Digital Communication (UEC-639)

Tutorial-4

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Question-1

Given an audio waveform

$$f(t) = 3\,sin(500t) + 4\,sin(1000t) + 4\,sin(1500t)$$

find the signal to quantization noise ratio if this is coded using delta modulation for sampling at

a) Nyquist rate

b) 32 times of Nyquist rate

Comment which one among 'a' and 'b' is practically suitable

Solution-1 (a)

Signal is $f(t) = 3\sin(500t) + 4\sin(1000t) + 4\sin(1500t)$

Therefore signal power is

$$S = \frac{3^2 + 4^2 + 4^2}{2} = 20.5$$

In delta modulation, the sampling period is flexible, the smaller is the sampling period, the smaller is the quantization error.

The maximum sampling period is at Nyquist rate, i.e.

$$T_{smax} = \pi/1500.$$

$w = 2\pi f_m$=1500

$$f_m = \frac{1500}{2\pi}$$

Now the slope of the signal is

f_s=$\frac{1}{T_s}$=2× f_m

$$\frac{df}{dt} = 3 \times 500\cos(500t) + 4 \times 1000\cos(1000t) + 4 \times 1500\cos(1500t)$$

The maximum slope is

$$\left.\frac{\mathrm{d}f}{\mathrm{d}t}\right|_{\max} = 3 \times 500 + 4 \times 1000 + 4 \times 1500$$

$$= 11500$$

To ensure no overloading, we have

$$\frac{\Delta}{T_s} \geq \left.\frac{\mathrm{d}f}{\mathrm{d}t}\right|_{\max}, \quad \text{i.e.} \quad \Delta \geq 11500 T_s$$

where Δ is the quantization step−size.

quantization noise power is

$$N_q = \frac{\Delta^2 \omega_m T_s}{6\pi}$$

$$= \frac{(11500T_s)^2(1500T_s)}{6\pi}$$

We know that : $T_{smax} = \pi/1500$

At Nyquist rate,

$$N_q = 11500 \times 11500 \times 1500 \times \frac{\pi^3}{1500^3}/(6\pi)$$

$$= 96.69$$

Therefore,

$$\frac{S}{N_q} = \frac{20.5}{96.69} = -6.74\text{dB}$$

This value is unacceptable.

Suppose, we increase the sampling rate 32 times, then

$$T_s = \pi/(32 \times 1500),$$

we have

$$N_q = 11500 \times 11500 \times 1500 \times \frac{\pi^3}{1500^3} \times \frac{1}{32^3}/(6\pi)$$

$$= 2.95 \times 10^{-3}$$

At this sampling rate

$$\frac{S}{N_q} = \frac{20.5}{2.95 \times 10^{-3}} = 38.42\text{dB}$$

which is acceptable.

Question-2

Determine the output SNR of a DM system if input signal is given as

$$x(t) = Cos(2000\,\pi\,t).$$

Assume sampling frequency 16 kHz, no slope overload condition.

Also determine the output if it is followed by a 4 kHz post reconstruction filter

Solution-2

We know that:

$$\frac{S}{N_q} = 3\frac{f_s^3}{8\,\pi^2\, f_m^2\, f_M}$$

Given $f_m = 1000\ Hz,\ f_s = 16000\ Hz,\ \ f_M = 4000\ Hz$

$$\frac{S}{N_q} = 3\frac{(16 * 10^3)^3}{8\,\pi^2\,(10^3)^2\,4\ 10^3}$$

$$= 38.94$$

$$= 15.9\ dB$$

Question-3

What is the data rate of DM system given in above question (Q2)?

What configuration is required for a PCM system to obtain same data rate?

Determine the SNR of this PCM system.

Solution-3

Rb=n*fs

(a) Since data is transmitted using one-bit quantizer, so the data rate is 16 kbps

(b) For PCM, 16 kbps can be achieved by using following:

Case-1 Sampling frequency = $f_s = 8\ kHz$;

no of bit in encoder = n = 2;

SNR for this system is = 1.76 + 6.02 * 2

= 13.8 dB

Case-2

Sampling frequency = $f_s = 4\ kHz$;

no of bit in encoder = n = 4;

SNR for this system is = 1.76 + 6.02 * 4

= 25.84 dB

Case-3

Sampling frequency = $f_s = 2\ kHz$;

no of bit in encoder = n = 8

SNR for this system is = 1.76 + 6.02 * 8

= 49.92 dB

Question-4

Draw the block diagram of adaptive delta modulation system and explain the algorithm of step generation.
Consider a suitable example with different sample values.

Note: Every students has to consider a different example.

Solution-4

Attempt yourself.

Question-5

Consider a mid-rise uniform quantizer (quantization level = 8, step size $\Delta = 1\ V$).

Find DPCM output to be coded for sampled sequence

$$\{0,\ 0.5,\ 1.5,\ 0.7,\ 1,\ 2.3, 3.5, 2.8\}$$

using first order prediction filter $\hat{m}[n] = m_q[n-1]$

Solution-5

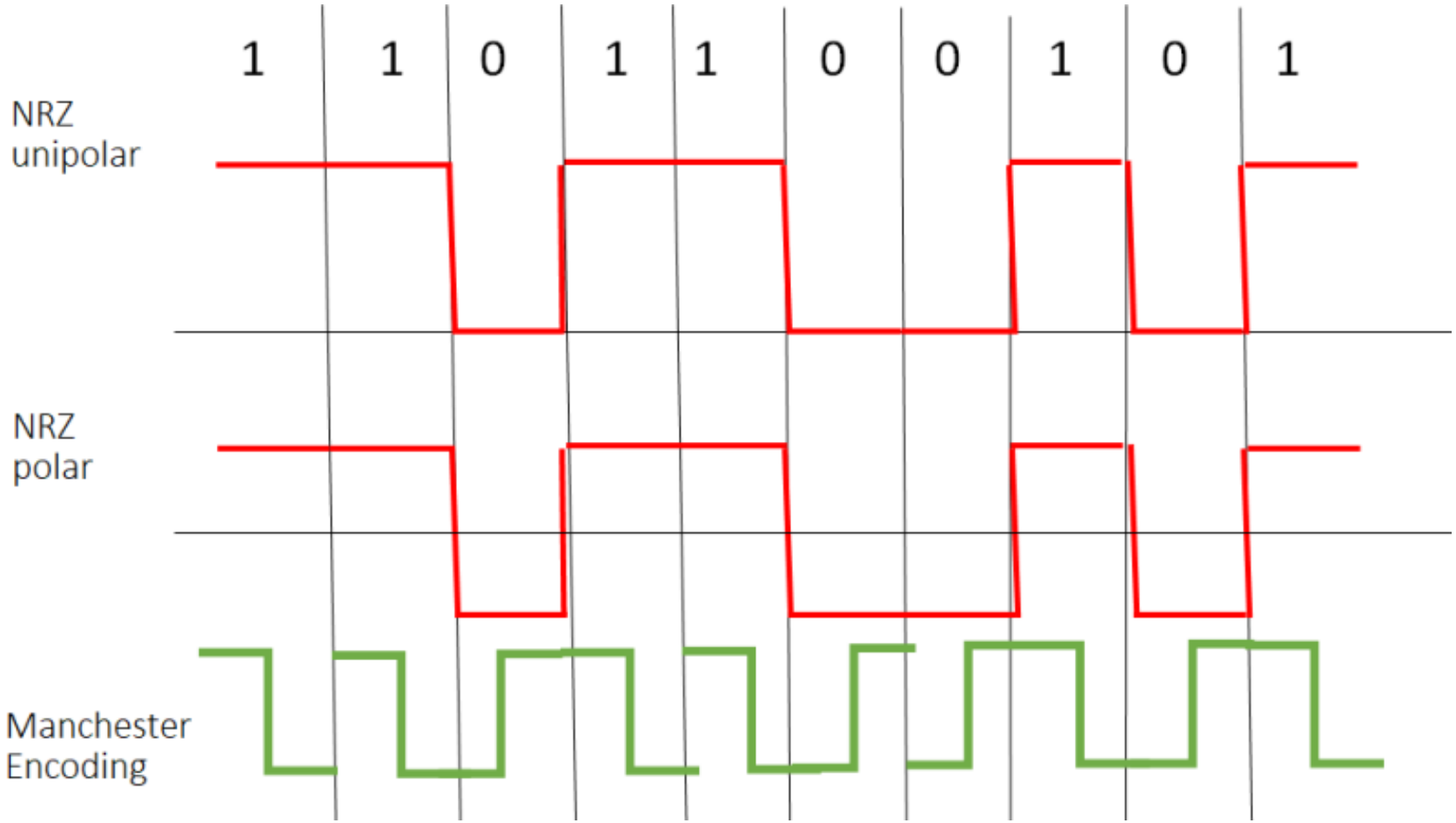
Attempt yourself.

Question-6

For a binary sequence 1101100101, draw the line coded waveform for the following signalling scheme

a) NRZ unipolar
b) NRZ bipolar
c) NRZ polar
d) Manchester coding

Solution-6



Thanks !