Telecommunication

Name _____ Date _____

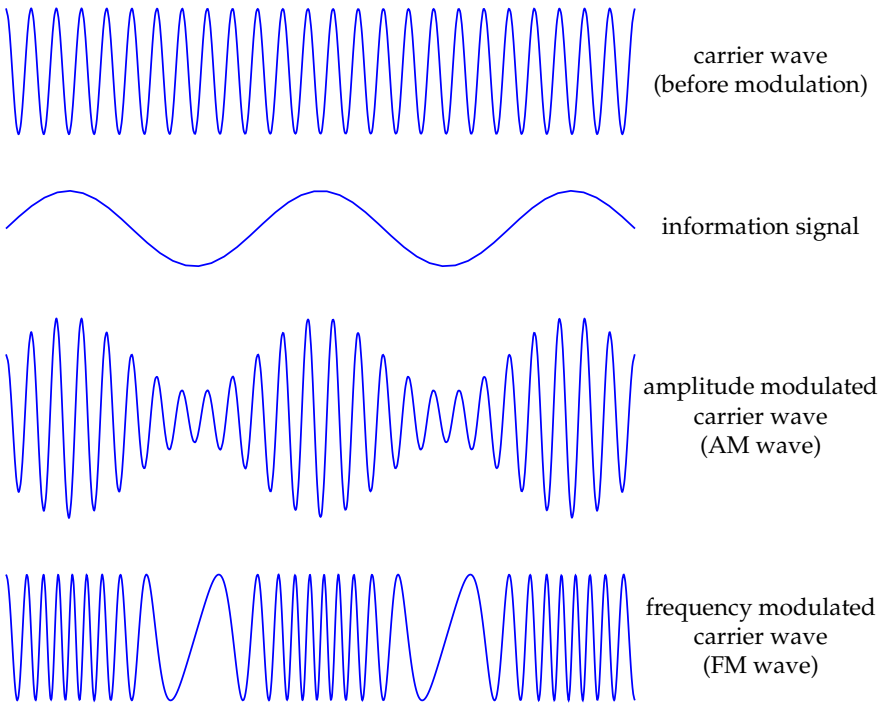
By the end of this topic I can…

- describe amplitude and frequency modulation, and find the bandwidth of an AM wave
- compare analogue and digital signals; convert binary numbers; describe ADC and DAC
- compare communication channels, radio paths and satellites
- use the decibel scale for attenuation, gain and signal-to-noise ratio

Telecommunication is transmitting _____ by electromagnetic means over long distances, with minimal loss of signal strength and _____. Three key parts: the _____, the _____ converters, and the communication _____.

Modulation

_____ means varying the _____ or the _____ of a carrier wave in synchrony with the _____ of an information signal.



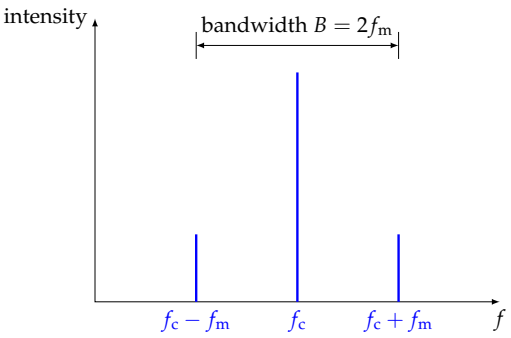
- **reasons for modulation**: a carrier has a shorter wavelength, so a _____; each signal can have a different carrier frequency, so many signals can share the air _____; modulated waves are less affected by _____; transmission over _____ is possible

Amplitude modulation (AM)

• the carrier _____ is unchanged. The _____ varies with time according to the information signal, whose waveform gives the _____.

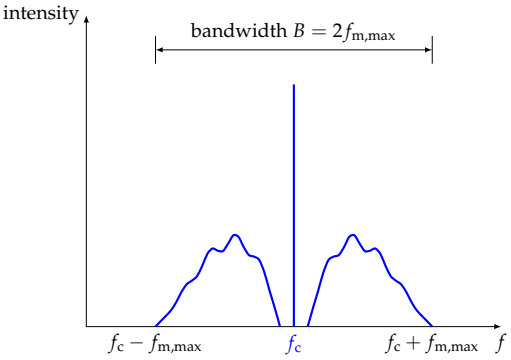
• **spectrum**: for an information signal $A_m \cos \omega_m t$ on a carrier $A_c \sin \omega_c t$, the AM wave is $(A_c + A_m \cos \omega_m t) \sin \omega_c t$. Using $\sin \alpha \cos \beta = \frac{1}{2}[\sin(\alpha + \beta) + \sin(\alpha - \beta)]$:

so the AM wave has _____ frequencies: f_c, $f_c + f_m$ and $f_c - f_m$ (the _____).

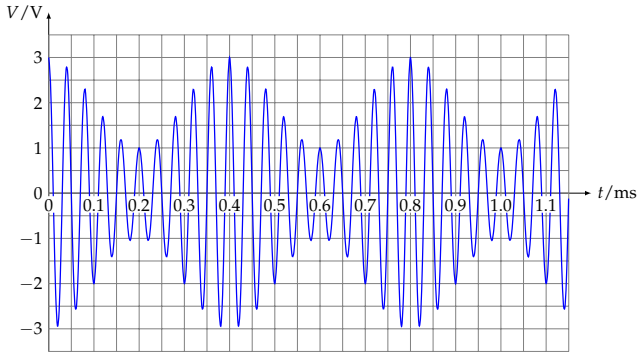


_____ is the range of frequencies occupied by the modulated signal. For AM: (for a range of signal frequencies, $B =$ _____).

• a range of signal frequencies (music) gives two _____ of sidebands either side of the carrier



• for speech $f_m \approx 10^3$ Hz, so B is a few kHz. A smaller bandwidth means _____ fit in a given frequency range:



Example 33.1 A radio station has carrier wavelengths available from 3.0×10^3 m to 1.5×10^4 m. The voltage of a modulated signal is shown (carrier period 0.04 ms, signal period 0.40 ms). Find (a) the carrier and signal frequencies, (b) the bandwidth, (c) the maximum number of channels broadcast at the same time.

Question 33.1 An AM radio wave carries a single-frequency audio signal. Its power spectrum has three frequencies: 45 kHz, 50 kHz and 55 kHz. Find (a) the carrier frequency, (b) the audio frequency, (c) the bandwidth.

Question 33.2 A 200 kHz carrier is amplitude modulated by music of frequencies 30 Hz to 4000 Hz. Sketch the power spectrum and find the bandwidth.

Frequency modulation (FM)

- the _____ is unchanged. The _____ varies with time according to the information signal.
- the _____ k (in kHz V^{-1}) is the change of carrier frequency per volt of signal:
- the FM spectrum is very _____ (you only need to know that), and each FM signal occupies a very _____

Example 33.2 A carrier of amplitude 5.0 V and frequency 80 kHz is frequency modulated by a sinusoidal signal of amplitude 3.0 V and frequency 4000 Hz. The frequency deviation is 2.0 kHz V^{-1}. Describe the modulated wave.

Question 33.3 A 900 kHz carrier is frequency modulated by a 6.0 kHz, 2.5 V signal. The deviation is 30 kHz V^{-1}. (a) Find the maximum and minimum frequency. (b) Describe the changes.

AM compared with FM

• **AM advantages**: simpler, _____ electronics; _____ bandwidth so more channels; lower frequency, longer wavelength, so it _____ around barriers and one transmitter covers a greater area

• **FM advantages**: less affected by _____ (noise changes the amplitude, but FM carries the information in the _____); greater bandwidth, so better _____; more _____ (AM sidebands carry only a small fraction of the power)

Question 33.4 Suggest two reasons why FM broadcasting is more costly than AM.

Digital transmission

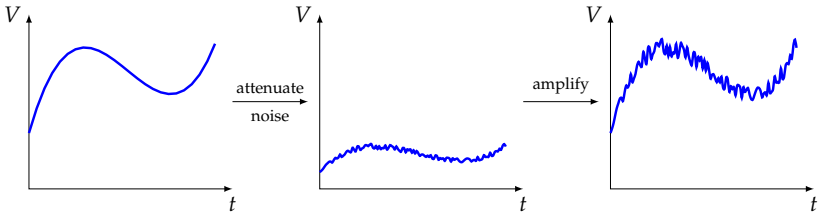
Analogue and digital signals

An _____ signal is continuous and can take _____. A _____ signal is discrete: only _____ (high and low).

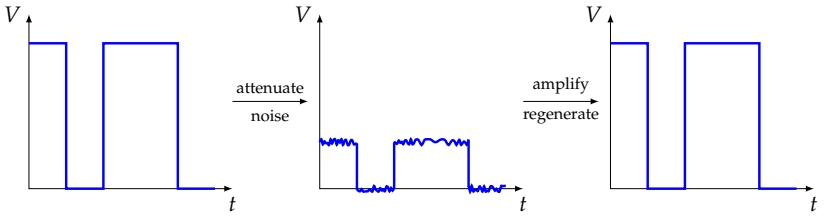
Regeneration

• _____: gradual loss of signal _____. _____: unwanted random interference that distorts the signal. At the receiver we want to remove the noise and amplify the signal: _____.

• **analogue**: noise _____ from the signal, so it is _____ along with the weakened signal



• **digital**: the signal is either 0 or 1, so any fluctuation is _____ and can be removed: the signal is _____



• **advantages of digital**: noise removed by regeneration; only two states, so more _____, easier electronics; can be _____; extra data allows _____; small bandwidth, so higher _____; easier to _____

Binary numbers

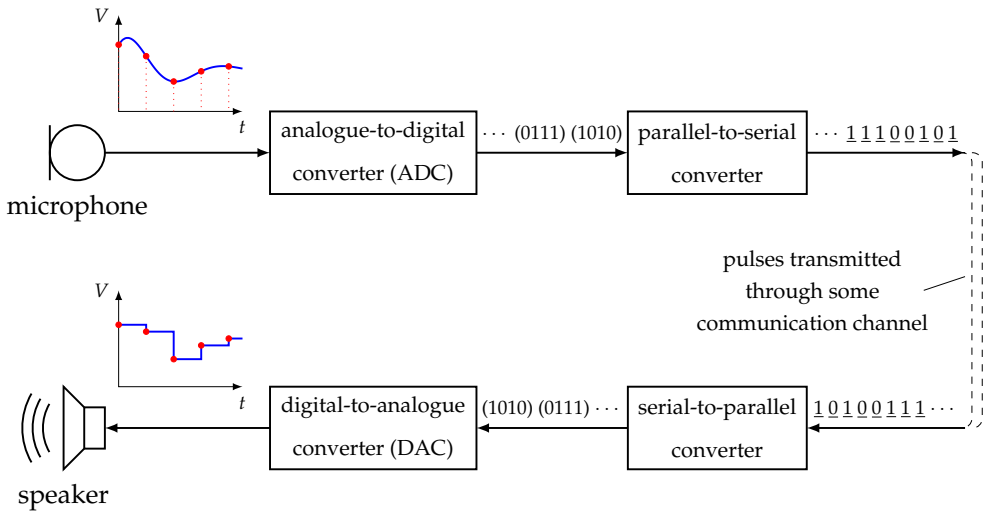
• each digit is a _____; each bit is an increasing power of ____. The left bit is the _____ (MSB), the right bit the _____ (LSB).

• an n-bit system represents _____ different numbers; more bits means more _____ voltage levels

Example 33.3 Convert to decimal: (a) 11001_2 (b) 10110_2.

Example 33.4 Convert to binary: (a) 13 (b) 28.

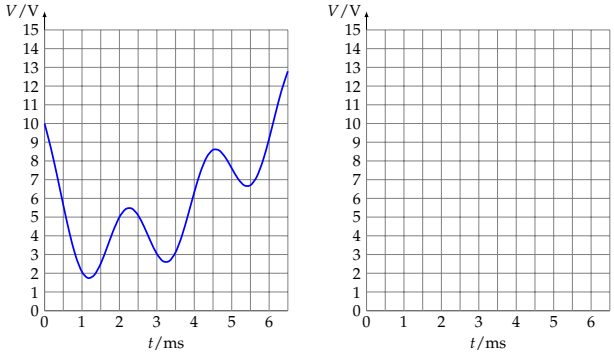
Analogue-to-digital conversion



• the microphone gives an _____ signal. The _____ takes _____ at regular time intervals and converts each sample to a _____.

• the _____ converter sends the bits of each number _____. At the receiver, the process is reversed: a _____ converter and a _____ reproduce the signal.

• **better quality**: increase the _____ (steps narrower, detects higher frequencies), and increase the _____ (steps smaller, more precise voltage)



original analogue signal reproduced signal

Example 33.5 An analogue signal is sampled at 1.0 kHz, each sample converted to a 4-bit number. (a) State the sample values. (b) Draw the reproduced signal on the second grid.

Communication channels

Wire pairs

• two insulated wires _____ together (noise is picked up equally and can be cancelled)

• **advantages**: low _____, easy to install

• **disadvantages**: affected by _____; _____ (a signal induces a copy in a nearby circuit); low _____; high _____ (radiates energy)

• **uses**: telephone to socket, amplifier to loudspeaker

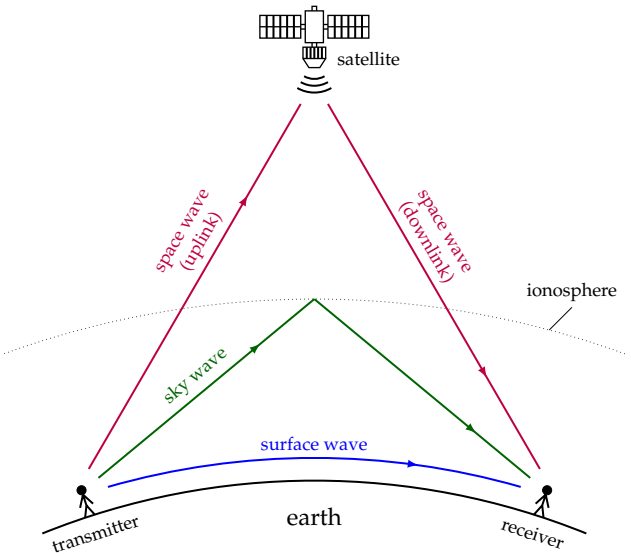
Coaxial cables

- a central _____ (the signal wire) shielded by an outer conductor that is _____; it is the return path and stops interference reaching the core
- **advantages**: less noise and cross-linking; less _____; greater _____; higher security
- **uses**: TV to aerial, computer to projector, landline to local exchange

Optic fibres

- a _____ with a higher refractive index than the surrounding transparent _____, so light stays in the core by _____
- **advantages**: very low _____; very little _____ (immune to electromagnetic interference); very large _____; ideal for _____ (light pulses switch rapidly); low weight and cost
- **uses**: internet broadband, transcontinental communication

Radio waves and microwaves



- **surface wave** ($\lambda \approx 0.1$ to 10 km, 30 kHz to 3 MHz): travels close to the ground; long wavelength so it _____ around obstacles
- **sky wave** ($\lambda \approx 10$ to 100 m, 3 to 30 MHz): reflected by the _____, travels far by multiple reflections; _____ (depends on the atmosphere)
- **space wave** ($\lambda \approx 10$ cm to 10 m, 30 MHz to 3 GHz): passes through the atmosphere to _____; short wavelength means little diffraction, so on the ground it must be _____
- **microwaves** ($f \approx 3$ to 300 GHz, $\lambda \approx 0.1$ to 10 cm): high frequency gives a large _____ and data rate, but _____ only. Uses: Wi-Fi, Bluetooth, mobile phones, satellite links.

Communication satellites

• **advantages over sky waves**: the satellite _____ the signal; higher frequencies give greater _____; consistent, not weather-dependent

• uplink and downlink use _____: the uplink is greatly attenuated and the downlink greatly amplified, so the same frequency would let the downlink _____ the uplink

• **geostationary**: equatorial orbit, period _____, west to east, fixed above a point. *Pros*: dish can be _____, no tracking. *Cons*: very high orbit (over 6 earth radii), so a long _____; cannot cover high _____.

• **polar**: pass over the poles at about 1000 km. *Pros*: shorter _____; better surface detail (maps, weather). *Cons*: not synchronous, so must be _____, and the channel must be _____ between satellites.

Causes of attenuation

• wire pair and coaxial cable: _____ (resistance) and radiation of energy

• optic fibre: _____ by impurities and defects (infra-red is used because its longer wavelength is scattered less)

• radio waves and microwaves: _____ by the atmosphere

The decibel scale

Engineers compare powers, often very large ratios, so use a _____ scale:

•

• dB has no true unit: it just reminds us the ratio is on a _____ scale

• **why use dB**: gives more _____ numbers; ratios in dB can be _____ (since $\log x + \log y = \log xy$)

Example 33.6 A signal of power 0.040 mW enters an amplifier of gain 36 dB. Find the output power.

Example 33.7 An optic fibre has attenuation 0.12 dB km^{-1}. The input power is 50 mW and the noise at the receiver is 8.0 μW. The signal-to-noise ratio must be at least 25 dB. Find the maximum length.

Example 33.8 A 60 mW signal travels along 94 km of cable with attenuation 3.2 dB km^{-1}. Repeater amplifiers of gain 27 dB are placed every 8.0 km. Find the received power.

Question 33.5 A 5.0 km cable has attenuation 12 dB km^{-1}. The received power is 2.9×10^{-7} W. Find the input power.

Question 33.6 A 28 mW signal passes along two cables with attenuation 29 dB and 38 dB, then an amplifier of gain 43 dB. Find the output power.

Question 33.7 A 12 mW signal is sent along an optic fibre. Noise at the receiver is 0.75 μW and the signal-to-noise ratio must not fall below 35 dB. The maximum uninterrupted length is 48 km. (a) Find the minimum acceptable received power. (b) Find the attenuation per unit length.