

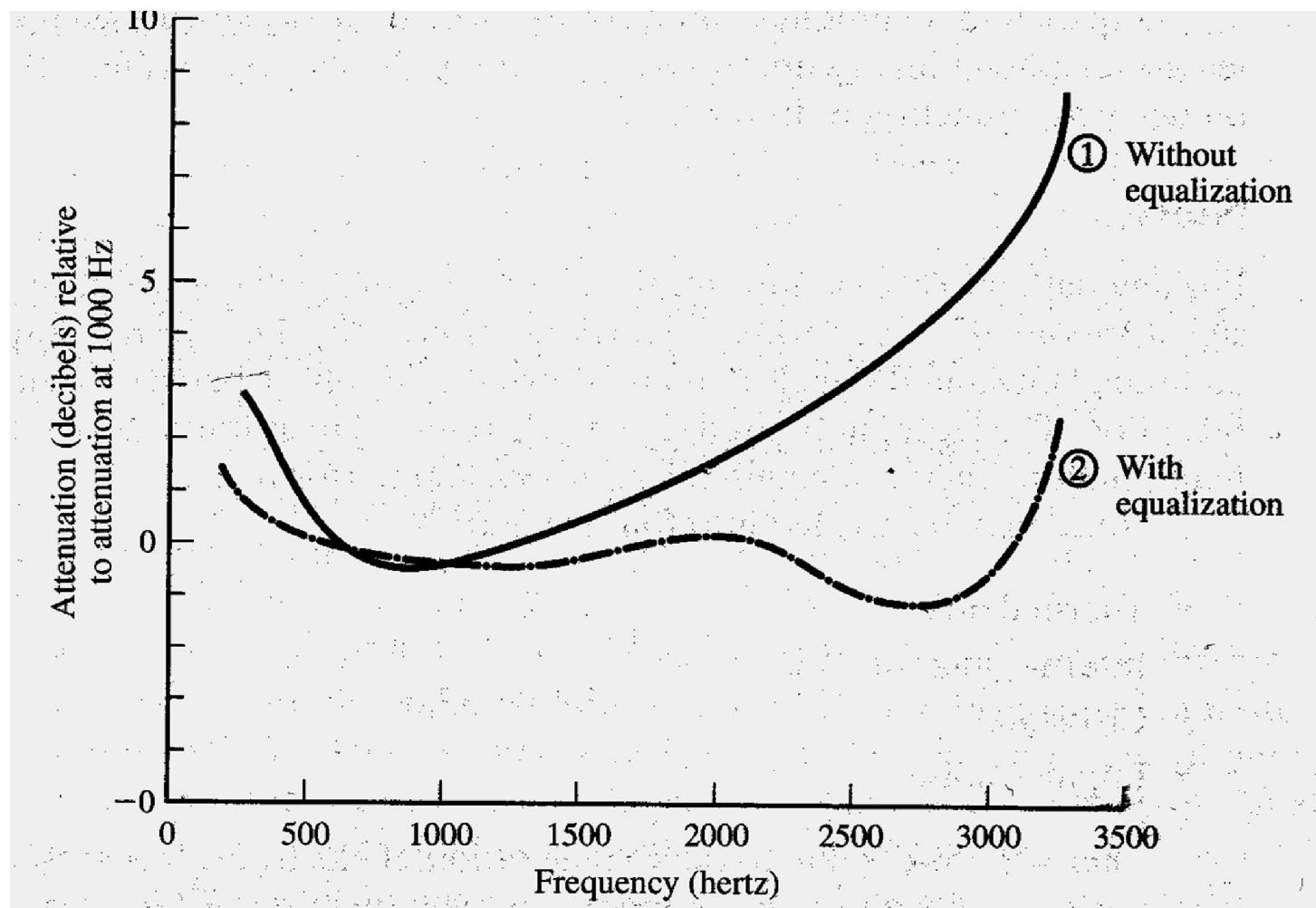
Transmission Impairments

- 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 received 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 evens 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

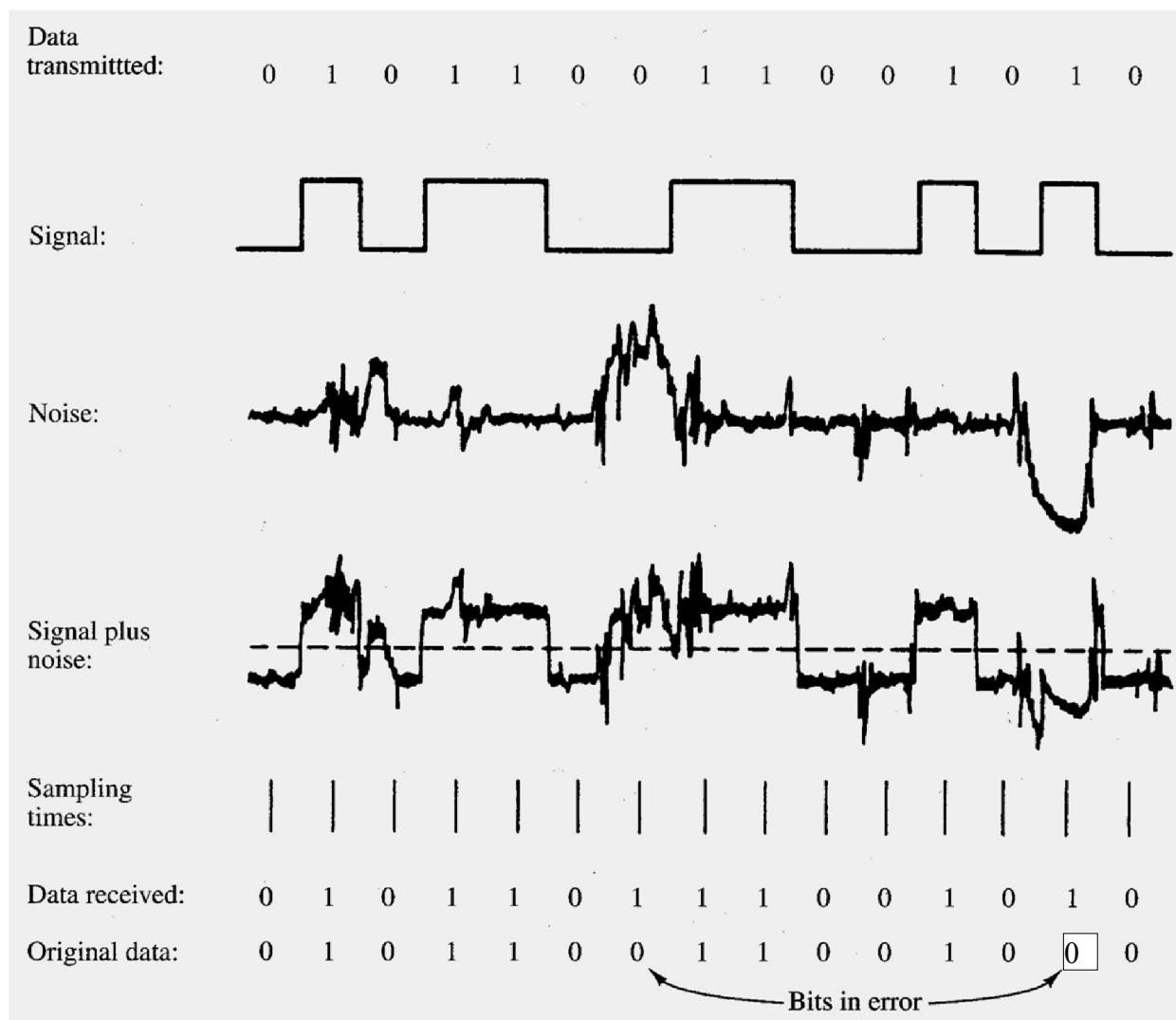
Cross Talk

- 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



Data received: 0 1 0 1 1 0 1 1 1 0 0 1 0 1 0

Original data: 0 1 0 1 1 0 0 1 1 0 0 1 0 0 0

Bits in error

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

$$C = 2B \log_2 M$$

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
 - $\text{SNR}_{\text{dB}} = 10 \log_{10} (\text{S}/\text{N})$
 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:

$$C = B \log_2 (1 + (S/N))$$

- 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 and 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.