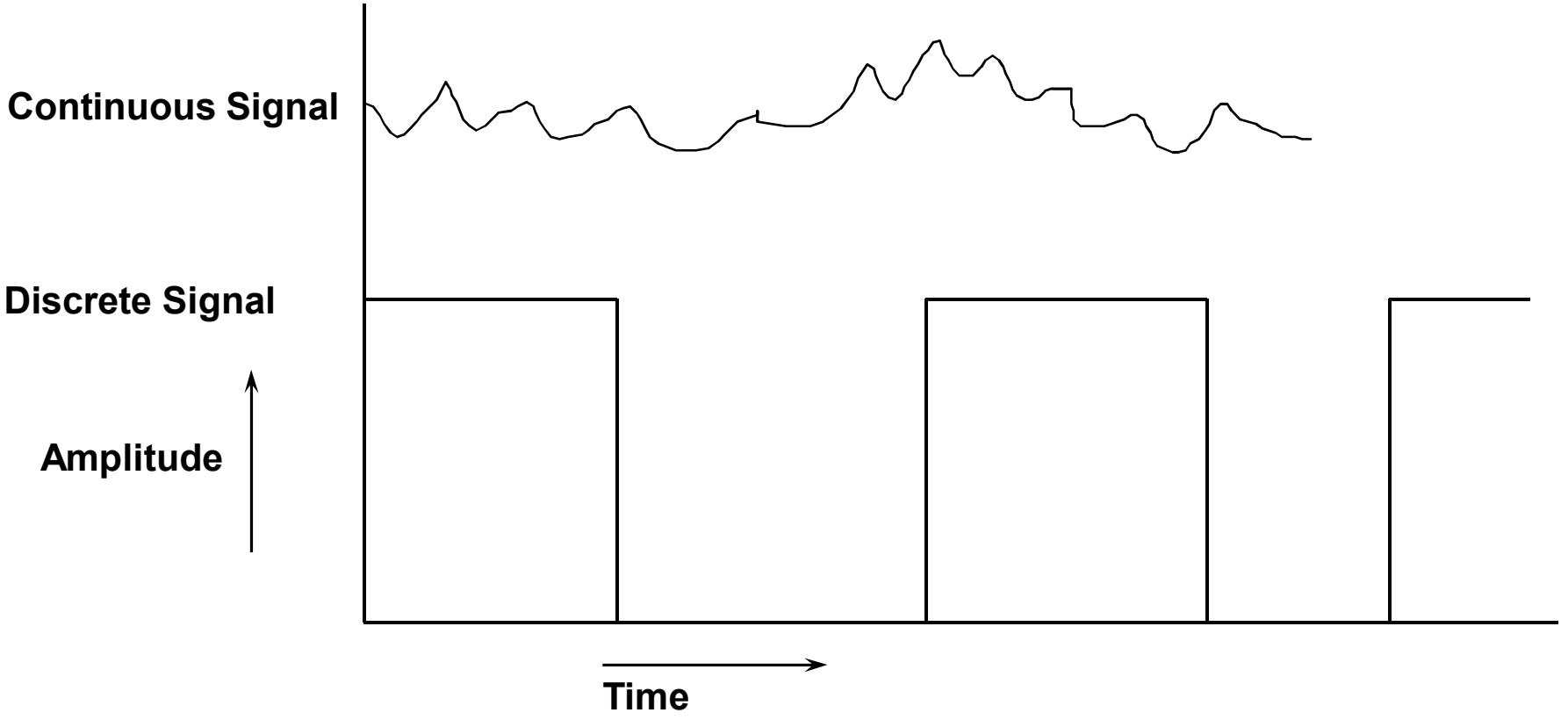
Data Transmission

- The successful transmission of data depends upon two 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

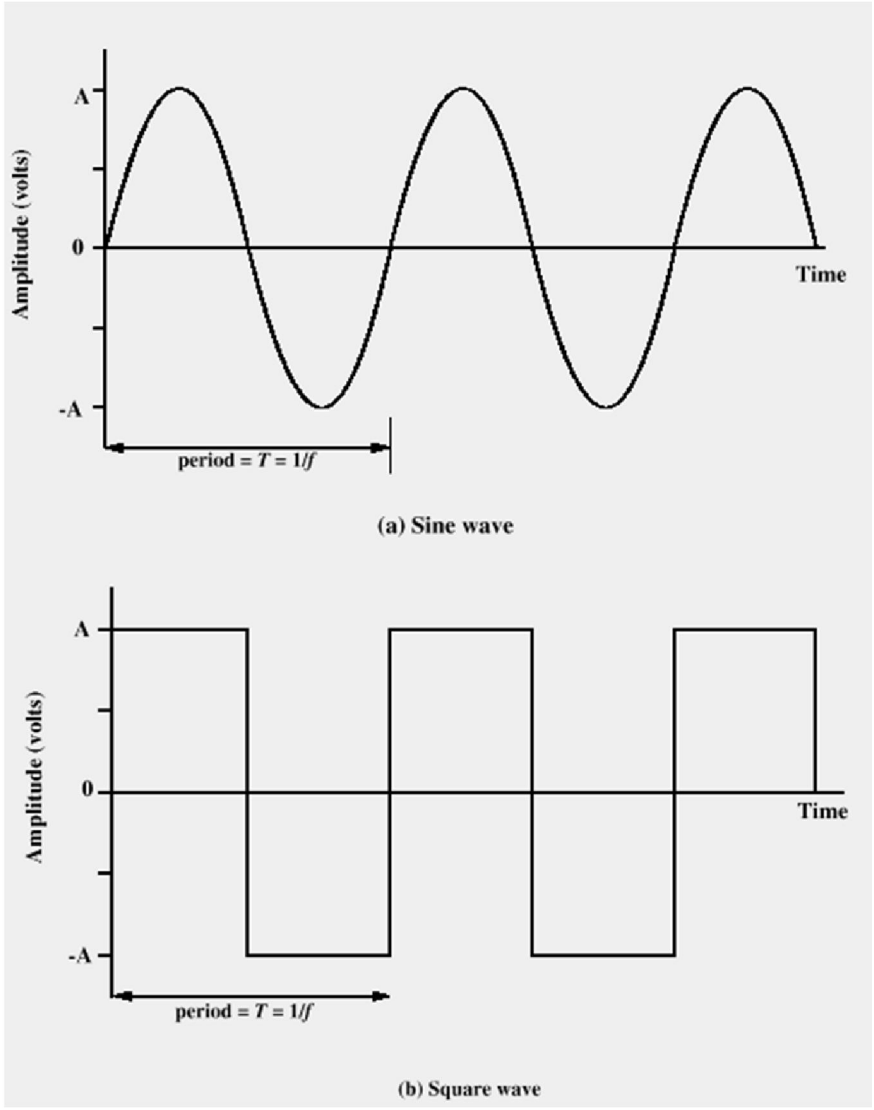
Signal Characteristics

- 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



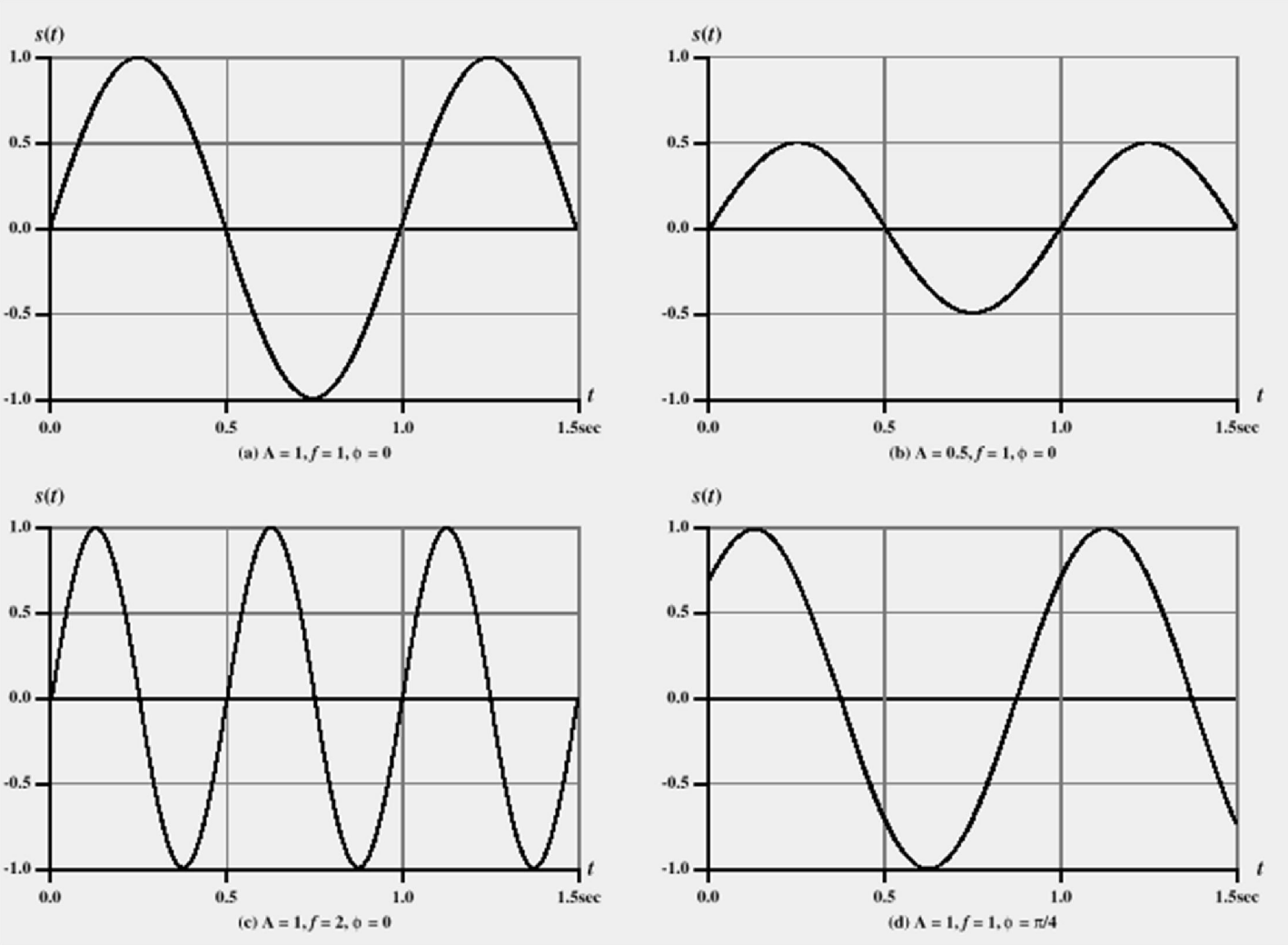
Sine Wave Characteristics

- The general equation applies:

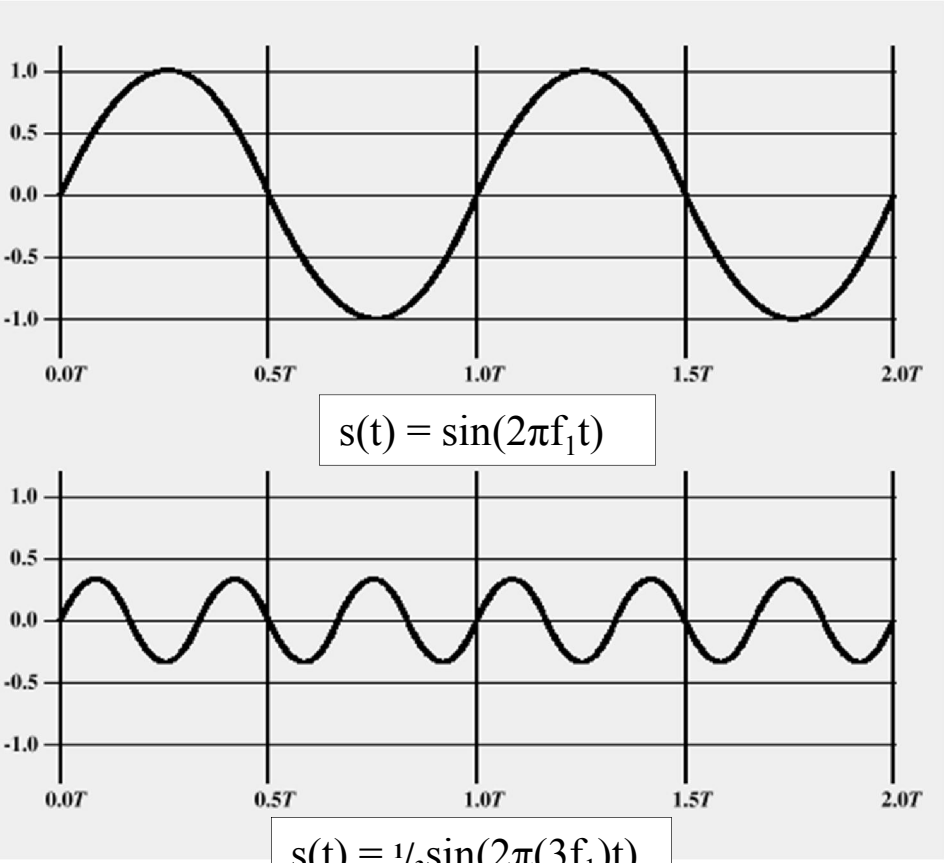
$$s(t) = A\sin(2\pi.ft + \phi)$$

- 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

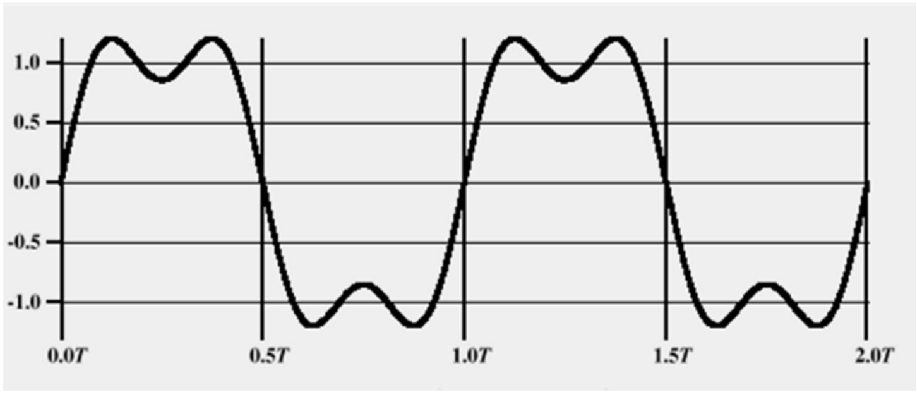


Addition of Frequency Components



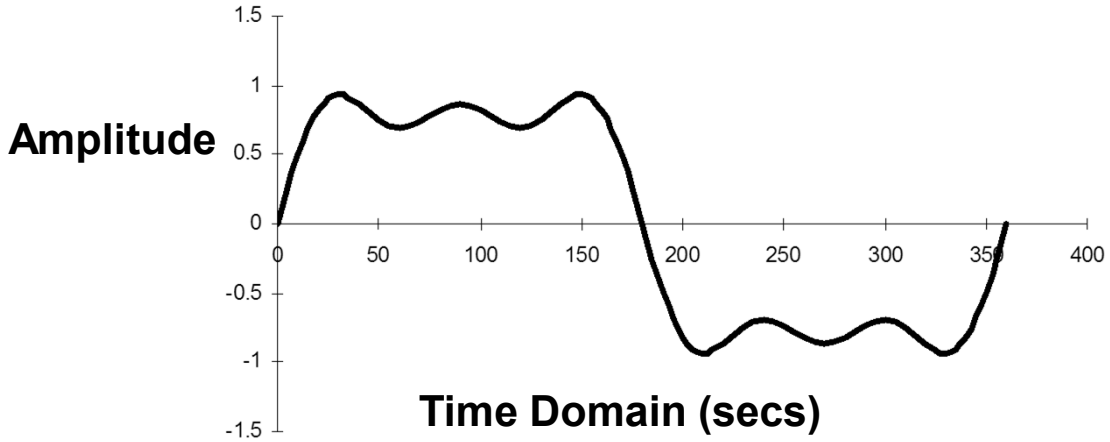
$s(t) = \sin(2\pi f_1 t)$

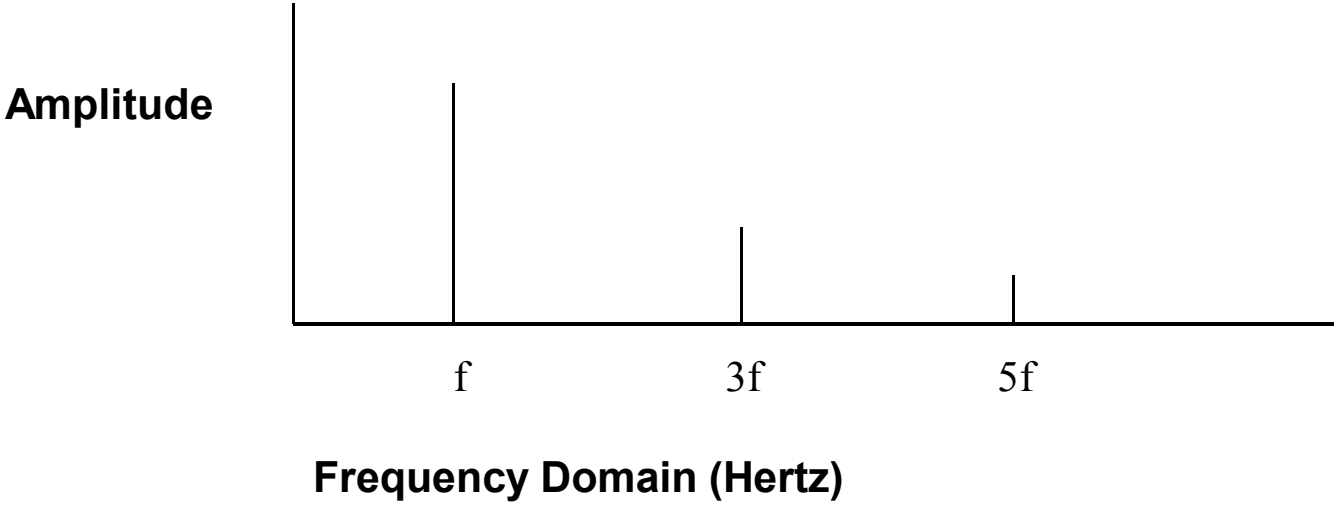
$s(t) = \frac{1}{3}\sin(2\pi(3f_1)t)$



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

Time Domain and Frequency Domain





Fourier Analysis

- By *Fourier Analysis* any signal can be expressed as the sum of a *series* of sinusoidal components of different frequencies
- This is of fundamental importance:
  - The effects 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

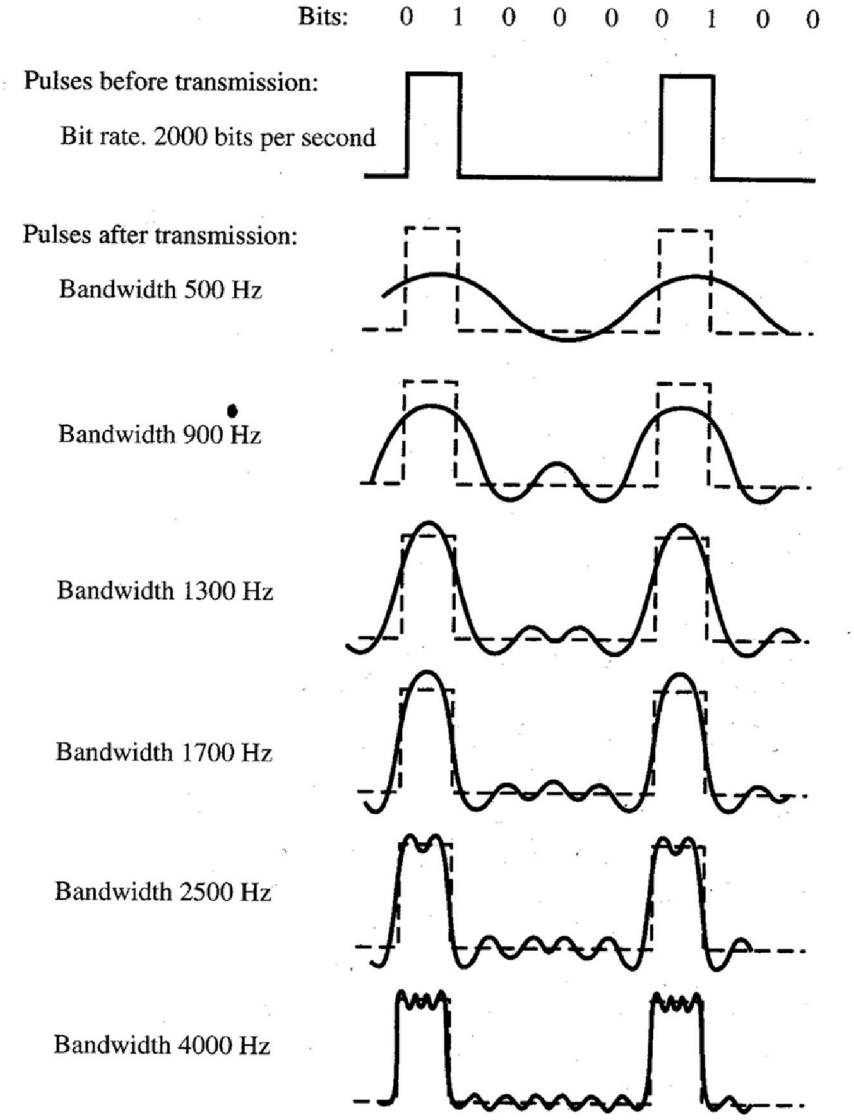
Fourier Analysis

- 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

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

Relationship between Data Rate & Bandwidth



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 medium
- Digital Signal
  - Sequence of discrete discontinuous voltage pulses that may be propagated over a 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 be conveyed by an *analogue* signal e.g. modem
  - *Analogue* data can be conveyed by a *digital* signal e.g. CODEC
  - *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 signal eventually becomes *distorted*

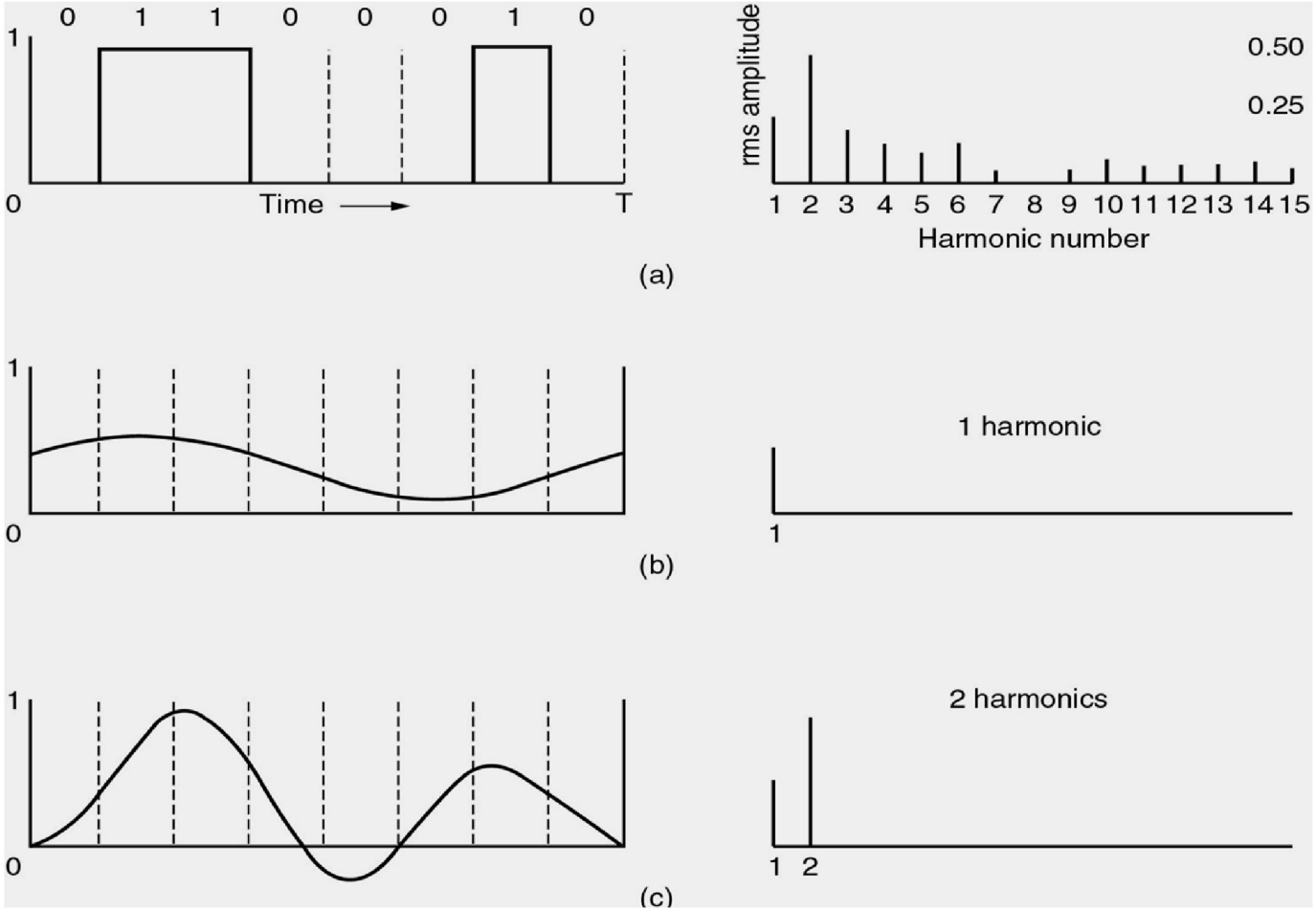
Digital Transmission - Defined

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

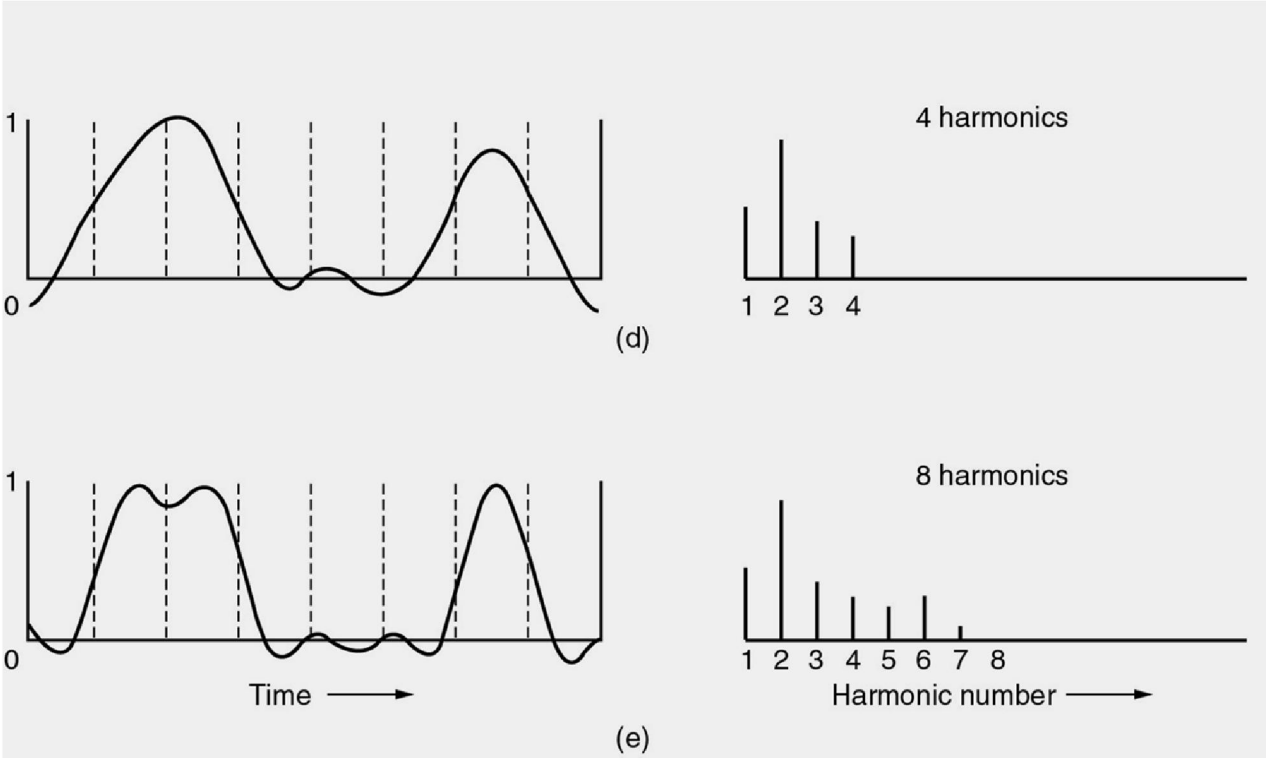
Analogue V Digital Transmission

- 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