Ricevitore e componenti non lineari

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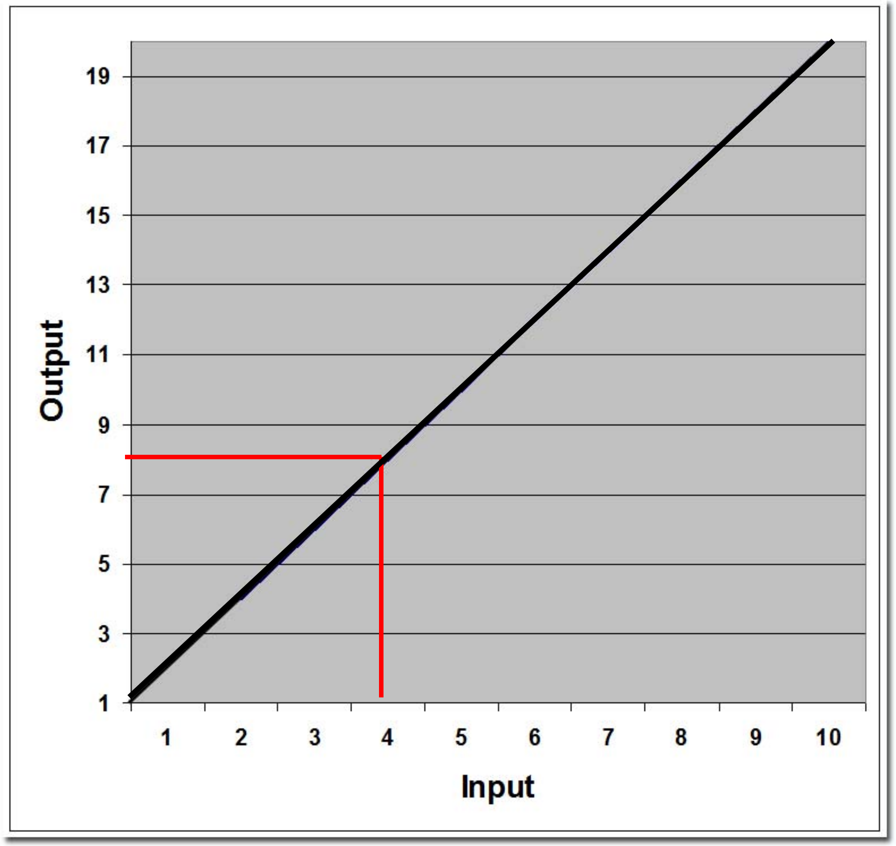
Linear Gain

$s_1(t) \longrightarrow y_1(t)$

$s_2(t) \longrightarrow y_2(t)$

$a_1 s_1(t) + a_2 s_2(t) \longrightarrow a_1 y_1(t) + a_2 y_2(t)$

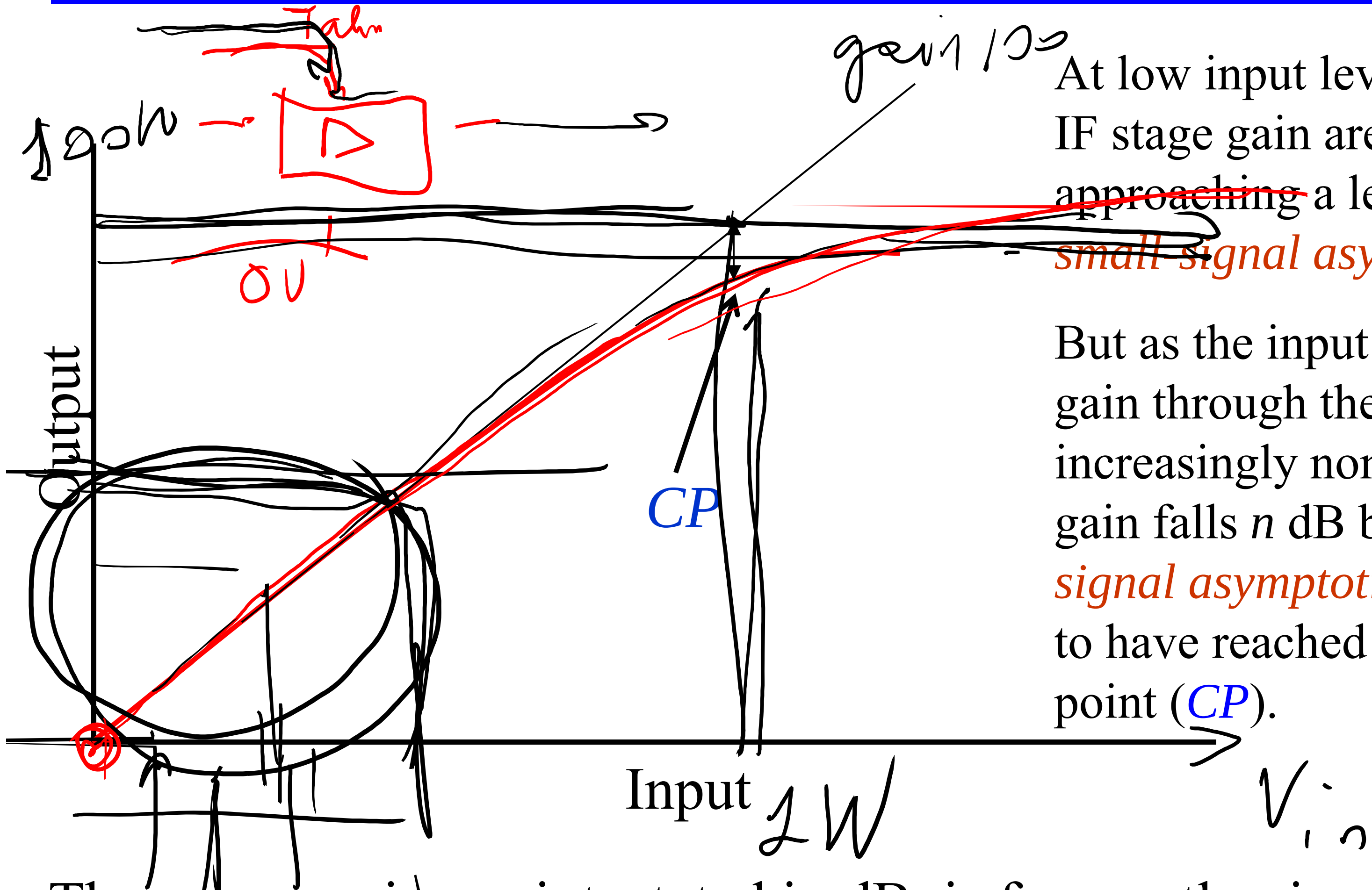


Linear gain in a circuit is normally represented by a straight line.

The scale on the Input and Output axis reflect the gain through the circuit. In this example, a gain of 2:1.

However, all RF & IF circuits are inherently nonlinear.

Gain and the Compression Point



At low input levels, receiver RF and IF stage gain are generally linear—~~approaching~~ a level called the *~~small-signal~~ asymptotic value.*

But as the input level increases, gain through the stage becomes increasingly nonlinear. When the gain falls *n* dB below the *small-signal asymptotic value*, it has said to have reached its compression point (*CP*).

The compression point, stated in dB, is frequently given as either 1 dB or 3 dB below the small-signal asymptotic value.

Why it is called 3rd order

$a_1 s_1(t) + a_2 s_2(t)$

$\Rightarrow A_2 a_1^2 s_1^2(t) + A_2 a_2^2 s_2^2(t) + A_2 2 a_1 a_2 s_1(t) s_2(t)$

The performance of an ideal amplifier can be represented by the transfer function:

$$\boxed{V_{out} = A_0 + A_1 V_{in}}$$

An amplifier with some distortion due to **nonlinearities** can be expressed by a transfer function in the form of a power series expansion:

dendw

$$V_{out} = A_0 + A_1 V_{in} + A_2 V_{in}^2 + A_3 V_{in}^3 + A_4 V_{in}^4 \ldots.$$

An input signal with two frequencies ω_1 and ω_2 may be shown as:

$$\boxed{V_{in} = V_1 \cos(\omega_1 t) + V_2 \cos(\omega_2 t)}$$

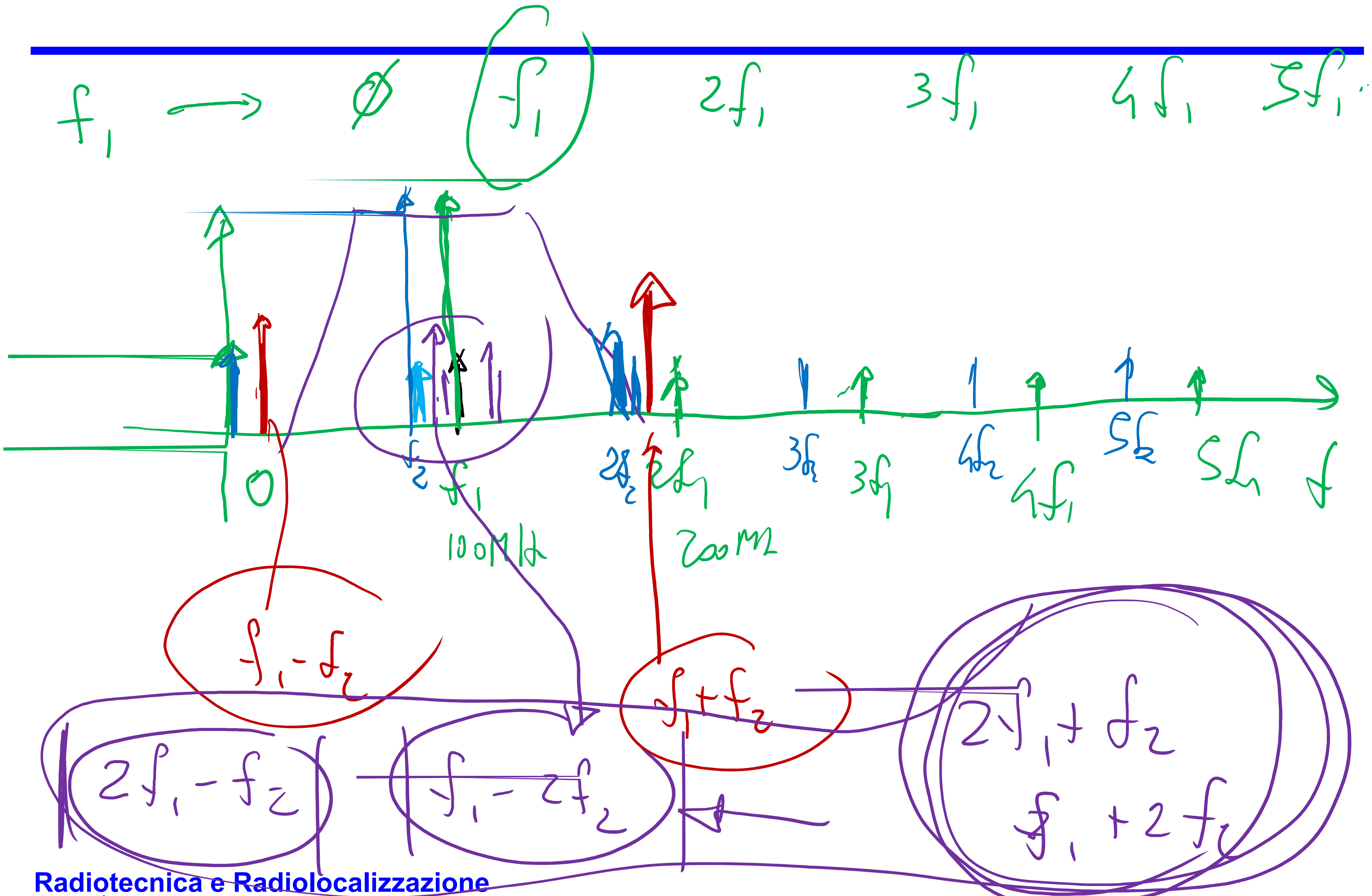
The **first** order term $A_0 + A_1 V_{in}$ gives the fundamental products

$$V_{out} = A_0 + A_1 V_1 \cos(\omega_1 t) + A_1 V_2 \cos(\omega_2 t)$$

The **second** order term $A_2 V_{in}^2$ determines the second order products:

$$A_2 V_{in}^2 = \frac{A_2 V_1^2}{2} + \frac{A_2 V_2^2}{2} + \frac{A_2 V_1^2}{2}\cos(2\omega_1 t) + \frac{A_2 V_2^2}{2}\cos(2\omega_2 t) + \frac{A_2 V_1 V_2}{2}[\cos(\omega_1 t + \omega_2 t) + \cos(\omega_1 t - \omega_2 t)]$$

DC terms   *2nd harmonic terms*   *2nd order IMD terms*


f1 → Ø f1 2f1 3f1 4f1 5f1
0
f2 f1
2f2 2f1
3f2 3f1
4f2 4f1
5f2 5f1
f
100MHz
200MHz
f1 - f2
f1 + f2
2f1 - f2
f1 - 2f2
2f1 + f2
f1 + 2f2

$V_1 = V_2$

Why it is called 3rd order (cont'd)

$A_1 V_1$ $A_1 V_2$

The **third** order term $A_3 V_{in}^{\ 3}$ determines the third order products:

$$A_3 V_{in}^3 = \frac{3A_3}{2}\left[V_1 V_2^2 + \frac{V_1^3}{2}\right]\cos(\omega_1 t) + \frac{3A_3}{2}\cos\left[V_1^2 V_2 + \frac{V_2^3}{2}\right]\cos(\omega_2 t) +$$

Fundamental frequency terms

$$\frac{A_3 V_1^3}{4}\cos(3\omega_1 t) + \frac{A_3 V_2^3}{4}\cos(3\omega_2 t) +$$

3rd harmonic terms

$$\frac{3A_3 V_1^2 V_2}{4}[\cancel{\cos(2\omega_1 t + \omega_2 t)} + \boxed{\cos(2\omega_1 t - \omega_2 t)}] + \frac{3A_3 V_1 V_2^2}{4}[\cancel{\cos(2\omega_2 t + \omega_1 t)} + \boxed{\cos(2\omega_2 t - \omega_1 t)}]$$

$\frac{3A_3 V_1^3}{4}$

3rd order IMD terms – The troublemakers

Nonlinearity and Intermodulation Distortion

- Nonlinearity in RF and IF circuits leads to two undesirable outcomes: harmonics and intermodulation distortion.
- Harmonics in and of themselves are not particularly troublesome.
- For example, if we are listening to a QSO on 7.230 MHz, the second harmonic, 14.460 MHz is well outside the RF passband.
- However, when the harmonics mix with each other and other signals in the circuit, undesirable and troublesome intermodulation products can occur.

Intermodulation Distortion Products: Example (I)

(1)	Fifth-Order	3f1-2f2	7.218
(2)	Third-Order	2f1-f2	7.221
(3)	**Signal One**	**f1**	**7.224**
(4)	**Signal Two**	**f2**	**7.227**
(5)	Third-Order	2f2-f1	7.230
(6)	Fifth-Order	3f2-2f1	7.233

Intermodulation Distortion Products: Example (II)

(1)	Fifth-Order	3f1-2f2	7.218
(2)	Third-Order	2f1-f2	7.221
(3)	**Signal One**		
(4)	**Signal Two**		
(5)	Third-Order		
(6)	Fifth-Order		

2f1 = 2 x 7.221 = 14.442

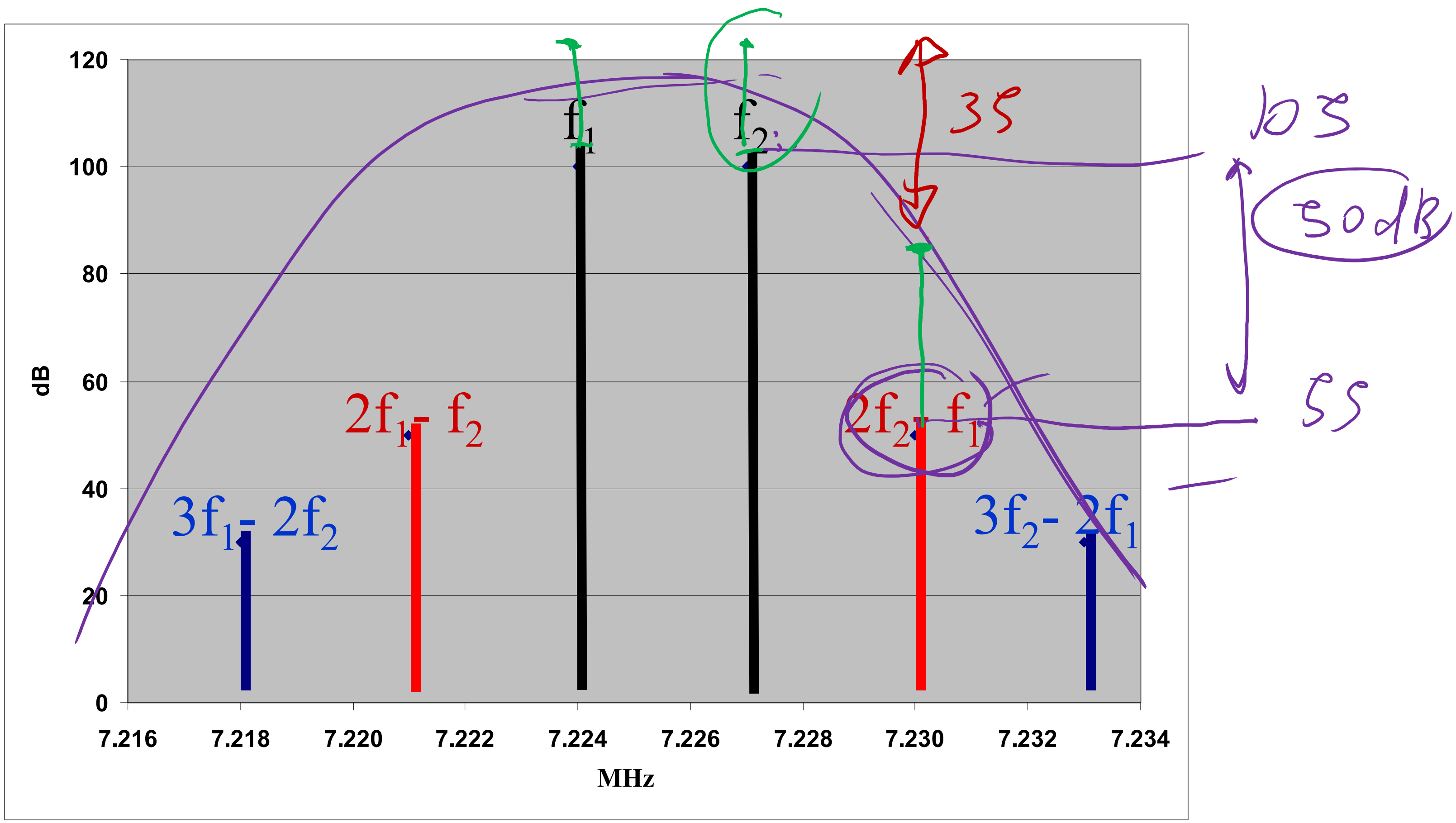
f2 = 7.227

14.442 - 7.227 = 7.221

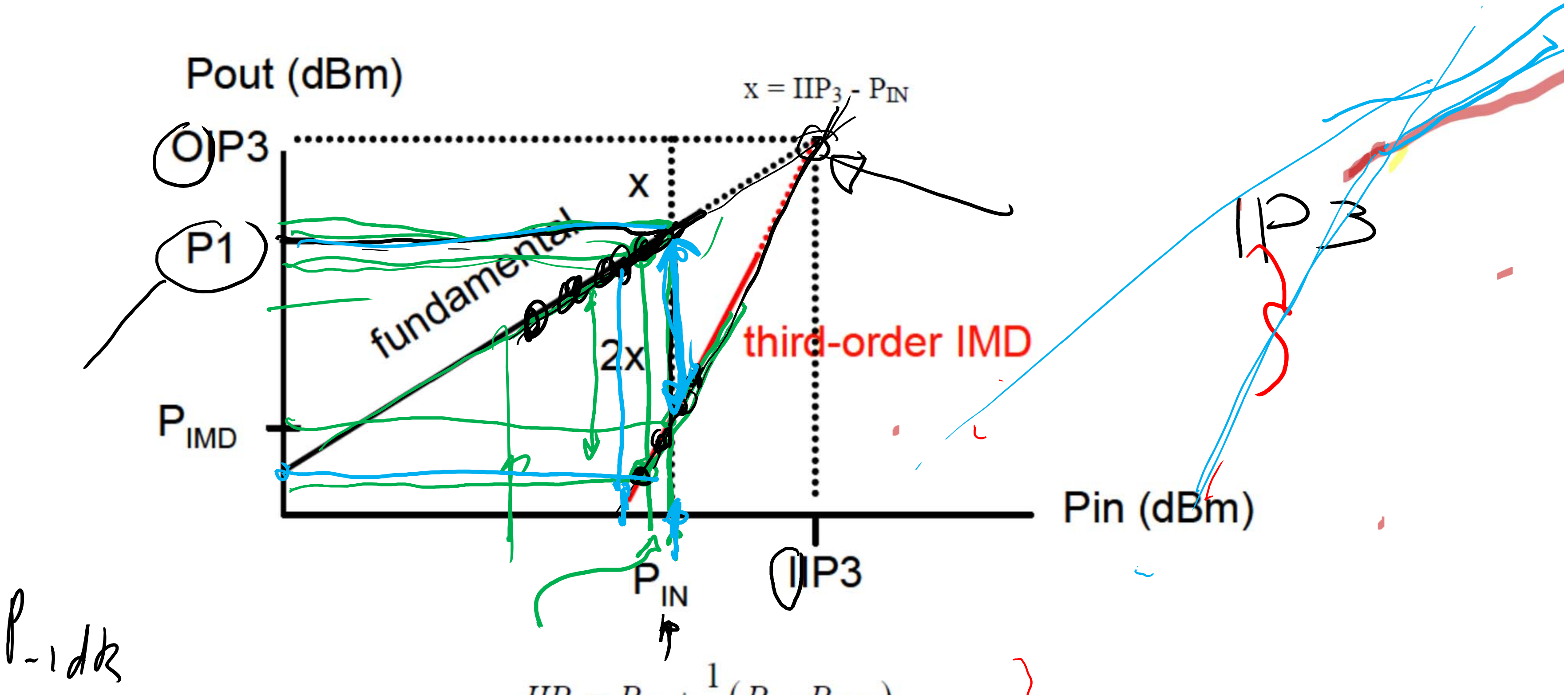
Intermodulation Distortion Products: Example (III)

(1)	Fifth-Order	3f1-2f2	7.218
(2)	Third-Order	2f1-f2	7.221
(3)	**Signal One**	**f1**	**7.224**
(4)	**Signal Two**	**f2**	**7.227**
(5)	Third-Order	2f2-f1	7.230
(6)	Fifth-Order	3f2-2f1	7.233

Intermodulation Distortion Products: Example (IV)

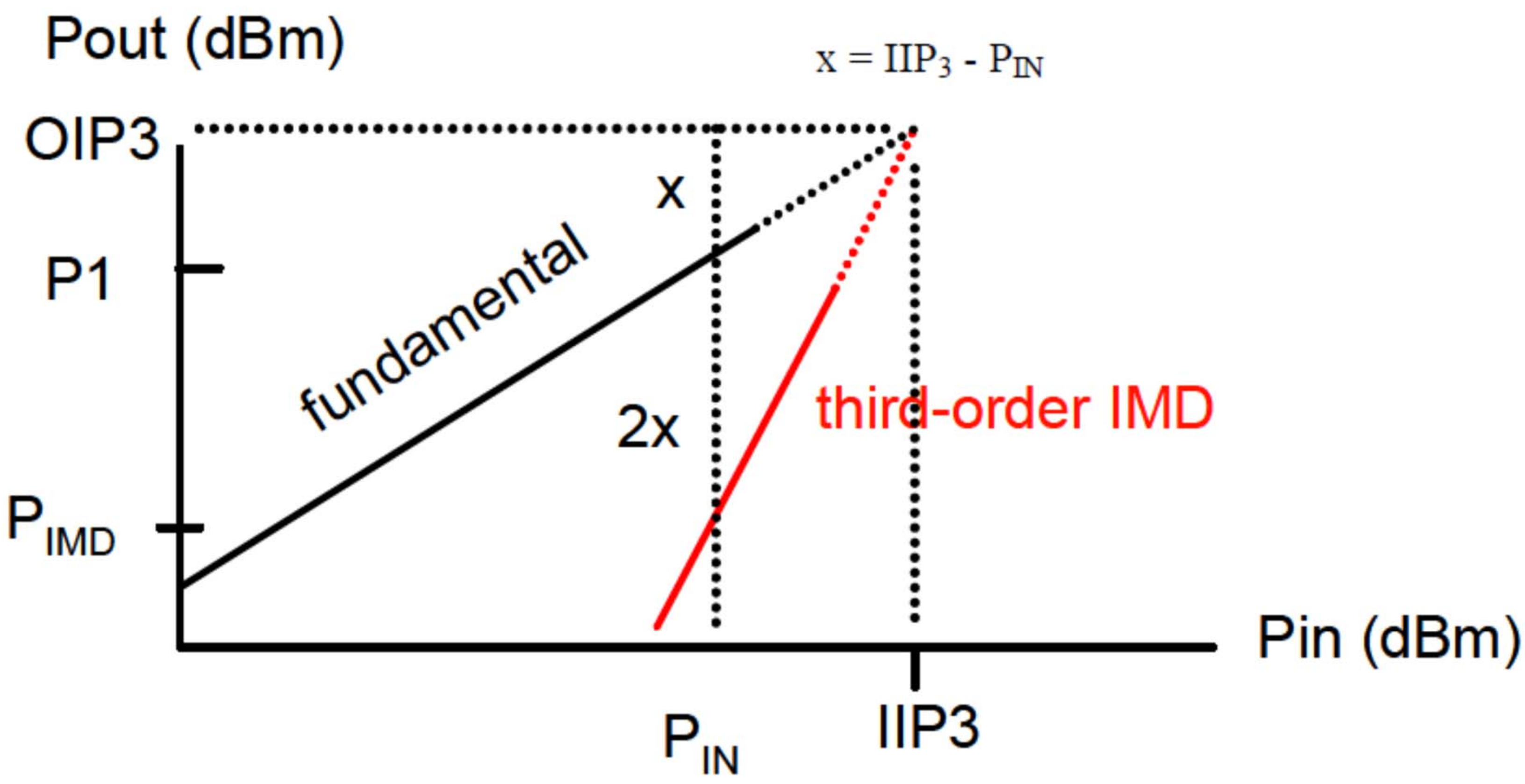


Spurious-Free Dynamic Range



$$IIP_3 = P_{IN} + \frac{1}{2}(P_1 - P_{IMD})$$

Spurious-Free Dynamic Range



- effetti di distorsioni lineari

- noise

- intermodulaz

- rumore di quantizzazione

Din. di 60 dB

IP3 for cascaded system

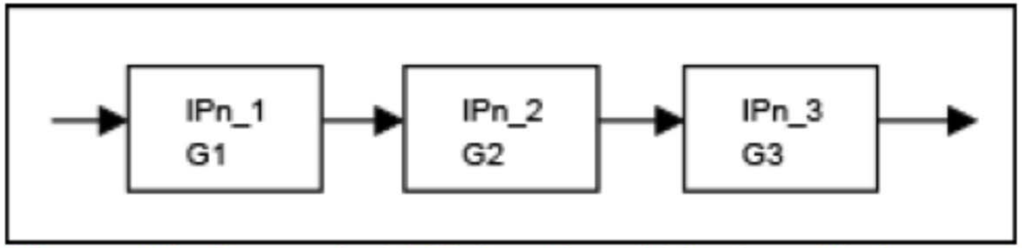


Figure 12. Cascaded RF functional blocks with known IPn.

The total gain of a cascaded structure is:

G = G1 × G2 × G3 (in linear)

or

g = g1 + g2 + g3 (in dB or dBm)

One can just use the equation, applied for three stages:

$$\left(\frac{1}{OIP_n}\right)TOT = \left(\frac{1}{OIP_{n\_1}} + \frac{G_2}{OIP_{n\_2}} + \frac{G_2 \times G_3}{OIP_{n\_3}}\right)$$

IP1=10 IP2=1000 G2=100

10

1/IP=1/10+100/1000=2/10

IF=5

1/IP=1/1000+100/10=10,001

IP=0.1