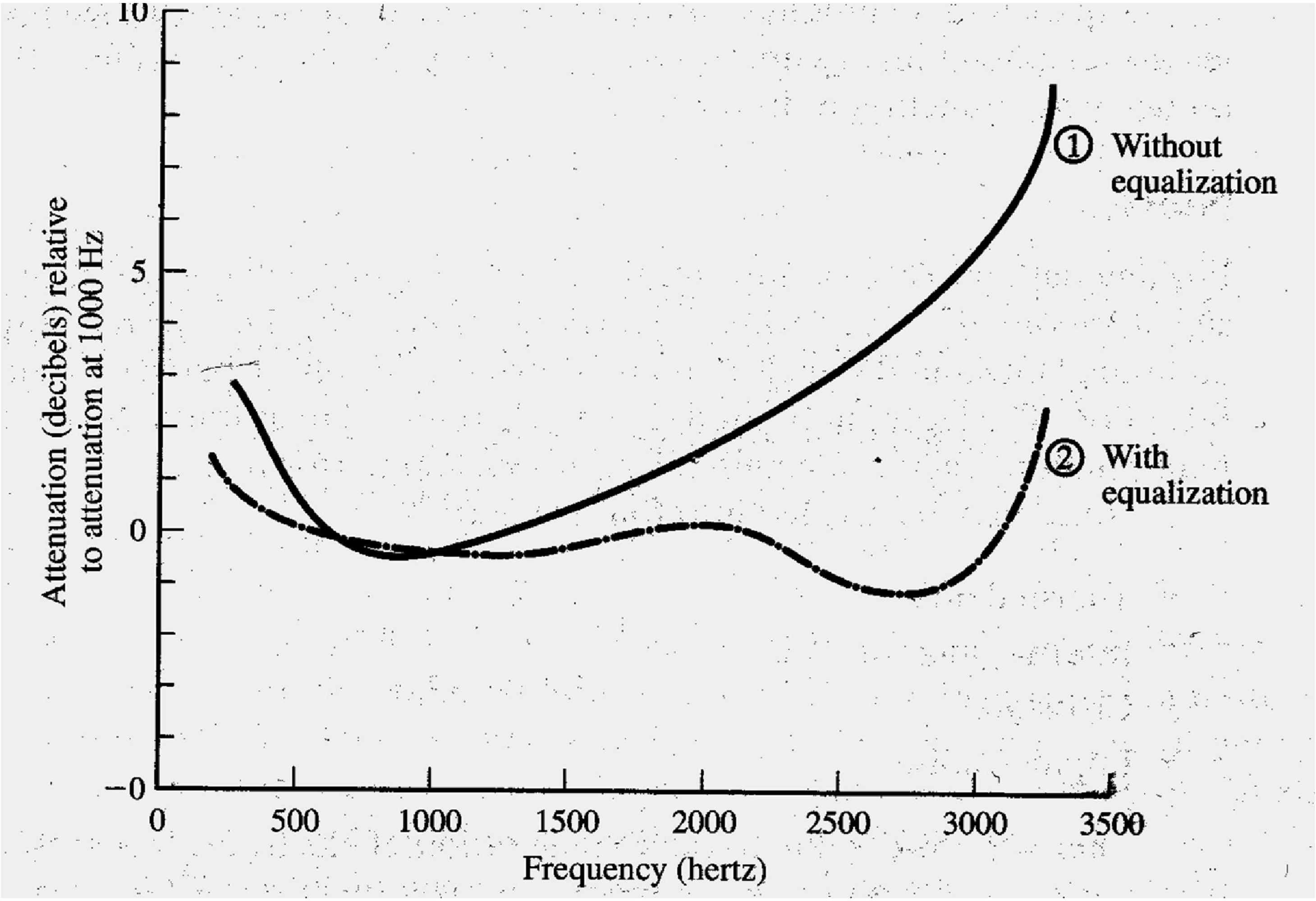
Transmission Impairments

- A transmitted signal becomes distorted due to *transmission impairments*
- For Analogue signals the quality can become *degraded*
- For Digital signals, *bit errors* can be introduced
- Types of Impairment:
  - Attenuation and Attenuation distortion
  - Noise

Attenuation & Attenuation distortion

- Attenuation – where the signal becomes weaker over distance
- Interestingly attenuation is a function of *frequency* (refer to graph 1)
- Attenuation distortion affects the *intelligibility* of the <u>received</u> signal especially ***Signal Pulses*** which can become distorted
  - One technique for addressing this problem is to use *equalizing amplifiers*:
    - This boosts higher frequency components (refer to graph 2) which <u>**evens**</u> out Signal Pulses

Attenuation & Attenuation distortion



Noise

- *Noise* is the insertion of unwanted signals onto the transmission signal
  - Its effect is to distort the signal during transmission (refer to diagram on slide entitled Effects of *Impulse and Thermal Noise)*
- It particularly affects digital signals
  - The greater the noise the greater the *bit error rate*
- Three categories of Noise:
  - Thermal Noise
  - Cross Talk
  - Impulse Noise

Thermal Noise

- Caused by the thermal agitation of electrons within a conductor
- Characteristics:
  - Present in all electronic devices and conductors
  - It is a function of *temperature* i.e. increased temperature leads to increase in thermal noise
  - It is uniformly distributed across frequency spectrum hence it is also known as *white noise*

Thermal Noise

- The presence of Thermal Noise places an upper limit on the data carrying capacity of a transmission system:
  - Must ensure that the strength of the data-carrying signal is much greater than the noise signal
  - Term used to describe this relationship is SNR – Signal to Noise Ratio

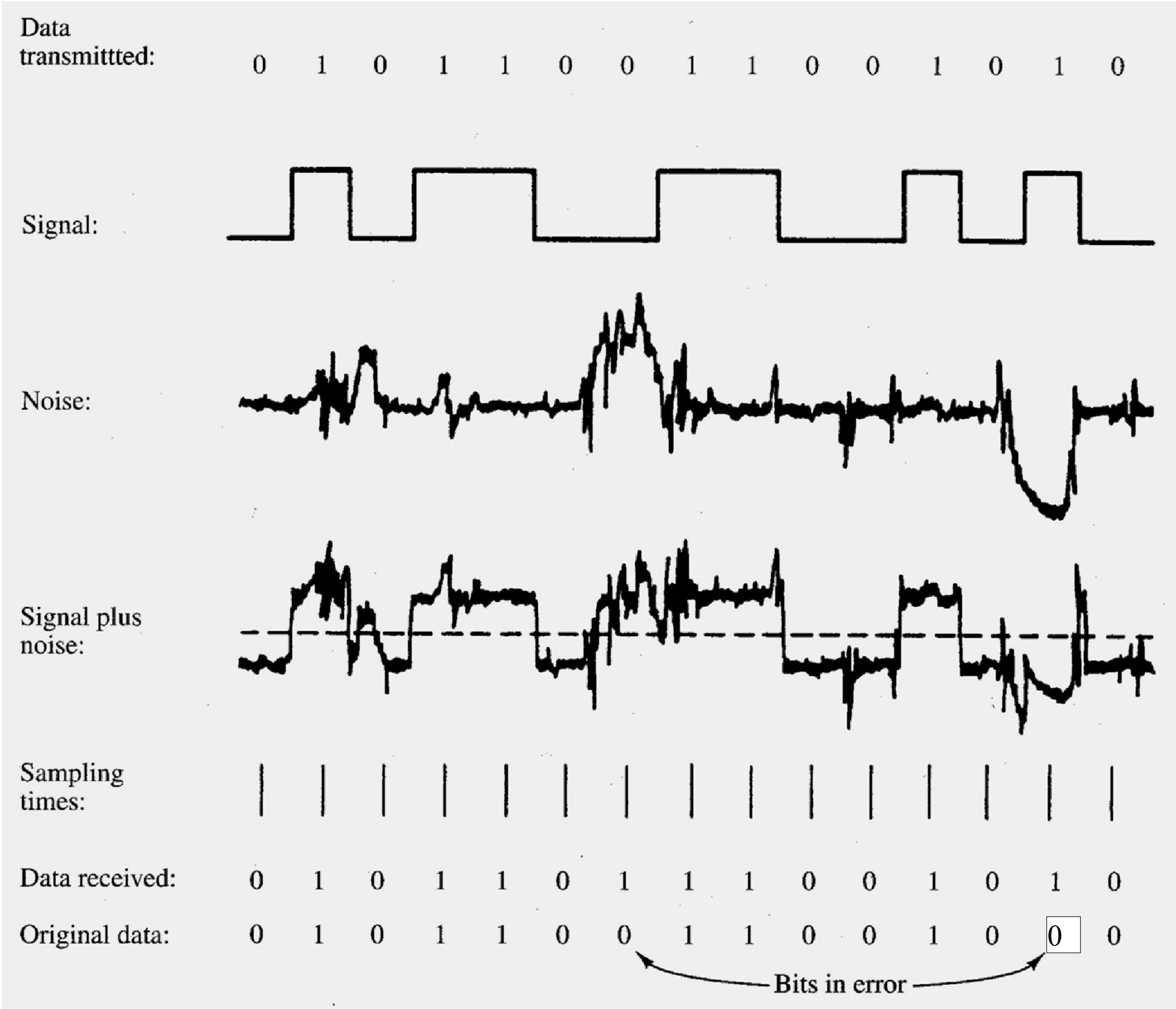
Cross Talk

- Unwanted *coupling* between signals on neighbouring transmission paths
  - The term *coupling* means connecting without actually touching
  - Coupling can occur between cables in close proximity or between radio signals close to the same frequency

Impulse Noise

- Irregular pulses or *noise spikes* of short duration and high amplitude
- Causes:
  - Lightning and static discharges
  - Switching of heavy electrical loads
  - Faults within the transmission system
- Analogue signals are less affected by this type of noise
  - E.g. a voice transmission, whilst affected by impulse noise, it can still be received intelligibly
- Digital signals are very susceptible
  - Can lead to corruption of data i.e. changing one to zero and vice-versa
  - This is demonstrated on the next slide

Effects of Impulse and Thermal Noise



Channel Capacity

- Channel capacity allows us to study the inter-relationships between Signal BW, System BW and Signal Impairments
- *Channel Capacity* is the maximum rate at which data can be transmitted over a communications path or channel
- The objective is to make the best use of a given bandwidth/channel
  - However, from previous discussions *Channel Capacity* is limited in practice by transmission *impairments* of which the main constraint is *noise*
- Two distinguished scientists had something to say on this subject namely Nyquist and Shannon

Nyquist's Noise Free Channel

- According to Nyquist the limitation on data rate is simply the bandwidth of the channel
- Nyquist's Theorem

$$C = 2BLog_2 M$$

C = maximum data rate measured in bits per sec.
B = bandwidth of the Transmission System Hz.
M = number of discrete states in digital signal

Limitation on Channel Capacity

- It appears from Nyquist's theorem that any data rate is achievable by:
  - increasing the bandwidth of the system
  - encoding more bits per signal cycle
- However, as the Data Rate increases:
  - The *bit error rate* increases
  - It becomes more and more difficult for the receiver to distinguish different signal *states*
- Noise and other transmission impairments put a practical limit on *M* and hence on the maximum Data Rate achievable

Noise and Data Rate

- Noise distorts a signal during transmission
- The greater the noise the greater the bit error rate for digital signals
- Key factor is Signal to Noise Ratio (SNR)
- Measured in Decibels
  - $SNR_{dB} = 10 \, Log_{10} \, (S/N)$

    S = Average signal power

    N = Average noise power

Shannon’s Noisy Channel

- Shannon extended Nyquist’s work and took into account the effects of *noise*
- Shannon's Capacity Formula is stated thus:

$$C = BLog_2\,(1 + (S/N)\ )$$

- Observations:
  - Increasing the bandwidth increases the maximum data rate
  - Increasing the noise reduces the maximum data rate
  - Shannon's Law defines an upper limit on the achievable data rate
  - Hence the data rate is limited by bandwidth <u>and</u> noise

Limitation on Channel Capacity

- According to Shannon the maximum data rate achievable is determined by:
  - The bandwidth of the system/channel and,
  - the noise on the channel
  - i.e. every system/channel has a maximum data carrying capacity that cannot be exceeded
- This is a more practical and realistic reflection on Channel Capacity as it takes into consideration the effects of noise

Worked examples of Channel Capacity

- Example calculations of Channel Capacity will be demonstrated in class.