Chapter 4

As a solution Quantizing was introduced. That is, instead of sending the actual sample, first the sampled signal was put into a known number of levels, which is informed to the receiver.

Suppose instead of sending a whole range of voltages, Robot 1 informs Robot 2 that it is going to send only 4 voltage levels, say 0-3V. For example if the sample is 2.7V, first, Robot 1 will convert it into a 3V sample. Then it will be sent through the transmission medium. Robot 2 at the receiving end gets a sample of 3.3V. Then immediately he knows that this is not an agreed level, hence the sent value has been changed. Robot 2 converts 3.3V sample back into a 3V.

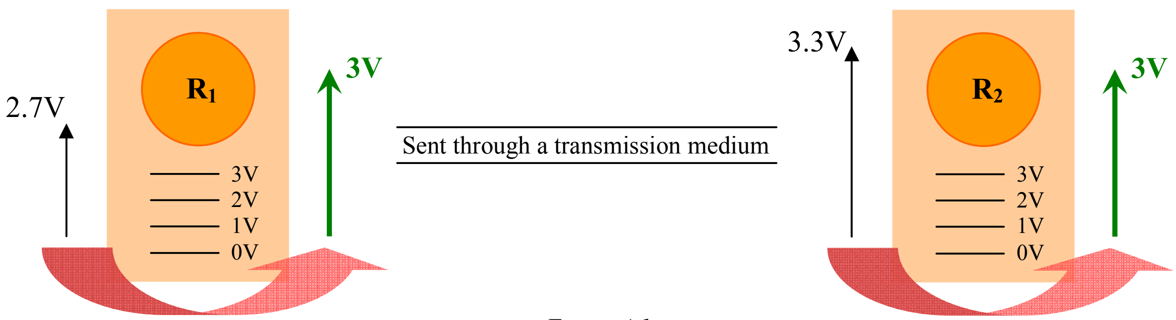


Figure 4.1

There are two types of Quantizing :-

I. Linear Quantizing
II. Non-linear Quantizing

Linear Quantizing

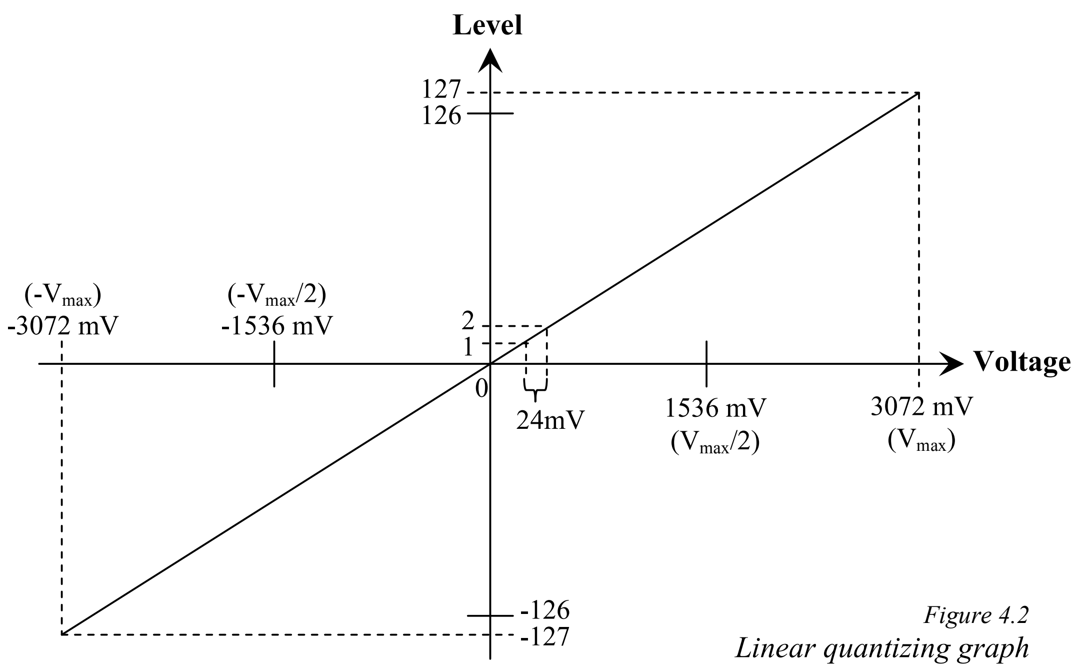


Figure 4.2
Linear quantizing graph

In the Linear quantizing graph each voltage level consists of (3072 / 128 =) 24mV. Therefore any value that has to be quantized is put into the nearest multiple of 24.

Take the example of 22mV. It has to be quantized as a 24mV, as 24mV is the nearest multiple. Take 3022mV.

Calculating the level	=	3022 / 24
	=	125.9
	=	level 126
Quantized value	=	126 x 24
	=	3024 mV

Therefore 3022mV is sampled as a 3024mV.

The quality of voice transmission is measured by signal to noise ratio. That is the division of the original signal value by the change made when quantizing.

$$\frac{S}{N} = \frac{\text{Value of the original signal}}{\text{Noise Introduced}}$$

The following S/N ratios were calculated using the above values.

Sample voltage which has to be sent	**Quantized Signal**	**Noise**	**S/N Ratio**
22 mV	24 mV	***2mV***	22/2 = 11
3022 mV	3024 mV	***2mV***	3022/2 = 1511

Linear quantizing is not used. Why….?

It is noticeable that even though the noise is the same for both these signals the S/N ratio is highly different. It seems that Linear Quantizing gives high S/N ratios for high signals and low S/N ratios for low signals.

There is another disadvantage in using Linear Quantizing. That is, according to CCITT experiments 90% of voice signals lie between $\pm V_{max}/2$. In order to give high S/N ratios for the range of $\pm V_{max}/2$, different ranges of voltages should be given to each level. In the Linear Quantizing graph, the voltage range is 24mV between any two successive levels. Therefore the small signals are not supported with.

Hence linear quantizing does not serve the purpose.

Non-Linear Quantizing

The main aim for using the non-linear graph is to have a good S/N ratio. In order to do so the gradient of the curve between $\pm V_{max}/2$ should be changed. Then the voltage ranges will not be the same like in the linear graph. The non-linear graph is shown on page 11.

It is divided into 8 parts. These are named as SEGMENTS. As 90% of the voice signals lie in the range of $\pm V_{max}/2$, only one segment is given for voltages beyond $\pm V_{max}/2$. The sample levels, which is the Y axis is divided into 8 parts each carrying (128/8=) 16 levels. These 8 parts correspond with the 8 segments, which mean each segment holds 16 levels.

The gradient of upper segments 0, 1 and lower segments 0, 1 are the same. Therefore they are considered as one segment. Hence, the non-linear graph is named as "13 segments graph".

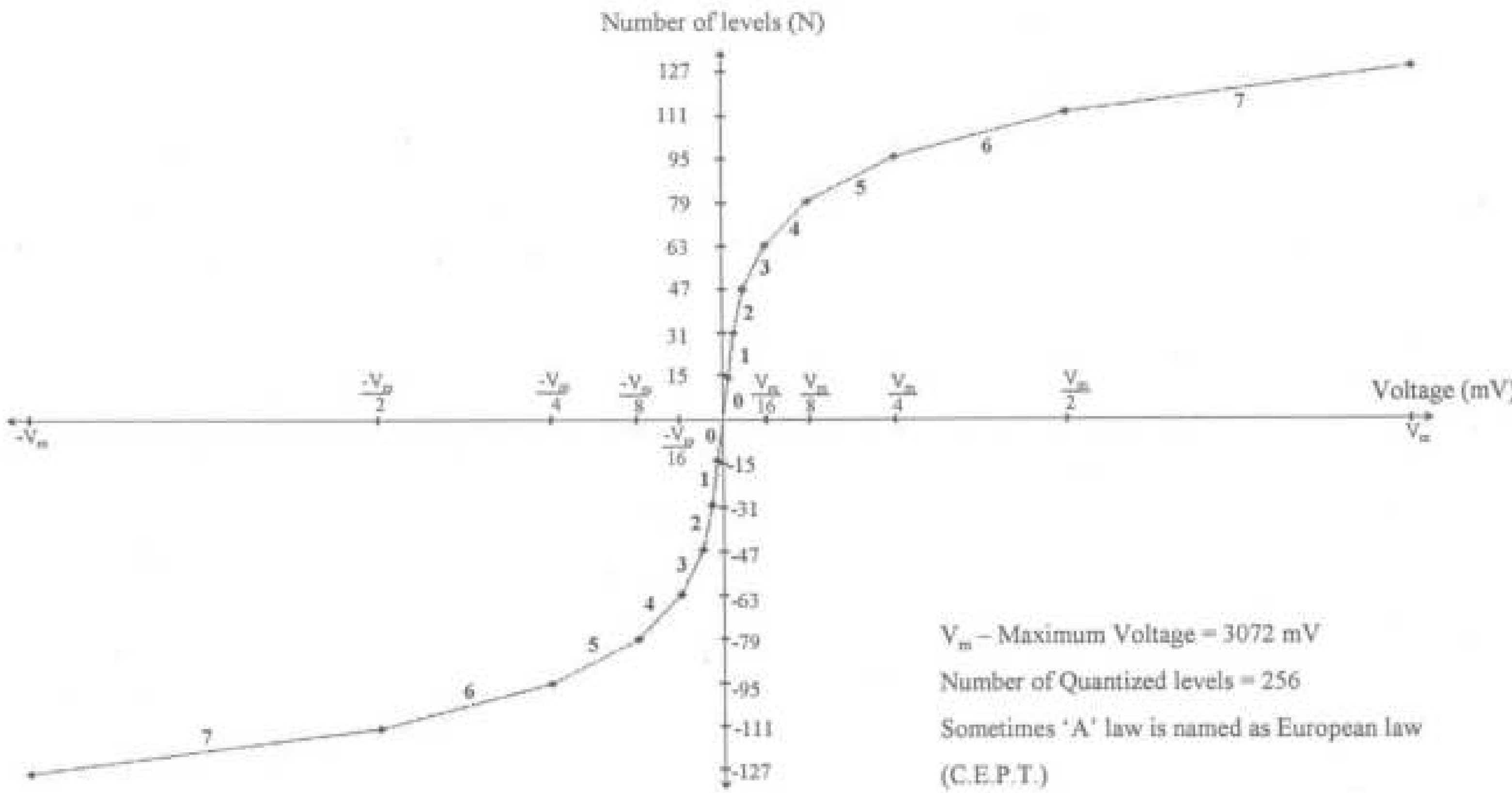
Summarized information on the graph :-

Segment Number	Voltage Range (mV)	Level Range	Increment per Level
7	1536 – 3072	111 – 127	96
6	768 – 1536	95 – 111	48
5	384 – 768	79 – 95	24
4	192 – 384	63 – 79	12
3	96 – 192	47 – 63	6
2	48 – 96	31 – 47	3
1	24 – 48	15 – 31	1.5
0	0 - 24	0 - 15	1.5

For example let's try to find the quantized value of 22mV.

The segment number for 22mV = Segment 0
Increment per level = 1.5
Calculating the level = (22 / 1.5)
= 14.6
= level 15
Quantized value = 15 x 1.5
= 22.5 mV
Hence the quantized value of 22mV is 22.5mV.

THE 'A' LAW SIGNAL-COMPRESSION CHARACTERISTICS OF 13 LINEAR SEGMENTS



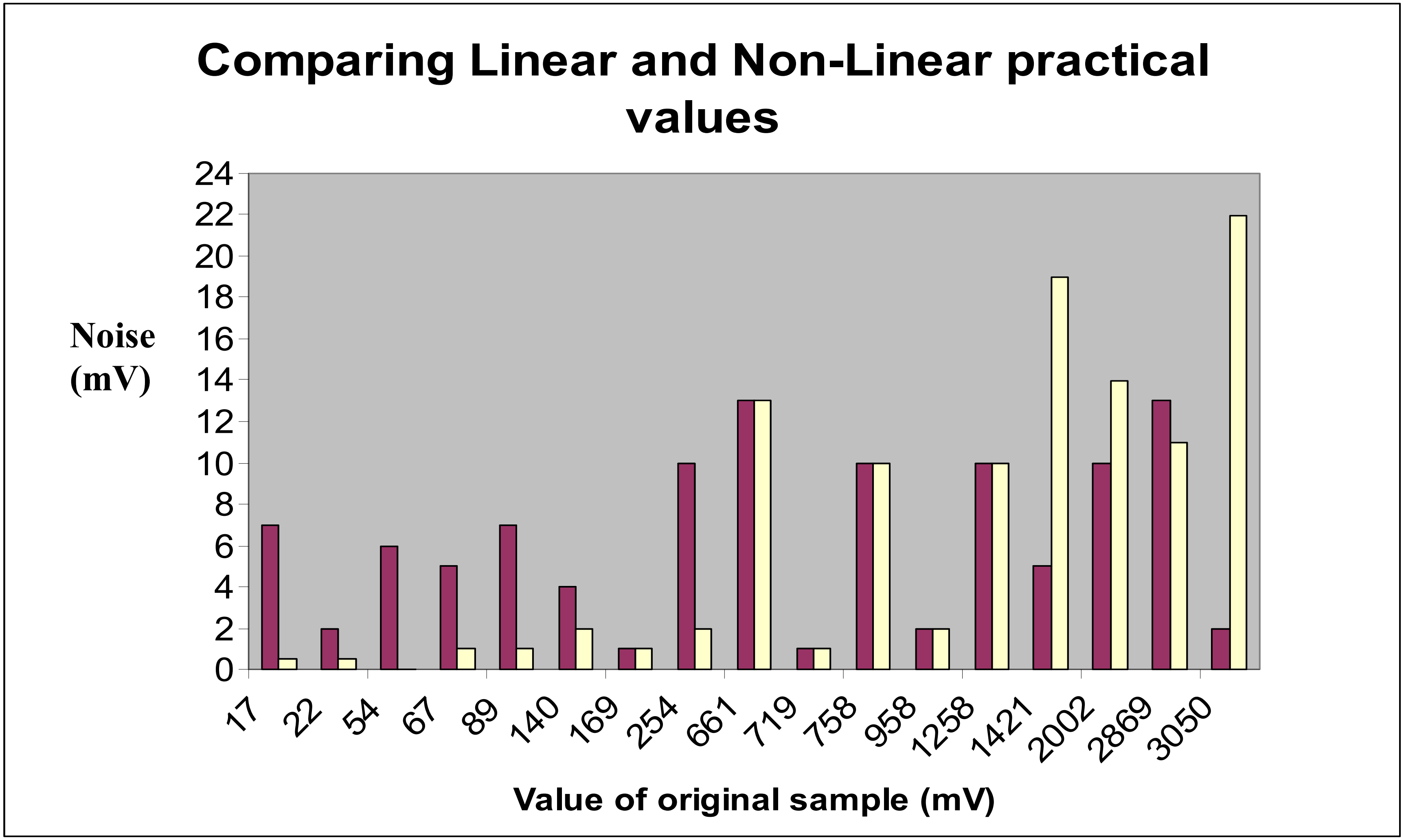
Study the following calculated values for linear and non-linear methods.

Original Sampled Voltage (mV)	Linear Quantizing		Non-Linear Quantizing	
	Quantized Value	S/N Ratio	Quantized Value	S/N Ratio
17	24mV	(17/7=) **2.4**	16.5mV	**34**
22	24	**11**	22.5	**44**
54	48	**9**	54	**No noise**
67	72	**13.4**	66	**67**
89	96	**12.7**	90	**89**
140	144	**35**	138	**70**
169	168	**169**	168	**169**
254	264	**25.4**	252	**127**
661	648	**50.8**	648	**50.8**
719	720	**719**	720	**719**
758	768	**75.8**	768	**75.8**
958	960	**479**	960	**479**
1258	1248	**125.8**	1248	**125.8**
1421	1416	**284.2**	1440	**74.8**
2002	1992	**200.2**	2016	**144**
2869	2856	**220.7**	2880	**260.8**
3050	3048	**1525**	3072	**138.6**

It can be seen that in non-linear quantizing the smaller sampled voltages have a higher S/N ratio than in the linear quantizing method. And the higher sampled voltage values have been reduced to a certain extent. Take a look at the graph on page 13.

In the linear quantizing method the difference between the highest S/N ratio and the lowest is (1525-9=) 1516. In the non-linear method it is (260.8-34=) 226.8. Therefore there is no major difference in the S/N ratios for higher and lower sampled voltages. These S/N ratio values in the non-linear method are sufficient enough to transmit a normal message.

Hence non-linear quantizing is used.



The light bars are for Linear Quantizing and the dark bars are for Non-Linear Quantizing