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| Project | **IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>** |
| Title | **802.16a OFDMA PHY suitability for mobile applications** |
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| Abstract | This document discusses channel models for mobile wireless channels, and discusses the suitability of the OFDMA PHY mode for operation over these channels |
| Purpose | For discussion |
| Notice |  |
| Release |  |
| Patent Policy and Procedures |  |

# Mobile Channel Models

### Path loss

Path loss in mobile wireless channel is typically much higher than the path loss for an equivalent fixed wireless channel. This happens because the mobile reception unit typically uses a low height omni-directional antenna, and. The higher path loss requires higher system gain, and the high variance of the path loss causes inter-cell interference. Several path loss models are widely used to characterize the path loss in mobile environments mostly based on the Okumura-Hata measurement [1], and modifications to adapt it to higher frequency bands.

### Multipath

Operation over broadband mobile wireless channels implies ability to operate even in fading channels in which significant multipath is present. In [1], [3], [4] and [5] it is shown that RMS delay spread for wireless mobile channels (mostly in 900MHz and 1900MHz) range anywhere between several hundreds of nanoseconds to several tens of microseconds. 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.

### Doppler and fast fading

Doppler frequency shift can be estimated by $f_{carrier} \cdot V_{Vehicle} / C$ (ignoring the angle of the movement). In order to estimate the Doppler effect at our target frequency bands, lets calculate for the MMDS (2.5GHz) and UNII (5.8GHz) bands. Assuming a vehicle speed of 100Km/H we get a maximal Doppler shift of about 230Hz for MMDS, and about 540Hz for UNII. The Doppler power spectrum used to characterize the fast fading can either be estimated as a flat spectrum as shown in [6], or follows the Jakes model [7].

# Impact of mobile channel on OFDMA PHY

### Timing synchronization

Timing synchronization in an OFDMA receiver is based primarily on the strong auto-correlation properties of the OFDMA waveform. This autocorrelation is a consequence of the cyclic prefix part of the waveform. The passage of the OFDMA waveform through the wireless channel smears the autocorrelation because the CP collects somewhat different multipath than original instance of the symbol. The longer the CP relative to the channel delay spread, the less the autocorrelation is smeared. For OFDMA, CP even for a fairly broad 14MHz channel can be up to 32usec, in conformance with delay spreads expected in a mobile environment.

### Frequency synchronization

Carrier frequency synchronization is an essential component in every coherent receiver. In OFDMA this synchronization is even more crucial as transmission bursts from several transmitters are synchronously combined in the uplink.

Frequency synchronization in OFDM receivers is generally based on a pre-FFT stage that handles the fractional frequency offset (i.e. the part that is not an integer multiple of sub-carrier spacing) and a post-FFT stage that handles the integer frequency offset.

The pre-FFT stage will usually utilize the OFDMA waveform autocorrelation. As discussed with regard to the timing synchronization, the OFDMA waveform displays strong autocorrelation even in severe multipath conditions due to the fact the duration of the CP greatly exceeds the channel delay spread.

The post-FFT stage will usually utilize the pilot tones to correct the integer frequency offset. In OFDMA 166 out of the 1702 used carriers are pilots. This provides a processing gain in excess of 20dB for the pilots PN series autocorrelation peak.
Frequency synchronization in a mobile environment is more challenging due to the Doppler frequency shift and the fast fading effects. These effects tend to smear the sub-carriers and introduce inter-carrier-interference. OFDMA symbols are short enough (a typical value would be 300usec in a 6MHz MMDS channel) even relative to the highest Doppler spectral component, so the channel response can be assumed fairly stable across one symbol. With the help of the carrier frequency synchronization techniques mentioned above, even one OFDMA symbol is enough to extract accurate carrier frequency estimations, and ensure both downlink and uplink synchronization.

### *Channel estimation and demodulation*

Channel estimation in OFDMA receivers is based on pilot sub-carriers. In OFDMA there are both constant location pilots and variable location pilots. The variable location pilots are arranged such that one of every 12 sub-carriers is a pilot. This means that by using the pilots from one symbol, a channel estimate with length of up to 1/12 of the symbol can be done. This capability, combined with the length of the OFDMA symbols enables fast, per symbol, estimation of the channel. Thus OFDMA does not require a downlink preamble, and does relay require that a transmission burst be shorter that the channel coherence time.

### *Channel coding*

The OFDMA PHY support a mandatory RS-Convolutional block code and optionally turbo codes. Both these codes are robust, and have been used in fixed as well mobile environments.

### *Ranging and power control*

The process of ranging has an important role in maintaining the uplink channel integrity by keeping the received power at the BST within the allowed bounds. In a mobile environment ranging has to be more frequent because of the existence of fast fading effects in the channel. The OFDMA PHY can support the fast power control loop necessary in a mobile environment. The features that enable this are,

- Short frame duration – 2mS is the current minimum supported.
- The CPE can do ranging frequently, with small chances of collision – CDMA code ranging enables multiple CPE to perform ranging in parallel without collisions and with excellent processing gain at the BST
- Fast power control – The downlink map contains a power control IE that provides a BW efficient means for controlling the CPE transmitted power

### *Inter-system interference*

Due to the large variance in a mobile system path loss, inter-cell interference is a common occurrence in mobile wireless systems. The OFDMA PHY is designed such that sub-channels can be composed from several distinct permutations of sub-carriers. This feature enables significant reduction in inter-cell interference because even on occasions where the same sub-channel is used at the same time in two different cells, there is only a partial collision on the actual sub-carriers.

## Performance estimates/simulations

In May 1998, a consortium of 17 broadcasters, network operators, manufacturers of professional and domestic equipment and research centers, lead by T-NOVA (formerly Deutsche Telekom Berkom), launched the MOTIVATE project funded by the European Commission in the ACTS Program (Advanced Communications Technologies and Services), to investigate the practical and theoretical performance limits of DVB-T for mobile reception. MOTIVATE partners performed a considerable amount of work both in the Laboratory (simulations, tests campaigns) and in the field (field trials, demonstrations) to achieve the project goals [8]. DVB-T is a close kin of 802.16a OFDMA PHY that operates in VHF/UHF frequencies and supports 8K and 2K FFT modes. The report demonstrates operation in a mobile environment at velocities exceeding 200Km/H.

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