Version 1.0

OFDM Overview

White Paper

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Introduction

One of the challenges in today's Wireless Broadband Access market is the ability to deploy and operate wireless systems while maintaining good performance, delivering high speed data rate in many different topographic and landscape areas. Natural and man made obstacles affect the performance of the wireless systems. Whether it is due to *non-line-of-sight* (NLOS) conditions or multi-path, it's a challenge that many operators face today. An emerging technology called OFDM solves these challenges.

Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation technique. It achieves high speed data rates, prevents inter-symbol interference (ISI), and overcomes *multi-path signals.* It also allows communications in areas where non-line-of-sight (NLOS) is a limiting factor for wireless deployments.

OFDM technology is not new. It is an innovative technique that has become commercially available and it meets the market's demand. OFDM provides a solid foundation for wireless operator's business plans for profitability based on a large subscriber base.

Multi-path and its Effect

Multi-path appears in conditions where the transmitted signal experiences reflections, diffractions, and scattering. These conditions cause multiple echoes of the same signal to arrive at the receiver at the same time or *delayed*. This is due to obstacles between transmitter and receiver. It causes the receiver to incur in additional processing time to identify the incoming signals. The receiver discards the unwanted signals in detriment to overall system performance. See Figure 1 below.

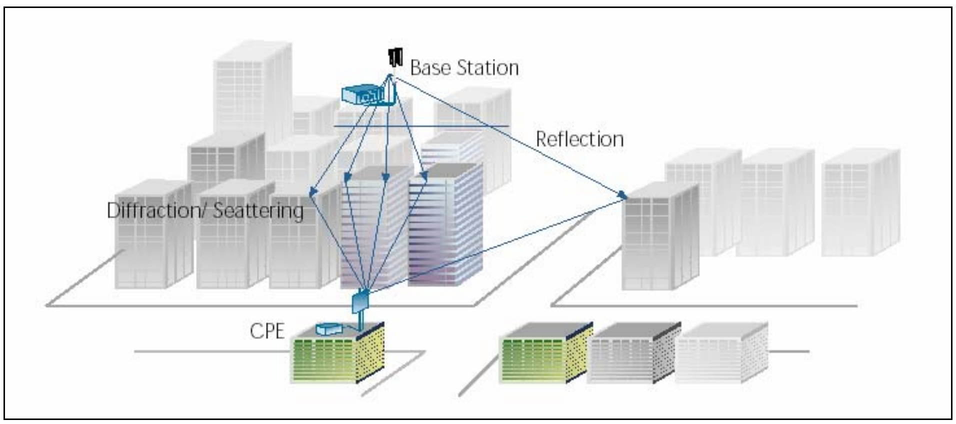

Figure 1: Multi-path

The effect of multi-path on wireless communications is known as Inter Symbol Interference (ISI). Each *symbol* contains a number of bits determined by a specific modulation. Since wireless systems use symbols for transmission, the echoes of a certain symbol resulting from multi-path conditions are seen as inter symbol interference (ISI) to the subsequent arriving symbol. See Figure 2 below.

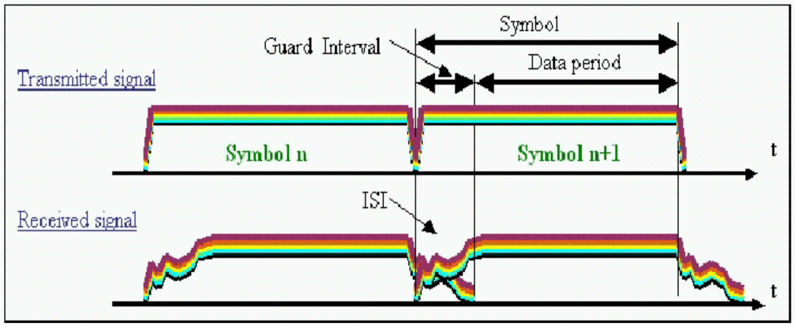

Figure 2: Inter Symbol Interference (ISI)

OFDM modulation is very robust against multi-path delay spread *(the time spread between the arrival of the first and last multi-path signal seen by the receiver).* OFDM minimizes the inter-symbol interference by having long symbol periods.

OFDM at Work

OFDM modulation divides the available spectrum channel into several independent sub-carriers. This is achieved by making all the sub-carriers orthogonal to one another, preventing interference between the closely spaced sub-carriers. In an OFDM signal, all the orthogonal sub-carriers are transmitted simultaneously.

Orthogonality is achieved by making the peak of each sub-carrier signal coincide with the nulls of other signals where the result is a perfectly aligned and spaced sub-carrier signal. See Figure 3 below.

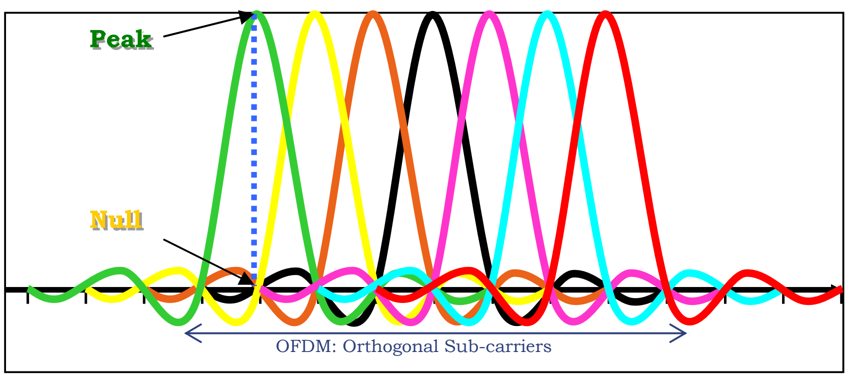

Figure 3: OFDM Orthogonal Sub-carriers

The signals in the independent sub-carriers are individually modulated and demodulated. If one or two sub-carriers are degraded or impacted by frequency selective fading *(signals at different frequencies travel at different energy propagation and velocity),* the impact is minimal since the information is spread across the remaining sub-carriers. The simultaneous transmission of several parallel sub-carriers delivers high data rates.

See Figure 4 in next page.

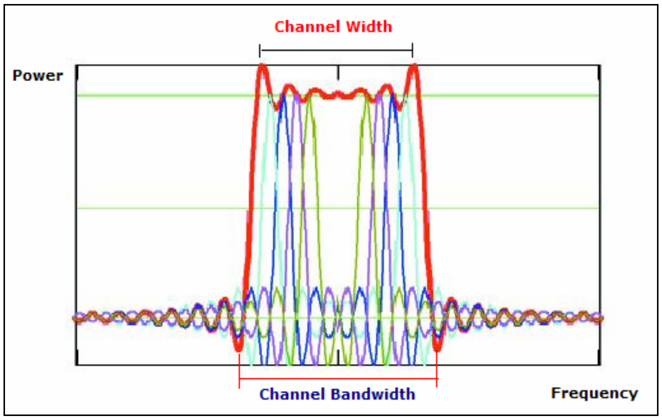

Figure 4: OFDM Channel

Since an OFDM signal is transmitted in several parallel sub-carriers, Forward Error Correction (FEC) bits are applied to the sub-carriers that the receiver uses to recover missing bits of information due to interference or multi-path. This error correction mechanism allows OFDM to maximize the reliability of the data transmissions.

Single Carrier vs. OFDM Systems

Single carrier systems transfer the data streams using a serial transmission while OFDM system uses a parallel transmission. The ability to sustain a higher throughput in a single carrier system becomes diminished as the symbol duration becomes smaller, as symbols need to be transmitted at a faster rate. This translates into a single carrier system being more susceptible to inter-symbol and external interference from multi-path and other RF sources (carrier wave). A single carrier system's ability for error recovery becomes more difficult and seriously impacted which results in loss of performance.

An OFDM system is able to achieve higher and reliable data rates, transmit symbols at a lower rate, and transmit more symbols in parallel streams. Since OFDM utilizes several parallel sub-carriers at the same time, it is able to recover from errors more efficiently, as not all of the information can be impacted from interference sources. This translates in to higher and sustainable throughput specifically in locations where non-line-of-sight (NLOS) conditions exist.

Benefits of OFDM for Operators in the Wireless Access market

OFDM technology is the ideal solution for Carriers, Operators and Service Providers who want to deploy profitable broadband networks.

Operators in the market today need to know that Wireless ACCESS equipment can be deployed anywhere, and can overcome natural obstacles in rural areas, and buildings in suburban and dense urban areas (NLOS).

Such capabilities allow for various deployment scenarios from private residential homes in suburban areas to offices and businesses in central urban areas, thus giving operators the advantage of catering for the whole wireless access market with an OFDM based system.

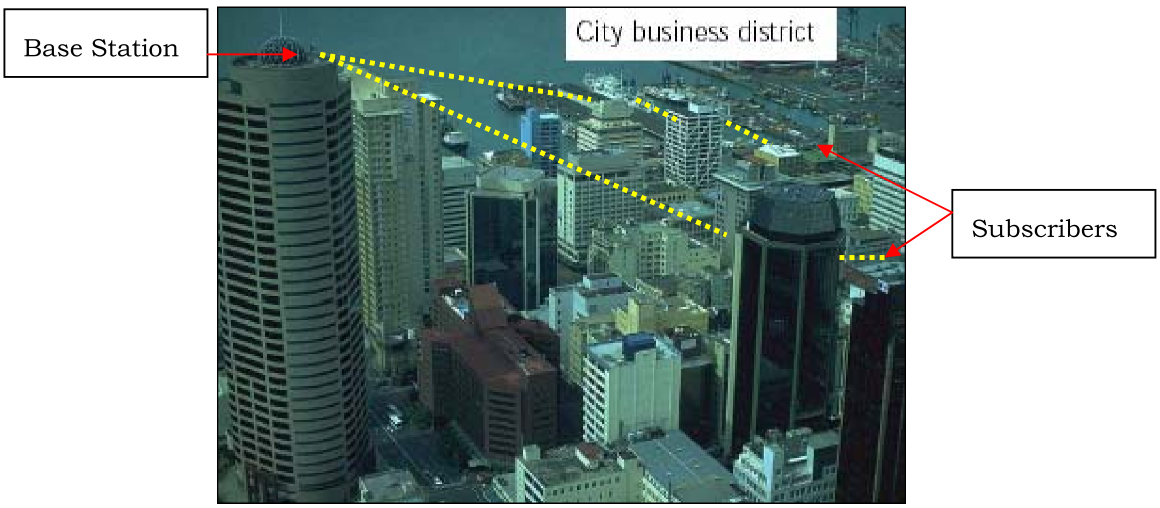

Figure 5: OFDM Solves the Non-Line-of-Sight (NLOS) limitations

The benefits of implementing an OFDM system are:

- Better coverage and penetration, which enables the provision of wireless access services to previously un-served customers, thus increasing the revenue potential for the Operator/Service Provider.
- Reduced operation and installation costs, resulting from faster and simpler installation procedures that do not dictate mandatory Line-of-sight (LOS) conditions and may save the need to install additional accessories.
- Ultrahigh spectrum efficiency translates into more data that can be transmitted over a smaller amount of bandwidth than competing technologies.
- High resistance to multi-path, typically found in suburban and urban environments where narrowband and DSSS (802.11b) systems cannot tolerate severe multi-path at high data rates.
- OFDM minimizes inter-symbol interference (ISI) using several types of adaptive modulations. Moreover, since each data sub-carrier in OFDM typically carries data at a rate under 1 Mbps, reflected multi-path signals are less likely to cancel the main signal.

- OFDM is designed to solve the limitations of deploying in wireless metropolitan network areas and to deliver broadband access to wide range of customers including residential, SOHO, SME and Multi Tenant Units.

References

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2. E Lawrey, “The suitability of OFDM as a modulation technique for wireless telecommunications, with a CDMA comparison”, Thesis, pp 29-33, 1997.
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