ITS323 – Path Loss Model

1 Path Loss Model

1.1 General Path Loss Model

A general model for path loss in a wireless transmission system can be expressed as:

$$P_r = \frac{P_t G_t G_r}{L_{path}} \tag{1}$$

where P_t is the transmit power, G_t is the gain of the transmit antenna, G_r is the gain of the receive antenna, L_{path} is the loss between transmit and receive antenna, and P_r is the receive power. All values are in their absolute (linear) form.

Intuitively, this model is explained as: a signal is transmitted with some power P_t. The transmit antenna introduces a gain in the signal strenth (a multiplying effect). However the signal attenuates between transmit and receive antennas, resulting in loss of signal strength by a factor of L_{path} (division). The receive antenna introduces another gain. The remaining signal strength is that which it is received, i.e. the receive power, P_r.

1.2 Free Space Path Loss Model

The amount of power lost between transmit and receive antenna depends on many factors. To design and analyse wireless transmission systems various mathematical models of the path loss have been developed. The basic model is *free space path loss*. In this model, the path loss is related to the distance between transmitter and receiver and the signal wavelength:

$$L_{path} = \frac{(4\pi d)^2}{\lambda^2} \tag{2}$$

Substituting (2) into (1) gives:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2} \tag{3}$$

or re-arranging:

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{G_t G_r \lambda^2} \tag{4}$$

Note that the free space path loss model is just one of many mathematical models. There are others that differ in how L_{path} is defined.

1.3 General Path Loss Model in dB

In the preceding general path loss model all the values were in the absolute (linear) form. However sometimes it is easier to deal with values in dB. Here we will convert equation (1) into an equation where the dB values can be used. First lets define the following:

$$P_{t_{dBW}} = 10\log\left(P_t\right) \tag{5}$$

$$P_{r_{dBW}} = 10\log\left(P_r\right) \tag{6}$$

$$G_{t_{dBi}} = 10\log\left(G_t\right) \tag{7}$$

$$G_{r_{dBi}} = 10\log\left(G_r\right) \tag{8}$$

$$L_{path_{dB}} = 10\log\left(L_{path}\right) \tag{9}$$

That is, the values expressed in their dB (logarithmic) form.

Now considering equation (1), take the logarithm (in base 10) of both sides, and then multiply by 10:

$$10\log\left(P_r\right) = 10\log\left(\frac{P_t G_t G_r}{L_{path}}\right) \tag{10}$$

Properties of logarithms include:

$$\log\left(a \times b\right) = \log\left(a\right) + \log\left(b\right) \tag{11}$$

and:

$$\log\left(\frac{a}{b}\right) = \log\left(a\right) - \log\left(b\right) \tag{12}$$

Using these two properties, equation (10) can be expanded to:

$$10\log\left(P_r\right) = 10\log\left(P_t\right) + 10\log\left(G_t\right) + 10\log\left(G_r\right) - 10\log\left(L_{path}\right) \tag{13}$$

Substituting in equations (5)-(9) gives:

$$P_{r_{dBW}} = P_{t_{dBW}} + G_{t_{dBi}} + G_{r_{dBi}} - L_{path_{dB}} \tag{14}$$

In closing, equations (1) and (14) represent the same general path loss model, however the values in (1) are absolute, whereas in (14) in dB. Either equation can be used to solve a problem regarding wireless transmission. Note of course if you have most values expressed in dB, equation (14) is very easy to use as it involves only addition and subtraction (rather than multiplication and division).