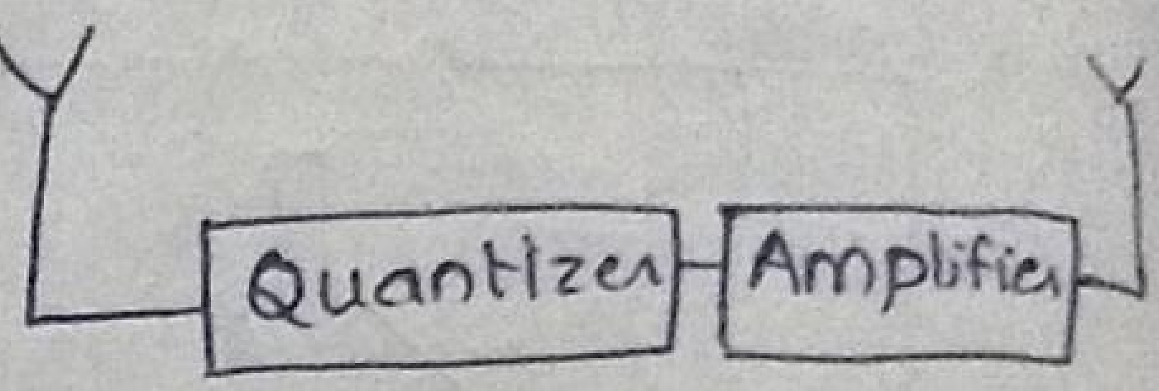
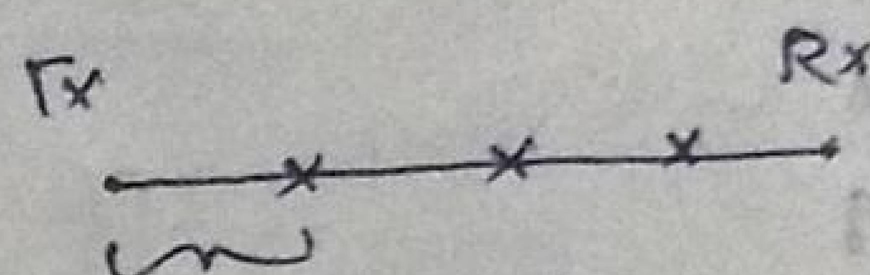
→ Problems (2) {4, 5}

→ Repeater :- Repeater is used to improve S/N ratio.

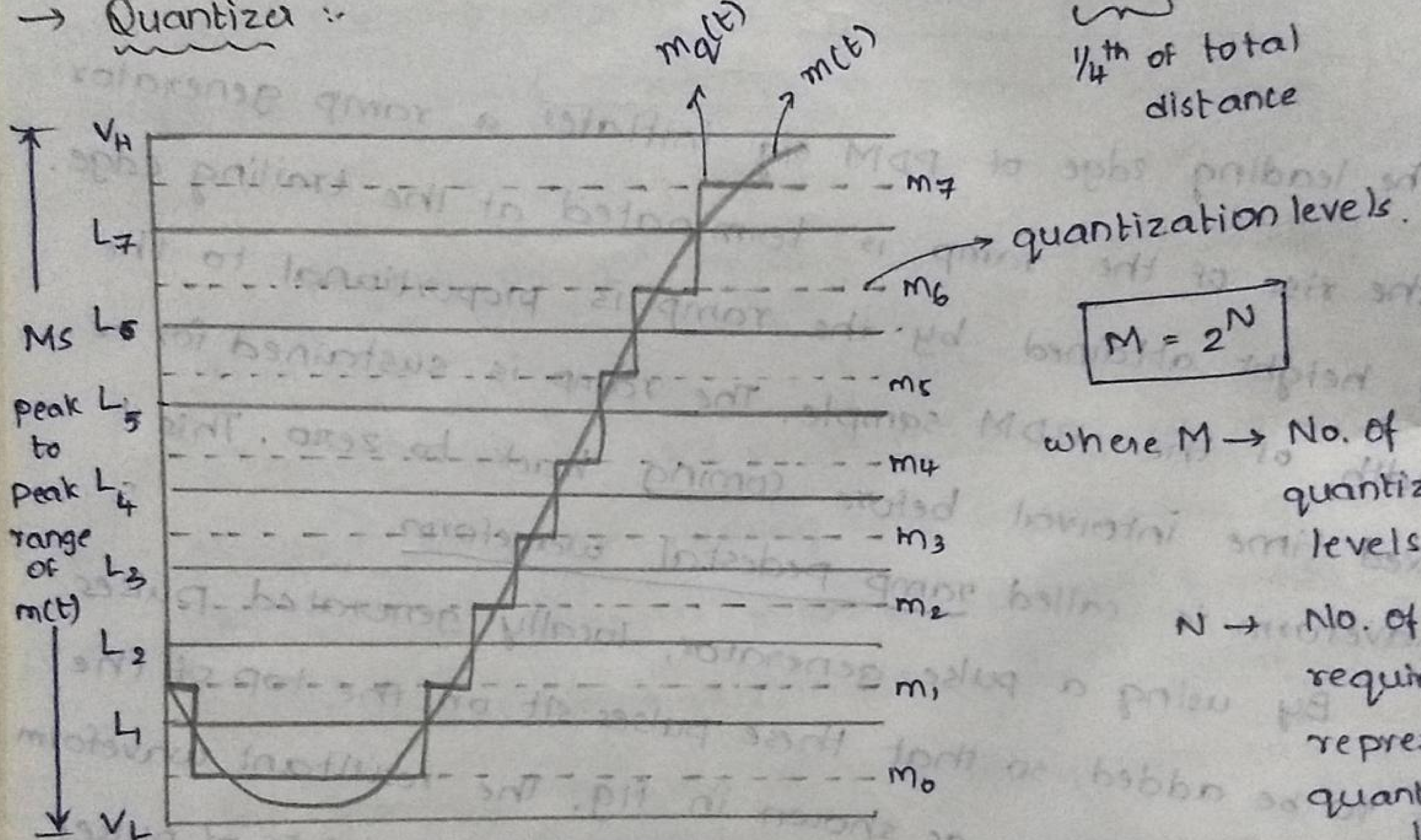
Quantizer is used to reduce the noise of small amplitudes. Thus Finally the repeater can increase s/g power or s/g strength.



Hardware of repeater



→ Quantizer :-



$$\boxed{M = 2^N}$$

where M → No. of quantization levels

N → No. of bits required to represent quantization level

step size, $\boxed{S = \frac{V_H - V_L}{M}}$

Quantization error, e(t) $e(t) =$ $\boxed{m(t) - m_q(t) = e(t)}$

where m(t) is original s/g

$m_q(t)$ is quantized s/g

For uniform quantizer, mean square quantization error is

$$\boxed{\overline{e^2(t)} = \frac{S^2}{12}}$$

$\left\{ N_q \propto e(t) \propto S \propto \frac{1}{M} \right\}$

∴ In order to reduce the error, the step size 's' should be reduced, so that we have to select large value of M.

$\{ e\downarrow \Rightarrow S\downarrow \Rightarrow M\uparrow \}$

→ Quantization error derivation.

→ Problems (3) { repeaters calculation. 6, 9 }

→ Note :- As long as the noise has an instantaneous amplitude $< S/2$, the noise will not appear at the o/p. But if this noise exceeds $S/2$, an error in level will occur.

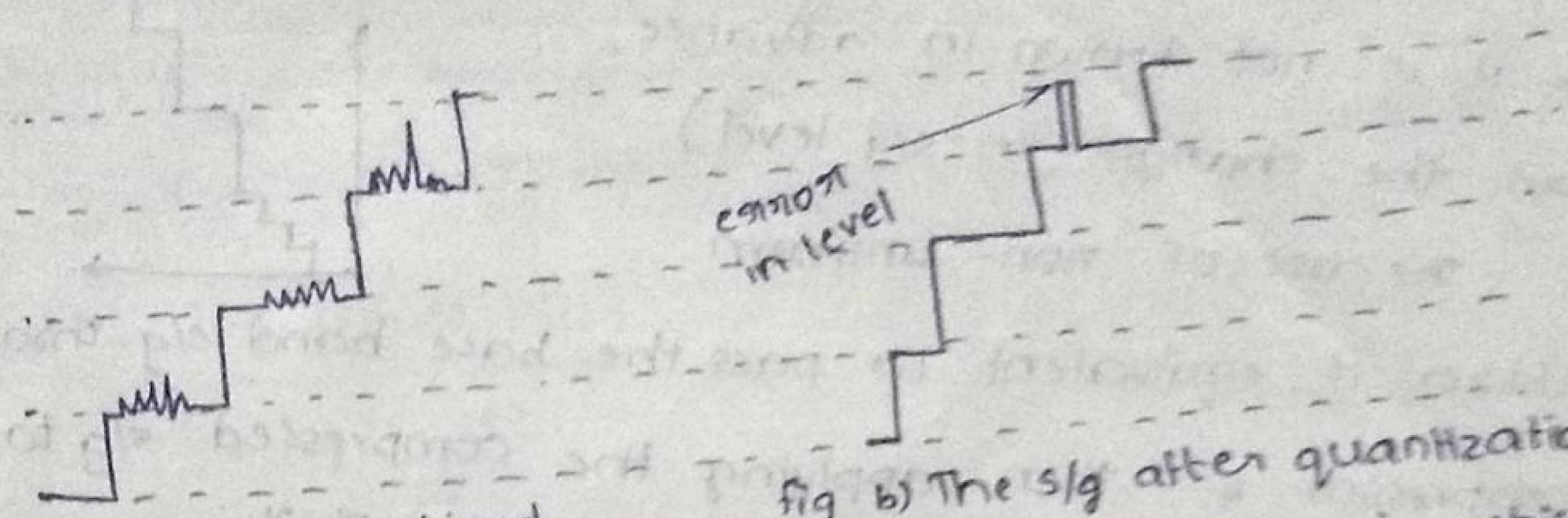


fig a) A quantized s/g with added noise.

fig b) The s/g after quantization, one instance is recorded in which the noise level is so large that an error results.

→ Quantization error

→ Companding :-

The difference b/w the original s/g & quantized s/g may be viewed as quantization noise & is called quantization error.

$$e(t) = m(t) - m_q(t)$$

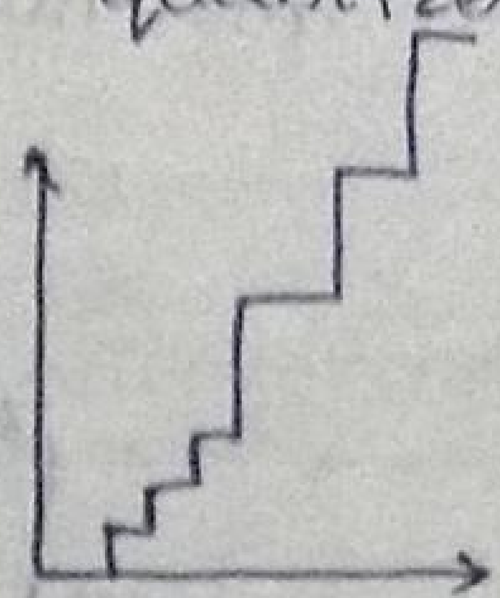
Mean-square quantization error :- $\overline{e^2(t)} = \frac{S^2}{12}$

This error results in quantization noise (N_q)

$\therefore N_q \propto S$ where S is step size. Therefore in order to reduce the quantization error, the step size must be as low as possible. This can be achieved by increasing no. of quantization levels 'M'.

In most cases, volume of human speech is very low & in very rare cases, the volume is high. The range of voltages covered by voice s/gs from the peak of loud s/gs to the peak of weak s/gs is in the order of 1000 to 1.

By using a uniform quantizer, since the step size is fixed, Nq is same for every quantized s/g level which gives rise to low avg SNR. So in order to improve avg SNR, we use non-uniform quantizer which increases the step size for s/gs of large amplitude, while it decreases the step size for s/gs of small amplitudes. But in practice, it is difficult to implement the non-uniform quantizer (since it is not known in advance, about the changes in s/g level)



The use of non-uniform quantizer is equivalent to pass the base band s/g through a compressor & then applying the compressed s/g to a uniform quantizer.

This compressed & quantized s/g is Txed through a channel & this compression produces s/g distortion. To undo this distortion at the Rxer, the recovered s/g is passed through an expander n/w. An expander n/w has an i/p - o/p characteristic which is the reverse of the characteristic of compressor. Finally, an o/p s/g is generated without distortion due to this reverse characteristics of compressor & expander.

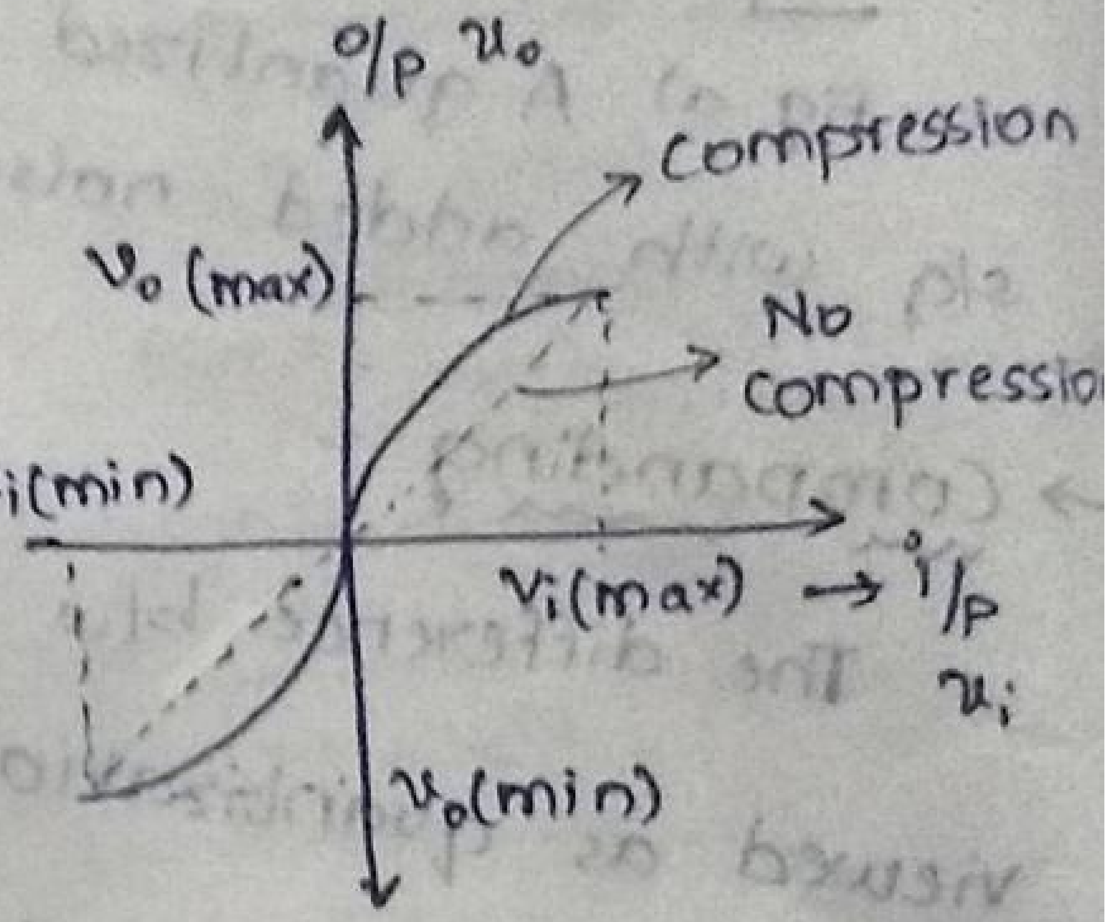


fig :- An i/p - o/p characteristic which provides compression.

From above fig., slope is larger at low amps than at larger amplitudes.

Thus the compression of s/g at the Txer & expansion at Rxer is called companding.

From fig 2), for small amplitude s/gs there is great improvement in SNR, but for large amp s/gs over a slight range

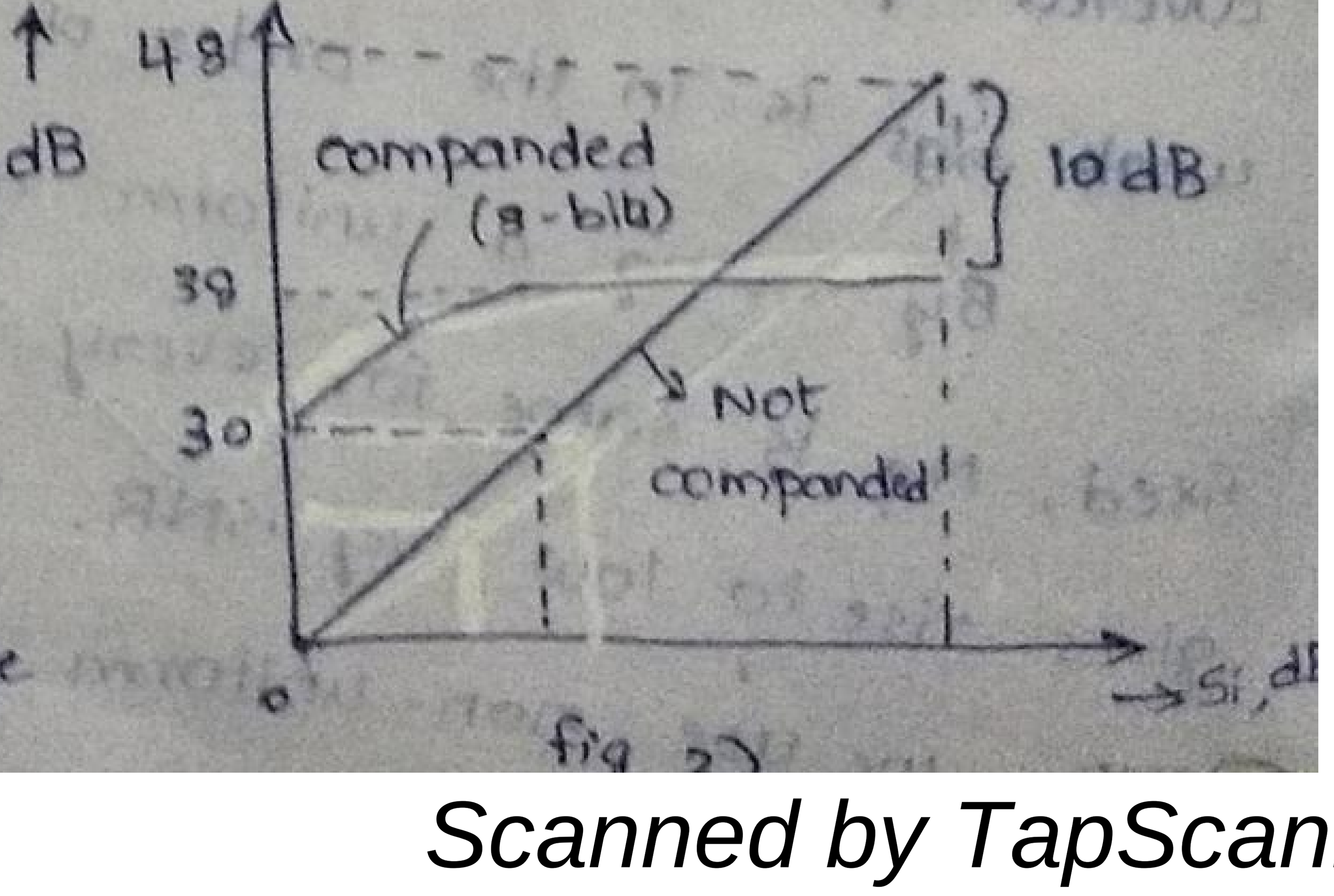


fig 2)

at peak s/gs, a slight reduction in SNR is observed.

A particular form of compression laws are in use, the following expressions specifies μ-law & A-law compression techniques.

<u>μ-law</u> (U.S., Canada, Japan)

$$|v_o| = \frac{\log(1+\mu|v_i|)}{\log(1+\mu)}$$

<u>A-law</u> (rest of world)

$$|v_o| = A|v_i| \quad ; \quad 0 \le |v_i| \le \frac{1}{A}$$

$$= \frac{1+\log(A|v_i|)}{1+\log A} \quad ; \quad \frac{1}{A} \le |v_i| \le 1$$

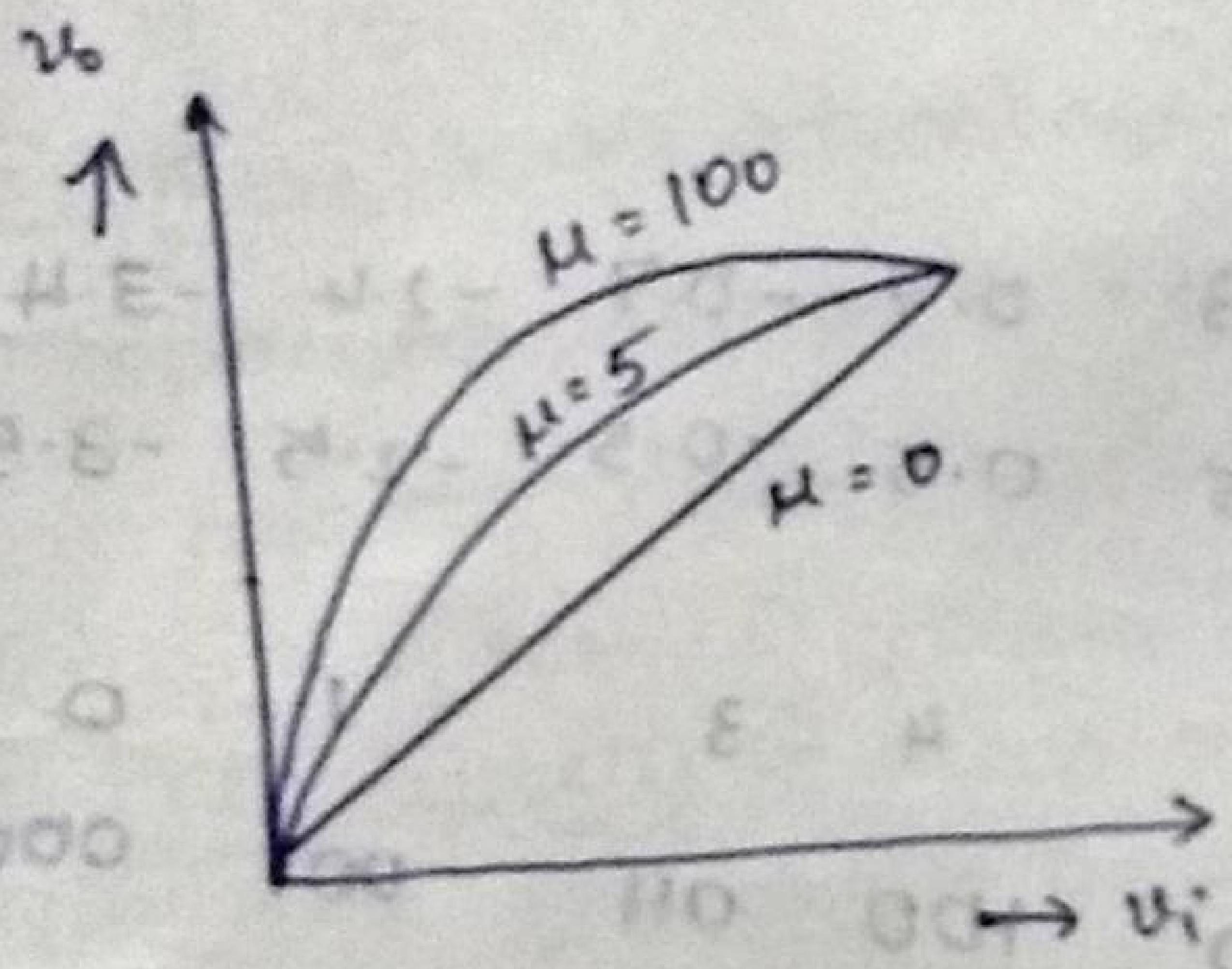


fig :- compressor characteristic of μ-Law compressor.

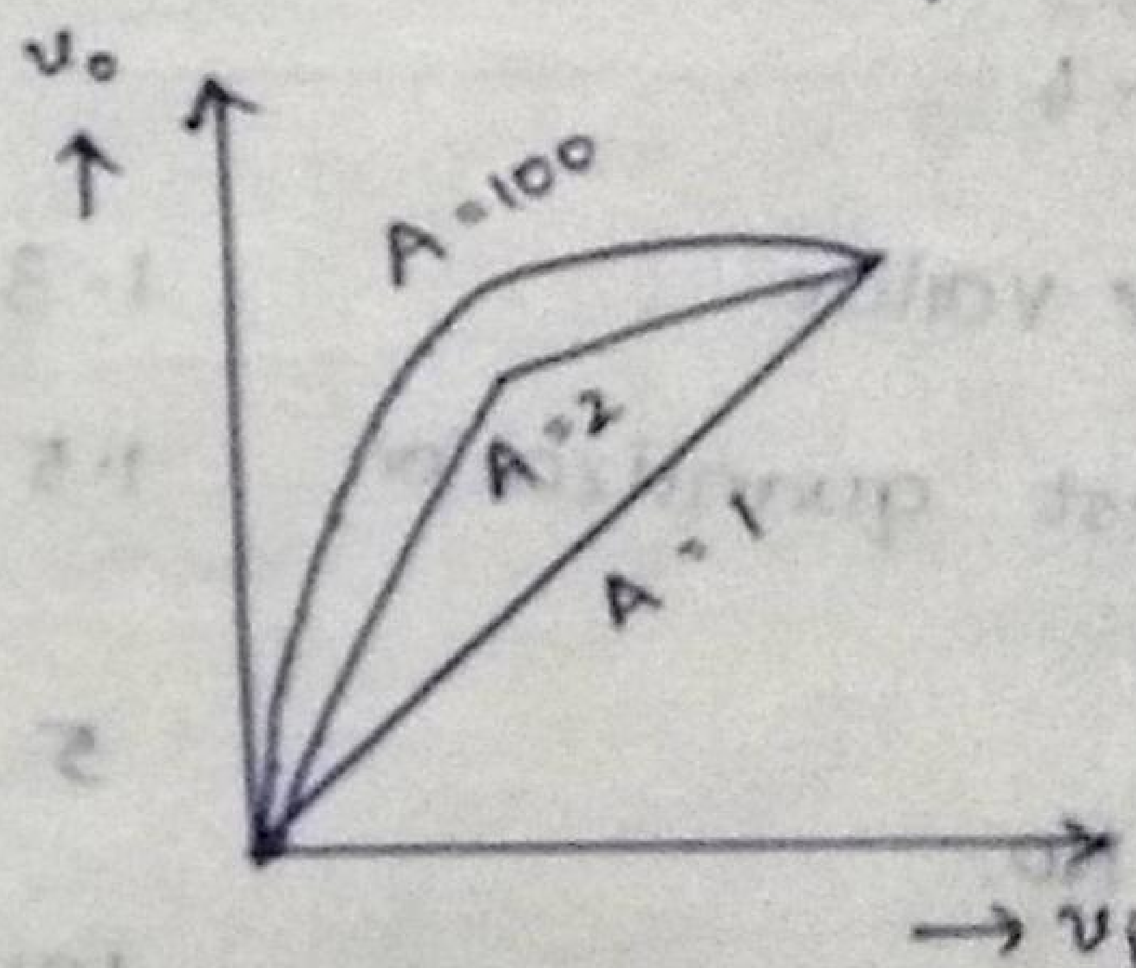


fig :- compressor characteristic of A-law compressor

This law is used in US, Canada, Japan.

This law is not used in US, Japan & Canada & used in rest of the world.

If the s/g is compressed at Txer, then it is expanded at the Rxer. Then the combination of compression & expansion is called companding.

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