





• Digitization

- -Conversion of analog data into digital data
- Digital data can then be transmitted using NRZ-L or any other code other than NRZ-L
- -Digital data can then be converted to analog signals
- Analog to digital conversion done using a codec (coder-decoder)
- Two techniques:
 - -Pulse code modulation (PCM)
 - —Delta modulation









PCM Example				
Example: PCM signal obtained for voice data				
Voice:	maximum frequency Sampling rate (1 / <i>T</i>) (quality comparable with Sampling period (<i>T</i>)	= 4 kHz voice >= 2 x 4000 or 8000 samples/second analog transmission) = 1 / 8000 = 125 microseconds		
For digital telephony, no. of levels (<i>L</i>) used in the uniform quantizer are 256 Number of bits (<i>n</i>) to represent a level = $\log_2(L) = \log_2(256) = 8$ bits Data rate = 8000 x 8 or 64 kbps				
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- Quantization levels not evenly spaced
- Reduces overall signal distortion
- Can also be done by companding (compressingexpanding) the input analog signal
 - -Significantly improves the PCM SNR ratio





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PCM versus DM

- DM is simpler to implement than PCM
- but has worse SNR
- issue of bandwidth used
 - -e.g. for good voice reproduction with PCM
 - want 128 levels (7 bit) & voice bandwidth 4khz
 - need 8000 x 7 = 56kbps
- data compression can improve on this
- still growing demand for digital signals —use of repeaters, TDM, efficient switching
- PCM preferred to DM for analog signals























Performance of Digital to Analog Modulation Schemes

- bandwidth
 - -ASK/PSK bandwidth directly relates to bit rate
 - -multilevel PSK gives significant improvements
 - —FSK bandwidth related to data rate for lower frequencies, but to offset of modulated frequency from carrier at high frequencies
- in presence of noise:
 - bit error rate of PSK and QPSK are about 3dB superior to ASK and FSK
 - —for MFSK and MPSK \Rightarrow tradeoff between bandwidth efficiency and error performance

Performance of Digital to Analog Modulation Schemes

- Transmission bandwidth:
 - ASK and PSK bandwidth directly related to bit rate
 - FSK bandwidth related to data rate for lower frequencies, but to offset of modulated frequency from carrier at high frequencies

ASK:	$B_T = (1+r)R;$	$r \implies \text{rolloff factor}; 0 \le r \le 1$
FSK:	$B_T = 2\Delta f + (1+r)R;$	$\Delta f = f_2 - f_c = f_c - f_1$
PSK :	$B_T = (1+r)R;$	
Multilevel PSK :	$B_T = \frac{(1+r)}{\log_2 L} R;$	$L \Rightarrow$ no. of levels







Transmission Bandwidth of Analog Modulation Schemes • FM and PM require greater bandwidth than AM



Reading

- Chapter 5, Stallings' book
- Exercise: Prove that for AM, $B_7 = 2B$ (hint: see Example 5.4 on page 169 (Example 5.3 on page 160 in the 7th edition)).