The Significance of Rayleigh Fading in Coverage Measurements

&

40-Lambda Criteria

by Jim Bush

There are two types of fading that are relevant to performing coverage measurements, fast fading, also know as Rayleigh fading, and terrain based fading due to obstructions and propagation loss. The goal of coverage measurement is to measure the local signal strength in presence of terrain based fading.

Rayleigh fading is due to close in reflections. It produces drops in signal strength that are only a fraction of a wavelength in size (often on the scale of inches). These fades always exist and are only of interest in the sense that coverage measurements must be made in a manner that rejects Rayleigh fading, so that actuate measurements of terrain based fading can be made.

William C. Y. Lee derived a well accepted criteria for removing Rayleigh fading and retaining slower terrain based fading, known as 40 Lambda averaging [W.C. Y. Lee and Y. S. Yeh, "On the Estimation of the Second-Order Statistics of Log Normal Fading in Mobile Radio Environment", IEEE Trans. Comm., vol. 22, June 1974, pp. 869-873] (You can find an easier to read version of this criteria in most mobile communications text books). In order to remove Rayleigh fading, you should average data for a time period equal to the time it takes to traverse 40 wavelengths in your measurement vehicle and you should have no less than 36 to 50 points in that time. For the remainder of this text we will assume 40 points to make the calculations easier.

The biggest misconception with applying the 40-Lambda criteria to coverage measurements is that all measurements should be made with an averaging time exactly equal to 40-Lambda. While 40-Lambda is the minimum filtering that needs to be done to reject Rayleigh, it is not the most appropriate averaging time for coverage analysis. In almost all coverage analysis, the 40-Lambda averaged samples must be averaged further. Due to the accuracy and reporting rate of position measurement devices (GPS for instance) and the real practical problem of too much data this extra averaging is valid and necessary. Clearly, the averages of averages is just a longer average, and the resulting data no longer has an integration time of forty wavelengths.

That is not to say that the 40-Lambda criteria does not apply to coverage analysis. In fact it is very important. From the criteria, the minimum sampling rate is about once per wavelength at the fastest vehicle speed. At 800MHz, for example, a wavelength is about a foot. Using the 40-Lambda criteria, an initial sampling rate of 88 samples per second is needed to make measurements with a maximum drive speed of 60 mile per hour.

It is important to realize that Rayleigh fading is a spatial phenomenon not a time one. The averaging is actually intended to be done over a distance of forty wavelengths. Since most people performing coverage analysis average samples spatially after they are collected. That is to say, all the samples within a grid on a map are averaged to produce one point. To insure rejection of Rayleigh fading, the grid size must be larger than forty wavelengths. This in general is not a problem. At 800MHz, forty wavelengths is about 40 feet. Generally much larger grid sizes are used.

A Practical Example

A BVS Fox receiver and Gator transmitter are going to be used to do pre-site survey at 800MHz. The Gator transmitter is hoisted up on a crane and the drivers are sent out to perform the drive study.

The Fox receiver will be set to single channel mode with 4096 ADC samples. This produces 1 report a second that is the average of 4096 samples. Since we want to have at least one sample per wavelength, as per 40-Lambda, the maximum speed would be 1ft*4096/sec or 2792 miles per hour! Obviously, the Fox can be used for coverage analysis at any speed.

Each report is the average of all data received during that second, so we still have an initial sampling rate of 4096 samples per second. This setting is the most convenient since the internal GPS receiver in the Fox reports position once per second. At this point we have statistically correct data samples each with a position stamp.

The data should be spatially averaged in post processing. Since forty wavelengths is only forty feet at this frequency, almost any convenient grid size will do. Remember that the accuracy of GPS, with selective addition off, is only about 30 meters, so grid sizes larger than that would be appropriate. In expensive post processing software the grid size can be selected. When processing data yourself, it is often convenient to make the grid based on Latitude and Longitude from the GPS receiver. In the New York area, one degree of latitude is 69 miles and one degree of longitude is 50 miles. Therefore, averaging together data with the first three decimal places of the latitude and longitude the same would be an easy way of getting an appropriate grid size. The smallest side of that grid would be 264 ft.