

THEORY OF INTERMODULATION DISTORTION MEASUREMENT (IMD)

Introduction

Intermodulation distortion occurs when the non-linearity of a device or system with multiple input frequencies causes undesired outputs at other frequencies. In a communications system, this means that signals in one channel can cause interference with adjacent channels. As the spectrum becomes busier and the channels become more tightly spaced, minimizing intermodulation distortion becomes more important.

Two-Tone Intermodulation Testing

A convenient way to measure IMD is to combine two equal power signals with a set frequency spacing at the input of the device-under-test (DUT). The output spectrum will look like **Figure 1**. The two largest signals are the amplified carrier signals, and the smaller signals, moving away from the carriers in both directions, are the 3rd order, 5th order, and 7th order intermodulation products, respectively. The frequency spacing between all of the signals is equal. **Figure 3** shows a typical IMD measurement setup.

The ten measurement parameters of interest here are as follows:

Carrier (C): This is the power of the carrier signal in dBm units. It is similar to the Pout parameter, except that C is measured with a spectrum analyzer, and Pout is measured with the power meter with only one RF input signal.

3rd Order Intermodulation Product (I3): This is the power of the spurious 3rd order intermodulation signal in dBm units, measured with the spectrum analyzer.

Carrier to 3rd Order Intermodulation Ratio (C/I3): This is the ratio of the carrier power to the spurious 3rd order intermodulation power in dB.

3rd Order Intercept Point (IP3): This is a figure of merit in dBm for the device and normally varies with tuning.

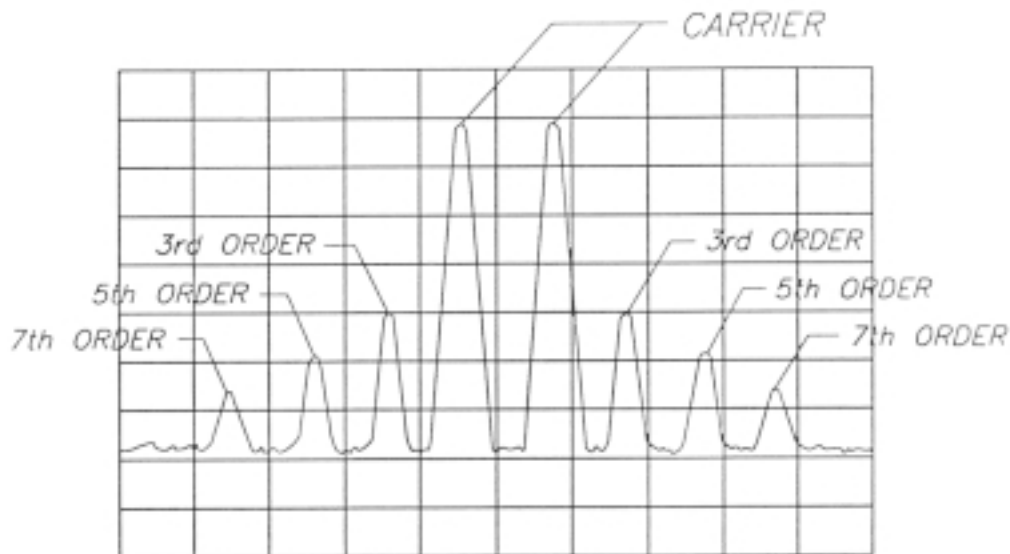


Figure 1: Output Spectrum of Two-Tone Intermodulation Test



5th Order Intermodulation Product (I5): This is the power of the spurious 5th order intermodulation signal in dBm units, measured with the spectrum analyzer.

Carrier to 5th Order Intermodulation Ratio (C/I5): This is the ratio of the carrier power to the spurious 5th order intermodulation power in dB.

5th Order Intercept Point (IP5): This is a figure of merit in dBm for the device and normally varies with tuning.

7th Order Intermodulation Product (I7): This is the power of the spurious 7th order intermodulation signal in dBm units, measured with the spectrum analyzer.

Carrier to 7th Order Intermodulation Ratio (C/I7): This is the ratio of the carrier power to the spurious 7th order intermodulation power in dB.

7th Order Intercept Point (IP7): This is a figure of merit in dBm for the device and normally varies with tuning.

3rd Order Intercept Point

The non-linear transfer function of a device or system can be expressed as a series expansion:

$$f(x) = a_0 + a_1(x) + a_2(x)^2 + a_3(x)^3 + a_4(x)^4 + \dots$$

The intermodulation signals shown in **Figure 1** come from the 3rd order term in the series expansion, hence the name 3rd order intermodulation product. Because of the 3rd order, it will increase with input power much faster than the carrier as shown in **Figure 2**. In dBm units, which is a logarithmic function, the intermodulation signal will increase with power three times as fast as the carrier signal.

The measurement of the 3rd order intercept point is illustrated in **Figure 2**. If the linear portion of the C v. Pin and the I v. Pin curves are extrapolated out, the intersection point is called the 3rd order intercept point (IP3). In **Figure 2**, this is the intersection of the dotted lines. This theoretical point is never reached in practice, because both curves will saturate before reaching it. However, IP3 is often used as a merit function for the device.

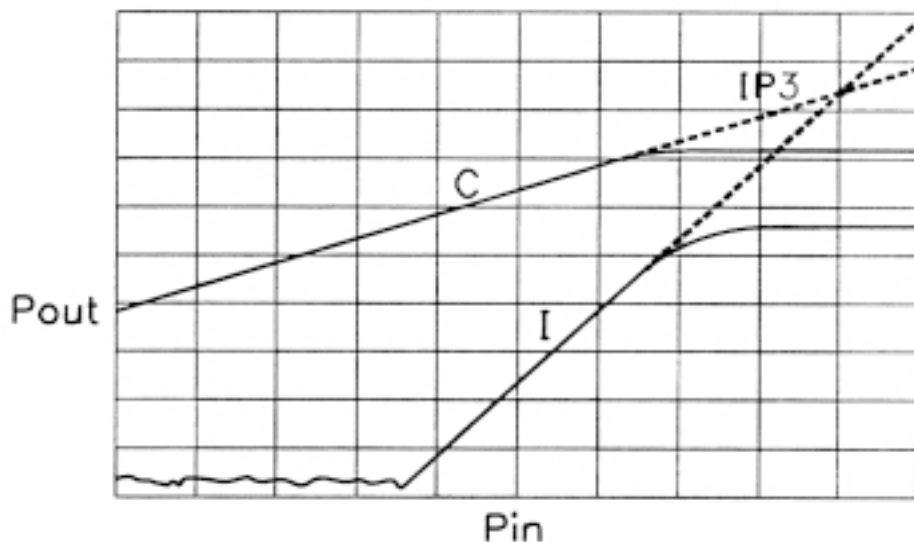


Figure 2: Measurement of 3rd Order Intercept Point

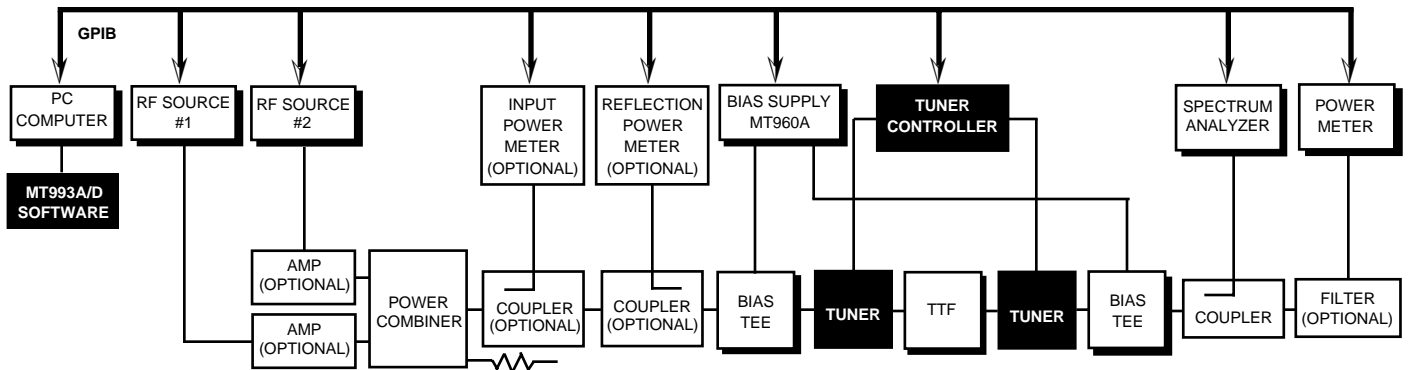


If the 3:1 theoretical slope difference is assumed, then the IP3 can be calculated from only one power level. If a power sweep is done, IP3 calculated this way will be constant in the linear region if the 3:1 slope assumption was correct. As the carrier and intermodulation signals saturate, the IP3 value will usually drop off, indicating an invalid measurement. At the lower power levels, IP3 will start to change as the spectrum analyzer noise floor is reached, also indicating an invalid measurement. The correct measurement is therefore in the power range where IP3 stays constant.

5th and 7th Order Intercept Points

The 5th and 7th order intercept points (IP5 and IP7) are determined in a manner to IP3. The main difference is that the 5th order intermodulation increases with input power five times as fast as the carrier (in dBm units). The 7th order intermodulation increases with input power seven times as fast as the carrier (in dBm units).

NOTE: Theoretically, IP3 is not a function of power level. However, the dynamic range is limited by the spectrum analyzer noise floor on the low end, and DUT saturation or spectrum analyzer intermodulation on the high end. Looking at IP3 as a function of power provides a good way of checking the valid measurement range.



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Figure 3: Typical Setup for Performing Power/Intermodulation Measurements