Multipath Measurement in Wireless Communication Systems

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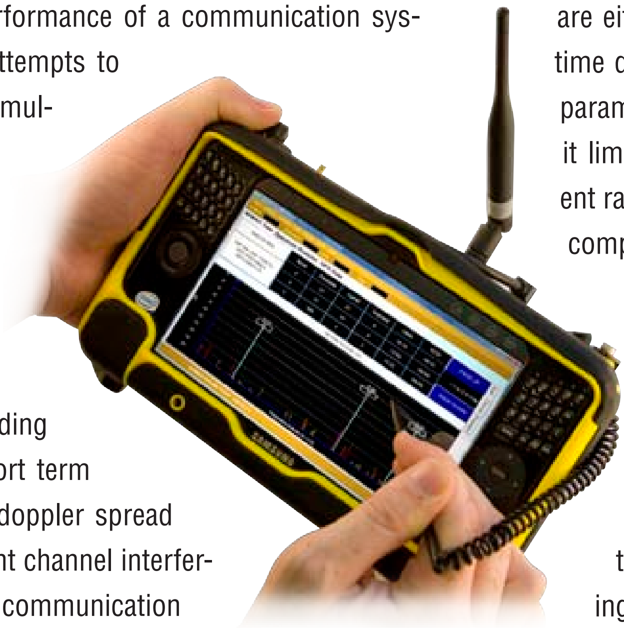
The behavior of a communication channel is not always well defined. Wireless communication relies on a propagation channel to carry information from one point to another. Hence, it is mandatory to characterize wireless communication channels for optimizing the performance of a communication system. This technical brief attempts to clarify the requirement of multipath measurement for a wireless communication system.



The radio propagation effects can be characterized by free space path loss, long term fading (including shadowing), short term fading (multipath fading), doppler spread and co-channel and adjacent channel interference. In a mobile wireless communication system, a transmitted signal follows different paths before arriving at the receiver causing fluctuations in the received signal's amplitude, phase and angle of arrival resulting in multipath fading. Behavior of a wireless communication channel depends on location, time and frequency. As a result, channel models are realized to mimic real world propagation scenarios. Since the performance computed by the channel models are close to the physical reality, these models can be used to evaluate performance of a system in non-real time.

The quality of the communications link depends on a communication medium, and there is a significant probability that the channel will experience a deep fade due to destructive interference (signals adding and subtracting from each other). Lossless operation over broadband channels implies ability to operate even with faded channels where significant multipath is present. Any signal with a large bandwidth is susceptible to the potentially destructive effects of fading such as time dispersion and frequency selective fading. Time dispersion stretches signal in time so that the duration of the received signal is greater than that of the transmitted signal. Frequency selective fading causes the transmitted signal to attenuate certain frequencies more than others.

Radio frequency propagation parameters, in practice, are either measured in the frequency domain or in the time domain. Multipath delay spread is one of the key parameters used to define a multipath channel model as it limits the use of different systems deploying different rates in their operations. If the delay spread is small compared to the inverse of the signal bandwidth, then there is little time spreading in the received signal. However, when the delay spread is relatively large compared to the symbol time there is significant time spreading of the received signal. This can lead to substantial signal distortion in non-spreading systems where as it provides time diversity in spread systems (RAKE combining in CDMA). The large delay spreads are present in both vehicular and pedestrian mobility situations due to the small height of the antennas, and the fact that the mobile unit is typically using omni-directional antennas.

The root-mean-square (RMS) delay spread is the most important single measure for the delay time extent of a multipath radio channel. RMS delay spread for channels range anywhere between several hundreds of nanoseconds to several tens of microseconds. The impulse response of mobile radio channel exhibit delay spread and doppler spreading. The first effect results in time dispersion and frequency selective fading whereas the second results in frequency dispersion and time selective fading. The delay in the signal that comes from a distant Base Station (BS) translates to a delayed impulse response which increases the delay spread of the equivalent channel causing channel distortion and dispersion leading to inter-symbol interference (ISI). ISI, in turn, can cause transmission errors. As the distance range or the data rate of the system increases, ISI becomes more severe due to frequency selective fading, requiring powerful channel estimation and equalization algorithms. Orthogonal Frequency Division Multiplexing (OFDM) systems combat frequency selective fading by splitting the data stream into many parallel streams thus increasing the symbol duration (being inversely proportional to the data rate) of each stream such that the delay spread is only a small fraction of the symbol duration. OFDM eliminates ISI completely by inserting a cyclic prefix (CP), whose length is chosen to be larger than the maximum excess delay of the channel, making OFDM symbol length greater than the delay spread of the channel, or else the dispersion that occurred degrades system performance considerably.

The main parameters of the channel are the user's velocity and the channel delay spread. These parameters affect the correlation functions, which are used for channel estimation. It is thus indispensable to have a better understanding of these phenomenon. Ability to tackle adverse effects due to this phenomenon is required to design a reliable and high performance systems that can adapt themselves to the changing nature of the transmission medium.

Time dispersion of the channel due to delay spread can be estimated using the channel impulse response (CIR). Delay spread is the time duration of the autocorrelated channel's time-varying impulse response. CIR can be efficiently estimated in the frequency domain (as in OFDM) or in time domain (as in CDMA) using known reference symbols.

Multipath measurement for mobile WiMAX under vehicular speed of 60 Km/hr is shown in the figure-1. RMS delay spread can be calculated from the delay profile of the channel under consideration. From this figure it can be observed that the multipath exist at CP length of TFFT/8 where TFFT is the FFT size. This helps network operators analyze and to chose the best suited CP length for various scenario for network optimization and while improving the quality of transmission.

Multipath fading effects can also be combated using diversity and combining techniques. OFDM system exploits frequency diversity using frequency slicing, whereas CDMA system exploits time diversity through Rake receiver. Performance of different communication systems are compared in terms of the delay spread that can be tolerated. But delay spread is not an indicator of performance unless the parameter is well defined and is related to a known channel model. Measuring the performance of a system in various channel conditions could help device manufactures/OEMs' in deploying an efficient system. An accurate description and emulation of wireless channel characteristics allows thorough testing of wireless devices such as access points, base stations, mobile stations, and other wireless devices.

Multipath delay spread can be a major transmission problem, which must be characterized before design of modulation, equalization and diversity can be finalized.

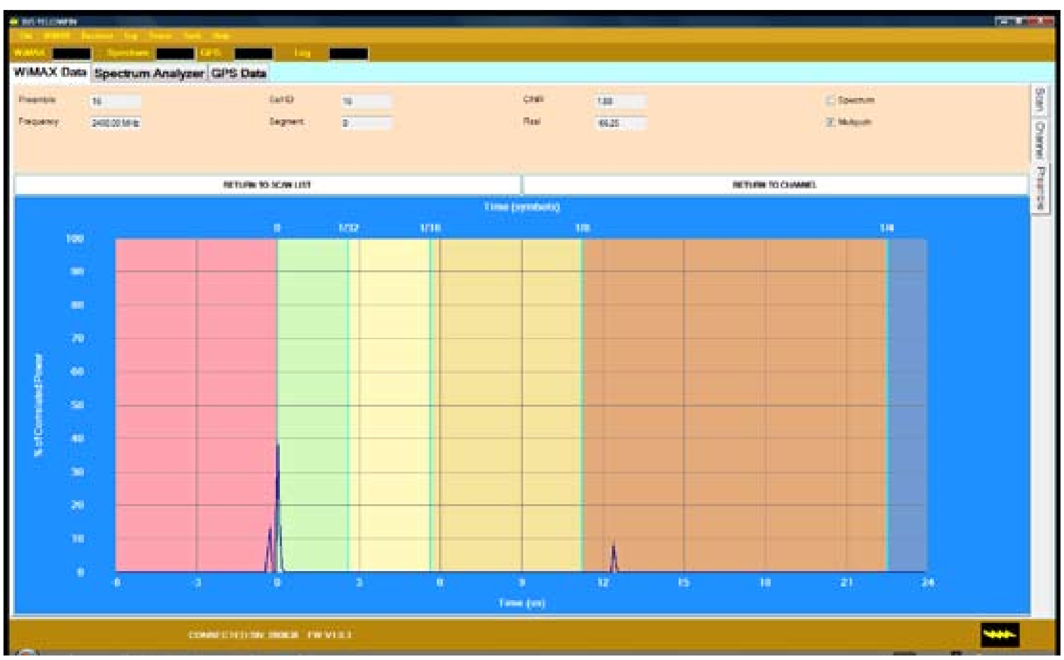


Figure 1 Multipath measurement using BVS' YellowFin -WiMAX analyzer

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