What everyone should know about RF Propagation Modeling

Abstract

Radio wave propagation modeling & simulation plays an important role in planning for any wireless communication system. The presentation introduces the basics of propagation modeling, with a brief overview of historical and modern models. Differences between empirical and deterministic models are discussed. Database structures such as terrain and clutter, which are the foundation of many models, are considered. We compare how path profiles and area studies differ based on assumptions inherent in the model. Finally, some misconceptions of what a propagation study represents are examined. The presentation concludes with a call to action to consider the implications of uncertainty on predictive propagation studies.

Overview

Radio waves decrease in strength as they propagate away from the transmitter, and are affected by complex environmental variables. Simulating radio wave signal strength is therefore an important consideration in system planning. Statistical and deterministic models of radio wave propagation have evolved over the history of radio. Along with increased computing power, a situation now exists where dozens of models are available to software users and system planners. The choice of statistical or deterministic model, indeed each individual model, has its pros and cons — which may or may not be apparent to the casual user. Computer simulated propagation results should be tested against real-world measurements in order to refine There is ultimately no ‘one size fits all’ propagation model, and project stakeholders need to appreciate the level of their partner’s domain expertise.

What everyone should know about RF Propagation Modeling

Radio waves are the electromagnetic energy emanating from a radio transmitter. Waves travelling outward from an ideal transmitter are said to be in “free space” when they are perfectly unobstructed. In this case of perfect line-of-sight (LOS) propagation, the free space loss of the link is proportional to the square of the distance and the square of the frequency (Fig. 1). This relationship between distance, frequency and signal loss applies to all radio waves; however, it is complicated by the fact that the typical radio communication system is land-based, close to earth, and affected by the environment through which it passes. Even terrestrial links that are unobstructed, such as links between mountaintop towers, may be affected by atmospheric conditions, rain, or ground reflections, and are therefore technically not “free space.”

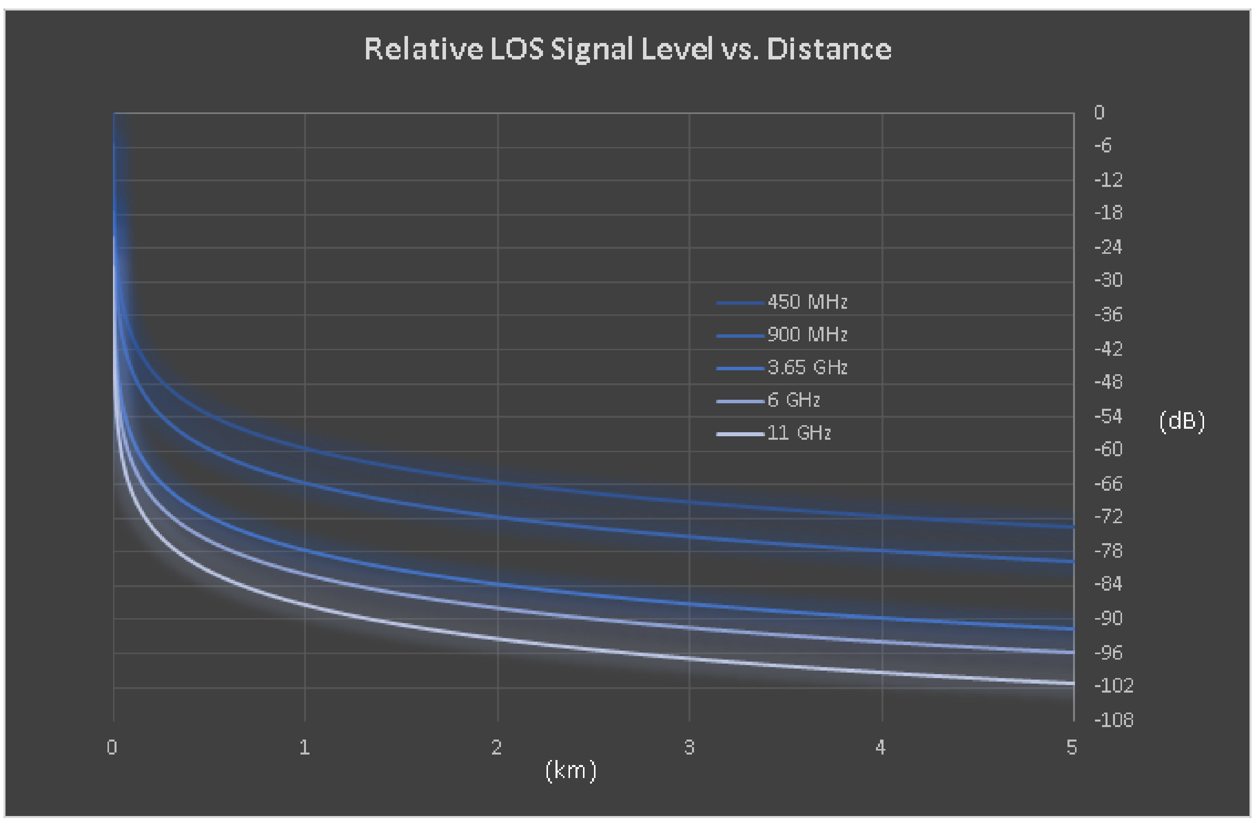


Fig. 1

Radio waves travel through the atmosphere like ripples traveling through water. The environment through which the signal propagates includes macro elements such as the conductive properties of the earth's surface or climate types, and micro elements like vegetation or man-made objects. In addition, the environment constantly changes. Variations in temperature, pressure and humidity change the refractive properties of air causing the signal to bend, scatter or become trapped in a duct. Trees and vegetation move in the wind and experience seasonal changes and growth. Potential reflectors may be static or in motion: for example, cars and trucks moving with varying density along roads at different times of day. Buildings are constructed or torn down. Signals can be reflected, refracted, diffracted, scattered and absorbed by any number of environmental elements. Simulating the environment's effects on radio signals is a complex undertaking.

A market review from late 2014 shows over twenty vendors providing RF Propagation software, ranging anywhere from free tools to enterprise level network planning suites. These tools provide a more accurate analysis of radio coverage than the user could get from general knowledge of RF radio propagation. However it is important to understand the benefits and limitations of these types of software when beginning a network design project.

When we discuss propagation models, we are actually talking about dozens of different models that have been developed over many years. Propagation models tend to emphasize the major component of the radio link - the amount of path loss the signal undergoes between the transmitter and the receiver. The model calculates loss as a function of distance and frequency, and may include the effects of obstructions and other environmental factors.

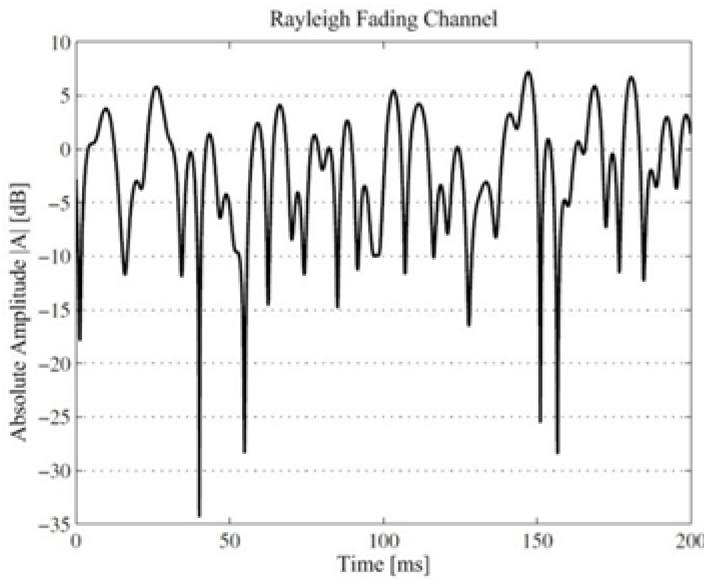
Models can be generally categorized as empirical or deterministic. Empirical models like the well-known Okumura are based on extensive field measurements and statistical analysis. These models are based on a specific frequency range in a specific environment, and are usually a simple formula so they are not computationally intensive. Okumura, for example, applies to 150-1920 MHz and has separate results for urban, suburban, and open areas. Besides being easy to implement and quick to deploy, their basis in field measurements means that they are accounting for every propagation mechanism in the environment. The downside of an empirical model is that it does not account for environmental variability. For example, if the service area includes a mix of urban, suburban and open areas, Okumura may not be the best choice of model.

Deterministic, or physical models attempt to estimate path loss by simulating the link with the math and physics of wave theory. At a minimum these models use terrain databases to calculate terrain roughness and/or the extent of individual path obstructions. At their most complex, these models can include high resolution terrain, clutter and building databases to simulate the environment in three dimensions. Wave theory predicts losses on the simulated path from reflection, diffraction, scattering, or absorption. Besides taking more time to set up and implement, the underlying databases can increase costs as the resolution of the database increases. It is also important to understand that the mechanisms creating signal loss are not necessarily more certain with a deterministic model. For example, the margin of error of knife-edge diffraction modeling when compared to real world diffraction will be compounded in the case where multiple diffractors exist.

[image]

Simulated path profile at 6 GHz

There are still other limitations of propagation models to consider. It is assumed in a path profile like the one shown above that only the topography in a vertical plane between the two antennas will affect the signal prediction. Clearly this is not the case; however, most propagation modeling software relies on this assumption in order to be time and cost effective. Real world signal levels experience local fluctuations within an area for which the model will predict no change. Finally, there is the fallacy of false precision to contend with. For example, wave theory and predictive software gives a predicted signal level of -84.37 dBm. The implication is that the calculation and therefore the prediction is accurate to two decimal places. However the logical flaw is obvious, when one considers that radio signals continuously experience 'fast fades' and 'slow fades' in a typical channel. Ultimately, different models will give different results for the same radio link. Knowing which model is appropriate to the environment becomes key to quality propagation studies.



Fast fade of radio signal vs. time

Complicating the issue further, few if any studies have been done to determine the extent to which higher resolution terrain and clutter databases result in more accurate predictions. There is unfortunately no 'one size fits all' model that can predict every link at every frequency with perfect accuracy.

Modeling radio wave propagation is not a simple task. Understand the implications of so-called "do-it-yourself" RF system design, particularly when subcontracting to partners who might only spend a few hours a week using a software package that may or may not be suited to your particular project. Know the experience your partners bring to the table with their propagation tools, but be aware that all tools have their limitations.

Council Rock has the experience and expertise to simulate your planned networks for feasibility, as well as conduct field studies to refine existing propagation models to help ensure your build-out goes smoothly. We have full time RF system designers with years of experience using multiple propagation software packages. Contact us for details at 585-471-6007 or email info@council-rock.com.