Overview of Propagation Modes

The existence of electromagnetic (EM) waves is what makes wireless communication possible. In earlier courses, you had studied the propagation of EM waves in free space. However, just by looking around you, one quickly realizes that there is more cluttered space than free space. An important part of wireless system design is the modeling of the **wireless channel**; in other words, how the radio signal is affected going from point A to point B. We begin our study of wireless channels by looking at three simple propagation scenarios.

(a) Free Space or Line of Sight (LOS)

(b) Reflection

(c) Diffraction

Huygen's Principle: each point on a wavefront acts as a point source for further propagation. However, the point source does not radiate equally in all directions, but favors the forward direction of the wavefront.

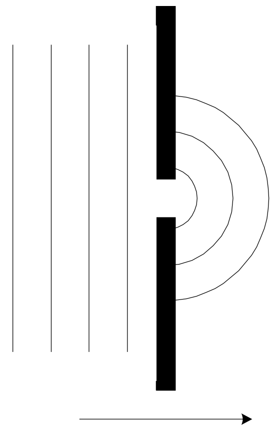

Figure 1 – Behavior of a Plane Wave moving thru a slit from left to right

This is analogous to

Note that diffraction can cause constructive or destructive interference when the signal reaches the receiver.

1. Free Space Path Loss

Common experience tells us that the further away we are from a radio station, the weaker the received signal is. Hence the signal loss increases with distance between the TX and RX. We will quantify this loss using the ideal scenario, namely propagation in free space.

Definition: Isotropic Radiator

Over time, power radiates out from this point source in the shape of a sphere. If we could collect all the power on the surface of this sphere, it would still be P_{TX}. The **power density** on the surface of the sphere is:

Recall that typical antennas have physical dimensions on the order of a wavelength, for example $\lambda/4$ or $\lambda/2$. Such an antenna is used at the receiver to "collect" the transmitted power. It can be shown that the effective area of an antenna is:

The total received power is thus given by:

Note that the concept of an isotropic radiator is an useful theoretical construct, but real antennas do not behave that way. Real antennas have some sort of **directionality**, ie. more power is radiated in certain directions, and less power in other directions. Hence, relative to an isotropic radiator, we will see more power if we are standing in the right place. This is characterized as the **gain** of an antenna, with units of dBi (dB difference relative to an isotropic radiator).

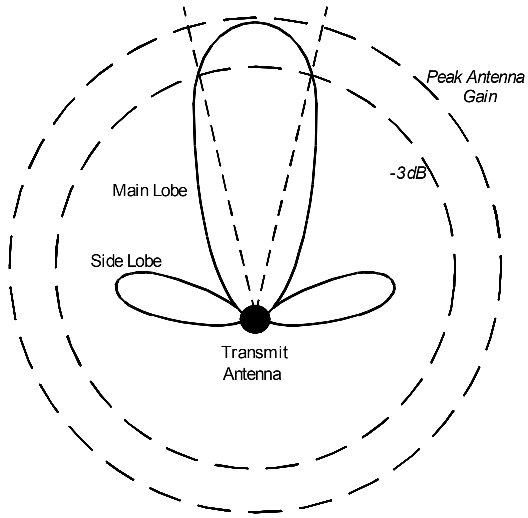

Figure 2 – Example of an Antenna Radiation Pattern

Incorporating both the TX and RX antenna gains into the free space equation, we arrive at the well publicized version of **Friis's law**:

Friis's Law in dB:

Example

A transmitter is outputting 100mW at 4GHz. The transmit and receive antenna are 40 km apart, and each has an antenna gain of 30.5 dB.

Using Friis's Law, find the received power in dBm.

Definition: Receive Sensitivity

Receive sensitivity depends on various factors, including:

1. ______________________________
2. ______________________________
3. ______________________________

Example

802.11g Wireless LAN, commonly known as WiFi, operates in the 2.4GHz frequency band.

A typical router has a transmit power of +20 dBm.

The highest data rate supported by 802.11g is 54 Mbits/s. At this rate, the standard specifies a minimum receive sensitivity of -65 dBm.

Assuming that the TX and RX antenna gains = 0 dB, find the Maximum Acceptable Path Loss (MAPL)?

Using the MAPL, calculate the range assuming a free space scenario.