Common Radio Propagation Impairments

Here is quick review of the most common effects that can cause a radiowave signal to vary from its intended signal level (or signal-to-noise ratio) as it travels between transmitting and receiving antennas.

Free-space path loss of a radio signal in a vacuum (and nearly the same in clear, stable air) is:

$$\text{Path Loss (dB)} = 20 \log (4\pi d/\lambda)$$

where d is the distance and λ is the wavelength, both in the same units.

For example, at 1 GHz, where λ is approximately one foot, a one-mile signal path will have a loss of 96 dB. A ten-foot path has 42 dB loss. With such a small portion of the total radiated signal reaching the receive antenna, allowing for additional losses and disturbances is an important part of system design.

1. In-Path Losses

Water vapor absorption increases with frequency, and becomes a realistic factor for signals above two or three GHz. In the 10 GHz region, it is common for rainstorms, fog and haze to disrupt communications.

Vegetation such as the leaves of deciduous trees behaves similarly to water vapor absorption, being more prominent as frequency increases. As a side note, this was one of the key discussion topics of early proposals for mm-wave band (e.g 27-32 GHz) point-to-multipoint wireless distribution systems.

Building penetration losses, predominant at VHF and higher frequencies, involves lossy wall materials as well as the restricted areas of lower-loss paths through windows.

Interior walls and *clutter* disturb and attenuate signals. These things were widely studied during the development of wireless LAN technologies.

2. Reflections (Multipath)

This widely-discussed propagation impairment involves the combined direct signal and one or more reflected signals that arrive at a receiving antenna. The reflected signals can have a wide range of signal levels, depending on the frequency and the efficiency of the intervening reflecting surfaces.

Multipath impairments can be mitigated somewhat by using antenna directivity and polarization to enhance the direct path signal, but truly robust high speed communication usually requires time-domain signal processing, along with supporting coding that offers means of characterizing the delayed multipath signals. In a mobile environment, there is the additional need to constantly monitor the channel for changing conditions.

In some cases, the direct path is blocked and the only signal received is the reflection. This may provide some coverage, but will be subject to reflection losses, changes in polarization, and possibly additional reflections (multipath) with nearly equal signal amplitudes.

3. Refraction and Scattering

These behaviors usually apply to areas where the direct signal path is blocked by an obstruction, and only a portion of the signal is propagated beyond via optical-type effects along the edges of the obstruction. Sharp edges such as buildings or even mountain peaks and ridges may allow a significant amount of signal to be “bent” into the shadowed area. However, there may be multiple pathways that give rise to multipath type time delays.

Scattering usually refers to the least definite type of diffraction, perhaps combined with diffuse reflections, from irregular, or smooth but undulating, surfaces. The portions of the original signal that survive beyond these areas will have a wide “blur” of time delay, and with less-efficient reflection/refraction, losses are high.

4. Noise and Interference

The unpredictability of local noise and interference makes any type of compensation difficult. System designers should consider the operating environment and allow for increased noise and interference levels in areas of high population density, as well as industrial areas. Known communication facilities can be obtained from license databases (FCC in the U.S.).

Interference is also highly dependent on operating frequency, especially in unlicensed bands where a large number of units may be operating nearby. Interference may also take the form of overload if the interfering source is extremely close, or is a high-powered licensed radio service at a distance where field intensity is high enough to affect normal operation of receiving equipment.

Noise also takes various forms, from wide bandwidth impulse noise caused by arcing within electrical equipment, to relatively narrowband sources where physical resonances “tune” the noise spectrum. Atmospheric noise is a potential problem for sensitive systems operating at frequencies where significant energy is periodically generated by solar emissions interacting with the earth’s magnetic field.