

LTE Propagation Studies

Narrow-Band, Wide-Band & the Effects of Multipath



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INTRODUCTION

LTE signals propagate through a channel that often exhibits broadband fading characteristics due to multipath. Narrow-band pre-deployment studies use 40-lambda averaging to eliminate fast fading. Narrow-band pre-deployment studies rely solely on received signal strength, and do not consider wide-band fading, multipath and other channel characteristics. Wide-band pre-deployment studies can consider received signal strength as well as, broad-band fading, multipath, channel noise sources, and the cyclic prefix length. These are important because LTE and OFDM technology cannot eliminate fading or multipath.

NARROW-BAND PROPAGATION STUDIES

Two types of fading are relevant to narrow-band propagation studies. Fast fading, also known as Rayleigh fading is due to multipath reflections. Terrain based fading is due to propagation loss and obstructions. Rayleigh fading can produce large variations of signal strength over a fraction of a wavelength. Narrow-band coverage studies are conducted in a manner that rejects Rayleigh fast fading so that accurate measurements of terrain based fading can be made. A data filtering technique known as 40-lambda averaging is a well accepted method of removing Rayleigh fast fades and retaining the slower terrain based fades.

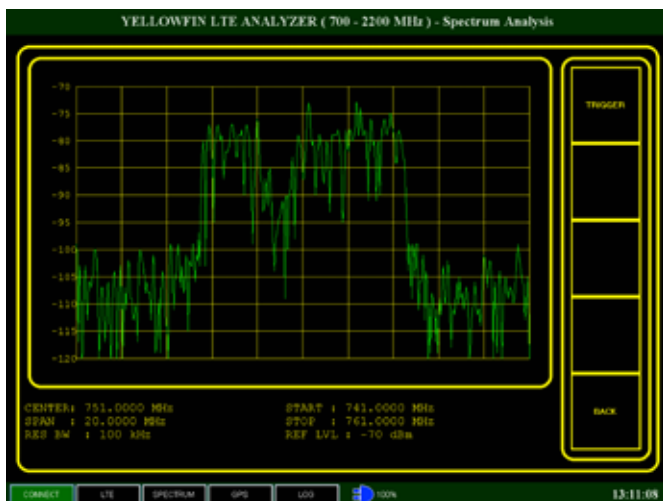


Figure 1. A YellowFin-LTE™ spectrum shot of an LTE signal propagating through a channel with broadband fading.

WIDE-BAND PROPAGATION STUDIES

LTE and OFDM technology cannot eliminate fading or multipath. LTE signals suffer from the frequency selective fading effects of multipath and exhibit broadband fading characteristics that can be very apparent in the spectrum of the received LTE signal, see figure 1. LTE, however, can eliminate inter symbol interference (ISI) through the use of long symbol times and a guard interval. The elimination of ISI enables LTE receivers to mitigate multipath with a channel estimator that can flatten the spectrum, and does not require knowledge of the data that is modulated on the OFDM carriers.

Multipath, delay spread, inter-symbol interference and the cyclic prefix all affect the performance of LTE, primarily via the performance of the channel estimator algorithms needed at the receiver to flatten, and correct the phase, of the received spectrum. Let's examine and differentiate these and how they apply to LTE.

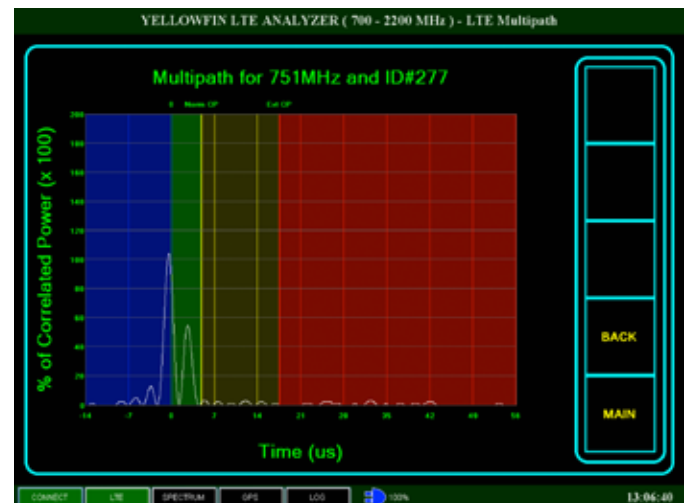


Figure 2. A YellowFin-LTE™ multipath display. This multipath creates broadband frequency selective fading. Note 2 distinct paths within the normal guard period (NormCP).

Multipath is the propagation of an RF signal to a receiver via two or more paths, see figure 2. There are two distinct paths shown, and one path is delayed over $3\mu\text{S}$ relative to the first path. The multipath display was generated by correlating, over time, the LTE synchronization codes and the received signal. Multipath can result in constructive interference, destructive interference and phase shifting of the signal. The two most obvious cases are two sinusoids of

the same frequency that are in phase, constructive, and two sinusoids of the same frequency that are a $\frac{1}{2}$ cycle out of phase, hence destructive. Combining any number sinusoids of the same frequency with any arbitrary phase still results in a sinusoid of the same frequency, but it may have a different amplitude and phase! These sinusoids, the RF carriers, are OFDM modulated in both amplitude and phase to carry data, and this modulation requires that we also consider the effects of ISI, if present, on the received spectrum.

Delay spread, T_d , intuitively, is the amount of time between the first (non-negligible) path and the last (non-negligible) path received, see figure 2. LTE adds a guard time between each OFDM symbol that is called the cyclic prefix, of length T_{cp} . If the $T_{cp} < T_d$, ISI is present. The receiver cannot sample the signal without having a mixture of two or more symbols with different data modulated onto them. The LTE system must be set-up so that $T_{cp} > T_d$ and ISI is not present. If ISI exists, the receiver would need knowledge of both the multipath and the data modulated onto the RF carrier to flatten the received spectrum, and this requires a more complex equalizer that typically suffers from poorer performance when compared to a system that does not need to correct for ISI.

Figure 1 is a spectrum plot of a received LTE downlink signal experiencing broadband fading. This frequency selective fading is quite severe, over 10 dB, in some frequency bins. A channel frequency response estimate is calculated from reference signals that are placed into LTE packets. LTE has several reference signals that can all be used for channel estimating; the Primary Synchronization Signal (PSS), the Secondary Synchronization Signal (SSS) and the Reference Signal (RS) that is placed on a few subcarriers on each OFDM symbol throughout the LTE packet. These reference codes are known a priori and are compared to the received frequency bins that contain the reference code, and a channel estimate is generated for each frequency bin that contains a reference code. Bins that do not contain a reference code are interpolated to calculate a complete channel estimate for all frequency bins. The channel estimator may use linear interpolation across the frequency bins, interpolation across frequency bins and time (successive channel estimates) or adaptive estimates that also require some statistical knowledge of the channel. The channel estimate for each frequency bin is then multiplied onto the received signal's corresponding frequency bin to correct for both amplitude and phase.

The channel estimate may perfectly correct the magnitude and phase of each subcarrier, but subcarriers that are received (assuming equally distributed noise across the band) with lower signal strength will have a lower carrier-to-interference plus noise ratio, CINR, since both the signal and noise are amplified. This is one reason why LTE utilizes interleaving and forward error correction, FEC.

CONCLUSIONS

Narrow-band pre-deployment studies use 40-lambda averaging to eliminate narrow-band fading. Narrow-band pre-deployment studies rely solely on received signal strength, and do not consider wide-band fading, multipath and other channel characteristics.

Wide-band pre-deployment studies can consider received signal strength, as well as, broad-band fading, multipath, channel noise sources, and the cyclic prefix length.

The delay spread, in a LTE system, must be less than the length of the cyclic prefix ($T_d < T_{cp}$) to avoid ISI. LTE channel estimators are designed to correct for the effects of multipath and ISI will compromise LTE performance.

Multipath can reduce the signal strength of frequency bins that experience a fade and compromise performance since the bins experiencing the fade (assuming uniform noise across the band) will have a lower CINR. These effects can be estimated with CINR measurements.

Wide-band received signal strength, CINR, multipath and delay spread are all important measurements for pre-deployment studies as well as for debugging and optimizing deployed LTE networks.



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