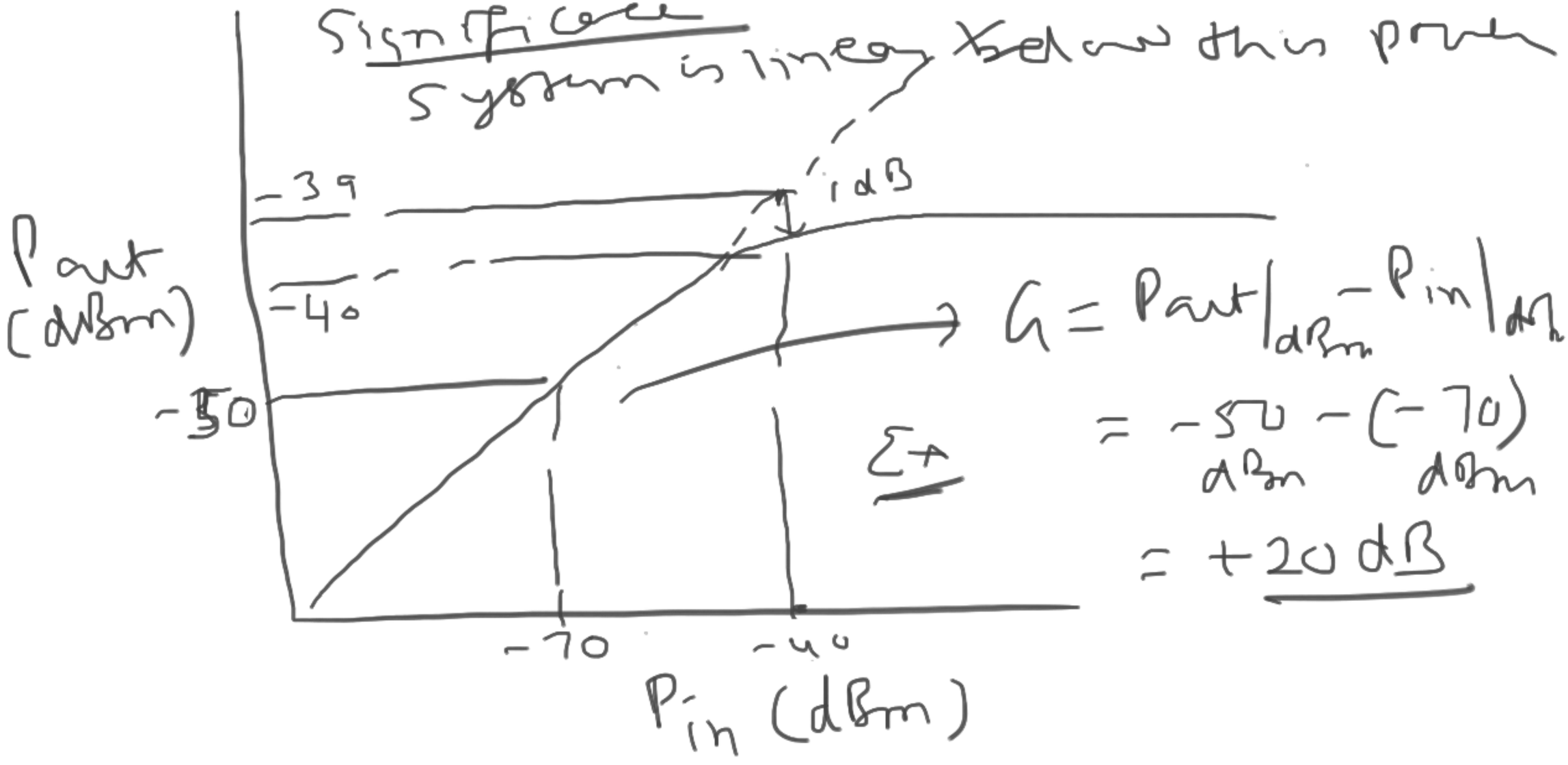
26/Feb/2021

P_{-1dB} (input power) = -40 dBm

Significance

System is linear below this point



$G = P_{out}|_{dBm} - P_{in}|_{dBm}$

$= -50_{dBm} - (-70)_{dBm}$

$= +20\ dB$

$$v_i = V_0 \cos \omega_0 t$$

$$v_0 = a_0 + a_1 v_i + a_2 v_i^2 + \cdots$$

$$\cos^2 \omega_0 t \Rightarrow \cos 2\omega_0 t$$

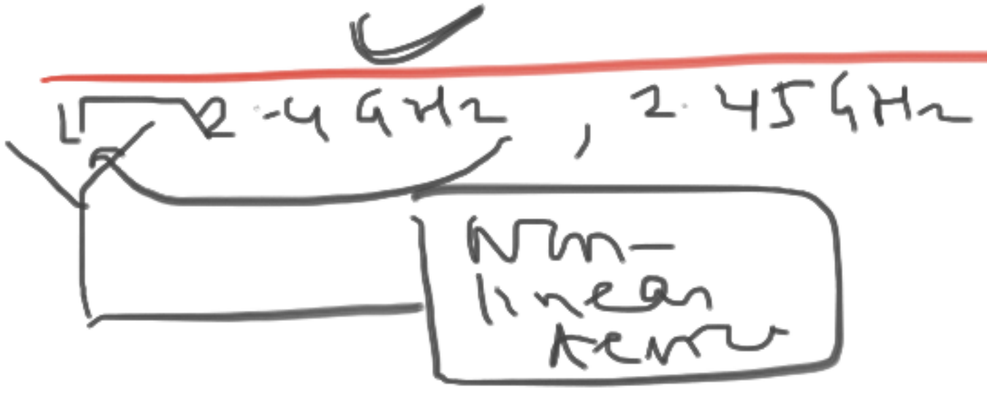
$$\cos 3\omega_0 t \rightarrow \cos 3\omega_0 t$$

$2\omega_0, 3\omega_0 \rightarrow$ harmonics

$0.25\omega_0, 0.5\omega_0 \rightarrow$ sub-harmonics

Harmonic Distortion

Inter-Modulation Distortion (IMD)



$$v_i = V_0(\cos\omega_1 t + \cos\omega_2 t) \quad \text{— (1)}$$

$\omega_1 \rightarrow$ desired ; $\omega_2 (\approx \omega_1) \rightarrow$ some other freq (not desired)

Assume both have same amplitude (V_0)

$$v_o = a_0 + a_1 v_i + a_2 v_i^2 + a_3 v_i^3 + - \text{ —} \quad \text{— (2)}$$

Substitute (1) in (2)

$$v_0 = a_0 + a_1 V_0 (\cos\omega_1 t + \cos\omega_2 t) +$$

$$a_2 V_0^2 (\cos\omega_1 t + \cos\omega_2 t)^2 +$$

$$a_3 V_0^3 (\cos\omega_1 t + \cos\omega_2 t)^3 + \cdots \quad (3)$$

using $\cos^2\theta = \frac{1}{2}(1 + \cos 2\theta)$, $\theta = \omega t$

in (3), $\cos^3\theta = \frac{1}{4}(3\cos\theta + \cos 3\theta)$,

$\cos\theta_1 \cos\theta_2 = \frac{1}{2}[\cos(\theta_1 + \theta_2) + \cos(\theta_1 - \theta_2)]$

$$\Rightarrow v_0 = a_0 + a_1 V_0 \cos\omega_1 t + a_1 V_0 \cos\omega_2 t + \frac{1}{2} a_2 V_0^2 (1+\cos 2\omega_1 t) + \frac{1}{2} a_2 V_0^2 (1+\cos 2\omega_2 t) + a_2 V_0^2 \cos(\omega_1-\omega_2)t + a_2 V_0^2 \cos(\omega_1+\omega_2)t$$

$$+ a_3 V_0^3 \left(\frac{3}{4}\cos\omega_1 t + \frac{1}{4}\cos 3\omega_1 t\right) +$$

$$a_3 V_0^3 \left(\frac{3}{4}\cos\omega_2 t + \frac{1}{4}\cos 3\omega_2 t\right) +$$

$$a_3 V_0^3 \left[\frac{3}{2}\cos\omega_2 t + \frac{3}{4}\cos(2\omega_1-\omega_2)t + \frac{3}{4}\cos(2\omega_1+\omega_2)t\right.$$

$$+ a_3 V_0^3 \left[\frac{3}{2}\cos\omega_1 t + \frac{3}{4}\cos(2\omega_2-\omega_1)t + \frac{3}{4}\cos(2\omega_2+\omega_1)t\right.$$

$$+ - - - - - - -$$

ω_1 = desired

4

In Eqn (4) above, o/p spectrum consists of harmonics of the form

$$mw_1 \pm nw_2$$

where $m = 0, \pm 1, \pm 2, \pm 3, \ldots$

↳ This combination of two input frequencies (w_1, w_2) are called intermodulation (IMD) products (cross-products)

Order of IMD product = $|m| + |n|$

order=1 : ω_1 , ω_2 (2 nos)

$(|m|+|n|=1)$

$m=1, n=0$ ✓ $m=0, n=1$ ✓

order-2 : $2\omega_1 \Rightarrow m=2, n=0$

$2\omega_2 \Rightarrow m=0, n=2$

$\omega_1-\omega_2 \Rightarrow m=1, n=-1$

$\omega_2+\omega_2 \Rightarrow m=1, n=1$

(4 nos)

$(|m|+|n|=2)$

order-3 : $3\omega_1 \Rightarrow m=3, n=0$

$3\omega_2 \Rightarrow m=0, n=3$

$2\omega_1+\omega_2 \Rightarrow m=2, n=1$

$2\omega_2+\omega_1 \Rightarrow m=1, n=2$

$2\omega_1-\omega_2 \Rightarrow m=2, n=-1$

$2\omega_2-\omega_1 \Rightarrow m=-1, n=2$

(6 nos)

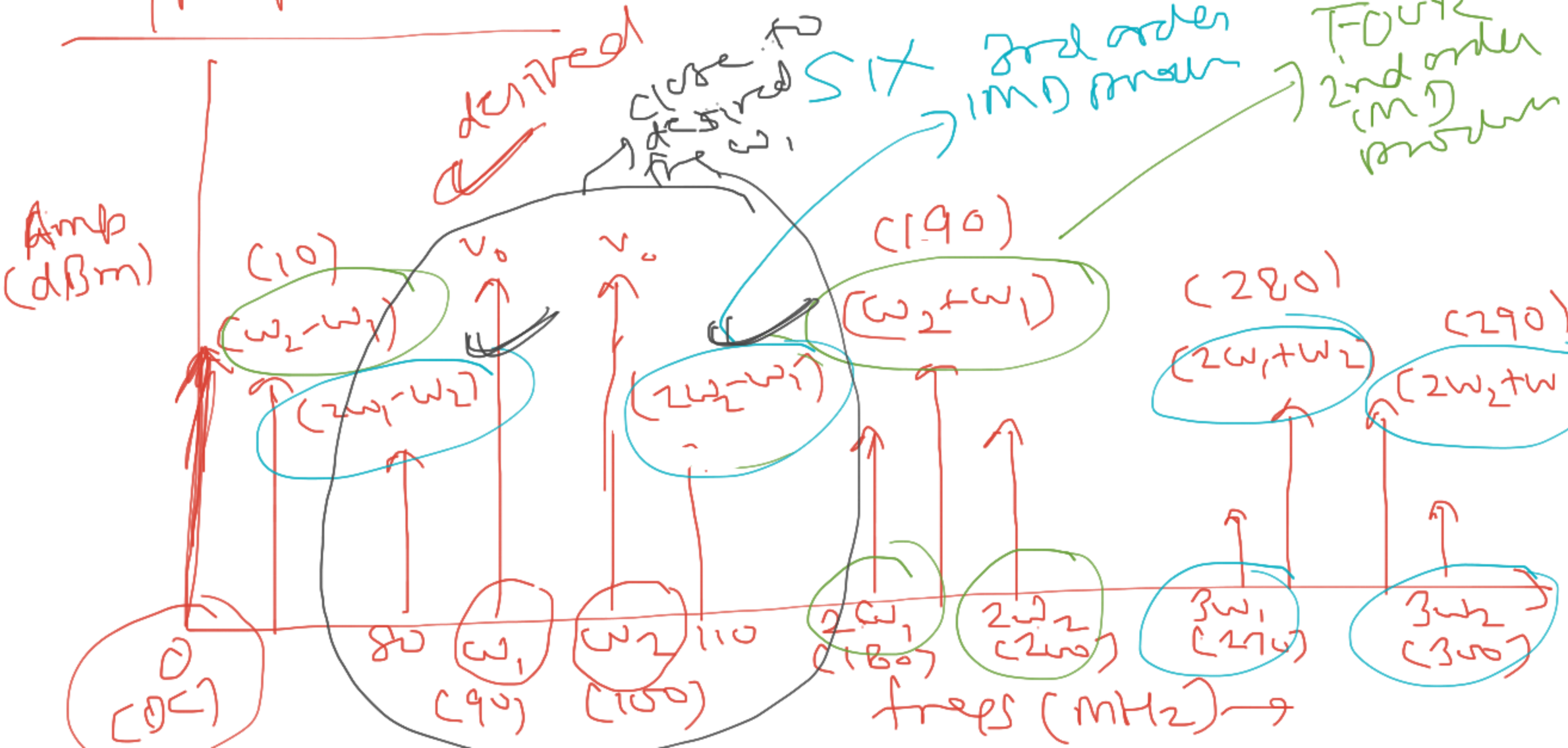
$(|m|+|n|=3)$

+ − − −

+ DC term

Example : $\omega_1 = 90$ MHz (derived)
$\omega_2 (> \omega_1) = 100$ MHz

O/p Spectrum



Freqs $(2\omega_1 - \omega_2)$ or $(2\omega_2 - \omega_1)$

$\downarrow$ $\delta\upsilon$ $\qquad$ $\downarrow$ $\delta\upsilon$

Two 3rd order IMD products are very serious for us in design

2nd order products are not serious because they can be easily filtered out

3rd order Intercept Point (IP_3)

(IIP_3)

($IIIP_3$)

↓

after Mid-sem Exams

↓

Tuesday

Thu 4/3/2025 at 2pm (Exam (mid-sem)) → 1 hr (2-15 - 3:15 pm)

→ MCQs (jumbled Qs | optics) — 4 mks

→ 50% weightage (25 Qs x 2 marks)

— 0.5 mark for wrong answer

→ No calculators

→ °C → K

→ till today's lecture

→ lecture notes (more than sufficient)

20 dBm = 100 mW

100 mW = 20 dBm

0 dBm = 1 mW = -30 dBW

10^{-3} W

$10\log(100) = 10 \times 2 = 20$ dBm