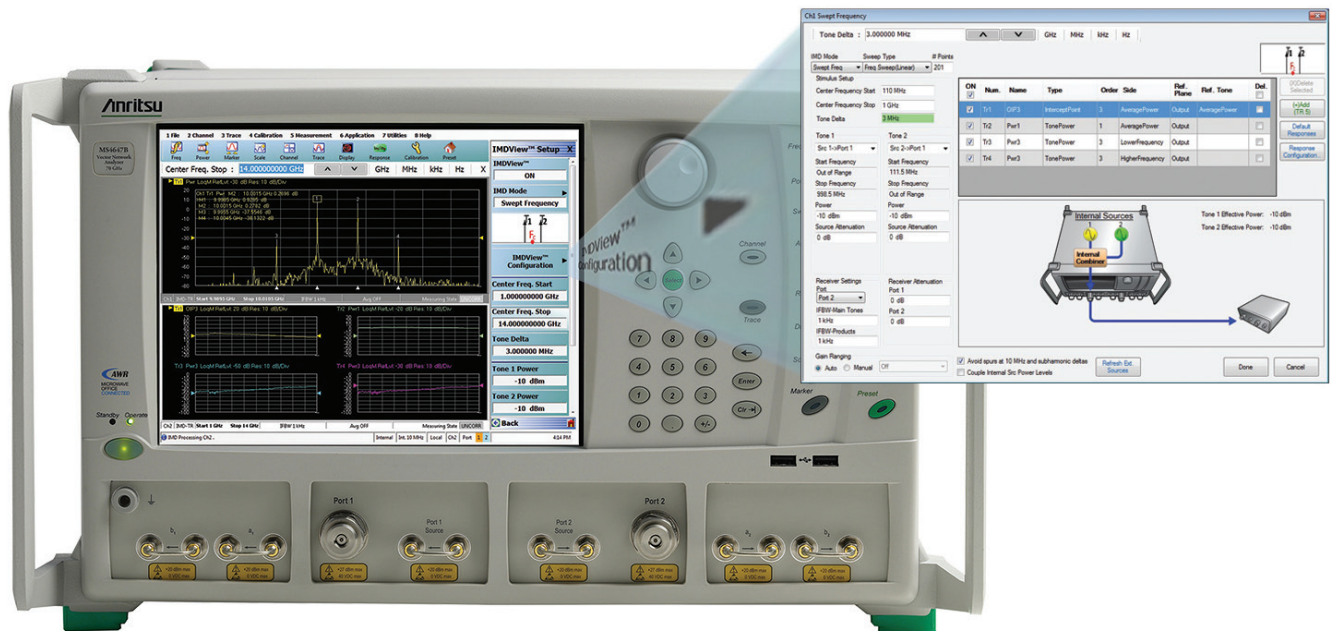


# IMD Measurements with IMDView™

## MS4640B Series Vector Network Analyzer



## 1. Introduction

Intermodulation distortion (IMD) is an important consideration in microwave and RF component design. A common technique for testing IMD is the use of two tones. Two-tone testing for IMD has been used to characterize the non-linearity of microwave and RF components, both active and passive, for a very long time. Traditionally, this has been done at fixed frequencies using multiple signal generators, a combiner, and a spectrum analyzer. Because IMD varies with frequency, these measurements must be repeated at various frequencies to get a clear picture of what a device's true behavior is across its specified operating range. This can be a time consuming process using the traditional signal generators and spectrum analyzers. The Anritsu VectorStar MS4640B Series Vector Network Analyzers can be used to quickly and accurately make S parameter, gain compression, fixed and swept frequency IMD measurements using a single cable connection to the DUT.

This Application Note will discuss the meaning of the measurement, discuss some measurement considerations, and provides a measurement example that describes how to make two tone fixed frequency and swept frequency intermodulation distortion (IMD) measurements using the Anritsu VectorStar MS4640B series Vector Network Analyzer with Dual Sources (Option 31), Internal Combiner (Option 32) and IMDView Software (Option 44).

## 2. What is Intermodulation Distortion (IMD)

Harmonic distortion can be defined as a single-tone distortion product caused by device non-linearity. When a non-linear device is stimulated by a signal at frequency  $f_1$ , spurious output signals can be generated at the harmonic frequencies  $2f_1$ ,  $3f_1$ ,  $4f_1$ , ...,  $Nf_1$ . The order of the distortion product is given by the frequency multiplier. For example, the second harmonic is a second order product, the third harmonic is a third order product, and the  $N^{\text{th}}$  harmonic is the  $N^{\text{th}}$  order product. Harmonics are usually measured in dBc, dB below the carrier (fundamental) signal.

Intermodulation distortion is a multi-tone distortion product that results when two or more signals are present at the input of a non-linear device. All semiconductors inherently exhibit a degree of non-linearity, even those which are biased for “linear” operation. The spurious products which are generated due to the non-linearity of a device are mathematically related to the original input signals. Analysis of several stimulus tones can become very complex so it is a common practice to limit the analysis to two tones. The frequencies of the two-tone intermodulation products can be computed by the equation:

$$M * f_1 + N * f_2$$

Where M & N are integers (can be positive or negative)

The order of the distortion product is given by the sum of M + N. The second order intermodulation products of two signals at  $f_1$  and  $f_2$  would occur at  $f_1 + f_2$ ,  $f_2 - f_1$ ,  $2f_1$  and  $2f_2$  (see Figure 1).

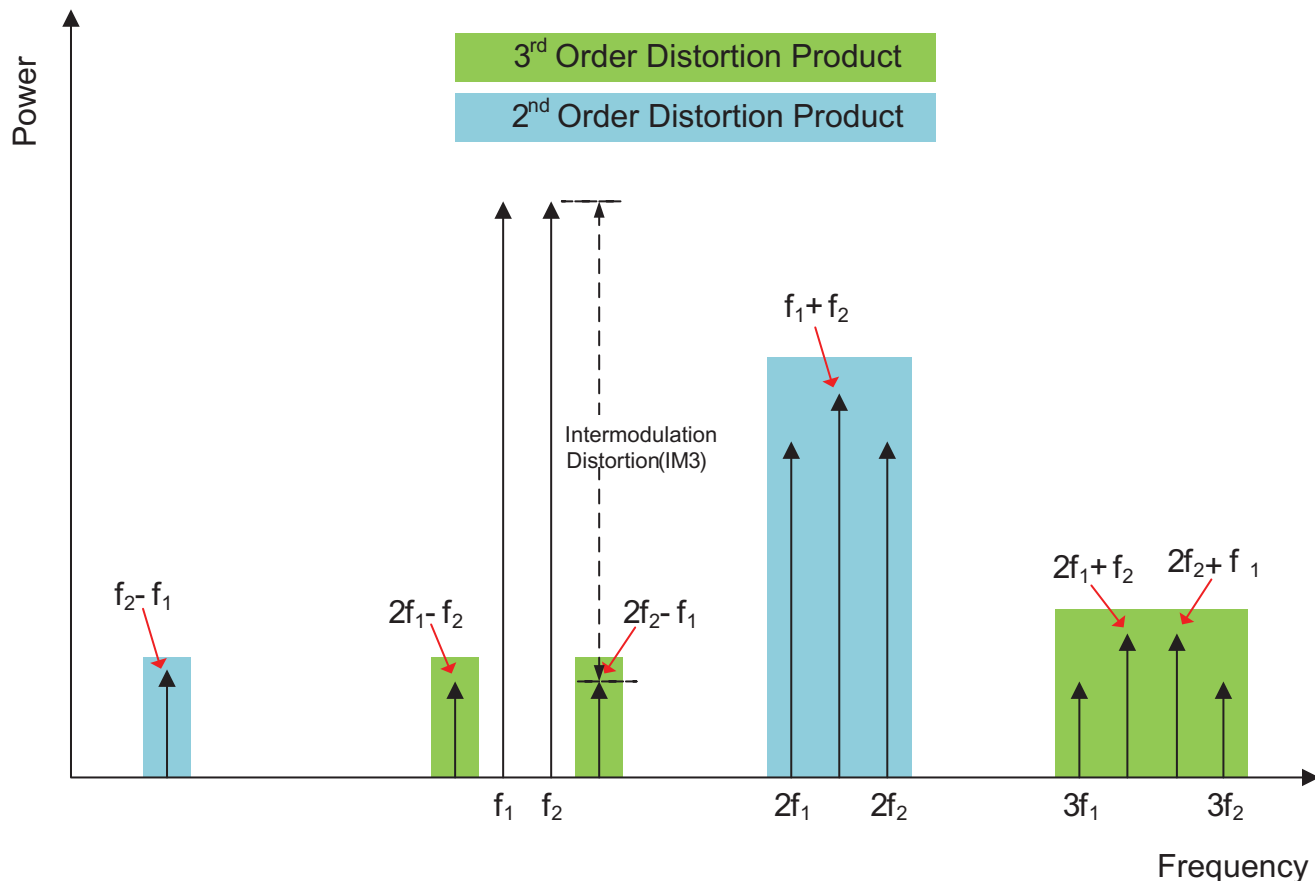


Figure 1: Harmonics and Intermodulation Distortion Products

Third order intermodulation products of the two signals,  $f_1$  and  $f_2$ , would be:

$$2f_1 + f_2, 2f_1 - f_2, 2f_2 + f_1 \text{ and } 2f_2 - f_1$$

Where  $2f_1$  is the second harmonic of  $f_1$  and  $2f_2$  is the second harmonic of  $f_2$ .

Mathematically the  $f_2 - 2f_1$  and  $f_1 - 2f_2$  intermodulation product calculation could result in a “negative” frequency. However, it is the absolute value of these calculations that is of concern. The absolute value of  $f_1 - 2f_2$  is the same as the absolute value of  $2f_2 - f_1$ . It is common to talk about the third order intermodulation products as being  $2f_1 \pm f_2$  and  $2f_2 \pm f_1$ . Two of the most challenging distortion products are the signal content due to third-order distortion that occurs directly adjacent to the two input tones at  $2f_1 - f_2$  and  $2f_2 - f_1$ . IMD measurement, then, describes the power ratio between the power level of the output fundamental tones ( $f_2$  and  $f_1$ ) and the third-order distortion products ( $2f_1 - f_2$  and  $2f_2 - f_1$ ).

Broadband systems may be affected by all the non-linear distortion products. Narrowband circuits are only susceptible to those in the passband. Bandpass filtering can be an effective way to eliminate most of the undesired products without affecting inband performance. However, third order intermodulation products are usually too close to the fundamental signals to be filtered out. For example, if the two signals are separated by 1 MHz then the third order intermodulation products will be 1 MHz on either side of the two fundamental signals. The closer the fundamental signals are to each other the closer these products will be to them. Filtering becomes impossible if the intermodulation products fall inside the passband. As a practical example, when strong signals from more than one transmitter are present at the input to the receiver, as is commonly the case in cellular telephone systems, IMD products will be generated. The level of these undesired products is a function of the power received and the linearity of the receiver/preamplifier.

### 3. Third-Order Intercept

As discussed earlier, spurious output signals can be generated at the harmonic frequencies of the fundamental signals, and the order of the distortion products is given by the frequency multiplier. The third order products are of particular interest for designers of RF and microwave systems as these products are usually too close to the fundamental signals to be filtered out. Therefore, it is important to measure and characterize these distortion products.

Fundamentally, IMD describes the ratio between the power of fundamental tones and the  $N^{\text{th}}$  order distortion products. For our discussion, we will focus on the 3<sup>rd</sup> order IMD ratio, commonly call IM3. It is important to understand that the IM3 ratio greatly depends on the power levels of the fundamental tones. As one continues to increase the power level of a two-tone stimulus, the IM3 ratio will decrease as a function of input power. At some arbitrarily high input power level, the 3rd order distortion products would theoretically be equal in power to the fundamental tones (for amplifiers, it is important to understand that this is an unrealistic condition since most amplifiers will saturate long before the intercept point is reached). This theoretical power level at which the fundamental and third-order products are equal in power is called the third-order intercept (TOI) and is also called IP3.

Figure 2 illustrates this concept. Notice that the calculated IP3 value can be referenced to either the input (IIP3) or the output (OIP3) power. IP3 is a useful specification that combines the notion of IMD with the power level at which it was measured.

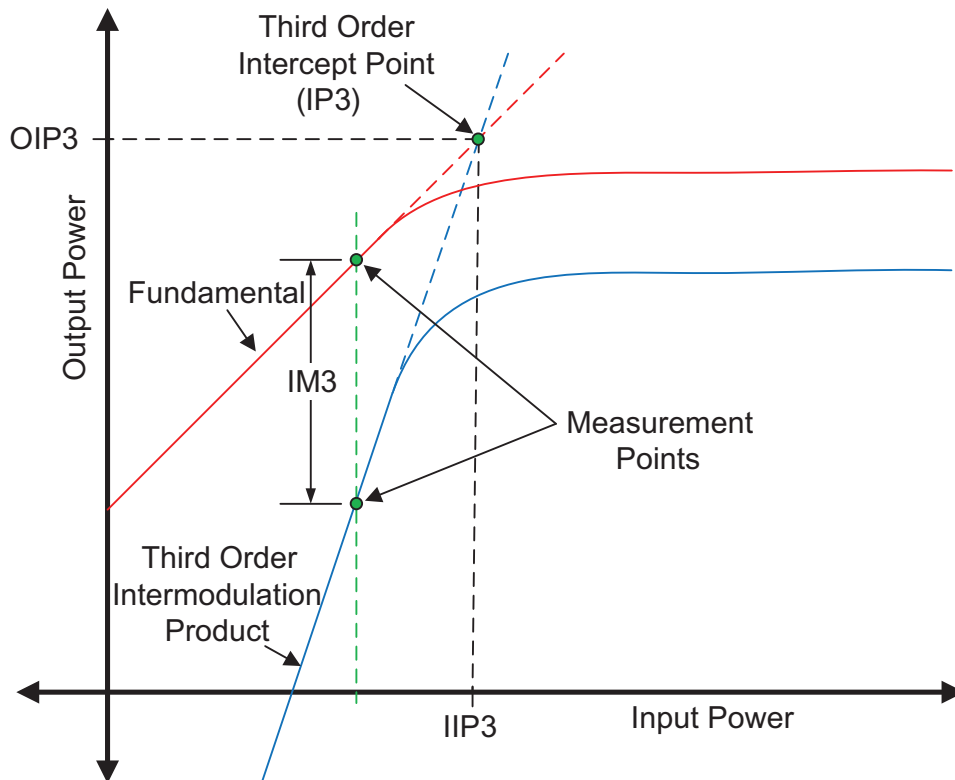


Figure 2: Concept of Third Order Intercept Point (TOI or IP3). For ideal 3<sup>rd</sup> order nonlinearity, the TOI concept is that for every 1 dB increase in the power of the input tones, the third-order products will increase by 3 dB.

## Calculation of Third Order Intercept Point

The intercept point can be determined by measuring and plotting both the fundamental signal and an intermodulation product at a few different input or output levels, graphing the intercept point, and extrapolating the intercept.

Since the power slope is known for both the fundamental signal (slope of 1) and the third order intermodulation product (slope of 3), the third order intercept point can be calculated by first measuring both the intermodulation product and output power of the fundamental signal at just one input level. Next, calculate IM3 using the following equation:

$$IM3 = P_{out} - P_{3rd\ order\ intermodulation\ product}$$

IIP3 and/or OIP3 can then be solved by applying the following formulas:

$$IIP3 = P_{in} + \left| \frac{IM3}{2} \right| \quad \text{and} \quad OIP3 = P_{out} + \left| \frac{IM3}{2} \right|$$

Where: IIP3 and OIP3 are the input and output referred third order intercept points respectively,  $P_{in}$  is the input power of the fundamental signal,  $P_{out}$  is the measured output power of the fundamental signal, and IM3 is the level (in dBc) of the intermodulation product relative to the output power of the fundamental.

For example, if a device is driven by two signals,  $f_1$  and  $f_2$ , at an input power of +10 dBm each, with a resulting 10 dB gain of the main tones and 3rd order intermodulation products of -40 dBm, then the calculated value for IIP3 would be +40 dBm:

$$\begin{aligned} IIP3 &= +10dBm + \left| \frac{20\ dBm - [-40\ dBm]}{2} \right| \\ &= +10\ dBm + \left| \frac{60\ dBm}{2} \right| \\ &= +40\ dBm \end{aligned}$$

While it is important to take the data with the device in the linear region, from the standpoint of practical intermodulation distortion measurements, the products should be as high above the noise floor of the measuring device as possible. This can be achieved by setting the power of the main tones as high as possible without compressing the DUT. Using the previous example, if the input power is dropped 10 dB to 0 dBm, the third order intermodulation product will drop by 30 dB to -70 dBm.

$$\begin{aligned} IIP3 &= 0\ dBm + \left| \frac{10\ dBm - [-70\ dBm]}{2} \right| \\ &= 0\ dBm + \left| \frac{80\ dBm}{2} \right| \\ &= +40\ dBm \end{aligned}$$

While the calculation still yields +40 dBm for the third order intercept point, making an accurate measurement of a signal at -70 dBm may be much more difficult and slower than one at -40 dBm.

#### 4. Using VectorStar's Internal Dual Sources, Internal Combiner, and IMDView Software (Options 31, 32, & 44 respectively) to measure IMD

The method of performing an IMD measurement is to inject two tones into the input of the device and monitor the spectral purity of the output. The level of the IM products due to the dual tone input signal is an indicator of the nonlinear performance of the device.

From a VectorStar perspective, the two signals are generated by the two internal sources (Opt 031). The two tones are then combined by the internal combiner (Opt 032) and presented at test port 1. The IMDView software (Opt 044) then provides all of the configuration, computation, and display of the intermodulation properties of the device. This is illustrated in Figure 3.

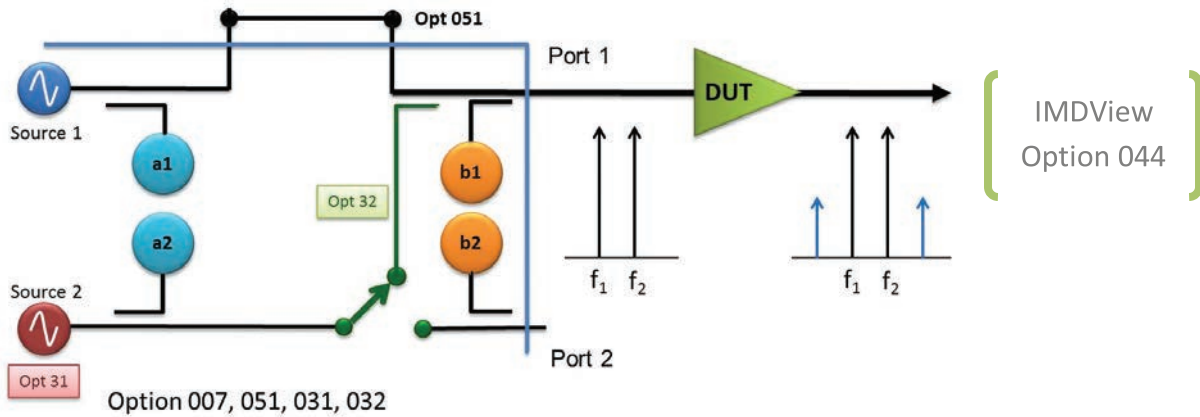


Figure 3: Block diagram of the three primary options used during IMD measurements

In a perfectly linear device the two tones are amplified and only two tones are emitted; however, in a real world device, multiple tones are emitted and the levels of the intermodulation products are an indication of the nonlinear properties of the DUT. Additionally, the intermodulation products have a range of possibilities as shown in Figure 4.

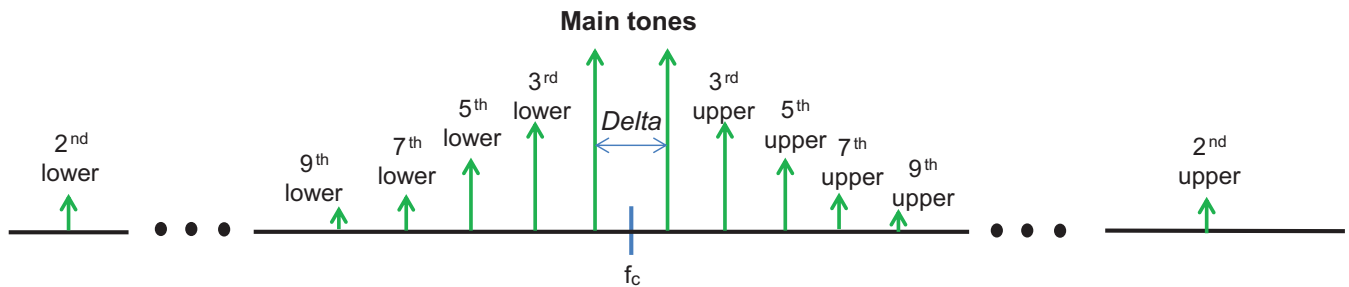


Figure 4: Possible Intermodulation Distortion Products

The locations of the IM products are determined by the tone delta and frequency of the tones as shown in Figure 5 below.

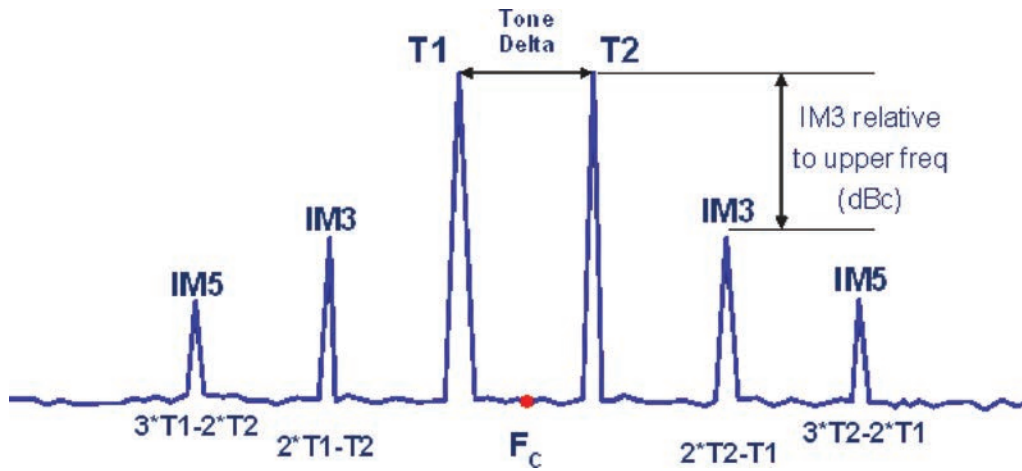


Figure 5: IM Products

From Figure 4 and Figure 5, we can start to appreciate the range of potential measurements that are often made during IMD analysis. There is the need to measure different IM products (IM3, IM5, IM7, etc.) as well as the absolute power of the tones. Thus, absolute power level measurements at specific frequency points are a key aspect in IMD measurements. In addition, the IM product power can be referenced to the lower or upper main tones, relative to the max, min, or average power, asymmetrical properties, etc. Other important measurements are the calculated intercept points of the DUT. These intercept points, OIPn and IIPn (Output or Input referred Nth order intercept point respectively), are calculated after measuring the power of two appropriate tones as shown in Figure 6.

With the need to make so many measurements, configuration of the measurement system becomes a challenge. The VectorStar Series VNAs with IMDView software solves this problem by providing an easy to use graphical user interface to conveniently configure the instrument to make these measurements.

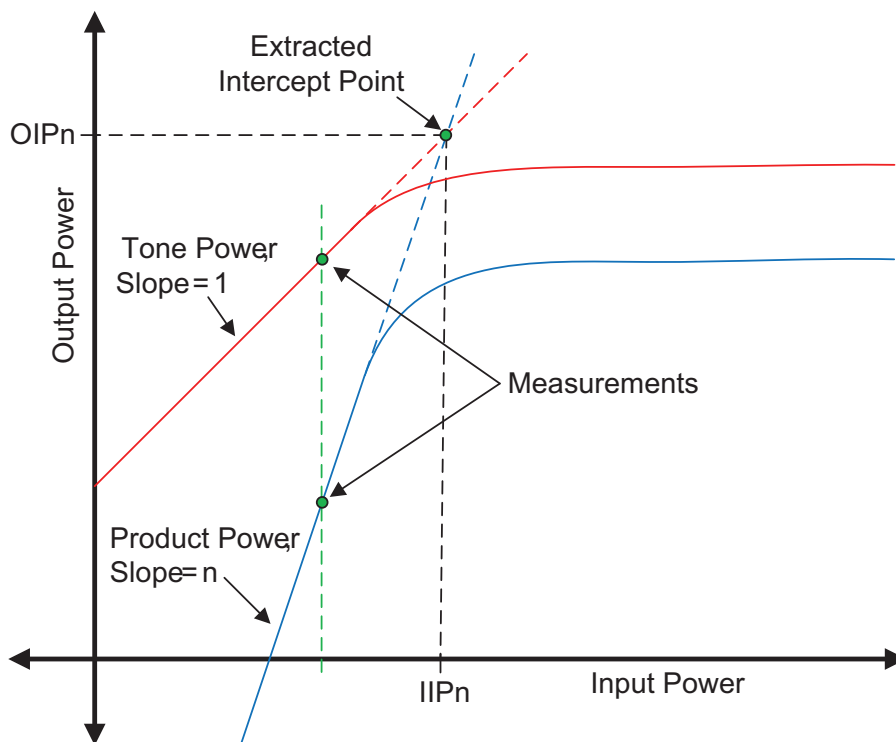


Figure 6: OIPn and IIPn are the calculation of the intercept point at the DUT output or input planes respectively. The intercept point is based on the assumption that the output main tone power and input power have a slope of 1, which is usually true for non-compressed devices. The IMn product will have a slope of n relative to the main tone power. So OIPn and IIPn are the intersection of the main power slope and the IMn slope.

## 4.1 Definitions

The following are some useful definitions.

***fc*** (Center frequency): In the IMD mode, it refers to the frequency half-way between the two main tones.

***Delta*** (The spacing between the main tones): In other literature, it is sometimes called the 'offset' or 'tone spacing'.

***IPn*** (Nth order intercept point): This is usually a calculated point in power where the main tone power and Nth order IMD product are equal based on linear (of dB quantities) extrapolation. This is an absolute-power-like quantity so power calibrations take on additional significance.

***OIPn/IIPn*** (Output or input referred Nth order intercept point respectively): The calculation of intercept point can be done at the DUT output or input planes with the difference being the DUT gain. Generally the output referred value is more directly found.

***Asymm*** (Product asymmetry or the difference in amplitude of the upper vs. the lower product of a given order): This can be a useful measure of bias network or thermal interactions in the DUT and can also be a hallmark of some system nonlinearities (source contamination or certain IF network issues).

***Order*** (The level of nonlinearity that is being observed in a given product): The most interesting odd order products are localized around the main tones at one delta from a main tone (for 3rd order) to 4 deltas from a main tone (9th order). Second order nonlinearities produce direct mixing products at the sum and difference of the main tones.

## 4.2 Measurement Considerations

There are a number of things to consider when making intermodulation product measurements. This section will present some of the most common things to be aware of.

### **Combiner Isolation**

Isolation between the two input ports of the combiner is important. To understand why this is the case, one must understand how the VectorStar's internal Automatic Level Control (ALC) treats unwanted signals. The presence of a signal from one source port at the output of the second source port will cause its output level to modulate (this is not specific to the VectorStar, as it is common to most signal generators). When the unwanted signal is detected by the VectorStar's ALC, the VectorStar will try to remove the unwanted signal by generating AM onto the desired signal, thus canceling the modulation caused by the foreign signal. This results in the VectorStar no longer producing a single signal at the required frequency, but also producing side bands (beat notes) at an offset from this signal. This offset is equal to the difference between the desired and unwanted signals which makes them indistinguishable from intermodulation products that may be generated by the device under test. In general, 20 dB of isolation is recommended if one is to measure IMD products in the  $-80$  to  $-90$  dBc range. The isolation of the VectorStar's internal combiner (Option 32) is nominally between 25-30 dB.

### **DUT Considerations**

Input power level requirements can be quite different depending on the type of device being tested and the test specifications. Some devices need to be tested at or near compression and others must be tested below the compression point. Thus, the input drive level for a particular DUT must be chosen with care. In our example, we are using a wideband amplifier with the compression point being different at differing frequencies. Care must be taken when selecting the proper power level of the input tones such that when they are swept in frequency, the DUT is still driven at the desired test levels.

## **Signal Source Considerations<sup>1</sup>**

### **Power:**

As stated above, different DUTs have differing drive level requirements. The VectorStar Series VNAs have a wide available power range to meet the demands of a large variety of devices. The maximum drive level of the VectorStar depends on the frequency at which it is operating.

### **Harmonics:**

Source harmonic performance, specifically the second harmonic, must be taken into account when making IMD measurements, especially two-tone third-order measurements (which is what we are doing). To understand the reason for this, remember that we are mainly interested in the 3<sup>rd</sup> order intermodulation products,  $2f_1 - f_2$  &  $2f_2 - f_1$ . If source one is used to generate  $f_1$ , it will also generate a second harmonic at  $2f_1$ . The unintended harmonic generated by source one at  $2f_1$  will mix with the intended signal generated at  $f_2$  by generator two, producing a signal at the same frequency as the 3<sup>rd</sup> order intermodulation distortion signal ( $2f_1 - f_2$ ) from the DUT. The same thing will happen with the second harmonic of source two, generating a signal at  $2f_2 - f_1$ . In other words, the third-order distortion signals generated by the DUT from the two intended incident tones ( $f_1$  &  $f_2$ ) occurs at the same frequencies ( $2f_1 - f_2$ ,  $2f_2 - f_1$ ) as those produced as a result of mixing one tone and the second harmonic of the other tone. Therefore if the second harmonics of the sources are incident upon the DUT, the DUT will generate signals at the intermodulation frequencies that will add to the signals we are trying to measure, thus causing errors in the measurements. The magnitude of this error depends upon the levels of the incident harmonic signals and the efficiency of the mixing process in the DUT.

### **Spurious Signals:**

All signal generators generate low-level spurious signals at some frequencies. These spurs can cause errors in IMD measurements if the spurious responses occur at or near the intermodulation frequencies being measured.

## **Receiver Considerations<sup>2</sup>**

### **Receiver Linearity:**

If the receiver generates its own IMD products, these will convolve with the products generated by the DUT and make results difficult to interpret.

### **Dynamic Range & Noise Floor:**

Dynamic range is the ratio between the largest and smallest possible signals that can be measured within a given receiver band. This is important if your Nth order IM products are very low level signals. At mm-wave frequencies, this becomes a major issue since the noise floor of traditional mm-wave modules can be high. The non-linear shockline technology of the VectorStar Broadband system improves noise floor performance to significantly improve mm-wave IMD measurements.

The specified noise floor of the VNA will dictate the absolute minimum power level of the intermodulation signals it is able to measure. The typical receiver dynamic range of the VectorStar VNA at ports 1 and 2 is about 120 dB from 10 MHz to 50 GHz and 113 dB to 70 GHz at 10 Hz IF BW.

### **Low-Level and High Level Random Noise:**

Random noise occurs both as low-level noise, which is independent of the signal power, and high-level noise, which is relative to the signal power. Both low and high level noise can contribute to measurement uncertainties.

### **Receiver Compression:**

Care must be taken to avoid overdriving the VNA's receivers. The receiver compression level at ports 1 and 2 of the VectorStar VNA is about +10 dBm depending on options fitted.

### **Mixing Products (Images):**

VNAs typically will not have Image rejection filters. Care must be taken to ensure the IMD products are not at the same frequencies as the images of the input signals

<sup>1</sup> Consult the VectorStar MS4640B Series Technical Data Sheet (Anritsu Document # 11410-00611) for detailed Signal Source specifications.

<sup>2</sup> Consult the VectorStar MS4640B Series Technical Data Sheet (Anritsu Document # 11410-00611) for detailed Receiver specifications.



## **Power accuracy**

This has two different aspects:

1. Often the DUT IMD products will be extremely power sensitive so an inaccurate drive level will put the DUT into an unintended state
2. Some expressions of intermodulation distortion have absolute power dependencies (intercept point and IMD (dBm) among them) so power inaccuracies will translate directly to the result. The latter effect happens in part since the drive power accuracy is coupled to the receiver calibration. A tertiary effect can occur with these calibrations if interpolation is invoked by changing the frequency list after calibration; these interpolation effects are most severe for highly mismatched test structures and a low density of calibration points.

## **Mismatch:**

Aside from simple issues of how much power is actually delivered to the DUT (reduced by mismatch at the input plane) and inaccuracies induced in the receiver calibration (from mismatch between source and receiver), there can be issues of different mismatch levels at a product frequency versus that at a main tone frequency. This is mainly an issue for large tone Deltas and longer electrical length setups (which follows from this situation allowing a major standing wave change on the scale of a tone Delta). A well-matched combiner and receiver structure can help with this effect. There are a number of different dependencies that may be of interest in the IMD class. Obvious ones include bias and tone power. Since this is usually a quasi-linear measurement, these dependencies will often be far more severe than for S-parameter measurements. Another obvious dependency is that with frequency (of the main tone average). Less obvious perhaps is the dependence on the separation between tones. Some interesting behaviors can be seen where the tone difference frequency can excite bias thermal and trapping behaviors causing an intermodulation response at other orders. These effects often show up in intermodulation product asymmetry.

## **4.3 Calibration Considerations**

When performing any VNA measurements, proper calibrations must be performed in order to get accurate measurements. For IMD measurements, a full 12-term 2-port calibration is neither required nor possible. This is because the intermodulation products that we are measuring are at different frequencies than the fundamental signals. However, we will have to do power and receiver calibrations as the IMD measurements rely on absolute power measurements.

Since a combiner is used to provide the two tones at the input of the DUT, the insertion loss of the combiner must be taken into account. The power calibration therefore calibrates the power of the two tones, individually and through their respective paths, in order to present two calibrated power tones at the input of the DUT. The IMDView option automatically sets up the power calibrations to take into account the specific configurations and measurements.

User power calibrations for VectorStar are valid for the path set up for the internal source(s). However, the power calibrations in VectorStar do not apply to external synthesizers. External synthesizers have their own power calibration routines and those will be used during the IMD measurements. Refer to the Appendix for more information.

## 4.4 Measurement Example

For this example measurement, the following functionality will be demonstrated:

- Intermodulation (IMD) measurements using IMDView Option 044
- Configuration of dual source Option 031 and internal combiner Option 032
- Spectrum View during two tone measurements
- Frequency swept IMD measurements of dual tones

### Equipment Requirements

There are a wide variety of possible configurations for the IMD measurement when using the VectorStar MS464xB depending on measurement requirements, installed options on the MS464xB, and availability of other equipment.

A typical VectorStar configuration may consist of three options; dual source option 031, combiner option 032, and IMDView software option 044. However, it is not mandatory to have all three options installed to perform IMD measurements. The dual source option simplifies the integration and control of the second tone during the measurement. The combiner option locates the combiner inside the VectorStar for easier setup and provides the ability to perform single connection measurements of S parameters and IMD measurements. The IMDView software option provides an excellent graphical interface that simplifies the configuration and setup of the traces, responses, and display of the IMD measurements.

The following are descriptions of possible configurations:

#### **Configuration 1:**

VectorStar with Dual Sources, Internal Combiner, and IMDView (Options 31, 32, 44)

- When combined with the dual source option (opt 031) and combiner option (opt 032), IMDView software option 044 provides the ability to combine and control the two tones emerging from port 1 of the VectorStar.

#### **Configuration 2:**

VectorStar with Dual Sources and IMDView (Options 31, 44)

- VectorStars with Opt 031 and no Opt 032 are supported by IMDView Opt 044. These units will require external combiners.

#### **Configuration 3:**

VectorStar with IMDView Only (Option 44)

- VectorStars with no Opt 031 or Opt 032 can still make use of the improved graphical interface of IMDView Opt 044. In this case, an external source will be used as the second tone and an external combiner is used for combining the tones.

The measurement example presented here requires the following equipment

- Configuration 1: VectorStar **MS464XB** VNA equipped with Options 031, 032 and 044
- Anritsu **ML24XXA** Power Meter with Power Sensor
- Mini-Circuits **ZX60-14012L-S+** 300 kHz – 14 GHz Amplifier (DUT) and +12 V Power supply

## 4.4.1 Measurement Procedure

### Initialize VectorStar

1) Press Preset to ensure the Instrument is in a known state

### Setup IMDView for SpectrumView Measurement

- 1) Application -> IMDView Setup -> IMDView Configuration to open the IMD Configuration Menu
- 2) Configure the measurement as show in Figure 7.
  - a) IMD Mode = Spectrum Mode
  - b) Sweep Type = Freq Sweep (Linear)
  - c) Center Frequency = 10 GHz
  - d) Tone Delta is set at 3 MHz
  - e) Highest Order = 5 (The Order box displays the highest order number for the setup. This ensures that the display will properly present the highest order product on the Spectrum View. There is no other entry available that will widen the frequency display beyond the 9th order product)
  - f) Tone 1 = Src 1 > Port 1, Power = -10 dBm, Source Attenuation = 0
  - g) Tone 2 = Src 2 > Port 1, Power = -10 dBm, Source Attenuation = 0 (This routes the signal from the second internal source through the combiner and out Port 1 combined with Source 1. Note the diagram changes when the configuration changes.)
  - h) Receiver Settings
    - i) Port = 2
    - ii) IFBW = 1 kHz
    - iii) Receiver Attenuation for both Port 1 and Port 2 = 0
  - i) Select Done to apply the settings.

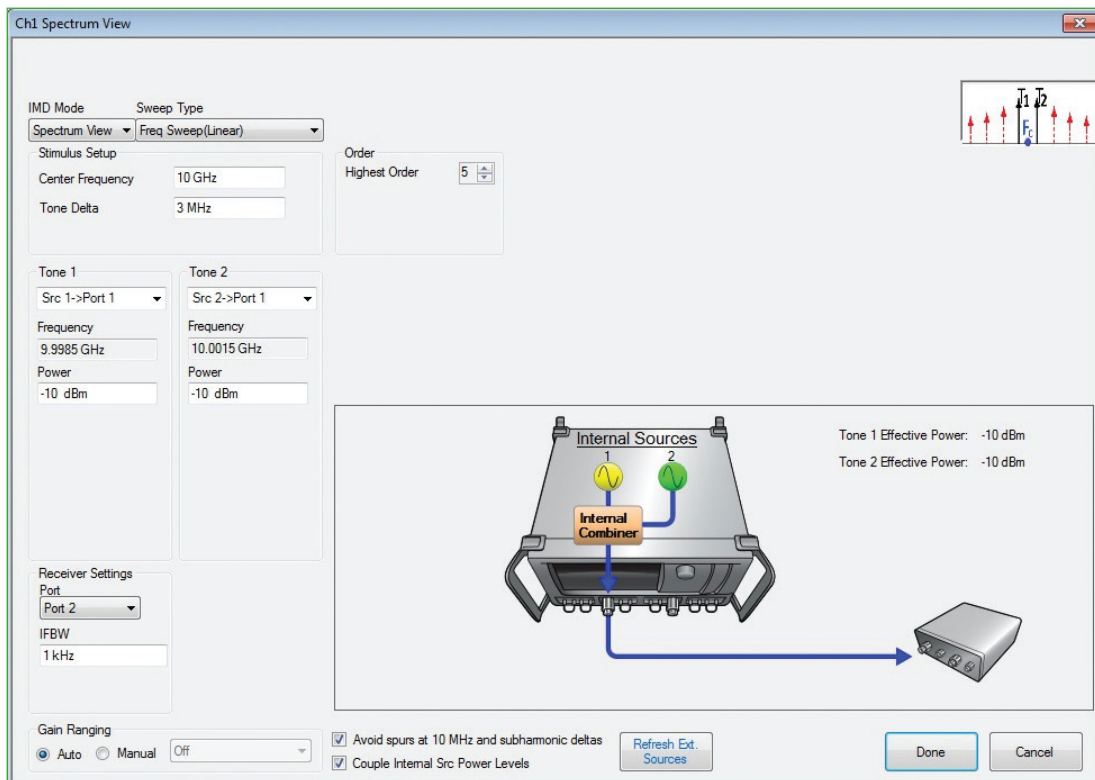


Figure 7: IMDView Configuration Menu

## Perform Power Calibrations

As mentioned earlier, absolute power is an important aspect of IMD measurements. Consequently, power calibrations (and receiver calibrations) must be performed for accurate IMD analysis.

1. Connect a GPIB cable from the ML24XXA Power Meter to the VectorStar's dedicated GPIB port
2. Verify VectorStar and Power Meter GPIB address is set to 13
  - 2.1. Utilities -> System -> Remote Interface -> Power Meter -> Ext. Power Meter = 13
3. Connect an appropriate Power Sensor to the Power Meter
  - 3.1. Zero and Calibrate the sensor
4. Calibrate Source 1
  - 4.1. On the VectorStar, Go to the Power menu and verify the power levels for both sources are set for -10 dBm as shown in Figure 8. Note that one of the selections is "Src2 Out Port 1". This is automatically configured when the IMDView is set up.
  - 4.2. Select Power Cal
    - 4.2.1. Confirm Source Selection is for Port 1 and Target Power is -10 dBm
    - 4.2.2. Connect cable from Port 1 to the Power Sensor
    - 4.2.3. Select Perform Cal to start the calibration
5. Calibrate Source 2 out Port 1
  - 5.1. Select Source Selection.
    - 5.1.1. From the menu, Select Src 2 out Port 1. This sets up the system to turn off source 1 in order to calibrate source 2 out of port 1.
  - 5.2. Verify the target power is set for -10 dBm.
  - 5.3. Select Perform Cal to start the calibration
6. Perform the receiver calibration.
  - 6.1. Disconnect the power sensor and connect a thru between ports 1 and 2.
  - 6.2. Select Power -> Receiver Cal -> Perform Receiver Cal
  - 6.3. Confirm the configuration
    - 6.3.1. Receiver Type = Test, Receiver Port = Port 2, Driver Port = Port 1.

Note: Even though the current setting is for both Src1 and Src2 to be turned on and routed through port 1, we do not need to select a specific source to perform the receiver cal. The software will automatically position the source and receiver to the correct frequencies for proper calibration.
    - 6.3.2. Select Begin Cal

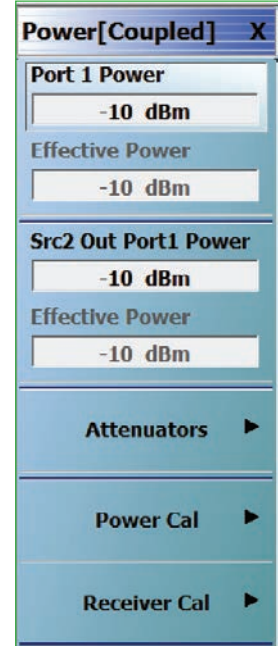


Figure 8: Power Calibration Menu

## Setup Display

Spectrum View is often used when configuring an IMD measurement. It is an easy way to quickly confirm the tone settings are correct and the device is behaving normally.

7. Reduce the number of traces to 1 and set Trace Format to Log Magnitude.
  - 7.1. Trace -> # of Traces = 1.
  - 7.2. Trace -> Trace Layout = Single.
  - 7.3. Display -> Trace Format = Log Mag.

## Measure DUT

8. Connect the DUT.
9. Adjust the Scale and Reference Position for best viewing.

The display now shows the two tones spaced 3 MHz apart including the intermodulation products from the amplifier as shown in Figure 9.

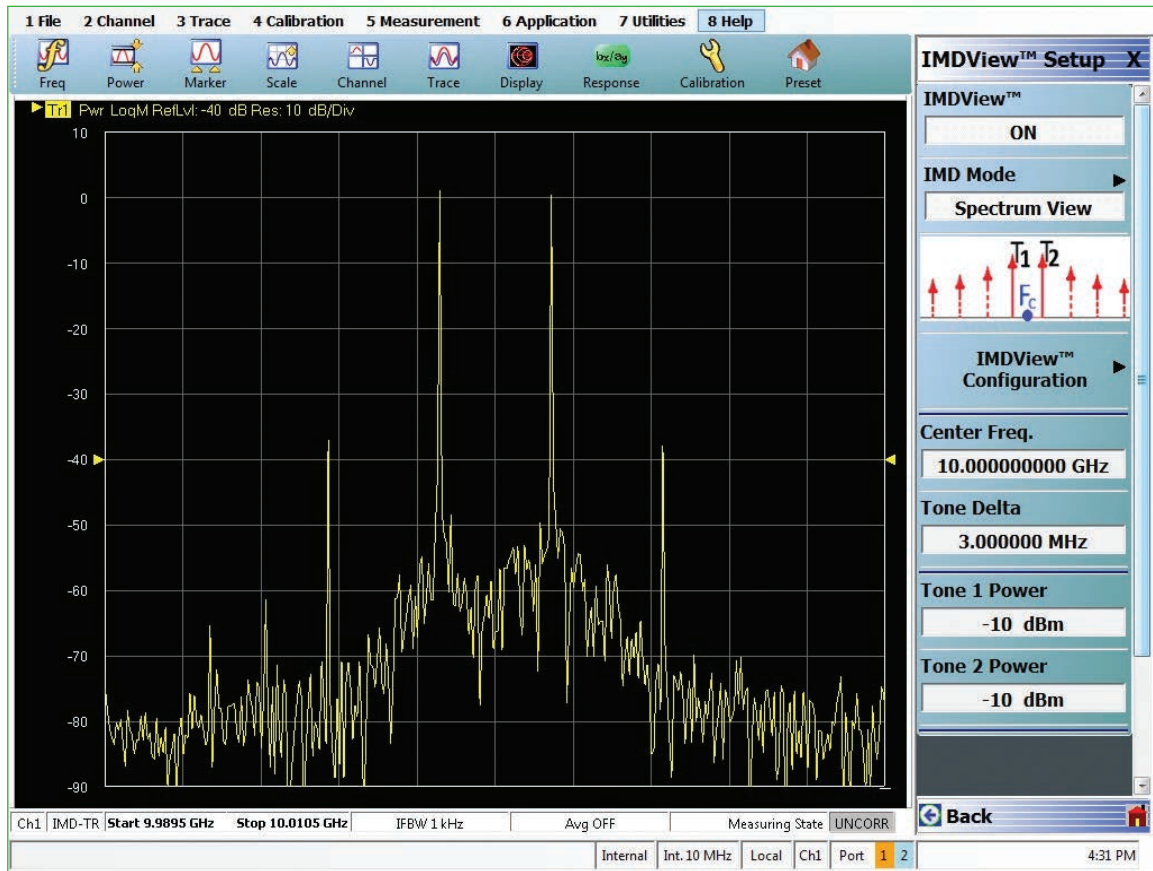


Figure 9: SpectrumView showing the two calibrated input tones with 3 MHz spacing and intermodulation products

## Use Markers to display intermodulation information

We can now use markers and the marker search function to display the intermodulation information.

1. Select Marker
  - 1.1. Turn ON Markers 1 through 4
2. Go to Marker Search -> Advanced Search -> Multi Peak.
  - 2.1. Set Peak Excursion for 10 dB. This sets up the marker trigger to activate when the trace transitions more than 10 dB.

2.2. Set the Threshold to around  $-45$  dB. If needed, select Search Multi Peak to activate the markers. There should now be markers at the 3<sup>rd</sup> order intermodulation products and at the two fundamental tones as shown in Figure 10.

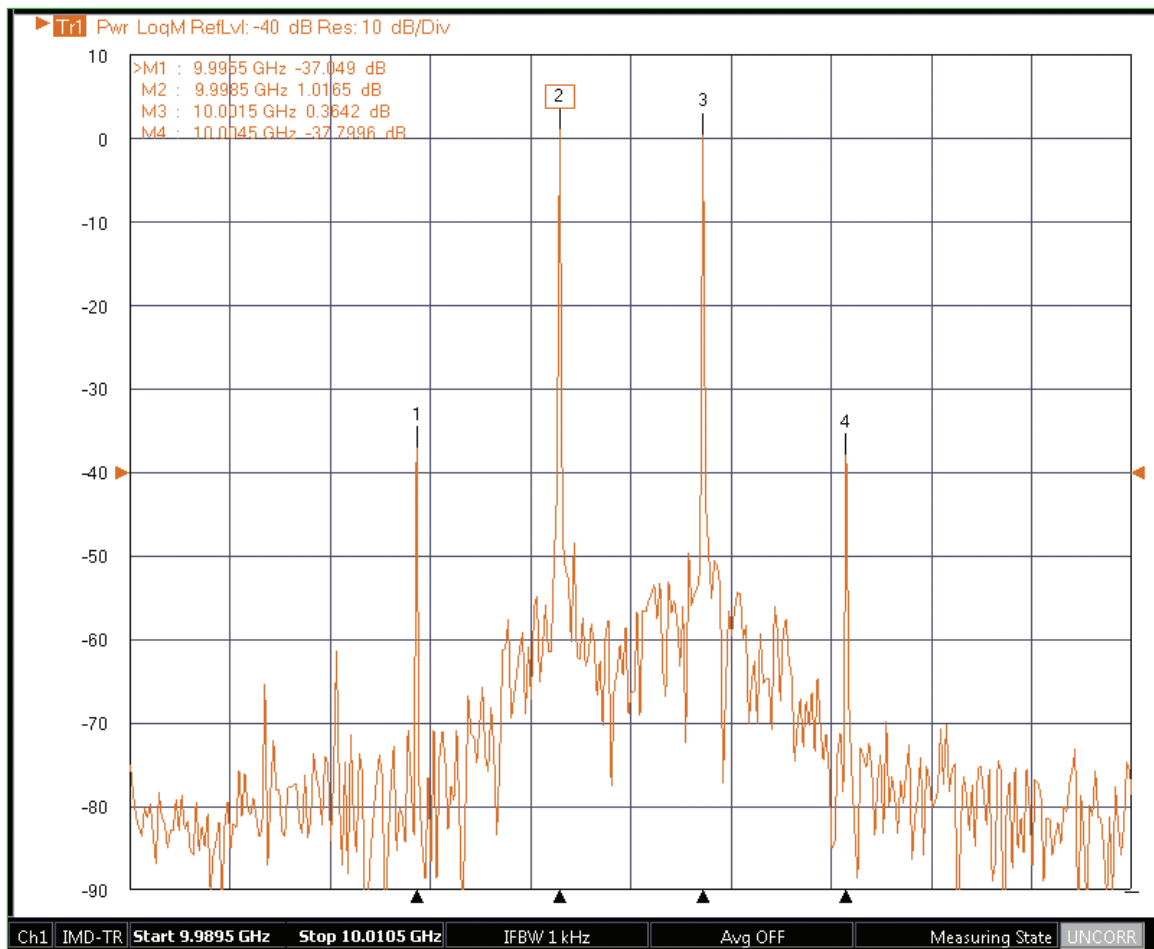



Figure 10: Marker display

The display is providing information on the main 3<sup>rd</sup> order intermodulation tones and helps to confirm there are not additional issues (e.g. an oscillating amplifier) and is a convenient method for configuring VectorStar as a power calibrated, simple spectrum analyzer.

We can now configure a second channel on the VectorStar for a Swept Frequency IMD measurement and display both the Spectrum View measurement on channel 1 and the Swept Frequency measurement on channel 2 at the same time.

## Swept IMD Frequency

1. Setup Channel 2 for Swept Frequency IMD Measurements
  - 1.1. Select Channel
  - 1.2. # of Channels = 2
  - 1.3. Chan. Layout =  (Two Channels, one on top of the other)
  - 1.4. Configure all traces on Channel 2 to display Log Magnitude Trace Format
2. Ensure Channel 2 is the active channel
3. Go to the IMDView Setup and enter the IMDView Configuration panel.
4. Setup for a Swept Frequency IMD Measurement as shown in Figure 11.

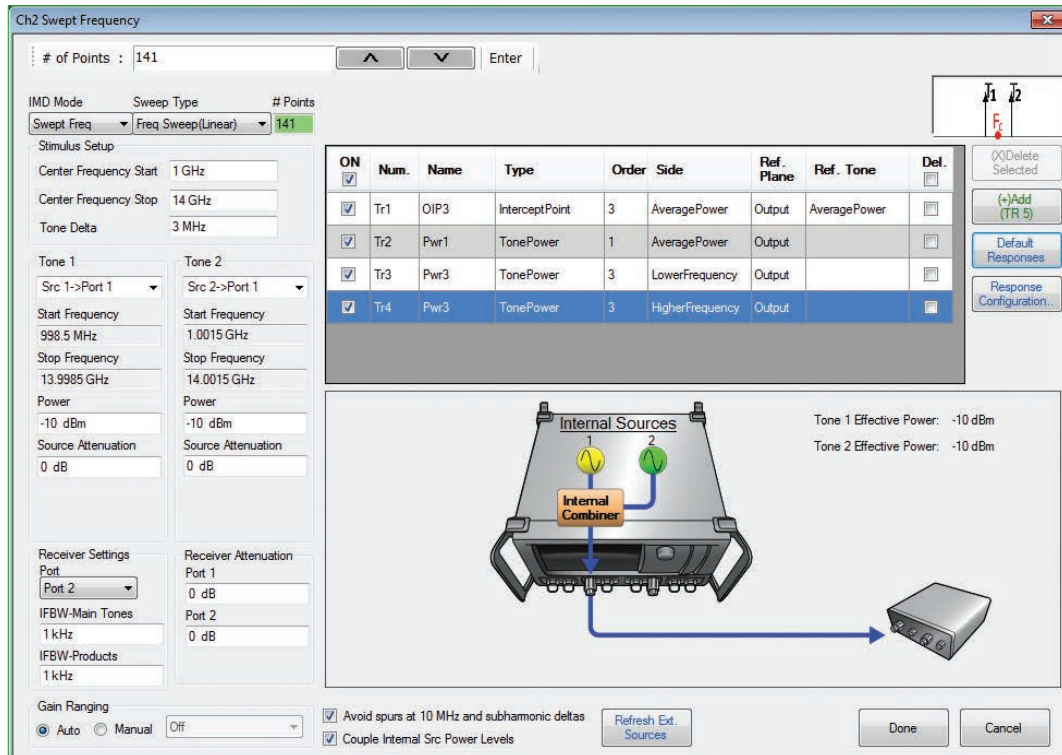


Figure 11: Channel 2 Swept Frequency IMD Measurement Configuration

- 4.1. IMD Mode = Swept Freq
- 4.2. Sweep Type = Freq Sweep(Linear)
- 4.3. # Points = 141
- 4.4. Stimulus Setup
  - 4.4.1. Center Frequency Start = 1 GHz,
  - 4.4.2. Center Frequency Stop = 14 GHz
  - 4.4.3. Tone Delta = 3 MHz delta
- 4.5. Tone 1 = Src 1 > Port 1, Power = -10 dBm, Source Attenuation = 0
- 4.6. Tone 2 = Src 2 > Port 1, Power = -10 dBm, Source Attenuation = 0
- 4.7. Receiver Settings
  - 4.7.1. Port = 2
  - 4.7.2. IFBW = 1 kHz, IFBW-Products = 1 kHz
  - 4.7.3. Receiver Attenuation for both Port 1 and Port 2 = 0
- 4.8. Select Default Responses
- 4.9. Select Done to apply the settings.

## Swept Frequency IMD Power Calibrations

As in Spectrum View, the tone power plots are uncalibrated at this time. Since the previous power calibration was for a separate channel, and that channel may be set up for different power levels, port paths, etc. we will now perform a power calibration for Channel 2. By setting up the IMDView measurement above, the power calibration settings should be already set. Repeat the procedure for port power and receiver calibrations that were done for Channel 1 above.

### Reconnect the DUT to make the measurements

1. Reconnect the DUT
2. The channel 2 display is now plotting the OIP3 of the amplifier, the power of one of the main tones and the IM3 products as shown in Figure 12.

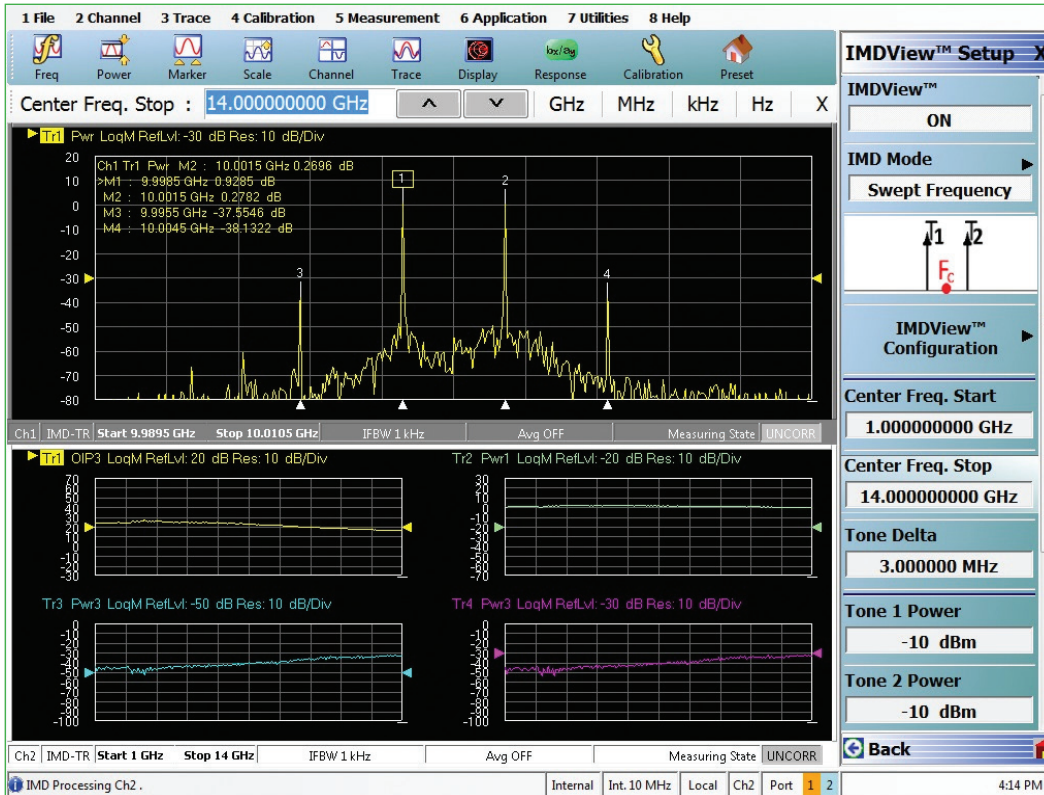


Figure 12: Two Channel IMD Measurement. Channel 1 (top) shows a SpectrumView measurement and Channel 2 (bottom) shows a swept frequency IMD Measurement. The display of Channel 2 shows the OIP3 of the amplifier, the power of one of the main tones and the upper and lower IM3 products.

## 4.5 Summary

Intermodulation distortion can degrade performance of RF components and networks. To minimize IMD, engineers must measure and characterize these distortion products. With Dual Sources, Internal Combiner, and IMDView (Options 31, 32, 44), the VectorStar MS4640B Series Vector Network Analyzers can be used to easily measure these products so that they can be minimized or eliminated.

IMDView provides many useful features for displaying and analyzing the intermodulation performance of active devices. The ability to quickly switch between S parameter, gain compression, spectrum view and swept frequency IMD settings make the VectorStar IMDView an ideal active device analytic tool. The industry-best IM performance of the VectorStar receiver ensures accurate IMD performance analysis of active devices. The ability to easily manipulate the power input to the device while monitoring the IMD performance means that identifying optimum performance parameters are both quick and easy.

## 5. References

1. "VectorStar MS464xB Calibration and Measurement Guide", Anritsu Measurement Guide 10410-00318, Feb. 2015
2. "Intermodulation distortion", Anritsu Application Note 11410-00213, Apr. 2000 and "Intermodulation distortion measurements," Anritsu Application Note 11410-00257, Sept. 2000.
3. "Millimeter-wave intermodulation distortion measurements," Anritsu Application Note 11410-0684A, Oct. 2012.

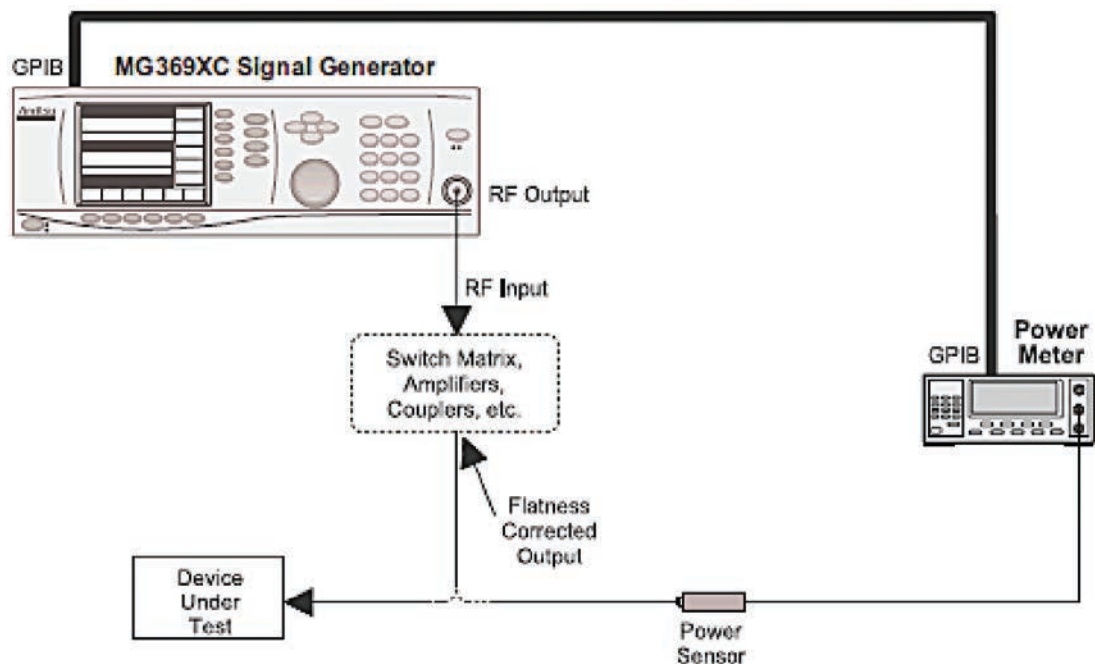


## Appendix

### Utilizing external MG369xC synthesizers:

User power calibrations for VectorStar are valid for the path set up for the internal source(s). However, the power calibrations in VectorStar do not apply to external synthesizers. External synthesizers have their own power calibration routines and those will be used during the IMD measurements.

- Up to five tables with 2-801 frequency points can be stored
- The synthesizer must not be under VNA control when the calibration is performed.
- A power meter is connected to the synthesizer GPIB bus and the sensor connected to the relevant reference plane (usually after the combiner).
- The frequency sweep should be manually set up on the synthesizer to correspond to the tone range to be used for the IMD measurement.
- The power level should be manually set to somewhere around the level that will be used for the IMD measurement (the penalty for missing the exact level is quite small due to the linearity of the synthesizer ALC system).
- The power meter GPIB address does need to be correct for what the synthesizer expects although the default values are common between the VNAs and the synthesizers from Anritsu.
- After performing the calibration (and assigning it to one of the user offset tables) and activating the calibration, the synthesizer can be returned to VNA-control (after reconnecting GPIB cables).



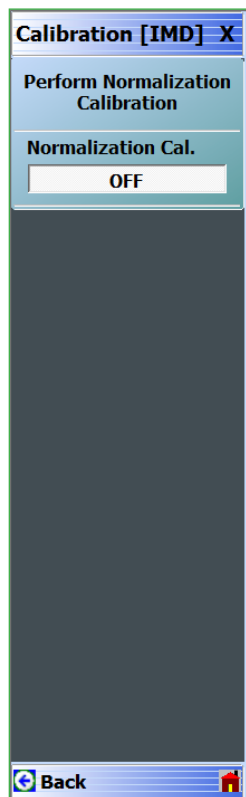
## Receiver calibrations

When in IMD mode, the receiver calibration frequency list will automatically be configured to include the measurement locations (which product orders, upper vs. lower, etc.) requested. As such, the point count can increase significantly relative to what the frequency menu says. The higher order product locations will be discarded first as the maximum number of points is reached with the 2<sup>nd</sup> order points discarded last (if they have been requested) since they are furthest away from the main tones. The reasoning on the others is that the odd orders are closer to the main tones and hence likely to suffer less interpolation errors. The highest odd orders are likely to be dominated by the noise floor in an actual measurement so any interpolation error on those will have the lowest net effect.

The receiver calibration can still be performed outside of IMD and will be applied correctly but may utilize additional interpolation depending on the IMD frequency requirements. As long as the receiver reference plane position has not changed, there would be no further accuracy penalty.

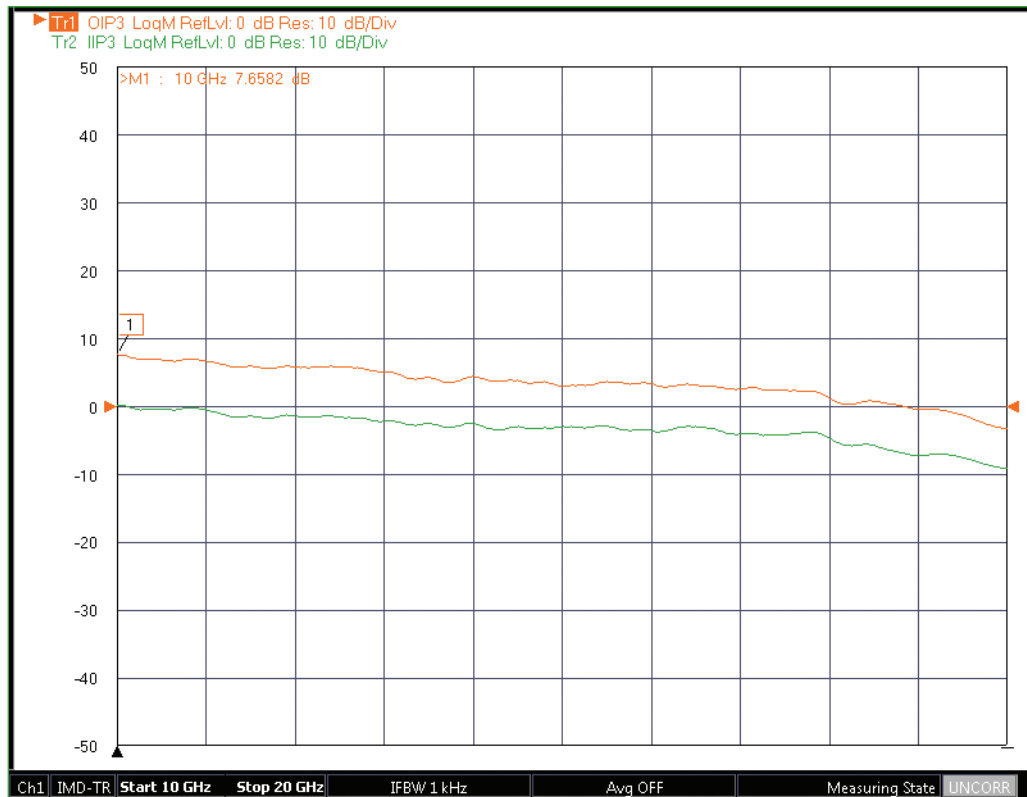
## Normalization calibrations

The normalization calibration is intended to allow on-the-fly DUT gain computations to allow for input-referred tone power and intercept point measurements. This calibration is not required for other measurements and is not used in SpectrumView. The calibration is performed with a thru line connected between the power calibration and receiver reference planes just as with the receiver calibration. The difference is that a different (simpler) frequency list is used and the normalization calibration can only be performed within IMD and uses the current power level (nominally the power level at which the test was specified). The receiver calibration can be performed in non-IMD modes and can be performed at other power levels (as long as there are no linearity or noise issues induced by that choice).



*The Calibration menu when in an IMD mode is shown here. The normalization calibration (requiring only a thru line connection like the receiver calibration) is performed with the first button and the application of the calibration is controlled with the second. This calibration is only used for input-referred tone power and intercept point measurements.*

To show the effect of this calibration and the behavior of the input- and output-referred parameters, consider the measurement of a reasonably broadband amplifier with about 7 dB of gain across 10-20 GHz. The input- and output-referred IP3 values for this amplifier are shown below (using averages among both the upper and lower products and the upper and lower main tones) and one can see that the difference between the values is the gain of the DUT. If the normalization calibration was not performed or was turned off, the OIPn and IIPn values would be the same (the same is true for input- and output-referred absolute tone values).



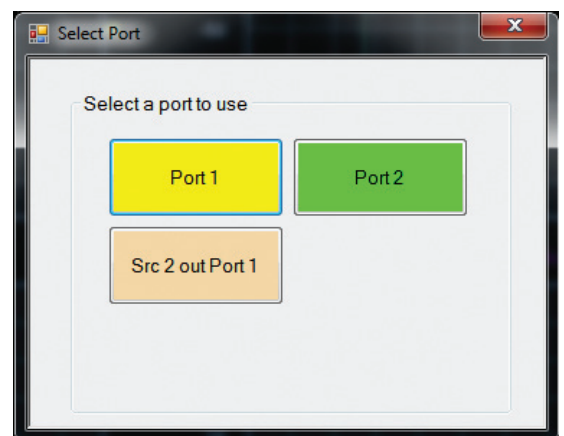
*IIP3 and OIP3 are plotted here for an example amplifier to show the effect of the normalization calibration to find DUT gain in real-time.*

An important aspect of this process is that the gain of the DUT is evaluated real-time and used to appropriately generate the IIPn (or input-referred tone power). Thus if one is adjusting the DUT bias, tuning the DUT, or drift in the DUT is occurring, errors from gain misconceptions will not affect the input-referred results.

### Combiner Option 032 Port Power

When option 032 is installed and the two internal sources are being used, some of the power issues are handled for the measurement. Note that the step attenuators of option 062 are before the combiner so they can be used to independently adjust tone level if both internal sources are being used. There is an additional factory ALC calibration for source 2 when routed to source 1 so the power at the port for both tones will be reasonably accurate (to within nominal specifications). User power calibrations, used to get additional accuracy, also make a distinction on source 2 whether it is driving port 2 or is being routed to port 1. The dialog for this selection is shown to the right.

Note that because of the internal loss on the redirect (5-10 dB), -10 dBm may not be achievable at all frequencies on 50 and 70 GHz systems.



*When equipped with option 032, the power calibration port selection menu has 3 choices (2 port system). The 'Src 2 out Port 1' selection enables the redirection path for the calibration and the corresponding calibration will store values for use when that path is active.*

• **United States**

**Anritsu Company**

1155 East Collins Boulevard, Suite 100,  
Richardson, TX, 75081 U.S.A.  
Toll Free: 1-800-267-4878  
Phone: +1-972-644-1777  
Fax: +1-972-671-1877

• **Canada**

**Anritsu Electronics Ltd.**

700 Silver Seven Road, Suite 120,  
Kanata, Ontario K2V 1C3, Canada  
Phone: +1-613-591-2003  
Fax: +1-613-591-1006

• **Brazil**

**Anritsu Eletrônica Ltda.**

Praça Amadeu Amaral, 27 - 1 Andar  
01327-010 - Bela Vista - São Paulo - SP - Brazil  
Phone: +55-11-3283-2511  
Fax: +55-11-3288-6940

• **Mexico**

**Anritsu Company, S.A. de C.V.**

Av. Ejército Nacional No. 579 Piso 9, Col. Granada  
11520 México, D.F., México  
Phone: +52-55-1101-2370  
Fax: +52-55-5254-3147

• **United Kingdom**

**Anritsu EMEA Ltd.**

200 Capability Green, Luton, Bedfordshire LU1 3LU, U.K.  
Phone: +44-1582-433280  
Fax: +44-1582-731303

• **France**

**Anritsu S.A.**

12 avenue du Québec, Batiment Iris 1-Silic 612,  
91140 Villebon-sur-Yvette, France  
Phone: +33-1-60-92-15-50  
Fax: +33-1-64-46-10-65

• **Germany**

**Anritsu GmbH**

Nemetschek Haus, Konrad-Zuse-Platz 1  
81829 München, Germany  
Phone: +49-89-442308-0  
Fax: +49-89-442308-55

• **Italy**

**Anritsu S.r.l.**

Via Elio Vittorini 129, 00144 Roma Italy  
Phone: +39-06-509-9711  
Fax: +39-06-502-2425

• **Sweden**

**Anritsu AB**

Kistagången 20B, 164 40 KISTA, Sweden  
Phone: +46-8-534-707-00  
Fax: +46-8-534-707-30

• **Finland**

**Anritsu AB**

Teknobulevardi 3-5, FI-01530 VANTAA, Finland  
Phone: +358-20-741-8100  
Fax: +358-20-741-8111

• **Denmark**

**Anritsu A/S**

Kay Fiskers Plads 9, 2300 Copenhagen S, Denmark  
Phone: +45-7211-2200  
Fax: +45-7211-2210

• **Russia**

**Anritsu EMEA Ltd.**

**Representation Office in Russia**

Tverskaya str. 16/2, bld. 1, 7th floor  
Moscow, 125009, Russia  
Phone: +7-495-363-1694  
Fax: +7-495-935-8962

• **Spain**

**Anritsu EMEA Ltd.**

**Representation Office in Spain**

Edificio Cuzco IV, Po. de la Castellana, 141, Pta. 8  
28046, Madrid, Spain  
Phone: +34-915-726-761  
Fax: +34-915-726-621

• **United Arab Emirates**

**Anritsu EMEA Ltd.**

**Dubai Liaison Office**

P O Box 500413 - Dubai Internet City  
Al Thuraya Building, Tower 1, Suite 701, 7th floor  
Dubai, United Arab Emirates  
Phone: +971-4-3670352  
Fax: +971-4-3688460

• **India**

**Anritsu India Pvt Ltd.**

2nd & 3rd Floor, #837/1, Binnamangla 1st Stage,  
Indiranagar, 100ft Road, Bangalore - 560038, India  
Phone: +91-80-4058-1300  
Fax: +91-80-4058-1301

• **Singapore**

**Anritsu Pte. Ltd.**

11 Chang Charn Road, #04-01, Shriro House  
Singapore 159640  
Phone: +65-6282-2400  
Fax: +65-6282-2533

• **P. R. China (Shanghai)**

**Anritsu (China) Co., Ltd.**

27th Floor, Tower A,  
New Caohejing International Business Center  
No. 391 Gui Ping Road Shanghai, Xu Hui Di District,  
Shanghai 200233, P.R. China  
Phone: +86-21-6237-0898  
Fax: +86-21-6237-0899

• **P. R. China (Hong Kong)**

**Anritsu Company Ltd.**

Unit 1006-7, 10/F., Greenfield Tower, Concordia Plaza,  
No. 1 Science Museum Road, Tsim Sha Tsui East,  
Kowloon, Hong Kong, P. R. China  
Phone: +852-2301-4980  
Fax: +852-2301-3545

• **Japan**

**Anritsu Corporation**

8-5, Tamura-cho, Atsugi-shi,  
Kanagawa, 243-0016 Japan  
Phone: +81-46-296-1221  
Fax: +81-46-296-1238

• **Korea**

**Anritsu Corporation, Ltd.**

5FL, 235 Pangoyeok-ro, Bundang-gu, Seongnam-si,  
Gyeonggi-do, 463-400 Korea  
Phone: +82-31-696-7750  
Fax: +82-31-696-7751

• **Australia**

**Anritsu Pty Ltd.**

Unit 21/270 Ferntree Gully Road,  
Notting Hill, Victoria 3168, Australia  
Phone: +61-3-9558-8177  
Fax: +61-3-9558-8255

• **Taiwan**

**Anritsu Company Inc.**

7F, No. 316, Sec. 1, Neihu Rd., Taipei 114, Taiwan  
Phone: +886-2-8751-1816  
Fax: +886-2-8751-1817



Anritsu utilizes recycled paper and environmentally conscious inks and toner.



©Anritsu All trademarks are registered trademarks of their respective companies.  
Data subject to change without notice. For the most recent specifications visit:  
[www.anritsu.com](http://www.anritsu.com)

11410-00859, Rev. B Printed in United States 2015-04  
©2015 Anritsu Company. All Rights Reserved.