Answers to Coursebook questions – Chapter F4

1 For copper wires, wire pairs and coaxial cables the main source of attenuation is ohmic thermal losses when the current is established in the wires (collisions of electrons with atoms in the wires).
For optical fibres it is glass impurities. The atmosphere is especially transparent to microwaves (as opposed to infrared, for example), and most of the attenuation is due to the spreading of the beam, which makes less power received per unit area at a distance from the emitter.

2 The distances involved are small and so attenuation is not a problem, so this solution is the cheapest.

3 Because the bandwidth provided by the coaxial cable is much larger and you need the large bandwidth for an internet connection.

4 Advantages include:

i the low attenuation per unit length, which means that a signal can travel large distances before amplification,

ii increased security because the signal can be encrypted and the transmission line itself cannot easily be tampered with,

iii large bandwidth and so a large information carrying capacity,

iv not susceptible to noise,

v they are thin and light and

vi do not radiate, so there is no crosstalk between lines that are close to each other. The signal is transmitted as laser light pulses.

5 **a** It is obvious that the power loss of the signal over 5.0 km is 30 dB. If this is not obvious then, explicitly, from the graph we see that over a distance of 5.0 km the power decreases from $50 = 10\log\frac{P_{\text{signal}}}{P_{\text{noise}}} \Rightarrow P_{\text{signal}} = P_{\text{noise}} \times 10^5$ m to

$$20 = 10\log\frac{P_{\text{signal}}}{P_{\text{noise}}} \Rightarrow P_{\text{signal}} = P_{\text{noise}} \times 10^2 .$$

The power loss over the 5.0 km is therefore $10\log\frac{P_{\text{noise}} \times 10^2}{P_{\text{noise}} \times 10^5} = 10\log 10^{-3} = -30\text{ dB}$.

The attenuation per unit length is therefore $\frac{30}{5.0} = 6.0\text{ dB km}^{-1}$.

b Each amplifier must then provide a gain of 30 dB.

c The loss of power over 15 km without amplifiers would be $15 \times 6.0 = 90\text{ dB}$ and so

$$-90 = 10\log\frac{P_{\text{signal}}}{600} \Rightarrow P_{\text{signal}} = 600 \times 10^{-9}\text{ mW} = 0.6\text{ nW} .$$

6 **a** Satellites operate at frequencies in the GHz range (10 GHz) with the downlink frequency being less than that for the uplink frequency.

b The receiver on the satellite is very sensitive (in order to be able to receive weak signals from earth). The emitter on the satellite is very powerful. If it operated at the same frequency as the uplink frequency of the receiver, the receiver would constantly be getting the signals emitted by the emitter.

7 **i** broadcasting TV signals to very large areas (that would require very many different emitters based on earth),

ii operate as microwave links redirecting signals, for example telephone signals, from one station on earth to another very far away,

iii monitoring weather conditions,

iv being part of the global positioning system etc.

8 A satellite is a very expensive device so it must be able to handle the transfer of huge amounts of data and information if it is to be profitable. This requires huge bandwidth.

9 Advantages include

i no tracking required to send signals to these satellites,

ii a very small number of satellites can cover almost the entire earth surface,

iii they are above the same point on the equator all the time.

10 **a** **i** All geosynchronous satellites orbit with an orbit radius of about 42 000 km or about 42 000 − 6400 = $42000-6400=35600\approx 36000\text{ km}$ above the equator.

ii A low polar orbit satellite might have an orbit radius of just a few hundred km above the earth's surface, i.e. an orbit radius of under 7000 km.

b If the power emitted is P we can think of this as being distributed over the surface of a sphere centred at the emitter. Then at a distance d away, the area of this imaginary sphere would be $4\pi d^2$.

The power received per unit area therefore (the intensity) is then $\frac{P}{4\pi d^2}$.

c $\frac{P_{\text{geo}}}{4\pi d_1^2}=\frac{P_{\text{polar}}}{4\pi d_2^2}$ and so $\frac{P_{\text{geo}}}{P_{\text{polar}}}=\frac{d_1^2}{d_2^2}\approx\frac{36000^2}{400^2}\approx 8\times 10^3$.

d The estimate in **c** assumes radiating in all directions equally. The emissions to the satellites are directed and focused and so take less power.

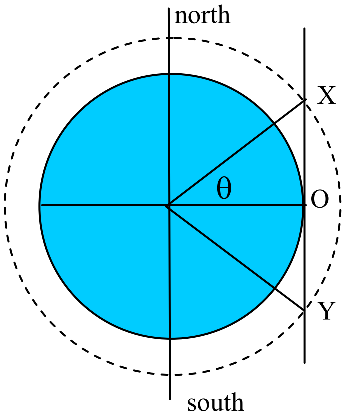
11 **a** The earth makes one full revolution in 24 hr and so in 97 minutes it will rotate by

$$\frac{97}{24\times 60}\times 360^{\circ}=24.25^{\circ}\approx 24^{\circ}$$

b In a full revolution a point on the equator moves a distance of $2\pi R$, where R is the radius of the earth. So in 97 minutes it will move a distance of

$$2\pi R\times\frac{24.25^{\circ}}{360^{\circ}}=2\pi\times 6400\times\frac{24.25^{\circ}}{360^{\circ}}=2709\approx 2700\text{ km}.$$

c See figure. The satellite will be in O's view, from when it is in position X until it gets to position Y. (In the time it takes the satellite to move from X to Y, O will move a bit since the earth rotates, but this is only a very small effect that we can safely ignore for the purpose of this estimate.)



Now, $\cos\theta=\frac{R}{R+h}=\frac{6400}{7000}=23.9^{\circ}$ and so the arc XY subtends an angle $2\times 23.9^{\circ}=47.8^{\circ}$.

The time taken by the satellite to move from X to Y is then $\frac{47.8^{\circ}}{360^{\circ}}\times 97=12.9\approx 13\text{ min}$.

