ITS323 – Transmission Media Examples

Wireless Transmission

When a signal is transmitted over any medium, the signal is attenuated. That is, some energy of the transmitted signal is lost before it arrives at the receiver. The amount of energy lost depends on the medium. Let's look at the air as a medium, that is, wireless transmission.

As an example, assume we have a transmitter with antenna, separated by d metres from the receiver antenna. The transmitter transmits with power P_t watts. Some energy of the signal is lost between the transmitter and receiver, and the signal is arrives at the receiver with power P_r watts.

How much energy is lost? That depends on many physical factors, but a popular theoretical approach to calculating the loss is based on what would happen in "free-space". By free-space we mean there are no obstructions (trees, people, etc.), and the signal is sent in a perfect vacuum. Under these conditions, the free-space propagation equation is defined as:

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

Where, in addition to P_t, P_r and d, we have:

- λ, the wavelength of the signal. Remember from basic physics, that λ is equivalent to the speed of light divided by the frequency of the wave (c/f). Lets assume the speed of light, c, is 3×10^8 metres per second.
- G_t, the gain of the antenna at the transmitter. We assume there is a standard (called isotropic) antenna that transmits energy in all directions. But many practical antenna concentrate their energy in a particular direction, hence the energy is stronger at a receiver the same distance as if using an isotropic antenna. The gain of an antenna refers to how much stronger the signal is, compared to an isotropic antenna. This depends on the shape and size of the antenna. For a parabolic (dish) antenna, the gain can be calculated based on the area (A) of the antenna:

$$G = \frac{4\pi A}{\lambda^2}$$

- G_r, the gain of the antenna at the receiver.

Lets look at a specific example. Our two parabolic antenna's are separated by a distance of 1km. Both antenna's have a diameter of 1 metre (radius = 50cm). We are transmitting with a frequency of 5GHz. If we transmit at a power of 1 Watt, what is the received power?

First, lets calculate the gain of the transmit antenna:

$$
\begin{aligned}
G &= \frac{4\pi A}{\lambda^2} \\
&= \frac{4\pi^2 r^2}{(c/f)^2} \\
&= \frac{4\pi^2 (0.5)^2}{\left(\frac{3\text{x}10^8}{5\text{x}10^9}\right)^2} \\
&= 2741
\end{aligned}
$$

Note that this is an absolute measure of the gain (not in dB). It is equivalent to 34.37dBi. The gain at the receive antenna will be identical.

Re-arranging the free-space propagation equation gives:

$$
\begin{aligned}
P_r &= P_t \frac{G_t G_r \lambda^2}{(4\pi d)^2} \\
&= 1.\frac{2741 \times 2741 \times \left(\frac{3\times 10^8}{5\times 10^9}\right)^2}{(4\times\pi\times 1000)^2} \\
&= 1.71\times 10^{-6} W
\end{aligned}
$$

Over the distance of 1000 metres, the 1 Watt transmitted signal is reduced to a 1.71 microWatt received signal! In order to be able to receive the signal successfully, the receive antenna must have a Receive Threshold below this level.

In real systems, the free-space propagation model will not apply (because of obstructions and the atmosphere means the signal is not sent in a vacuum). However it is a good starting point, and there are more complex models to represent different transmission mediums.