IP3 (3rd Order Intercept)

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TestEdge
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The presence of 2 or more tones in a non-linear device generates intermodulation products. These products are the sum and difference of multiples of the fundamental tones. Equation 1 shows the series expansion of multiplying two monotones f_1 and f_2. Notice that the order is characterized by the sum of the fundamental factors.

$$
\begin{aligned}
P_{out} = \; & a_1 f_1 + a_2 f_2 + && \leftarrow \text{Fundamentals} \\
& a_3(f_1 \pm f_2) + && \leftarrow 2^{nd} \text{ Order Products} \\
& a_4(f_1 \pm 2f_2) + a_5(2f_1 \pm f_2) + && \leftarrow 3^{rd} \text{ Order Products} \\
& a_6(2f_1 \pm 2f_2) + && \leftarrow 4^{th} \text{ Order Products} \\
& \ldots + a_\infty(\infty f_1 \pm \infty f_2) && \leftarrow \text{etc.}
\end{aligned}
\tag{1}
$$

Many of the spurious tones are out-band and cause no problem. The third order difference tones are nearest the fundamentals. They very likely fall in-band and add non-linearity and distortion to the output. Figure 1 illustrates intermodulation products and their relative frequency.

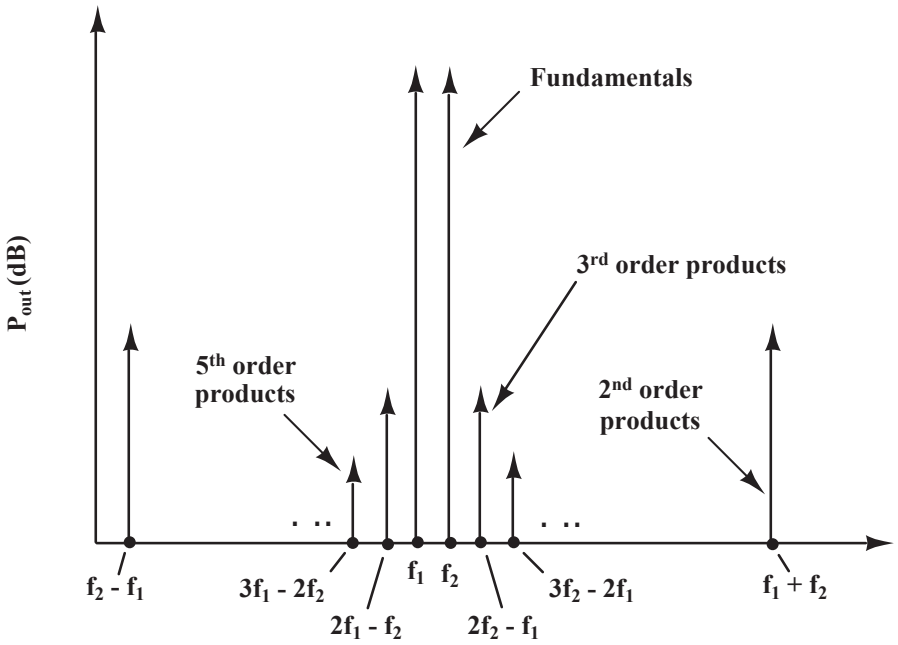

Figure 1

A metric of 3rd order products is important for evaluating device performance particularly in amplifiers which are not perfectly linear. IP3 is an important parameter for system designers to estimate spurious free dynamic range (SFDR).

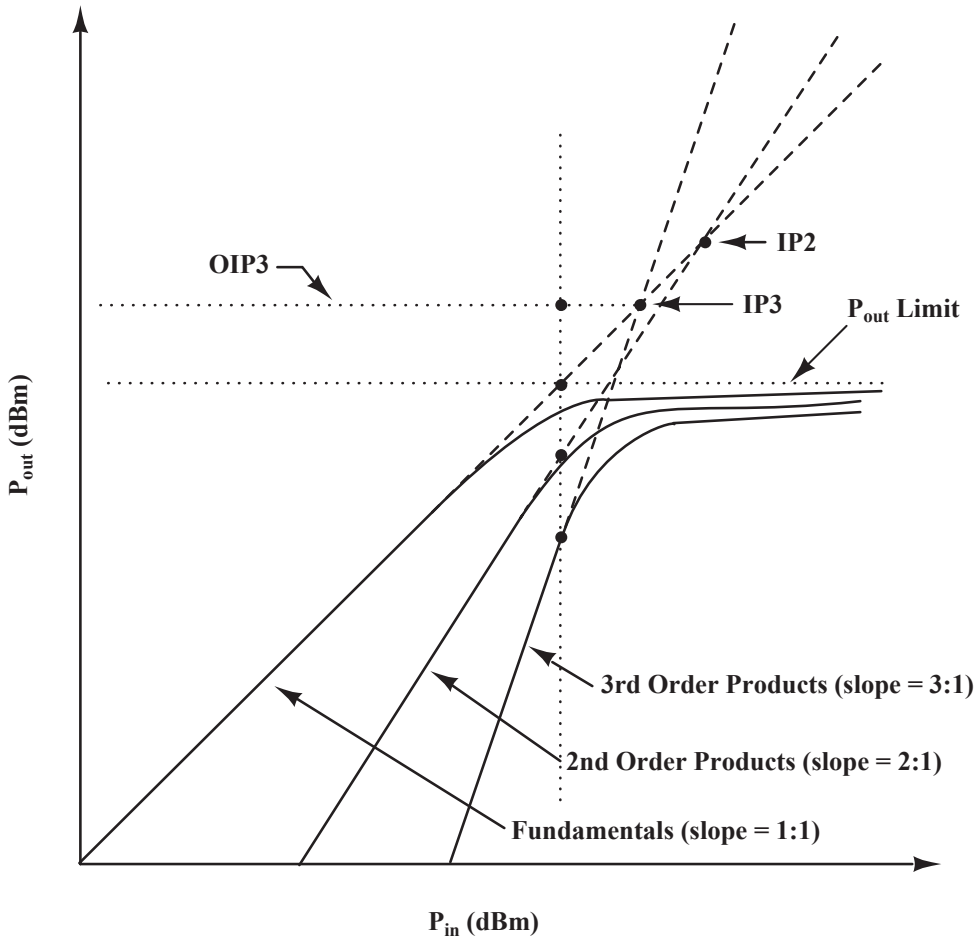

Figure 2

Intermodulation products increase at rates that are multiples of the fundamentals. If not for the output power saturating limit, intermodulation products would overtake the fundamentals as shown in Figure 2. IP3 is the point where 3rd order products would overtake fundamentals in output power.

Assuming a fundamental gain slope of 1:1 (0dB) and fundamentals of equal amplitude, some clear relationships are established. The gain slope of 3rd order products is 3:1 or, stated another way, 3rd order products power is always 3 times farther away from IP3 than the fundamental power is from IP3. Let's establish a relationship between fundamentals and 3rd order products using IP3 as a reference. Consider the imaginary vertical line shown in Figure 2.

$$P3rd + 3(IP3 - P1st) = IP3 \quad (2)$$

$$P3rd + 2IP3 = 3P1st \quad (3)$$

$$IP3 = 3/2\ P1st - 1/2\ P3rd \quad (4)$$

IP3 can be determined by applying 2 equal power monotones and measuring a fundamental power and a 3rd order power (either $2f_2-f_1$ or $2f_1-f_2$) at the output. Then apply these measured values to Equation 4. As always, it is important to ensure that unwanted spurious harmonics do not land on the 3rd order or fundamental frequencies. Also, the measurements should be made in a region clear of output compression.

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