Homework 1 Solution

Problem 1:

The energy is distributed equally over the area of a sphere of radius r. Since the area is $4\pi r^2$, the attenuation is proportional to $\frac{E4\pi 1^2}{E4\pi r^2} = r^{-2}$.

Problem 2:

Propagation speed of light is 299 792 458 m/sec or

$$60 \times 60 \times 299792.458 \text{ km/h} = 1.07925 \times 10^9 \text{ km/h}.$$

The signal to and from the space craft uses 40 hours, so the distance is given by 20 times this amount or

$$20 \times 1.07925 \times 10^9 \text{ km} = 2.15851 \times 10^{10} \text{ km}.$$

Problem 3:

(a) The Shannon capacity formula gives you

$$1 \text{ Mbps} = 100 \text{ K 1/sec} \log_2(1+\text{SNR}).$$

We solve for the SNR:

$$10 = \log_2(1+\text{SNR})$$
$$2^{10} = 1+\text{SNR}$$
$$\text{SNR} = 1023.$$

(b) Attenuation at 1 km is ten times the attenuation at 100 meters or -41.7db.

If X denotes the energy at the sender, then for the energy at the receiver to be 1W, we need to have

$$-41.7 = 10 \log_{10}(\frac{1W}{X}).$$

We solve this to get

$$10^{-4.17} = \frac{1\text{W}}{X} \quad \Rightarrow \quad X = \frac{1\text{W}}{10^{-4.17}} \quad \Rightarrow \quad X = 14791.1\text{W}.$$

(c) We need to have a signal that is at least 1023 stronger than the noise of 10mW. Thus, we need to have a signal of strength 10.23W. The attenuation definition gives us

$$-41.7 = 10 \log_{10}(\frac{10.23W}{X})$$

so that $X = 10.23 \times 14791.1$ W $= 151.313$ kW, which is a fantastic number.

Problem 4:

A single T1 line can transmit at 1.544 Mbps. Per week, this is

$$7 \times 24 \times 60 \times 60 \times 1.544 \times 10^6 \text{ bps}.$$

Divide by 8 to obtain 1.16726×10^{11} Bytes per Week or 116.726 GB per week. So, we need about 103 T1 lines. If we lease them individually, this would cost around $20000.00 per week or

about a million dollars per year.

If we buy several tape drives ($20,000 plus tape cassettes), and hire a driver / use FedEx, we bring down the monthly costs to about $4000.00 or $500.00 per month. Details will vary. If you use disks (HDD / SSD), you will have to also worry about the amount of data that you can load on a drive.

Of course, in real life, no-one would even think of doing something as stupid as this. Backup over the internet only the most important data, use at the very least delta compression, and use tape drives or disk drives instead.