Analogue Data / Digital Signals

- As stated before a **CODEC** is used to generate a **Digital Signal**:
  - Hence this is the device to be considered here,
  - This device was also used to encode Digital Data onto a Digital Signal:
    - Recall the use of NRZ, Bipolar AMI and Manchester techniques.
- There are two encoding methods to consider:
  - Pulse Code Modulation,
  - Delta Modulation.

Analogue Data / Digital Signals

- To encode **Analogue Data** onto a **Digital Signal** requires two steps:
  - Convert *analogue data* into *digital data,*
  - Encode the *digital data* onto a *digital signal.*
- The first step requires the use of ***Sampling***:
  - This is necessary as an Analogue Data signal has an infinite amount of data. Consequently, it is not feasible to send all of the Analogue Data.
- Nyquist also did some work on sampling.

Analogue Data / Digital Signals

- The Sampling Theorem (from Nyquist):

"If a signal f(t) is sampled at regular intervals of time and at a rate higher than twice the highest signal frequency, then the samples will contain all the information necessary for the reconstruction of the original signal."

Pulse Code Modulation

- The original analogue signal is *sampled* at regular intervals to produce *PAMS.*
- The PAMS are *quantized* i.e. assigned a binary value.
- There are considerations to be given to the number of bits to use to represent each sample:
  - These will be explored in class.

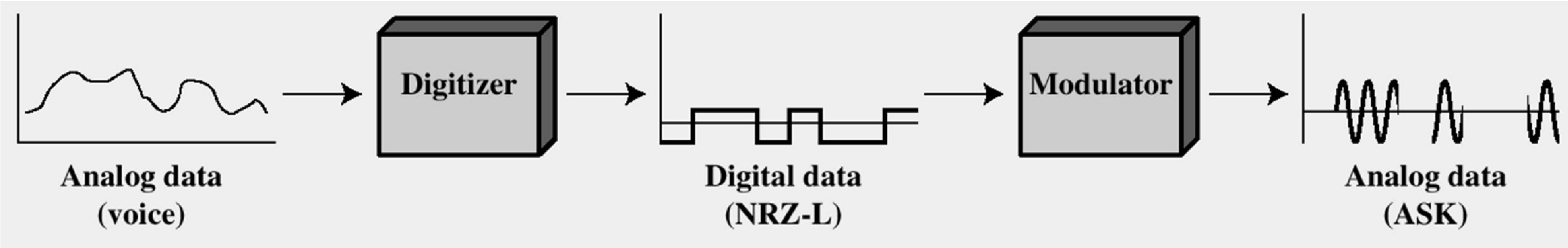
Pulse Code Modulation

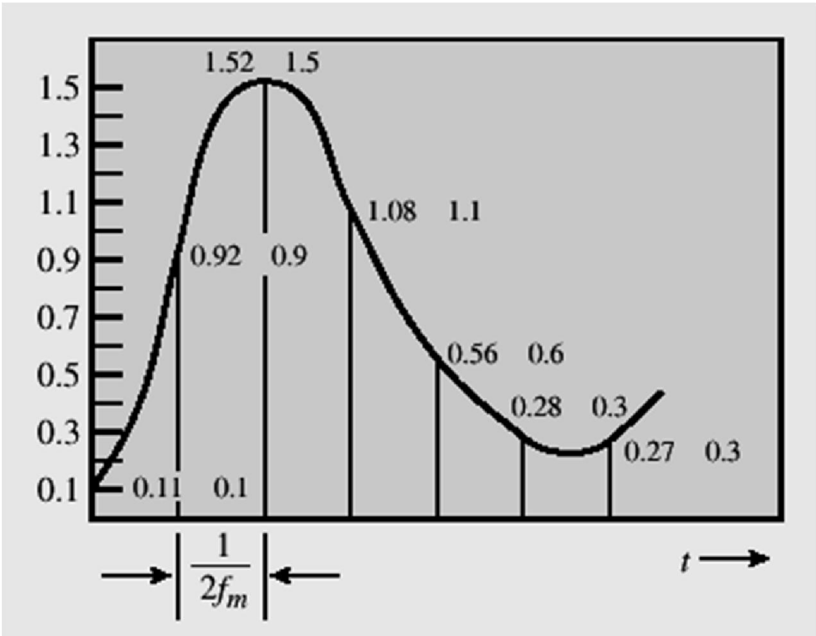
- Regardless of the number of bits chosen there will always be some level of ‘rounding’:
  - This is known as *Quantization* which gives rise to *Quantization error* or *Quantizing noise.*
  - Hence, the original Analogue Data signal can <u>never</u> be truly reproduced.

Pulse Code Modulation

- Using PCM to encode voice data results in:
  - A stream of 8-bit samples,
  - Each sample is assigned an 8-bit value,
  - Resulting in a Data Rate of 64Kbps in Europe.
  - This calculation will be demonstrated in class.

Pulse Code Modulation





Digit	Binary Equivalent	PCM waveform
0	0000	
1	0001	
2	0010	
3	0011	
4	0100	
5	0101	
6	0110	
7	0111	
8	1000	
9	1001	
10	1010	
11	1011	
12	1100	
13	1101	
14	1110	
15	1111	

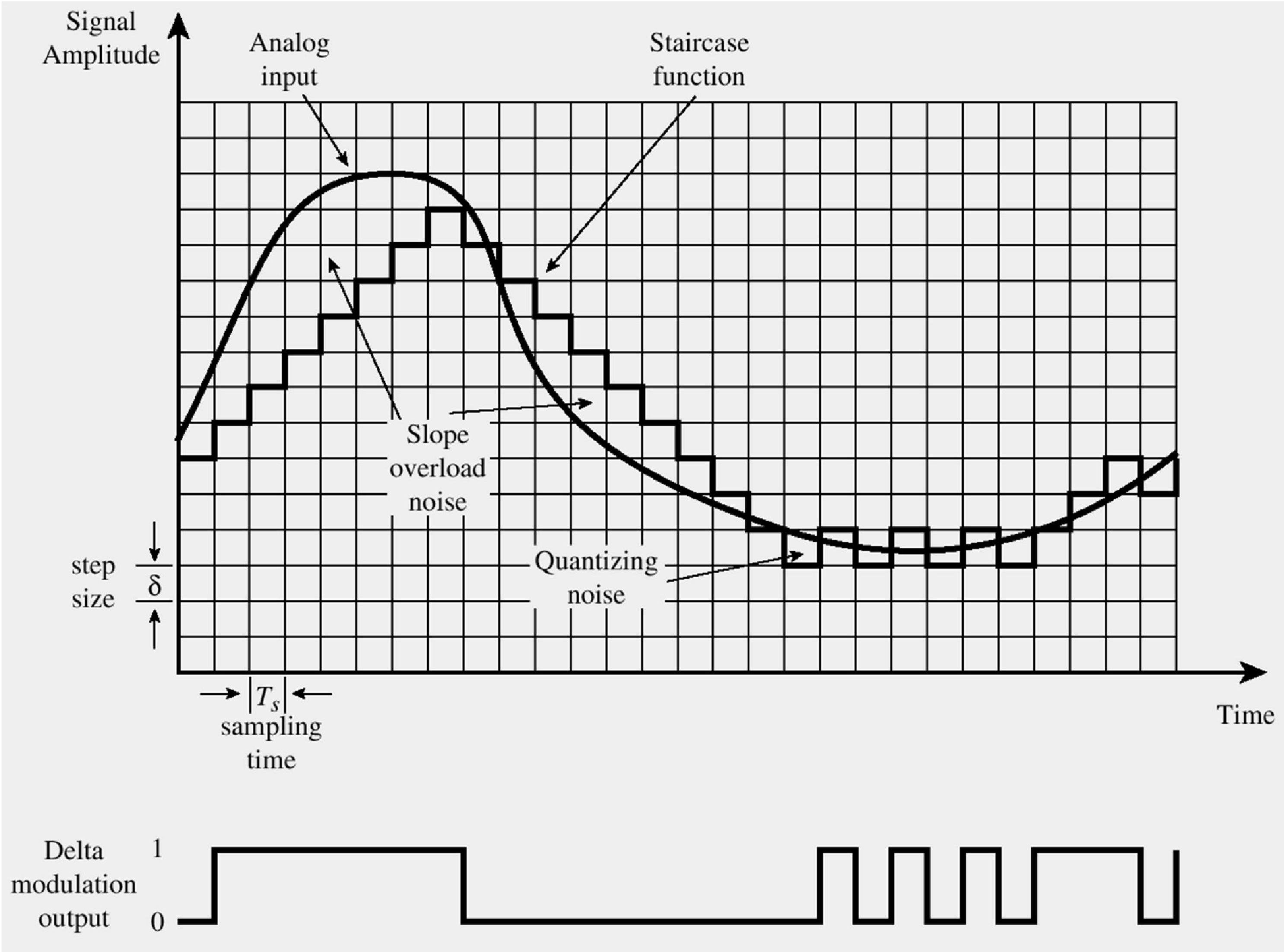
Delta Modulation

- This technique involves the use of a *staircase function:*
  - Here the analogue signal is approximated by a simple mathematical function,
  - At each sampling interval a positive or negative *quantization step* is added to the output.

Delta Modulation

- The result is a *single* binary digit for <u>each</u> sample indicating a positive or negative slope in the original analogue signal.
- An explanation will be given in class.

Delta Modulation



Delta Modulation

- Two Significant Parameters:
  - Quantization step *delta* (δ)
    - large delta reduces *Slope Overload Noise*
    - small delta reduces *Quantization Noise*
  - Sampling rate
    - Large rate reduces noise but increases data rate of output signal
- DM compared to PCM:
  - DM is easier to implement
  - PCM produces better SNR characteristics

Voice data: Digital V's Analogue

- Digital (PCM):
  - Good voice reproduction with 256 quantisation levels i.e. 8-bit coding
  - Required sampling rate of 8000 per second for 4000hz voice i.e. 64Kbps voice channels
  - 64Kbps voice channel requires approx. 32KHz. of BW
- Analogue (PoTS):
  - Voice channel requires approx. 4KHz. of BW
- However, digital is still preferable to analogue for the following reasons (see next slide)

Analogue Data / Digital Signals

- Popularity increasing
  - Repeaters can be used so no additive noise
  - Time-division multiplexing (TDM) can be used eliminating intermodulation noise which occurs with FDM
  - Digital signalling allows use of digital switching techniques

Analogue Data / Analogue Signals

- Analogue data can be used to modulate an analogue signal
- This is often used to:
  - Obtain a more appropriate frequency for a particular transmission
  - Allow a number of analogue signals to share a transmission medium (Frequency Division Multiplexing) – will examine later
- Three basic techniques available

Analogue Modulation Techniques

- Amplitude Modulation
  - Carrier amplitude varies in proportion to the amplitude of the analogue data
- Frequency Modulation
  - Frequency deviation is proportional to the analogue data
- Phase Modulation
  - Phase is proportional to the analogue data
- These techniques were examined previously (see Digital Data/Analogue Signal slides)