

# **BPIM OPERATING & MAINTENANCE MANUAL**

Passive IM Analyser System

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Document Issue	IR	Description of Document Change	Date	Edited By	Authorization
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E	8779	Added notes in Sections 1.3 & 3.3 regarding importance of grounding for EMC compliance	12/2011	MJH	CJH
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G		Implementation of new Kaelus format	14/11/2017	SR	LJ
H		Removal of Infinite Electronics Branding	02/11/2020	RA	LJ

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Standard(s) to Which Conformity is Declared:

<b>Electromagnetic Immunity</b>	EN 50082-1: 1992 (IEC 1000-4-2, IEC 1000-4-3, IEC 10000-4-4)
<b>Electromagnetic Emissions</b>	EN55011 Class B; EN 61000-3-3
<b>Safety</b>	EN 61010-1; Part 1 General Requirements: 1993/A2: 1995

Manufacturer's Name: Kaelus, Inc.

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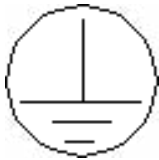




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# 1. Safety Considerations

## 1.1 General Information

Before connecting or using this product, the following safety information must be read and understood to prevent harm to personnel and/or damage to the equipment.

The following symbols are used throughout this manual to call attention specifically to safety-related information:

	HAZARDOUS VOLTAGES: The product is marked with this symbol whenever potentially hazardous voltages exist. These voltages can cause serious injury or death upon contact with personnel.
	PROTECTIVE CONDUCTOR TERMINAL: The product is marked with this symbol to indicate a connection to Earth ground potential.
	CAUTION: SEE SYSTEM DOCUMENTATION: This symbol is placed next to ports on the instrument which may be damaged if the information provided in the system documentation is not carefully considered and understood.
 <b>WARNING</b>	WARNING: This symbol indicates information, which, if not carefully considered, could result in personal injury. Carefully read and fully understand information denoted with this symbol before proceeding with the use of this product.
 <b>CAUTION</b>	CAUTION: This symbol indicates information that, if not carefully considered, could result in damage or destruction to all or part of the product. Carefully read and understand information denoted with this symbol before proceeding with the use of this product.
	IMPORTANT NOTE: This symbol indicates information that may be helpful in properly using or understanding the operation of the instrument.

## 1.2 Before Applying Power

### CAUTION

This instrument is capable of operating with the following AC line voltages: 110-120 VAC or 220-240 VAC, 50 or 60 Hertz line frequency. However, the AC power receptacles on the Frequency control (RF) and Power Amplifier (PA) Modules must be correctly configured for the available line voltage. Before connecting AC power to the unit, ensure the proper fuse is installed in the fuse-holder.

See Section 1.4 for additional information on installing fuses and configuring the Frequency control (RF) and Power Amplifier (PA) Modules.

## 1.3 Grounding

The RF and PA Module Power Supplies must be connected to a grounded (earth ground) outlet.

### WARNING

Do not operate this equipment without the power connected to an earth-grounded outlet. Disconnecting or bypassing the earth ground could result in potential personal injury from electrical shock.

*In order to comply with EMI/EMC requirements, it is recommended that all equipment be grounded to a common frame ground point. Provision for this grounding is made on the rear panel of each major 19" rack chassis in the form of a M6 stud.*

## 1.4 Fuse Replacement/Voltage Setting

The RF and PA Modules are equipped with fuse protection on the AC main connector. This fuse is accessible from the rear panel AC receptacle.

### **WARNING**

For continued protection against both fire and injury, replace the TR Module fuse according to the following table:

Fuse Type for 110-120 VAC Operation	Fuse Type for 220-240 VAC Operation
250 Voltage, 10A	250 VAC, 5A
Speed: Time Delay	Speed: Time Delay
Size: 5x20 mm	Size: 5x20 mm
No. Required: 1	No. Required: 1

To replace the fuse on the TR Module, follow the following procedure:

1. Remove the AC power cord from the receptacle at the rear of the module.
2. Remove the fuse housing by clamping the release clips with your fingers and pulling the fuse housing from the module.
3. Install the appropriate time-delay fuse in the right-hand fuse socket.
4. Insert the fuse housing back into the module.

## 1.5 RF Power Precautions

This test equipment is capable of delivering RF powers well in excess of 75 Watts to the front panel of the Front End (FE) Module. A yellow LED above the active RF port indicates when RF power is present on that port.

### **WARNING**

To avoid the potential for RF burns or shock, do not touch an exposed RF port when it is active (yellow LED is on). As a further safety precaution against personal injury, do not energize an RF port unless a device is connected to that port.

If a device that radiates RF energy (such as an antenna) is connected to an active RF port, adhere to the appropriate Non-ionizing RF Radiation Safety Standards for your facility.

## 1.6 Equipment Ratings

Complete technical specifications and equipment ratings may be found in the “Technical Specifications” Section of this manual.

### **CAUTION**

If this instrument is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

## 2. Product Overview

### 2.1 System Description

The Kaelus line of Passive IM (PIM) Analyzers measure the forward and reverse (reflected) intermodulation distortion from passive RF components such as cables, filters, antennas, etc. The analyzer consists of four main units:

1. System Controller (Computer, and Virtual Front Panel Software)
2. Transceiver (TR) Module
3. Front End (FE) Module

The basic configuration is illustrated in Figure 1. The System Controller is common to all configurations of the PIM Analyzer. The Transceiver, and Front End Modules vary according to the specific model number and configuration options. Please refer to the Appendix for specific information on the Transceiver, and Front End Modules supplied with this PIM Analyzer.



**Figure 1 Complete System Block Diagram for the Kaelus Passive IM Analyzer.**

Common to all standard configurations of the PIM Analyzer are the following characteristics:

- Dual-Frequency Synthesizers: Each TR Module provides the ability to independently synthesize two carrier tones at any frequency within the transmit band of the unit.
- Internal High Power Amplifiers (one for each carrier).
- Low-Noise Amplification: The received signal is low-noise amplified with a high gain amplifier prior to conversion to the IF frequency.
- High Speed Digital Receiver: Each TR Module converts the received signal to an IF frequency which is directly digitized. Processing of this digitized IF signal is performed to achieve very low random noise floors.

Each of the major components that make up the PIM Analyzer is described in the following paragraphs.

### 1.1.1 System Controller

The System Controller for the Kaelus PIM Analyzer is a standard PC-style computer. Please refer to the systems documentation for specific information relating to processor type and speed as well as information on the supplied operating system.

The System Controller is a standard x86 based PC configured to provide high-performance communications with the connected analyzer. Equipped with USB v2.0 support, the controller can be connected (via the provided USB 2.0 cable) to any 'E' style PIM analyzer to process analog signals and communicate digital information between the system controller and the analyzer

### 1.1.2 TR Module

The RF Module performs RF signal generation operations. The LED indicators on the front panel of the TR Module receive their power from the System Controller (via the included USB 2.0 interface cable). When the System Controller is powered on, and the USB Cables are properly connected, the Status LED's should be illuminated.

Please refer to the Appendix for the specific RF Module performance characteristics, port descriptions, and performance information.

### 1.1.3 Front End (FE) Module

The Front End Module performs RF processing functions including filtering and down-conversion operations. As the FE Module receives its power from the RF Module, no external power switch is available for this chassis.

The LED indicators placed above each carrier port will indicate when RF power is being applied to that carrier.

The FE Module requires that all other modules are powered on, and interconnected via their RF and USB required connections. Please refer to the Appendix for specific module connections, characteristics, port descriptions, and performance information.

### 1.1.4 System Control Software

Installed on the System Controller is the PIM Distribution software.

- Passive IM Virtual Front Panel: The VFP application (vfp.exe) is the primary control software used to operate the analyzer.

The software is factory installed to the c:\Program Files\Kaelus\PIM folder on the System Controller. Complete procedures for re-installing the software are contained in the Service section of this manual.

## 2.2 For Additional Technical Assistance

For additional information or technical assistance, please contact:

Kaelus

PHONE 303-768-8080

FAX 303-768-8181

[info@Kaelus.com](mailto:info@Kaelus.com)

<http://www.Kaelus.com>

## 3. Installation

### 3.1 Unpacking and Initial Inspection

Inspect each shipping container for unreasonable damage. If the equipment has been damaged in transit, the original packing materials will be required to submit a claim against the carrier.

Notify both the carrier and Kaelus upon the following conditions:

1. The packaging material shows signs of water damage.
2. The protective plastic bag surrounding the equipment is torn.
3. The internal cushioning material shows signs of excessive damage or stress.

The contents of each container should be checked against the packing slip attached to the outside of the container. Please notify Kaelus of any discrepancies.



#### WARNING

To avoid personal injury, do not connect the equipment to an AC power source if there are obvious signs of damage to the equipment.



**IMPORTANT NOTE:** RETAIN ALL PACKING MATERIALS FOR USE IN THE EVENT THE EQUIPMENT MUST BE SHIPPED AGAIN. IF UNITS ARE NOT RETURNED IN PROPER PACKAGING, A CHARGE OF USD \$50.00 PER BOX WILL BE CHARGED FOR THE RETURN SHIPMENT.

### 3.2 Preparation for Installation

Complete the following checklist prior to continuing with the installation:

- Check the AC input fuse on the RF and PA Modules to make sure they are of the correct type and rating for the available AC line voltage. The standard fuse should be a 250V, 5A, Slo-Blo fuse. See Section 1 for instructions on installing the proper fuse and configuring the AC receptacle for the local supply voltage.
- Ensure the AC power cables supplied with each powered module are compatible with the available AC wall receptacle. These cables must supply an earth ground to the equipment to ensure personnel safety.
- Ensure the circuit to which the four system AC power cords are connected is capable of supplying 1800 VA.

### 3.3 Installation

Select a hard surface capable of supporting a minimum of 110 lb. (50 kg) for the RF, PA, and FE Modules. This surface must have a solid surface so as not to impede the airflow from beneath the component modules. All other surfaces must be at least 15 cm (6 inches) from the analyzer module enclosures.

#### CAUTION

To avoid damaging the equipment, ensure the power switches are turned off on the monitor, the System Controller, and each of the PIM modules before connecting the equipment together.

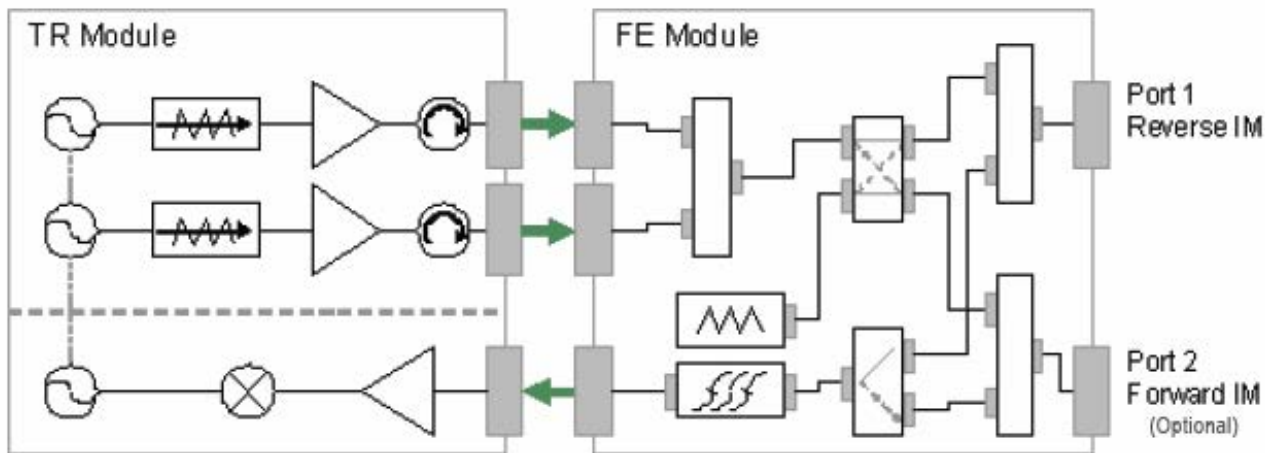
#### CAUTION

To avoid damaging the equipment, do not mate or de-mate the Power Supply cables when the power is turned on.

Connect the equipment as shown in Figure 2. The individual analyzer modules must be stacked vertically (as pictured) in order to properly make each connection. The provided connection cables limit the distance between each module to enhance PIM performance. The System Controller may be separated from the analyzer modules by up to 6 feet (1.8 m).



**IMPORTANT NOTE:** EARTH STRAPS ARE TO BE CONNECTED BETWEEN THE TR AND FE MODULES AND THE MOUNTING RACK (IF USED). THIS WILL ENSURE CORRECT GROUNDING OF THE UNITS FOR EMC/EMI PERFORMANCE.



**Figure 2 Interconnection Diagram for the Passive IM Analyzer**

To avoid the possibility of ground loops, ensure all PIM modules and the Controller PC are plugged into the same AC power circuit (i.e., they share a common circuit breaker).

Once the connections shown in Figure 2 have been verified, the PIM Analyzer may be turned on to confirm the unit will pass initial self-tests and diagnostics. This procedure is described in Section 4.

For information on connecting a device under test (DUT) to the PIM Analyzer, please refer to the Applications Information contained in Section 7.

## CAUTION

The Front End (FE) Module is supplied with connector savers (male-female adapters) for each external carrier port. These adapters are provided to protect the analyzer's port connectors from wear. To help ensure the maximum possible connector life, do not remove these connector savers until they are worn, which is indicated by high and/or intermittent residual IM. Please refer to Section 7.3.

View showing interconnecting cables



## 4. Operation in Engineering Mode

### 4.1 Turning On the Analyzer

The following sequence should be followed in turning on the PIM Analyzer. Although performing these steps out of sequence will not harm the equipment, it is a good practice to follow the same procedure each time.

1. Turn on the System Controller's monitor.
2. Remove the floppy disk, if any, from the System Controller floppy drive.
3. Power up the computer by firmly pushing and releasing the On/Off button on the front panel of the System Controller. The power indicator on the System Controller should illuminate, the hard disk and fan should begin to run.
4. Turn on the power to the RF and PA Modules.
5. Double click on the desktop icon entitled "Virtual Front Panel".
6. The PIM Analyzer starts up with the high power RF turned off. In addition, all Status LED's on the front panel of the RF Module should illuminate indicating that each PIM module has been initialized by the VFP.



#### WARNING

Although the high power output port (Port 1) is internally protected from operating into an open or short circuit at full power, this is not a recommended operating condition. For maximum RF Module reliability, ensure the high power RF port is properly terminated before turning on the RF power.

### 4.2 Shutting Down the Analyzer

To shut down the PIM Analyzer, the following procedure may be used:

1. Exit the VFP application by clicking on the "Exit" or Close button in the upper right corner of the window, selecting "Exit" from the File menu, or pressing CTL+F4 on the keyboard.
2. Turn off the power to both the RF and PA Modules.
3. Reveal the PIM Hardware engine by double clicking the PIM HW icon located in the system tray, then exit by pressing the Exit button or the close window button on the right side of the title bar.
4. Exit the Windows Operating System by using the Start Menu on the Task Bar.
5. Turn off the power to the monitor.

**NOTE:** The VFP software will automatically restore the last saved front panel configuration file on its next startup. To take advantage of this feature, remember to save your front panel configuration once it's setup to meet your requirements.

### 4.3 Connecting a Device for Testing

Please refer to the Applications Information section (Section 7) for details on how to connect typical devices to the analyzer for IM testing.

#### CAUTION

The FE Module is supplied with connector savers (male-female adapters) for each carrier port. These adapters are provided to protect the analyzer's port connectors from wear. To help ensure the maximum possible connector life, do not remove these connector savers until they are worn.



#### WARNING

For operator safety the carrier power on both channels must be turned off prior to the connection or disconnection of a DUT to the Front End Module.



## 4.4 Using the Front Panel Controls

The front panel of the PIM Analyzer is displayed on the monitor. Operation of the front panel may be performed with the mouse or from the keyboard. Keyboard operations for each front panel control are indicated on the control. Figure 3 shows the typical front panel configuration. This panel may appear slightly different depending upon the specific analyzer model in use.

There are a variety of ways to change the value or status of each control. These include:

- Click anywhere on a control to change the status. On controls that have only a fixed number of states, the control will either change state or present a list of options from which you can select the desired control state.
- Click on the Up/Down Arrows adjacent to the numeric entry controls to increment/decrement the control by a fixed increment.
- Double-click on the numeric field to highlight the entire field. A specific numeric value may be entered on the keyboard. After entering a new value, press the ENTER key, or click to another portion of the front panel to make the new value active.
- Single-click within a numeric field and you can then edit the existing value using the BACKSPACE, DELETE, and other normal editing operations from the keyboard. The arrow keys may be used to increment/decrement the value.
- Single-click within a slide tuner and the tuner will hop directly to the value you clicked on.
- Drag a slide tuner to the desired value. The numeric display field will update as you drag the tuner. To drag a tuner, point to the tuner, hold down the left mouse button, and drag across the control area.
- Drag a knob to rotate the knob to the desired value. The numeric display field will update as you drag the knob as if you were turning it.
- Press the TAB key to move around between active controls.

With practice and use, you will find the combination of control techniques that are easiest and fastest for your specific needs.

## 4.5 Front Panel Description

The front panel, as shown in Figure 3, is divided into two sections. In general, the left-hand side is used to control and monitor the stimulus functions (e.g., carrier power and frequency). The right-hand side is used to monitor the test results.

### 1.1.1 Left Side: RF Carrier Control (Stimulus-Side)

The left side of the panel controls the two RF sources within the test set. RF power level, carrier frequencies, and power offset/leveling options are all controlled from this half of the panel. The graphical display shows the status of the two carrier tones in both frequency and amplitude using a spectrum analyzer-style display.

### 1.1.2 Right Side: Passive IM Data Display (Response-Side)

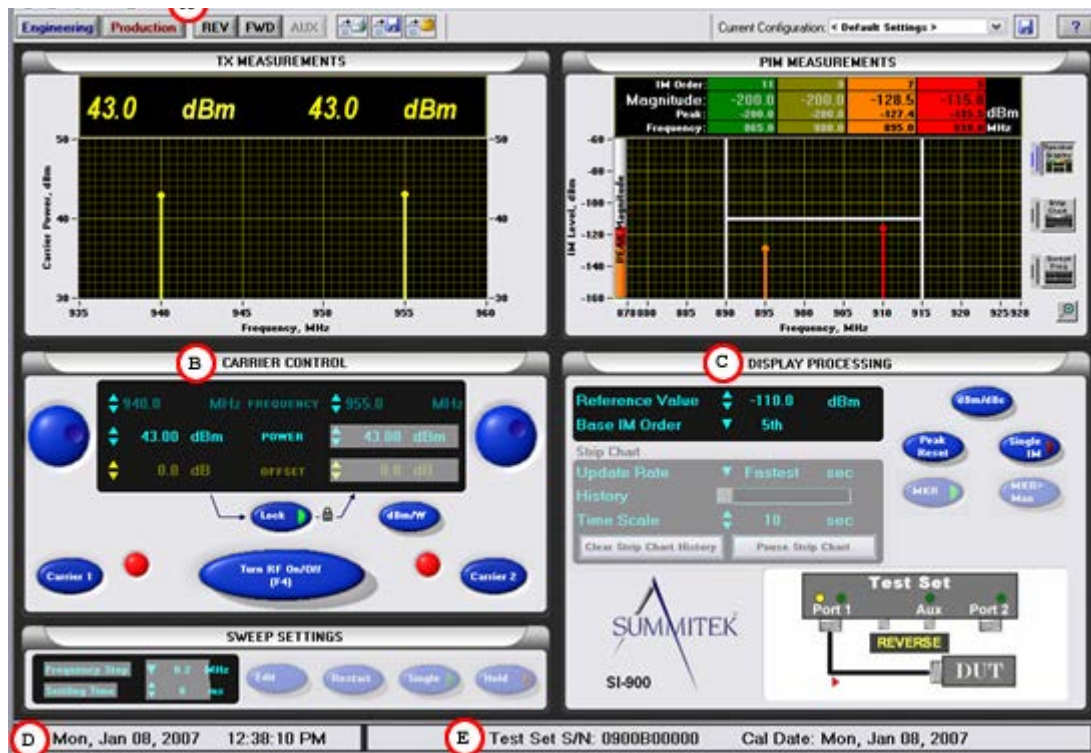
The right side of the panel displays the measured IM values and allows the selection of units, measurement mode, and averaging. The graphical display shows the measured IM response frequency and amplitude levels. The amplitude values are also indicated in a numeric format immediately above the graphical display. Those IM values that fall within the pass band of the RF Module are shown with brighter colors than those responses that fall outside of the pass band.



**IMPORTANT NOTE:** To optimize measurement speed, the analyzer actually measures only those IM responses which fall within the receive band of the RF unit. Those responses falling outside the receive band are assigned an arbitrarily low number.



**IMPORTANT NOTE:** When displaying IM data in units of dBc, a very large (negative) dBc value (-200.00) is displayed when the RF carriers are turned off. This is because the analyzer uses the measured carrier power to normalize the dBm-unit data to convert to units of dBc. When the carriers are turned off, the measured carrier power is very small and the resulting dBc value becomes quite large. The value of -200.00 dBc is used as a reminder that IM measurements in units of dBc are meaningless while the carriers are turned off.



(A) Menu and Button Bar (D) Current Date and Time  
 (B) Stimulus Display and Controls (E) Test Set Calibration Information  
 (C) Response Display and Controls

Figure 3 Virtual Front Panel (VFP) for Engineering Mode

### 1.1.1 Detailed Front Panel Description-Stimulus Controls

The specific controls and displays provided on the front panel are summarized below (see Figure 4):

#### A Engineering Mode:

This control selects the Engineering Mode variant of the front panel. This mode allows the detailed diagnosis of passive IM signals with a quick response time and the ability to view multiple IM products near simultaneously. This mode provides three display options:

- Spectral Mode Display (Correct PIM value generated by a Fixed Frequency Pair)
- Strip Chart Mode Display (PIM versus Time)
- Swept Frequency Mode Display (PIM versus Swept Frequency)

#### B VFP Configuration Menu:

Save your configurations and restore them for future use.

- **Save:** Use this option to save VFP configurations under a file name of the user's choosing.
- **Open:** Use this option to open a saved configuration file.
- **Open Recent:** When available, this menu lists the 5 (or less) most recent configuration files used with your instrument.
- **Save As:** Use this option to save your current configuration to another filename.
- **Reinitialize:** Use this option to reinitialize the VFP. Note: All un-saved configuration options will be lost, and the VFP will re-detect your PIM hardware (loading default values).

**C Production Mode:**

This control selects the Production mode variant of the front panel. This mode provides a simple user interface for personnel to characterize passive IM in a production environment.

**D Measure Reverse (Reflected) IM:**

This control selects the measurement mode of reverse (reflected) IM. This mode measures the IM generated in the device-under-test (DUT) by monitoring the magnitude of the IM signal flowing in the reverse direction relative to the direction of propagation of the two carrier signals.

**E Measure Forward (Through) IM:**

This control selects the measurement mode of Forward (Through) IM. This mode measures the IM generated in the device-under-test (DUT) by monitoring the signal flowing in the same direction as the direction of propagation of the two carrier signals.

**F Transmission Measurements Indicator:**

This panel displays the carrier frequencies and power levels after the manner of a spectrum display.

**G Lock Carrier 2 power to Carrier 1:**

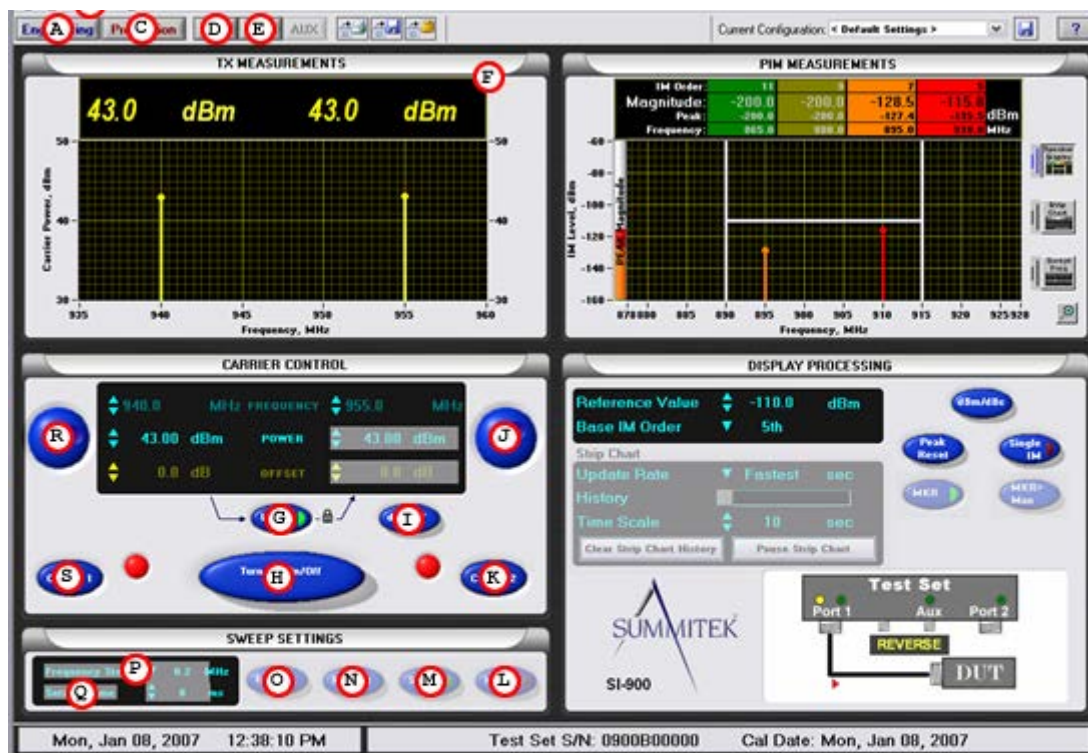
This control toggles between LOCKED and UNLOCKED carrier powers and their offsets, if any. When the carrier powers are LOCKED (shown by the lighted switch), Carrier Power 2 is equal to Carrier Power 1. When the carrier powers are UNLOCKED (shown by the absence of light in the switch), Carrier Power 1 and 2 may be set independently.

**H Toggle both Transmit (Tx.) Carriers On or Off (F4):**

Changes the on/off status of both carriers with a single button. If one carrier is on when this button is pushed, both carriers are turned off. Pressing the "F4" key on the System Controller's keyboard is another convenient way of toggling the RF power status.

**I Toggle between dBm and Watt units:**

Selects "dBm" or "Watts" as the currently displayed carrier power units. This also affects the units used for the measured carrier power display in the composite Frequency/Power/Offset panel.



- (A) Engineering Mode
- (B) Control VFP Configuration
- (C) Production Mode
- (D) Measure Reverse (Reflected) IM
- (E) Measure Forward (Through) IM
- (F) Transmission Measurements Indicator
- (G) Lock Carrier 2 power to Carrier 1
- (H) Toggle both Carriers On/Off (F4)
- (I) Toggle between dBm and Watt units
- (J) Change selected Carrier 2 parameter
- (L) Hold Sweeping Carrier Positions
- (M) Perform Single Sweep Measurement
- (N) Reset and Restart Sweep
- (O) Edit Sweep Frequencies
- (P) Frequency Step-size Increment
- (Q) Carrier Step Settling Time
- (R) Change selected Carrier 1 parameter
- (S) Turn Carrier 1 On/Off

Figure 4 Virtual Front Panel (VFP) in Engineering Mode (Stimulus Controls)

**J Change Selected Carrier 2 Parameter:**

Depending upon the parameter highlighted, (Frequency, Power, or Offset) change or edit

- **Frequency.** The frequency of Carrier 2 in units of MHz. The frequency resolution is 200 KHz. The frequency of Carrier 2 must always be greater than that of Carrier 1.
- **Power.** The carrier power level for Carrier 2. If “Lock” is selected (using “G”), this control makes the power level of Carrier 2 dependent upon the power of Carrier 1. This field changes units between dBm and Watts depending upon “I”.
- **Offset.** The offset power level for Carrier 2 to match a user-specified value. This same offset is also applied to the measured carrier power display “F” and displayed IM units (dBc calculations only). When the analyzer is calibrated, all power indicators are referenced to the power present at the Port 1 output when the Offset is set to zero (0). Offsets are used to move the power reference point. For example, if the analyzer is being used to measure an antenna, and the antenna is connected to the analyzer with a coaxial cable with 0.8 dB of insertion loss, then the operator would choose an Offset of 0.8 dB to move all power reference indications to the output side of the cable.

**K Turn Carrier 2 On or Off:**

This control turns the RF On/Off for Carrier 2 only. This action takes place irrespective of the status of the “Locked” control (using “G”)

**L Hold Carriers at Current Positions (Swept Frequency Mode Only):**

This pertains to the Swept Frequency Mode only. This control “freezes” the carriers during a sweep to enable a closer study of the IM products for a particular carrier frequency pair.

**M Single. Perform a Single Sweep Swept Frequency Measurement (Swept Frequency Mode Only):**

This pertains to the Swept Frequency Mode only. This control enables the user to conduct a single swept frequency measurement containing two frequency sweeps. In the first sweep, Carrier 2 sweeps towards Carrier 1 with Carrier 1 fixed at the lowest frequency specified by the Edit (O) control. In this sweep, the Carrier 2 frequency begins at the highest frequency specified by the Edit (O) control and steps down in frequency increments (P) to measure all combinations of Carrier 1 and Carrier 2 frequencies that result in an IM frequency that lands within the receive band. The second sweep keeps Carrier 2 fixed at the highest frequency defined in Edit (O) and sweeps Carrier 1 up in the selected frequency step size (P).

**N Restart. Reset Carriers to Beginning of Sweep (Swept Frequency Mode Only):**

This pertains to the Swept Frequency Mode only. The carriers are reset to their respective starting frequencies for those particular sweep parameters and the sweep restarts.

**O Edit. Edit Start Frequencies for Both Carriers (Swept Frequency Mode Only):**

This pertains to the Swept Frequency Mode only. This control pops up a dialog box used to define the sweep frequency band edges for Carriers 1 and 2. The default is the full band capability of the PIM Analyzer.

**P Frequency Step. Frequency Step-size Increment. (Swept Frequency Mode Only):**

This pertains to the Swept Frequency Mode only. This control defines the frequency step increment in a swept frequency measurement.

**Q Settling Time. Time to Wait After Carrier Step Before Measuring the IM (Swept Frequency Mode Only):**

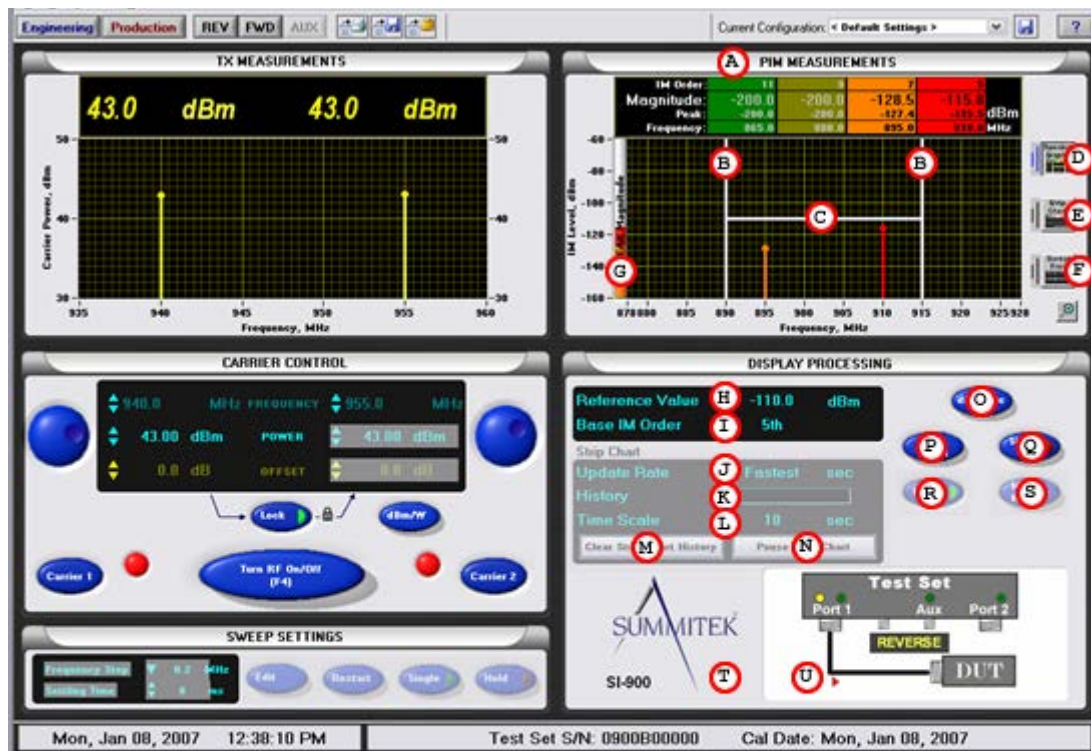
This pertains to the Swept Frequency Mode only. This control defines the settling time between frequency changes prior to each measurement. Certain devices under test require a finite settling time to adjust to the new frequency, before an IM measurement is made.

**R Change selected Carrier 1 parameter:**

This is similar to (“J”), but for Carrier 1.

**S Turn Carrier 1 On or Off:**

This is similar to (“K”), but for Carrier 1.



- (A) PIM Measurement Indicator
- (B) Rx Band High/Lo Frequency Limits
- (C) Reference Line Position
- (D) Spectral Mode Switch
- (E) Strip Chart Mode Switch
- (F) Swept Frequency Mode Switch
- (G) Peak IM Value Indicator
- (H) Reference Line Position Value
- (I) Lowest IM Order Displayed
- (J) Strip Chart Update Rate
- (K) Strip Chart Review History
- (L) Strip Chart Time Scale
- (M) Strip Chart Clear History
- (N) Strip Chart Pause Measurement
- (O) Toggle Units (dBm/dBc)
- (P) Peak IM Value Reset
- (Q) Toggle Single IM Measurements
- (R) Swept Frequency Markers On/Off
- (S) Swept Frequency Marker Max
- (T) PIM Analyzer Model Number
- (U) IM Measurement Mode Display

Figure 5 Virtual Front Panel in Engineering Mode (Response Controls)

**A PIM Measurement Indicator:**

Depending upon the selected display type, this panel shows one of the three display types: Swept Frequency, Strip Chart, or Spectral (Fixed Frequency). The IM products that this indicator can display can vary from 3rd order up to 27th order depending upon user choice.

**B Receive Band (Rx.) High/Low Frequency Limits:**

Depending upon the analyzer connected to the System Controller, these vertical lines indicate the high and low frequency limits of the receiver. Outside these limits, the displayed amplitude is not accurate due to the cut-off characteristics of the internal filters. Therefore, the analyzer does not to measure IM responses that fall outside the Receive Band frequency limits. For this reason, the displayed values are set to an arbitrarily low value when the frequencies fall outside the pass band of the receiver.

**C Reference Line Position:**

This line is defined by the user setting using “E”.

**D Spectral Mode Switch:**

This control launches the Spectral Mode Display variant of the Engineering Mode. This is the mode shown in Figure 5.

**E Strip Chart Mode Switch:**

This control launches the Strip Chart Mode Display variant of the Engineering Mode.

**F Swept Frequency Mode Switch:**

This control launches the Swept Frequency Mode Display variant of the Engineering Mode.

**G Peak IM Value Indicator:**

The peak IM values for each IM order displayed on the plot are stored in this thermometer indicator. Please note these values are also visible in the numeric indicators above the plot. These values display the maximum IM value measured as of the last frequency change or peak reset operation.

**H Reference Line Position Value:**

This control defines a user adjustable reference level line that appears on the display.

**I Base IM Order (Lowest IM Order displayed):**

The PIM Analyzer will measure up to four IM Products simultaneously. The Base IM Order control selects the lowest IM order that will be measured. The selectable values range from 3rd to 27th order IM products. Note that only those IM Products with a frequency landing within the pass band of the analyzer will be measured. The selected IM order will appear in the pass band of the display.

Whenever the passive IM receiver receives a signal that drives the receiver into approximately 0.2 dB compression, an IM OVERLOAD indicator lights up on the PIM Measurements panel. The accuracy of the display IM amplitude is not reliable when this indicator is active. *When the IM Overload indicator illuminates, the true IM level is greater than the indicated IM level by more than 0.2 dB.* The 0.2 dB compression level for the “SI-xx00-Series” Analyzers is approximately -68 dBm and may vary several dBs depending upon the specific RF head being used.

**Note:** With devices known or expected to generate extremely high IM levels, it is possible to overdrive and saturate the receiver to an extent where the IM overload warning does not illuminate. To test for this condition, run the power sweep test defined in Section 6.6. If the IM power level of the DUT exceeds -70 dBm, use a low IM directional coupler to decrease the IM power to a level that does not saturate the receiver.

**J Strip Chart Update Rate:**

The Strip Chart is updated at this speed. This pertains to the Strip Chart Display Mode only. This control enables the user to determine the approximate time between data samples. The choices are “FASTEST, 1, 2, 5, 10, 15” seconds. The size of the strip chart buffer is 20,000 samples. Using 15 seconds per sample, up to 5000 minutes (approximately 83 hours) of IM data can be recorded on the strip chart.

**K Strip Chart Review History:**

Scroll back through strip chart data history (Strip Chart display only). This control enables the user to scroll back through the entire recorded strip chart history (up to the maximum of 20,000 samples) of IM data measured on the strip chart. Note: Unless the strip chart is activated, data will not be measured or added to the strip chart history. However, a user may switch between display modes without losing the stored strip chart history data.

**L Strip Chart Time Scale:**

This control allows the user to expand the Strip Chart window to display more time than the default values. The shortest time available is based on the default value for this measurement speed.

**M Strip Chart Clear History:**

This pertains to the Strip Chart Display mode only. This control clears the strip chart for a fresh measurement. The elapsed time indicator will be reset to zero.

**N Strip Chart Pause Measurement:**

This pertains to the Strip Chart Display mode only. This control stops the data acquisition process and “freezes” the strip chart recorder the moment the control is activated. When “Continue Strip Chart” is pressed, the recording of the data resumes. No data will be recorded during the Pause time, however the strip chart clock will continue to count so accurate measurement time will not be lost (while this expands the strip chart history, it does not effect the history length since data is not being collected).

**E Toggle Units (dBm/dBc):**

This control changes the units used to display the PIM data between dBm and dBc. When dBc is selected, the carrier power level used to calculate the dBc level is the largest measured actual carrier response. **Please note:** Because measured carrier power values are used for the dBc calculation, the display measured IM results when both carriers are off, are set arbitrarily to -499.99 dBc. The units of dBc are obtained by normalizing the dBm unit data by the largest measured carrier power level. If the carriers are off, the displayed dBc data is meaningless.

**O Peak IM Value Reset:**

This control will reset the Maximum IM values measured for ALL IM Orders displayed. These values will be reset on the PIM Measurements display Peak IM thermometer, as well as the numerical indicators.

**P Toggle Single IM Measurements:**

This control allows the user the ability to measure only a single Order IM value (based on the selected **Base IM Order**). Enable this feature to enhance measurement speed and collect only necessary data when only interested in one IM order (i.e. 3rd Order IM only).

**Q Swept Frequency Markers On/Off:**

This pertains to the Swept Frequency Display mode only. This control turns on two markers, one red and one yellow on the PIM Measurement Indicator (**A**) in the Swept Frequency display mode. The red marker pertains to the “Carrier 1 Up” sweep whereby Carrier 2 remains constant and Carrier 1 sweeps up. The marker indicates in red color the power level at the marker position, the carrier frequencies that generated the IM product, and the frequency at which the IM product occurs. The yellow marker indicates similar details, but pertains to the case when Carrier 1 is constant and Carrier 2 sweeps down.

**R Swept Frequency Marker Max:**

This pertains to the Swept Frequency display mode only. Whenever this control is pressed, the two markers automatically move to the maximum IM level currently displayed on the swept frequency plot. The information displayed above the plot indicates the maximum IM power for each sweep and the frequencies at which they occur.

**S PIM Analyzer Model Number Display:**

The PIM software automatically determines what model analyzer is connected and displays this information.

**T IM Measurement Mode Display:**

This display shows the type of measurement being carried out (i.e. Reverse IM or Forward IM). The user must pay careful attention to this display and should ensure that their instrumentation is connected accordingly.



## 6. Operation in Engineering Mode - Tutorial

### 6.1 Overview

Engineering Mode is used, primarily, during design and development and for diagnosing the source of passive IM. There are three different presentation methods in Engineering Mode. These display modes are selectable by pressing the icon to the right of the IM response display area.



**Spectral Mode.** Spectral Mode provides a display of the magnitude of each of the IM products that lands within the pass band of the analyzer for two fixed frequency pairs. For example, if the selected frequency pair results in IM3 (third order IM product), IM5 and IM7 within the pass band, all three IM products will be measured and displayed. This mode allows the operator to observe the inter-relationship of the IM products. Note that although this is a fixed frequency mode, the operator can manually vary frequency and/or power and observe the change in this relationship.



**Strip Chart Mode.** Strip Chart measures and displays the IM response as a function of time. It displays the IM response for all IM products that land within the pass band for the analyzer. This mode is particularly useful for observing how the IM changes with time due to environmental and/or mechanical stress.



**Swept Frequency Mode.** Swept frequency mode is used to determine how the IM response changes with different pairs of frequencies. The analyzer actually performs two frequency “sweeps”. In the first sweep, it sets Carrier 1 to the lowest frequency in the transmit band and sets Carrier 2 to the highest frequency in the transmit band. It then steps Carrier 2 down in frequency covering all frequency pairs that generate an IM product that lands in band. In the second “sweep”, Carrier 2 is kept constant and Carrier 1 is stepped up in frequency. Swept frequency is a valuable test mode in that it exposes problems that may go unfound if only two fixed frequency carriers are used. This is particularly true on band-limited devices.

#### 1.1.1 IM Measurement-Spectral Display

This example assumes that the test object is a low IM termination (SI-20A, SI-30A or equal) connected directly to Port 1 of the PIM Analyzer. The result of this test is a measurement of the “Residual IM” of the test setup. The Residual IM is a critical performance parameter, because it establishes the minimum level of PIM that can be measured by the test setup. If the PIM of the device under test (DUT) is lower than the Residual IM, the measurement will display the Residual IM level and not the PIM of the DUT. Note that even when the Residual PIM is lower than the PIM of the DUT, this ratio impacts the measurement uncertainty (please refer to Section 7 for more information). It is always desired that the Residual PIM be at least 10 dB below the PIM specification for the device being measured. Note that the measurement is not simply a measurement of the PIM of the test instrument, but the combination of the test instrument, any interconnecting cables and/or adapters, and the termination.

1. If you are not already in Engineering Mode, press Engineering Mode (switch “A”, Figure 4-2).
2. Load the “Factory Default Configuration” by selecting this Configuration in the top, right corner of the Virtual Front Panel display. This loads the default parameters onto the view screen.
3. Note on the Carrier Control Panel, the following default values are given in the table for the respective test set:

Test Set	Freq. (MHz) Start/Stop	Power (dBm)	Offset (dBm)	Lock On/Off
SI-400	138/510	30	0	On
SI-800	869/894	30	0	On
SI-900	935/960	30	0	On
SI-900E	925/960	30	0	On
SI-1800	1805/1880	30	0	On
SI-1900	1930/1990	30	0	On
SI-2000	2110/2170	30	0	On
SI-2000E	2110/2170	30	0	On
SI-2600	2620/2695	30	0	On
SI-3500	3510/3594	30	0	On

**Table 1 Default Values for the Respective Test Sets**

**Note:**

Lock “On” indicates that Carrier 1 and Carrier 2 are at the same power level of 30 dBm each. Frequency values are set at the transmit band edges in the Factory Default Configuration.

4. The measurement mode defaults to Spectral Mode.
5. To switch the power selection to Watts, press the dBm/W switch (switch “I”, Figure 4-2). Note that the power and offset readings change to “Watts”. Press the dBm/W switch to return to dBm for the rest of this tutorial.
6. The “D” Version of the Kaelus PIM Analyzers has a residual IM specification of –125 dBm with 2 carriers at +43 dBm (20 watts) when terminated with a high performance, low IM termination (SI-30 or equal). To assist in viewing the measured performance relative to the specification limit, set the Reference Value to –125 dBm. The Reference Value level can be set one of two ways.
  - Up/Down Arrow. Using the Down arrow next to the Reference Value field, click down (the value changes in 5 dB increments) until the value is –125 dBm.
  - Key in the Value. Point to the current Reference Value number and double click. This will highlight the current value. Type in –125 dBm and press Enter or click anywhere else on the screen to accept the value. This is the fastest and easiest way to enter this information.
7. Upon start-up, the RF power is off and the measured IM value is the system noise floor.
8. Switch on the RF power (using switch “H”, Figure 4-2). The carrier status indicator lights change to red indicating the RF is on.
9. The actual, measured power being transmitted from the Port 1 output connector is displayed on the “Tx. Measurements” panel (“E”, Figure 4-2). The two vertical lines on the left side (stimulus) of the screen give a visual indication of the frequency and the power of each of the two carriers.
10. With Carrier 1 and Carrier 2 frequencies set at the maximum and minimum frequency for the analyzer (“band edges”), we see that one IM product lands within the receive band. This is indicated in color and its magnitude and frequency are shown in the legend display. IM products that are not present in the pass band are shown dimmed and set to arbitrarily low levels. The following table gives the specific IM product number and frequency depending upon the test set:

Test Set	Carrier 1 Frequency	Carrier 2 Frequency	IM Product	IM Frequency
SI-800	869 to 871.6 MHz	889 to 894 MHz	IM3	844 to 849 MHz
SI-900	935 to 937.6 MHz	955 to 960 MHz	IM3	910 to 915 MHz
SI-900/E	925 to 930 MHz	950 to 960 MHz	IM3	890 to 915 MHz
SI-1800	1805 to 1820 MHz	1850 to 1880 MHz	IM3	1730 to 1760 MHz
SI-1900	1930 to 1945 MHz	1960 to 1990 MHz	IM3	1870 to 1895 MHz
SI-2000	2110 to 2122 MHz	2153 to 2170 MHz	IM7	1930 to 1978 MHz
SI-2000E	2110 to 2122 MHz	2153 to 2170 MHz	IM3	2050 to 2060 MHz
SI-2600	2620 to 2640 MHz	2658 to 2695 MHz	IM3	2545 to 2580 MHz
SI-3500	3510 to 3539 MHz	3558 to 3594 MHz	IM3	3426 to 3462 MHz

**Table 2 Specific IM Product Number and Frequency**

11. Note on the “Display Processing” panel the following settings:
  - Reference Value = -125 dBm.
  - Base IM Order = 3rd Order, except for the SI-2000, which is 7th order.
 Note also that the “Strip Chart Controls” (“J – M” Figure 4-3) are dimmed, since they do not pertain to the Spectral Mode. Similarly, all buttons unrelated to Spectral Mode are dimmed.
12. Click on the dBm/dBc switch and note that all dBm readings revert to dBc values. These values are all relative to the strongest carrier signal; i.e., 30 dBm in our case.
13. Note the power levels of the IM products.
14. Increase the carrier power from the present 30 dBm to 43 dBm on the Carrier Control Panel using any of the following techniques. Before changing the power, you must first highlight the POWER display in the Carrier Control display by clicking anywhere near the POWER selection area.
  - a. Tuning Knob. Using the Carrier 1 tuning knob, rotate the knob clockwise until the requested power indication is 43 dBm.
  - b. Up/Down Arrows. Point to the Up arrow and click. The requested power will increase in fixed increments.
  - c. Key in the Requested Power. Point to the Carrier 1 Requested Power area and double click to highlight the currently selected power (30 dBm). Key in the new power level requested (43 dBm). Press Enter or click anywhere on the display. The new requested power is now displayed. The actual carrier power present at the Port 1 output is displayed in the Tx Measurement area.
15. Note that the power levels of both Carriers 1 and 2 have risen to 43 dBm, since they are locked. The IM power levels have also increased due to the increase of power in the transmit carrier signals.
16. Press the LOCK button (“F”, Figure 4-2). This will unlock the carriers and the LOCK indicator light will switch off. Decrease the power level of Carrier 2 to 40 dBm.
17. Note that the “Tx. Measurement” panel shows the power of Carrier 2 to be lower than Carrier 1.
18. Press the LOCK button to relock the carrier powers. Note that Carrier 2 increases to the same 43 dBm selected for Carrier 1.
19. The Spectral Mode data can be printed, recorded to a file, or cut to the system clipboard.
  - a. Printing Data.
    - i. Point and click on the Print icon on the top menu bar. This brings up a Description dialog box that can be used to enter additional descriptive information about the test. After pressing OK, the Print dialog box appears. Press OK, and the data currently displayed will be printed to the default printer. The print output includes the description information entered, Carrier Status, and PIM Response.
  - b. Logging Data to File.
    - i. Point and click on the Save icon on the top menu bar. This brings up a Description dialog box that can be used to enter additional descriptive information about the test. After entering this information and pressing OK, the Save To dialog box appears. Enter the file location and name and press OK. The data will be saved in a Tab Delimited ASCII text (.txt) format.
    - ii. To view this data in Excel, start up Excel; open the file being sure to indicate a file type of .txt. Press Finish on the open Wizard and the data will be displayed. This data can then be saved in Excel (.xls) format.
  - c. Cutting Data to the Clipboard.
    - i. Point and click on the Clipboard icon on the top menu bar. This will place the data on the system clipboard.
20. This completes the tutorial on the Spectral Display Mode.

## 6.2 IM Measurement-Strip Chart

Strip Chart Mode measures and displays the IM performance of the device under test (DUT) as a function of time. This creates a history of the IM performance, which can be used to determine how the device performs under mechanical stress (tapping, flexing, etc.) and/or environmental stress (temperature, moisture, etc). For this example, the DUT is assumed to be a low IM termination (Kaelus SI-20, SI-30 or equal) that is attached directly to Port 1 of the PIM Analyzer or attached by a high quality, low IM cable assembly.

1. Load the Configuration “Factory Default Configuration”. This results in the analyzer being in Engineering, Spectral Display Mode.
2. To switch to Strip Chart, point and click on the Strip Chart icon to the right of the PIM Measurements display area. The analyzer will begin plotting the measured IM level as a function of time.
3. Every IM product (up to four) that lands within the pass band of the analyzer will be measured and displayed. You can check what IM products meet these criteria by selecting the Spectral Display Mode (click on the Spectral Display icon). After doing this, return to Strip Chart by clicking on the Strip Chart icon.
4. Note that until the RF Power is turned on, the indicated measurement value is the system noise floor.
5. Now observe that the marker buttons “Clear” (switch “F”, Figure 4-3) and “Hold” (switch “P”, Figure 4-3) become active as they pertain to Strip Chart Mode.
6. With Port 1 connected to the DUT, turn the RF Power on.
7. If you click the “Hold” button, the trace immediately halts at that point in time, while the legend continues to display the most current values. If you click “Hold” again, the trace jumps to the “present” time and continues from there. No data is recorded while the Strip Chart is on Hold.
8. Continue to record data until the trace reaches the right side of the display area. Note that the display continues to update with the current measurement and the prior measurements move off of the display to the left. Although this data is no longer visible on the chart, it is not erased.
9. To look back at data no longer on the display, point the cursor to the scroll bar to the right of “History”, click, and hold the left mouse button and slide the control to the left. This will move back in time as indicated to the time scale at the bottom of the chart. If you release the scroll bar, it remains at that point in the history. Note that the analyzer continues to measure and record data even when the operator is looking back at prior data. To return to the current data point, slide the tuner all the way to the right.
10. The rate at which data is recorded in Strip Chart Mode is selectable between:
  - a. Fastest. Data is recorded at the highest possible update rate. The actual update rate is determined by the speed of the computer. The update rate is fastest when only one IM product is being measured.
  - b. 1 second. Data is recorded and displayed in 1-second intervals.
  - c. 2 seconds. Data is recorded and displayed in 2-second intervals.
  - d. 5 seconds. Data is recorded and displayed in 5-second intervals.
  - e. 10 seconds. Data is recorded and displayed in 10-second intervals.
11. The Strip Chart Mode data can be printed, recorded to a file, or cut to the system clipboard.
  - a. Printing Strip Chart Data.
    - ii. Point and click on the Print icon on the top menu bar. This brings up the Print dialog box. Press OK, and the data currently displayed on the Strip Chart display will be printed to the default printer. If you want to print data recorded, but not currently displayed, use the History scroll bar to move back to that data, and then press Print. Only the data on the display is printed.
  - b. Logging Data to File.
    - i. Point and click on the Save icon on the top menu bar. This will bring up the Save To dialog box. Enter the file location and name and press OK. The data will be stored. Note that all data recorded from zero (0) seconds up to the point that the Save icon was pressed is saved in a Tab Delimited text (.txt) format. Note that although the PIM Analyzer continues to record data after the Save button was pressed, data recorded after pressing Save is not saved to the file.
    - ii. To view this data in Excel, start up Excel; open the file being sure to indicate a file type of .txt. Press Finish on the open Wizard and the data will be displayed. This data can then be saved in Excel (.xls) format.
  - c. Copying Data to the Clipboard.
    - i. Point and click on the Clipboard icon on the top menu bar. This will copy the data to the system clipboard.
12. Press the “Clear” button and we note that the display clears and commences to record afresh.
13. This completes the tutorial on the Swept Frequency/Strip Chart Mode.

### 6.3 IM Measurement-Swept Frequency

The Swept Frequency Mode of the PIM Analyzer allows the characterization of the DUT across the full bandwidth of the communications band. While one carrier remains parked at the band edge, the other carrier sweeps across the full range of frequencies producing an IM response within the receive band of the analyzer. Both carriers are swept using this technique thus producing a two-trace plot on the screen. For this example, the DUT is assumed to be a low IM termination (Kaelus SI-20, SI-30 or equal) that is attached directly to Port 1 of the PIM Analyzer or attached by a high quality, low IM cable assembly.

1. Load the Configuration “Factory Default Configuration”. This results in the analyzer being in Engineering, Spectral Display Mode.
2. Press Swept Frequency Mode switch (“M”, Figure 4-3).
3. Note that the Sweep Settings panel on the bottom left of the VFP is now active. There is a default sweep frequency step interval of 0.2 MHz (200 KHz) with 0 ms settling time.
4. Also note that the MKR (turn Markers on) button (“G”, Figure 4-3) and the MKR > Max (move Markers to the Maximum value) button (“O”, Figure 4-3) are now active. We shall study their role further on in this tutorial.
5. Note on the Carrier Control Panel, the following default values as given in the table for the respective test set:

Test Set	Freq. (MHz) Start/Stop	Power (dBm)	Offset (dBm)	Lock On/Off
SI-400	138/510	30	0	On
SI-800	869/894	30	0	On
SI-900	935/960	30	0	On
SI-900E	925/960	30	0	On
SI-1800	1805/1880	30	0	On
SI-1900	1930/1990	30	0	On
SI-2000	2110/2170	30	0	On
SI-2000E	2110/2170	30	0	On
SI-2600	2620/2695	30	0	On
SI-3500	3510/3594	30	0	On

**Table 3 Default Values for the Respective Test Sets**

Note:

- Lock = On indicates that Carrier 1 and 2 are at the same power level of 30 dBm each.
  - Frequency values in the Carrier Control portion of the VFP are dimmed as these are defined in the Sweep Settings portion of the VFP, which is below the Carrier Control section of the display.
6. On start-up, the RF power is off and the analyzer will begin sweeping frequencies. The displayed IM power level is the system noise floor as has been discussed in the previous sections.
  7. There are two frequency sweeps performed:
    - a. Carrier 1 Up. This sweep is the red color trace. In this measurement, at the beginning of the sweep, Carrier 1 is set to the lowest transmit frequency defined using the Edit control. Carrier 2 is set to the highest transmit frequency defined using the Edit control. Carrier 1 is then stepped up in frequency in the increment specified with the Frequency Step control. Carrier 2 is kept constant at the high frequency specified. Every pair of frequencies that results in an IM frequency that falls within the passband of the analyzer is measured.
    - b. Carrier 2 Down. This is the yellow color trace. In this measurement, at the beginning of the sweep, Carrier 1 is set to the lowest transmit frequency defined using the Edit control. Carrier 2 is set to the highest transmit frequency defined using the Edit control. Carrier 2 is then stepped down in frequency in the increment specified with the Frequency Step control. Carrier 1 is kept constant at the low frequency specified. Every pair of frequencies that results in an IM frequency that falls within the pass band of the analyzer is measured.
  8. Switch on the RF power (using “G”, Figure 4-2). The result is a swept frequency measurement for the third order IM product (IM3) using the full transmit carrier bands of the analyzer. Note that the analyzer does not sweep all the way up to the highest frequency on the Carrier 1 Up sweep; nor does it sweep all the way down to Carrier 1 on a Carrier 2 Down sweep. This is because the analyzer only measures those combinations of frequencies that result in an IM frequency that falls within the receive band. These are summarized in the following table:

Test Set	Carrier 1 Frequency	Carrier 2 Frequency	IM Product	IM Frequency
SI-800	869 to 871.6 MHz	889 to 894 MHz	IM3	844 to 849 MHz
SI-900	935 to 937.6 MHz	955 to 960 MHz	IM3	910 to 915 MHz
SI-900/E	925 to 930 MHz	950 to 960 MHz	IM3	890 to 915 MHz
SI-1800	1805 to 1820 MHz	1850 to 1880 MHz	IM3	1730 to 1760 MHz
SI-1900	1930 to 1945 MHz	1960 to 1990 MHz	IM3	1870 to 1895 MHz
SI-2000	2110 to 2122 MHz	2153 to 2170 MHz	IM7	1930 to 1978 MHz
SI-2000E	2110 to 2122 MHz	2153 to 2170 MHz	IM3	2050 to 2060 MHz
SI-2600	2620 to 2640 MHz	2658 to 2695 MHz	IM3	2545 to 2580 MHz
SI-3500	3510 to 3539 MHz	3558 to 3594 MHz	IM3	3426 to 3462 MHz

**Table 4 Combinations of Frequencies that Result in an IM Frequency that Falls within the Receive Band**

9. The Markers can be turned on and moved to any point on the data to determine the magnitude of the IM response, the IM frequency, and the transmit carrier frequencies that generated the IM.
  - a. Turn the markers on by pressing the MKR button. There is a marker (vertical line) associated with each of the frequency sweeps. That is, one for Sweep Up and one for Sweep Down.
  - b. To move a marker, point, click and hold the left mouse button down. Then, drag the selected marker across the display. Note that the marker information displayed above the plot area changes as the marker moves across the data points.
  - c. Each of the markers can be automatically moved to the maximum IM response for the currently displayed data by pressing the MKR>Max button.
10. The swept frequency measurement will be repeated continuously unless one of the following actions is taken.
  - a. Press the Restart Button. This will interrupt the current sweep, clear the screen, and start a new sweep.
  - b. Press the Single Button. This causes the current sweep to stop, the screen is cleared, and one sweep of Carrier 1 Up and one sweep of Carrier 2 Down are performed, and then the sweep goes on Hold.
  - c. Press Hold. This stops the sweep and the data acquisition process at this point. The sweep will resume when Hold is pressed again.
11. The Swept Frequency data can be printed, saved to a file, or cut to the system clipboard.
  - a. Printing Swept Frequency Data.
    - ii. Point and click on the Print icon on the top menu bar. This brings up a Description dialog box that can be used to enter additional descriptive information about the test. After pressing OK, the Print dialog box appears. Press OK, and the data currently displayed will be printed to the default printer. The print output includes the description information entered, Carrier Sweep information, and a plot of the swept frequency response.
  - b. Logging Data to File.
    - i. Point and click on the Save icon on the top menu bar. This will bring up the Save To dialog box. Enter the file location and name and press OK. The data will be stored in a tab delimited ASCII format (.txt file).
    - ii. To view this data in Excel, start up Excel; open the file being sure to indicate a file type of .txt. Press Finish on the open Wizard and the data will be displayed. This data can then be saved in Excel (.xls) format.
  - c. Copying Data to the Clipboard.
    - i. Point and click on the Clipboard icon on the top menu bar. This will place the data on the system clipboard.
12. In some cases, it may be desired to test over a narrower bandwidth than the full transmit band capability of the analyzer. For example, a duplexer designed for just a segment of the full band. In these cases, where a reduced bandwidth swept frequency test is preferred, the sweep limits can be changed using the Edit button in the Sweep Settings.
  - a. Press the Edit button.
  - b. This brings up the Enter Sweep Frequencies screen. Figure 5-1 shows this dialog box for an SI-1900 PIM Analyzer.

- c. The top portion of this screen shows the current sweep limits for the lowest base order IM product that can be measured with this combination of frequencies. The lower half provides the means to enter new sweep limits.
- d. Enter a new start and/or stop frequency limit as necessary for the DUT. Press enter on the keypad or click on OK. The new sweep limits are entered. Note that these new frequency limits now appear in the Frequency portion of the CARRIER CONTROL display.
- e. The new sweep limits are now used for the measurement. If as a result of changing the sweep limits, the base IM order has changed, an informational message is presented to the operator, and the base IM order is changed to the lowest IM order number that lands within the passband of the analyzer given the new frequency sweep limits.

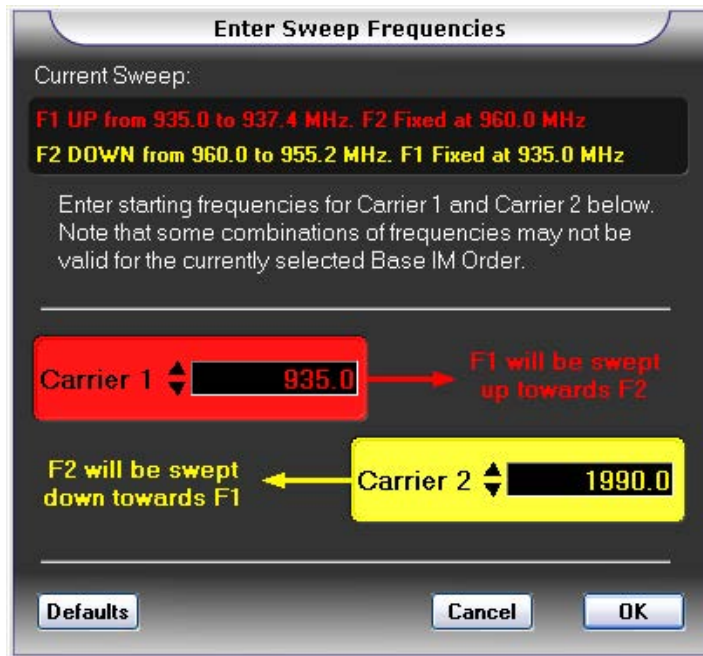
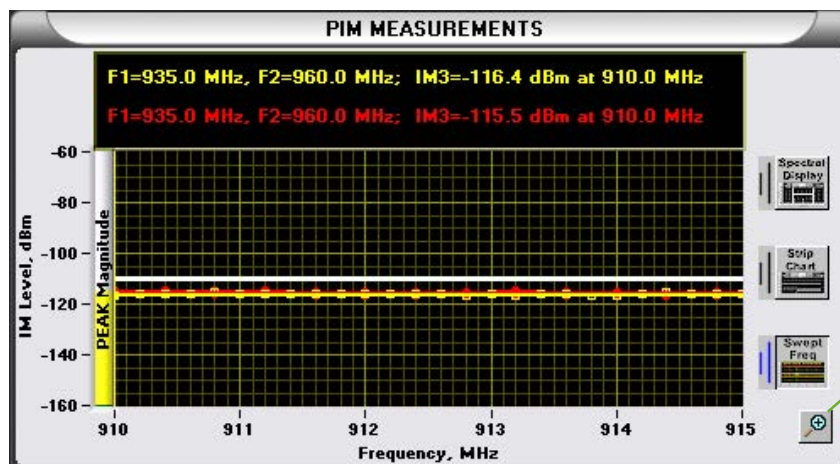


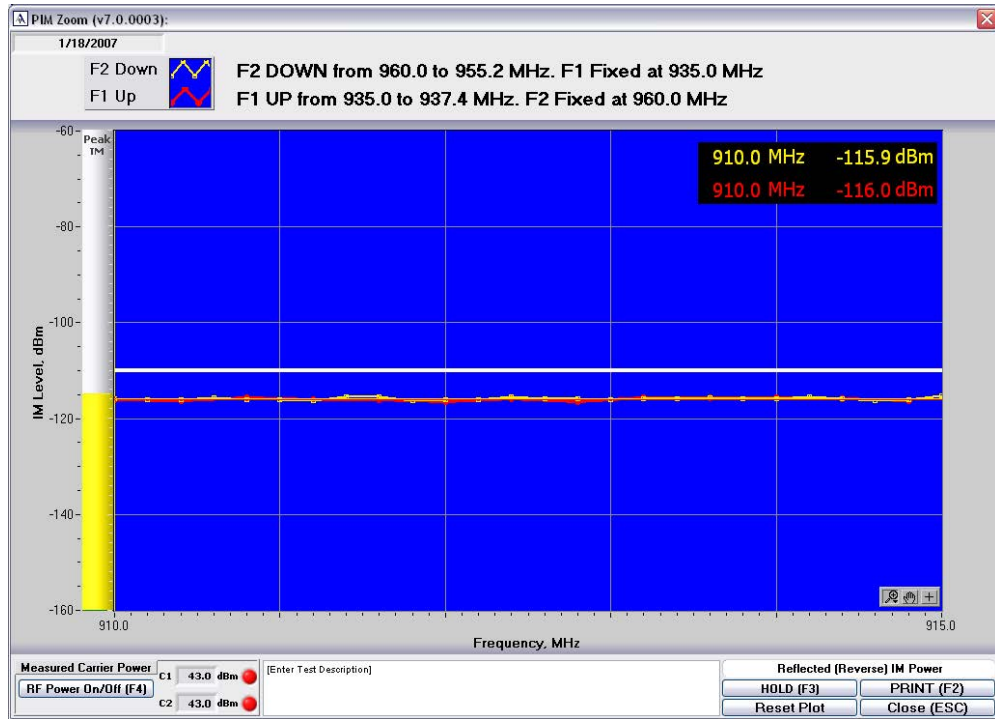
Figure 6 Edit Sweep Frequencies Screen

## 6.4 IM Measurement-Swept Frequency – Zoom Capability

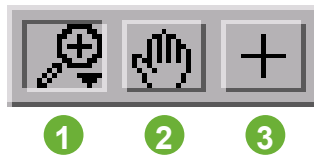
In Swept Frequency Mode, if greater resolution or a larger display is desired, a zoom feature is available by clicking on the Magnifying Glass icon in the lower right corner of the Swept Frequency Measurement Display.



The Swept Frequency Zoom Display Window pops up with the markers enabled. From this display it is possible to print this window by clicking on the “Print” icon. At any time, if an error is made, the display can be restored to its original default setting by clicking on the “Restore” icon. When the window is no longer required, it may be closed by clicking on the “Close” button.



In the lower right hand corner of the swept frequency display, there are three icons that allow the user access to advanced zoom capabilities.



**1 Advanced Features**

Brings up separate window of features.

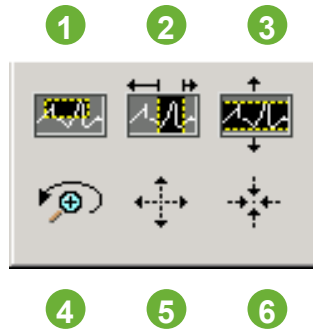
**2 Move Display**

Allows the user to click on the Swept Frequency Display and move the trace.

**3 Cursor Mode**

Allows the user to click on and drag the markers to the desired position. Also allows the user to use the pointer to change the frequency scale by double clicking on the X-axis frequency values and entering a new step size.





#### 1 **Box Zoom**

Using the Pointer, click on this icon and click and drag the pointer over the desired area for greater resolution.

#### 2 **X-Axis Zoom**

Using the Pointer, click on this icon and click and drag the pointer over the desired section of the X-Axis for greater resolution.

#### 3 **Y-Axis Zoom**

Using the Pointer, click on this icon and click and drag the pointer over the desired section of the trace for greater resolution in the Y-Axis range.

#### 4 **Undo One Level Zoom**

Clicking on this button will undo one zoom level.

#### 5 **Zoom In**

Clicking on this button will zoom in one level for the entire display.

#### 6 **Zoom Out**

Clicking on this button will zoom out one level for the entire display.

## 6.5 Save, Recall, and Delete an Engineering Mode Configuration

The test setup configurations saved in Engineering Mode are completely independent of the Production test scenarios, which are described in Section 6. If Production tests and information have already been configured however, they will also be saved to the configuration file (this feature allows you to have a dual functionality configuration file which contains pre-configured Engineering and Production mode settings).

Continuing the example from Swept Frequency Mode above, we will now save this test scenario.

1. Point and click on the Configuration entry on the top menu bar. This produces a drop down list of options regarding configuration. These are:
  - f. Load Default. Loads the factory default settings.
  - g. Save Current. This saves the current configuration.
  - h. Delete Current. Deletes the currently selected configuration.
2. Press Save Current. This brings up the Save dialog box. Enter in a name to be used for the current configuration. It can be up to 40 characters long.
3. Press OK. The new configuration name now appears in the Configuration display box on the right.
4. Loading a different Engineering Mode configuration is done as follows.
  - a. Point and click on the Configuration file list field on the top right. This drops down a list of all saved configurations.
  - b. Click to highlight "New". This loads the factory default settings for the connected analyzer.
  - c. To load the Engineering Mode configuration saved in Step 2, again point and click on the Configuration file list. Click "Open" and browse to highlight the configuration name previously saved. The test settings saved in Step 2 are restored.

## 7. Operation in Production Mode

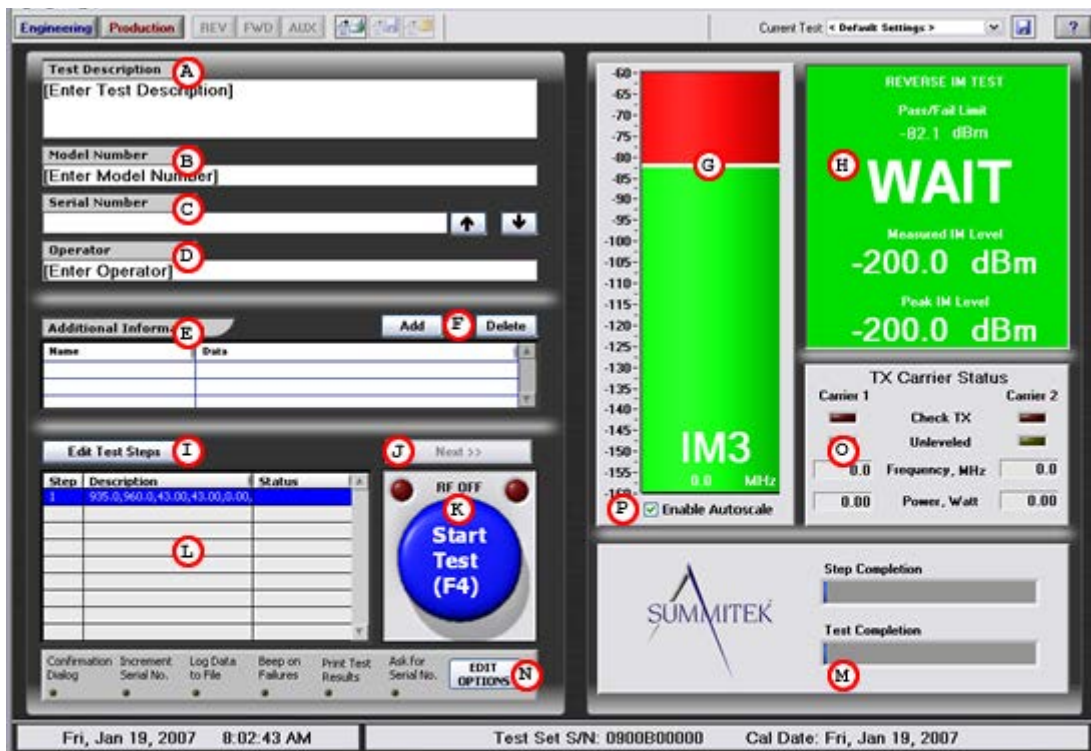
### 7.1 Front Panel Description

The front panel as shown in Figure 7 comprises two sections. One panel is the main panel itself, while the second panel is called "Production PIM Test Designer" and it is invoked from the main panel. This second panel is shown in Figure 6-2.

The overall front panel is further sub-divided for convenience into 12 sub-panels. Starting counter-clockwise these are:

- Test Description Field
- Model Number Field
- Serial Number Field
- Operator ID Field
- Additional Information Field
- Test Steps Field
- Test Output Options
- Start/Stop Switch
- Test Progress Indication Panel
- Tx. Carrier Status Panel
- Pass/Fail Test Display
- IM Level Indicator

We shall examine the function of each of these in the subsequent paragraphs.



- |                                       |                                    |
|---------------------------------------|------------------------------------|
| (A) Test Description Field            | (I) Production PIM Test Designer   |
| (B) Model Number Field                | (J) Next Step (Manual Tests Only)  |
| (C) Serial Number Field               | (K) Start/Stop Switch              |
| (D) Operator ID Field                 | (L) Test Steps Field               |
| (E) Additional Information Field      | (M) Test Progress Indication Panel |
| (F) Add/Delete Additional Information | (N) Test Output Options            |
| (G) IM Level Indicator                | (O) Tx. Carrier Status Panel       |
| (H) Pass/Fail Test Display            | (P) Enable Autoscale               |

Figure 7 Production Mode Front Panel

## 7.2 Detailed Front Panel Description

The specific controls and displays provided on the front panel are summarized below (see Figure 7):

### A Test Description Field:

Enter a description of the device-under-test (DUT). The ENTER key will move the cursor down to the next line. This information is saved with all logged files and printed on all hard copies of the test data.

### B Model Number Field:

Enter the model number of the DUT. This must be a one-line entry. This information is saved with all logged files and printed on all hard copies of the test data.

### C Serial Number Field:

Enter the serial number of the DUT. This must be a one-line entry. If the “Increment Serial Number” option is exercised on the “Test Output Options” panel (see “P”, Figure 7), then the serial number is automatically incremented when either a print or log-to-file operation is performed. This information is saved with all logged files and is printed on all hard copies of the test data.

### D Operator ID Field:

Enter the operator identification information (e.g. name, employee number, etc.). This information is saved with all logged files and is printed on all hard copies of the test data.

### E Additional Information Field:

This facility is provided in case the user desires to enter any additional information like lot number, past history, etc. This information is saved with all logged files and is printed on all hard copies of the test data.

### F Add/Delete Additional Information:

These buttons are used for editing the additional information.

### G IM Level Indicator:

Graphically displays the currently measured IM level. The area above the white line is red, indicating the failure zone. The area below the white line is green, indicating the pass zone. The white line is the pass/fail value entered using the “Production PIM Test Designer” front panel (see Figure 8). This aspect is discussed below. The currently measured IM level is indicated by the black horizontal line. The indicator also displays the peak IM level value as a blue line.

### H Pass/Fail Test Display:

The display shows the following information:

- Type of measurement, i.e. Reverse or Forward IM.
- Pass/Fail limit as set in the Engineering Mode panel or in the Production PIM Test Designer.
- Pass/Fail Text: Indicates “FAIL” when the measured IM level exceeds the pass/fail limit. Indicates “PASS” when the measured IM level is below the pass/fail limit. In case we set “Peak Hold Last” option on the “Production PIM Test Designer”, then this peak value is used to determine the pass/fail status.
- Measured IM Level: Shows the currently measured IM level. This value corresponds to the IM level shown on the bar-graph indicator just to the left (“G”).
- Peak IM Level: Shows the measured peak IM level.

This information is saved with all logged files and printed on all hard copies of the test data.

### I Production PIM Test Designer:

This is a control button for accessing the panel shown in Figure 8. This panel enables the user to define custom tests. The parameters so selected appear in the “Test Steps Field” (“L”).

## **J Next Step (Manual Tests Only):**

Using the “Production PIM Test Designer”, we can create an automatic test cycle, wherein the system automatically executes each step in a complex multi-step test for a predetermined interval. Alternately, we can opt for the “Manual Measurement” option, in which case the user is required to press this button to move on to the next step.

## **K Start/Stop Switch:**

This switch is used to initiate the testing. If a fully automated test scenario has been defined, the entire process will proceed without operator intervention. The RF power is turned on, the tests performed, and then the RF turned off at the end of the test. Note that the test sequence stops automatically when the DUT fails. This eliminates needlessly taking data in subsequent steps when the unit has already failed.

## **L Test Steps Field:**

This display presents an outline of the test parameters for each step of a single/multi-step test cycle as defined in the Production PIM Test Designer. If the test cycle selected has only a single step, we shall see only one line on this display. If multi-step, we shall see multiple lines on this display, one for each step.

## **M Test Progress Indication Panel:**

This panel displays the progress of each test cycle. The “Step Completion” bar graph shows the progress of each step under execution (current step), while the “Test Completion” bar graph display the progress of the overall testing cycle. However, in the manual mode the step completion bar is non-operative, as the system does not have control of the test duration for those test steps that are under manual control.

## **N Test Output Options:**

Clicking this panel displays a dialog box with the following check boxes:

- Confirmation Dialog. The Confirmation dialog box, when selected, has two functions.
  - In case of a failed test, this dialog box appears and asks the user whether they want to save the test results or discard the data.
  - If Log Data to File is also selected, the Confirmation dialog box comes up at the end of the test to give the operator the option to save the data to the file selected in Log Data to File or to specify a new file location.
- Increment Serial Number: This facility automatically increments the serial number of the items being tested at the end of each test. Note that if a single digit serial number is used, then it will go back to 0 after 9. If a two-digit serial number is used, it will go back to 0 after 99; three-digit serial numbers go up to 999, etc. Serial numbers can be alphanumeric, but only the numeric portion is used in determining the serial number increment.
- Log Data to File: When selected, the file location box becomes available. This allows the operator to specify where the data will be stored. The default is C:\Program Files\Kaelus\data with a file name dependent upon the specific RF unit connected to the System Controller. As an example, for the SI-1900B PIM Analyzer, the default file name is DATA1900.txt.
- At the end of the test, the data is automatically stored in the selected file in a tab delimited ASCII format. If the file location is the same for multiple tests, the new test data is appended to the existing test data.
- Beep on failures. The analyzer will emit an audible tone at the end of the test, if external speakers are available.
- Print Test Results: Results in the automatic printing of a hard copy test report to the default printer at the end of the test.

## **O Tx. Carrier Status Panel:**

This panel displays the carrier status. The following parameters are monitored for each carrier:

- Frequency.
- Power Level.
- Unleveled: If this indicator illuminates, one or both carrier power levels are not within approximately 0.35 dB of the requested carrier power level when the ALC is turned on. This indicator may occasionally illuminate for a short period while the System Controller is leveling the carrier power. This is normal and does not impact the accuracy of the test.
- Check Tx.: If this indicator illuminates, one or both carrier power levels are not within approximately 2 dB of the requested carrier power level.

**P Enable Autoscale:**

Check this option to allow the VFP to Autoscale the IM Level Indicator. When this option is not checked, the user may change the scale of the IM Level Indicator by double-clicking on a maximum or minimum scale value and manually typing a new value. The altered scale values can be accepted by pressing the “Enter” key or clicking the mouse somewhere else on the screen. **NOTE:** Manual Scale and Autoscale options cannot be changed while a test is in progress.

### 7.3 Production PIM Test Designer

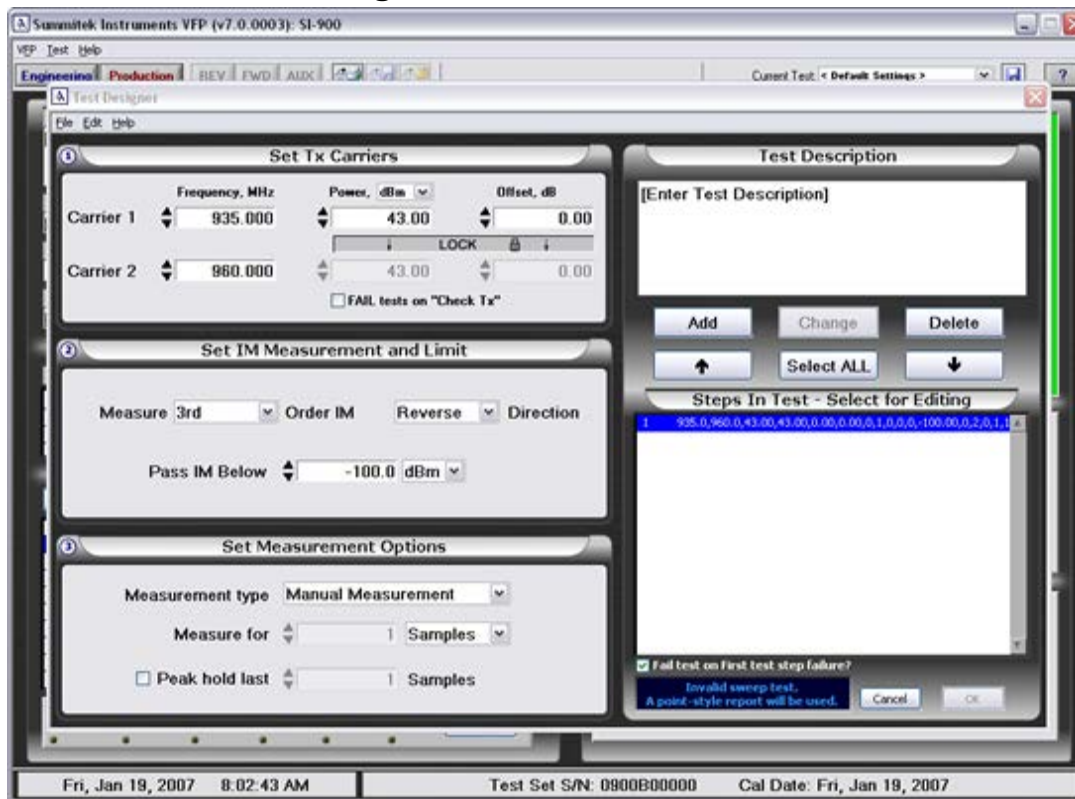


Figure 8 Production PIM Test Designer

The Production PIM Test Designer is a powerful tool for defining a wide variety of tests to fully evaluate the device under test.

This panel is invoked from the Production Mode front panel by clicking button “I” (Figure 6-1). It is used to create custom test cycles with single or multiple steps.

The best way to understand the use of the Production PIM Test Designer is through example.

**Example 1: Fixed Pair, Single Step Test with Test Timer**

In this first example, a test will be defined where data is measured using a single fixed pair of frequencies. The measurement will proceed for three seconds, and at the end of the test, the data will be written to a file. It is assumed the test device is a low IM termination (SI-20, SI-30 or equivalent) attached directly to Port 1 of the analyzer or through a high quality, low IM cable.

1. Enter Production Mode screen by selecting Production on the top menu bar of the Engineering Mode screen.
2. Click on Test Description Field and type in a test description. Clicking anywhere else on the screen will save the test description.
3. Enter a Model Number, Serial Number, and Operator Name following the same procedure as used for the Test Description.
4. Click on the Add button. This brings up a dialog box that allows you to enter a label name and associated data. Type “Company” in the Name field. Then, type your company name in the Data field. Press OK. Note that the Name and Data fields contain this newly input data.

5. The new test is going to be based upon the Standard Band Edges test. Therefore, before proceeding to the PIM Production Test Designer, verify that this is the selected test as indicated in the test name box below the Edit/New button. If this is not the currently selected test, click on the arrow on the right side of this display box. This brings up a list of all defined production tests. Locate the Standard Band Edges test and click on it to make it the current test.
6. With the Standard Band Edges selected as the current test, click on the Edit/New button to bring up the Production PIM Test Designer.
7. Note that in Part 1 of the PIM Production Test Designer (Set Tx Carriers), the Carrier 1 and Carrier 2 frequencies are set to the band edges for your particular analyzer. In addition, the carrier powers are locked such that both carriers are set for 43 dBm with an Offset of 0 dB.
8. Increase the Carrier 1 frequency by 2 MHz by double clicking on the Carrier 1 frequency to highlight the current value. Type in the new Carrier 1 frequency.
9. Decrease the Carrier 2 frequency by 2 MHz.
10. No other changes will be made to the Set Tx. Carriers definition.
11. Part 2 of the Production PIM Test Designer is used to define:
  - a. IM order to be measured. Leave this at 3rd.
  - b. Direction of Measurement: Reverse or Forward. Leave this as Reverse.
  - c. Pass/Fail limits in dBm or dBc. Double click on the -100 value next to Pass IM Below to highlight the number. Key in -120 and leave the units as dBm. A well performing analyzer and good quality load should be below this level.
12. In Part 3, we set parameters related to the timing of the measurement, and whether to capture peak responses or simply use the last measured response.
  - a. Manual/Timed Measurement. This parameter determines whether the measurement will be manually started and ended. In most cases, the preferred method is a timed measurement based on either a fixed period of time or a fixed number of data samples. For this example, select Timed by pointing and clicking on the Manual Measurement field. This will produce a drop down list with the two options. Point to Timed Measurement and click the mouse button. Note that the "Measure for" field entry is no longer grayed out.
  - b. Measure for. This field is used to indicate duration of the test. The test time can be based on a fixed number of seconds or a fixed number of data samples. Enter 3.
  - c. Seconds/Samples. For this test, the test time is to be based on Seconds, so no change is required. Leave the measurement units in Seconds.
  - d. Peak Hold. Peak Hold is used to capture the peak IM level of any data transients that may occur during the test sequence. For example, if the goal was to find the peak PIM response while flexing an RF cable. For this test, we will not use Peak Hold. Do not check the box.
13. The test has now been defined, but must now be entered in "Steps in Test" before it is saved. Because this is the only measurement in this test, we need to replace the parameters in the "Steps in Test" box, since these were the original test parameters for Standard Band Edge test. Since this step is already highlighted, it is only necessary to change this step. Point and click the Change button. The new test parameters are now entered into Step 1.
14. Before exiting the Production PIM Test Designer, you must give this new test a name. In the Test Name/Description box, enter any name up to 40 characters. This is the name that will be used to recall this test scenario in future test sessions.
15. After entering the Test Name/Description, press Done. This returns you to the Production Mode screen. Note that the new test name is now displayed in the Test Name box below the Edit/New button. The test is now fully defined and ready to run. However, if we do not specify what to do with the test data upon completion, the result will only be displayed. No data will be stored and no hard copy of the test results will be printed.
16. For this example, we will only specify the saving of data to a file. If you have a printer connected to your System Controller, you might also select printing.
  - a. Point and click on Test Output Options at the bottom of the screen. This is the area containing the options: Confirmation Dialog, Increment Serial Number, Log Data to File, Beep on Failures, and Print Test Results. This brings up the Test Output Options screen shown in Figure 6-3.
  - b. Click on the box next to Log Data to File. Note that the file location input is now available. You can type in the file location and name where you want to store the data, or you can click on the File Open icon to browse to a file location at which point you can either select an existing file or create a new file.
  - c. If you have a printer connected to the PIM Analyzer, click next to the Print Test Results to select the printing of a test report at the conclusion of the test.

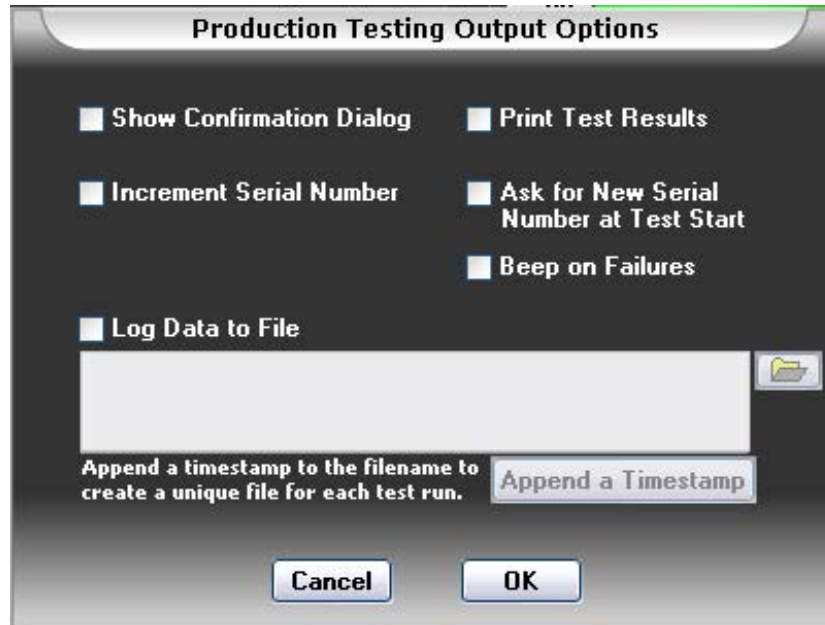


Figure 9 Test Output Options Screen

17. Press the Start Test button. This will cause the test parameters to be loaded and the test will then begin. Note the two bar graphs (Step Completion and Test Completion) to the right. Because there is only one step, the Test Completion bar immediately goes to 100 percent as it performs the first and only step. The Step Completion bar will fill the bar from left to right during the three-second sequence. At the end of the test, the RF power is turned off and the data is stored to the specified file. If the Print Test Results option was selected, a test report will be printed to the default printer.
18. Next, repeat the test, but first select the Show Confirmation Dialog option in the Production Testing Output Options. Now, at the end of the test, you are prompted to confirm that this is the file location you want to use.

## 7.4 Example 2: Fixed Pair, Multiple Step Test with Test Timer and Peak Hold

This example is a test that might be performed on a cable assembly where the objective is to measure the PIM before flexing the cable, and then find the maximum PIM level during the flexing of the cable, and finally, measure the PIM level after the cable has returned to a static condition. This procedure would also be used on filters where the filter is measured before tapping, and then worst case PIM measured during tapping, and then the resting state PIM measured after tapping. In this example, it is not necessary to have a cable or filter for the test. The test can be performed by attaching a low IM termination to Port 1 of the analyzer, since the actual data measured is not important. If you are measuring a cable assembly, attach one end to Port 1 and attach the other end to a low IM termination (SI-20, SI-30, or equivalent). Although Port 2 of the PIM Analyzer contains an internal termination, it is not recommended to measure a cable assembly by attaching it between Port 1 and Port 2. A Reverse IM measurement with the cable assembly terminated with a low IM termination will yield the most accurate result.

1. Enter Production Mode screen by selecting Production on the top menu bar of the Engineering Mode screen.
2. Click on Test Description Field and type in a test description. Clicking anywhere else on the screen will save the test description.
3. Enter a Model Number, Serial Number, and Operator Name following the same procedure as used for the Test Description.
4. Click on the Add button. This brings up a dialog box that allows you to enter a label name and associated data. Type "Company" in the Name field. Then, type your company name in the Data field. Press OK. Note that the Name and Data fields contain this newly input data.
5. The new test is going to be based upon the Standard Band Edges test.
6. With the Standard Band Edges selected as the current test, click on the Edit/New button to bring up the Production PIM Test Designer.

7. Note that in Part 1 of the PIM Production Test Designer (Set Tx Carriers), the Carrier 1 and Carrier 2 frequencies are set to the band edges for your particular analyzer. In addition, the carrier powers are locked such that both carriers are set for 43 dBm with an Offset of 0 dB. We will use these test carrier parameters for the test.
8. Part 2 of the Production PIM Test Designer is used to define:
  - a. IM order to be measured. Leave this at 3rd.
  - b. Direction of Measurement: Reverse or Forward. Leave this as Reverse.
  - c. Pass/Fail limits in dBm or dBc. Double click on the data entry field next to Pass IM Below to highlight the current entry. Type in a specification limit of -110. Leave the units as dBm.
9. In Part 3, we set parameters related to the timing of the measurement, data averaging, and whether to capture peak responses or simply use the last measured response.
  - a. Manual/Timed Measurement. This parameter determines whether the measurement will be manually started and ended. In most cases, the preferred method is a timed measurement based on either a fixed period of time or a fixed number of data samples. For this example, select Timed by pointing and clicking on the Manual Measurement field. This will produce a drop down list with the two options. Point to Timed Measurement and click the mouse button. Note that the "Measure for" field entry is no longer grayed out.
  - b. Measure for. This field is used to indicate the duration of the test. The test time can be based on a fixed number of seconds or a fixed number of data samples. Enter "3".
  - c. Seconds/Samples. For this test, the test time is to be based on Seconds, so no change is required. Leave the measurement units in Seconds.
  - d. Peak Hold. Peak Hold is used to capture the peak IM level of any data transients that may occur during the test sequence. In this first step, we are interested in the PIM level before applying mechanical stress. Therefore, we will not use peak hold. The PIM value that will be recorded will be the last PIM measurement at the end of the three-second interval.
10. This completes the definition of Step 1. To save this step, since the old Step 1 for Band Edge Test is the currently highlighted step, and we no longer need this step, point and click on Change. This will put the newly defined test parameters in Step 1. We are now ready to define Step 2.
11. The test parameters in Part 1 will not be changed. We want to perform the dynamic portion of this test with the same carrier frequencies and power levels.
12. In Part 2, we will not change any test parameters.
13. In Part 3, we want to change the timing for the test to allow enough time to fully stress the DUT, and we want to turn on Peak Hold so that we capture the maximum PIM response during stress.
  - a. In the "Measure for" data entry field, double click on the "3" to highlight the number. Enter "10".
  - b. Click on the check box in front of Peak hold last to select the peak hold function.
  - c. Enter "8" in the data entry field for Peak hold last. This will set up the analyzer to ignore any transients in the first two seconds, and then capture the maximum response during the last eight seconds of the test.
14. This completes the definition of Step 2 in our test. Now, we need to add it to the test sequence. To do this, point and click on Add. You will now see a second step in our sequence.
15. For the last part of the test, we want to perform the test in exactly the same way as we did in the first step. To duplicate Step 1, in the "Steps in Test" box, click to highlight Step 1. Then point and click on Add. A duplicate of Step 1 is now displayed as Step 2. And the Step 2 defined previously has moved down to Step 3. We need to change this order. To do that, point and click on the down arrow key to move Step 2 down to Step 3. The test is now defined in the proper sequence.
16. The new test must now be given a name and then saved. Enter a test name in the Test Name/Description field. Point and click on Done. This returns you to the Production Mode screen. The test is now fully defined and ready to run. However, if we do not specify what to do with the test data upon completion, the result will only be displayed. No data will be stored and no hard copy of the test results will be printed.
17. Please refer to Step 16 in the first example for an explanation on how to set up the output options.
18. Press the Start Test button. This will load the test parameters and the test will begin. You can follow the progress on the Step Completion and Test Completion progress bars.



## 7.5 Example 3: Creating a “Swept” Power Measurement

It is sometimes of interest to characterize the PIM performance as a function of the carrier power. Theoretically, PIM increases in magnitude as you increase the carrier power by an amount directly proportional to the increase in the carrier powers. For example, the third order IM product measured by the Kaelus PIM Analyzers is generated by

$$2 \times \text{Carrier 1} + 1 \times \text{Carrier 2}$$

Therefore, if the Carrier 1 power is increased 1 dB and the Carrier 2 power is increased 1 dB, according to theory, the PIM level increases by 3 dB ( $2 \times 1 + 1 \times 1$ ). IM5 would increase by 5 dB ( $3 \times 1 + 2 \times 1$ ). IM7 would increase by 7 dB ( $4 \times 1 + 3 \times 1$ ). However, in reality, the IM rarely increases at this rate. This can be demonstrated by the test to be performed with this example.

Some of the detail of the test definition is omitted from this example. It is assumed the reader has already performed Example 1 and Example 2 and now understands how to perform certain functions. Please refer back to the prior examples as needed.

To make this measurement more meaningful, the DUT should create IM. This could be a nickel plated adapter, a PIM reference standard, a high power attenuator, or any other device known to create high levels of IM. Attach one end of the device to Port 1 and terminate the other end with a low IM termination.

1. Enter Production Mode screen by selecting Production on the top menu bar of the Engineering Mode screen.
2. Enter any documentary data of interest in Description, Model Number, Serial Number, Operator, and Additional Information.
3. The new test is going to be based upon the Standard Band Edges test. Therefore, before proceeding to the PIM Production Test Designer, verify that this is the selected test as indicated in the test name box below the Edit/New button. If this is not the currently selected test, click on the arrow on the right side of this display box. This brings up a list of all defined production tests. Locate the Standard Band Edges test and click on it to make it the current test.
4. With the Standard Band Edges selected as the current test, click on the Edit/New button to bring up the Production PIM Test Designer.
5. Note that in Part 1 of the PIM Production Test Designer (Set Tx. Carriers), the Carrier 1 and Carrier 2 frequencies are set to the band edges for your particular analyzer. In addition, the carrier powers are locked such that both carriers are set for 43 dBm with an Offset of 0 dB.
6. For this test, we will keep all of the test parameters the same except for the carrier power, which will be varied in 1 dB increments from 36 dBm to 43 dBm. Therefore, for Step 1, change the carrier power to 36 dBm.
7. Part 2 of the Production PIM Test Designer is used to define:
  - a. IM order to be measured. Leave this at 3rd. Note: This will be 7th order for an SI-2000.
  - b. Direction of Measurement: Reverse or Forward. Leave this as Reverse.
  - c. Pass/Fail limits in dBm or dBc. If the DUT generates high levels of IM, we need to set the pass/fail limit high enough to assure that the test does not fail. Otherwise the test will be automatically terminated. Double click on the data entry field next to Pass IM Below to highlight the current entry. Type in a specification limit of  $-70$ . Leave the units as dBm.
8. In Part 3, we set parameters related to the timing of the measurement, data averaging, and whether to capture peak responses or simply use the last measured response.
  - a. Manual/Timed Measurement. This parameter determines whether the measurement will be manually started and ended. In most cases, the preferred method is a timed measurement based on either a fixed period of time or a fixed number of data samples. For this example, select Timed by pointing and clicking on the Manual Measurement field. This will produce a drop down list with the two options. Point to Timed Measurement and click the mouse button. Note that the “Measure for” field entry is no longer grayed out.
  - b. Measure for. This field is used to indicate duration of the test. The test time can be based on a fixed number of seconds or a fixed number of data samples. Enter “20”.
  - c. Seconds/Samples. For this test, the test time is to be based on Samples. Point to the Seconds field entry and click. This drops down the list of options (Seconds, Samples). Point and click on Samples.
  - d. Peak Hold. Peak Hold is used to capture the peak IM level of any data transients that may occur during the test sequence. For this test, we only want the last data sample value, which will be the 20th sample. Therefore, we will not select Peak Hold.

9. This completes the definition of Step 1. To save this step, since the old Step 1 for Band Edge Test is the currently highlighted step, and we no longer need this step, point and click on Change. This will put the newly defined test parameters in Step 1. We are now ready to define Step 2.
10. Step 2 is identical to Step 1, except for the carrier power. In Part 1 of the Production PIM Test Designer, change the Carrier 1 power to 37 dBm.
11. We want to add this to our test scenario. Point and click on Add.
12. Repeat Steps 10 and 11 for carrier powers of 38 dBm, 39 dBm, 40 dBm, 41 dBm, 42 dBm, and 43 dBm.
13. There are now eight steps in the test. Name and save the test as in the prior examples.
14. Set the Test Output Options to save the data to file.
15. Run the test.
16. Using Excel or some similar program, you can create a table and/or graph showing how the PIM level varies as a function of carrier power.

## 7.6 Example 4: Using “Select All:” to Modify a Test Scenario

When a previously defined test scenario contains a large number of similar steps, and the goal is to define a similar test with a change to only one of the test parameters, Select All provides a convenient means to change all of the steps at the same time. As an example, we will begin with the predefined Swept Frequency Test, which defaults as a Reverse measurement at 43 dBm, and redefine it as a Forward measurement at 40 dBm.

For this test to be meaningful the input port of the DUT is connected to Port 1 and the output port of the DUT is connected to Port 2. A good test item would be a coax cable.

Some of the detail of the test definition is omitted from this example. It is assumed the reader has already performed Examples 1, 2, and 3 and now understands how to perform certain functions. Please refer back to the prior examples as needed.

1. Enter Production Mode screen by selecting Production on the top menu bar of the Engineering Mode screen.
2. Enter any documentary data of interest in Description, Model Number, Serial Number, Operator, and Additional Information.
3. The new test is going to be based upon the Standard Swept Frequency test. Therefore, before proceeding to the PIM Production Test Designer, verify that this is the selected test as indicated in the test name box below the Edit/New button. If this is not the currently selected test, click on the arrow on the right side of this display box. This brings up a list of all defined production tests. Locate the Standard Swept Frequency test and click on it to make it the current test.
4. With the Standard Swept Frequency test selected as the current test, click on the Edit/New button to bring up the Production PIM Test Designer.
5. Note in the “Steps in Test” window that there are a large number of steps representing each pair of carriers required to perform the swept frequency measurement. To quickly see what parameters are identical in each step of the test, click on “Select All” at the bottom of the “Steps in Test” area. All parameters that are not grayed out (shaded) are identical in each step and can be changed for all steps by entering a new value. Follow these steps to redefine the Carrier Power and the Direction of the test.
  - a. Double click on the Carrier 1 power to highlight the current entry.
  - b. Type in “40”.
  - c. Click on “Reverse” in the Direction field entry area to produce a drop down list with the available choices.
  - d. Point and click on Forward.
  - e. The Standard Swept Frequency test is the standard Carrier 1 Up and Carrier 2 Down sweep performed in Engineering Mode. Note that it is a Timed Measurement with one Sample measured for each frequency pair. These parameters will not be changed for this example.
  - f. Point and click on Change to enter these new settings into the Steps.
6. This completes the definition of the test. Name and save the test as in the prior examples.
7. Set the Test Output Options to save the data to file.
8. Press Start Test to perform the measurement. You can track the progress in the Step Completion and Test Completion.

**Note:** If you print the results, the output is not a swept frequency plot. Instead it is a tabular listing of the PIM level at each frequency pair. To create a plot similar to the output of Engineering Mode, you can bring the data into Excel and use the Chart features to create the plot.

## 8. Applications Information

### 8.1 Introduction

For first-time users who require additional information on how to effectively utilize the Passive IM Analyzer, this section presents typical measurement scenarios and applications information

### 8.2 Noise Floor vs. Residual IM Floor

Understanding how the random noise floor of the analyzer and the residual IM floor of the analyzer are related is essential.

- The noise floor of the analyzer is defined as the mean value of the measured signal when Port 1 and Port 2 of the analyzer are terminated into 50 Ohms and the RF is turned off. This noise is random and is typically due to a combination of phase noise in the local oscillator and kTBF noise from the receiver’s pre-amplifiers. You cannot make a meaningful IM measurement at a level below the noise floor of the receiver.
- The residual IM level of the analyzer is caused by internally generated IM within the analyzer’s cabling, internal connectors, filters, and duplexers. This level is typically larger than the noise floor of the receiver for the third-order IM product. When an IM measurement is performed on a DUT whose true IM level is near that of the analyzer, measurement errors can occur. This is because the residual IM of the analyzer vectorially combines with the true IM of the DUT producing a measurement with a potentially high uncertainty level.

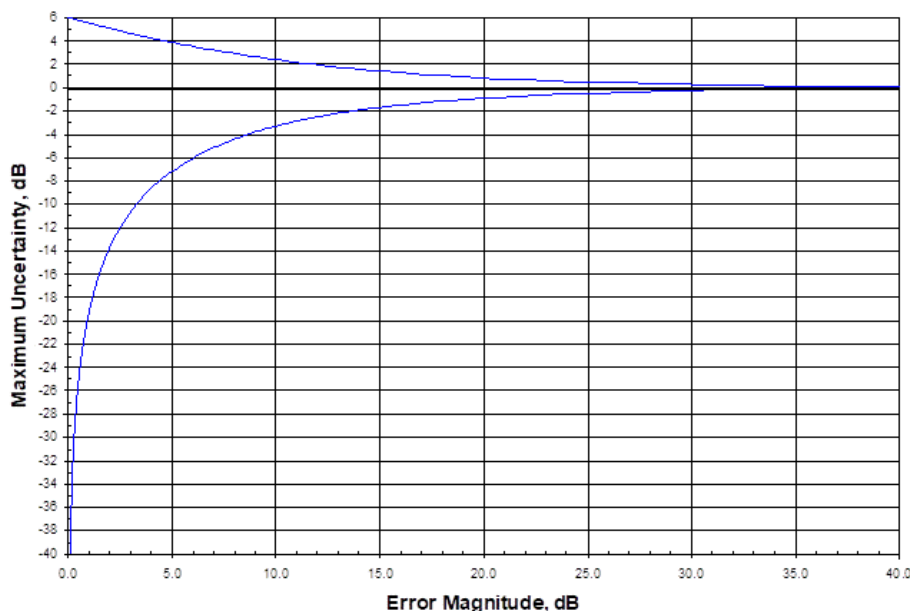
Figure 10 shows the classical measurement uncertainty curve. The x-axis shows the magnitude of the error source relative to the true magnitude of the response being measured. The y-axis shows the maximum measurement uncertainty in the measurement due to this single error source assuming worst-case coherent addition and subtraction between the error source and the true response.

Some useful data points from this curve are presented in Table 5.

Error Relative to True Value, dB	(+) Uncertainty, dB	(-) Uncertainty, dB
-10.0	2.39	-3.30
-20.0	0.83	-0.92
-30.0	0.27	-0.28

**Table 5 Key Measurement Uncertainty Values for 10,20, and 30 dB-Down Error Sources**

In practical terms, what this means is that if the residual IM is 10 dB below the actual IM of the DUT, the Measurement Uncertainty due to the residual IM is +2.39dB and –3.30dB.



**Figure 10 Standard Voltage Error Curve Showing the Maximum Measurement Uncertainty Due to a Single Error Source**



**Note:** When using the Passive IM Analyzer, the fluctuations in the measured value due to the receiver noise floor are not as great as the values in Figure 7-1 indicate. This is because the internal receiver in the analyzer utilizes significant amounts of video filtering to effectively reduce the magnitude of random noise errors to their mean value.

### 8.3 Measuring Residual IM

Measuring the residual IM of the test setup prior to testing the DUT is highly recommended. This measurement establishes the lower limit below which the DUT's IM characteristics cannot be accurately measured. For the typical passive IM measurement, it is desired that the residual IM level be at least 5 to 10 dB below the IM level of the DUT. From Table 7-1, a residual IM level 10 dB below the DUT IM level allows the measurement of the DUT's IM with an approximate +2.4 and -3.3 dB uncertainty.

To measure the residual IM of the test setup, the high power transmitter must be terminated into a load. This load must not generate significant levels of IM. For example, the SI-20A Low-IM Termination produces an IM level not exceeding -120 dBm with 2 x 20W carriers. Placing this load at the end of a cable (which would normally connect to the DUT) allows the user to certify the residual IM of the test setup does not exceed -120 dBm.

When using a connecting device (such as a cable or adapter) between the analyzer and the DUT, it is good practice to ensure that the residual level is stable under all conditions that might be encountered during the DUT measurement. For example, if stress will be placed on the cable or adapter during the test, place a similar stress on the cable or adapter when terminated into the load to ensure the residual level remains at or below the desired limit under all test conditions.

### 8.4 IM Troubleshooting

When measuring a device, it is sometimes necessary to determine the source of an unacceptably high IM level within the device. There are several techniques that have been found to be useful:

- **Tap Testing:** By lightly tapping on individual locations around the DUT, the IM level will sometimes jump dramatically. Use the lightest possible tapping pressure to induce the jump in IM so the location of the IM problem can be localized. This technique works well on tuning screws, connector joints, and antenna feed networks.
- **Cold Spray:** By spraying a suspect location with a cold spray (such as a Freon-equivalent), the mechanical properties of a junction can be changed slightly. This can result in a dramatic change in IM level thus indicating a possibly poor mechanical joint.

If the IM level remains constant and at an unacceptably high value during the above two tests, the high IM level may be intrinsic to the design, or may be caused by a materials problem somewhere in the high-power RF path.

### 8.5 Unique Considerations for Antenna IM Testing

When measuring the IM of antennas, it is important to eliminate the following common sources of error:

- **Residual IM Stability:** Ensure the residual IM of the cable connecting to the antenna remains below the desired DUT IM level. This can be tested by placing a low-IM termination at the end of the cable and then moving the cable through the entire range of motion required for antenna IM testing.
- **Ambient IM:** Ensure the environment into which the antenna is radiating is not generating a significant IM level. This is readily demonstrated by physically moving the antenna while monitoring the reverse (reflected) IM level. If the IM level changes with antenna movement, it is possible IM is being generated beyond the antenna itself.
- **Tx Power Loss:** When using a cable with losses in excess of 1 dB, the passive IM measurement error can become significant. For example, if the analyzer indicates a +43 dBm carrier power level, but the cable connecting to the antenna has 1 dB of loss at the carrier frequencies, only +42 dBm is reaching the antenna. This can result in an IM3 measurement error of up to 3 dB compared to a true 2 x +43 dBm carrier measurement.

To reduce the errors associated with cable losses, use the Carrier Power Offset feature of the analyzer. First, measure the insertion loss of the cable assembly using a network analyzer or equivalent instrument. This should be done at the middle of the transmit band of the analyzer. After determining the insertion loss, use the Carrier Power Offset and enter the measured insertion loss as a negative number. The result is that the power reference point is moved to the end of the cable. Therefore, all power indications displayed and printed are accurate for the power present at the end of the cable.

## 8.6 Interpreting IM Test Results

The Kaelus PIM Analyzer provides three unique displays for evaluating the IM performance of a device-under-test. These are:

1. Spectral Mode: Displays up to four IM products simultaneously.
2. Strip-Chart Mode: Displays up to four IM products simultaneously as a function of time in seconds.
3. Swept-Frequency Mode: Displays one IM product at a time as the transmit carriers are swept in frequency.

Each of these modes provides a unique insight into the behavior of a device.

### 3.0.1 Spectral Mode

Spectral Mode allows the side-by-side comparison of the IM responses for multiple IM orders. This is useful when troubleshooting an intermittent IM response. Typically, an IM response produced by a mechanical junction will jump when lightly tapped. By observing the behavior of the higher-order IM products relative to the IM3 response, the suspect junction may be more easily identified. This is because the higher order products typically are much more sensitive to changes induced by tapping than the IM3 product. Although the IM3 response may change by only 1 or 2 dB, the higher order products will often change by 4 or more dB.

### 3.0.2 Strip-Chart Mode

Strip-Chart Mode allows the measurement and recording of IM versus time. When performing some tests on the DUT, it is not always possible for the operator to monitor the measured results while inducing changes on the DUT. Strip-Chart Mode records data that can be reviewed after the DUT has been disturbed.

By slowing down the update rate in the Strip-Chart Mode, the measured IM response can be recorded over an extended length of time. In this way, the device's IM can be measured over a period of hours while the impacts of RF heating are monitored. The data can then be saved to a file for further statistical or correlation with data from an external temperature monitor.

### 3.0.3 Swept-Frequency Mode

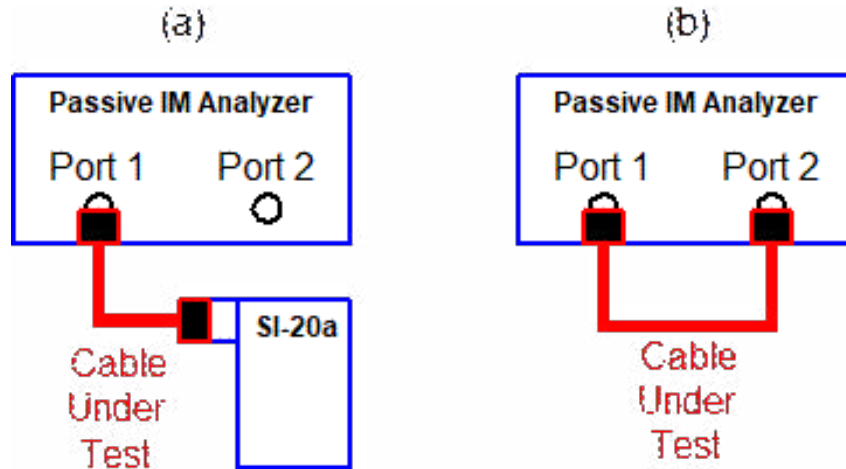
By varying the IM frequency, the frequency-domain behavior of the IM response can be analyzed. This can be quite helpful in identifying the source of an IM problem. For example, if the measured forward (through) IM level from a filter closely follows the known S21 curve, it is likely the IM is either being generated prior to the filter, or is being generated at the stimulus (input) side of the filter. If the IM response is virtually flat with frequency, it is likely the IM is originating at the side of the filter from which the IM response is measured (e.g. the output port of a transmit filter).

For a cable assembly, a reverse (reflected) IM measurement that is frequency-dependent typically indicates the presence of more than two IM sources. A frequency-independent reverse (reflected) cable IM response typically indicates only one end of the cable is generating IM.

## 8.7 IM Measurement Examples

### 1.1.1 Cable Assemblies

There are two approaches to measuring the passive IM response from a cable assembly. Figure 11 illustrates the connection diagrams associated with each method.



**Figure 11 Typical Test Connections for Measuring Cable Passive IM**

The most accurate measurements are made using the connection shown in Figure 11 (a). With this method, the cable is terminated into a low-IM termination. This termination should be capable of handling the combined carrier power used for the test while generating a minimum level of IM. The termination should present a good return loss to the cable not only at the carrier and IM frequencies of interest, but also at the low-order harmonics of the carrier frequencies. Because IM is the result of a combination of harmonics (such as  $2^*F1$  and  $F2$  for IM3), maintaining a near-unity VSWR for each of the relevant harmonics enhances measurement accuracy.

The disadvantage to using the termination technique shown in Figure 11 (a) is the possibility of a frequency-dependent IM response. As the IM sources contained within the cable assembly may combine both in and out of phase (depending upon the electrical length of the cable at the IM frequency), a single-frequency test is insufficient to characterize the cable's worst-case performance across an entire communications band. This requires the use of the Swept Frequency Mode to identify the IM peaks and nulls that might occur in a reverse (reflected) IM measurement.

Figure 11 (b) illustrates how the analyzer itself may be used to terminate the cable assembly. Port 2 of the analyzer presents a low-IM termination to the cable. However, because this port is actually a filter input, the impedance match at frequencies other than the transmit band or receive band is not typically well behaved. This can result in a high VSWR value within the cable assembly at frequencies that are harmonically related to the carrier frequencies. This can increase the measurement uncertainty of the cable IM measurement.

The advantages to using the method illustrated in Figure 11 (b) are two-fold. First, both the reverse (reflected) and forward (through) IM responses can be readily measured and compared in a single connection. This can help diagnose the location of an IM response on a long cable assembly. Further, the forward (through) IM response of a lossless cable assembly is theoretically frequency independent. This is because each of the IM sources adds in-phase (for a worst-case measurement) at Port 2 of the analyzer.

In summary, both techniques provide unique advantages and disadvantages for assessing the IM performance of a cable assembly. The one-port method (shown in Figure 11 (a)) provides optimal measurement accuracy, but requires an external termination and the use of swept-frequency mode. The two-port technique (shown in Figure 11 (b)) provides measurement flexibility at the expense of increased measurement uncertainty.

### 1.1.1 Duplexers

Figure 12 illustrates a typical connection diagram for evaluating the IM of a three-port duplexer. The transmit port of the analyzer (Port 1) is connected to the transmit port of the duplexer. The residual IM from Port 1 of the analyzer and the interconnecting cable to the transmit port of the duplexer should be no greater than the expected IM level of the duplexer plus the Rx isolation of the duplexer. For example, if the duplexer has 40 dB Rx-band isolation between the Tx. port and the Antenna port, and the IM specification for the duplexer is  $-120$  dBm, a maximum of  $-80$  dBm of IM is allowable at the input port of the duplexer.

The antenna port of the duplexer is terminated in a low-IM termination that has a residual IM below the expected IM measurement level.

Finally, the Rx port of the duplexer is connected to Port 2 of the analyzer. A “Forward” (or through) IM measurement mode is selected on the analyzer. By monitoring the reverse (reflected) IM power, the integrity of the Tx-port connection can be monitored to ensure a high IM level is not being injected into the duplexer.

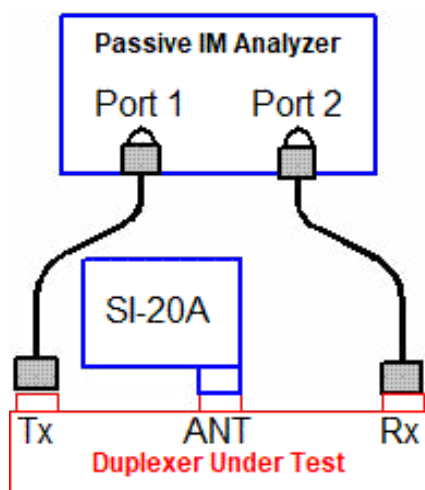
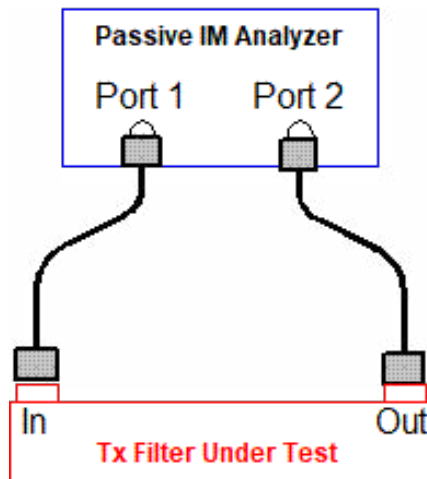


Figure 12 Typical Connection Diagram for Evaluation Duplexer Passive IM

When evaluating the measured IM of a duplexer connected as shown in Figure 12, key information is available for analysis by comparing the Reverse and Forward modes. If a high IM level is present on both the antenna- and transmit-ports of the duplexer, and these two levels differ by the known S21 isolation between these two ports, a failure is likely within the duplexer near the antenna port connection. If a frequency-independent IM level is measured with a low IM level present on the antenna port, the failure is likely located near the duplexer’s antenna port.

### 1.1.1 Transmit Filters

Figure 13 illustrates a typical connection diagram for evaluating the IM response from a transmit filter.



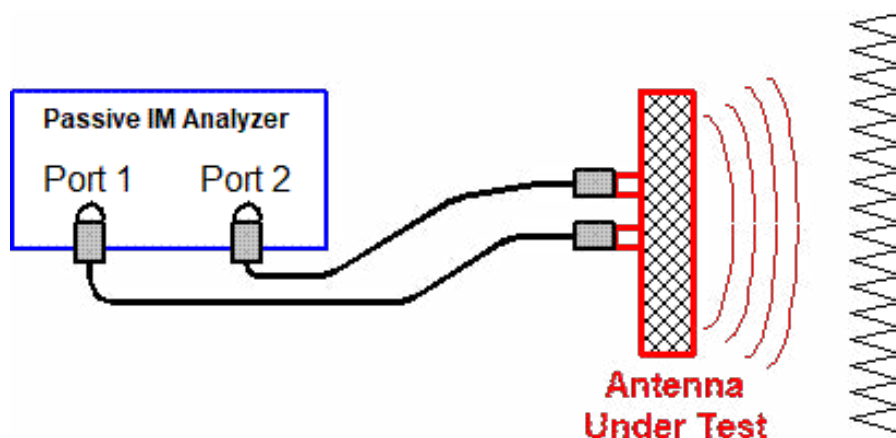
**Figure 13 Typical Connection Diagram for Evaluating Transmit Filter Passive IM**

By comparing the Reverse and Forward IM responses, the IM of each side of the transmit filter can be evaluated in a single connection. These two responses may be significantly different as the filter itself prevents the receive-band IM from one port from leaking into the other port.

If the IM specification for the transmit filter calls for a precise power level to be present at the port under test, it may be necessary to reverse the filter to evaluate the response from each port. This would be the case when the transmit (pass band) losses of the filter attenuated the transmit carriers by an unacceptable level before reaching the output port of the filter.

### 1.1.1 Antennas

Measuring the IM generated by an antenna requires careful attention to the instrumentation, cabling, and surrounding environment. Figure 14 illustrates a typical connection diagram used to measure a dual-polarized (2-port) antenna. Port 1 of the analyzer is connected to one of the two antenna ports. The second port of the antenna can be terminated with a low-IM termination, or can be terminated into the Port 2 of the analyzer. This second approach has the added advantage of being able to measure the IM present on the orthogonal antenna port while the other port is driven with two high power carriers.



**Figure 14 Typical Connection Diagram for Evaluating Antenna Passive IM**

The main beam of the antenna must be allowed to radiate freely. That is, absorbing structures should not be placed in the reactive near field of the antenna. This can adversely impact measurement accuracy. If absorber is used to contain the radiated field, ensure that the conductive backing to the absorber is not generating IM. Also ensure that RF is not leaking around the absorber in co-polarized gaps between the absorber pieces.



### 1.1.1 Measuring High IM Level Devices (e.g. Ferrites)

The PIM Analyzers provided by Kaelus are optimized for receiving IM signals between approximately  $-75$  and  $-140$  dBm. Signals that compress the instrument in excess of approximately 0.5 dB will result in an “IM OVERLOAD” error being displayed. However, if the IM signal is more than 20 dB higher than the instruments maximum measurable power, the internal receiver actually begins to shut down. The result is that a very, very strong IM signal ( $-50$  dBm or higher) can erroneously be reported by the instrument as a valid IM power level anywhere between  $-70$  and  $-140$  dBm (depending upon the shutdown mode of the receiver).

This application note demonstrates how to configure the test setup to ensure a strong IM signal can be accurately measured by the analyzer without the risk of over-driving the analyzer’s internal receiver.

**Configure the Test Setup.** Figure 15 illustrates the connection used to measure the forward IM of a device that is expected to produce IM levels in excess of  $-80$  dBm. Such a device might be a ferrite isolator. In this configuration, the two carrier tones are injected directly into the DUT). IM generated within the DUT propagates back towards Port 1 of the test set and also into the directional coupler (connected to the DUT output port).

The directional coupler is oriented so that a sample of both the carrier tones and the IM signal are routed to the coupled port. The through arm of the coupler is terminated into a low IM termination such as the Kaelus Model SI-20A.

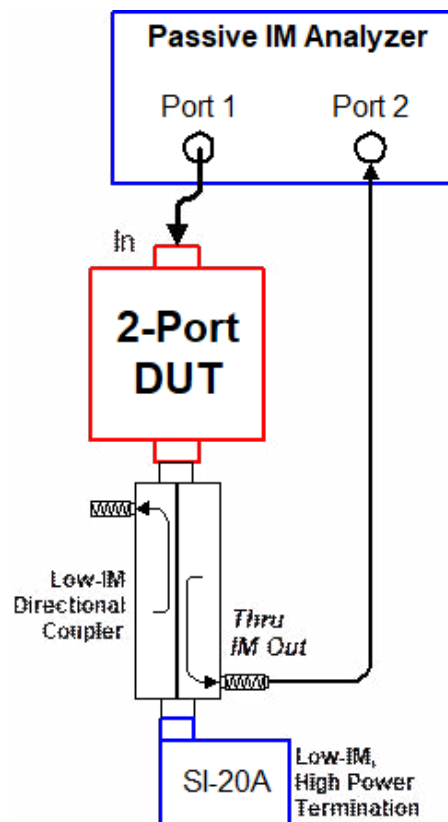
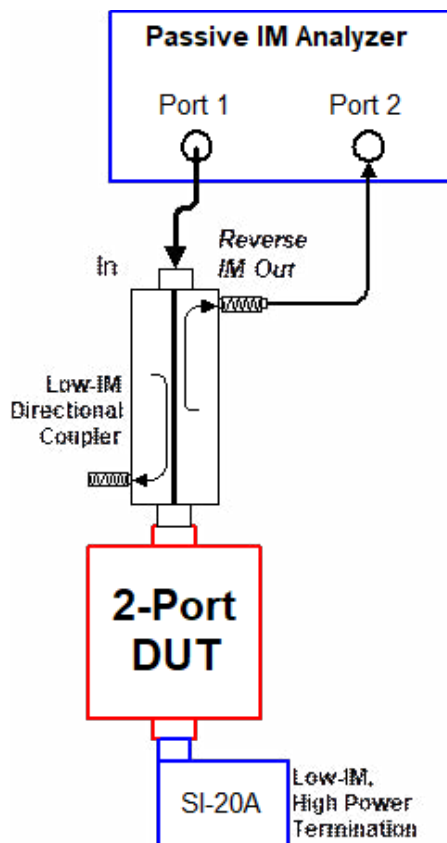


Figure 15 Measuring High Forward IM Levels with the PIM Analyzer

Figure 16 shows how the same approach may be used to measure the reverse IM from a DUT. Notice the coupler direction is reversed in this application compared to Figure 15. This allows the IM signal traveling towards Port 1 of the analyzer to be sampled and eventually measured at Port 2.

In both figures, a fixed attenuator is attached to the coupled arm of the directional coupler. The value of this attenuator is determined by the expected IM level. If unsure, start with two 30 dB attenuators placed back-to-back. The purpose of the attenuators is to further reduce the IM power below the level achieved with the directional coupler alone.



**Figure 16 Measuring the IM of a Power Combiner Using Individual CW Tones**

The output of the fixed attenuator is then connected to Port 2 of the analyzer. Using the mouse (or by pressing the “F10” key), change the analyzer’s measurement mode to “Forward/ Thru.” The green indicator above Port 2 should be illuminated for this test. This means that the IM power incident on Port 2 of the analyzer will be displayed on the screen. In both forward and reverse test setups, ensure the IM generated by the test setup does not generate significant IM levels (relative to the DUT) for the power levels used in the testing. This may be done by simply removing the DUT and checking the residual IM prior to making the measurements.

**Making the Measurement.** Turn on the carrier power and begin with the carriers set to a very low level. Be sure and disable ALC (power leveling) if you are working below a carrier power level of 1 Watt (30 dBm). Increase the power in small increments (3 dB per step) until an IM signal is detected. If an IM signal is not detected at the maximum desired carrier power, remove some attenuation from the coupled port of the directional coupler and repeat this test. It is desirable to find a combination of coupling coefficients and attenuator values that will result in an IM signal that ranges between -130 and -75 dBm over the range of carrier powers of interest. For example, if the indicated IM level on the analyzer’s display is -80 dBm for the lowest carrier power level of interest, increase the value of the attenuator by at least 40 dB.

Once the IM power level has been placed within the dynamic range of the analyzer, you must manually add back the combined loss inserted by the directional coupler and the attenuator(s). For example, if the display indicates a forward IM level of -90 dBm, and you are using a 30 dB directional coupler and 40 dB of attenuation, the true IM level is -20 dBm (-90 dBm + 70 dB).

**Helpful Hints.** These quick tips can help reduce measurement uncertainty:

- Choose the IM Units to be displayed in “dBm” for the best measurement accuracy. This removes the uncertainty associated with the carrier power level measurement from the receive IM power level results.
- Minimize the length of cable between Port 1 of the analyzer and the DUT.
- Make sure the IM signal decreases when the carrier power decreases. If not, the receiver may be in hard compression and not properly reporting an “IM OVERLOAD.”
- Use the “Log to ASCII” capability of the analyzer to generate an ASCII data file. A spreadsheet program may then be used to add the required offsets to the measured data.

## 9. Maintenance

### 9.1 Operating Environment

For maximum life, operate the equipment within the following environmental limits:

- Relative Humidity: 10% to 90%, non-condensing
- Ambient Temperature: 60 Degrees to 80 Degrees Fahrenheit (16 to 26.6 Degrees Celsius)
- Away from Direct Sunlight
- Away from High Levels of Dust or Dirt

### 9.2 Transporting

It is recommended to retain the original packing materials shipped with the unit for use in the event the equipment must be shipped again. There is a packaging fee of USD \$50.00 per box for return shipments to the customer if the units are returned in inadequate packing.

### 9.3 Cleaning

#### CAUTION

*Both the RF Module and the DC Power Supply require fan-forced air-cooling to dissipate the large quantity of internally generated heat. For this reason, it is required that the intake air filters remain clean. **Check these filters weekly to ensure they are free from dust and dirt.** Check the filters more frequently when operating the unit in dust or dirt-filled environments.*

The intake filter located at the rear of the separate Modules can be cleaned with a vacuum cleaner and an attachment restricting the airflow to a small diameter (restrictor nozzle). **Do not use compressed air to clean the filters** as this pushes the contaminants further into the filter (and possibly into the unit itself). Note that the fan filters cannot be removed without opening the chassis case. **Do not attempt to remove the fans.**

If the exterior of the instrument modules become dirty, use only a damp, dust-free cloth to clean. **Do not use abrasive cleansers or excessive moisture to clean the units.**

When cleaning the monitor screen, do not spray the monitor directly. Spray the cloth first, and then wipe the monitor screen.

If the analyzer is operated in an environment heavy with dust or smoke, you should occasionally clean the inside of the computer case. This is best performed using a special vacuum cleaner and nozzle specifically designed for cleaning computer equipment. Take care not to loosen any components by striking them with the vacuum nozzle.

If liquid is spilled into any part of the analyzer, immediately disconnect the AC power at the wall. Disconnect all equipment from the AC power source, not just the unit soaked by the spill. Orient the soaked units for maximum drainage and allow them to dry completely. Once dry, the system can be evaluated for proper performance to see if permanent damage occurred.

### 9.4 Protection

It is highly recommended that the computer and monitor be connected to an uninterruptible power source (UPS) or commercial-grade surge protection device. This will reduce the chance of computer damage in the event of a lightning strike nearby or areas of poor power regulation.

If a lightning storm enters your area, disconnect the computer, monitor, and powered PIM Module devices from the wall and wait until the storm passes.

During normal operations, it is recommended not to repeatedly turn the AC power to the computer and power supply on and off with very short intervals of on-time. The life span of the equipment will be increased if the equipment is left on for more than 30 minutes at a time. Should you need to re-start the computer, do so using the reset button located on the computer's front panel. Do not use the AC power switch for this purpose. If, for some reason, the AC power must be cycled off, and then back on again, make sure the disk drive comes to a complete stop before turning the computer back on again.

The computer and powered PIM modules must be connected into the same AC power circuit (i.e., they share a common circuit breaker) for proper operation.

## 9.5 Routine Verification of Performance and Maintenance


On a daily basis, it is a good practice to ensure the proper operation of the PIM Analyzer. The verification process determines the baseline performance of the test equipment as well as the accuracy of the measurements being made.

### 1.1.1 Verifying Residual IM Performance and Operation of the Analyzer

Verifying the residual IM performance of the analyzer ensures proper operation of the analyzer as well as providing a performance baseline for future testing.

To verify proper IM performance of the analyzer, several items are required: 1) A known low IM termination and 2) A test item that will generate IM. For example: a nickel-plated device, a high power attenuator, a PIM reference standard such as Kaelus PIS-0002A, or a failed device.

1. Start the Virtual Front Panel and enter "Engineering Mode".
2. Select and enter desired operating frequencies for Carriers 1 and 2 as described in Section 4.5.3.
3. Select and enter desired testing power levels for Carriers 1 and 2 as described in Section 4.5.3. Typically, set to 43.0 dBm or 20 Watts. If the Power Lock Control is "ON" only Carrier 1 will need to be set.
4. Select which IM order is to be tested as described in Section 4.5.3.
5. Attach a low IM termination such as a SI-20A or SI-30A to Port 1 of the analyzer. If a SI-20A or similar is used, make the attachment with a 7/16 DIN (male to male) adapter. If a SI-30A or similar termination is used, a short cable with known low IM performance may be used to make the connection.
6. **IMPORTANT NOTE:** The interconnecting adapters, terminations, and cables used in this application should have known good IM performance. Typically, the performance of the adapters, terminations, and cables should be nominally,  $-120$  dBm or better than the specification value of the required test.
7. Turn the Carrier powers "ON" by either pressing the "F4" key or clicking on the "Master Carrier ON/OFF" button.
8. Read the displayed IM response for the IM order being measured on the right side of the Engineering Mode display. At this point, if the interconnections are properly attached the IM level should be below the specification limit.
9. Turn the Carriers "OFF" by either pressing the "F4" key or by clicking on the "Master Carrier ON/OFF" button, located on the Virtual Front Panel.

 **IMPORTANT NOTE:** At these low signal levels, variations of  $\pm 3$  dB are not uncommon. However, there should not be intermittent spikes of high IM.

If large fluctuations in the IM level are noticed, ensure that the interconnections are clean, properly attached, and that they do not show signs of excessive wear.

The resulting IM value being displayed can be considered the Residual IM Performance of the system. This measurement is the total IM being produced by the internal components of the analyzer, the corresponding adapters and/or cables, and the termination. This measurement can be considered a "Baseline" measurement for future testing reference or analyzer performance.

Once the Residual IM performance of the analyzer has been measured, it is a good practice to determine if the analyzer's receiver is operating properly. One of the best ways to determine accuracy of measurements is to place an IM reference such as a Kaelus PIS-0002A into the test setup mentioned in steps 1-8. This will allow the user to measure the IM generated by a known IM source and compare the source's expected IM performance to that of the analyzer. Use of a known PIM source allows the operator to verify and have confidence in the test setup.

Full technical specifications of the Kaelus PIS-0002A PIM Source, shown below, can be found at [www.Kaelus.com](http://www.Kaelus.com).



Expected PIM levels from PIS-0002A:

20W: -80dBm (-123dBc)  $\pm$ 3dB

4W: -101dBm (-137dBc)  $\pm$ 4dB

**Note:** Nominal values shown. PIM sources can vary between -74 dBm to -86 dBm from the factory, dependent on frequency. During equipment verification, ensure that the performance is within  $\pm$  3dB of nominal for that particular PIM source.

### 1.1.1 Front Panel Connections and Connector Savers

As with any sensitive measurement equipment, great care must be taken when making connections to either Port 1 or Port 2 on the analyzer. At this point please refer to Kaelus' Application Note #1900-4, "Proper Mate/De-Mate Procedure for DIN 7/16 Connectors", available in Section 10 or at: [www.Kaelus.com](http://www.Kaelus.com).

### 1.1.2 Use and Care of Front Panel Connector Savers

Kaelus ships two connector savers with every unit. The use of the connector savers is highly recommended and will contribute to the overall preservation of the residual performance of the analyzer. The connector savers are attached to Ports 1 and 2 on the front panel of the FE Module to protect the analyzer's 7/16 connectors from excessive wear and damage. Kaelus recommends the use of the connector savers as they are easier and less expensive to replace than the front panel connectors.

The use of proper mating/de-mating procedures is highly recommended. This will ensure optimum mechanical endurance and residual performance. When applying or replacing the connector savers, it is recommended that a torque wrench be used, with a 25 – 30 Nm (Newton meter) setting.



**IMPORTANT NOTE:** Care should be taken when applying torque to the front panel connectors. Exceeding the torque specifications may cause permanent damage.

When connector savers are worn, the residual IM performance becomes high. High usage analyzers, such as in a production environment, should have connector savers regularly replaced to ensure measurement accuracy. Daily maintenance may be performed by using a soft, cotton-like probe such as a Q-tip soaked with Ethyl alcohol. Using Ethyl alcohol and cotton tipped swab, clean out the connector and before the connector dries, use compressed air to blow out the remaining particulates and alcohol. This cleaning will remove tiny particles, such as silver plating, which may lead to high residual IM levels.

## 9.6 Care and Maintenance of the SI-20A or SI-30A Low IM Terminations

The SI-20A and SI-30A Low IM loads provide a convenient way of terminating devices and test ports without generating significant levels of IM products. To ensure reliable operation of either termination, the following procedures have been included to maintain and verify proper operation. For detailed specifications, please refer to the Operating and Maintenance Manual for the specified termination.

### 1.1.1 SI-20A and SI-30A Connector Maintenance

The SI-20A and SI-30A were designed to provide a minimum 16 dB return loss from 800 MHz to 2.2 GHz. The level of any single IM response generated in the reverse direction from the termination is less than -120 dBm for the SI-20A and less than -120 dBm for the SI-30A when two, +43 dBm carriers are incident upon the termination.

As with any sensitive measurement equipment, great care must be taken when making connections to either Port 1 or Port 2 on the analyzer or when attaching Terminations. At this point please refer to Kaelus' Application Note #1900-4, "Proper Mate/De-Mate Procedure for DIN 7/16 Connectors", available in Section 10 or at: [www.Kaelus.com](http://www.Kaelus.com). Occasionally, the measured IM level from the termination may appear to exceed the specification limits. This can occur due to one or more of the following causes:

1. The connector or device mating to the termination also has an approximate 120 dBm IM level. This results in the IM from the termination and the connector adding in-phase to produce a resultant IM level as much as 6 dB higher than any one device's individual IM level.
2. The connector is not torqued properly. This results in partially mated electrical contacts within the connector. The termination's connector is designed for a coupling torque of 30 Newton-meters (approx. 22 foot-pounds). If "O"-rings are installed in the mating connector, or if the mating connector is designed for a higher coupling torque, up to 50 Newton-meters (approx. 36 foot-pounds) may be used. Do not exceed this maximum torque as the termination's connector may be damaged.
3. The connector is contaminated. Ensure both the termination and the mating connector are clean and free of contaminants. Use a lint-free swab and alcohol to clean the interfaces, followed by a blast of clean air. For more detailed connector/connector saver care information, please refer to Section 8.1.3.
4. The connector is excessively worn. After many mate and de-mate cycles, the connector on the termination may become worn. When the silver plating thins, this exposes metals, which can produce an IM response. Please refer to the appropriate termination's manual for more information on replacing the connector on termination or contact Kaelus directly.

## 9.7 Advanced Verification and Troubleshooting Techniques

The following section has been provided to allow the user to make some simple measurements to verify proper operation of the analyzer.

### 1.1.1 Power Output

To verify the proper carrier power output of the analyzer, a power meter can be used to measure the output power of each carrier.

With the analyzer turned on:

1. Start the Virtual Front Panel and enter Engineering Mode.
2. With the RF power turned off, connect a power meter to the front panel connector labeled “Port 1”.



**IMPORTANT NOTE:** Be sure to attach the necessary attenuation or the properly rated power sensors to prevent damage to the power meter and or sensor.

3. In the Engineering Mode display, disable the “Lock Carrier Power Control” as described in Section 4.5.3.E.
4. Set Carrier 1 Power Control to 40.0 dBm, as described in Section 4.5.3.A.
5. Turn Carrier 1 power on.
6. The power meter should read within  $\pm 1.0$  dBm of the requested power value (accounting for any attenuation placed “in-line”).



**IMPORTANT NOTE:** Care should be taken when interpreting displayed power measurements. Cabling loss, calibration inaccuracy in the power sensor, and calibration inaccuracy in the attenuator all need to be considered in determining if there is a discrepancy in measurements. Typically, for this measurement, a calibrated attenuator should be used and allowances must be made for changing attenuation values with the heating of the attenuator.

7. Increase the Power for Carrier 1 to 43.0 dBm and verify.
8. Turn Carrier 1 “OFF” and repeat steps 4 - 9 for Carrier 2.

### 8.1.1 Frequency Output

To verify the proper frequency output of the analyzer, a frequency counter can be used to measure the frequency of each carrier.

With the analyzer turned on:

1. Start the Virtual Front Panel and enter Engineering Mode.
2. With the RF power turned off, connect a frequency counter to the front panel connector labeled “Port 1”. Set Carrier 1 Frequency Control to a valid frequency within the analyzers’ transmit band, as described in Section 4.5.3.B.



**IMPORTANT NOTE:** Be sure to attach the necessary attenuation to prevent damage to the frequency counter.

3. Turn Carrier 1 power on.
4. The frequency counter should read within a few hundred Hertz of the requested frequency.
5. Vary the Transmit Frequency for Carrier 1 and verify proper operation.
6. Turn Carrier 1 “OFF” and repeat steps 2 - 7 for Carrier 2.

## 10. Service

If the analyzer appears to require service, please contact Technical Support at Kaelus at (303) 768-8080. If, following a telephone consultation, it appears the unit is malfunctioning; an RMA number will be issued to allow the return of the suspect unit to the factory for repair. **Do not return equipment without first obtaining an RMA number from Kaelus.** If the hard disk fails (crashes), the operating system can be reloaded on the System Controller. Sections 9.3, 9.4, and 9.5 provide instructions on how to install the necessary data acquisition boards and software assuming a fresh operating system installation.

### 10.1 System Controller

The System Controller is a standard, PC-compatible computer. Please refer to the System Controller's literature for information regarding servicing this unit.

***The system is intended for use only as a System Controller for the PIM Analyzer. Installing additional peripheral hardware and/or associated software in the controller is NOT recommended.***

### 10.2 System Controller Software

This section of the manual refers to the installation of the PIM Analyzer software and instrument drivers under Windows 2000 only.

The System Controller is shipped with all support disks such as operating system recovery software and device drivers. Please retain these for future use, should a reload of the operating system become necessary. The Product Key code for the operating system appears on a label affixed to the side cover of the System Controller. It is recommended that this number be recorded and stored with the System Controller's documentation and support materials for safekeeping.

The Administrator password is left blank upon initial set-up of the operating system. If it is necessary to enter a password for security purposes, it is strongly recommended that this number be recorded and stored in a safe place. Loss of the Administrator password requires a reload of the operating system.

Additionally, a unique Calibration File is required to maintain the calibration coefficients of a particular RF Module. The calibration file is stored on a 3½" floppy disk and shipped in the Operating and Maintenance Manual. The contents of this floppy disk must be transferred to the System Controller connected to the particular RF Module for which the floppy disk has been created. Please ensure that the serial number on the calibration floppy disk matches the serial number found on the rear panel of the RF Module.

#### 1.1.1 Operating System

The entire operating system and recovery software are contained on the PC Operating System Recovery CD. Boot to this CD-ROM to perform an automated recovery and reload of the operating system. Refer to the Reinstalling Factory Software section of the PC User's Guide for additional information.

Following a reload of the operating system, the following settings should be adjusted to maintain normal operation of the Virtual Front Panel Software:

1. Right-click anywhere on the Desktop and select Properties. Click on Settings tab. Set Colors to High Color (16bit). Set Screen Size to 1024 by 768.
2. Click on Screen Saver tab. Set Screen saver to None.
3. Under Energy saving features of monitor, click on Power. Select Turn off monitor: Never.
4. Click OK to close Power Options Properties window.
5. Click OK to close Display Properties window.
6. Right-click on the Taskbar along the bottom of the Desktop. Select Properties.
7. Deselect Always on top.
8. Click OK to close.



## 1.1.1 PIM Analyzer Software

The PIM Analyzer Software CD-ROM contains all necessary Low-Level instrument drivers, Runtime Libraries, and Virtual Front Panel (VFP) software. Additionally, the disk contains application notes, manuals, and technical information in PDF format. A PDF reader may also be installed from the disk.



**IMPORTANT NOTE:** The PIM Software Distribution CD-ROM will typically “autorun” when inserted into the CD-ROM drive on the System Controller. If the PC is not set to autorun inserted CD-ROM’s, insert the disk in drive, click on Start>Run>Browse. Select the CD-ROM drive from the “Look In” menu (the label Kaelus will appear). Select Setup and open. Click OK to run setup.exe.

Once the Setup program has started, a setup wizard will appear to walk you through the setup process. Follow the wizard steps to install your PIM Distribution Software to the PIM controller PC. The wizard will install the VFP (Virtual Front Panel), PIM Hardware Engine, and LVRT Run-Time Libraries, as well as PIM documentation. In order to communicate with an instrument however, the NI-DAQmx Hardware Drivers (v8.3 or higher) must be installed (available for download from <http://www.ni.com>).

### A Installing PIM Hardware Drivers

To configure the PIM Hardware on a PIM controller, each device must be properly configured through National Instruments’ Measurement and Automation Explorer (NI-MAX). The following steps detail the proper connection and configuration procedures.

#### A.1.1 Install the RF Module

Connect the included 6’ USB cable from the back panel of the PIM controller to the RF Module. Install the USB-6259 (OEM) driver using the following steps:

- a. Tell windows to automatically detect the device driver by selecting “Yes, always detect this driver type”.
- b. Windows will automatically load the NI-DAQmx driver for the USB-6259 (OEM device)
- c. When completed, a dialog may popup with the message

*NIDAQmx has detected a new data acquisition device:  
USB-6259 (OEM)*

*What would you like to do?*

Select the option labeled: *Configure and Test this Device Using Measurement and Automation Explorer.*

- d. Use the mouse to right-mouse-click the new device listed under **NI-DAQmx Devices** in the configuration window. Select the “Rename” option and label the device: **PIM\_RFModule**

#### A.1.2 Install the PA Module

Connect the included USB cable from the back panel of the RF Module to the back of the PA Module. Install the USB-6501 driver using same steps detailed above (see step 9.3.1)

- a. When driver installation is complete, Configure and Test this device using Measurement and Automation Explorer
- b. Use the mouse to right-mouse-click the new device listed under **NI-DAQmx Devices** in the configuration window. Select the “Rename” option and label the device: **PIM\_PAModule**

#### A.1.3 Install the FE Module

Connect the included USB cable from the back panel of the RF Module to the back of the FE Module. Install the USB-6501 driver using same steps detailed above (see step 9.3.1)

- a. When driver installation is complete, Configure and Test this device using Measurement and Automation Explorer
- b. Use the mouse to right-mouse-click the new device listed under **NI-DAQmx Devices** in the configuration window. Select the “Rename” option and label the device: **PIM\_FEModule**



**IMPORTANT NOTE:** For proper operation, the PIM Module boards must be labeled correctly (see module names above). Make sure all capitol letters and underscore characters ( \_ ) are typed exactly as detailed above, or the controller will be unable to communicate with your analyzer. See Figure 9-1 to view a proper NI-DAQmx Devices configuration.

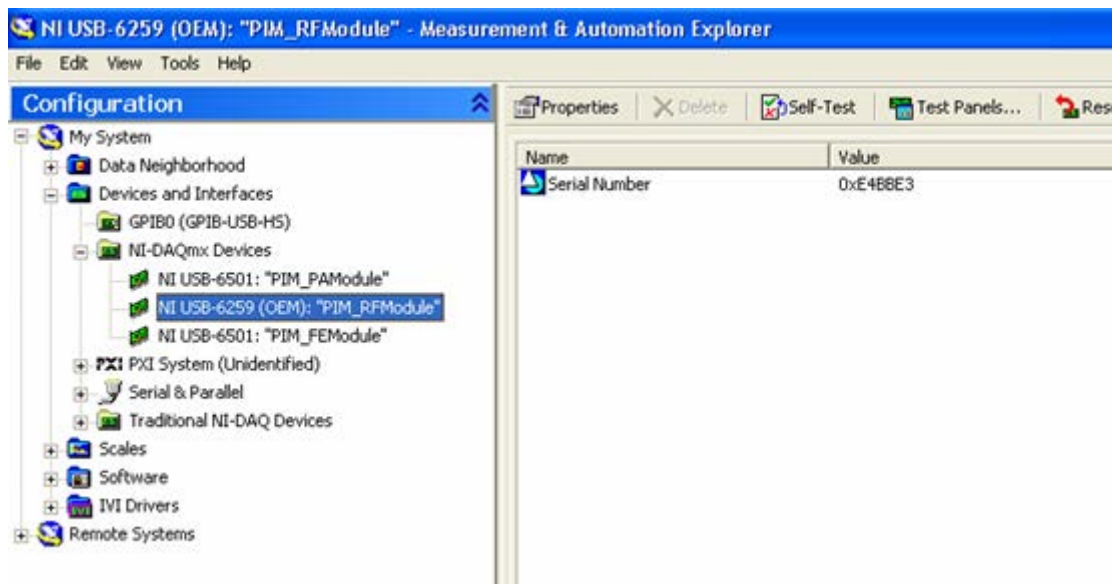


Figure 17 MAX–NI Measurement & Automation Explorer showing each PIM module device installed.

**Note:** The assignment of specific device names to each device is necessary for device communication.

### 10.3 Calibration Files

The calibration coefficients for each PIM Analyzer must be placed in the directory with the PIM Application (vfp.exe). This is found in the C:\Program Files\Kaelus\PIM folder. These calibration coefficients are located on a floppy disk in this manual entitled “Factory Calibration Data.” If you use one System Controller to interface with more than one RF Module, the Calibration File for each module must be installed in the Kaelus folder.

**IMPORTANT NOTE:** The Calibration Files used to store the calibration coefficients for a particular RF Module are unique and must be maintained with the System Controller connected to a particular RF Module. The serial numbers on the RF Module and on the Calibration Floppy disk must match in order to maintain accurate measurements.

1. Insert the disk entitled “Factory Calibration Data” into the floppy disk drive.
2. Right-click the mouse on the Start button, and select “Explore” by clicking the left mouse button.
3. Click on the 3½ Floppy (A:) to see the contents of the floppy disk. Select all the files shown on the right-hand side of the screen. If there is more than one file on the floppy disk, then press the CTL+A keys on the keyboard. This will select all the files on the floppy disk.
4. Right-mouse click on these selected file(s), and choose copy with the left-hand mouse button.
5. Using Explorer, find the C:\Program Files\Kaelus\PIM folder. Right-mouse click in the area displaying the file passive.exe (and other files). Select the paste command. This will place a copy of the calibration coefficient files into the selected directory.

**The calibration coefficient files for the RF hardware are now installed.**

### 10.4 RF Module

Please refer to the appropriate Appendix for information specific to the RF Module of interest.

## **11. Technical Specifications/Application Notes**

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