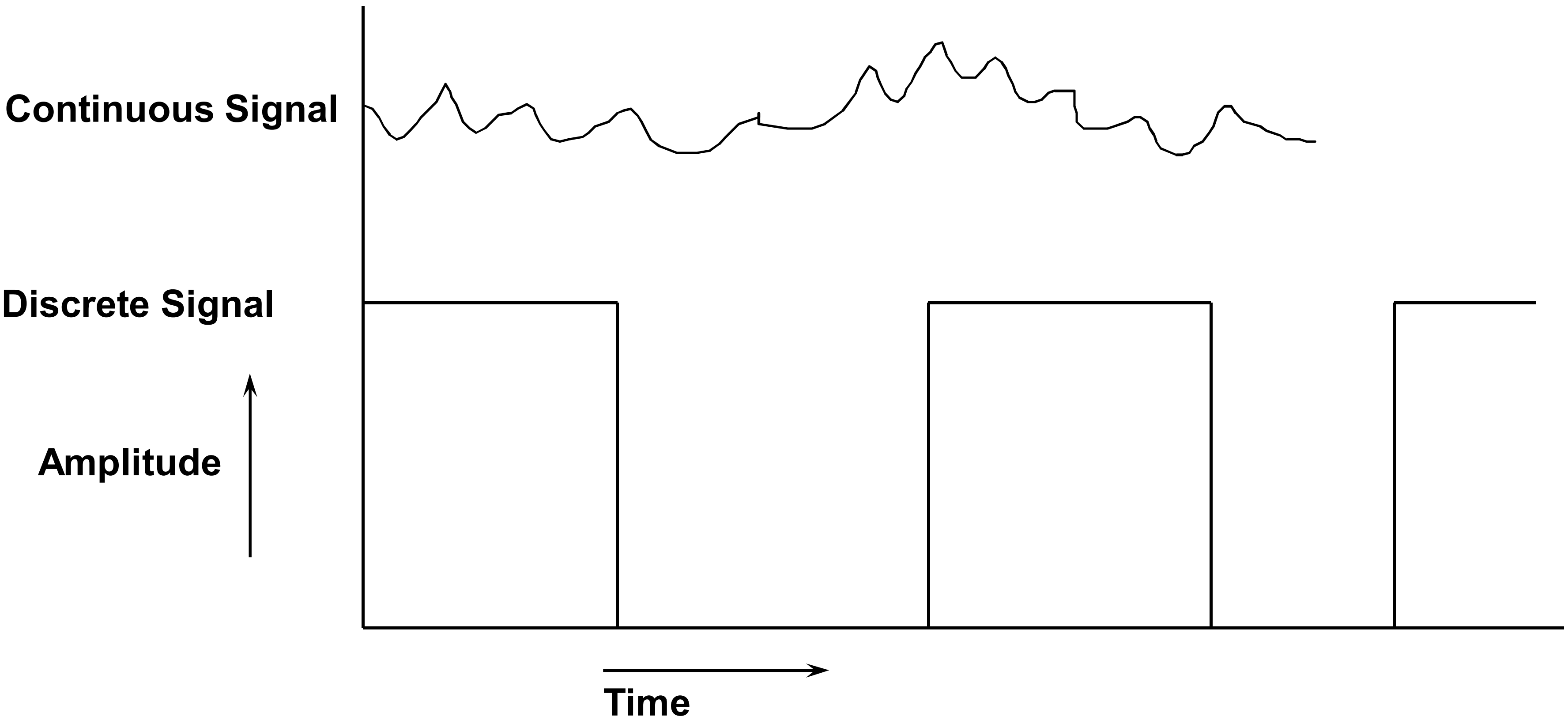
# Data Transmission

- The successful transmission of data depends upon <u>two</u> factors:
  - The quality of the transmission *signal*
  - The characteristics of the transmission *medium*
- Some type of transmission *medium* is required for transmission:
  - Guided e.g. Electric Cable, Fibre Optic Cable
  - Unguided - Electromagnetic Waves in Space

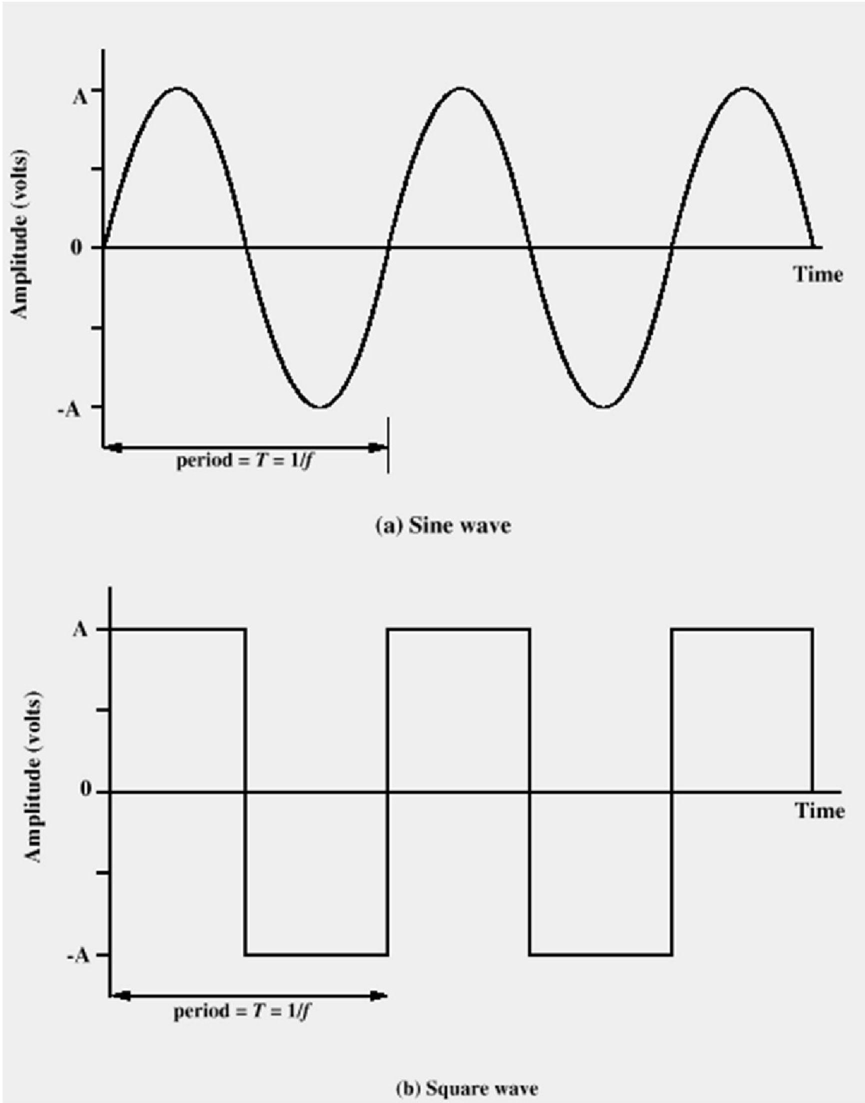
# Signal Characteristics

- Continuous
  - No breaks or discontinuities within signal
  - Example is a speech signal
- Discrete
  - Contains a finite number of discrete values
  - Example is computer or binary data
- Periodic
  - Repeats itself after some fixed time
- Aperiodic
  - No repetition of signal pattern

# Continuous and Discrete Signals



# Periodic Signals



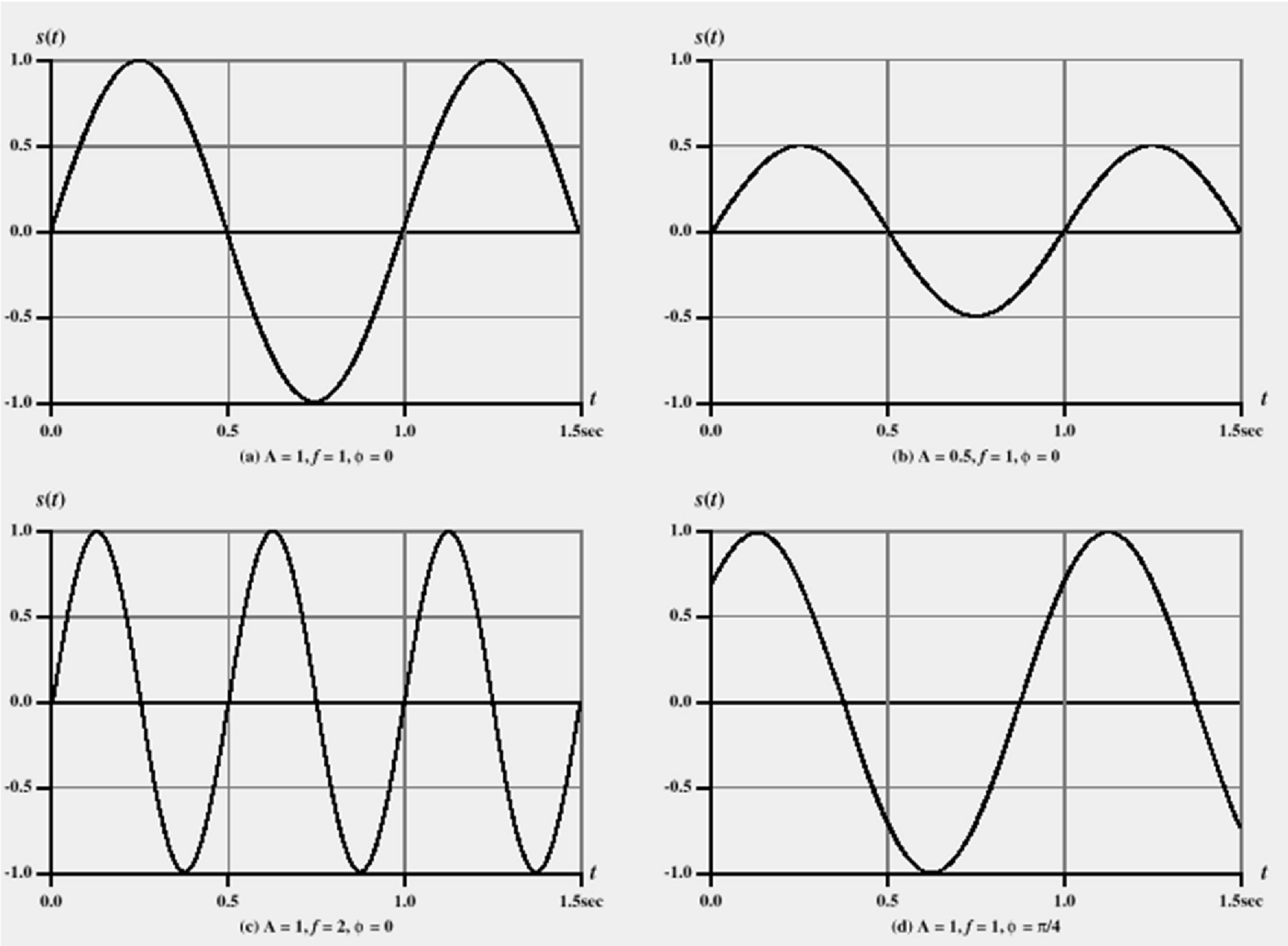
# Sine Wave Characteristics

- The general equation applies:

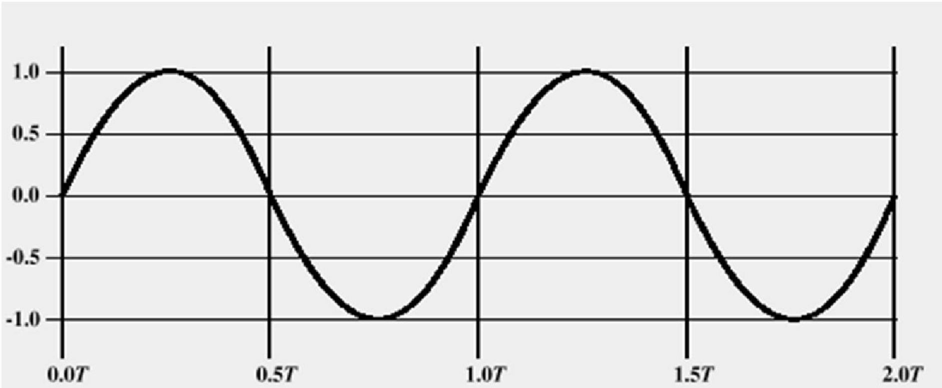
$$\boxed{s(t) = A\sin(2\pi . ft + \phi)}$$

- Where:
  - Amplitude ( *A* ) is the peak value of the waveform
  - Frequency ( *f* ) is the number of repetitions per sec. Measured in Hertz (Hz.). Inverse of the period
  - Phase ( Ø ) is a measure of the relative position within a cycle of a signal. Measured in degrees or radians
- All three characteristics can be varied to give different waveforms

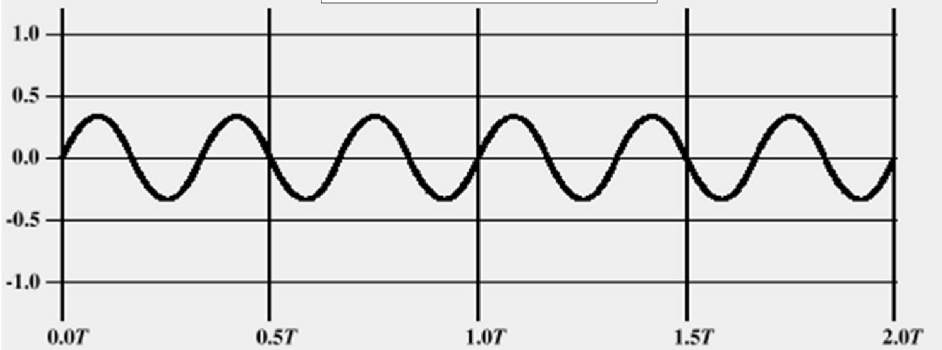
# Varying Sine Wave Characteristics



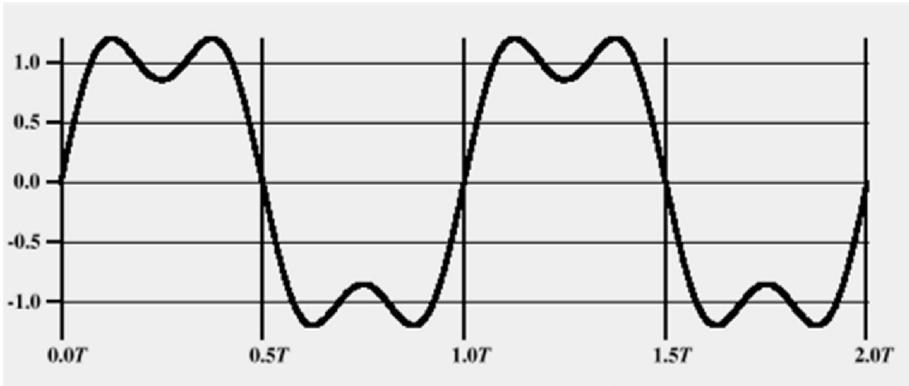
# Addition of Frequency Components




$s(t) = \sin(2\pi f_1 t)$

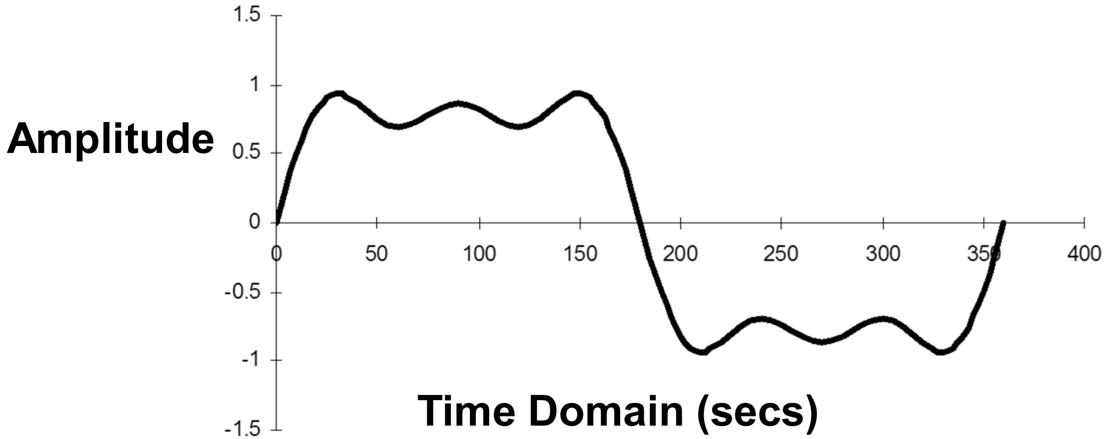


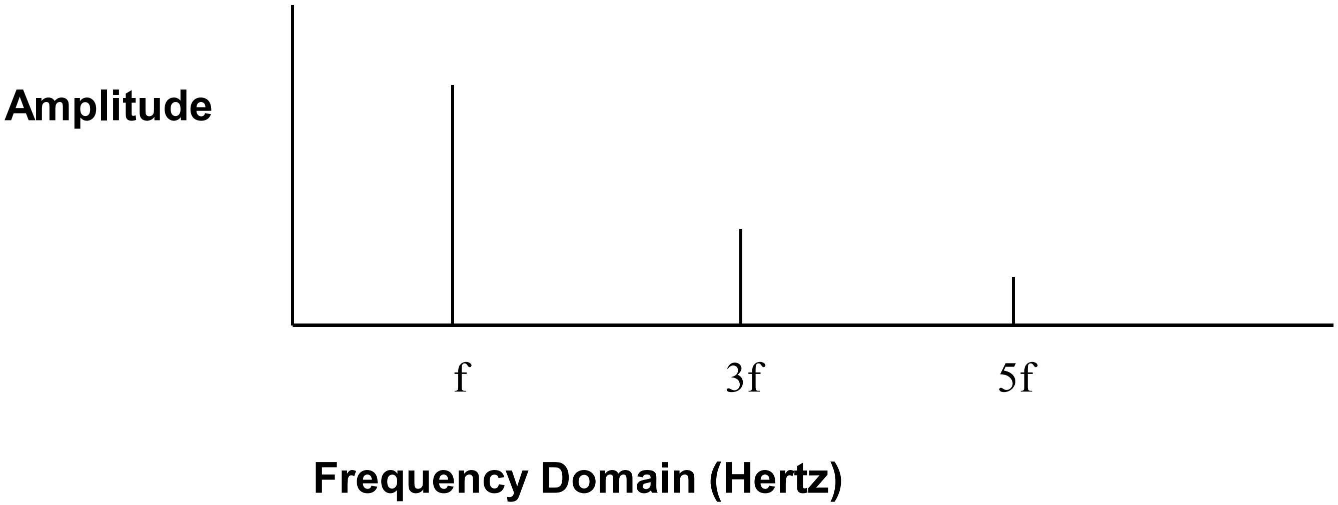

$s(t) = {}^1/_3 \sin(2\pi(3f_1)t)$




$s(t) = \sin(2\pi f_1 t) + {}^1/_3 \sin(2\pi(3f_1)t)$

# Time Domain and Frequency Domain



# Fourier Analysis

- By *Fourier Analysis* <u>any</u> signal can be expressed as the <u>sum</u> of a *series* of sinusoidal components of different frequencies
- This is of fundamental importance:
  - The <u>effects</u> of *transmission media* on a *signal* can be analysed by examining the effects on these *component sinusoids*

# Signalling Concepts

- Spectrum
  - The range of frequencies contained in a signal.
    - For the above sample signal the spectrum *ranges from* $f_1$ to $3f_1$
- Absolute Bandwidth = width of spectrum
    - For the above sample signal the bandwidth is $2f_1$ (i.e. $3f_1 - f_1$)
- Effective Bandwidth
  - Signals with sharp rising and falling edges in the time domain have very wide Absolute Bandwidth
  - Most energy is contained in relatively narrow band called the *Effective Bandwidth*
- DC Component
  - Signals with a component at zero frequency

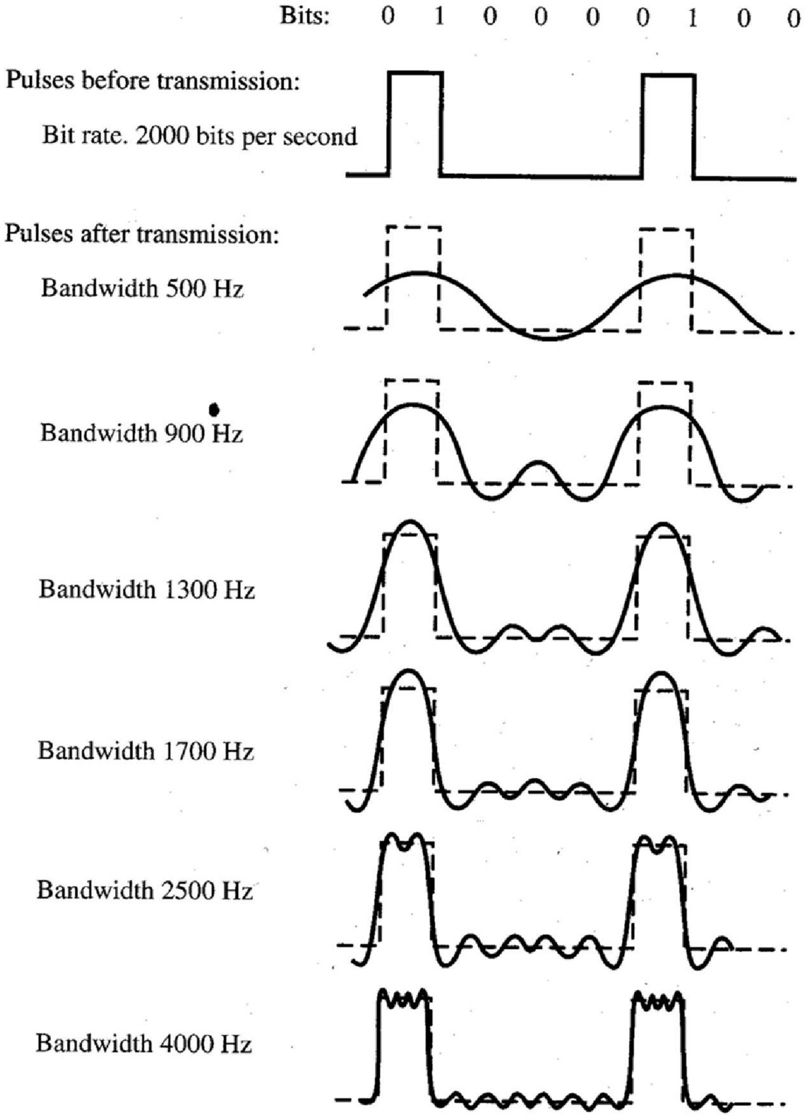
# Fourier Analysis

- By Fourier Analysis any signal can be expressed as the sum of a series of sinusoidal components of various frequencies
- This is of fundamental importance since effects of transmission media on a signal can be analysed by analysing the effects on component sinusoids

# Full Representation of Square Wave

$$s(t) = A \sum_{\substack{K=1 \\ \text{K } odd}}^{\infty} \frac{1}{K} SIN(2\pi . kft)$$

# Relationship between Data Rate & Bandwidth



# Explanation of previous slide

- The Source transmits a *digital* signal with the bit pattern shown (010000100).
- The first Tx System imposes a significant BW restriction on the signal such that only one component (harmonic) passes through.
- The last Tx System allows more components (harmonics) to pass through which results in a more *‘readable’* signal

# Explanation of previous slide

- From our simplistic calculations performed in class on Data Rates:
  - If a less complex signal could used to carry the data through the last Tx System, the frequency would be higher than the more ‘readable’ signal shown.
  - This affects the Data Rate as it is directly related to the frequency of the signal used to carry the data i.e higher frequency signals carry data faster.

## Relationship between Data Rate & Bandwidth

- The bandwidth of a transmission system can be described as:

*“The fastest continuously oscillating signal that can be sent (transmitted) across the transmission system. It is represented in Hertz (Hz).”*

- This limitation arises from the physical properties of matter and energy

## Relationship between Data Rate & Bandwidth

- This limitation has a direct effect on the maximum *data rate* achieveable across a transmission system
- Consider a transmission system that has a bandwidth of 4MHz…..

## Relationship between Data Rate & Bandwidth

- For a Transmission *System* the greater the bandwidth of the system the higher the data rate that can be achieved
- For a Transmission *Signal* the greater the speed (frequency) of the signal:
  - The greater the bandwidth of the signal
  - The more data can be transmitted

# Conclusions

- In digital transmission the *square wave* is usually used to encode data
  - A *digital* waveform has infinite *Absolute Bandwidth*
- All transmission systems have a *limited bandwidth*
- The more limited the bandwidth the greater the *distortion* i.e. not all components will get through
- In general for a digital signal of *W* bps, very good representation can be achieved with a *transmission bandwidth* of *2W* Hz.
- Hence, there is a relationship between *data rate* and *bandwidth*

# Data and Signals - Concepts

- Data
  - Entities that convey meaning
- Signal
  - Electromagnetic wave with *encoded* data
- Transmission System
  - The entity over which the *signal* is transmitted
- Analogue Data
  - Take on continuous values on some interval e.g. voice, temperature, pressure etc.
- Digital Data
  - Take on discrete values e.g. integers, text

# Signals - Defined

- Analogue Signal
  - Continuously varying electromagnetic wave (representing data) that may be propagated over a transmission medium
- Digital Signal
  - Sequence of discrete, discontinuous voltage pulses (representing data) that may be propagated over a transmission medium

# Data Transmission - Defined

- *Data Transmission* is the communication of data by the propagation and processing of signals:
  - *Analogue* data can be conveyed by an *analogue* signal e.g. ordinary telephone
  - *Digital* data can also be conveyed by an *analogue* signal when a ***MODEM*** is used.
  - *Analogue* data can be conveyed by a *digital* signal when a ***CODEC*** is used
  - *Digital* data can be conveyed by a *digital* signal e.g. digital transmitter

# Analogue Transmission - Defined

- *Analogue Transmission* is the propagation of analogue signals only i.e. some physical quantity (e.g. voltage) that changes continuously as a function of time
- There is **no** regard to the content of the signal i.e. the *encoded* data
- A transmitted analogue signal can be boosted by amplifiers periodically to extend range but this also boosts *noise* so the signal eventually becomes *distorted*

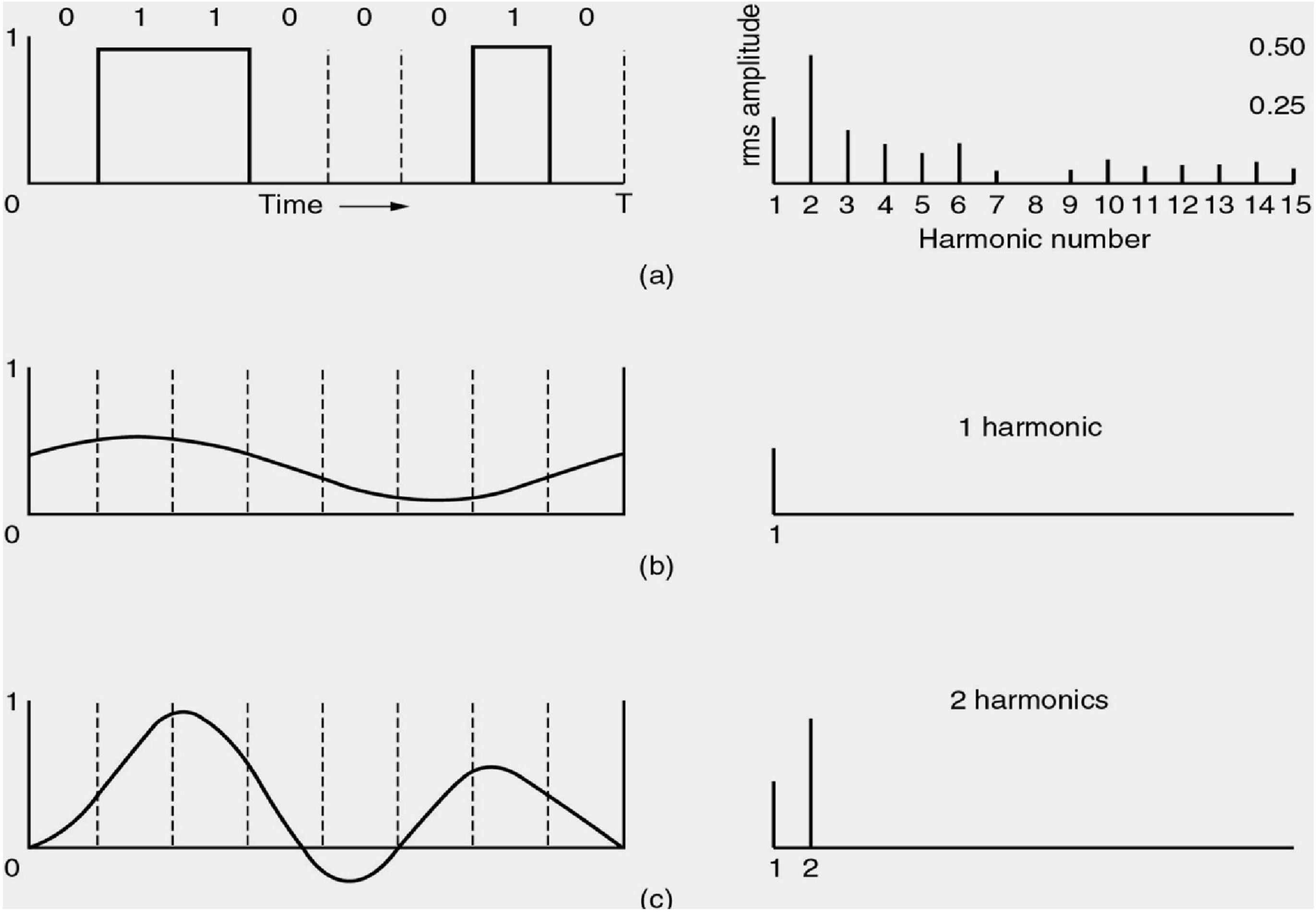
# Digital Transmission - Defined

- Digital transmission – is the propagation of analogue signals (with encoded *digital data*) **OR** digital signals with regard to the encoded data.
  - Digital signals switch between a number of discrete levels.
- As the transmitted digital signal becomes *attenuated* with distance a ***repeater*** can extend the range
- A repeater receives the signal, recovers the digital data and re-transmits a new signal with no noise added

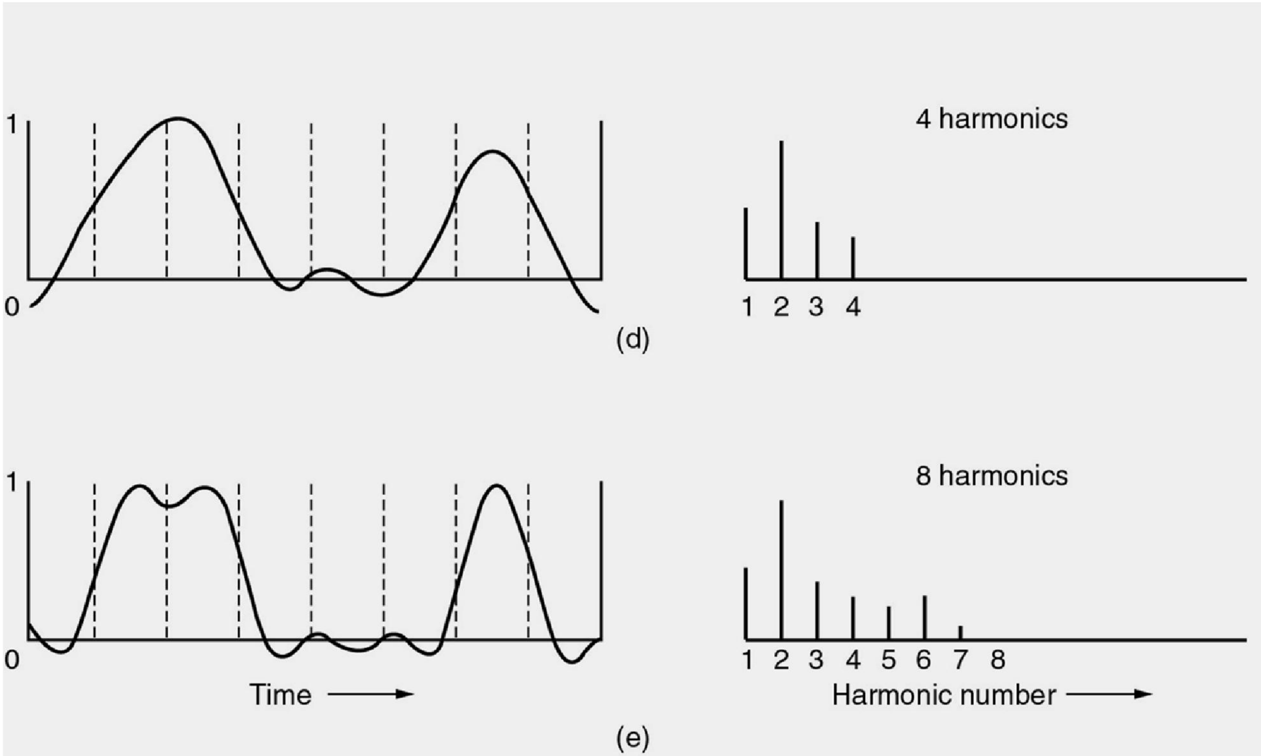
# Analogue V Digital Transmission

- Digital is Superior
  - Low cost of digital electronics
  - Data integrity - signal can be maintained free of noise
  - Capacity Utilisation - different digital signals can be ‘Multiplexed’ and ‘De-multiplexed’ more easily and thus share a signal channel
  - Security - Encryption can be more easily applied to digital data
  - Integration - Digitised analogue data can be mixed with digital and share the same facilities as other digital data

# Bandwidth-Limited Signals



# Bandwidth-Limited Signals (2)



# Bandwidth-Limited Signals (3)

| Bps | T (msec) | First harmonic (Hz) | # Harmonics sent |
|---|---|---|---|
| 300 | 26.67 | 37.5 | 80 |
| 600 | 13.33 | 75 | 40 |
| 1200 | 6.67 | 150 | 20 |
| 2400 | 3.33 | 300 | 10 |
| 4800 | 1.67 | 600 | 5 |
| 9600 | 0.83 | 1200 | 2 |
| 19200 | 0.42 | 2400 | 1 |
| 38400 | 0.21 | 4800 | 0 |