to make a through connection, i.e. connect the detector on input A to the RF output of the MTS (via any cables or adapters that will be used to connect the RF output to the DUT). |
| ***[Continue]*** | Initiates the path calibration. |

Having completed the through path calibration for the measurement path, the path cal data is automatically applied to measurement 1. This is indicated by the presence of **PC1** in the trace information box for that measurement, and shows that path cal store 1 has been applied. If the path calibration becomes invalid (e.g. due to subsequent changes in measurement parameters), a warning message will be displayed and the path cal indication changes to **PC1?**.

Now connect the filter between the connecting cable and the scalar detector.

## Step 6 - Choose the format

When the [PRESET] key was pressed in Step 1 the default format for a scalar channel was set to dBm. Since the measurements are now relative to the path calibrations their units are displayed in dB. No change is therefore required to the default format setting.

## Step 7 - Select appropriate scaling

The default scaling is satisfactory for this measurement, i.e. a reference level of +20 dB located at the top graticule line and a scale factor of 10 dB/div.

Alternatively, suitable scaling could be achieved through the use of the autoscale facility which results in setting the reference level and scaling such that the trace occupies approximately 80% of the graticule height.

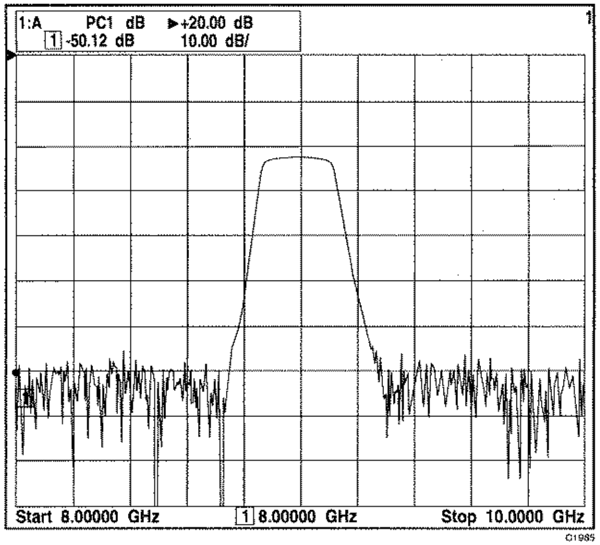



*Fig. 2-3 Insertion loss measurement*

## Step 8 - Use markers and other MTS features to get detailed information about the measurement

It is often necessary to obtain detailed information about a specific feature of a measurement. This can be achieved through the use of markers. By default (i.e. following the use of the [PRESET] key) the active marker will be enabled. Use of the rotary control will allow the marker to be moved anywhere across the graticule, and the frequency domain and response values at any measurement point will be displayed.

If it is required to determine the maximum point of the response, for example, carry out the following steps:

| | |
|---|---|
| **[MARKERS]**<br>***[Mkr Functions]*** | Presents a sub-menu which allows access to a number of functions which provide automatic manipulation of the markers to measure performance features such as -3 dB cutoff points (for bandwidth measurements) and peak-to-peak ripple. These functions are particularly useful for measuring the performance of the band-pass filter used in this example. |
| ***[Marker to Max/Min]*** | Presents a sub-menu. |

| | |
|---|---|
| *[Active Mkr to Maximum]* | Places the active marker (marker 1 by default) at the maximum point of the response. This is the point of minimum insertion loss in the filter pass band, and the value is displayed in the trace information box. The frequency at which this occurs is displayed below the graticule. |
| *[Return to Mkr Funcs]* | Returns to the Mkr Funcs menu. |

A bandwidth measurement can be carried out in the following way:

| | |
|---|---|
| *[Bandwidth]* | Selects the Bandwidth menu. |
| *[Set n dB Value]* [-] [3] [x1] | Sets the dB value that is used to determine the bandwidth. In this case, the bandwidth will be determined corresponding to the -3 dB points on the trace. |
| *[Bandwidth Search]* | Initiates the bandwidth search and displays the result in a form overlaying the graticule. The form is removed if there is any change in the measurement or markers, or if the [ENTRY OFF] key is pressed. If the bandwidth function is successful, marker number 7 will be placed at the lower frequency -3 dB point, and marker number 8 will be placed at the upper one. |

If the filter is tuneable, the tracking facility can be turned on using the *[Tracking]* soft key, the bandwidth function is applied automatically at the end of each sweep, thus continually updating the bandwidth measurement.

Other features of the Markers menu include:

| | |
|---|---|
| [MARKERS] *[Position Active Marker]* | Used to enter a specific frequency value to which the active marker will be set. |
| *[Delta Mkr ●]* | Enables the delta marker; this is indicated by Δ on the display. Measurements are now made relative to the delta marker position. |

Another way of checking that the device under test (DUT) meets its specification is through the use of limit checking. A limit 'mask' is set which defines the acceptable performance for the DUT against which it will be checked. A pass/fail indication is then displayed on the screen. As an example, consider the passband response of the filter, which we will assume should fall within the limits -1 dB and -2.5 dB relative to the path calibration, over the frequency range 8.9 GHz to 9.1 GHz. To test for this you can use limit checking in the following way:

| | |
|---|---|
| [MEASURE] *[Limit Checking]* *[Edit Specification]* | A window is displayed containing **Limit Checking Specification 1** (by default). This consists of fields for **start** and **stop** domain values i.e. stimulus and the corresponding **upper** and **lower** response values. |

| | |
|---|---|
| ***[Add Segment]*** | A new segment is added to the table with zero values in all fields. The start field value is highlighted. |
| ***[Flat]*** | It is possible to set **slope** and **point** segments but to test the filter passband a **flat** segment is required. |
| **[8] [.] [9] [$G_n$]** | This sets the **start** domain value to 8.9 GHz. The highlight moves to the **upper** response field. |
| **[-] [1] [x1]** | An **upper** response value of -1 (dB) is selected. The highlight moves to the **lower** response field. |
| **[-] [2] [.] [5] [x1]** | A **lower** response value of -2.5 (dB) is selected. The highlight now moves to the **stop** domain field. |
| **[9] [.] [1] [$G_n$]** | This sets the **stop** domain value to 9.1 GHz. The highlight moves back to the **start** field since you don't need to specify upper and lower response values for the stop domain as they are the same as those of the start domain value for a flat segment. |
| ***[Return to Edit Spec]*** ***[Return to Lim Checking]*** | Returns to the Lim Checking menu. |
| ***[Limit Checking ●]*** | When this key is pressed the indicator in the bottom right corner of the soft key label is illuminated to indicate that limit check is now 'on'. The upper and lower limit lines appear on the graticule along with a window which contains the pass/fail indication as to whether the measurement falls within the limit specification at every measurement point. The result is updated every sweep. |

Four different limit specifications can be defined. By default, each specification will be associated with a particular trace, but any of the others can be applied. Before applying a limit checking specification to a measurement, make it the active one (if there is more than one measurement), then press:

| | |
|---|---|
| ***[Assign Spec 1-4]*** | Enter the required specification number and terminate with the [x1] key. |

Since limits are checked only at the actual measured data points, it is possible for the device to be out of specification without a limit test failure indication if the point density is insufficient. Either specify a sufficiently high number of measurement points in the Source menu, or reduce the span of the frequency sweep so that the passband occupies more of the display.

## Step 9 - Create a permanent record of the measurement results

Having obtained the measurement information required for the filter under test, it may be necessary to produce a hard copy of the information. Note that a hard copy can also be created at a later time by storing the measurement with [SAVE/RECALL] (see Step 10) and using the hard copy feature on the recalled measurement.

Use of the [COPY] key provides access to menus which allow choice of either graphical plot (via HPGL GPIB plotter) or graphical print (via a suitable parallel printer). It is also possible to print measurement information in a tabular form.

To create a graphical plot of the measurement connect the plotter to the GPIB connector. Also ensure that the MTS is in GPIB Controller Mode; if necessary press [UTILITY] *[GPIB] [Controller Mode]*. When this mode is in this effect, it is indicated by the box surrounding the *[Controller Mode]* soft key label being highlighted.

If necessary, set the GPIB address to suit the device in use:

| | |
|---|---|
| **[UTILITY]**<br>***[GPIB]***<br>***[Plotter Address]*** | Press these keys and set the GPIB address to suit the device in use. |
| **[COPY]**<br>***[Graphical Plot]*** | Starts the plotting operation. The plotting will proceed as a background task since the data is buffered. This allows further measurements to be made whilst the plotting proceeds. |

To create a print of the measurement connect the printer to the PARALLEL PRINTER connector.

| | |
|---|---|
| **[COPY]**<br>***[Select Printer]***<br>***[Epson FX]***<br>**or**<br>***[HP DeskJet / LaserJet]***<br>**or**<br>***[Canon BJ]*** | Specifies the type of printer that is to be used. Note that only instruments which have software at Version 4 or higher can support all three printer types shown here. |
| **[COPY]**<br>***[Graphical Print]*** | Starts the printing operation. As for plotting, this will be done as a background task. |

The Copy menus also allows plots and prints to be customised by choosing which graphical attributes are to be copied (for example graticule or marker information).

## Step 10 - Save the instrument settings or measurement traces for future use

Having configured the source conditions, and the measurement format and scaling for a particular DUT, it may be desirable to save them in non-volatile memory for future use. This removes the need to perform the set-up sequence (steps 1, 2, 3, 4, 6 and 7) from the start each time a similar device is measured.

| | |
|---|---|
| **[SAVE/RECALL]**<br>***[View Current Settings]*** | Before saving the current instrument settings it may be preferable to examine the current major instrument settings values. |
| ***[Return to Save/Recall]***<br>***[Save Settings]***<br>**[1] [x1]** | Saves the current instrument settings to settings store number 1. Instrument settings can be stored either in internal MTS memory or on a memory card. |

If the same device were to be measured in the future the instrument settings required are simply recalled:

| | |
|---|---|
| **[SAVE/RECALL]**<br>***[Recall Settings]***<br>**[1] [x1]** | Recalls the instrument settings stored in store 1. |

To save the currently active measurement trace to a specified memory location press

| | |
|---|---|
| **[SAVE/RECALL]**<br>***[Save Trace to Memory]***<br>**[1] [x1]** | When prompted, enter the memory location identity number. The trace can be stored either in internal MTS memory or on a memory card. A text editor is then presented which enables a measurement title to be entered, if required. |

Some of the instrument settings are also saved with the measurement. These are required in order that the instrument can re-create the channel and measurement setup necessary to display the trace as it appeared at the time when it was stored.

If a stored measurement needs to be displayed (e.g. for comparison with the current measurement), the memory can be recalled using:

| | |
|---|---|
| **[SAVE/RECALL]**<br>***[Display Memory]***<br>**[1] [x1]** | Recalls the measurement trace in store 1. |

It should be noted that when a trace memory is recalled, the instrument settings that were saved with it may affect the other measurement that is displayed. The option is given of using either the saved settings or the current settings.

## Improving the measurement

Although the above trace displays the required response of the filter, it lacks any detail of the passband ripple due to the vertical scaling being 10 dB/div. This could be improved by setting the reference level to 0 dB and the scale factor to 0.2 dB/div, for example:

| | |
|---|---|
| **[SCALING]**<br>***[Set Ref Level]***<br>**[0] [x1]** | Sets the reference level to 0 dB. |
| ***[Set Scale]***<br>**[0] [.] [2] [x1]** | Sets the scale factor to 0.2 dB/div. |

In addition, the span of the frequency sweep could be reduced so that only the passband is displayed, giving better horizontal resolution.

The measurement can be further improved by maximising the dynamic range so as to lower the noise floor. The amount of noise on the trace can be reduced by turning on averaging and setting a longer sweep time. The procedure is similar to that described above, but with some additional settings in the Source and Measure menus.

## Steps 1 to 2

These are the same as before.

## Step 3 - Define the source conditions

| | |
|---|---|
| [SOURCE]<br>*[Set Start Frequency]*<br>[8] [$G_n$]<br>*[Set Stop Frequency]*<br>[1] [0] [$G_n$] | Sets the start and stop frequencies to 8 GHz an 10 GHz. |
| *[Set Output Power]*<br>[8] [x1] | Sets to the highest levelled output power (8 dBm). |
| *[Sweep Time]*<br>*[User Set Sweep Time]*<br>[2] [x1] | Sets the sweep time to 2 seconds; this has the effect of reducing noise. Longer sweep times may also be necessary to prevent incorrect operation when testing certain devices. |
| [ENTRY OFF] | Terminates numeric entry. |
| *[Return to Source]* | Returns to the Source menu. |
| *[RF ●]* | Turns on the RF power. |

## Steps 4 to 7

These are the same as before.

## Step 8 - Use markers and other MTS features to get detailed information about the measurement

| | |
|---|---|
| [MEASURE]<br>*[Averaging]*<br>*[Averaging ●]* | Turns on averaging; this is indicated by the **A** flag in the trace information box. In this example, the **average number** is left at the default value of 16, but can be changed using the *[Set Average Number]* soft key. The minimum amount of averaging should be selected to reduce noise to an acceptable level, in order to maintain a sufficiently fast response. |

The trace that results when the dynamic range is maximised in this way is shown in Fig. 2-4.

When making measurements on a filter with a pass band below 2 GHz, measurement inaccuracies can arise due to spurious RF signals appearing at the

RF output during the frequency change switching points. These signals can be removed by pressing [SOURCE] *[RF Blanking]*.

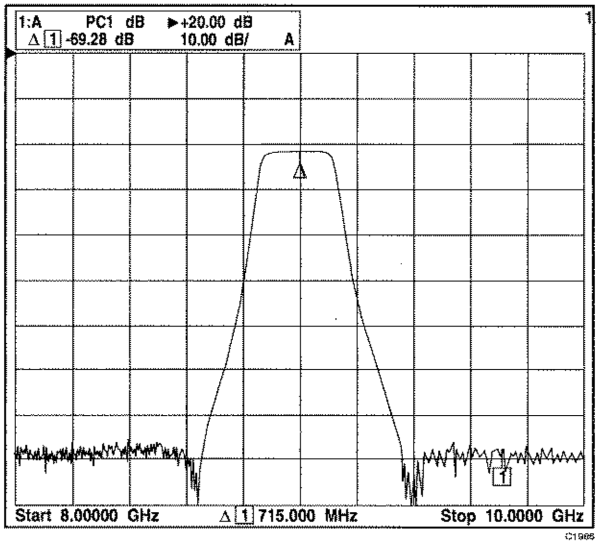



*Fig. 2-4 Effect of maximising dynamic range and reducing noise*

## Example 2: Insertion and return loss measurement using an autotester

In the second example measurement, we will measure both the insertion loss and return loss responses of a 9 GHz band-pass filter. As in the first example, this will be a narrowband measurement so that the passband responses can be examined in detail. The measurement system is shown below:

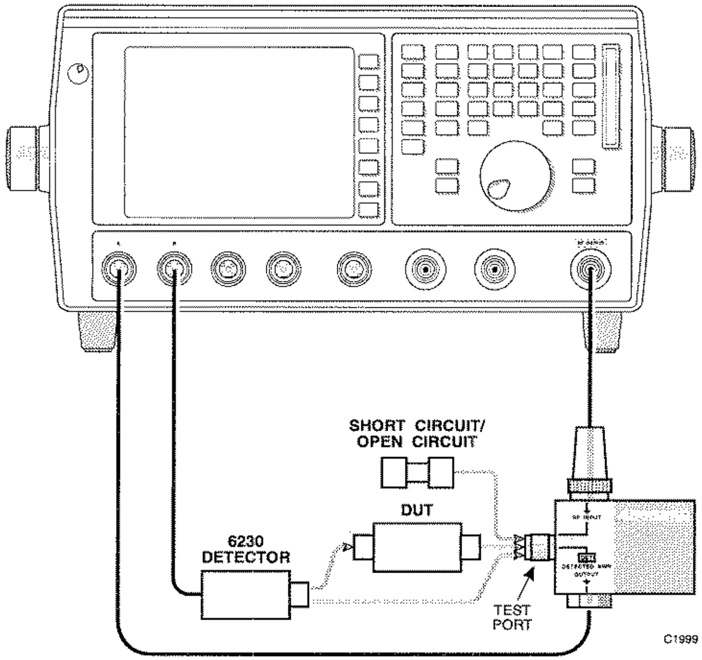



*Fig. 2-5 Setup for simultaneous measurement of insertion and return loss*

Connect the detector and autotester as shown in Fig. 2-5. Both the 6230 detector and the autotester adapter cable contain a self-identification mechanism which results in the appropriate linearity correction data being applied automatically.

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]** | Sets the instrument to its default state. |
| ***[Default Settings]*** | |

### Step 2 - Define the display configuration

A single channel will be used to display both the insertion loss and return loss of the filter. Since the default state of the instrument is a single scalar channel displaying measurement 1, it is only necessary to enable measurement 2.

**[MEAS 2 ON/OFF]** Determines whether measurement 2 is enabled for the active channel. When this key is pressed measurement 2 appears on channel 1.

## Step 3 - Define the source conditions

**[SOURCE]**

*[Set Start Frequency]* Sets the start frequency to 8 GHz.
**[8] [$G_n$]**

*[Set Stop Frequency]* Sets the stop frequency to 10 GHz.
**[1] [0] [$G_n$]**

**[ENTRY OFF]** Terminates numeric entry.

*[RF ●]* Turns on the RF power.

## Step 4 - Define the measurements

From Fig. 2-5 we see that insertion loss is measured by the scalar detector connected to input B and return loss is measured by the autotester connected to input A. Since all measurements default to input A (following PRESET) it is necessary to define the insertion loss measurement to be made from input B.

Before any changes can be made to the parameters of a measurement it must be the 'active measurement'. This is indicated by its trace information area being surrounded by a highlight box (red when the display is in colour mode). It can be seen that measurement 1 is the currently active measurement as indicated by the presence of the highlight box surrounding the trace information area, and as such it can have its parameters altered.

The first measurement we want to define is the insertion loss measured by the scalar detector connected to input B. We choose to display this as measurement 1. Before this can be done we must make it the 'active measurement'.

**[SELECT MEAS]** Selects which of the displayed measurements is the active measurement. As the key is pressed the active measurement highlight box will move between the displayed measurements. Make sure you leave the display with measurement 1 as the active measurement.

**[MEASURE]**
*[Single Input A, B, C or D]*
*[B]* Defines measurement 1 to measure input B, i.e. the insertion loss through the filter. This is indicated by **1:B** appearing in the active measurement trace information box.

As in Example 1, **detector autozeroing** is enabled following an instrument preset, which means that detector zeroing will be performed as a background task in the inter-sweep period. This process removes any drift in the zero level for both detectors or autotesters connected to the instrument. If you change the detector/autotester connected to a particular input, you should perform a manual detector zero by selecting [CAL] *[Det/Sensor Zero] [Zero Detectors]*.

## Step 5 - Calibrate the measurement system

Before making any measurements on the filter the measurement system must be calibrated to remove the effects of power variations with frequency of the components that comprise the measurement system.

We do this by performing a through path calibration for the transmitted power path (i.e. insertion loss). In this example we also need to perform a short/open path calibration for the reflected power path (i.e. return loss).

Firstly, for input B the insertion loss path.

| | |
|---|---|
| **[SELECT MEAS]** | Use this key to make measurement 1 the active measurement. |
| **[CAL]**<br>***[Through Cal]*** | Presents a text box informing you that you are about to perform a through path cal and that the path cal store to be used is store 1. The message also prompts you to make a through connection, i.e. connect the scalar detector on input B directly to the Test Port of the autotester. |
| ***[Continue]*** | Initiates the path calibration. |

When calibration is completed for the insertion loss path, the path cal data is automatically applied to measurement 1, and is indicated by the presence of **PC1** in the trace information box for that measurement. If the path calibration becomes invalid (e.g. due to subsequent changes in measurement parameters), a warning message will be displayed and the path cal indication changes to **PC1?**.

In order to measure return loss, the system must first be calibrated against a known reference. Open circuit or short circuit terminations are chosen as both these devices theoretically reflect 100% of the power incident upon them, and therefore have a return loss of 0 dB. If only an open circuit or short circuit is used, however, there is an uncertainty added to the measurement due to test port impedance mismatch. This uncertainty can be minimized by calibrating the system against both open and short circuits, then calculating the average (done automatically by the MTS). The short/open path cal for the return loss path is done as follows:

| | |
|---|---|
| **[SELECT MEAS]** | Use this key to make measurement 2 the active measurement. |
| ***[Short AND Open Cal]*** | Presents a message stating that the path cal store about to be used for the calibration is store 2, and prompts you to connect a short (i.e. a short circuit) to the Test Port of the autotester. |
| ***[Continue]*** | Initiates the short circuit calibration. After completing the short circuit cal, a message will be displayed stating that an open (i.e. an open circuit) should be connected to the Test Port of the autotester. |
| ***[Continue]*** | Initiates the open circuit calibration. |

Upon completion of the short/open path calibration for the return loss path, the path cal data is automatically applied to measurement 2. This is shown by **PC2** which indicates that path cal store 2 is being applied to that measurement.

Now connect the filter between the autotester Test Port and the scalar detector.

## Step 6 - Choose the format

When the [PRESET] key was pressed in Step 1 the default format for a scalar channel was set to dBm. Since the measurements are now relative to the path calibrations their units are displayed in dB. This is satisfactory for the insertion and return loss measurements of this example.

## Step 7 - Select appropriate scaling

The default settings for scaling will be used i.e. a reference level of +20 dB and a scale factor of 10 dB/div.

Alternatively, suitable scaling could be achieved through the use of the autoscale facility which results in setting the reference level and scaling such that the trace occupies approximately 80% of the graticule height.

Fig. 2-6 shows the insertion loss / return loss measurement.

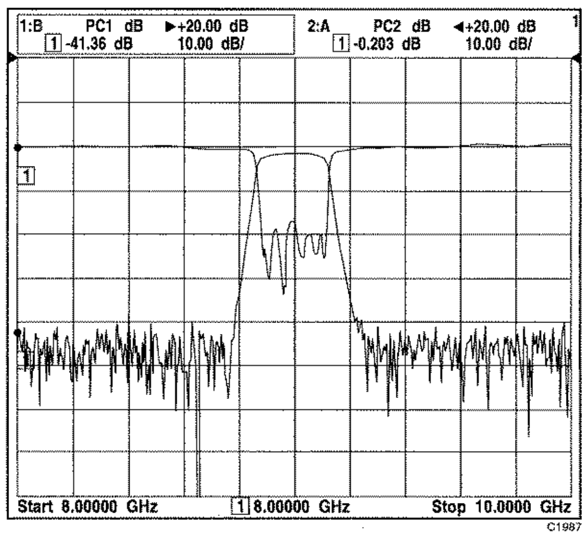



*Fig. 2-6 Insertion and return loss measurement*

### Step 8 - Use markers and other MTS features to get detailed information about the measurement

Markers and limit checking can be used to obtain detailed information about specific features of the measurement, as outlined in Example 1.

### Step 9 - Create a permanent record of the measurement results

A hard copy of the measurement can be created via the menus accessed with the **[COPY]** key, as with Example 1.

### Step 10 - Save the instrument settings or measurement traces for future use

Instrument settings or measurement traces can be saved and recalled using the **[SAVE/RECALL]** facilities, as with Example 1.

## Example 3: Dual channel insertion and return loss measurement of a band-pass filter using an autotester

In this example measurement, the passband insertion loss and return loss responses will be displayed on one channel, as in the Example 2, but in addition the broadband insertion loss will be displayed on the other channel. Most of the steps are the same as in Example 2, so they will not be described in detail. The measurement system is the same and is repeated below.

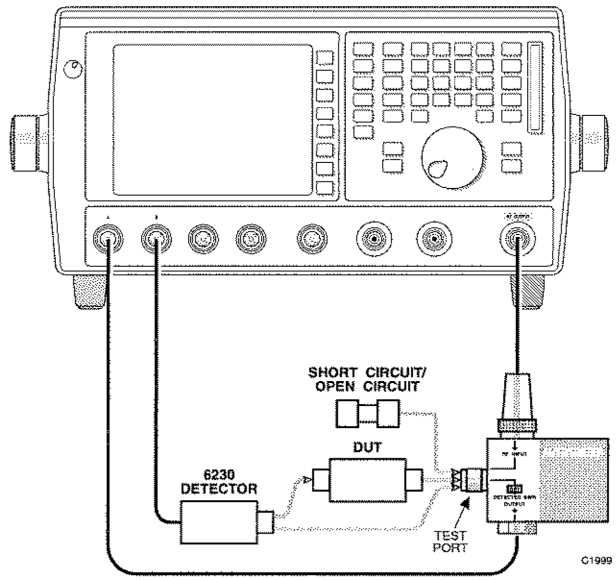



*Fig. 2-7 Setup for dual channel insertion and return loss measurement*

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]**<br>***[Default Settings]*** | Sets the instrument to its default state. |

### Step 2 - Define the display configuration

We choose to display the three measurements as follows:

On channel 1 we will display simultaneous narrowband insertion and return loss measurements and on channel 2 we will display the broadband insertion loss of the filter.

| | |
|---|---|
| **[CHANNEL MODE]**<br>***[Dual Channel Display ●]*** | Sets the display to dual channel mode. The Channel Mode menu is the default following an instrument preset, so it is not necessary in this case to press the [CHANNEL MODE] key. |

**[MEAS 2 ON/OFF]** Turns on measurement 2 of channel 1.

The display should now be as shown in Fig. 2-8.

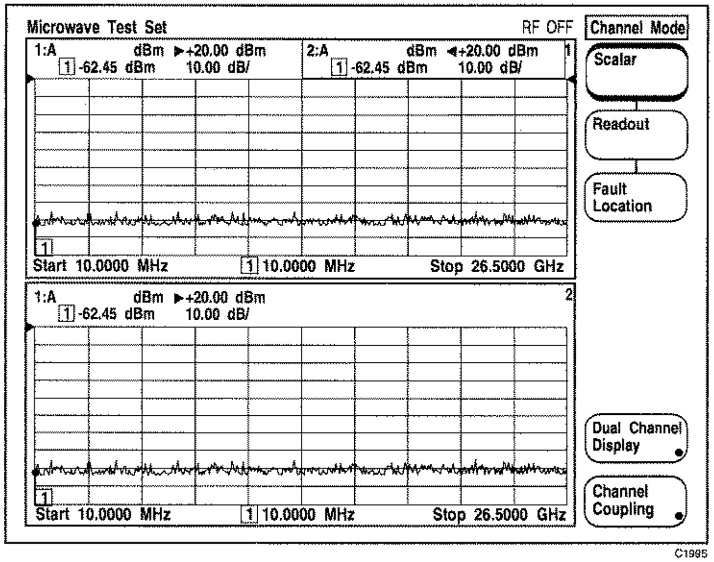



*Fig. 2-8 Two channel display*

## Step 3 - Define the source conditions

The sweep range will be set to 10 MHz - 20 GHz for the broadband insertion loss measurement on channel 2. Ensure channel 2 is the active channel, using [SWITCH CHANNEL] if necessary.

**[SOURCE]** Sets the stop frequency to 20 GHz.
***[Set Stop Frequency]***
**[2] [0] [$G_n$]**

Since the passband of the filter we wish to measure is centred at 9 GHz, it is necessary to change the start and stop frequency values for channel 1.

By default, channels 1 and 2 are coupled, i.e. the source conditions are the same for both channels. In order to have different conditions for each channel it is first necessary to uncouple the channels.

**[CHANNEL MODE]** The indicator in the bottom right hand corner of
***[Channel Coupling O]*** the soft key label is extinguished to indicate that the source channels are no longer coupled.

We can now alter the start and stop frequencies for channel 1 to 8 GHz and 10 GHz respectively, provided it is the currently active channel.

**[SWITCH CHANNEL]** Use this key to ensure channel 1 is the active channel.

| | |
|---|---|
| **[SOURCE]**<br>***[Set Start Frequency]***<br>**[8] [$G_n$]** | Sets the start frequency to 8 GHz. |
| ***[Set Stop Frequency]***<br>**[1] [0] [$G_n$]** | Sets the stop frequency to 10 GHz. |
| **[ENTRY OFF]** | Terminates parameter entry. |
| ***[RF ●]*** | Turns on the RF power. |

## Step 4 - Define the measurements

Return loss is measured by the autotester connected to input A, and will be displayed as measurement 2 of channel 1. Since the default measurement definition is input A, no change is required here. Measurement 1 of channel 1 will be used to display the narrowband insertion loss measured by the scalar detector connected to input B, so the measurement definition is changed as follows:

| | |
|---|---|
| **[SELECT MEAS]** | Makes measurement 1 of channel 1 the active measurement. |
| **[MEASURE]**<br>***[Single Input A, B, C or D]***<br>***[B]*** | Defines measurement 1 of channel 1 to measure input B, i.e. the insertion loss through the filter. This is indicated by **1:B** appearing in the active measurement trace information box. |

We now need to define the broadband insertion loss response on measurement 1 of channel 2.

| | |
|---|---|
| **[SELECT MEAS]** | Makes measurement 1 of channel 2 the active measurement. |
| **[MEASURE]**<br>***[Single Input A, B, C or D]***<br>***[B]*** | Defines measurement 1 of channel 2 to measure input B. This is indicated by **1:B** appearing in the active measurement trace information box. |

## Step 5 - Calibrate the measurement system

The measurement system must now be calibrated to remove the effects of power variations with frequency within the system. As in Example 2, this is done by performing a through path calibration for the transmitted power path (i.e. insertion loss), and a short/open path calibration for the reflected power path (i.e. return loss).

Firstly, for input B, the passband insertion loss path, with the detector on input B connected directly to the test port of the autotester.

| | |
|---|---|
| **[SELECT MEAS]** | Makes measurement 1 of channel 1 the active measurement. |
| **[CAL]**<br>***[Through Cal]***<br>***[Continue]*** | Performs the path calibration. When completed, the path cal data is automatically applied to the measurement, as indicated by the presence of **PC1** in the trace information box for that measurement. |

Now perform a short/open path cal on the autotester for the return loss path.

**[SELECT MEAS]** Makes measurement 2 of channel 1 the active measurement.

***[Short AND Open Cal]***
***[Continue]*** Initiates the short circuit calibration.

***[Continue]*** Initiates the open circuit calibration.

Upon completion of the short/open path calibration for the return loss path, the path cal data is automatically applied to measurement 2 of channel 1. This is shown by **PC2** which indicates that path cal store 2 is being applied to that measurement.

Path calibrations are now being applied to both of the passband measurements on channel 1, but not to the broadband insertion loss measurement on channel 2, measurement 1. Since this measurement is to be made over a greater frequency range, the same path calibration cannot be used as for the passband insertion loss measurement, since the path cal data only applies to the region in between the start and stop frequency values of channel 1. A further path cal must be performed for the broadband insertion loss measurement.

**[SELECT MEAS]** Makes measurement 1 of channel 2 the active measurement.

***[Through Path Cal]***
***[Continue]*** Performs the path calibration and applies the path cal data to the measurement. **PC3** is displayed in the trace information box for the measurement.

Note that a path cal could first be done for the broadband response on channel 2, which could then also be applied to the narrowband insertion loss measurement on channel 1. In this case, however, there would be fewer than 401 calibrated measurement points and the intermediate ones would have to be obtained by linear interpolation. Performing a unique path calibration for the narrowband measurement avoids the use of interpolated data.

Now connect the filter between the autotester Test Port and the scalar detector.

## Step 6 - Choose the format

**[FORMAT]**
***[VSWR]*** If required, use these keys to change the format of the return loss measurement to VSWR, after making measurement 2 of channel 1 the active measurement. (This would not be appropriate, however, for the filter measurement of this example.)

## Step 7 - Select appropriate scaling

The default settings for scaling will be used.

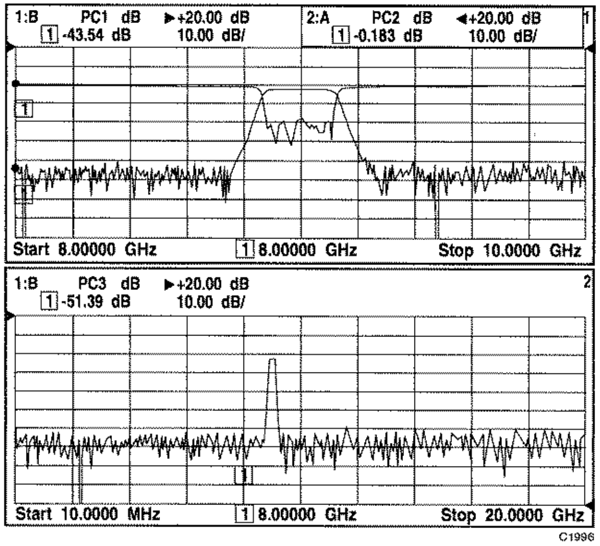



*Fig. 2-9 Passband insertion and return loss and broadband insertion loss*

## Step 8 - Use markers and other MTS features to get detailed information about the measurement

Markers and limit checking can be used to obtain detailed information about specific features of the measurement, as outlined in Example 1.

## Step 9 - Create a permanent record of the measurement results

A hard copy of the measurement can be created via the menus accessed with the **[COPY]** key, as with Example 1.

## Step 10 - Save the instrument settings or measurement traces for future use

Instrument settings or measurement traces can be saved and recalled using the **[SAVE/RECALL]** facilities, as with Example 1.

# Example 4: Return loss measurement of a coaxial cable using a return loss bridge

This example shows how to make a return loss measurement using a separate return loss bridge and detector rather than an Autotester or Test Head. The return loss bridge and detector would normally be used with a 6202B RF Test Set, enabling users working in the RF band to make return loss measurements at relatively low cost. However, the bridge/detector arrangement can also be used with other instruments of the 6200B series.

The following procedure describes a return loss measurement on a 30 m length of coaxial cable. The measurement setup is shown below:

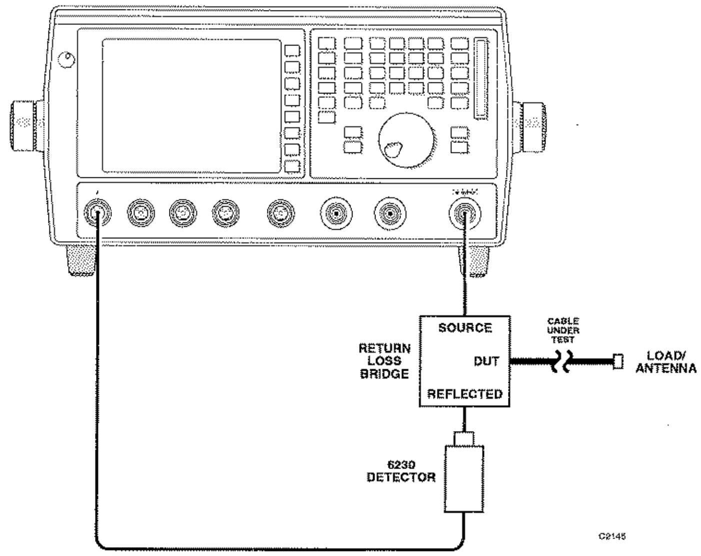



*Fig. 2-10 Setup for return loss measurement using a return loss bridge and detector*

## Step 1 - Preset the instrument to a known state

**[PRESET]** Sets the instrument to its default state.
***[Default Settings]***

## Step 2 - Define the display configuration

Measurement 1 of channel 1 will be used to display the return loss of the transmission line. Since the default state of the instrument is a single scalar channel displaying measurement 1, we can proceed immediately to Step 3.

## Step 3 - Define the source conditions

| | |
|---|---|
| **[SOURCE]** | |
| ***[Set Start Frequency]*** **[8] [7] [0] [Mμ]** | Sets the start frequency to 870 MHz. |
| ***[Set Stop Frequency]*** **[1] [$G_n$]** | Sets the stop frequency to 1 GHz. |
| **[ENTRY OFF]** | Terminates numeric entry. |
| ***[RF •]*** | Turns on the RF power. |

## Step 4 - Define the measurements

Since the return loss is measured by a scalar detector connected to input A, no change needs to be made to the measurement definition since all measurements default to input A following PRESET.

| | |
|---|---|
| **[MEASURE]** ***[General Set-up]*** ***[AC Detection]*** | AC detection is used to reject signals from other sources (such as transmitters) which could interfere with the measurement. |

## Step 5 - Calibrate the measurement system

In order to measure return loss, the system must first be calibrated against a known reference. Open circuit or short circuit terminations are chosen as both these devices theoretically reflect 100% of the power incident upon them, and therefore have a return loss of 0 dB.

| | |
|---|---|
| **[CAL]** ***[Short OR Open Cal]*** | A message is displayed asking for either a short circuit or open circuit to be connected to the test (DUT) port of the bridge. In this example, it is only necessary to leave the DUT port open for the calibration, since this will result in 100% reflection at lower frequencies. |
| ***[Continue]*** | Initiates the short circuit calibration. |

Upon completion of the calibration, the path cal data is automatically applied to the return loss measurement, as indicated by **PC1** in the trace information box.

Now connect the cable under test to the DUT port of the bridge, and terminate the cable with either the antenna or a suitable load.

The remaining steps would be similar to those of the previous examples.

## Example 5: Insertion and return loss measurement using an autotester and a reference channel

It might be assumed that, having performed a path calibration, the traces obtained are a true representation of the response of the device under test (DUT). This assumption may not always be correct, however, since:

There may be changes in the input power to the DUT caused, for example, by drift in the RF source or flexing of the RF cable introducing a changed loss between the source and the DUT.

Errors can be caused by a poor source match, which particularly affects highly reflecting and low loss device measurements. This results in relatively large amounts of signal returning to the RF output of the MTS and being re-reflected back towards the DUT. This is seen as a ripple superimposed on the measurement.

In this example, insertion and return loss will again be measured for the 9 GHz band-pass filter, but a reference channel will be used to reduce the effects of the above errors. The measurement system is shown in Fig. 2-11. The RF output is fed to a power splitter in order to provide a separate reference channel to monitor the power near the measurement port, i.e. the actual incident power reaching the DUT. Any variations in the DUT input level are measured by the reference channel, and the MTS compensates for the variation by ratioing the reference signal with the reflected and transmitted signal measurements. Using this technique, measurement ripples up to 1 dB due to multiple reflections can be reduced to less than 0.2 dB.

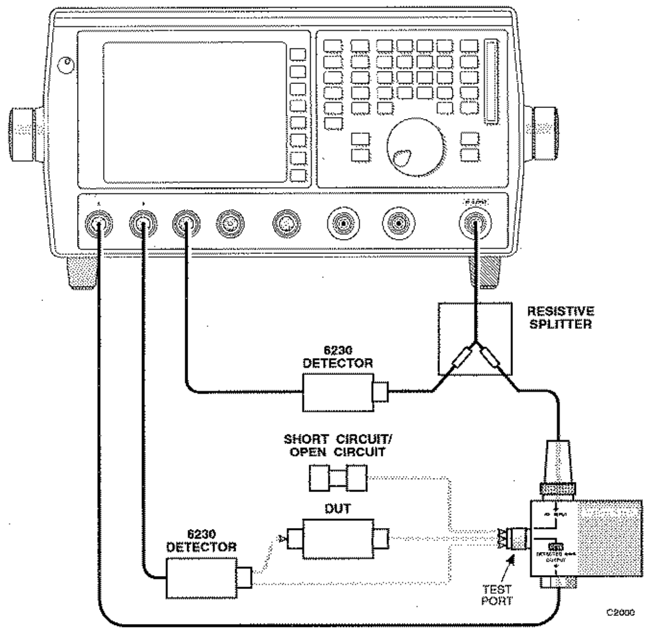



*Fig. 2-11 Setup for insertion and return loss measurement using an autotester and a reference channel*

Because of the power loss through the resistive splitter, there is a corresponding loss in the maximum displayed dynamic range of the measurement. Alternatively, a high directivity directional coupler could be used instead of a splitter to sample the actual power incident upon the DUT.

A power divider should not be used as these devices have an unacceptably high SWR

## Step 1 - Preset the instrument to a known state

**[PRESET]** Sets the instrument to its default state.
***[Default Settings]***

## Step 2 - Define the display configuration

A single channel will be used to display both the insertion loss and return loss of the filter. Since the default state of the instrument is a single scalar channel displaying measurement 1, it is only necessary to enable measurement 2.

**[MEAS 2 ON/OFF]** Turns on measurement 2.

## Step 3 - Define the source conditions

| | |
|---|---|
| **[SOURCE]**<br>***[Set Start Frequency]***<br>**[8] [$G_n$]** | Sets the start frequency to 8 GHz. |
| ***[Set Stop Frequency]***<br>**[1] [0] [$G_n$]** | Sets the stop frequency to 10 GHz. |
| **[ENTRY OFF]** | Terminates numeric entry. |
| ***[RF ●]*** | Turns on the RF power. |

## Step 4 - Define the measurements

From Fig. 2-11 it can be seen that insertion loss is measured by the scalar detector connected to input B and return loss is measured by the autotester connected to input A. The detector that measures the reference signal is connected to input C. Since all measurements default to input A (following PRESET) it is necessary to define the insertion and return loss measurements to be made from the appropriate ratios.

The first measurement we want to define is the ratioed insertion loss measured by the detectors connected to inputs B and C. We choose to display this as measurement 1.

| | |
|---|---|
| **[SELECT MEAS]** | Makes measurement 1 the active measurement. |
| **[MEASURE]**<br>***[Input Ratio]***<br>***[B/]***<br>***[B / C]***<br>***[Return to Input Ratio]*** | Defines measurement 1 to measure the ratio B / C. This is indicated by **1:B/C** appearing in the active measurement trace information box. |
| **[SELECT MEAS]** | Make measurement 2 the active measurement. |
| ***[A/]***<br>***[A / C]*** | Defines measurement 2 to measure the ratio A / C. This is indicated by **2:A/C** appearing in the active measurement trace information box. |

## Step 5 - Calibrate the measurement system

The measurement system must now be calibrated to remove the effects of power variations with frequency within the system. As in previous examples, this is done by performing a through path calibration for the transmitted power path (i.e. insertion loss), and a short/open path calibration for the reflected power path (i.e. return loss).

Firstly, for input B, the insertion loss path, with the detector on input B connected directly to the test port of the autotester.

| | |
|---|---|
| **[SELECT MEAS]** | Makes measurement 1 the active measurement. |
| **[CAL]**<br>***[Through Cal]***<br>***[Continue]*** | Performs the path calibration. When completed, the path cal data is automatically applied to the measurement, as indicated by the presence of **PC1** in the trace information box for that measurement. |

Now perform a short/open path cal on the autotester for the return loss path.

| | |
|---|---|
| **[SELECT MEAS]** | Makes measurement 2 the active measurement. |
| ***[Short AND Open Cal]***<br>***[Continue]*** | Initiates the short circuit calibration. |
| ***[Continue]*** | Initiates the open circuit calibration. |

Upon completion of the short/open path calibration for the return loss path, the path cal data is automatically applied to measurement 2. This is shown by **PC2** which indicates that path cal store 2 is being applied to that measurement.

Now connect the filter between the autotester Test Port and the scalar detector connected to input B.

## Step 6 - Choose the format

| | |
|---|---|
| **[FORMAT]**<br>***[VSWR]*** | If required, use these keys to change the format of the return loss measurement to VSWR, after making measurement 2 the active measurement. (This would not be appropriate, however, for the filter measurement of this example.) |

## Step 7 - Select appropriate scaling

The default settings for scaling will be used.

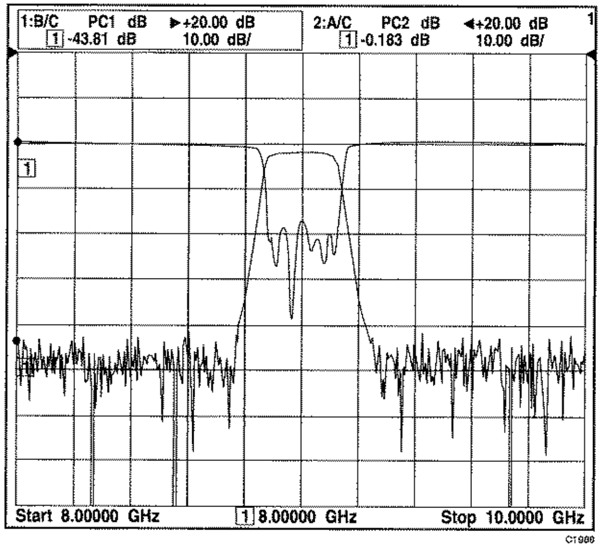



*Fig. 2-12 Insertion and return loss measurement using a reference channel*

## Step 8 - Use markers and other MTS features to get detailed information about the measurement

Markers and limit checking can be used to obtain detailed information about specific features of the measurement, as outlined in Example 1.

## Step 9 - Create a permanent record of the measurement results

A hard copy of the measurement can be created via the menus accessed with the **[COPY]** key, as with Example 1.

## Step 10 - Save the instrument settings or measurement traces for future use

Instrument settings or measurement traces can be saved and recalled using the **[SAVE/RECALL]** facilities, as with Example 1.

## Example 6: Return loss measurement of a waveguide using a single waveguide coupler

In this example a return loss measurement will be made on a section of waveguide over the frequency range 8 GHz to 12.4 GHz. The measurement setup is shown in Fig. 2-13.

The principles involved in making measurements on waveguide devices are the same as for coaxial components. However, there are some practical differences in the measurement methods, as described below:

Coaxial-to-waveguide adapters are required to allow the system detectors to be used. The match of the detector will be degraded by the VSWR of the adapter, so these should be of low VSWR to reduce measurement uncertainty.

Waveguide directional couplers are used instead of an autotester or bridge. Couplers should have a directivity of at least 40 dB and a coupling factor of less than 20 dB.

To obtain a reference short circuit for the return loss measurement, a polished flat metal plate is bolted across the output port of the coupler in place of the DUT.

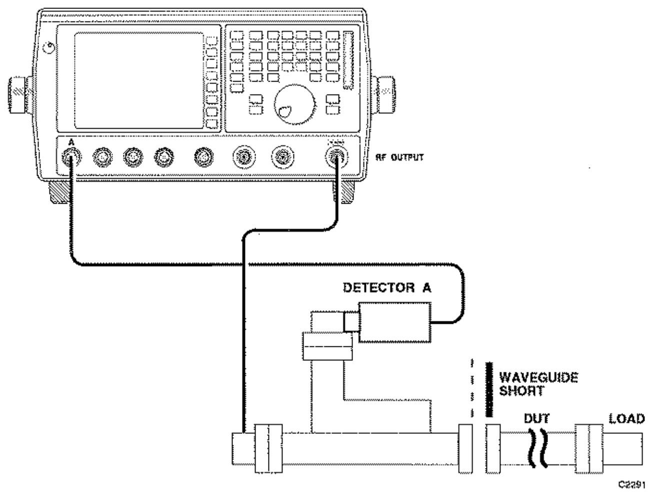



*Fig. 2-13 Setup for return loss measurement using a single waveguide coupler*

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]** *[Default Settings]* | Sets the instrument to its default state. |

## Step 2 - Define the display configuration

Measurement 1 of channel 1 will be used to display the return loss of the cable. Since the default state of the instrument is a single scalar channel displaying measurement 1, we can proceed immediately to Step 3.

## Step 3 - Define the source conditions

| | |
|---|---|
| [SOURCE] | |
| *[Set Start Frequency]* | Sets the start frequency to 8 GHz. |
| [8] [G $_n$] | |
| *[Set Stop Frequency]* | Sets the stop frequency to 12.4 GHz. |
| [1] [2] [.] [4] [G $_n$] | |
| [ENTRY OFF] | Terminates numeric entry. |
| *[RF ●]* | Turns on the RF power. |

## Step 4 - Define the measurements

Since the detector is connected to input A of the MTS it is not necessary to define the input used as it defaults to input A.

| | |
|---|---|
| [MEASURE]<br>*[General Set-up]*<br>*[AC Detection]*<br>*[Return to Measure]* | Sets the detection mode to AC in order to reject signals from other sources (such as transmitters) which could interfere with the measurement. |

## Step 5 - Calibrate the measurement system

| | |
|---|---|
| [CAL]<br>*[Short OR Open Cal]* | A message is displayed asking for either a short circuit or open circuit to be connected. In this case a waveguide short is connected to the output port of the coupler. |
| *[Continue]* | Initiates the short circuit calibration. |

Upon completion of the calibration the path cal data is automatically applied to the measurement, as indicated by **PC1** in the trace information box.

Now connect the waveguide under test to the coupler, and terminate with a suitable load, as shown in Fig. 2-13.

## Step 6 - Choose the format

| | |
|---|---|
| [FORMAT]<br>*[VSWR]* | If required use these keys to change the format of the return loss measurement to VSWR. |

## Step 7 - Select appropriate scaling

To improve the detail of the measurement the scaling can be changed from the default setting of +20 dB reference level and 10 dB/div scale factor.

**[SCALING]**
***[Set Ref Level]***
**[0] [x1]** Sets the reference level to 0 dB.
***[Set Scale]***
**[5] [x1]** Sets the scale factor to 5 dB/div.

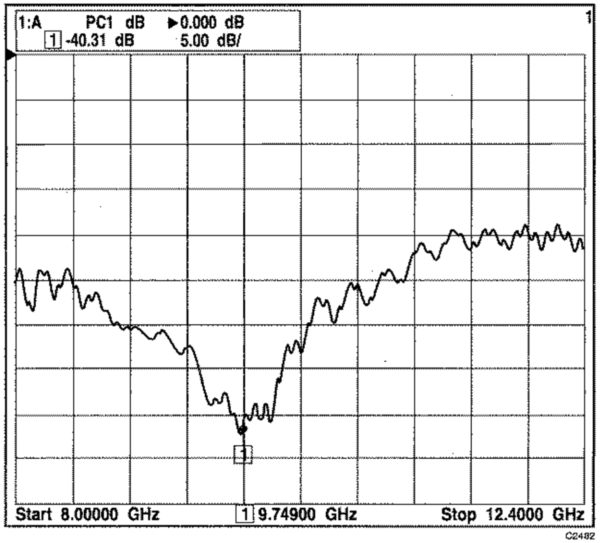



*Fig. 2-14 Return loss measurement of a waveguide*

The remaining steps would be similar to those of Example 1.

## Example 7: Return loss measurement of a waveguide using a dual waveguide coupler

This example is similar to the previous one, except that an additional coupler is used to provide a reference channel. A reference channel is used to minimise errors due to the following:

> There may be changes in the input power to the DUT caused, for example, by drift in the RF source or flexing of the RF cable introducing a changed loss between the source and the DUT.
>
> Errors can be caused by a poor source match, which particularly affects highly reflecting and low loss device measurements. This results in relatively large amounts of signal returning to the RF output of the MTS and being re-reflected back towards the DUT. This is seen as a ripple superimposed on the measurement.

The measurement setup is shown in Fig. 2-15. The RF output is fed to a directional coupler in order to provide a separate reference channel to monitor the power near the measurement port, i.e. the actual incident power reaching the DUT. Any variations in the DUT input level are measured by the reference channel, and the MTS compensates for the variation by ratioing the reference signal with the reflected and transmitted signal measurements. Using this technique, measurement ripples up to 1 dB due to multiple reflections can be reduced to less than 0.2 dB.

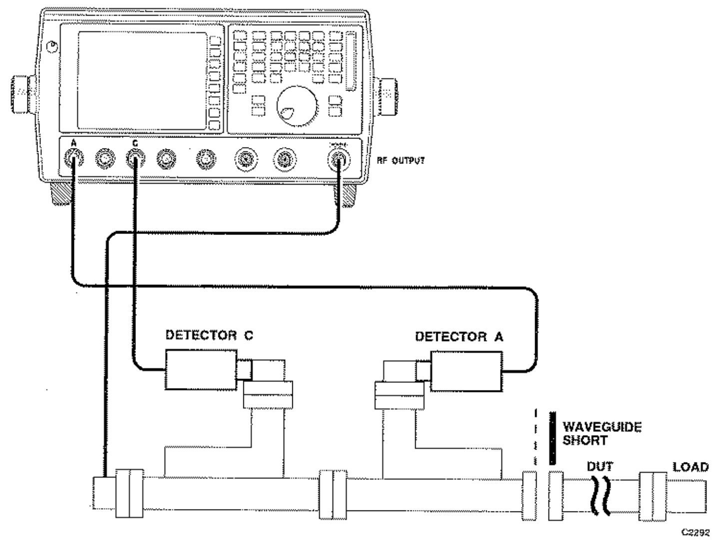



*Fig. 2-15 Setup for return loss measurement using a dual waveguide coupler*

## Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]**<br>***[Default Settings]*** | Sets the instrument to its default state. |

## Step 2 - Define the display configuration

Again, the default configuration will be used, i.e. a single scalar channel displaying measurement 1.

## Step 3 - Define the source conditions

| | |
|---|---|
| **[SOURCE]**<br>***[Set Start Frequency]***<br>**[8] [G $_n$]** | Sets the start frequency to 8 GHz. |
| ***[Set Stop Frequency]***<br>**[1] [2] [.] [4] [G $_n$]** | Sets the stop frequency to 12.4 GHz. |
| **[ENTRY OFF]** | Terminates numeric entry. |
| ***[RF ●]*** | Turns on the RF power. |

## Step 4 - Define the measurements

From Fig. 2-15 it can be seen that return loss is measured by the detector connected to input A, with the reference signal connected to input C.

| | |
|---|---|
| **[MEASURE]**<br>***[General Set-up]***<br>***[AC Detection]***<br>***[Return to Measure]*** | Sets the detection mode to AC in order to reject signals from other sources (such as transmitters) which could interfere with the measurement. |
| ***[Input Ratio]***<br>***[A/]***<br>***[A/C]*** | Defines measurement 1 of channel 1 to measure the ratio A/C. This is indicated by **1:A/C** appearing in the trace information box. |

## Step 5 - Calibrate the measurement system

| | |
|---|---|
| **[CAL]**<br>***[Short OR Open Cal]*** | A message is displayed asking for either a short circuit or open circuit to be connected. In this case a waveguide short is connected to the output port of the coupler. |
| ***[Continue]*** | Initiates the short circuit calibration. |

Upon completion of the calibration the path cal data is automatically applied to the measurement, as indicated by **PC1** in the trace information box.

Now connect the waveguide under test to the coupler, and terminate with a suitable load, as shown in Fig. 2-15

## Step 6 - Choose the format

**[FORMAT]** *[VSWR]* — If required use these keys to change the format of the return loss measurement to VSWR.

## Step 7 - Select appropriate scaling

To improve the detail of the measurement the scaling can be changed from the default setting of +20 dB reference level and 10 dB/div scale factor.

**[SCALING]**
*[Set Ref Level]*
**[0] [x1]** — Sets the reference level to 0 dB.
*[Set Scale]*
**[5] [x1]** — Sets the scale factor to 5 dB/div.

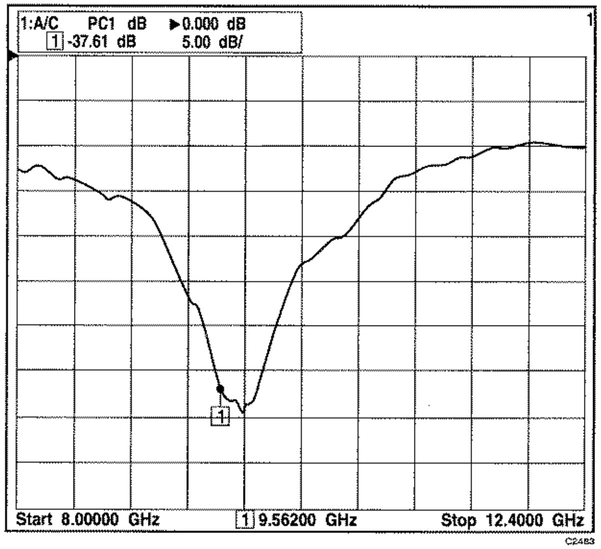



*Fig. 2-16 Return loss measurement of a waveguide*

By comparing the trace with that of the previous example using a single coupler, it can be seen that the measurement ripple has been significantly reduced.

The remaining steps would be similar to those of Example 1.

# Example 8: Return loss measurement of a coaxial cable using a test head

This example shows how to make a return loss measurement on a length of coaxial cable using a 6581/6583 Transmission Line Test Head. In the example, the return loss will be measured over a frequency range of 1.75 to 1.95 GHz.

Connect the test head to the MTS via the respective inputs A, B and C. Connect the RF input of the test head to the RF output of the MTS. Refer to Fig. 2-17.

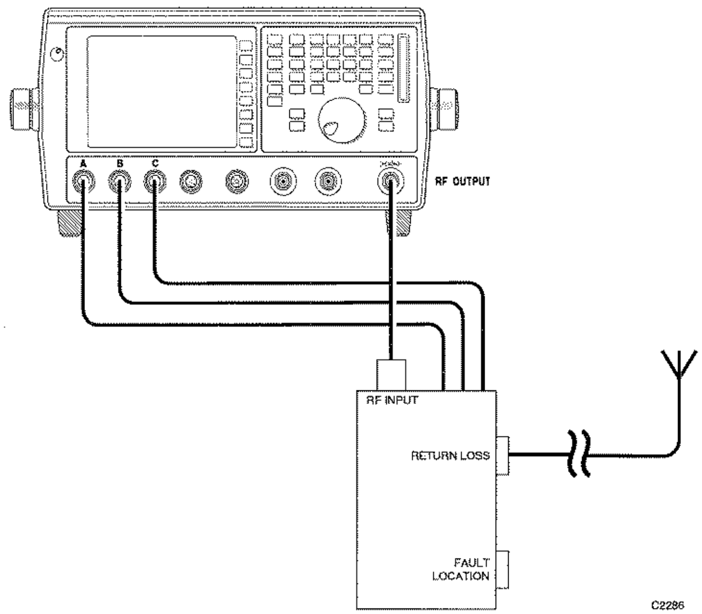



*Fig. 2-17 Setup for return loss measurement using a test head*

## Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]** | Sets the instrument to its default state. |
| ***[Default Settings]*** | |

## Step 2 - Define the display configuration

Measurement 1 of channel 1 will be used to display the return loss of the cable. Since the default state of the instrument is a single scalar channel displaying measurement 1, we can proceed immediately to Step 3.

## Step 3 - Define the source conditions

| | |
|---|---|
| [SOURCE]<br>*[Set Start Frequency]*<br>[1] [.] [7] [5] [G n] | Sets the start frequency to 1.75 GHz. |
| *[Set Stop Frequency]*<br>[1] [.] [9] [5] [G n] | Sets the stop frequency to 1.95 GHz. |
| [ENTRY OFF] | Terminates numeric entry. |
| *[RF ●]* | Turns on the RF power. |

## Step 4 - Define the measurements

To measure the return loss the MTS should be configured to measure the ratio A/C. Input A is the reflected signal, and input C is a reference signal derived from a power splitter within the test head..

| | |
|---|---|
| [MEASURE]<br>*[General Set-up]*<br>*[AC Detection]*<br>*[Return to Measure]* | Sets the detection mode to AC in order to reject signals from other sources (such as transmitters) which could interfere with the measurement. |
| *[Input Ratio]*<br>*[A/]*<br>*[A/C]* | Defines the measurement in channel 1 to measure the ratio A/C. This is indicated by **1:A/C** appearing in the active measurement trace information box. |

## Step 5 - Calibrate the measurement system

| | |
|---|---|
| [CAL]<br>*[Short AND Open Cal]* | Presents a message stating that the path cal store about to be used for the calibration is store 1, and prompts you to connect a short circuit termination to the RETURN LOSS port of the test head. |
| *[Continue]* | Initiates the short circuit calibration. When this is completed, a message will be displayed stating that on open circuit termination should be connected to the RETURN LOSS port. |
| *[Continue]* | Initiates the open circuit calibration. |

Upon completion of the short/open path calibration the path cal data is automatically applied to the measurement. This is indicated by **PC1** being displayed in the trace information box.

Now connect the cable under test to the test head, and terminate with an antenna or a suitable load.

## Step 6 - Choose the format

| | |
|---|---|
| [FORMAT]<br>*[VSWR]* | If required use these keys to change the format of the return loss measurement to VSWR. |

## Step 7 - Select appropriate scaling

| | |
|---|---|
| [SCALING] | |
| *[Set Ref Level]* | |
| [0] [x1] | Sets the reference level to 0 dB. |
| *[Set Scale]* | |
| [5] [x1] | Sets the scale factor to 5 dB/div. |

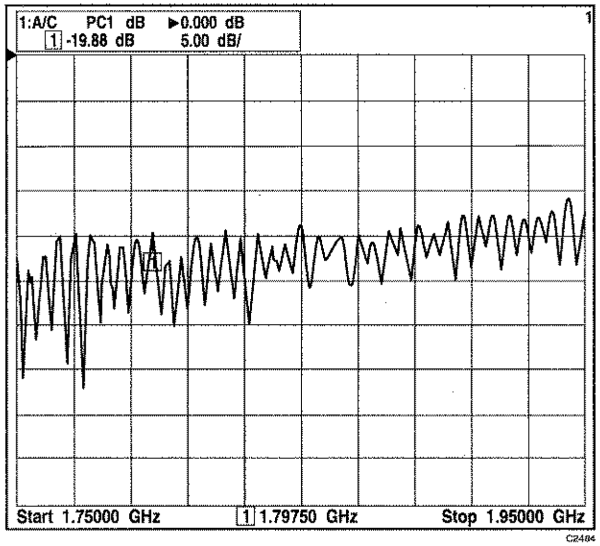



*Fig. 2-18 Return loss measurement of a coaxial cable*

The remaining steps would be similar to those of Example 1.

# Example 9: Fault location measurement of a coaxial cable using a test head

The objective of this example measurement is to give you an understanding of the fault location capabilities of the MTS. It is recommended that the principles and requirements of a fault location measurement should first be understood by referring to Appendix C the MTS Operating Manual.

In this example, the transmission line under test consists of two sections of coaxial cable, with lengths 3 m and 24 m, connected together using an adapter. The measurement can be performed using either a 6581/6583 Transmission Line Test Head or 6581E/6583E Fault Location Test Head. (The 'E' versions do not contain the components necessary to make return loss as well as fault location measurements.)

Connect the test head to the MTS and transmission line as shown in Fig. 2-19.

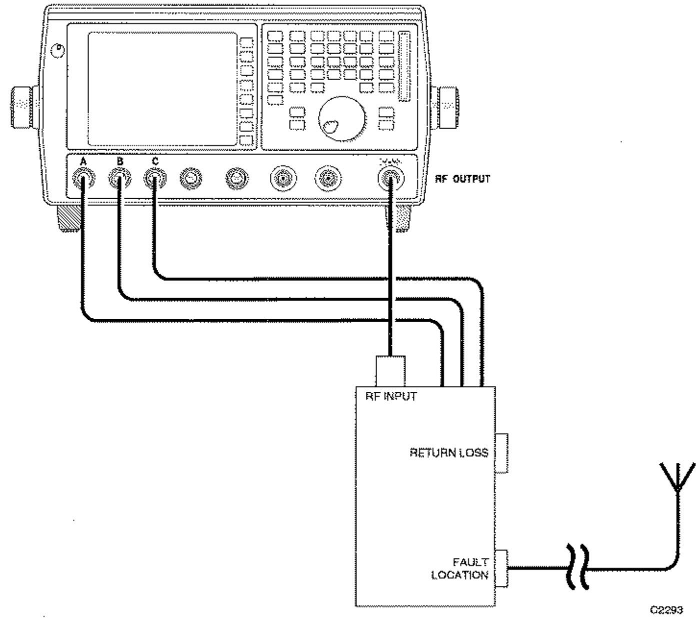



*Fig. 2-19 Setup for fault location measurement*

## Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]** *[Default Settings]* | Sets the instrument to its default state. |

## Step 2 - Define the display configuration

| | |
|---|---|
| **[CHANNEL MODE]** *[Fault Location]* | Sets up the channel to display fault location measurements. The Channel Mode menu is the default following an instrument preset, so it is not necessary in this case to press the [CHANNEL MODE] key. |

## Step 3 - Define the source conditions

Due to the nature of a fault location measurement, control of the source is not performed in the same way as for a scalar measurement. The output power level and sweep time are specified in the normal way via the [SOURCE] key, but the frequency sweep parameters must be done whilst setting up the measurement configuration, as described in the next step. It is not necessary to turn on the RF power since, for a fault location channel, it is turned on during the fault location calibration.

## Step 4 - Define the measurements

Note that when a channel is set to fault location mode, the instrument will assume that a Test Head is connected and set up the input configuration accordingly (i.e. a measurement of the ratio B/C). Input B is used by the MTS in order to create the fault location response; input C is a reference signal derived from a power splitter within the test head.

In a fault location measurement, the frequency span of the sweep and the distance range to be displayed are related by

$$\text{Frequency Span (GHz)} = \frac{\text{Constant} \times V_r \times \text{Number of Points}}{\text{Range (metres)}}$$

and so two methods of parameter entry are provided.

In the 'range entry' mode (the default mode), the range is entered and this determines the frequency span over which the source is swept. The system adjusts the centre frequency to the centre of the span previously set. A different band of frequencies may be chosen by adjusting the centre frequency, but the value of span (and hence range) will always be preserved. In the 'frequency entry' mode, a frequency span can be entered by adjusting the start/stop values. The range will then be calculated from the entered span.

| | |
|---|---|
| **[MEASURE]** *[Configure Fault Loc]* *[Range Entry]* *[Coax Medium]* | Selects 'range entry' mode, and specifies coaxial transmission line. |
| *[Display Units Feet]* **or** *[Display Units Metres]* | Sets the display units to feet or metres, as required. |
| *[Return to Measure]* | Returns to the top level Measure menu. |

| | |
|---|---|
| ***[Set Up Measurement]*** | A form is displayed showing the current values for the fault location measurement definition. |
| ***[Set Range]***<br>**[3] [0] [x1]** | Enter a range which is about 10 to 20% greater than the estimated length of the cable under test. (The start and stop frequency values are automatically calculated.) |
| ***[Set Cntr Frequency]***<br>**[4] [$G_n$]** | Sets a centre frequency suitable for the cable under test. Higher frequencies may show up faults better. If an antenna is connected to the end of the transmission line, the centre frequency should be the operating frequency of the antenna. A value of 4 GHz is used in this example. |
| ***[Set Number of Points]***<br>**[4] [0] [1] [x1]** | This step would normally be left out, since in most circumstances the number of measurement points can be left at the default setting of 401. In exceptional cases fewer points may be selected to reduce the sweep bandwidth. |
| ***[Set Parameters]***<br>***[Set Relative Velocity]***<br>**[0] [.] [8] [1] [x1]** | In coax mode the value entered for relative velocity is important for accurate distance calculation. A value for the cable under test is usually known, and will usually lie between 0.6 and 1. For the coaxial cable used in this example a velocity factor of 0.81 is used. |
| ***[Set Attenuation]***<br>**[0] [.] [2] [6] [x1]** | A value of 0.26 dB/m is entered to compensate for the attenuation of the cable. Note that since attenuation varies with frequency, a figure appropriate to the centre frequency of the measurement should be used. |
| ***[Return to Set Up Meas]***<br>***[Return to Measure]*** | Returns to the top level Measure menu. |

If a transmission line consists of more than one section and the attenuation figures are significantly different, enter the value for the longer section. If the two sections have similar length use an average value for the two cables.

The relative velocity and attenuation parameters could also be entered by using the Transmission Line Database Memory Card. This allows fault location parameters to be set up automatically by specifying the transmission line type. Use of the database is covered in detail in the MTS Operating Manual.

## Step 5 - Calibrate the measurement system

**[CAL]**
***[Fault Location Cal]***

As for a scalar channel, the measurement system must be calibrated before making any measurements. The MTS provides on-screen instructions for doing this. A matched load is connected to the FAULT LOCATION test port of the test head, then a detector zero is automatically performed, followed by calibration of the measurement system. The calibration data is stored, path calibration is applied and you are then returned to the main Cal menu.

Now connect the cable under test to the FAULT LOCATION port of the test head, and connect a load (or antenna) to the end of the cable. Alternatively, a detector can be used as a termination.

## Step 6 - Choose the format

When the [PRESET] key was pressed in Step 1 the default format for a fault location channel was set to dB (i.e. return loss). However, if it is required to express the measurement as VSWR, change the format as follows. (If the performance of the transmission line is good, it is often easier to see faults or discontinuities with a vertical scale of VSWR.)

**[FORMAT]**
***[dB]* or *[VSWR]*** — Use these keys to switch between dB and VSWR format.

## Step 7 - Select appropriate scaling

It may be necessary to change the scaling to suit the measurement. The default scaling for the two formats is given below:

| Format | Ref. Level | Scale Factor |
|---|---|---|
| dB | 0 | 10.0 dB/div |
| VSWR | 1.0 | 0.1 /div |

The default reference position for dB format is the top graticule line; for VSWR format the reference position is the bottom graticule line.

For the example measurement, the scale factor is changed as follows:

**[SCALING]**
***[Set Scale]***
**[5] [x1]** — Sets the scale factor to 5 dB/div.

The resulting display is shown below:

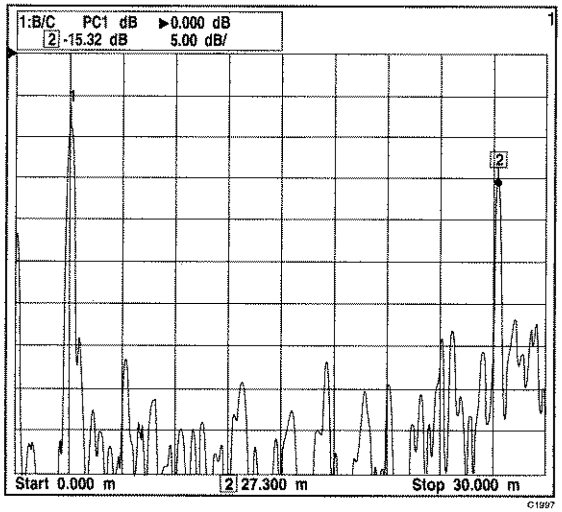



*Fig. 2-20 Fault location measurement*

Alternatively, more suitable scaling could be achieved through the use of the autoscale facility, where the instrument determines the optimum values of scale and reference level, as for a scalar measurement. The fault location channel uses, in addition, an algorithm in which automatic baseline clipping is employed to eliminate noise and emphasise peaks. The reference level is selected such that the positive peaks of the measurement are not clipped by the top graticule line; the scale factor is selected such that 10% of the measurement points are visible above the bottom graticule line, the remaining 90% being clipped.

## Step 8 - Use markers and other MTS features to get detailed information about the measurement

More detailed information about the measurement (including the actual length of the cable) can be obtained through the use of markers. The facilities provided by the marker menus are similar to those available for a scalar channel. For fault location measurements, an additional function locates peaks in the trace and places the active marker at those positions; the response values can be read off from the trace information area. To use this feature press the following keys:

**[MARKERS]**
***[Mkr Functions]***
***[Find Next Peak]***

***[Find Next Peak Right]*** Positions the active marker at the next peak in the trace to the right of its current position.

**and**

***[Find Next Peak Left]*** Positions the active marker at the next peak in the trace to the left of its current position.

In the example shown in Fig. 2-20, it can be seen that the return loss measured at the load (indicated by marker 2) is 15 dB. If the cable were not terminated a large reflection (0 dB) would be seen at the open end of the cable.

The peak at marker 1 is due to a discontinuity resulting from a poor connection where the two cable sections are joined together. Marker 1 shows the fault to be located at approximately 3 m, which is the length of the first section of cable. Since this marker is not active, it is represented on the display by a number '1' which is not enclosed in a box.

Although only information on the active marker is displayed on the screen, the position and response values of all displayed markers can be printed/plotted when a hard copy of the measurement trace is created.

The limit checking feature of the MTS can be used to check that the performance of the cable is satisfactory. For example, a flat limit line could be set up to check that the return loss at any point along the cable is better than 20 dB.

| | |
|---|---|
| **[MEASURE]**<br>***[Fault Loc Functions]***<br>***[Limit Checking]***<br>***[Edit Specification]***<br>***[Add Segment]***<br>***[Flat]*** | Limit Checking Specification 1 (the default) is displayed in a window, and a flat line segment is specified. |
| **[0] [x1]** | Sets the **start** domain value to 0 m. |
| **[-] [2] [0] [x1]**<br>**[-] [2] [0] [0] [x1]** | Sets the **upper** limit value to -20 dB. Since no **lower** limit is required, the lower limit value is forced out of range by setting it to -200 dB. |
| **[3] [0] [x1]** | Sets the **stop** domain value to 30 m. The highlight moves back to the **start** field since upper and lower limit response values for the stop domain value are not required for a flat line segment. |
| ***[Return to Edit Spec]***<br>***[Return to Lim Checking]*** | Returns to the Lim Checking menu. |
| ***[Assign Spec 1-4]***<br>**[1] [x1]**<br>***[Limit Checking ●]*** | Applies limit checking specification 1 to the measurement, and turns on limit checking. The limit line is displayed on the graticule along with a window containing the pass/fail indication. |

For some measurements *masking correction* can be used to give more accurate results for amplitude. A large peak in a fault location measurement (due to a discontinuity or mismatch) can cause an error in the apparent magnitude of a fault beyond it, leading to underestimates in the severity of distant faults. This effect is cumulative, but can be compensated for by applying masking correction. Masking correction is enabled using:

| | |
|---|---|
| **[MEASURE]**<br>***[Fault Loc Functions]***<br>***[Masking Correction ●]*** | Use this key to toggle masking correction on and off. |

Fig. 2-21 shows the trace that results when masking correction is applied. For both this trace and the original one shown in Fig. 2-20, the active marker has been placed at the peak at the end of the cable. It can be seen that this peak measures about 2 dB higher when masking correction is applied.

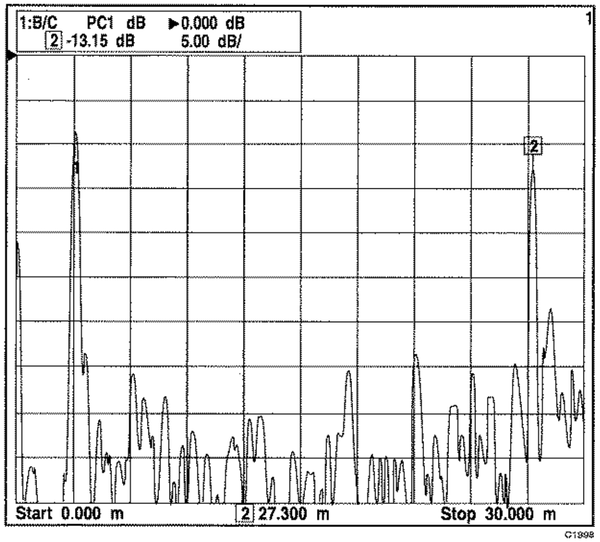
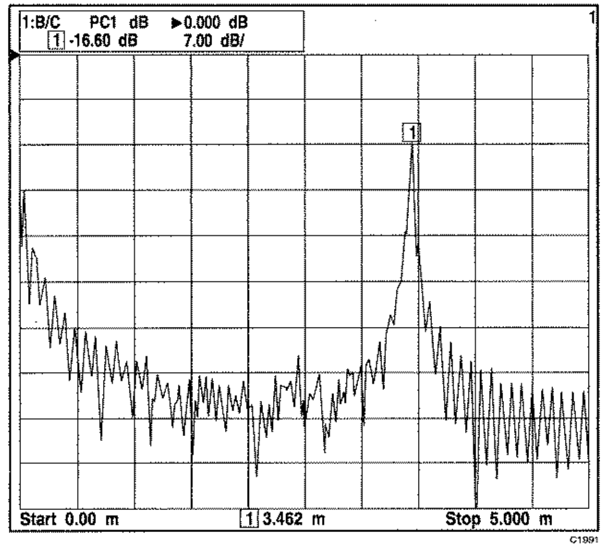



*Fig. 2-21 Effect of masking correction*

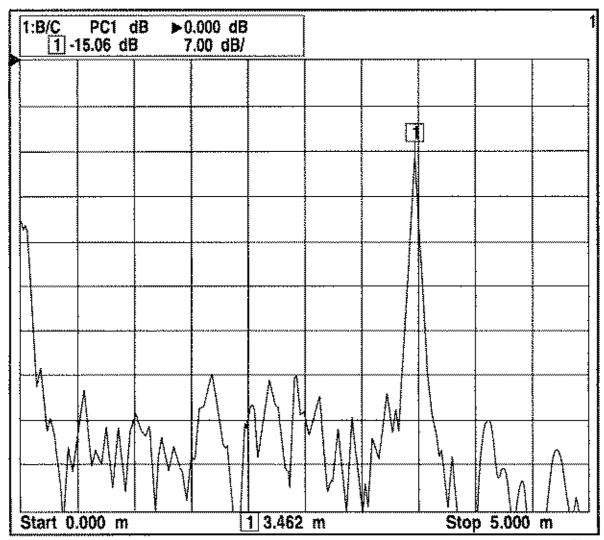
*Windowing* is a function which is applied to the acquired fault location data. Data windowing reduces the amplitudes of the sidelobes associated with the main peak of the display, but gives reduced distance resolution. Thus variation of the windowing level provides a trade-off between distance resolution and the height of the sidelobes. Three levels of windowing are provided. A low windowing level gives greater distance resolution but higher sidelobes; a high windowing level gives reduced sidelobe height but with some loss of distance resolution. A medium windowing level gives an optimum trade-off between distance resolution and sidelobe height for most applications; this is the default setting.

| | |
|---|---|
| **[MEASURE]** | |
| ***[Fault Loc Functions]*** | |
| ***[Windowing Low]* or** | Use these keys to select the windowing level |
| ***[Windowing Medium]* or** | |
| ***[Windowing High]*** | |

Fig. 2-22 shows the effect on the display of two levels of data windowing. In order that the effect can be seen more clearly, the measurement was performed on a different section of cable, of length 3.5 m.




LOW




HIGH

*Fig. 2-22 Effect of windowing*

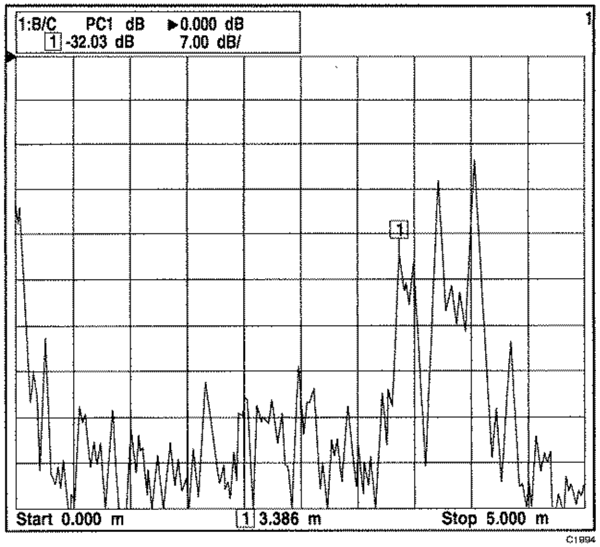
The MTS provides a function that allows you to "zoom in" on a part of the transmission line that is of particular interest, for example, connectors or the interface between two sections of transmission line. Following calibration, the horizontal axis will display distance from zero to the range specified in the Set Up Meas menu. This zoom facility enables you to specify a sub-range of displayed distance values by entering the required start and stop values, or by specifying centre and span values.

In this example, the interface between two sections of transmission line will be examined. The sections are approximately 3.5 and 0.5 m in length, and the range of the measurement was initially set up to be 0 to 5 m.

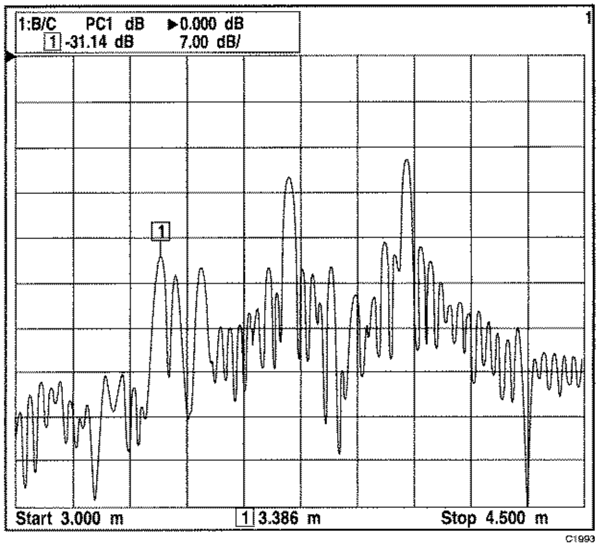
**[MEASURE]**
***[Fault Loc Functions]***
***[Enhanced Mode]***
***[Enhanced Mode ●]*** Turns on the Enhanced Mode feature. This gives an optimally interpolated display trace resulting in improved distance and amplitude accuracy, particularly when displaying a sub-range, as in this example.

***[Set Display Start]*** Sets the start distance to 3 m.
**[3] [x1]**
***[Set Display Stop]*** Sets the stop distance to 4.5 m.
**[4] [.] [5] [x1]**

The MTS now displays the response of the transmission line over the range 3 m to 4.5 m, showing more detail in this region (Fig. 2-23). The peak in the response at which the active marker has been placed corresponds to the connection between the two cables. The next peak represents a fault in the second section and the following peak is the response at the end of this section.




NORMAL DISPLAY




SUB-RANGE DISPLAY

*Fig. 2-23 Display of sub-range*

The display start and stop values can also be set to the distances corresponding to the position of the active marker. Position the active marker on the trace, press either ***[Set Display Start]*** or ***[Set Display Stop]***, then press the **[x1]** key on the numeric keypad. Repeat for the other parameter.

Improved distance and amplitude accuracy can be achieved, although with an increase in measurement time, by turning on *Enhanced Mode*. This can be toggled on and off using the ***[Enhanced Mode]*** soft key.

## Step 9 - Create a permanent record of the measurement results

A hard copy of the measurement can be created via the menus accessed with the **[COPY]** key, as with Example 1.

## Step 10 - Save the instrument settings or measurement traces for future use

Instrument settings or measurement traces can be saved and recalled using the **[SAVE/RECALL]** facilities, as with Example 1.

## Example 10: Fault location measurement of a waveguide using a test head

In this example the transmission line under test is a waveguide comprising four sections, of total length approximately 10 m. It is normally terminated with an antenna whose operating frequency is 10 GHz.

The procedure is essentially the same as in Example 9. The measurement setup is shown in Fig. 2-24. It will be necessary to make connections to the waveguide via suitable coaxial-to-waveguide adapters (which should be of low VSWR).

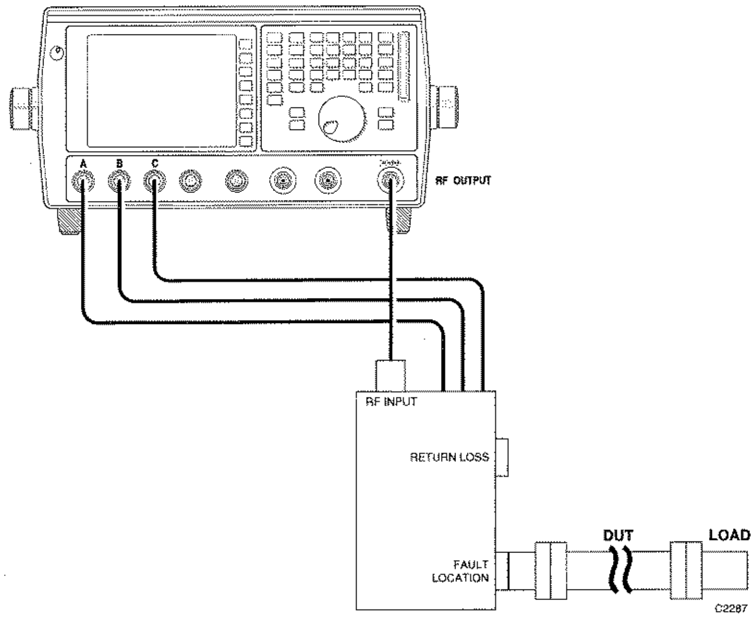



*Fig. 2-24 Setup for fault location measurement*

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]** *[Default Settings]* | Sets the instrument to its default state. |

### Step 2 - Define the display configuration

| | |
|---|---|
| **[CHANNEL MODE]** *[Fault Location]* | Sets up the channel to display fault location measurements. |

## Step 3 - Define the source conditions

The output power level and sweep time can be changed from the default values, if necessary, by using the [SOURCE] key.

## Step 4 - Define the measurements

| | |
|---|---|
| **[MEASURE]**<br>***[Configure Fault Loc]***<br>***[Range Entry]***<br>***[Waveguide Medium]*** | Selects 'range entry' mode, and specifies waveguide transmission line. |
| ***[Display Units Feet]***<br>**or**<br>***[Display Units Metres]*** | Sets the display units to feet or metres, as required. |
| ***[Return to Measure]*** | Returns to the top level Measure menu. |
| ***[Set Up Measurement]*** | A form is displayed showing the current values for the fault location measurement definition. |
| ***[Set Range]***<br>**[1] [2] [x1]** | Sets the range to 12 m. |
| ***[Set Cntr Frequency]***<br>**[1] [0] [$G_n$]** | Sets the centre frequency to 10 GHz. |
| ***[Set Parameters]***<br>***[Set Cutoff Frequency]***<br>**[6] [.] [5] [5] [7] [$G_n$]** | This specifies the frequency below which propagation ceases in the waveguide. This parameter is required in order that the MTS can generate the non-linear frequency sweep that is required for waveguide measurements (to eliminate the effects of dispersion). |
| ***[Set Attenuation]***<br>**[0] [.] [1] [8] [7] [x1]** | A value of 0.187 dB/m is entered to compensate for the attenuation of the waveguide. |

If a transmission line consists of more than one section and the attenuation figures are significantly different, enter the value for the longer section. If the 2 sections have similar length use an average value for the two cables.

| | |
|---|---|
| ***[Return to Set Up Meas]***<br>***[Return to Measure]*** | Returns to the top level Measure menu. |

The cutoff frequency and attenuation parameters could also be entered by using the Transmission Line Database Memory Card. This allows fault location parameters to be set up automatically by specifying the transmission line type. Use of the database is covered in detail in the MTS Operating Manual.

## Step 5 - Calibrate the measurement system

| | |
|---|---|
| [CAL]<br>*[Fault Location Cal]* | The MTS provides on-screen instructions for calibrating the measurement system. After a load is connected to the FAULT LOCATION test port of the test head, a detector zero is automatically performed, followed by calibration of the measurement system. The calibration data is stored and path calibration is applied to the measurement. |

Now connect the waveguide under test to the FAULT LOCATION port of the test head, and connect the antenna to the end of the waveguide.

## Step 6 - Choose the format

| | |
|---|---|
| [FORMAT]<br>*[dB]* or *[VSWR]* | Use these keys to switch between dB and VSWR format. |

## Step 7 - Select appropriate scaling

For the example measurement, the scaling is set as follows:

| | |
|---|---|
| [SCALING]<br>*[Set Scale]*<br>[7] [x1] | Sets the scale factor to 7 dB/div. |

The resulting display is shown below:

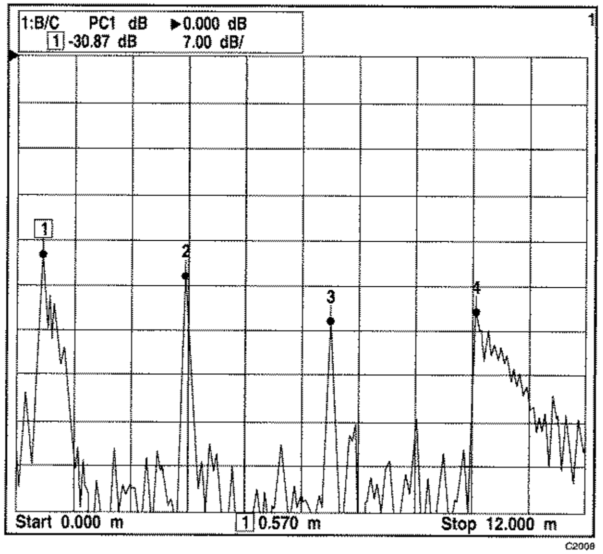



*Fig. 2-25 Waveguide fault location measurement*

## Step 8 - Use markers and other MTS features to get detailed information about the measurement

The facilities provided by the MTS to aid examination of the fault location measurement have been covered in Example 9.

It can be seen from Fig. 2-25 that there are four main peaks on the trace, on which markers have been placed. Marker 1 indicates the connection between the test head and the waveguide. Markers 2 and 3 each indicate a connection between two sections of waveguide, and marker 4 represents the antenna connection.

## Step 9 - Create a permanent record of the measurement results

A hard copy of the measurement can be created via the menus accessed with the **[COPY]** key, as with Example 1.

## Step 10 - Save the instrument settings or measurement traces for future use

Instrument settings or measurement traces can be saved and recalled using the **[SAVE/RECALL]** facilities, as with Example 1.

## Example 11: Dual channel insertion loss and fault location measurement of a coaxial cable using a test head

This example illustrates the simultaneous display of fault location and insertion loss measurements. It is a continuation of Example 9 and it is assumed that steps 1 to 7 have been performed to give a fault location display on channel 1.

Connect a 6230 detector as shown in Fig. 2-26. (For fault location measurements, the 'A' input lead from the Test Head is not used and does not need to be connected to the MTS.)

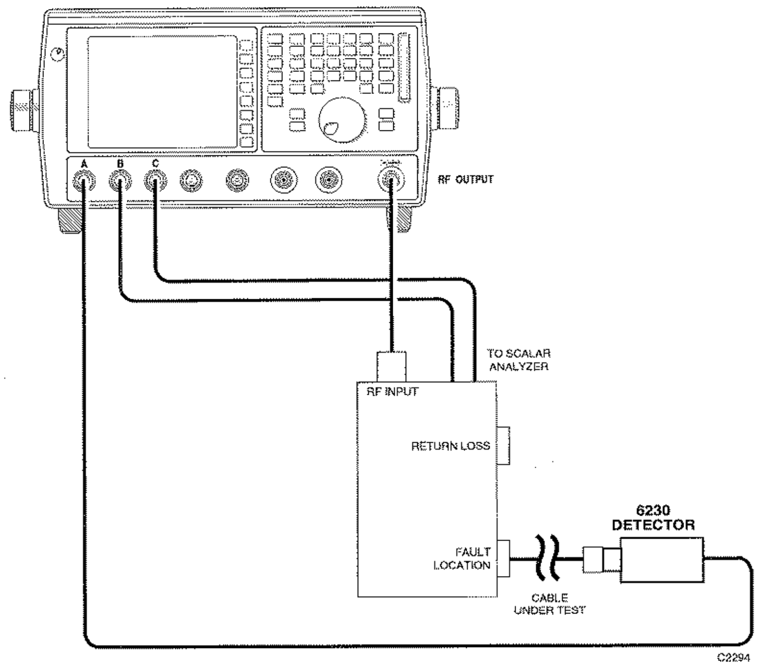



*Fig. 2-26 Setup for simultaneous measurement of fault location and insertion loss*

| | |
|---|---|
| **[CHANNEL MODE]** ***[Dual Channel Display]*** | The display now shows two channels. The fault location measurement is shown on channel 1, and channel 2 is a scalar channel that is used to measure the insertion loss of the transmission line. |
| **[SELECT MEAS]** | Make measurement 1 of channel 2 the active measurement. |

**[MEASURE]** Defines measurement 1 of channel 2 to measure the ratio of inputs A and C, where input C is the reference input.
***[Measurement Definition]***
***[Input Ratio]***
***[A/]***
***[A / C]***

Alternatively, input D of the MTS can be used to measure the insertion loss, and the 'A' lead of the Test Head can remain connected to input A. The measurement will then be the ratio D/C. It will be necessary to ensure that input D is configured as a scalar detector input, rather than a power sensor input. An error message will be displayed if a detector is connected to input D and it has not been configured to accept it.

**[MEASURE]** Configures all four inputs A, B, C and D to accept scalar detectors.
***[General Set-up]***
***[Input Configuration]***
***[All Inputs are Scalar]***

**[SOURCE]** Sets the frequency range for the insertion loss measurement to 500 MHz - 18 GHz.
***[Set Start Frequency]***
**[5] [0] [0] [Mμ]**
***[Set Stop Frequency]***
**[1] [8] [Gn]**

Ensure the cable under test is not connected to the FAULT LOCATION port of the test head and connect the detector to the FAULT LOCATION port.

**[CAL]** Performs a through path calibration for the insertion loss path, and applies the path cal data to the measurement.
***[Through Cal]***
***[Continue]***

Reconnect the cable to the FAULT LOCATION port and connect the detector to the end of the cable. The display now shows the insertion loss measurement on channel 2; the scaling is set as follows:

**[SCALING]**
***[Set Ref Level]***
**[1] [x1]** Sets the reference level to +1 dB.
***[Set Scale]***
**[0] [.] [5] [x1]** Sets the scale factor to 0.5 dB/div.

The resulting two channel display is shown in Fig. 2-27.

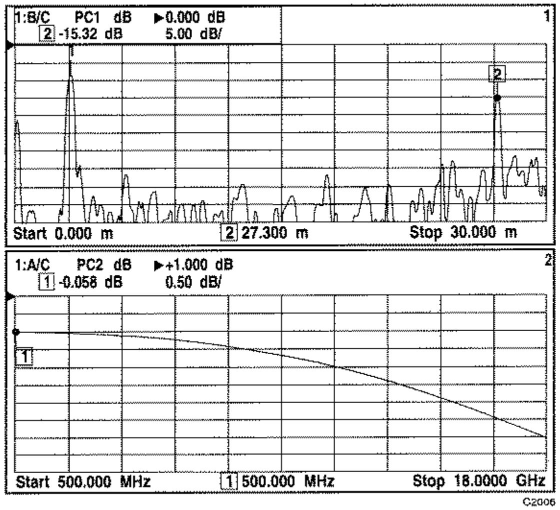



*Fig. 2-27 Simultaneous fault location and insertion loss measurements*

Note that simultaneous live measurements of fault location and return loss are not possible, since one measurement requires that the DUT be connected to the FAULT LOCATION port of the test head, while the RETURN LOSS port is used for the other measurement. However, it is possible to freeze the display of one measurement using the [HOLD] key, and then set up the other as a live measurement on the other channel.

## Example 12: Return loss measurement of a coaxial cable using a fault locator

The 6240 Series Fault Locator, when used with the MTS, enables both return loss and fault location measurements to be made from a single test port. The display can show the measurements simultaneously on two channels.

This example describes a measurement of the return loss of a coaxial cable using a 6240 Series Fault Locator. Connect the Fault Locator to input A and input B of the MTS and the RF input of the Fault Locator to the RF output of the MTS (Fig. 2-28).

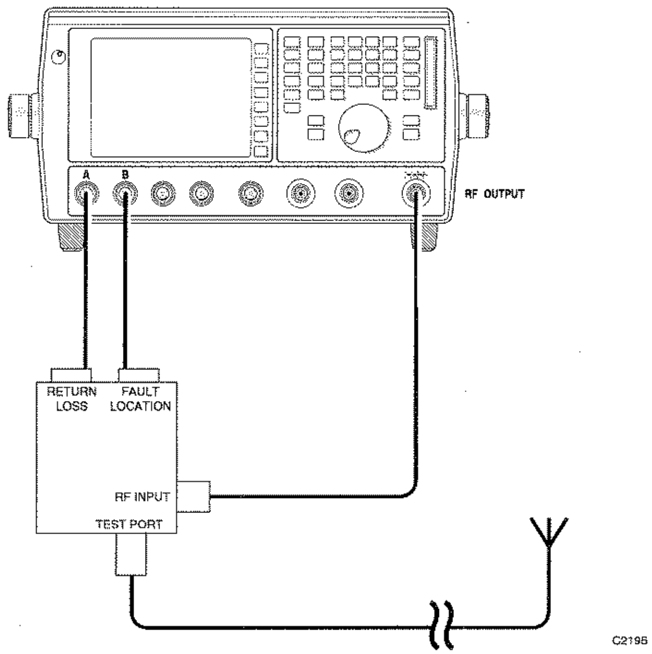



*Fig. 2-28 Setup for return loss measurement using a Fault Locator*

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]** | Sets the instrument to its default state. |
| ***[Default Settings]*** | |

## Step 2 - Define the display configuration

Measurement 1 of channel 1 will be used to display the return loss of the cable. Since the default state of the instrument is a single scalar channel displaying measurement 1, we can proceed immediately to Step 3.

## Step 3 - Define the source conditions

| | |
|---|---|
| **[SOURCE]**<br>***[Set Start Frequency]***<br>**[1] [.] [7] [5] [G $_n$]** | Sets the start frequency to 1.75 GHz. |
| ***[Set Stop Frequency]***<br>**[1] [.] [9] [5] [G $_n$]** | Sets the stop frequency to 1.95 GHz. |
| **[ENTRY OFF]** | Terminates numeric entry. |
| ***[RF ●]*** | Turns on the RF power. |

## Step 4 - Define the measurements

| | |
|---|---|
| **[MEASURE]**<br>***[Single Input A,B,C or D]***<br>***[A]***<br>***[Return to Measure]*** | This is dependent on which input the return loss cable from the fault locator is connected to. In this example input A has been selected. |
| ***[General Set-up]***<br>***[AC Detection]*** | Sets the detection mode to AC. |

## Step 5 - Calibrate the measurement system

| | |
|---|---|
| **[CAL]**<br>***[Short AND Open Cal]*** | Presents a message stating that the path cal store about to be used for the calibration is store 1, and prompts for connection of a short circuit (termination) to the Fault Locator test port. |
| ***[Continue]*** | Initiates the short circuit calibration. When completed a message will be displayed stating that an open circuit termination should be connected to the test port. |
| ***[Continue]*** | Initiates the open circuit calibration. Upon completion, the path cal data is automatically applied to the measurement. |

Now connect the cable under test to the Fault Locator.

## Step 6 - Choose the format

| | |
|---|---|
| **[FORMAT]**<br>***[VSWR]*** | If required use these keys to change the format of the return loss measurement to VSWR. |

## Step 7 - Select appropriate scaling

| | |
|---|---|
| [SCALING] | |
| *[Set Ref Level]* | |
| [0] [x1] | Sets the reference level to 0 dB. |
| *[Set Scale]* | |
| [5] [x1] | Sets the scale factor to 5 dB/div. |

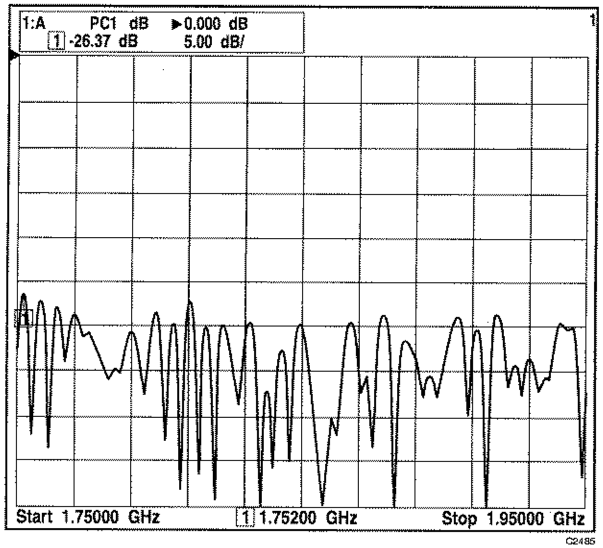



*Fig. 2-29 Return loss measurement of coaxial cable*

The remaining steps would be similar to those of Example 1.

## Example 13: Fault location measurement of a coaxial cable using a fault locator

In this example, a fault location measurement will be made on a transmission line consisting of two sections of coaxial cable, with lengths 3 m and 24 m, connected together using an adapter. The measurement will be performed using a 6240 Series Fault Locator, and the measurement setup is shown below:

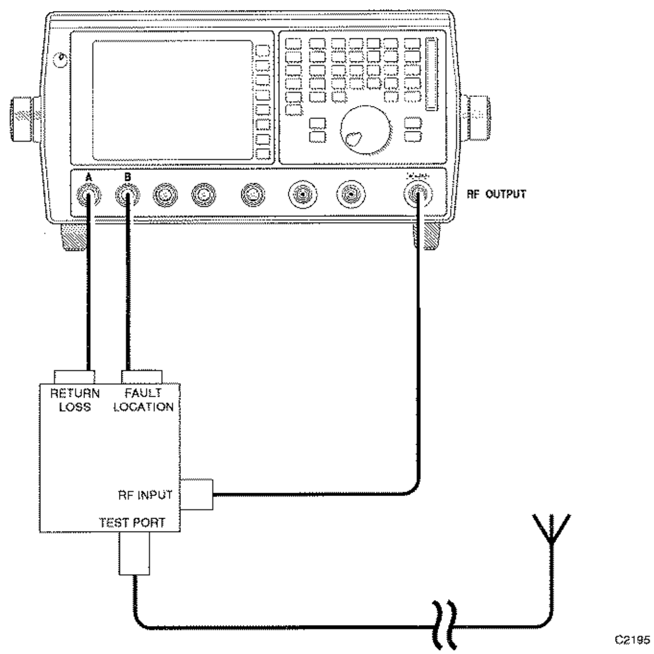



*Fig. 2-30 Setup for fault location measurement using a Fault Locator*

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| [PRESET]<br>*[Default Settings]* | Sets the instrument to its default state. |

### Step 2 - Define the display configuration

| | |
|---|---|
| [CHANNEL MODE]<br>*[Fault Location]* | Sets up the channel to display fault location measurements. The Channel Mode menu is the default following an instrument preset, so it is not necessary in this case to press the [CHANNEL MODE] key. |

## Step 3 - Define the measurements

When a Fault Locator is used, the MTS automatically recognises which input the fault location lead is connected to and selects this input automatically (input B in this example).

| | |
|---|---|
| **[MEASURE]**<br>***[Configure Fault Loc]***<br>***[Range Entry]***<br>***[Coax Medium]*** | Selects 'range entry' mode, and specifies coaxial transmission line. |
| ***[Display Units Feet]***<br>***or***<br>***[Display Units Metres]*** | Sets the display units to feet or metres, as required. |
| ***[Return to Measure]*** | Returns to the top level Measure menu. |
| ***[Set Up Measurement]*** | A form is displayed showing the current values for the fault location measurement definition. |
| ***[Set Range]***<br>**[3] [0] [x1]** | Enter a range that is about 10 to 20 % greater than the estimated length of the waveguide under test. (The start and stop frequency values are automatically calculated.) |
| ***[Set Cntr Frequency]***<br>**[8] [G $_n$]** | Sets a centre frequency suitable for the cable under test. Higher frequencies may show up faults better provided the frequency chosen is within the operating band of the cable. |
| ***[Set Number of Points]***<br>**[4] [0] [1] [x1]** | This step would normally be left out, since in most circumstances the number of measurement points can be left at the default setting of 401. In exceptional cases fewer points may be selected to reduce the minimum range. |
| ***[Set Parameters]***<br>***[Set Relative Velocity]***<br>**[0] [.] [8] [1] [x1]** | In coaxial mode the value entered for relative velocity is important for accurate distance calculation. |
| ***[Set Attenuation]***<br>**[0] [.] [2] [5] [x1]** | A value of 0.25 dB/m is entered to compensate for the attenuation of the cable. Note that since attenuation varies with frequency, a figure appropriate to the centre frequency of the measurement should be used. |
| ***[Return to Set Up Meas]***<br>***[Return to Measure]*** | Returns to the top level Measure menu. |

The relative velocity and attenuation parameters could also be entered by using the Transmission Line Database Memory Card. This allows fault location parameters to be set up automatically by specifying the transmission line type. Use of the database is covered in detail in the MTS Operating Manual.

## Step 4 - Calibrate the measurement system

[CAL] *[Fault Location Cal]* — The measurement system must be calibrated before making any measurements. Connect a matched load to the TEST PORT of the Fault Locator.

*[Continue]* — Initiates the calibration; when completed, the calibration data is stored and applied to the measurement.

Now connect the cable under test to the test port of the Fault Locator, and connect a load or antenna to the end of the cable under test.

## Step 5 - Choose the format

[FORMAT] *[dB] or [VSWR]* — Use these keys to change between dB and VSWR format.

## Step 6 - Select appropriate scaling

[SCALING]
*[Set Scale]*
[5] [x1] — Sets the scale factor to 5 dB/div.

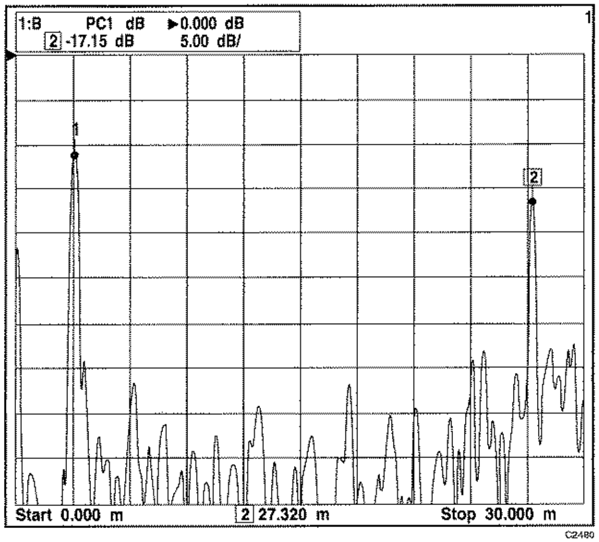



*Fig. 2-31 Fault location measurement of a coaxial cable*

The remaining steps would be similar to those of Example 9.

# Example 14: Fault location measurement of a waveguide using a fault locator

This example is similar to the previous one, except that the transmission line under test is a 10 m section of waveguide, which operates at a centre frequency of 10 GHz. It will be necessary to make connections to the waveguide via suitable coaxial-to-waveguide adapters (which should be of low VSWR).

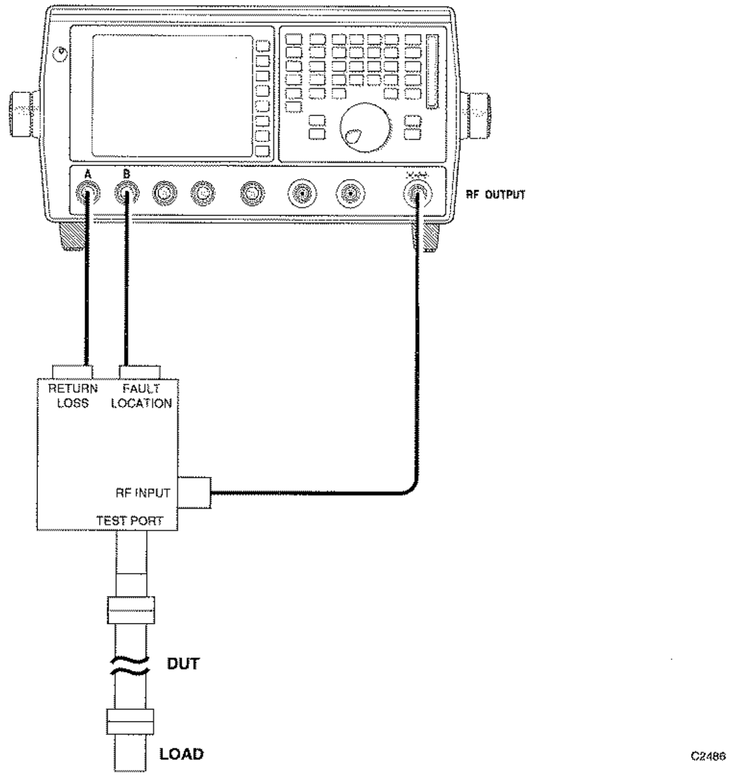



*Fig. 2-32 Setup for fault location measurement using a Fault Locator*

## Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]** | Sets the instrument to its default state. |
| ***[Default Settings]*** | |

## Step 2 - Define the display configuration

| | |
|---|---|
| **[CHANNEL MODE]**<br>***[Fault Location]*** | Sets up the channel to display fault location measurements. The Channel Mode menu is the default following an instrument preset, so it is not necessary in this case to press the [CHANNEL MODE] key. |

## Step 4 - Define the measurements

| | |
|---|---|
| **[MEASURE]**<br>***[Configure Fault Loc]***<br>***[Range Entry]***<br>***[Waveguide Medium]*** | Selects 'range entry' mode, and specifies waveguide transmission line. |
| ***[Display Units Feet]***<br>***or***<br>***[Display Units Metres]*** | Sets the display units to feet or metres, as required. |
| ***[Return to Measure]*** | Returns to the top level Measure menu. |
| ***[Set Up Measurement]*** | A form is displayed showing the current values for the fault location measurement definition. |
| ***[Set Range]***<br>**[1] [2] [x1]** | Enter a range that is about 10 to 20 % greater than the estimated length of the waveguide under test. (The start and stop frequency values are automatically calculated.) |
| ***[Set Cntr Frequency]***<br>**[1] [0] [G $_n$]** | Sets a centre frequency suitable for the waveguide under test. In this example the centre frequency is set to 10 GHz. |
| ***[Set Parameters]***<br>***[Set Cutoff Frequency]***<br>**[6] [.] [5] [5] [7] [G $_n$]** | This specifies the frequency below which propagation ceases in the waveguide. This parameter is required in order that the MTS can generate the non-linear frequency sweep that is required for waveguide measurements (to eliminate the effects of dispersion). |
| ***[Set Attenuation]***<br>**[0] [.] [1] [8] [7] [x1]** | A value of 0.187 dB/m is entered to compensate for the attenuation of the waveguide. |
| ***[Return to Set Up Meas]***<br>***[Return to Measure]*** | Returns to the top level Measure menu. |

## Step 5 - Calibrate the measurement system

| | |
|---|---|
| **[CAL]**<br>***[Fault Location Cal]*** | The measurement system must be calibrated before making any measurements. Connect a matched load to the TEST PORT of the Fault Locator. |

Now connect the waveguide under test to the test port of the Fault Locator, and connect a load to the end of the waveguide.

## Step 6 - Choose the format

| | |
|---|---|
| [FORMAT]<br>*[dB] or [VSWR]* | Use these keys to change between dB and VSWR format. |

## Step 7 - Select appropriate scaling

| | |
|---|---|
| [SCALING]<br>*[[Set Scale]*<br>[7] [x1] | <br><br>Sets the scale factor to 7 dB/div. |

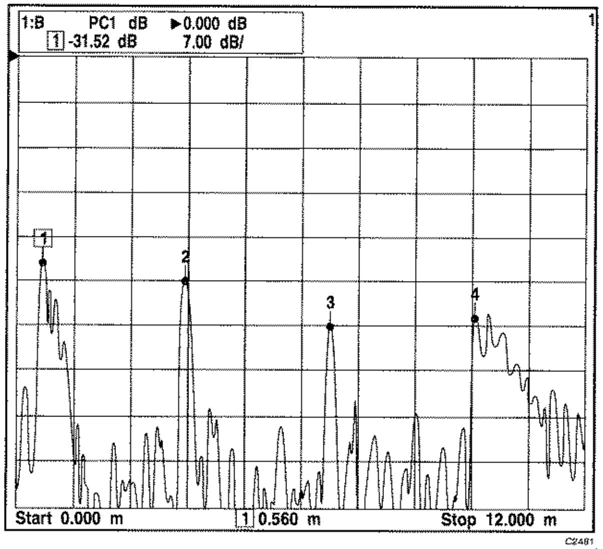



*Fig. 2-33 Fault location measurement of a waveguide*

# Example 15: Fault location measurement of a coaxial cable using an RF divider

This example shows how to make a fault location measurement using a single input rather than a ratio measurement of two inputs. In order to do this, an RF divider and detector is used instead of a Test Head. The divider/detector would normally be used with a 6202B RF Test Set, enabling users working in the RF band to make fault location measurements at relatively low cost. However, single input fault location measurements can also be made with the other instruments of the 6200B series.

The following procedure describes a fault location measurement on a 30 m length of coaxial cable (Andrew LDF2-50).

Connect the RF output of the instrument to port 1 of the divider, and connect the detector from input A of the instrument to port 2 of the divider (Fig. 2-34).

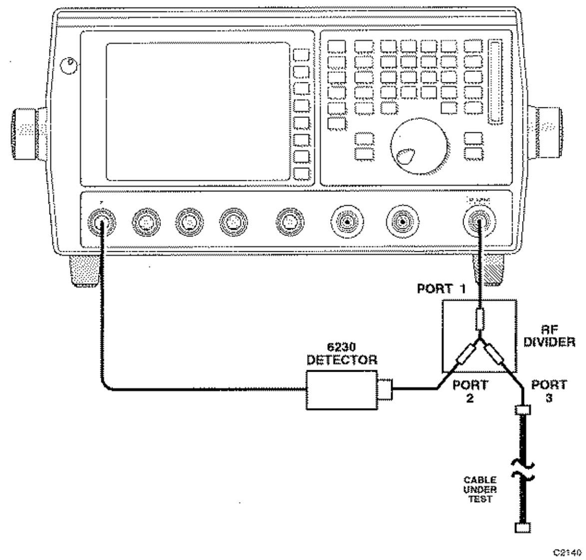



*Fig. 2-34 Setup for single input fault location measurement*

## Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]**<br>***[Default Settings]*** | Sets the instrument to its default state. |

## Step 2 - Define the display configuration

| | |
|---|---|
| **[CHANNEL MODE]**<br>***[Fault Location]*** | Sets up the channel to display fault location measurements. |

## Step 3 - Define the measurements

| | |
|---|---|
| [MEASURE]<br>*[Configure Fault Loc]*<br>*[Range Entry]*<br>*[Coax Medium]* | Selects 'range entry' mode, and specifies coaxial transmission line. |
| *[Display Units Metres]* | Sets the display units to metres. |
| *[Measurement Definition]*<br>*[Single Input A, B, C or D]*<br>*[A]* | The instrument assumes that a test head will be used for the fault location measurement, and so defaults to a ratio measurement of B/C. Since a divider is used a single input measurement needs to be defined. |
| *[Return to Meas Def]*<br>*[Return to Config F Loc]*<br>*[Return to Measure]* | Returns to the top level Measure menu. |
| *[Set Up Measurement]* | A form is displayed showing the current values for the fault location measurement definition. |
| *[Set Range]*<br>[3] [3] [x1] | Enter a range which is about 10 to 20% greater than the estimated length of the cable under test. |

It should be noted that the range entered determines the bandwidth used, and vice versa. The shorter the range the greater the bandwidth. The 6202B RF Test Set is most likely to be used with this measurement setup. This has an upper frequency of 2 GHz, so the minimum range possible is approximately 15 m using the default figure of 401 points. If a smaller distance range is required, this can be achieved by reducing the number of measurement points, using [MEASURE] *[Set Up Measurement] [Set Number of Points]*.

| | |
|---|---|
| *[Set Cntr Frequency]*<br>[9] [4] [0] [Mμ] | Sets the centre frequency to the system's nominal operating frequency. |
| *[Set Parameters]*<br>*[Set Relative Velocity]*<br>[0] [.] [8] [8] [x1] | A velocity factor of 0.88 is assumed in this example. |
| *[Set Attenuation]*<br>[0] [.] [1] [1] [x1] | A value of 0.11 dB/m is entered to compensate for the attenuation of the cable at the operating frequency. |

## Step 4 - Calibrate the measurement system

| | |
|---|---|
| [CAL]<br>*[Fault Location Cal]* | A matched load is connected to port 3 of the divider and calibration of the measurement system is performed. |

Now connect the cable under test to port 3 of the divider, and connect either the antenna or a suitable load to the end of the cable.

The remaining steps would be similar to those of Example 10.

## Example 16: Single-ended insertion loss measurement of a transmission line using a Fault Locator

A conventional insertion loss measurement on a transmission line requires simultaneous access to both ends of the line. This is not practical when the line is long, so the 6200B provides a method whereby insertion loss is derived from a measurement of return loss.

In a single-ended insertion loss measurement, either a short circuit termination or an open circuit termination is connected to the end of the line, so that theoretically 100% of the input power is reflected back to the source. A 6240 series Fault Locator is used as the bridge at the input end of the line to measure the reflected signal. As an alternative to the Fault Locator a dedicated bridge or coupler with a scalar detector can be used. Since this signal is attenuated twice (once in each direction), the measurement of the total attenuation in dB is halved by the MTS to produce a value for the insertion loss.

This method is not suitable for high loss cables, because the signal is attenuated in both directions by the cable.

The following procedure describes a single-ended insertion loss measurement on a 30 m length of coaxial cable. The procedure is similar to that described in Example 4, except for the calibration step. The measurement setup is shown in Fig. 2-35.

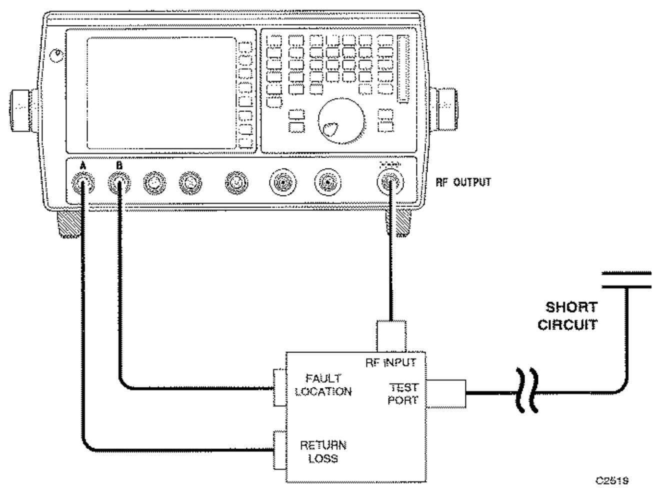



*Fig. 2-35 Setup for single-ended insertion loss measurement*

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]**<br>***[Default Settings]*** | Sets the instrument to its default state. |

## Step 2 - Define the display configuration

Measurement 1 of channel 1 will be used to display the insertion loss of the cable. Since the default state of the instrument is a single scalar channel displaying measurement 1, we can proceed immediately to Step 3.

## Step 3 - Define the source conditions

| | |
|---|---|
| **[SOURCE]**<br>***[Set Start Frequency]***<br>**[1] [0][$M_\mu$]** | Sets the start frequency to 10 MHz. |
| ***[Set Stop Frequency]***<br>**[2] [$G_n$]** | Sets the stop frequency to 2 GHz. |
| **[ENTRY OFF]** | Terminates numeric entry. |
| ***[RF ●]*** | Turns on the RF power. |

## Step 4 - Define the measurements

Since the return loss is measured by a scalar detector connected to input A, no change needs to be made to the measurement definition since all measurements default to input A following PRESET.

| | |
|---|---|
| **[MEASURE]**<br>***[General Set-up]***<br>***[AC Detection]***<br>***[Return to Measure]*** | Sets the detection mode to AC in order to reject signals from other sources (such as transmitters) which could interfere with the measurement |

## Step 5 - Calibrate the measurement system

| | |
|---|---|
| **[CAL]**<br>***[Single Ended Ins Loss]***<br>***[Short OR Open Cal]*** | Presents a message stating that the path cal store about to be used for the calibration is store 1, and prompts for connection of a short circuit termination to the test port. |
| ***[Continue]*** | Initiates the short circuit calibration. Upon completion, a message will be displayed stating that the transmission line under test should be connected to the test port, and the line terminated with a short circuit. |
| ***[Continue]*** | The trace now shows the insertion loss of the transmission line under test. |

## Step 6 - Choose the format

The default format of dB is appropriate to this measurement.

## Step 7 - Select appropriate scaling

| | |
|---|---|
| [SCALING] | |
| *[Set Ref Level]* | |
| [0] [x1] | Sets the reference level to 0 dB. |
| *[Set Scale]* | |
| [1] [x1][ | Sets the scale factor to 1 dB/div.. |

## Step 8 - Use markers and other MTS features to get detailed information about the measurement

It is likely that there will be a ripple superimposed on the measurement due to mismatch between the test port and the cable under test. This displayed effect of the ripple can be minimised using the smoothing feature of the MTS.

[MEASURE]
*[Smoothing]*
*[Set Aperture]*
[2] [x1]
*[Smoothing ●]*

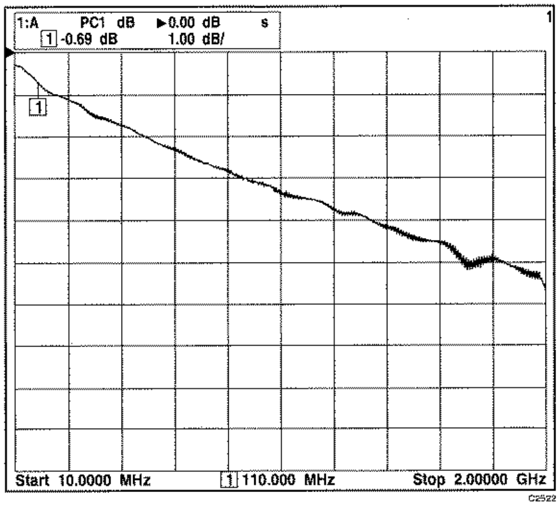



*Fig. 2-36 Single-ended insertion loss measurement*

# Example 17: Power meter and counter measurements

This example illustrates the use of the power meter and frequency counter features of the MTS.

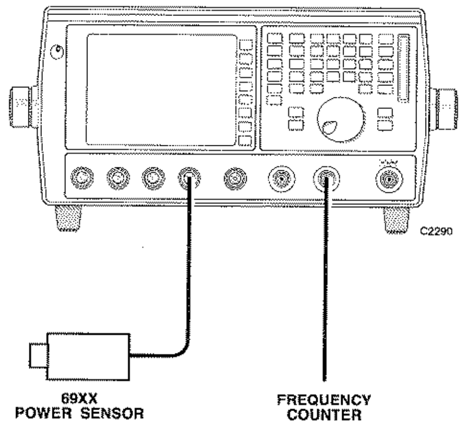



*Fig. 2-37 Power meter and counter measurements*

## POWER METER MEASUREMENTS

The power meter function can be used to measure the absolute power of a signal using the appropriate power sensor. The sensor must be connected to input D of the MTS using the supplied cable. Any of the MI 6900 series power sensors can be used, covering a power range of -70 dBm to +35 dBm and a frequency range of 30 kHz to 40 GHz.

A 50 MHz internal calibrator port is provided on the front panel to ensure precise power measurements; full calibration factor and linearity correction is incorporated to further ensure high accuracy. An analogue peaking meter is provided in addition to the four digit display to assist when tuning and peaking. The maximum/minimum hold function can be used in applications such as long-term drift monitoring. Upper and lower limits may be entered for automatic pass/fail indication.

Connect the power sensor to input D of the MTS.

### Step 1 - Preset the instrument to a known state

**[PRESET]** Sets the instrument to its default state.
***[Default Settings]***

## Step 2 - Define the display configuration

| | |
|---|---|
| **[CHANNEL MODE]**<br>***[Readout]*** | Sets up channel 1 to display readout measurements. The Channel Mode menu is the default following an instrument preset, so it is not necessary in this case to press the [CHANNEL MODE] key. |

## Step 3 - Define the measurements

| | |
|---|---|
| **[MEASURE]**<br>***[Power Meter]*** | By default, the quantity that will be measured and displayed is the power level detected by a power sensor connected to input D. So in this case it is not necessary to press these keys. The following soft key, labelled *[Counter]*, is pressed when it is required to display the frequency of the signal present at the COUNTER input. Ensure that you leave the display showing a power measurement. |

## Step 4 - Calibrate the measurement system

To measure power levels accurately, it is necessary to perform a power sensor calibration for the readout channel. This procedure utilises the 50 MHz, 1 mW power reference available from the front panel. The sensor is calibrated by connecting it to the POWER REF output. The supplied 30 dB attenuator must be used if measuring with a low power sensor (692X); the supplied adapter must be used if measuring with a 75 Ω sensor (6919). The system measures the difference between the sensor and reference outputs and uses this to correct subsequent measurements.

| | |
|---|---|
| **[CAL]**<br>***[Sensor Cal]*** | A window is displayed stating the current cal and linearity values and instructs you to connect the power sensor to the power reference. |
| ***[Set Cal Factor]***<br>**[9] [9] [x1]** | Enter the value of **reference calibration factor** given on the sensor label (e.g. 99%). Some sensors (e.g. 6910) do not have this information on the label; in these cases the default value of 100% is assumed. |
| ***[Set Lin Factor]***<br>**[7] [.] [5] [x1]** | Enter the value of **linearity factor** given on the sensor label (e.g. 7.5). |
| ***[Continue]*** | The MTS turns off the power reference and initiates zeroing of the sensor. When this is completed, the power reference is turned on and sensor calibration is performed. During both the zeroing and calibration phases a horizontal bar is displayed indicating their progress. |

| | |
|---|---|
| *[Power Ref ●]* | The quality of the power sensor calibration can be checked by turning on the power reference and ensuring that the value reads 0 dBm. When the power reference is turned on **PWRREF** is displayed in the General Information Area at the top of the display. Press the soft key again to turn the power reference off. |

The calibration factor must now be set to the correct value for the signal we wish to measure. For example, if we want to measure the power of a 14 GHz signal, read the calibration factor for 14 GHz from the sensor label (e.g. 96%).

| | |
|---|---|
| **[MEASURE]**<br>***[General Set-up]***<br>***[Sensor Correction]***<br>***[Cal Factor & Lin Factor]***<br>***[Set Cal Factor]***<br>**[9] [6] [x1]** | Sets the cal factor for the measurement to 96%. |

Alternatively, the cal factor information on the label could be entered into the MTS as a table of cal factor *versus* frequency. This would then allow **Cal Factor User Freq** to be specified, which means that only the measurement frequency need be entered and the MTS would automatically apply the appropriate calibration data.

Now connect the power sensor to the signal to be measured. Be careful not to overload the sensor, especially if it is a 6920 series high sensitivity type.

## Step 5 - Choose the format

| | |
|---|---|
| **[FORMAT]**<br>***[dB / dBm]***<br>**or**<br>***[Watts]*** | Use these keys to select Watts or dBm format. |

## Step 6 - Use markers and other MTS features to get detailed information about the measurement

Marker functions do not apply to power meter readout measurements, but the following useful features may be used.

An analogue peaking indicator is provided, below the power readout, whose length varies according to the power readout.

| | |
|---|---|
| **[MEASURE]**<br>***[Reset Peak Indicator]*** | This key causes the peaking indicator to be reset such that the current power measurement will give half full scale reading. |

The extremities of the line represent ±6 dB from the centre value, which is the power reading that was measured when the *[Reset Peak Indicator]* key was last pressed.

This analogue representation is not for measurement, but enables changes in the measurement to be seen more easily than with the digital display. It is normally used for tuning and peaking power levels.

*[Measurement Functions]*
*[Max Min Hold]*
*[Hold ●]*

This will display and hold the highest and lowest power levels measured.

*[Clear]*

Causes both the minimum and maximum values to be set to the current measurement.

Limit checking can be used to determine if the device under test meets its specification. Upper and lower limits can be defined and a pass/fail indication is then displayed above the readout value. As an example, assume that the power levels are required to be in the range -5 dBm to +5 dBm. To test for this you can use limit checking in the following way:

**[MEASURE]**
*[Measurement Functions]*
*[Limit Checking]*
*[Set Max Limit]*
**[5] [x1]**
*[Set Min Limit]*
**[-] [5] [x1]**
*[Limit Checking ●]*

Sets the upper and lower limit values to +5 dBm and -5 dBm and turns on limit checking. The limit values are displayed to the left of the readout.

**[MEASURE]**
*[dB Rel]*
*[Store Measurement]*

This causes the current power level in dBm to be stored, and subsequent power measurements are made relative to this value. The relative measurement mode is indicated by an **R** flag above the displayed readout value.

**[MEASURE]**
*[Averaging]*
*[Input D]*
*[User Set Averaging*
*[Set Average Number]*
**[1] [0] [0] [x1]**

Turns on averaging to reduce the effects of noise on the power measurement. This is indicated by the **A** flag above the readout value. In this example, the **average number** is set to 100. The minimum amount of averaging should be selected to reduce noise to an acceptable level, in order to maintain a sufficiently fast response. Alternatively, the *[Automatic Averaging]* key can be pressed, in which case the average number will be chosen automatically depending on the power range being measured and the power sensor type.

This menu also enables the display resolution for the readout to be selected. Resolutions of 0.01, 0.1 and 1 dB are available by pressing the appropriate soft key. When automatic averaging is enabled the display will be at the maximum resolution of 0.001 dB. Note that a higher resolution results in a longer averaging time, giving a slower response.

The power meter measures the average power of a signal. To measure the peak power of a pulsed signal, correction must be applied to compensate for the duty cycle of the waveform. Duty cycle is defined as the percentage ratio of RF on time to RF off. Duty cycle correction may be applied as follows:

| | |
|---|---|
| **[MEASURE]**<br>***[Measurement Functions]***<br>***[Duty Cycle correction]***<br>***[Set Duty Cycle Value]***<br>**[5] [0] [x1]**<br>***[Duty Cycle ●]*** | This would set a duty cycle value of 50% and turn on duty cycle correction. |

### Step 7 - Create a permanent record of the measurement results

Although not so meaningful it is still possible to obtain hard copy output of the power level readout, in either graphical plot or print format.

### Step 8 - Save the instrument settings for future use

Instrument settings can be saved and recalled using the **[SAVE/RECALL]** facilities, as with Example 1.

## FREQUENCY COUNTER MEASUREMENTS

The frequency counter function can be used to measure the absolute frequency of a signal from 10 MHz to 20 GHz (26.5 GHz for 6203B/6204B).

The counter has two principal functions within the MTS. When it is used in 'Readout' mode, a digital readout of frequency is given, with a resolution that is selectable from 1 Hz to 100 MHz. When the instrument is in swept mode, and the source is set to provide a voltage or current sweep, the frequency of a signal can be measured and displayed on the vertical axis. A typical example is VCO characterisation, whereby frequency against voltage is automatically plotted.

As for power measurements, maximum/minimum hold is provided for long-term drift monitoring, as well as automatic pass/fail indication against limits.

Connect the signal to be measured to the COUNTER input of the MTS. The optimum signal level is about 0 dBm, and should not be greater than +5 dBm.

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]**<br>***[Default Settings]*** | Sets the instrument to its default state. |

### Step 2 - Define the display configuration

| | |
|---|---|
| **[CHANNEL MODE]**<br>***[Readout]*** | Sets up channel 1 to display readout measurements. The Channel Mode menu is the default following an instrument preset, so it is not necessary in this case to press the [CHANNEL MODE] key. |

### Step 3 - Define the measurements

| | |
|---|---|
| **[MEASURE]**<br>***[Counter]*** | The quantity that will be displayed is the frequency of the signal present at the COUNTER input. |

## Step 4 - Calibrate the measurement system

The frequency counter is locked to an accurate and stable internal crystal frequency standard and therefore does not require any calibration.

## Step 5 - Use markers and other MTS features to get detailed information about the measurement

Marker functions do not apply to frequency readout measurements, but the following useful features may be used.

| | |
|---|---|
| [MEASURE}<br>*[Measurement Functions]*<br>*[Max Min Hold]*<br>*[Hold ●]* | The display will now show the highest and lowest frequencies measured, and is useful for assessing frequency drift. |
| *[Clear]* | Causes both the minimum and maximum values to be set to the current measurement. |

Limit checking can be used to determine if the device under test meets its specification. Upper and lower limits can be defined and a pass/fail indication is then displayed above the readout value. As an example, assume that the frequency is required to be within the range 1.4 GHz to 2 GHz. To test for this you can use limit checking in the following way:

| | |
|---|---|
| [MEASURE]<br>*[Measurement Functions]*<br>*[Limit Checking]*<br>*[Set Max Limit]*<br>[2] [$G_n$]<br>*[Set Min Limit]*<br>[1] [.] [4] [$G_n$]<br>*[Limit Checking ●]* | Sets the upper and lower limit values to 2 GHz and 1.4 GHz and turns on limit checking. The limit values are displayed to the left of the readout. |
| [MEASURE]<br>*[Measurement Functions]*<br>*[Counter Resolution]*<br>*[10 kHz]* | A sub-menu is presented which is used to select the resolution to which the counter readout is displayed. The resolution can be set between 1 Hz and 100 MHz in decade steps; the default setting is 100 kHz. In this example, the resolution has been set to 10 kHz. |
| [MEASURE]<br>*[Frequency Rel]*<br>*[Store Measurement]* | This causes the current frequency reading to be stored, and subsequent frequency measurements are made relative to this value. The relative measurement mode is indicated by an **R** flag above the displayed readout value. |

## Step 6 - Create a permanent record of the measurement results

Although not so meaningful it is still possible to obtain hard copy output of the frequency readout, in either graphical plot or print format.

## Step 7 - Save the instrument settings for future use

Instrument settings can be saved and recalled using the **[SAVE/RECALL]** facilities, as with Example 1.

## SIMULTANEOUS POWER METER AND FREQUENCY COUNTER MEASUREMENTS

Pressing the following keys will result in measurement 1 of channel 1 displaying a power meter readout, while measurement 2 displays frequency:

**[PRESET]**
***[Default Settings]***
**[MEAS 2 ON/OFF]**
**[MEASURE]**
***[Counter]***

The power meter and frequency counter measurements are set up as before, after first selecting the active measurement. This is done by using [SELECT MEAS] to position the red highlight box around the required measurement. Both readouts will display their current measured values, regardless of which measurement is the active one. The highlight box only shows which measurement the soft keys relate to.

## Example 18: Amplifier gain compression measurement

It is often necessary to characterise the power handling capacity of an amplifier. A key aspect of this is the output power at which the gain of the amplifier drops to 1 dB below its small signal value; this is known as the *1 dB compression point*. In other words, it is the output power at which the gain characteristic of the amplifier starts to become non-linear. The test system shown in Fig. 2-38 is designed to measure the 1 dB compression point of an amplifier.

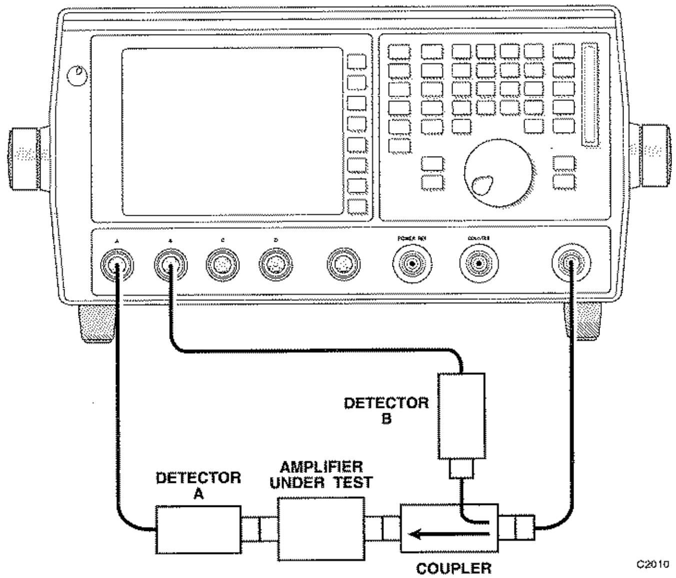



*Fig. 2-38 Setup for gain compression measurement*

Detector B is configured to monitor the incident power to the amplifier, while detector A measures the output power. A coupler with a 10 to 20 dB coupling factor is used to sense the incident power, so that most of the available power from the source can be used to drive the amplifier into compression.

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]**<br>***[Default Settings]*** | Sets the instrument to its default state. |

### Step 2 - Define the display configuration

On channel 1 will be displayed the gain of the amplifier; channel 2 will be used to display the output power.

| | |
|---|---|
| **[CHANNEL MODE]**<br>***[Dual Channel Display]*** | The display now shows two scalar channels. |

## Step 3 - Define the source conditions

Following an instrument preset the source mode defaults to **Start & Stop Freq Sweep**, but for this measurement setup the source mode required is **Power Sweep**. **Channel Coupling** has been left on so the source conditions will be duplicated on the other channel.

| | |
|---|---|
| **[SOURCE]**<br>***[Select Source Mode]***<br>***[Power Sweep]*** | This selects the power sweep mode of the source. The graticule start and stop annotation will change from frequency to power in dBm; both will be at 0 dBm at this stage. This example assumes a start power of -10 dBm and a stop power of 10 dBm. |
| ***[Return to Source]*** | Returns to the Source menu. |
| ***[Set Start Power]***<br>**[-] [1] [0] [x1]**<br>***[Set Stop Power]***<br>**[1] [0] [x1]** | Sets a power sweep of -10 dBm to +10 dBm. |
| ***[Set Frequency]***<br>**[4] [$G_n$]** | In this example, it is assumed that the source frequency is set to 4 GHz. |
| **[ENTRY OFF]** | Turns on the RF power. |
| ***[RF ●]*** | |

## Step 4 - Define the measurements

The default measurement definition for both measurements is input A. Since this is the power output of the amplifier no change needs to be made to measurement in channel 2. The amplifier gain is the ratio of input A to input B, so the measurement definition for channel 1 needs to be changed.

After ensuring that the measurement in channel 1 is the active one (using [SELECT MEAS] or [SWITCH CHANNEL] if necessary), define the amplifier gain measurement as follows:

| | |
|---|---|
| **[MEASURE]**<br>***[Input Ratio]***<br>***[A/]***<br>***[A / B]*** | Defines the measurement in channel 1 to measure the ratio A / B. This is indicated by **1:A/B** appearing in the active measurement trace information box. |

## Step 5 - Calibrate the measurement system

It is now necessary to calibrate the system by measuring the gain response with the two amplifier test ports connected together (detector A connected to the coupler output). The system is calibrated from the knowledge that this direct connection is equivalent to a 0 dB gain amplifier. Ensure that channel 1 is active.

| | |
|---|---|
| **[CAL]**<br>***[Through Cal]***<br>***[Continue]*** | Performs path calibration for the gain measurement. When completed, the path cal data is automatically applied to the measurement, as indicated by the presence of **PC1** in the trace information box for the measurement in channel 1. |

Now connect detector A to the amplifier output and the output of the directional coupler to the amplifier input (Fig. 2-38). Apply power to the amplifier.

## Step 6 - Choose the format

The default formats for the measurements are satisfactory, i.e. dB for channel 1 and dBm for channel 2

## Step 7 - Select appropriate scaling

| | |
|---|---|
| [SCALING]<br>*[Autoscale]*<br>[SWITCH CHANNEL]<br>[SCALING]<br>*[Autoscale]* | Suitable scaling for both measurements is achieved using the autoscale facility. |

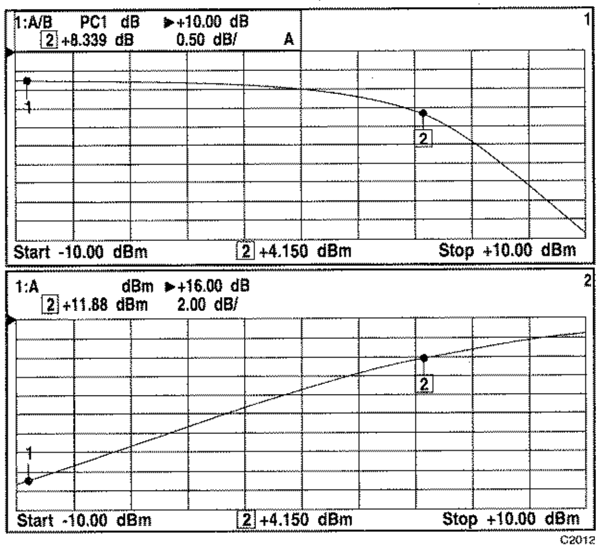



*Fig. 2-39 Gain compression measurement*

## Step 8 - Use markers and other MTS features to get detailed information about the measurement

The gain is calculated in the instrument by ratioing the measurement with the calibration readings. When the gain drops by 1 dB, the output power measurement directly gives the 1 dB compression value. Use the marker functions to read off the 1 dB compression point accurately:

| | |
|---|---|
| **[MARKERS]**<br>***[Mkr Functions]***<br>***[Marker to Max/Min]***<br>***[Active Mkr to Maximum]***<br>***[Return to Mkr Funcs]***<br>***[Return to Markers]*** | Places the active marker (marker 1 by default) at the maximum point on the gain response. |
| ***[Delta Mkr ●]*** | Turns on the delta marker; this is indicated by Δ on the display. Its position will initially be the same as that of the active marker. In the delta marker mode, the measured response is relative to the response at the delta marker position. |
| ***[Set Up Mkrs]***<br>***[Assign Active Mkr 1-8]***<br>**[2]**<br>***[Return to Markers]*** | Designates marker 2 as the active marker. The position of the active marker remains unchanged. |
| ***[Mkr Functions]***<br>***[Search]***<br>***[Set Search Value]***<br>**[-] [1] [x1]**<br>***[Search Right]*** | The instrument searches right from the current active marker position (i.e. the maximum point on the trace) in order to find the point where the response is 1 dB below the delta marker response. |
| ***[Return to Mkr Funcs]***<br>***[Return to Markers]*** | Returns to the top level Markers menu. |
| ***[Delta Mkr O]*** | Turns off the delta marker. The active marker now gives the actual response instead of relative to the delta marker. |

Marker 1 gives the small signal gain measurement (i.e. maximum gain). Marker 2 (the active marker) measures the 1 dB compressed gain, and is positioned at the source input power which causes that compression. The corresponding output power can be determined from the response of marker 2 on channel 2 (by default, marker coupling between channels is enabled).

## Step 9 - Create a permanent record of the measurement results

A hard copy of the measurement can be created via the menus accessed with the **[COPY]** key, as with Example 1.

## Step 10 - Save the instrument settings or measurement traces for future use

Instrument settings or measurement traces can be saved and recalled using the **[SAVE/RECALL]** facilities, as with Example 1.

A power sensor could be used for more accurate measurement of power at the compression point. However, the accuracy obtained using the 6230A/L series EEPROM corrected detectors would be close to that achievable with a power sensor measurement and should be sufficient for most applications.

## Example 19: VCO characterisation

In this example, both measurements of both channels will be used to characterise a voltage controlled oscillator (VCO). The aim is to determine the maximum and minimum frequencies of operation and to measure the maximum and minimum power levels of the device.

In addition to the synthesized frequency source, the MTS also provides a voltage/current stimulus which can be used to characterise such devices. The measurement setup is shown in Fig. 2-40. The VCO should not be connected to the VOLTAGE/CURRENT output at this stage, since the default voltage produced at this output port may be sufficient to damage the VCO under test.

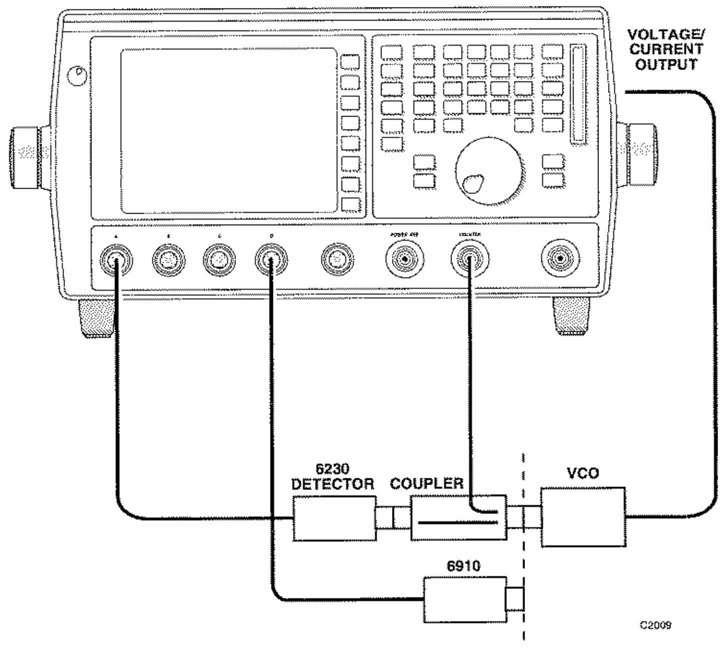



*Fig. 2-40 Setup for VCO measurement*

### Step 1 - Preset the instrument to a known state

| | |
|---|---|
| **[PRESET]**<br>***[Default Settings]*** | Sets the instrument to its default state. |

## Step 2 - Define the display configuration

We need to display four measurements:

Channel 1, measurement 1 - VCO power output as a function of applied voltage.

Channel 1, measurement 2 - VCO frequency as a function of applied voltage.

Channel 2, measurement 1 - counter readout giving the frequency of the VCO as measured via the coupled arm of the coupler.

Channel 2, measurement 2 - power meter readout representing the output power of the VCO.

| | |
|---|---|
| **[CHANNEL MODE]** *[Dual Channel Display]* | Sets the display to dual channel mode. |
| **[MEAS 2 ON/OFF]** | Displays two measurements on channel **1.** |
| **[SWITCH CHANNEL]** | Makes channel 2 active. |
| **[MEAS 2 ON/OFF]** | Displays two measurements on channel 2. |

Channel 2 is currently displaying two swept measurements where we require readouts.

| | |
|---|---|
| *[Readout]* | Pressing this soft key results in the measurements of channel 2 changing from swept to power meter readout measurements. |

## Step 3 - Define the source conditions

Following an instrument preset the source mode defaults to **Start & Stop Freq Sweep**. For this measurement setup the source mode required is **Voltage Sweep**, since the stimulus for the VCO is to be a voltage. For reasons which will become apparent later **Channel Coupling** will be left on, so it does not matter at this stage which is the active channel.

| | |
|---|---|
| **[SOURCE]** *[Select Source Mode]* *[Voltage Sweep* | This selects the voltage sweep mode of the source. The graticule start and stop annotation will change from frequency to voltage; both will be at 0 V at this stage. For this particular VCO, however, a 2 to 8 V voltage sweep is required. |
| *[Return to Source]* | Returns to the Source menu. |
| *[Set Start Voltage]* **[2] [x1]** | Sets the start sweep voltage to 2 V. |
| *[Set Stop Voltage]* **[8] [x1]** | Sets the stop sweep voltage to 8 V. |
| **[ENTRY OFF]** | |

## Step 4 - Define the measurements

From Fig. 2-40 it can be seen that the 6230 detector used for measuring the swept power output of the VCO is connected to input A. Since this is the default setting for measurement 1 of channel 1 there is no need to make any changes. Measurement 2 is required to measure frequency, so first make it the active measurement using [SELECT MEAS].

| | |
|---|---|
| **[MEASURE]**<br>***[Counter]*** | Sets up measurement 2 of channel 1 to measure the VCO frequency and display it on the vertical axis. |

Both measurements of channel 2, by default, are currently displaying a power meter readout for the power measured by the 6910 sensor connected to input D. It therefore only remains to change measurement 1 of channel 2 to a frequency counter readout to measure the frequency output of the VCO. Firstly, make this the active measurement using [SELECT MEAS].

| | |
|---|---|
| **[MEASURE**<br>***[Counter]*** | Results in measurement 1 of channel 2 being configured as a frequency counter readout. |

It is important to note here that by default (i.e. following an instrument preset), **Detector Autozeroing** is enabled. For this measurement we need to disable this function and perform a manual detector zero instead. The reason for this is that to perform a detector zero any RF signal to the detector should be turned off. When autozeroing is enabled, the MTS automatically switches off the RF at the end of a sweep so that the zero can be performed. There is no way for the MTS to control the RF on/off for the VCO and consequently autozeroing would not work properly and must therefore be disabled.

First ensure that no RF power is applied to the detector by disconnecting it from the coupler.

| | |
|---|---|
| **[CAL]**<br>***[Det / Sensor Zero]***<br>***[Detector Autozeroing O]*** | Turns off the autozeroing function. The **AZ** indicator that is displayed in the General Information Area when autozeroing is on should now be removed. |
| ***[Zero Detectors]*** | Performs a detector zero which removes any drift in the zero level of the detector. |

Now connect the equipment as shown in Fig. 2-40, with the 6230 detector connected to the output of the coupler and the COUNTER input connected to the coupled arm of the coupler. Also connect the VCO to the VOLTAGE/CURRENT OUTPUT connector on the rear panel of the MTS.

## Step 5 - Calibrate the measurement system

For this measurement we are only using the swept scalar response on measurement 1 of channel 1, i.e. the power output of the VCO, as an indication of the power response of the VCO. Calibration is therefore not necessary for this path, and the measurements will therefore not be very accurate because of the uncertainties introduced by the coupler and adapters.

The frequency counter is locked to an accurate and stable internal crystal frequency standard and therefore does not require any calibration. However, the power meter readout derived from the sensor connected to input D does require calibration if the output power of the VCO is to be measured accurately.

| | |
|---|---|
| **[CAL]**<br>***[Sensor Cal]*** | A window is displayed stating the current cal and linearity values and instructs you to connect the power sensor to the power reference. |
| ***[Set Cal Factor]*** | Enter the value of **reference calibration factor** given on the sensor label. Some sensors (e.g. 6910) do not have this information on the label; in these cases the default value of 100% is assumed. |
| ***[Set Lin Factor]*** | Enter the value of **linearity factor** given on the sensor label. |
| ***[Continue]*** | Initiates zeroing and calibration of the sensor. |

## Step 6 - Choose the format

The default format (dBm) is used in this example for both the swept measurement of output power and the power meter readout.

## Step 7 - Select appropriate scaling

Scaling is only appropriate for the swept scalar responses on channel 1. First make measurement 1 active.

| | |
|---|---|
| **[SCALING]** | |
| ***[Set Ref Level]*** | |
| **[-] [5] [x1]** | Sets the reference level to -5 dBm. |
| ***[Set Scale]*** | |
| **[2] [x1]** | Sets the scale factor to 2 dB/div. |

Now make measurement 2 active.

| | |
|---|---|
| ***[Set Ref Level]*** | |
| **[1] [.] [9] [$G_n$]** | Sets the reference level to 1.9 GHz. |
| ***[Set Scale]*** | |
| **[5] [0] [$M\mu$]** | Sets the scale factor to 50 MHz/div. |

Alternatively, suitable scaling could be achieved using the autoscale facility.

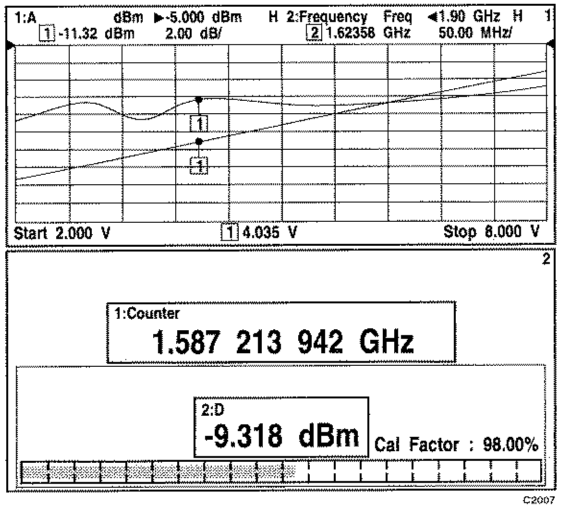



*Fig. 2-41 VCO measurement*

## Step 8 - Use markers and other MTS features to get detailed information about the measurement

Provided that a numeric entry window is not displayed, the rotary control can be used to move the active marker across the graticule of a swept measurement. As the active marker is moved slowly across the graticule, the frequency of the VCO as measured by the counter readout (measurement 1 of channel 2) will change. This is because the counter measurement of channel 2 is coupled to the active marker domain (voltage stimulus) value on channel 1, resulting in the counter taking a reading at the position currently defined by the active marker on the voltage sweep.

First make measurement 1 of channel 1 the active measurement using [SELECT MEAS].

| | |
|---|---|
| **[MARKERS]** | Presents a sub-menu. |
| ***[Marker Functions*** | |
| ***[Marker to Max/Min]*** | |
| ***[Active Mkr to Maximum]*** | This results in the counter displaying the frequency at the point of maximum power. |
| ***[Active Mkr to Minimum]*** | The counter now reads the frequency at the point of minimum power. |

We now wish to measure the maximum and minimum power output of the VCO more accurately. However, before changing the measurement connections we will hold the swept measurements on channel 1. Firstly, ensure that measurement 1 of channel 1 is the active measurement.

**[HOLD]** When this key is pressed the measurement trace is frozen and an **H** indicator appears in the trace information area for that measurement.

Now make measurement 2 of channel 1 the active measurement and press [HOLD] again.

Disconnect the coupler from the VCO and connect the 6910 power sensor in its place.

We know the range of frequencies over which we wish to measure power so we must first enter the appropriate cal factor for the sensor. Firstly, make measurement 2 of channel 2 the active measurement.

| | |
|---|---|
| **[MEASURE]**<br>***[General Set-up]***<br>***[Sensor Correction]***<br>***[Cal Factor & Lin Factor]***<br>***[Set Cal Factor]***<br>**[9] [8] [x1]** | Enter the value of cal factor from the sensor label for the frequency of interest. A value of 98% is assumed in this example. |

Alternatively, the cal factor information on the label could be entered into the MTS as a table of cal factor *versus* frequency. This would then allow **Cal Factor User Freq** to be specified, which means that only the measurement frequency need be entered and the MTS would automatically apply the appropriate calibration data.

As the active marker is moved using the rotary control, the stimulus to the VCO for the power meter measurement will be that for the particular point of the voltage sweep corresponding to the active marker position. Even though channel 1 is no longer making live measurements (it is only displaying the held measurements), the voltage source is still generating the required stimulus. The power meter readout displayed as measurement 2 of channel 2 is thus the power output of the VCO as measured by the 6910 power sensor.

It should be noted that the power meter readout will usually be slightly different from the swept response indicated by measurement 1 of channel 1. This is due to the different methods of measuring power. The power meter readout provides the most accurate results, and should be used when accurate measurements of absolute power are required. Also, the counter readout will give a more accurate measurement of frequency than the swept response in channel 1. This is due to the shorter counter gate time that must be used for swept measurements of frequency, and the fact that the response is limited to six digits (the readout can display frequencies to 1 Hz resolution).

## Step 9 - Create a permanent record of the measurement results

A hard copy of the measurement can be created via the menus accessed with the **[COPY]** key, as with Example 1.

## Step 10 - Save the instrument settings or measurement traces for future use

Instrument settings or measurement traces can be saved and recalled using the **[SAVE/RECALL]** facilities, as with Example 1.

# Example 20: Reflection analyzer measurements

The steps for using the 6210 for the first time are outlined here. The following sequence is recommended.

(1) Plan the required measurements

(2) Prepare the instrument

(3) Calibrate the instrument

(4) Make measurements

This example is presented in a different format from the previous examples because of the more detailed explanation that is required for reflection analyzer measurements. The measurement set up is shown below:

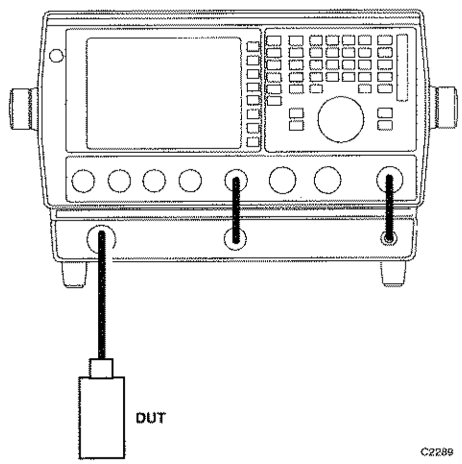



*Fig. 2-42 Setup for reflection analyzer measurements*

## Planning the required measurements

It is necessary to make some decisions about instrument configuration before measurements can be made with 6210. This is because measurements can only be made after calibration is carried out, and only the frequency points chosen for calibration may be used for subsequent measurements.

### Vector reflection coefficient

The 6210 is a reflection analyzer, which means that it is capable of measuring vector reflection coefficient. This is an advantage over scalar analyzer systems because it allows more accurate measurements to be made, and the addition of phase information permits a wider range of device characterisation and problem solving techniques to be employed.

## Connector types

Devices under test (DUTs) are fitted with many different types of connector. If a scalar autotester were to be used for the measurement, then it would be necessary to obtain a autotester having the correct connector type and sex for the DUT. With a reflection analyzer, this procedure is not necessary because the imperfections associated with any type of test port adapter are calibrated out. It is therefore necessary to obtain a calibration kit in the same connector type and sex as the DUT.

## Frequency domain measurements

Consider the frequency range, number of points, sweep speed and power level which are appropriate for the DUTs to be measured. 401 points is common for a broadband frequency sweep, but more points over a narrow range may be required for high-Q DUTs. A source power level of 2 dBm is optimum for most measurements, but less power may be appropriate for some small-signal active devices. It is preferable but not essential to use the same power level for calibration as will be used for measurements.

Slow sweep speeds are sometimes necessary for amplifiers with internal levelling mechanisms, such that the sweep rate allows them to settle. Normally, automatic sweep speed with an averaging factor of 8 gives the best compromise between speed of response and attainable dynamic range. Use averaging during the calibration for best accuracy, even if it is turned off later to improve measurement speed.

## Time domain measurements

The time domain analysis software built into the 6210 Reflection Analyzer allows the frequency domain reflection coefficient data to be transformed into the time domain. The measurement trace can be interpreted as reflection coefficient against distance into the device under test. It is possible to identify the location of impedance discontinuities and imperfections within the DUT from the time taken for the measuring signal to reach the discontinuity and return to the test port. This aids fault-finding and gives insight into DUT operation. Furthermore, it is possible to edit the time domain response, and return to the frequency domain, showing the frequency response of the edited DUT. This is explained further in 'Gating and Fencing'.

There are two types of time domain transform, Low-Pass and Band-Pass. The names come from the range of frequencies that have been used for measurement, as if a filter had been applied to an infinite range of frequencies. The Band-Pass transform uses a non-zero start and stop frequency. The Low-Pass transform is used when the measurement data points are extrapolated down to DC. For this reason, Low-Pass mode may only be used on broadband DUTs where there is a usable performance down to DC. This allows the characteristic impedance of transmission lines and the capacitive or inductive nature of discontinuities to be quantified. Alternatively, Band-Pass mode is used with band-pass DUTs, such as waveguide. However, the lack of DC information means that only the magnitude of individual reflections can be determined in the time domain. It is not possible to determine whether a discontinuity is inductive or capacitive, or whether a transmission line is too high or too low in characteristic impedance.

For both types of time domain analysis, the frequency points have to be carefully chosen for the mathematics to work properly. The Low-Pass Sweep mode must first be selected before calibration and measurements, in order that the Low-Pass time domain mode is selectable. This is because the frequency points are chosen to lie on a harmonic sequence stretching from DC to the highest frequency. The Band-Pass time domain mode can only be selected after a calibration using the Start & Stop Frequency Sweep mode or the Waveguide Sweep mode. The Waveguide Sweep mode is used to enable physical distance to be displayed in a waveguide run, by fully correcting for the effects of waveguide dispersion.

## Preparing the instrument

First, press [PRESET] to set the instrument to the [Default Settings] state. Then set the [CHANNEL MODE] to *[Reflection Analyzer]*. Unless a previous calibration can be automatically recalled, a warning message will appear stating "Reflection analyzer calibration invalid". It is now necessary to set up the instrument parameters for the new calibration. This involves choosing functions from the [CAL]*[Reflection Analyzer Cal][Set Up Calibration]* menu.

### Entering cal kit parameters

If this is the first time that this particular calibration kit has been used, it may be necessary to enter the calibration kit parameters into the instrument. From the [CAL] menu, the *[Edit Cal Kit Data]* soft key invokes a parameter editor. Further details are in the 'FUNCTION (Reflection Analyzer)' section of the MTS Operating Manual.

### Setting up the source and measurement parameters

From the [CAL]*[Reflection Analyzer Cal][Set Up Calibration][Set up Source]* menu, set the start and stop frequencies to 250 MHz and 8 GHz, for example. Set the power level to 2 dBm. If required, set the number of points to other than the default value of 401.

From the [CAL]*[Reflection Analyzer Cal][Set up Calibration]* menu, set the averaging factor to 8, and turn averaging on. Press *[AC Detection]* or *[DC Detection]* as required. DC detection is preferred unless external signals are likely to interfere with the measurement.

## Calibrating the instrument

### The reason for calibration

One of the main benefits of the 6210 Reflection Analyzer is its superior accuracy over a Scalar Analyzer system. This is achieved through calibration with a calibration kit. This is only possible because the reflection analyzer measures vector reflection coefficient, which makes possible the mathematical correction of the various microwave error vectors. Calibration involves making measurements of known reflection coefficients (standards), and computing the error correction required from the difference between the measured and true values. Therefore each calibration piece must be connected to the test port in turn during the calibration procedure, before measurements can be made.

CAUTION **Observe the precautions detailed in Appendix E of the MTS Operating Manual when handling and using calibration kit components.**

A major advantage of error correction is that test port adapters can be freely used. Any connector type or sex is permitted, providing that the calibration is performed with the matching calibration kit at the end of the adapter. The accuracy of measurement depends on the quality of the calibration kit. This is in direct contrast with the performance degradation experienced when adapters are used with scalar autotesters.

A number of different calibration techniques are available, each suited to different frequency ranges, transmission line types, and accuracies required. They are explained in detail below.

CAUTION **If the Bias Tee option is fitted to the 6210, disconnect the bias supply from the rear panel BNC connector, or set it to zero during calibration. The bias available at the test port can irreversibly damage short circuits by contact sparking, and matched loads by power overload. Do not re-connect the bias supply until the calibration pieces have been removed from the test port.**

## Short - open - fixed load cal

This is the simplest type of calibration. Excellent results are achieved up to 2 GHz, but at higher frequencies, the best measurement performance requires calibration with the sliding load.

From the [CAL] menu, press *[Reflection Analyzer Cal]*. Use *[Select Cal Kit]* to choose the cal kit parameters that match the Calibration Kit that will be used. Select the sex of the DUT that is to be measured using the *[Male]* or *[Female]* soft keys. Choose the *[Short, Open, Fixed Load]* Calibration method. Verify that the other instrument parameters displayed are correct. You may abort the calibration at this stage if settings outside this menu need to be altered.

When all is ready, press *[Measure Standards]*. If the upper frequency parameter for the fixed load is lower than your chosen stop frequency, the instrument will inform you now. This simply means that the quality of the load will compromise accuracy at the higher frequencies. Confirm that you wish to proceed. Connect the three calibration standards in turn, and press *[Measure Standard]* for each one. If anything is wrongly connected, you may select any standard for re-measurement using the arrow soft keys.

The short circuit takes longer than the other standards to be measured, because an internal automatic self-calibration also takes place.

After all three standards have been measured, press *[Process Measurements]*. The error correction parameters are now calculated. This takes about 10 seconds for 401 points. Press *[Select Store...]* to choose the store number for the calibration data. Then press *[Save Calibration]*. Confirm that you wish to overwrite the old store if it is not empty. At this point, alter the Calibration ID if required. This is a label to enable easy identification of stored calibrations at a later time.

Now the instrument will be making error-corrected reflection coefficient measurements.

## Short - open - sliding load cal

This calibration method is a refinement of the Short - Open - Fixed Load calibration described above. At frequencies above 2 GHz, the sliding load is used instead of the fixed load to achieve a higher degree of accuracy. The sliding load uses the mechanical properties of an airline to determine a 50 Ω impedance, rather than a perfect load element. It is constructed from a coaxial tube and inner rod, which together are known as an airline. The mechanical diameters of these two parts are controlled to a few microns accuracy, which governs their characteristic impedance. A tapered load element fits into the space between the tube and rod to absorb most of the microwave power. This element is able to slide along the length of the tube by means of a slider mechanism attached at the rear. Its key property is to have the same magnitude of reflection, regardless of slide position. Therefore, the vector reflection coefficient at any given frequency traces out a circle of constant radius as the load element slides. It can be shown that the centre of the circle is the 50 Ω characteristic impedance of the airline, and it is this property which is used for calibrating the Reflection Analyzer.

To perform a sliding load calibration, select *[Short, Open, Sliding Load]* instead of *[Short, Open, Fixed Load]*. Then follow the instructions above for the Short - Open - Fixed Load calibration, except that extra measurements now appear for eight positions of the sliding load. When it is time to measure the sliding load, extra care must be taken in connecting it. There are two methods for connection of the sliding load, although the construction of a particular sliding load may not permit both to be used. The zero gauge technique is more accurate. It involves setting up the centre conductor with a connector gauge and then mating it with the test port as if it were a standard connector. This requires a self - supporting centre conductor, which aligns properly with the test port. If the centre conductor is unsupported until it has been mated with the test port connector, then the centre conductor must be mated before the outer conductor. The following procedures should help to avoid damage :

### Sliding loads with self - supporting centre conductors

(1) Move the slider as far as it will go towards the connector (front) end and remove the centre conductor support from the sliding load connector.

(2) Set up an appropriate connector gauge and connect the sliding load to it.

(3) Carefully loosen the locking collet at the back end of the load, and adjust the centre conductor positioner so that the connector gauge reads zero.

(4) Remove the connector gauge.

(5) Hold the load with both hands. One hand should be on the centre conductor at the rear of the load, and the other at the front to guide the load towards the test port connector.

(6) Make sure that the load is squarely aligned with the test port, and offer it up to the centre conductor of the test port. Carefully do up the connector nut, WITHOUT rotating the load.

(7) Torque up the connector nut with the torque wrench, if provided in the Calibration Kit.

(8) Now proceed to make measurements of the sliding load positions. Each position is marked with a ring on the body of the load under the slider, except the first position where the slider is at the end of its travel nearest the Reflection Analyzer.

(9) Return the slider to the front-most position, untorque the connector, and remove the sliding load keeping it well supported.

(10) Replace the centre conductor support and return the sliding load to the cal kit.

As before, press *[Process Measurements]* and proceed as for the fixed load cal, above.

Sliding Loads with Unsupported Centre Conductors

(1) Hold the sliding load horizontally at all times. The centre conductor will slide completely out of the back of the load if the locking collet is loosened.

(2) Move the slider as far as it will go towards the connector (front) end and remove the centre conductor support from the sliding load connector.

(3) Carefully loosen the locking collet at the back end of the load, and push the centre conductor forward as far as possible so that it protrudes from the connector at the front.

(4) Hold the load with both hands. One hand should be on the centre conductor at the rear of the load, and the other at the front to guide the load towards the test port connector.

(5) Make sure that the load is squarely aligned with the test port, and offer the centre conductor of the load up to the centre conductor of the test port. Gently push the centre conductor fully home.

(6) Now slide the body of the load over the centre conductor and locate it on the outer conductor of the test port. Carefully do up the connector nut, WITHOUT rotating the load.

(7) Torque up the connector nut with the torque wrench, if provided in the Calibration Kit.

(8) Check that the centre conductor is still fully home, and tighten the locking collet.

(9) Now proceed to make measurements of the sliding load positions. Each position is marked with a ring on the body of the load under the slider, except the first position where the slider is at the end of its travel nearest the Reflection Analyzer.

(10) Return the slider to the front-most position, untorque the connector, and remove the sliding load keeping it well supported.

(11) Unlock the centre conductor, push it forward out of the connector as far as possible and then lock it in place. Replace the centre conductor support and return the sliding load to the cal kit.

As before, press *[Process Measurements]* and proceed as for the fixed load cal, above.

## Calibrating at the end of a cable

We have already seen that it is possible to calibrate out the effects of test port adapters. Similarly, it is possible to calibrate out a cable attached to the test port. However, the internal self-calibration that is normally performed with the short circuit at the test port can fail if insufficient signal is reflected back from the short circuit. A warning "Reflection analyzer calibration failure (reduction)" may be displayed after the *[Process Measurements]* function has completed. To overcome this, it is recommended to performed the self-calibration separately with the short circuit connected directly to the Reflection Analyzer test port. In the [CAL]*[Reflection Analyzer Cal]* menu, the *[Set Up Calibration]* option allows *[Calibrate at Test Port]* or *[Calibrate at End of Cable]* to be selected. In the latter mode, the first stage of measuring the calibration pieces involves measuring the short circuit directly on the test port, followed by a normal calibration at the end of the cable.

## Waveguide calibrations

The Reflection Analyzer supports calibration in waveguide through the use of a coax-to-waveguide adapter on the test port. The sequence of operations to set up the instrument is very similar to coaxial measurements. In the [CAL]*[Reflection Analyzer Cal][Set Up Calibration][Set Up Source]* menu, choose start and stop frequencies that are in-band for the type of waveguide that is to be used. For time domain measurements, use either the *[Start & Stop Freq Sweep]*, the *[Cntr & Span Freq Sweep]*, or the *[Waveguide Sweep]* modes. The latter mode uses a "warped" frequency sweep. This adjusts the spacing of the frequency points so that the time domain response is compensated for the dispersive effects of waveguide. The advantage of this mode is that the display of discontinuities is sharpened, and their exact physical distance is displayed directly.

Calibration involves the use of a waveguide Calibration Kit. The parameters for this type of kit are entered into the instrument using [CAL]*[Edit Cal Kit Data]*, and the *[Set Connector]* type is set to *[Waveguide]*. When a *[Reflection Analyzer Cal]* is invoked with a waveguide Cal Kit, the calibration methods available are either *[Short, Offset Short, Load]* , *[Short, Offset Short, Sliding Load]*, or *[Short, Offset Shorts]*, which uses two offset shorts.

## Calibration accuracy confidence check

The simplest way to check that there are no obvious problems with the calibration is to re-measure the fixed load used for calibration. This is not a check of true accuracy, because all loads reflect some signal. However, poor connections and set-up errors will be highlighted.

If the calibration type was Short - Open - Fixed Load or Short - Offset Short - Fixed Load, the calibration has assumed that the fixed load was perfect, and so measuring the same load again should indicate zero reflection coefficient. On a log magnitude display, this corresponds to an infinite return loss, but in practice, the noise floor of the instrument will limit this to typically -60 dB without averaging. If the trace is above -45 dB, especially over a narrow portion of the trace, suspect a connector resonance.

A calibration that uses a Sliding Load will not measure the fixed load as having infinite return loss. Below 2 GHz, the calibration uses the fixed rather than the sliding load, so the measurements will be the same as for the fixed load calibration. Above 2 GHz, the true return loss of the fixed load will be measured, to the accuracy limits of the sliding load. A typical response is shown in the figure below.

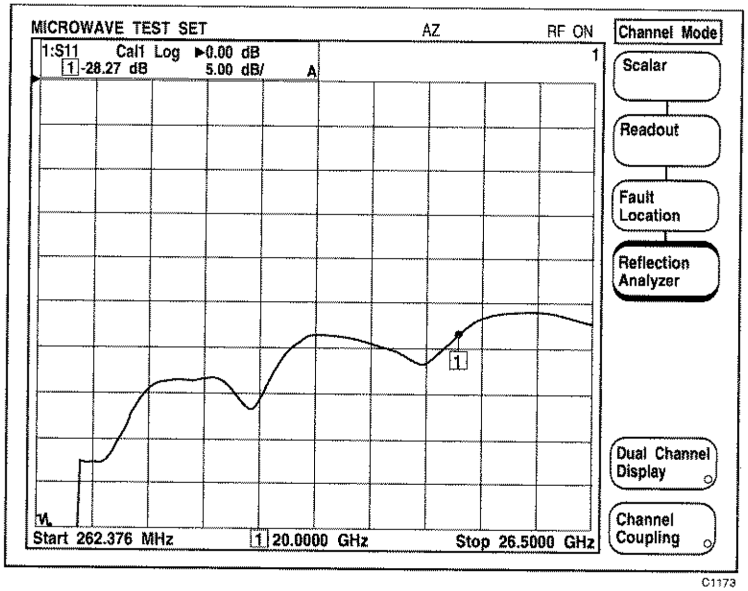



*Fig. 3-43 Fixed Load Measurement*

Full performance verification involves the use of a precision beadless airline. To avoid excess wearing of the airline connectors, this should not be undertaken routinely.

# Making measurements

## Frequency domain measurements

After calibration is complete, the instrument provides a continuously swept display of reflection coefficient. The general features such as formats, scaling, markers, and measurement functions are similar to the Scalar Analyzer channel mode. The main differences lie in the extra display formats appropriate to vector reflection coefficient.

Press [FORMAT] to select the different display formats. Of particular relevance is the [Phase] format for phase matching and the [Smith] chart format for device matching.

Under the [MEASURE] menu are the averaging controls and *[Restart Averaging]*. It may be preferable to switch averaging off completely. Also, *[Display Zoom]* is used to display just a subset of the measurement frequency range. This gives a similar effect to the common practice with a scalar analyzer of changing the source start and stop frequencies to view features of interest more clearly. Note that it is not possible to directly alter the source frequencies in a reflection analyzer channel without invalidating the calibration and preventing further measurements.

## Time domain measurements

One of the most powerful features of the Reflection Analyzer is its time domain capability. From the [MEASURE] menu, press the *[Time Domain]* soft key. The display will change to an appropriate cartesian format with a horizontal time axis. Pressing *[Time Domain Functions]* enables the type of time domain transform to be selected. See 'Time Domain Measurements' earlier in this section for a description of these options. *[Display Domain]* allows the horizontal axis to be labelled as either time or distance.

It is usual to use the log magnitude or linear magnitude display formats when viewing the Band-Pass time domain. Each peak shows the reflection coefficient magnitude of a discontinuity within the DUT.

With the Low-Pass time domain mode, more revealing display formats are possible. Set the time domain mode to [MEASURE]*[Time Domain Functions][Low Pass Transform]*. Press *[Step Response]*. Use the [FORMAT]*[Real]* display rather than log magnitude. This allows the reflection coefficient of the DUT to be displayed as a function of distance or time into it. Note that the display may be negative as well as positive. A value of +1 corresponds to an open circuit, and a value of -1 corresponds to a short circuit. If this were band-pass mode, the two responses would be indistinguishable. A steady trace above the zero line indicates that the characteristic impedance of that section of transmission line is too high. An upward transient indicates inductance, and a downward transient indicates capacitance. Fig. 3-44 shows typical responses for these conditions.

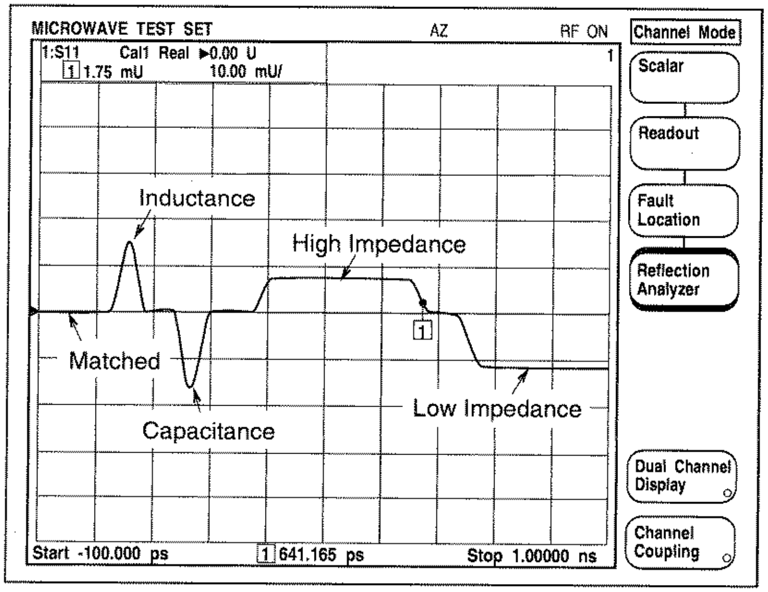



*Fig. 3-44 Typical responses due to discontinuities*

This information allows an engineer to locate the problem within a circuit, and predict the type of corrective action necessary. A useful approximation is that a change of 1 ohm = 10 mU for small reflections. For example, -20 mU = 48 Ω in a 50 Ω system.

## Gating and fencing

This is a powerful editing technique that allows particular sections of the DUT to be isolated or removed from the overall response. A mathematical function is applied to the measurement to make the chosen sections of the DUT appear matched. The editing is done in the time domain, and the result may then be transformed back into the frequency domain. This allows the effects of individual discontinuities to be evaluated, so that the section of a DUT to be improved can be determined with confidence.

For example, Fig. 3-45 shows the frequency domain return loss of a typical DUT.

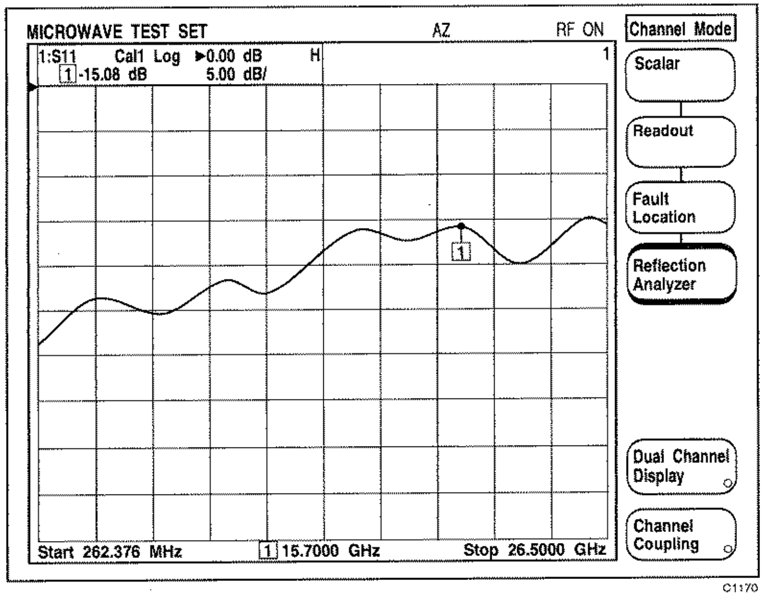



*Fig. 3-45 Typical DUT return loss*

Time domain may be used to further analyse the DUT. From the [MEASURE] menu, turn *[Time Domain]* on. Fig. 3-46 shows the Low-Pass step response of the DUT. A capacitive discontinuity is clearly visible at 230 ps delay. Therefore, in air, this corresponds to a distance from the test port of 69 mm, assuming the speed of light to be $3x10^{11}$ mm/s.

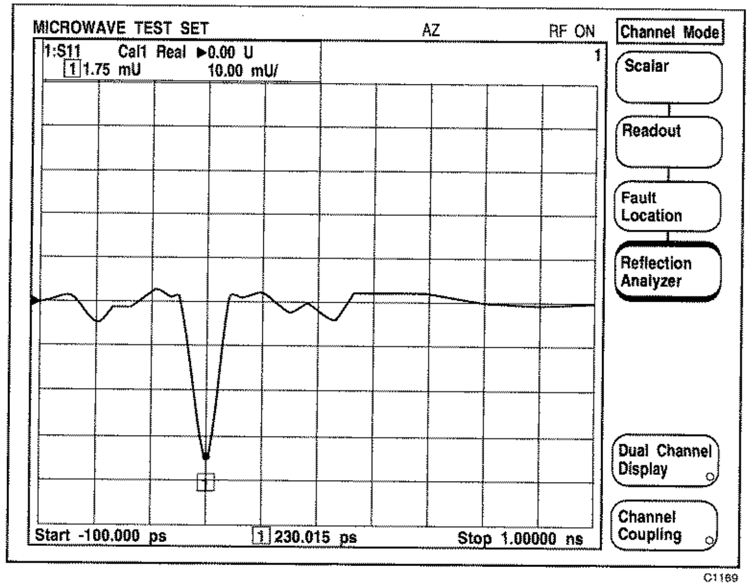



*Fig. 3-46 Low-pass step response of DUT*

Press *[Gating / Fencing]* and choose fencing rather than gating with *[Gating Mode]*. Gating is a function which keeps just the data within the gated region, and mathematically matches the rest of the trace outside the region. Fencing is the inverse of gating, which matches the fenced region and keeps the trace unchanged outside the region. Use *[Set Fence Start...]* and *[Set Fence Stop...]* to position the fencing markers around the region of interest. Either enter numeric values with the keypad or use the knob on the front panel. Once the fencing markers have been set up, apply *[Gating / Fencing]* to view the effect. The capacitive discontinuity between the fence markers has now been matched out. Note the "F" or "G" which appears with the measurement information above the trace. See Fig. 3-47.

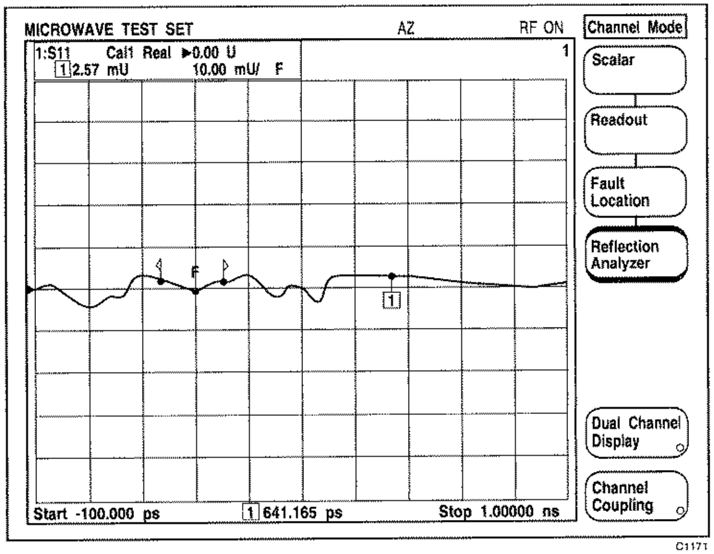



*Fig. 3-47 Low-pass step response of DUT with fence applied*

Return to the frequency domain with [MEASURE]*[Time Domain]* (off) to see the frequency response of the fenced measurement. The "F" in the measurement information box indicates that fencing is still applied. See Fig. 3-48.

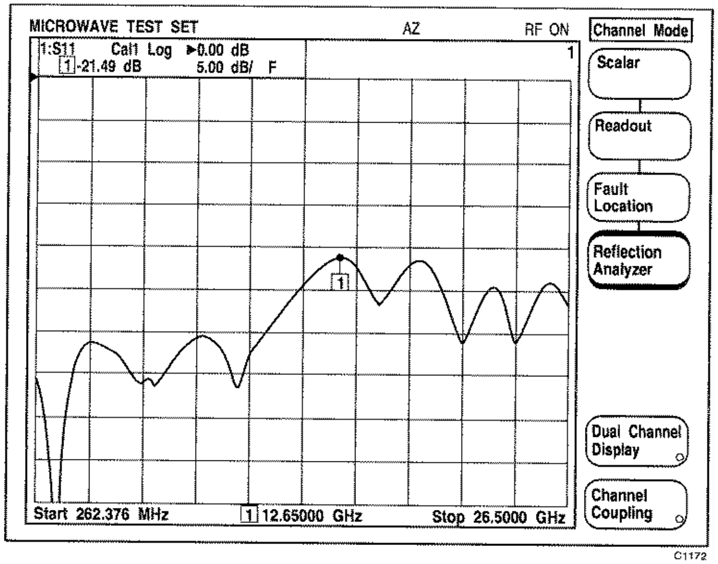



*Fig. 3-48 Frequency response of DUT with fence applied*

It is now possible to quantify the performance improvement that could be achieved if the major impedance discontinuity within the DUT was addressed.

# Miscellaneous features of the MTS

## Copying to a printer/plotter

Once a measurement has been made and a plot has been produced on the screen, it may be necessary to create a hard copy of the measurement. This can be done in two ways:

### Graphical plot

To create a graphical plot of the measurement connect the plotter to the rear panel GPIB connector. Ensure that the MTS is in GPIB Controller Mode; if necessary press [UTILITY] *[GPIB] [Controller Mode]*. When this mode is in effect, it is indicated by the box surrounding the *[Controller Mode]* soft key label being highlighted.

If necessary, set the GPIB address to suit the device in use. This is typically set to 5 for GPIB plotters:

| | |
|---|---|
| **[UTILITY]**<br>***[GPIB]***<br>***[Plotter Address]*** | Press these keys and set the GPIB address to suit the device in use. |
| **[COPY]** | Starts the plotting operation. The plotting will proceed as a background task since the data is buffered. This allows further measurements to be made whilst the plotting proceeds. |

### Graphical print

To create a print of the measurement connect the printer to the PARALLEL PRINTER connector.

| | |
|---|---|
| **[COPY]**<br>***[Select Printer]***<br>***[Epson FX]***<br>**or**<br>***[HP DeskJet / LaserJet]***<br>**or**<br>***[Canon BJ]*** | Specifies the type of printer that is to be used. |
| **[COPY]**<br>***[Graphical Print]*** | Starts the printing operation. As for plotting, this will be done as a background task. |

To simplify entering of trace titles, an external keyboard can be connected to the MTS via the standard keyboard interface on the rear panel.

# Entering a new password

A new password can be specified using the following sequence:

**[UTILITY]**
***[Service]***
***[Set-up]***
***[Set Passwords]***

A primary 6-digit password is must be entered in order to continue any further. Each instrument leaves the factory with the primary password held in the screen title associated with instrument settings store 1. This can be viewed using

[SAVE/RECALL]*[Recall Settings]*[1][×1]

(If this store is overwritten at any time before the primary password has been noted, contact Marconi Service Division at Luton.)

A sub-menu will then appear enabling the user to set the level 1 and level 2 passwords by pressing the *[Set Level 1 Password]* and *[Set Level 2 Password]* soft keys respectively and then entering a new password.

The level 1 password is a 4-digit number in the range 1000 to 9999, and the factory set default is 9999. The level 2 password is a 6-digit number in the range 100000 to 999999, and the factory set default is 999999.

# Calibrating 6230A/L Series EEPROM detectors

The following procedure shows how to calibrate a 6230A/L detector using the dynamic calibrator feature of the MTS. Normally a detector would be calibrated when the instrument is switched on to make a new set of measurements, or once a day if the instrument is left on for a longer period of time. Connect the detector to input A of the instrument.

| | |
|---|---|
| **[MEASURE]**<br>***[General Set-up]***<br>***[Detector Correction]***<br>***[Input A]*** | Select the input to which the detector has been connected, i.e. A, B or C. |
| ***[Linearity Calibration]***<br>***[Continue]*** | Connect the detector to the power reference.<br>The detector will then be calibrated. |

# Using the floppy disk drive

## Formatting a disk

To format a 3.5 in. floppy disk to accept MS-DOS files (1.44 MB capacity) proceed as follows

Insert the disk to be formatted into the disk drive at the side of the instrument, then press

**[UTILITY]**
***[Service]***
***[Set-up]***
***[Format Disk]***

## Saving traces to memory

Once a measurement has been made and a trace produced on the screen, it can be saved as an MS-DOS file on floppy disk. If required, a number of traces relating to a particular project can be saved under a specific directory.

**[SAVE/RECALL]**
***[Save Trace to Memory]***
***[Floppy Disk]***

This activates a sub-menu which enables file/directory selection, saving of new files and overwriting of existing files. New directories can be created using the *[Create Directory]* soft key.

New directories can also be created using the Disk Funcs menu, accessed by pressing

**[UTILITY]**
***[Service]***
***[Floppy Disk Functions]***

This menu also allows files and directories to be deleted.

Entering of file and directory names will be easier and quicker if an external keyboard is used; this is connected to the keyboard interface at the rear of the instrument.

## Copying traces between floppy disk and MTS / memory card

Measurement traces can be copied between floppy disk and internal MTS memory or between floppy disk and a memory card. This facility can be used, for example, to retrieve earlier traces stored on disk for comparison with a live trace.

**[UTILITY]**
***[Store Operations]***
***[Copy Trace Memory]***
***[Floppy Disk]***

This activates a sub-menu which enables directories and trace memory files to be selected using the arrow keys. Files are copied by pressing *[Copy from Disk]* or *[Copy to Disk]* as appropriate.

# Configuring a memory card

A memory card can be configured by using the following key presses:

**[UTILITY]**
***[Service]***
***[Set-up]***
***[Configure Memory Card]***

A level 1 password will be required to continue. The level 1 password is a 4-digit number in the range 1000 to 9999, and the factory set default is 9999. To allocate a specified number of stores for a particular type of data, press the appropriate soft key and enter the required number.

## Using an external keyboard

The MTS has a text entry function which can be used, for example, to enter screen/measurement titles, create/edit macros and when entering floppy disk file/directory names. The 6200B series allows these text entry operations to be performed more easily using an external keyboard connected to the rear panel KEYBOARD connector. Although a standard size IBM PC keyboard may be connected it may not function correctly with the MTS, and it is recommended that the compact keyboard available from Marconi Instruments as an optional accessory is used. The keys are mapped to the MTS keys as follows:

| MTS Key | Keyboard | MTS key | Keyboard |
|---|---|---|---|
| Soft keys 1 to 8 | F1 to F8 | [G n] | <Ctrl> G |
| [SOURCE] | <Alt> SO | [M µ] | <Ctrl> M |
| [MEASURE] | <Alt> ME | [k m] | <Ctrl> K |
| [CAL] | <Alt> CA | [x 1] | <ENTER> |
| [FORMAT] | <Alt> FO | [BACK SPACE] | <BACKSPACE> |
| [SCALING] | <Alt> SC | [COPY] | <Alt> CO |
| [MARKERS] | <Alt> MR | [SAVE/RECALL] | <Alt> SA |
| [SELECT MEAS] | <Alt> SE | [MACRO] | <Alt> MA |
| [MEAS 1 ON/OFF] | <Alt> M1 | [UTILITY] | <Alt> UT |
| [MEAS 2 ON/OFF] | <Alt> M2 | [HOLD] | <Alt> HO |
| [SWITCH CHANNEL] | <Alt> SW | [LOCAL] | <Alt> LO |
| [CHANNEL MODE] | <Alt> CM | [PRESET] | <Alt> PR or <Ctrl> C |
| [ENTRY OFF] | <Esc> | | |

| | |
|---|---|
| Increment (↑) | Up arrow key |
| Decrement (↓) | Down arrow key |
| Rotary control | Left/right arrow keys |

The numeric keys, including '.' and '-' are directly mapped.

# Marconi
Instruments

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