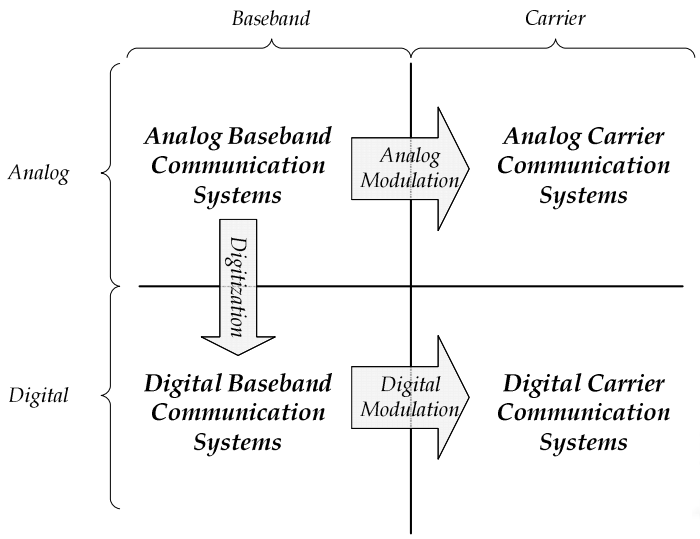
Lecture 5*a*: Sampling and Quantization

Dr. Mohammed Hawa
Electrical Engineering Department
University of Jordan

Digitization

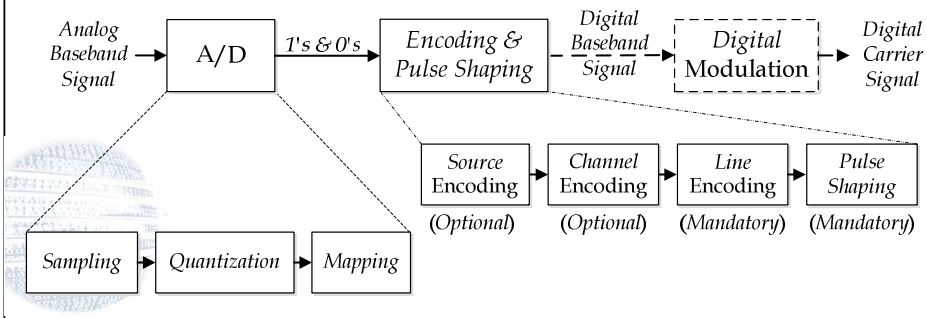


Digital Systems Advantages

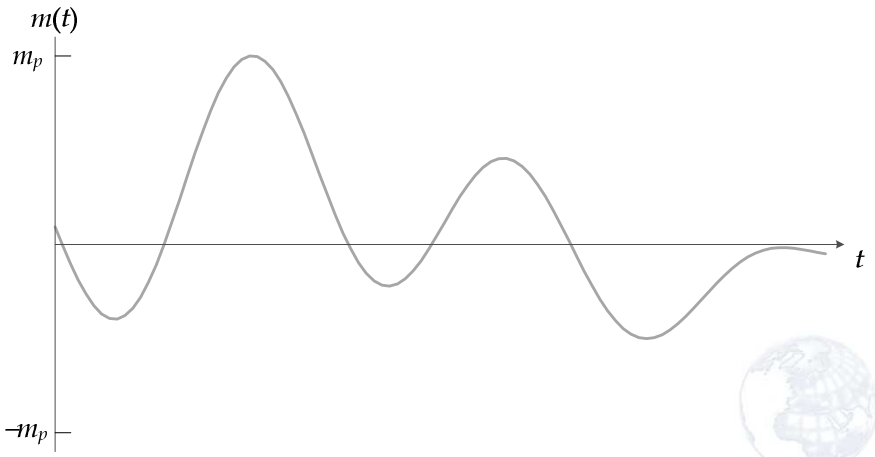
- Immunity to noise (threshold detection; regenerative repeaters).
- Multiplexing at the baseband level (e.g., TDM) and carrier level (e.g., FDM, CDMA and OFDMA).
- Spread spectrum techniques and orthogonality.
- Channel coding (i.e., error correcting codes).
- Source coding techniques (i.e., compression). *Also* Encryption.
- Exchanging SNR for bandwidth.
- Using microprocessors and DSP.
- Digital signal storage is relatively easy and inexpensive.

Digitization

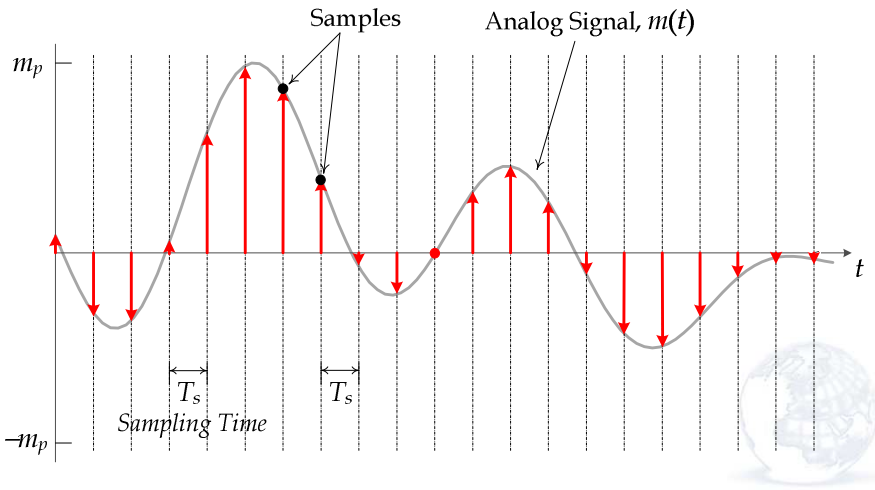
- **Sampling** (discrete analog signal).
- **Quantization** (quantized discrete signal)
- **Mapping** (stream of 1's and 0's).
- **Encoding** and **Pulse Shaping** (digital baseband signal).



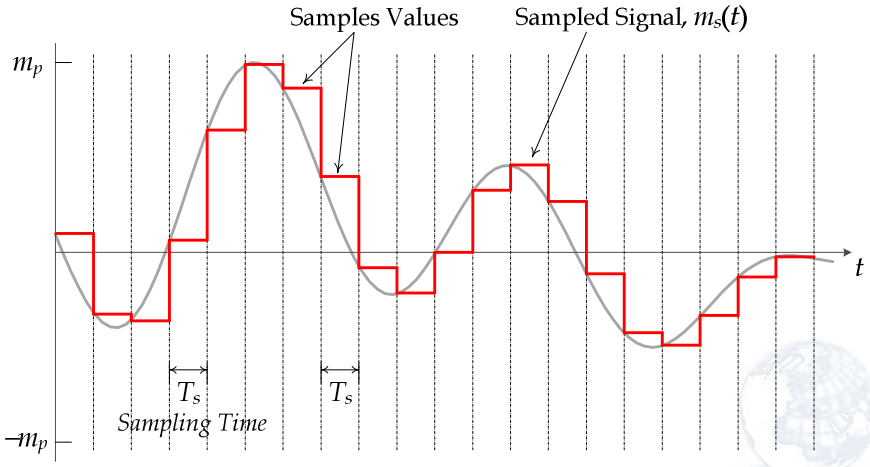
Analog Signal



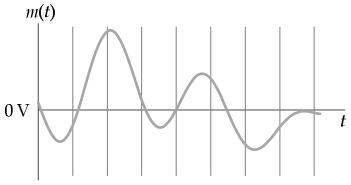
Ideal Sampling

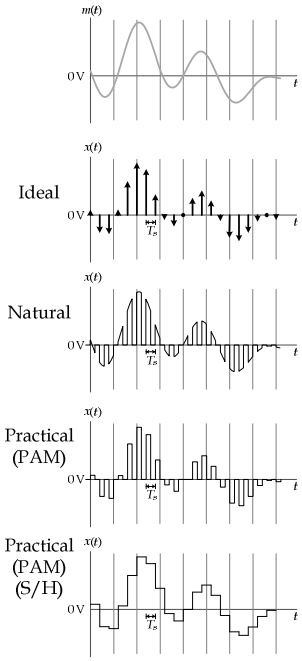


Practical Sampling

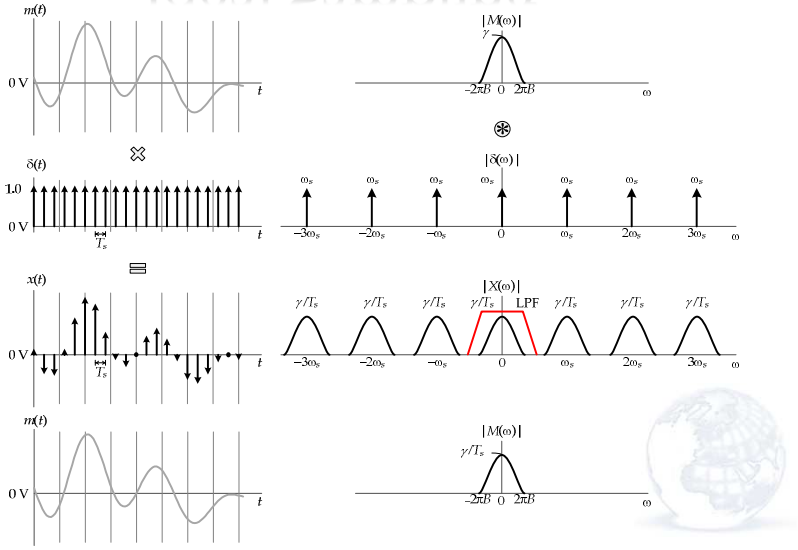


Samlping

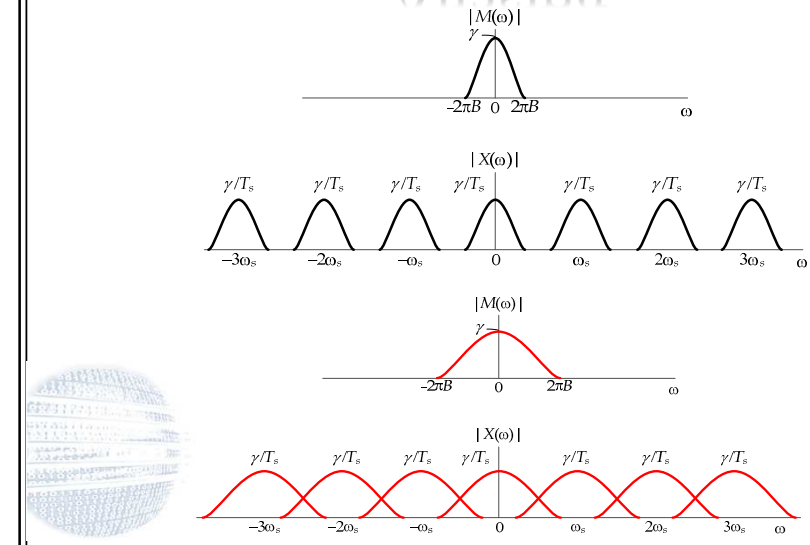




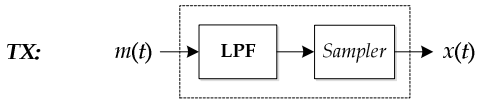
Ideal Sampling

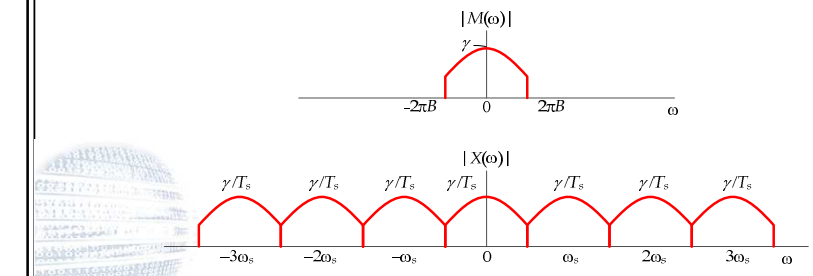


Aliasing

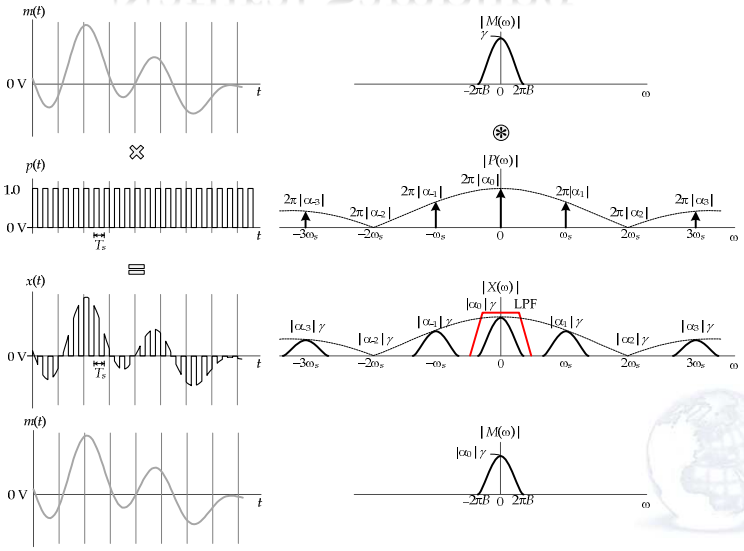


Anti-Aliasing Filter

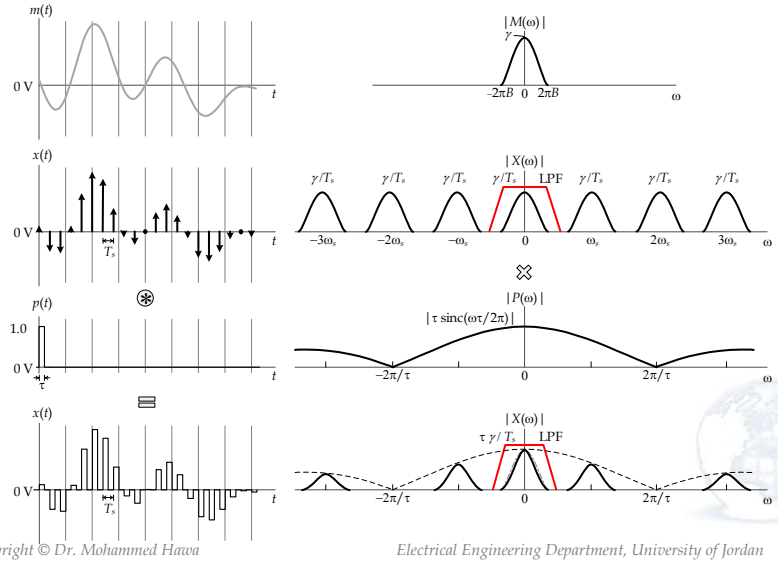




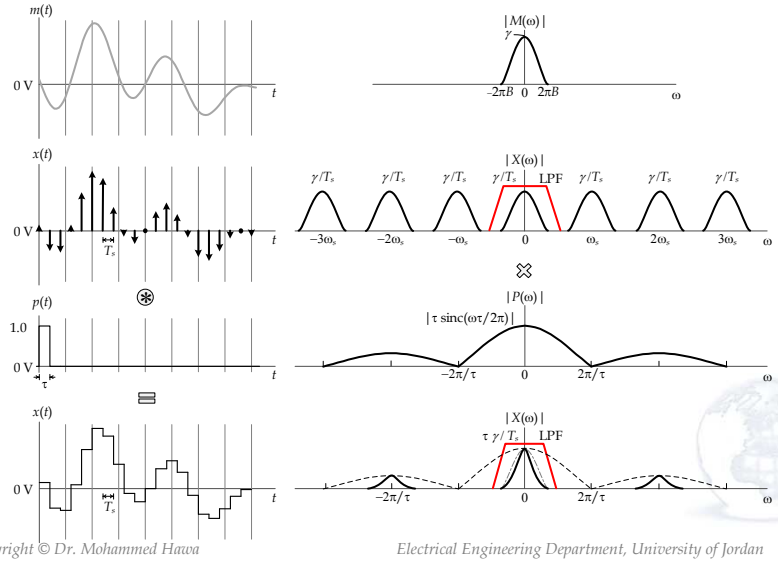
Natural Sampling



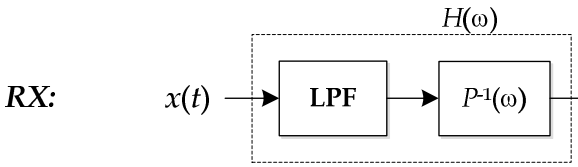
Practical Sampling: PAM

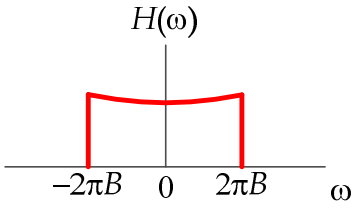


PAM: Wider Pulses (S/H)

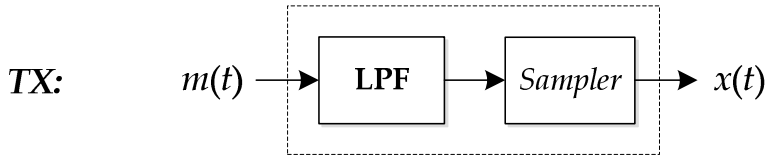


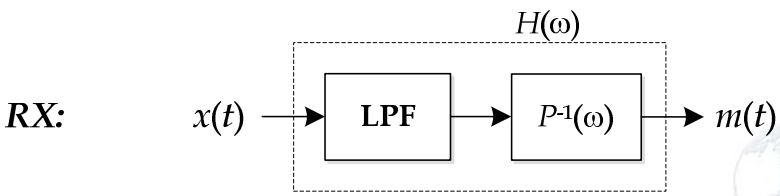
Distortion solved by Equalizer



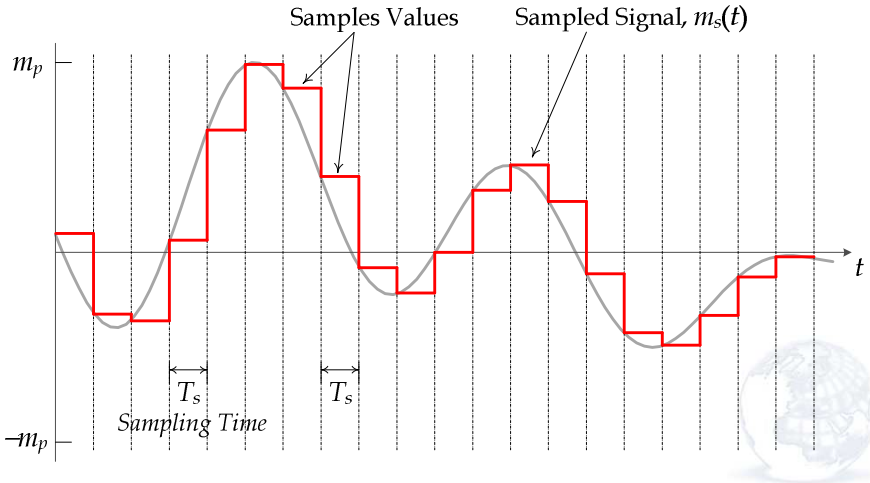


Summary

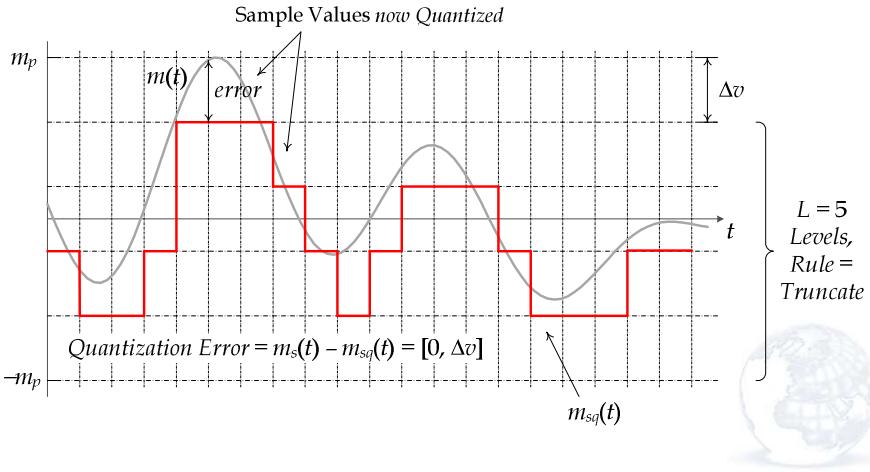




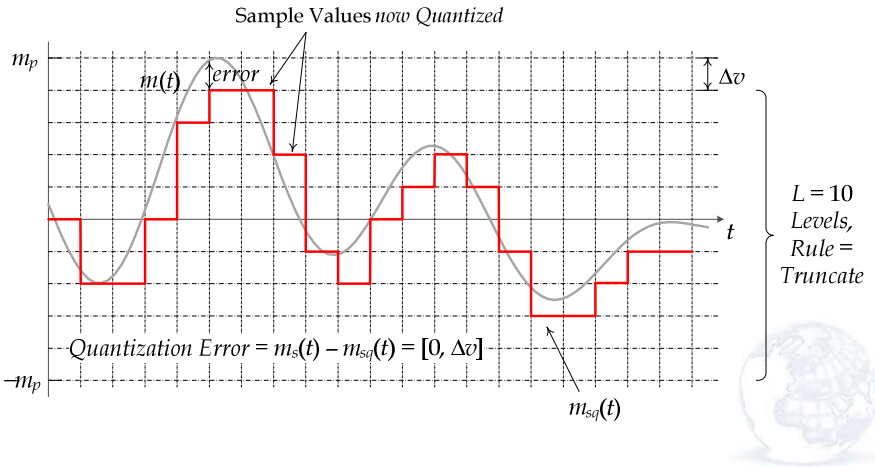
After Sampling!



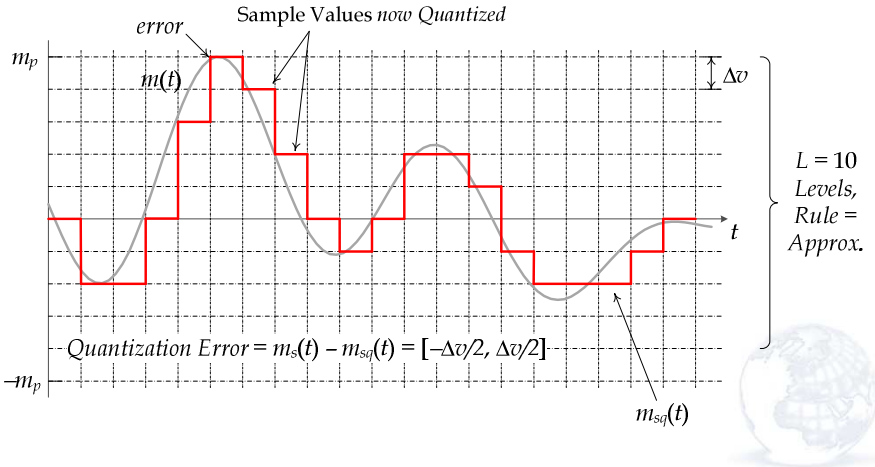
Quantization ($L = 5$)



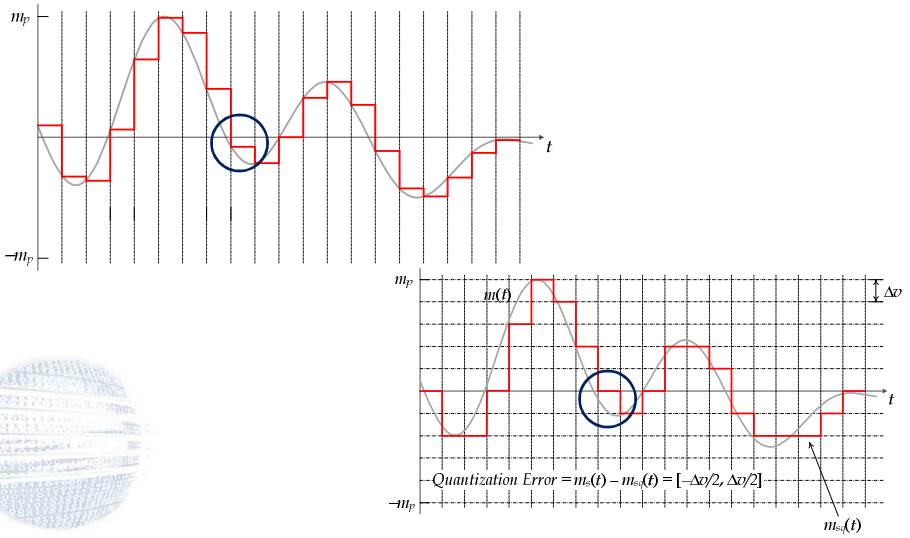
Quantization (L = 10)



Quantization (*Approx.*)

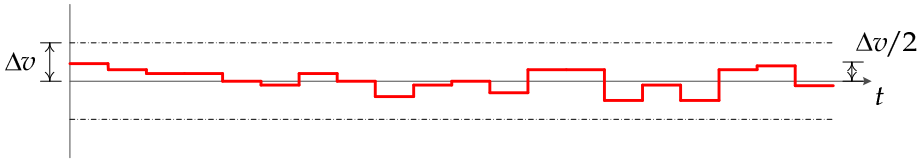


Quantization Error



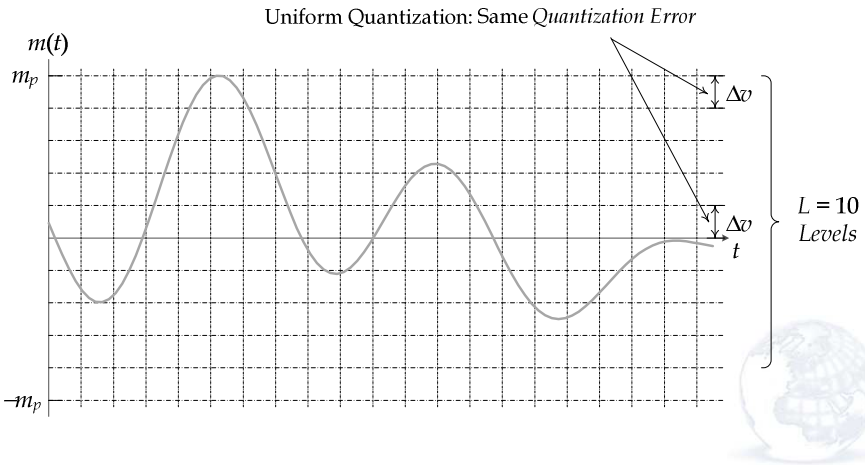
Quantization Error

$$q(t) = m_{sq}(t) - m_s(t)$$

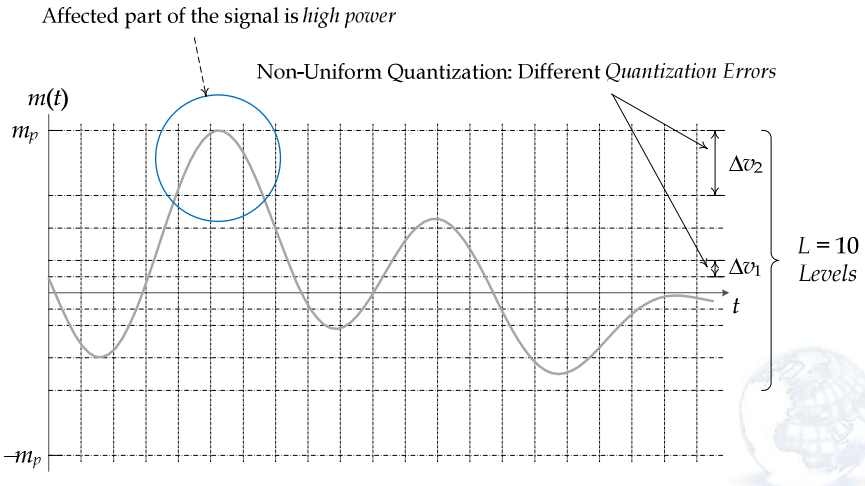


$$SQNR = \frac{\overline{m^2(t)}}{\overline{q^2(t)}} = \frac{\overline{m^2(t)}}{\left(\frac{m_p{}^2}{3L^2}\right)} = 3L^2 \frac{\overline{m^2(t)}}{m_p{}^2} = \frac{3L^2}{k_m^2}$$

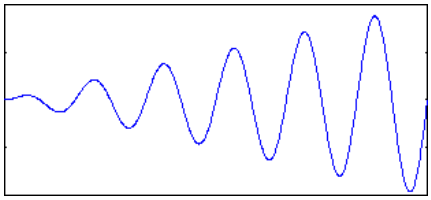
Uniform Quantization

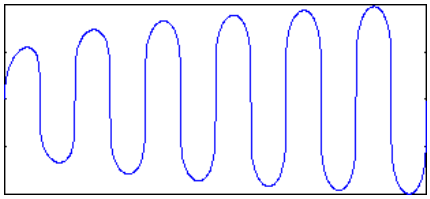


Companding

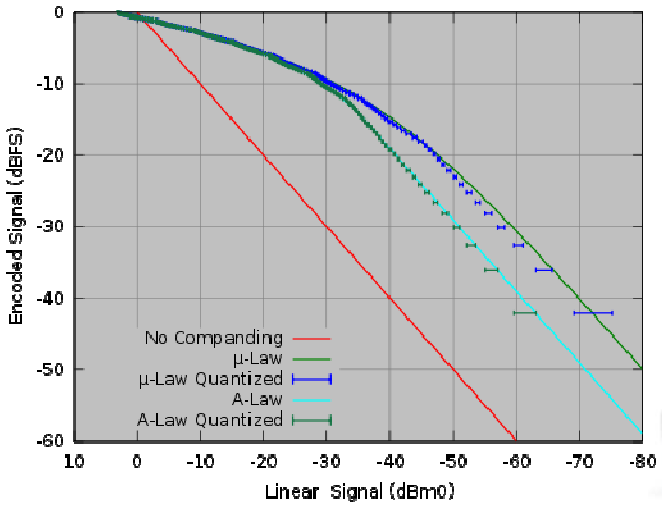


Effect is Expansion/Compression





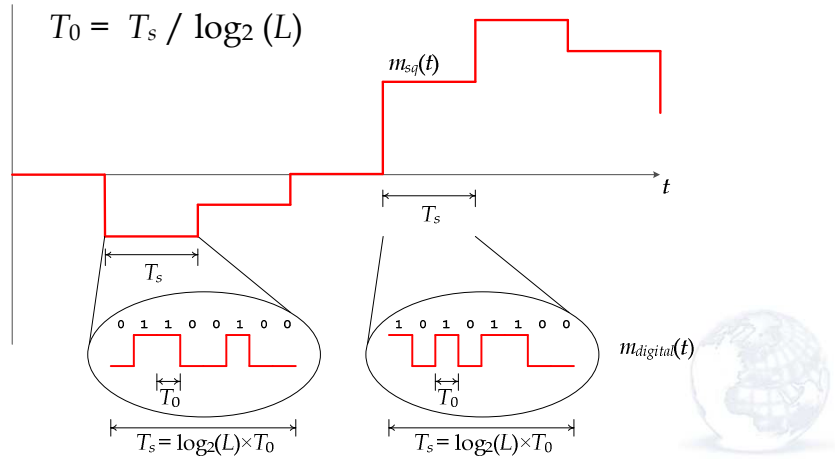
Compading Improvement (dB)



Mapping

f_0 [bps] = f_s [samples/s] × $\log_2(L)$ [bits/sample]

$T_0 = T_s / \log_2(L)$



Source Coding

0000	00
0001	01
0010	1000
0011	1001
0100	1010
0101	1011
0110	110000
0111	110001
1000	110010
1001	110011
1010	110100
1011	110101
1100	110110
1101	110111
1110	111000
1111	111001

Audio Compression

- Landline telephony (PCM, no compression)
  - **64 kbps**
- Linear Prediction Coding (LPC) vocoder
  - e.g., RPE-LTP (regular pulse excitation, long-term prediction) LPC codec (GSM cellular phones, Full Rate): **13 kbps**.
- Code-Excited linear Prediction (CELP) vocoder
  - Algebraic CELP(ACELP) (GSM cellular phones, Enhanced Full Rate): **12.2 kbps**
  - FS-1016 (United States Department of Defense): **4.8 kbps**

Video Compression

- **MPEG-2:** DVD, Digital TV Broadcasting.
- **H.261:** Videophone.
- **H.263:** Low bit rate Video Conferencing.
- **H.264:** Almost everything.

MPEG	**ITU-T**
MPEG-1	H.261
↓	↓
MPEG-2	H.263
↓	↓
H.264/MPEG-4 Part 10 *or* AVC (*Advanced Video Coding*)	
↓	↓
H.265/MPEG-H Part 2 *or* HEVC (*High Efficiency Video Coding*)	

- ITU-T: International Telecommunication Union - Telecommunication
- MPEG: Moving Picture Experts Group

Channel Coding

11100101011101000101010 0

⟶ 11100101011101000101010 0**1011**

⟶ 11100101011~~00~~1010001010100**1011**

⟶ 11100101011101000101010 0

$$C = B_{ch} \times \log_2(1 + SNR)$$

