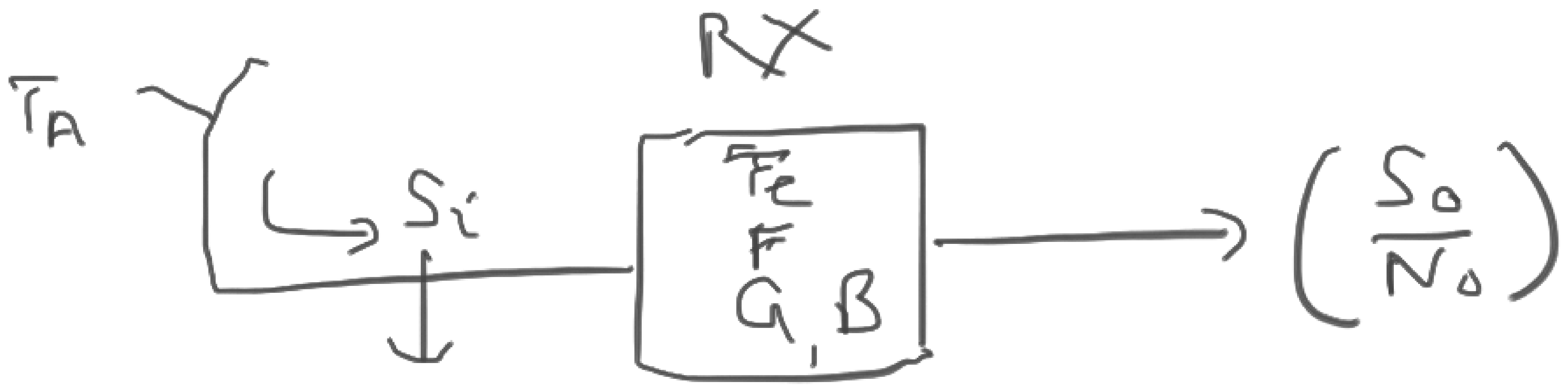
24 Feb 2021

MDS (Minimum Detectable Signal) or Sensitivity



$S_{i\,min}$ (MDS) $= ?$

B = bandwidth

$$S_{i_{min}} = \frac{S_{o_{min}}}{G} \qquad [\because S_o = G \cdot S_i]$$

$$= \frac{N_o}{G}\left(\frac{S_o}{N_o}\right)_{min} \qquad [\text{multiplied \& divided by } N_o]$$

N_o = input noise amplified (from antenna) + noise added because of device & amplified (RX)

$$N_o = kT_A BG + kT_e BG$$

$$\therefore S_{i_{min}} = \frac{kB\cancel{G}(T_A + T_e)}{\cancel{G}} \cdot \left(\frac{S_o}{N_o}\right)_{min}$$

$$\boxed{\underset{(MDS)}{S_{i_{min}}} = kB\left[T_A + T_e\right]\left(\frac{S_o}{N_o}\right)_{min}}$$

$$\boxed{\text{''} = kB\left[T_A + (F-1)T_o\right]\left(\frac{S_o}{N_o}\right)_{min}}$$

$$\because T_e = (F-1)T_o$$

$$k \to 1.38\times10^{-23}\ \frac{J}{K}$$

$$kTB = \frac{J}{\cancel{K}} \cdot \cancel{K} \cdot \frac{1}{sec} = \frac{J}{sec} = \text{watts}$$

$$\downarrow$$

$$mW$$

$$S_{i_{min}}(\text{dBm}) = 10\log(kT_A) + 10\log B + NF(\text{dB}) + \left(\frac{S_o}{N_o}\right)_{min}\Big|_{dB}$$

Ex: Satellite RX

$T_A = 400\,K$

$T_o = 17^{o} = 290\,K$

$NF = 8\,dB = 6.3$

$B = 30\,kHz = 30\times10^3$

$\left(\frac{S_o}{N_o}\right)_{min}$ reqd $= 15.5$ (factor)

$$S_{i_{min}} = kB\left[T_A + (F-1)T_o\right]\left(\frac{S_o}{N_o}\right)_{min}$$

$$= 1.38\times10^{-23}\times30\times10^3\times\left[900+(6.3-1)290\right]\times15.5$$

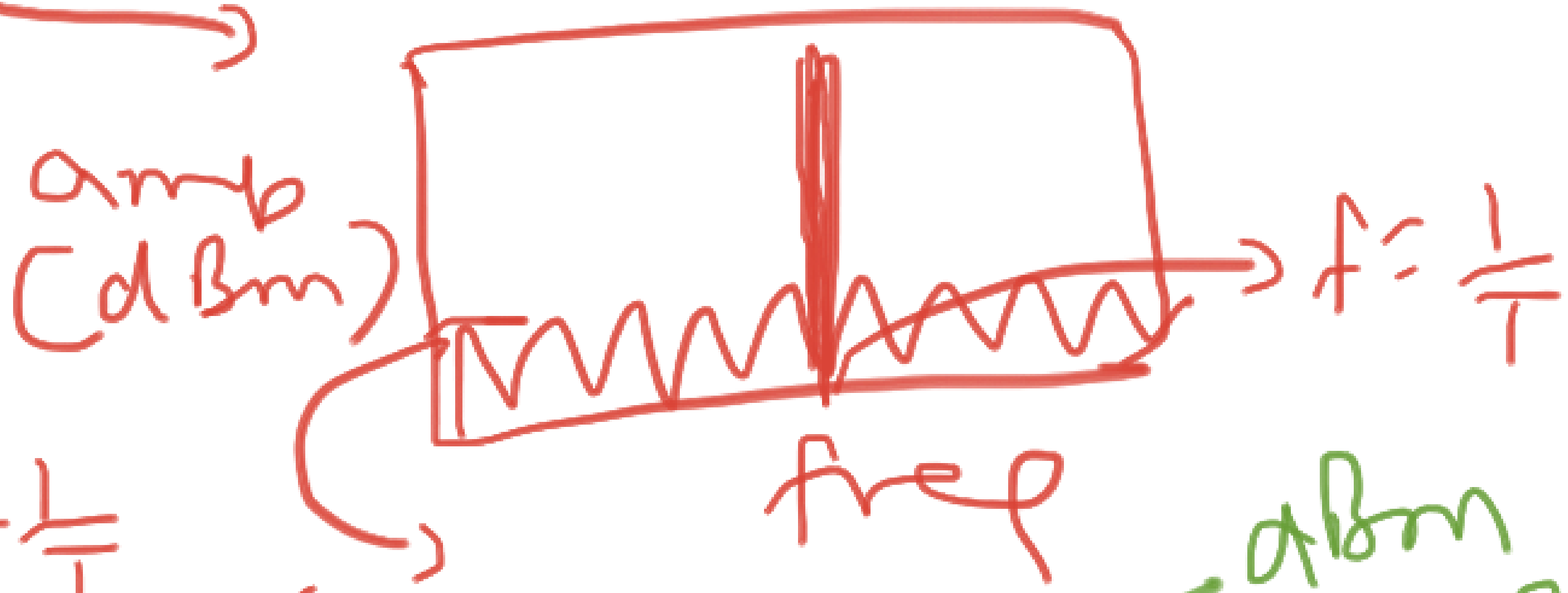
$$= 1.57\times10^{-14}\,(W) = 1.57\times10^{-11}\,mW$$

$$S_{i_{min}} = 10\log(1.57\times10^{-11}) = \underline{-108\,dBm}$$

Practical measurement of MDS (TSS = Tangential Signal Sensitivity)

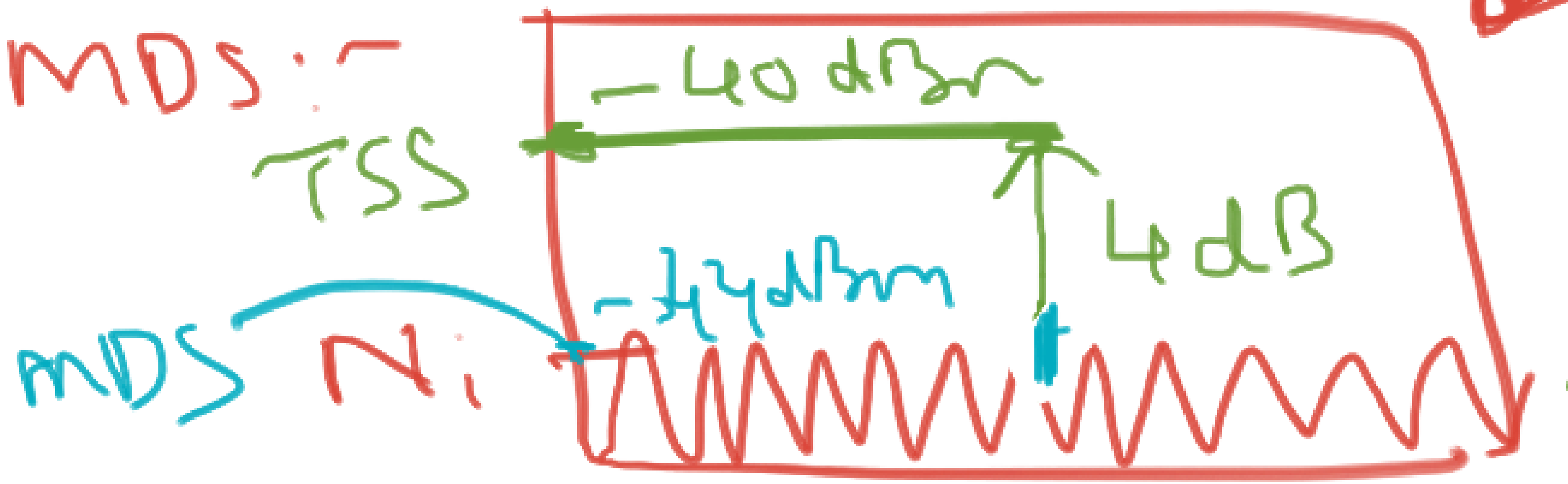
Spectrum Analyzer → freq domain input

oscilloscope → time " "



noise

$N_i = kT_oB \rightarrow$ dBm



$$\boxed{TSS = MDS + 4\,dB}$$

$-40\,dBm = MDS + 4\,dB$

$MDS = -44\,dBm$

Dynamic Range (DR) → dB

ratio of min power to max power

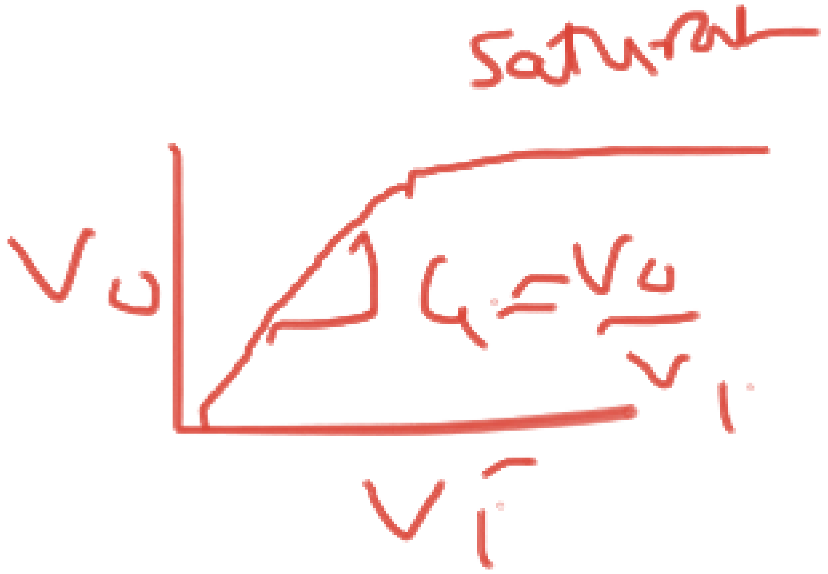
10 mW   100 mW

$\frac{100}{10} = 10$

100 → max power

10 → min power

$10\log(10) = 10\,\text{dB}$



10 dBm   20 dBm

10 dB

Every device is non-linear

R, L, C — $V \neq IR$ (ohm's law) not valid

KVL, KCL → " "

1

$$v_o = a_0 + a_1 v_i + a_2 v_i^2 + a_3 v_i^3 + \dots$$

(Taylor's series).

$a_0, a_1, a_2, \dots$ Taylor's coefficients

Spl cases : **A** only $a_0 \neq 0$

$a_1, a_2, \ldots = 0$

(rectifier)

Eqn 1 : $v_0 = a_0$

ac i/p → dc o/p

B only $a_1 \neq 0$; $a_0, a_2, \ldots = 0$

$= \left.\dfrac{dv_0}{dv_i}\right|_{v_0=0}$ (linear o/p)

Eqn 1 : $v_0 = a v_i$

= linear amp (if a +ve, gain)

" attenuator (if a −ve, loss)

(C) $a_2 \neq 0 = \frac{d^2 v_0}{d v_0^2}\Big|_{v_0=0}$

$a_0, a_1, a_3, \ldots = 0$

squared o/p (mixer)

$$\boxed{v_0 = a_0 + a_1 v_i + a_2 v_i^2 + a_3 v_i^3 + \ldots} \quad (1)$$

$$\cancel{v_0 = a v_i}$$

Gain Compression

$$v_i = V_0 \cos \omega_0 t \quad (2) \qquad , \quad \omega_0 = 2\pi f_0 t$$

v_i → ac i/p or (RF i/p)

V_0 → DC amplitude

f_0 → driving freq (f0)

Substitute (2) in (1),

$$v_0 = a_0 + a_1 V_0 \cos \omega_0 t + a_2 V_0^2 \cos^2 \omega_0 t$$
$$+ a_3 V_0^3 \cos^3 \omega_0 t + \cdots$$

$$\Rightarrow v_0 = a_0 + a_1 V_0 \cos\omega_0 t + \frac{1}{2}a_2V_0^2 + \frac{1}{2}a_2V_0^2\cos 2\omega_0 t + \frac{3}{4}a_3V_0^3\cos\omega_0 t + \frac{1}{4}a_3V_0^3\cos 3\omega_0 t + \cdots$$

$$\cos^2\theta = \frac{1}{2}(1+\cos 2\theta),\ \theta = \omega_0 t$$

$$\cos^3\theta = \frac{3}{4}\cos\theta + \frac{1}{4}\cos 3\theta,\ \theta = \omega_0 t$$

$$\Rightarrow v_o = \underline{\left(a_0 + \tfrac{1}{2} a_2 V_0^2\right)} + \quad \rightarrow \text{dc (offset)}$$

$$\left(a_1 V_0 + \tfrac{3}{4} a_3 V_0^3\right) \underline{\cos \omega_0 t} \quad +$$

$$\tfrac{1}{2} a_2 V_0^2 \cos \underline{2\omega_0} t \quad +$$

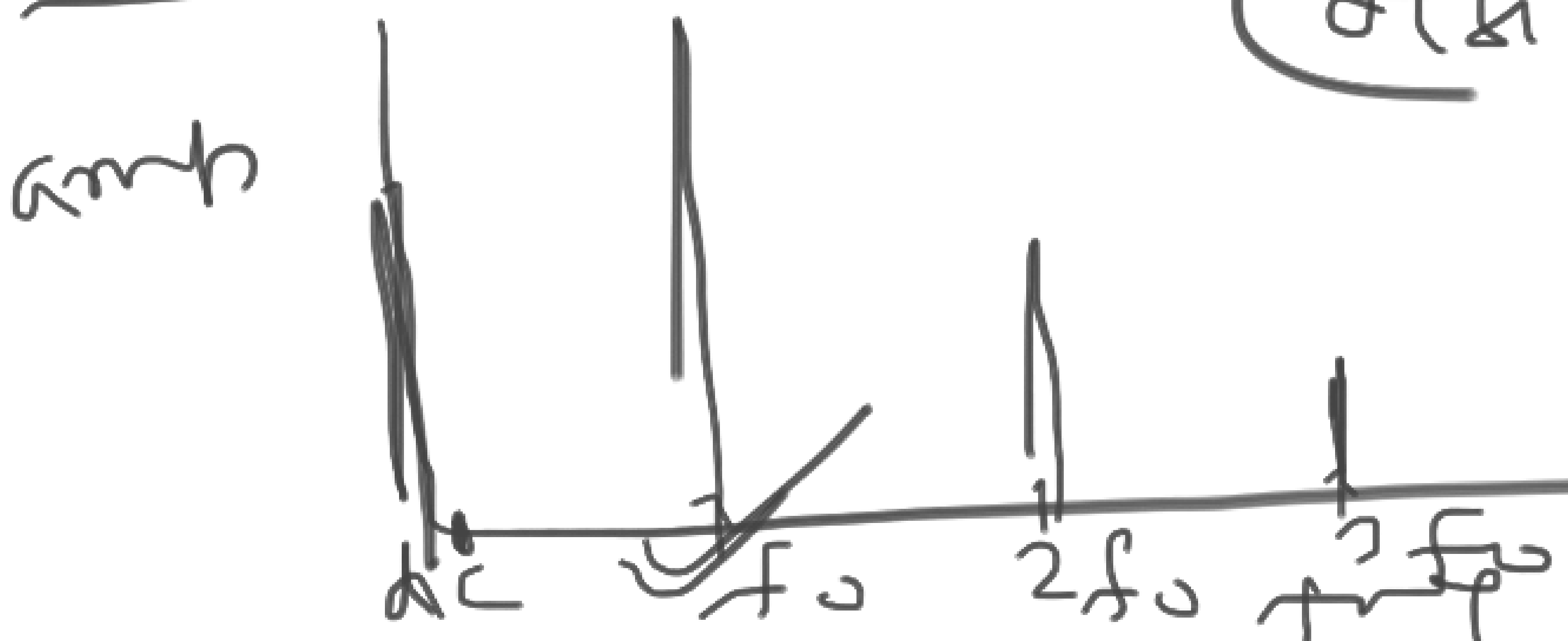
$$\tfrac{1}{4} a_3 V_0^3 \cos \underline{3\omega_0} t \quad + \cdots \qquad (3) \text{ Eqn}$$

→ **Harmonics** (because of non-linearity) – undesirable

(because of signal)

Harmonic Distortion

Spectrum Analyzer



Distortion → because of signal

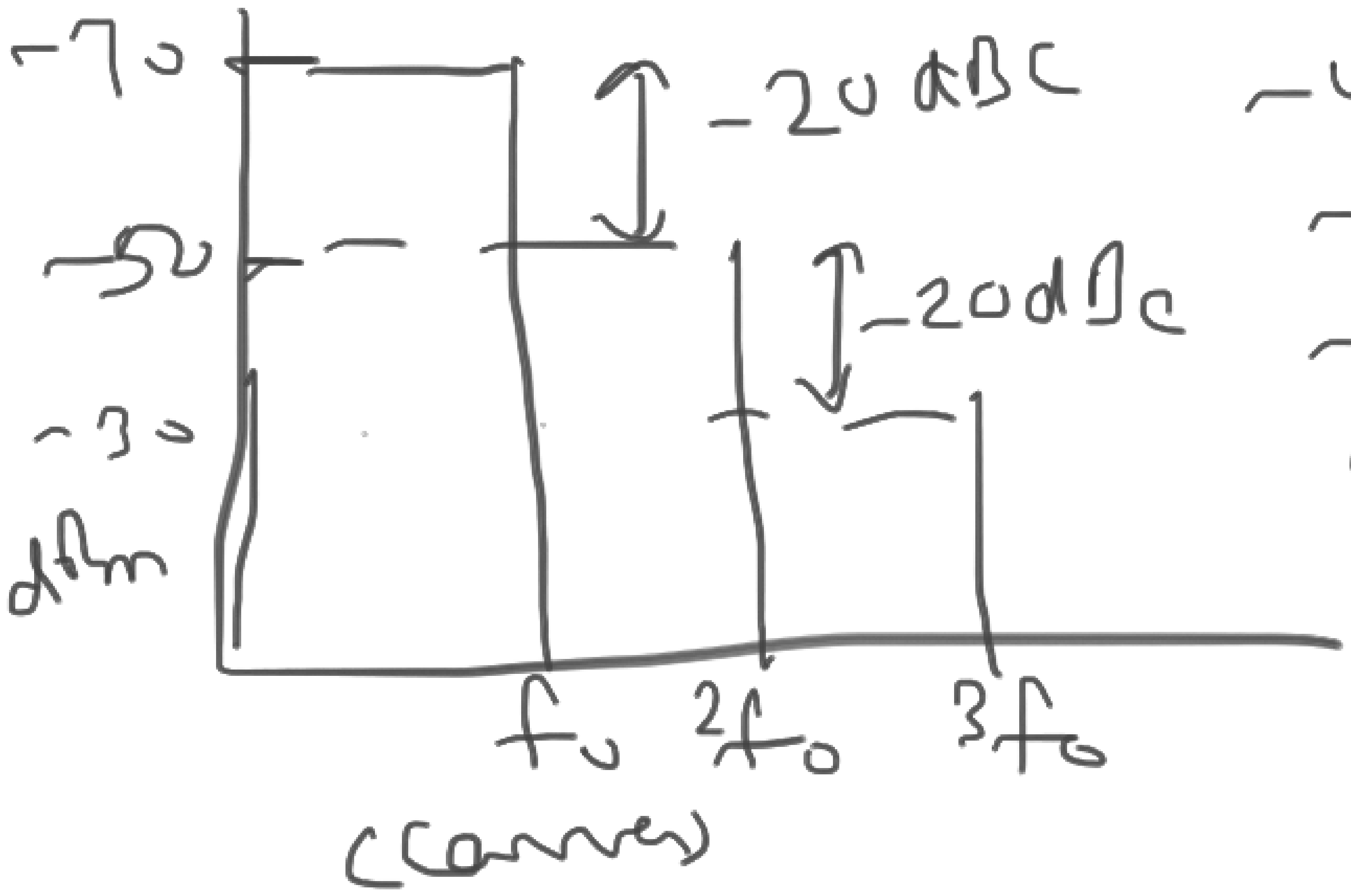
SINAD → $\dfrac{S}{I + N + D}$

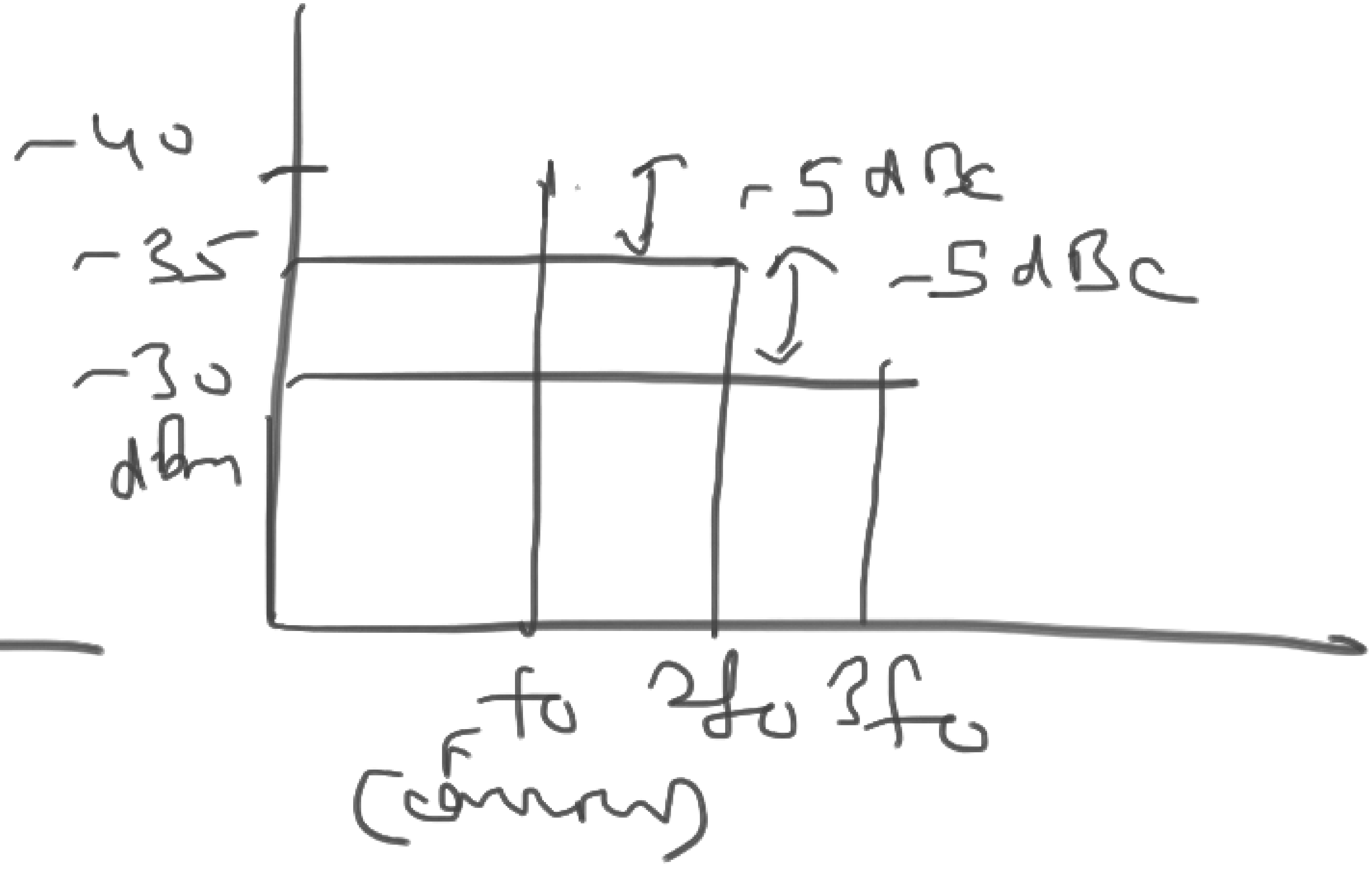
S → Signal

D → Distortion

I → Interference

N → Noise





Gain (G_v) = $\dfrac{v_o(\omega_o)}{v_i(\omega_o)}$ at desired freq
(voltage)

$\omega_o = 2\pi f_o$

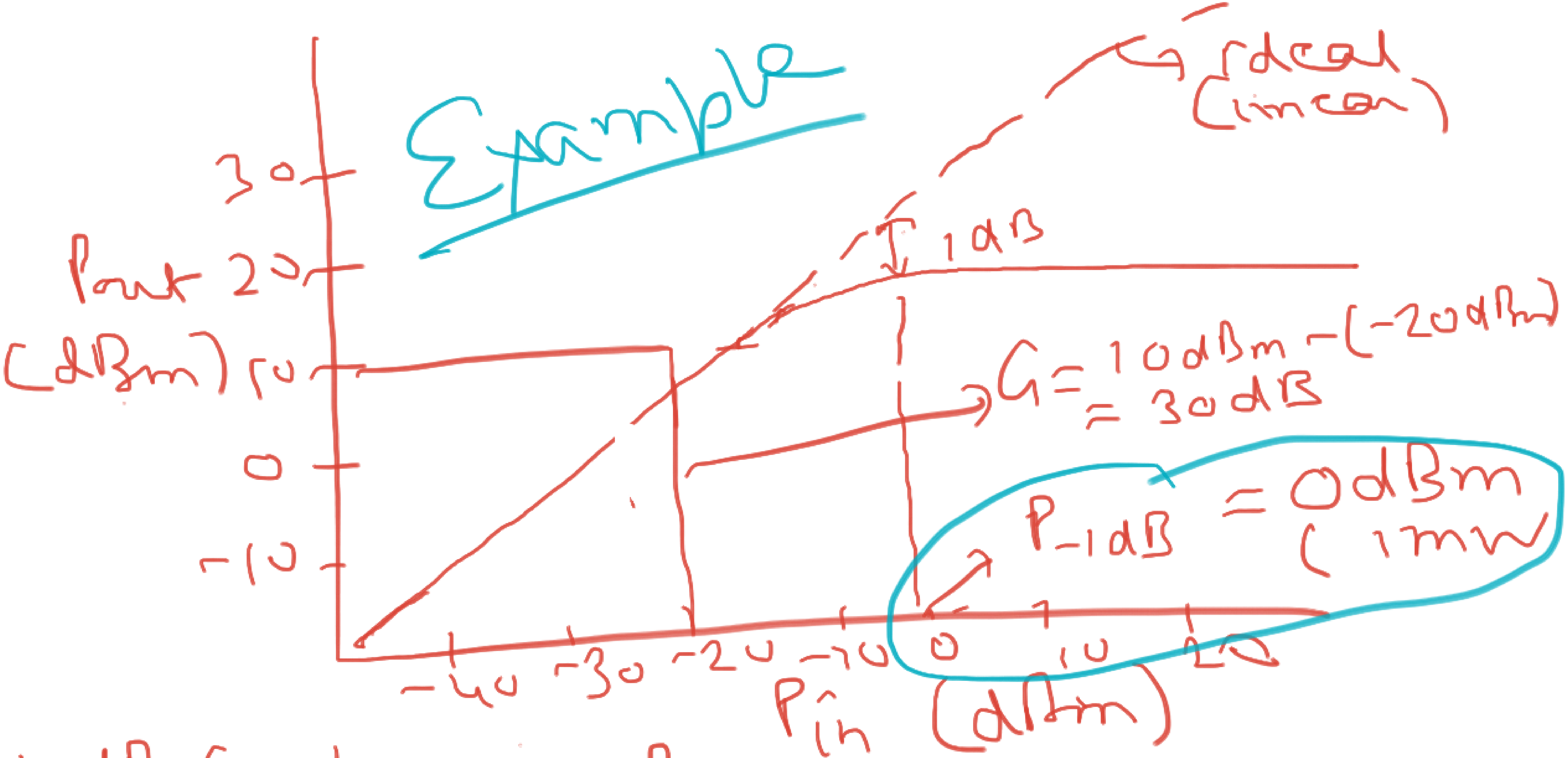
$$= \frac{a_1 V_o + \frac{3}{4} a_3 V_o^3}{V_o}$$ → from 1 → from 2

$$\boxed{G = a_1 + \frac{3}{4} a_3 V_o^3}$$ → $G = a_1$ (Basic electronics)

Typically, a_3 is −ve

[instantaneous o/p voltage of amplifier is limited by power supply voltage]

G_3 is -ve → gain compression



1 dB Compression Point $= P_{-1dB}$

1 dB compression Point (P_{-1dB})

It is the input power at which o/p power is compressed by 1 dB from its ideal characteristic

units of dBm (~~dB~~)

Two devices

$P_{-1dB} = 10\ mW = 10\ dBm$ (active)

$P_{-1dB} = 1\ mW = 0\ dBm$ (saturate)

(5 mW)

Significance: upto what power, device is linear