Lecture (01)
Data Transmission (I)

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Agenda

- The objective
- Transmission terminologies
- Bandwidth and data rate

The objective

- The successful transmission of data depends principally on two factors:

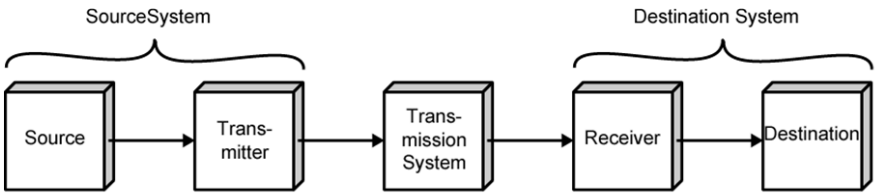
1. the quality of the signal being transmitted
2. and the characteristics of the transmission medium.

- The objective of this topic (data transmission) and the next (transmission medium) is to provide you with an intuitive feeling for the nature of these two factors.

Transmission terminologies

The process:

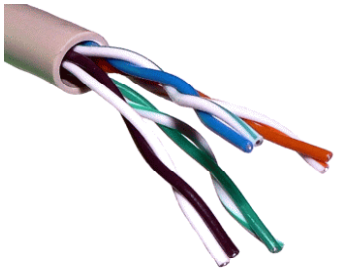
- Data transmission occurs between transmitter and receiver over some transmission medium.
- Transmission media may be classified as guided or unguided.
- In both cases, communication is in the form of Electrical or electromagnetic waves.



Transmission terminologies (cont,..)

guided media,

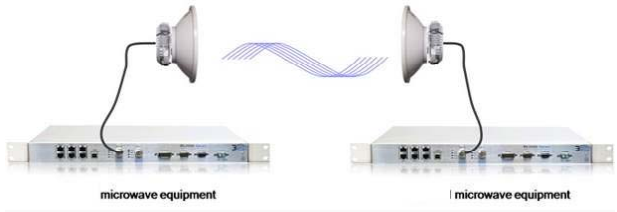
- the waves are guided along a physical path;
- examples of guided media are twisted pair, coaxial cable, and optical fiber.



Transmission terminologies (cont,..)

Unguided media, also called wireless,

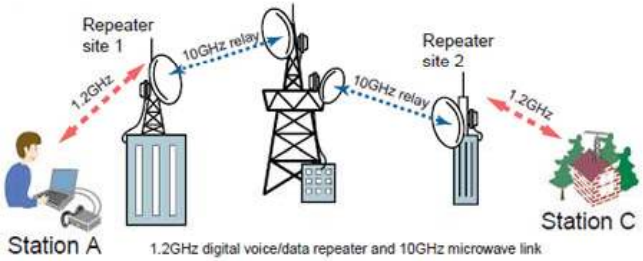
- provide a means for transmitting electromagnetic waves but do not guide them;
- examples are propagation through air, vacuum, and seawater.



Transmission terminologies (cont,..)

direct link is

- refer to the transmission path between two devices in which signals propagate directly from transmitter to receiver with no intermediate devices, other than amplifiers or repeaters used to increase signal strength.



1.2GHz digital voice/data repeater and 10GHz microwave link

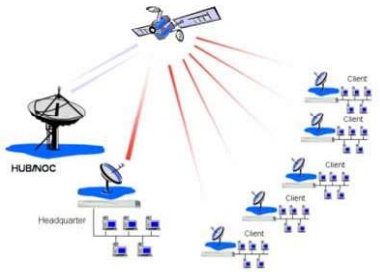
Transmission terminologies (cont,..)

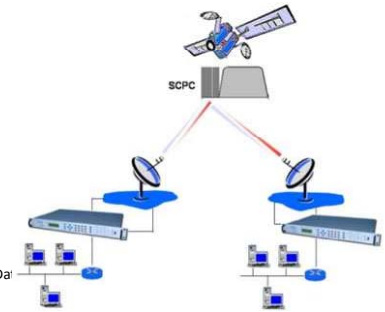
Point to Point Configuration

- is a direct link between two devices and those are the only two devices sharing the medium.

multipoint guided configuration,

- more than two devices share the same medium.

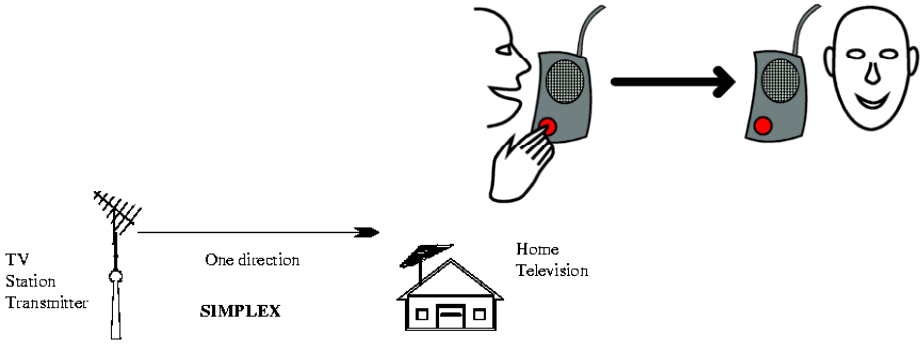




Transmission terminologies (cont,..)

Simplex transmission,

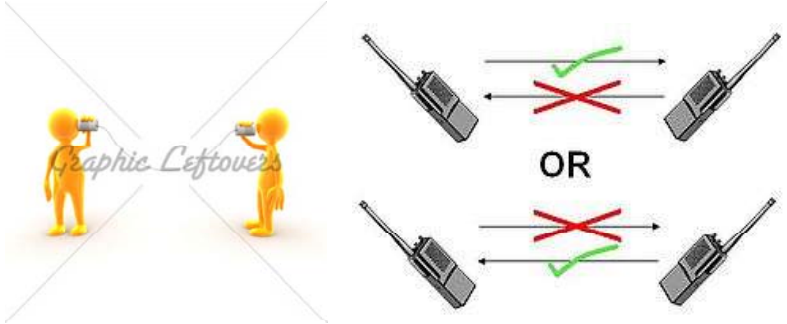
- signals are transmitted in only one direction; one station is transmitter and the other is receiver.



Transmission terminologies (cont,..)

half-duplex operation,

- both stations may transmit, but only one at a time.



Transmission terminologies (cont,..)

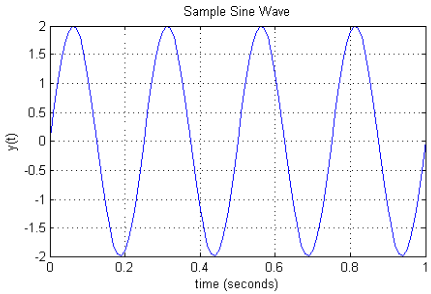
full-duplex operation,

- both stations may transmit simultaneously, and the medium is carrying signals in both directions at the same time.

Transmission terminologies (cont,..)

Time Domain

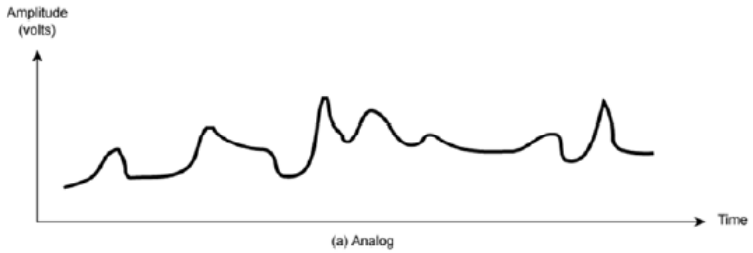
The electromagnetic or electrical signal is a function of time,



Transmission terminologies (cont,..)

Analog signal

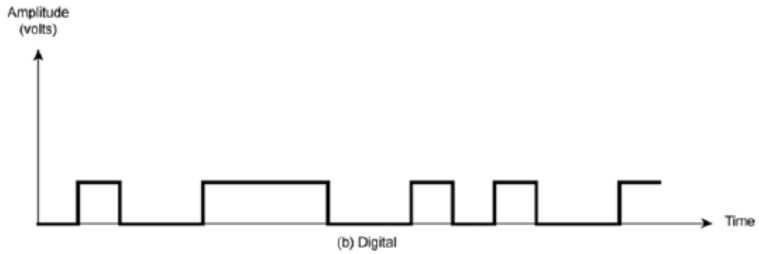
- signal intensity varies in a smooth fashion over time.



Transmission terminologies (cont,..)

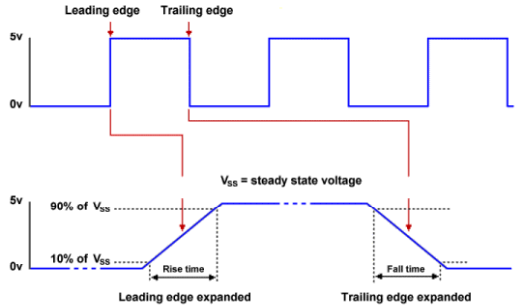
digital signal

- signal intensity maintains a constant level for some period of time and then abruptly changes to another constant level.



Transmission terminologies (cont,..)

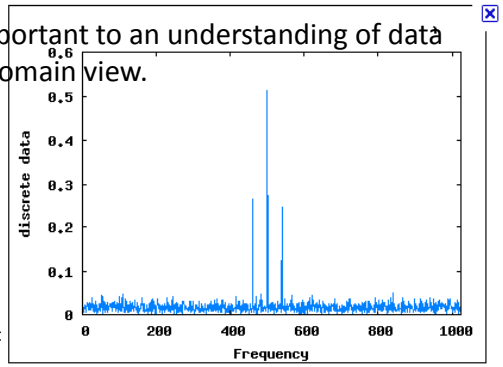
This is an idealized definition. In fact, the transition from one voltage level to another will not be instantaneous, but there will be a small transition period.



Transmission terminologies (cont,..)

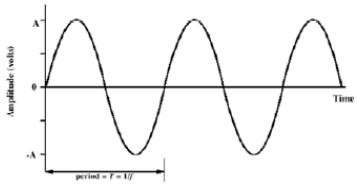
frequency domain

- Signal can be expressed as a function of frequency;
- that is, the signal consists of components of different Frequencies
- view of a signal is more important to an understanding of data transmission than a time domain view.

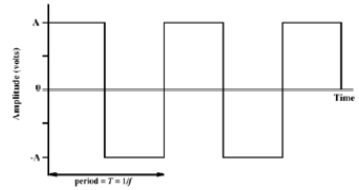


Transmission terminologies (cont,..)

The simplest sort of signal is a **periodic signal**, in which the same signal pattern repeats over time. Otherwise, a signal is **aperiodic**



(a) Sine wave



(b) Square wave

Transmission terminologies (cont,..)

The sine wave

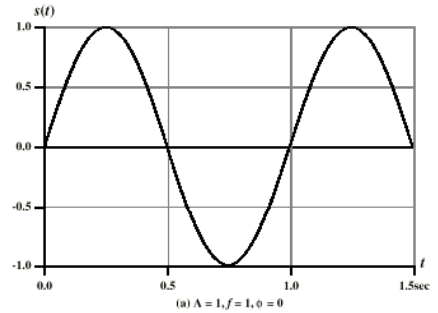
- is the fundamental periodic signal.
- A general sine wave can be represented by three parameters:
- **peak amplitude (*A*)** - *the maximum value or strength of the signal over time;* typically measured in volts.
- **frequency (*f*)** - *the rate [in cycles per second, or Hertz (Hz)] at which the signal* repeats.
- An equivalent parameter is the **period (*T*) *of a signal, so T = 1/f.***
- **phase (ϕ) -** measure of relative position in time within a single period of a signal

Transmission terminologies (cont,..)

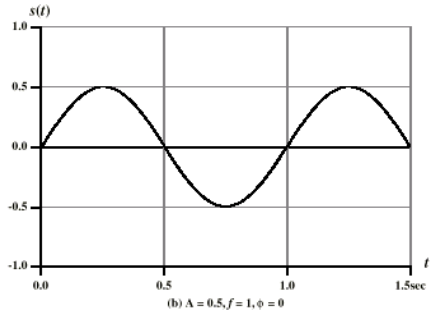
- The general sine wave can be written as:

$$s(t) = A \sin(2\pi f t + \varphi),$$

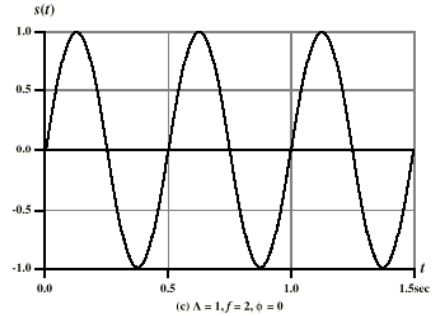
- *known as a* **sinusoid function.**



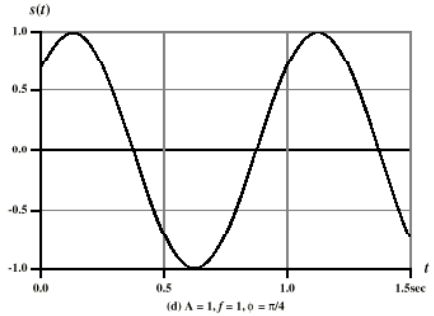
(a) A = 1, f = 1, ϕ = 0



(b) A = 0.5, f = 1, ϕ = 0



(c) A = 1, f = 2, ϕ = 0



(d) A = 1, f = 1, ϕ = π/4

Transmission terminologies (cont,..)

- In part (a) of the figure, the frequency is 1 Hz; thus the period is *T = 1 second.*
- Part (b) has the same frequency and phase but a peak amplitude of 0.5.
- In part (c) we have *f = 2, which* is equivalent to *T = 0.5. Finally,*
- *part (d) shows the effect of a phase shift of π/4* radians, which is 45 degrees (2π radians = 360° = 1 period).

Transmission terminologies (cont,..)

The wavelength (λ)

- is the distance occupied by a single cycle,
- or, the distance between two points of corresponding phase of two consecutive cycles.
- Assume that the signal is traveling with a velocity *v.*
- Then the wavelength is related to the period as follows:

$$\lambda = vT.$$

Equivalently,

$$\lambda = v/F \text{ (as } F=1/T)$$

- *Of particular relevance to this discussion is the case where v = c, the speed of* light in free space, which is approximately 3×10^8 m/s.

Transmission terminologies (cont,..)

Frequency

- It is the rate at which something occurs or is repeated over a particular period or in a given sample or period.
- Or it is the rate at which a vibration occurs that constitutes a wave in a second
- Because frequency refers to cycles

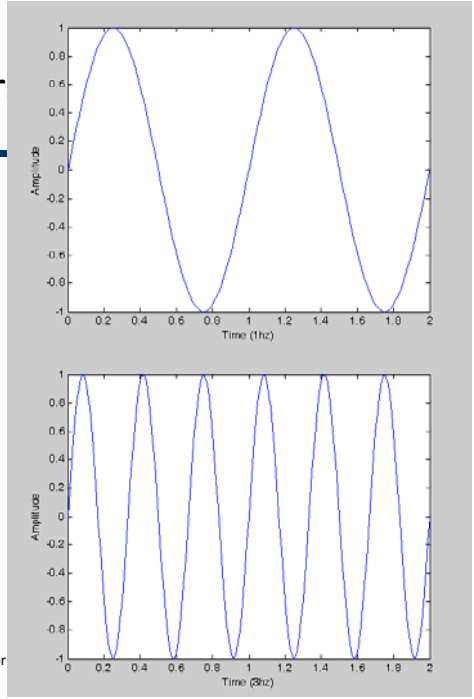
Transmission terminologies (cont,..)

- some facts
  - 1 cycle = 1 Hz
  - Higher frequencies travel shorter distances
  - When a waveform is seen once in a second = 1 Hz
  - 10 times in a second = 10 Hz
  - 1 million times in a second = 1 MHz
  - 1 billion times in a second = 1 GHz

Bandwidth and data r

y1=sin(t)

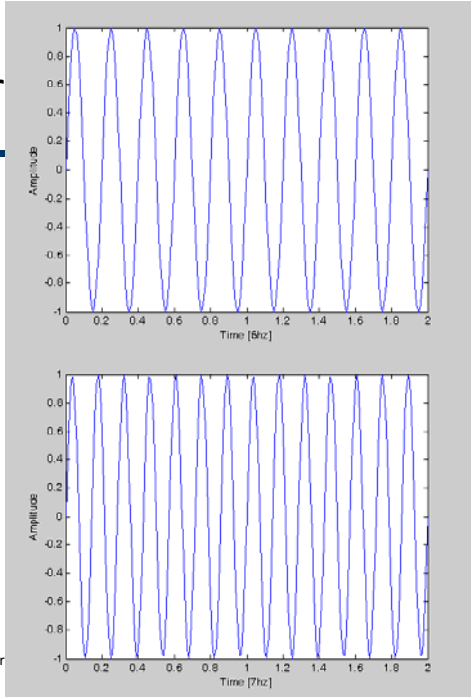
Y3=sin(3t)



Bandwidth and data r

Y5=sin(5t)

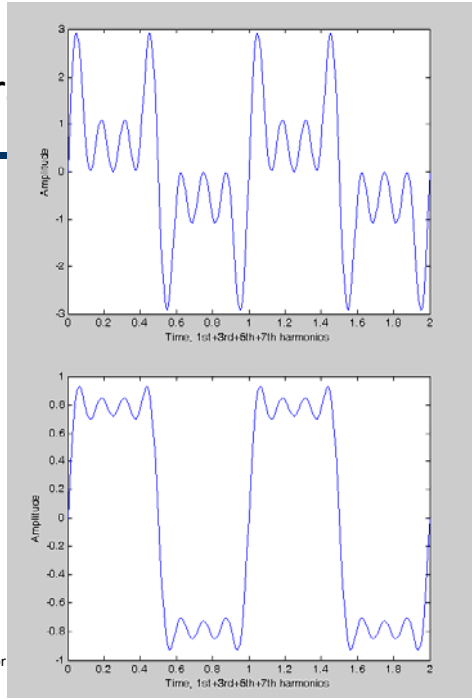
Y7=sin(7t)



Bandwidth and data r

Y=y1+y3+y5+y7

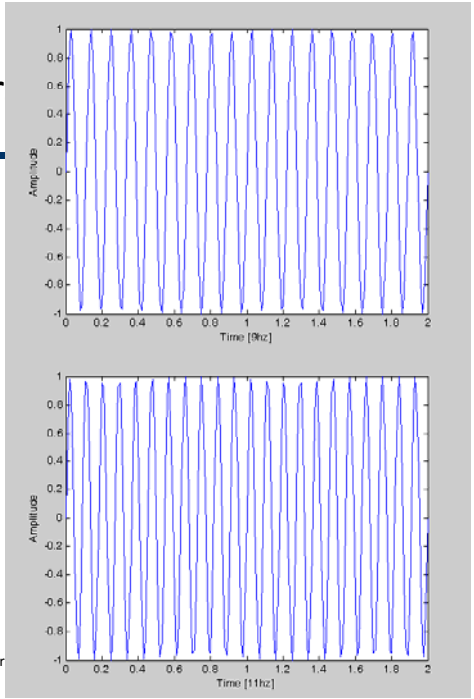
y=y1+(y3/3)+(y5/5)+(y7/7)



Bandwidth and data r

Y9=sin(9t)

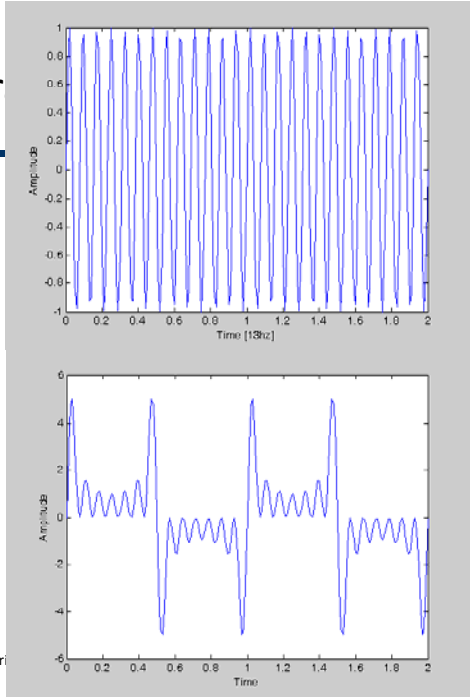
Y11=sin(11t)



Bandwidth and data r

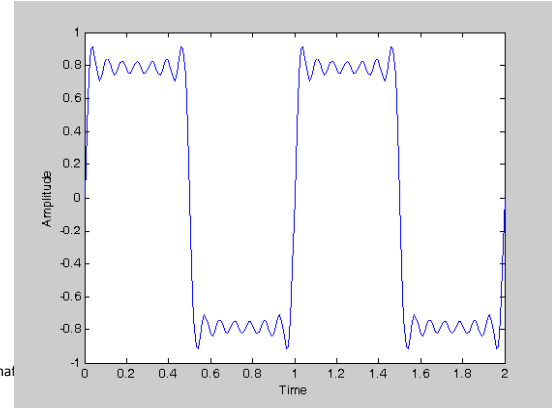
Y13=sin(13t)

Y=y1+y3+y5+y7+y9+y11+y13



Bandwidth and data rate

y=y1+(y3/3)+(y5/5)+(y7/7)+(y9/9)+(y11/11)+(y13/13)



Bandwidth and data rate (cont,..)

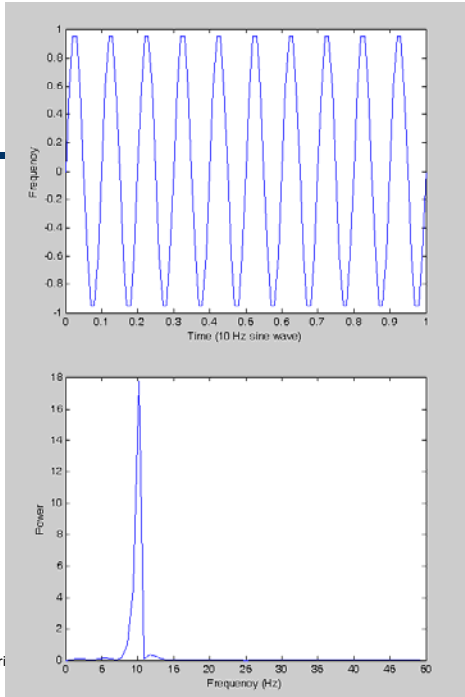
Fourier transform and Frequency domain

- signal will be made up of many frequencies.
- It can be shown, using a discipline known as Fourier analysis, that any signal is made up of components at various frequencies, in which each component is a sinusoid.
- By adding together enough sinusoidal signals, each with the appropriate amplitude, frequency, and phase, any electromagnetic signal can be constructed.

f1=10;

y1 = sin(2*pi*t*f1);

Y1=fft(y1);



```
f2=20;
y2 = sin(2*pi*t*f2);
Y2 = fft(y2);
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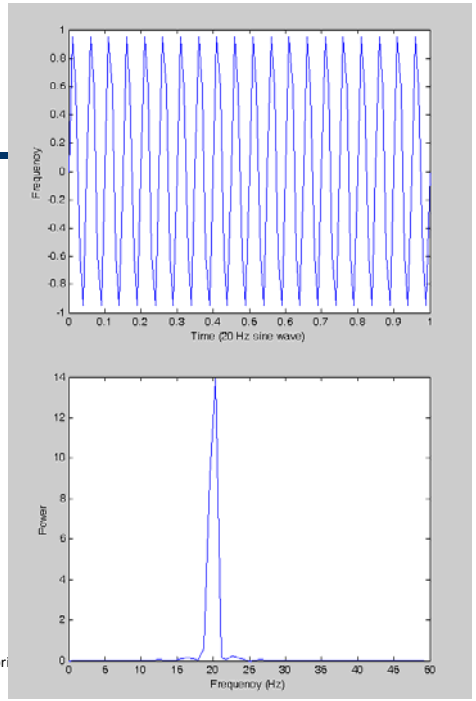


```
y3 = sin(2*pi*t*f3);

Y3 = fft(y3,n);
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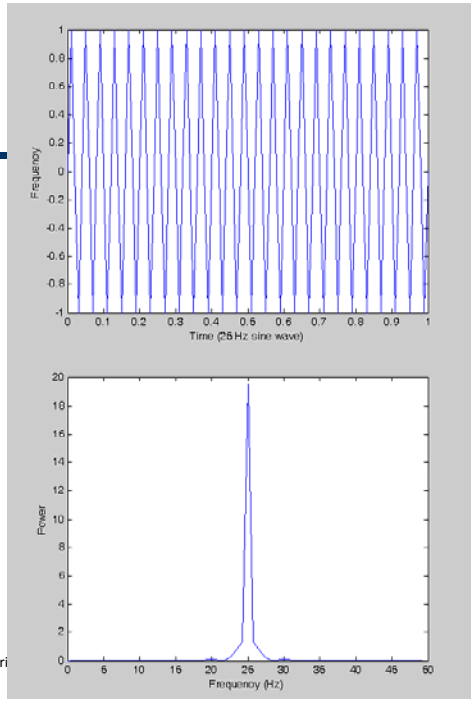


```
y=y1+y2+y3;
Y=fft(y);
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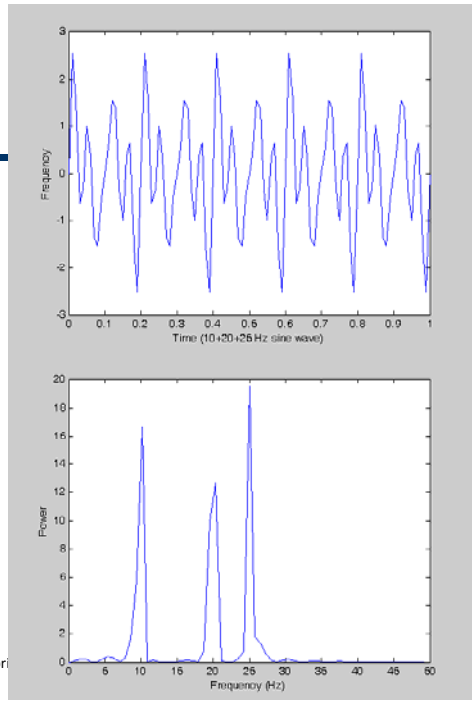
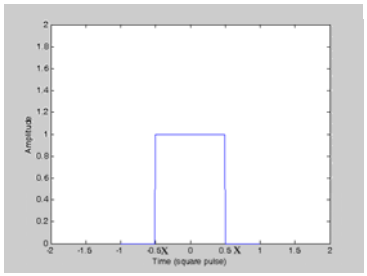
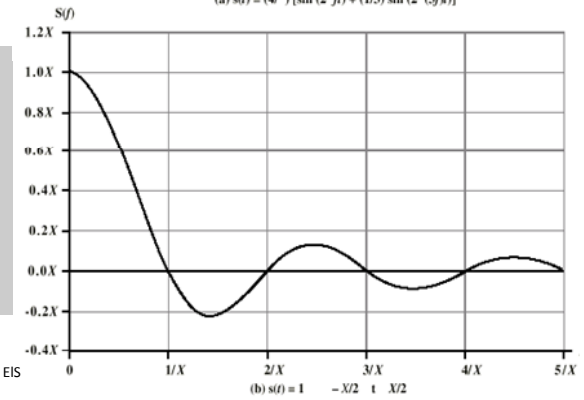


Bandwidth and data rate (cont,..)

Frequency domain of discrete pulse

- the frequency domain function for a single square pulse that has the value 1 between *–X/2 and X/2, and is 0 elsewhere.*



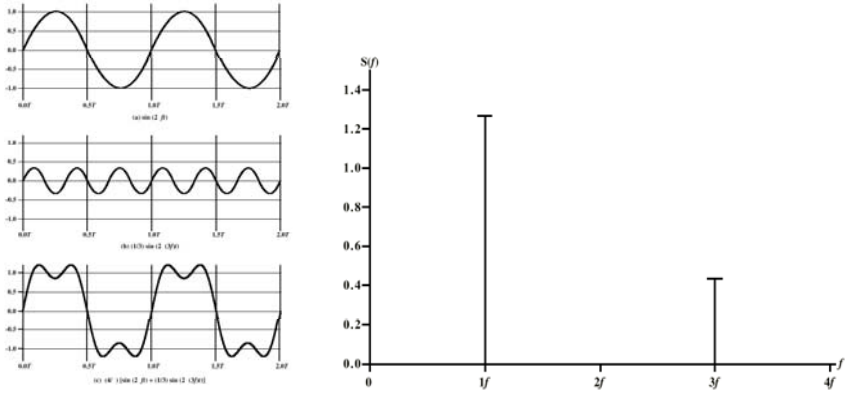


Bandwidth and data rate (cont,..)

- *Note that in this case S(f) is* continuous and that it has nonzero values indefinitely, although the magnitude of the frequency components rapidly shrinks for larger *f.*
- *These characteristics are* common for real signals.

Bandwidth and data rate (cont,..)

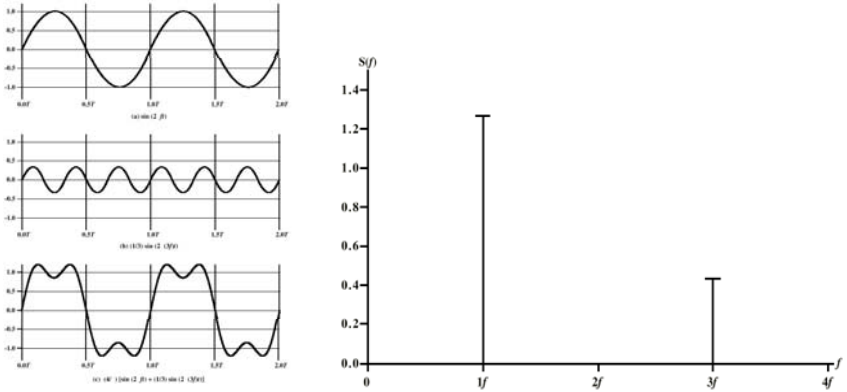
spectrum of a signal is the range of frequencies that it contains.



it extends from *f to 3f.*

Bandwidth and data rate (cont,..)

Absolute bandwidth of a signal is the width of the spectrum

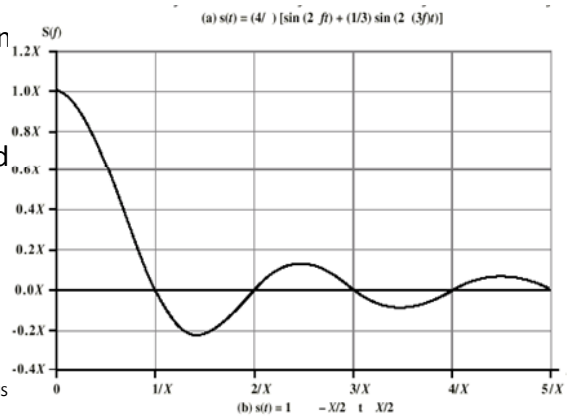


It's 2f

Bandwidth and data rate (cont,..)

effective bandwidth, or just bandwidth.

- Many signals, such as that of Figure, have an infinite bandwidth.
- Most of the energy in the signal is contained in a relatively narrow band of frequencies known as the **effective bandwidth, or just bandwidth.**

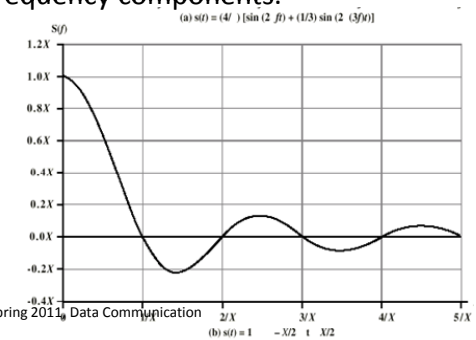


Bandwidth and data rate (cont,..)

- Although a given waveform may contain frequencies over a very broad range, as a practical matter any transmission system (transmitter plus medium plus receiver) will be able to accommodate only a limited band of frequencies.
- This, in turn, limits the data rate that can be carried on the transmission medium.

Bandwidth and data rate (cont,..)

- A square wave has an infinite number of frequency components and hence an infinite bandwidth.
- However, the peak amplitude of the *kth frequency* component, *kf, is only 1/k, so most of the energy in this waveform is in the first* few frequency components.



Bandwidth and data rate (cont,..)

- In general, any digital waveform will have infinite bandwidth.
- If we attempt to transmit this waveform as a signal over any medium, the transmission system will limit the bandwidth that can be transmitted.
- For any given medium, the greater the bandwidth transmitted, the greater the cost.
- The more limited the bandwidth, the greater the distortion, and the greater the potential for error by the receiver.
- There is a direct relationship between data rate and bandwidth: the higher the data rate of a signal, the greater is its required effective bandwidth.

Thanks,…