alvarion

We're on your wavelength.

Wireless Connectivity

Breaking the line-of-sight boundaries

BreezeACCESS OFDM

Introduction: current market demands

Today, more than ever, telecom operators providing last mile Broadband Wireless Access (BWA) solutions are facing a very challenging economic landscape. During the late 1990s being the fastest to grab a piece of the market was seen as the primary measure of success, however, today operators are required to present a sound & solid business plan that will lead to profitability faster and balance investment against expected revenues. This new economic climate has set the drive for the appearance of 2nd generation Broadband Wireless Access systems that were designed to fulfil these needs.

One of the key requirements in 2nd generation BWA systems is the ability to operate, while maintaining high performance, in Obstructed-Line-Of-Sight (OLOS) and Non-Line-Of-Sight (NLOS) conditions. Until recently, operation in OLOS and NLOS conditions has been problematic and limited the potential customers for the operators. Several earlier technologies, which claimed to provide a solution, proved to be a false dawn with the single carrier modulation approaches largely discredited for NLOS applications due to interference and multi path issues. Instead, it is Orthogonal Frequency Division Multiplexing (OFDM) - a multi-carrier modulation technique for transmitting large amounts of digital data over a radio wave that has triumphed, and is being heralded as achieving a major breakthrough in the Broadband Wireless Access market.

Alvarion's BreezeACCESS OFDM product line, a state-of-the-art 2nd generation Broadband Wireless Access system operating in the 3.5GHz-licensed band, is designed to answer the expressed needs of Telecom Carriers and Service Providers. This paper focuses on three topics related to Alvarion's OFDM solution and its NLOS capabilities. First, several field trials of Alvarion's BreezeACCESS OFDM system operating in OLOS and NLOS environments are discussed. Secondly, the technical advantages of OFDM technology are introduced and it is explained how OFDM operates in NLOS conditions and overcomes multi-path phenomena. Finally, the main benefits of NLOS capabilities to operators are presented.

1. Non-Line-Of-Sight Performance & Capabilities

Topographic and landscape conditions impact greatly on the performance of a Broadband Wireless Access system in real life deployments. The need to cope with various types of obstacles is evident in practically all deployment scenarios, be it rural, sub-urban or dense urban topographies. In this respect, a robust BWA system is one that can operate with high performance and high availability over a wide range of link conditions - a capability that enables operators to cover a wider range with fewer base stations.

BreezeACCESS OFDM is among the first BWA systems in the 3.5GHz-licensed band that supports NLOS operation capabilities. The combination of OFDM modem technology coupled with dynamic adaptive modulation are unique in the BWA marketplace and are the key factors that enable reliable operation with high availability and high performance in NLOS conditions with BreezeACCESS OFDM. These capabilities have been demonstrated in real life links in multiple locations around the globe. Here follow three real life examples that illustrate these capabilities:

a. Scandinavia - Residential Deployment

In this deployment, a specific subscriber unit was installed under severe NLOS conditions. The BreezeACCESS OFDM CPE was installed in a residential home located 3.5 km from the base station. As can be seen in figure 1 below, the CPE is located in a valley with small houses surrounded by trees and plantations. There is a hill that completely blocks line of sight between the base station and CPE. The topographic contour in figure 2 below shows the path profile simulation using a radio-planning tool, indicating the non-line-of-sight nature of this link. As illustrated in figure 2, the brown line that represents the earth level and shows the hill at the right end of the diagram blocks the green line that represents the clear line of sight path from the base station to the CPE. Utilizing the dynamic adaptive modulation characteristic of the BreezeACCESS OFDM system together with the OFDM capabilities to reject multipath phenomenon, this link is constantly operational working in data rates of 4 or 8 Mb/s. The data rates automatically change adapting to the radio link quality that varies according to the weather conditions, thus maintaining high availability of this difficult link.

Figure 1 - Alvarion BreezeACCESS OFDM CPE location

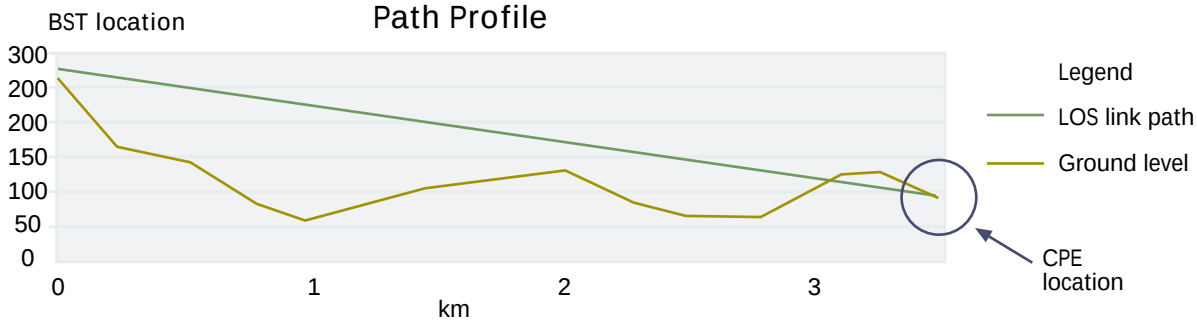


Figure 2 - Link path profile simulation

b. Field Trial New Zealand

In this trial, the BreezeACCESS OFDM system was tested in many locations in Auckland simulating various installation scenarios. The tests were performed at distances of up to 20 km in LOS, OLOS and NLOS conditions. Figure 3 shows a diagram of the city marked with the base station location and three areas where the system was tested.

Figure 3 - Auckland map

1. The first area that was tested is the famous Domain Park, which is covered in trees growing very densely, as illustrated in figure 4 below. Tests were performed in various locations - all obstructed by trees- at a distance of 2 km from the base station. The tests were done using a mobile Alvarion OFDM unit mounted on top of a truck. The system performed at a maximum data rate of 12MB/s in all locations tested, representing OLOS and NLOS conditions. A typical test location is seen in figure 4 below, showing the environment with heavy tree obstacles.

Figure 4 - Domain Park installations

2. The second area tested was Auckland's business district, an area with high-rise buildings and skyscrapers as seen in figure 5 below. The BreezeACCESS OFDM system was tested at several sites, all of them at street level. Distances varied from 0.5 to 2 km. The OFDM CPE was able to establish an operational link in all tested locations at data rates between 4 and 12 Mb/s.

Figure 5 - City Business District installations

3. The third area tested was Devonport Island. Several links were tested at distances of between 4 and 5 km from the base station in OLOS and NLOS conditions and over water, which creates strong reflections resulting in difficult multi-path conditions. Once again, the OFDM CPE was able to establish operational links in all locations tested at data rates from 4 to 12 Mb/s. A typical test location is presented in figure 6 below.

Figure 6 - Devonport installation locations

c. Field trial, Latin America.

In this field trial performed in an urban environment in Latin America the operator focused on testing the system in NLOS and OLOS conditions. Figure 7 below shows a picture of the type of area where the system was examined. The figure shows a Non-Line-Of-Sight link at distance of 3 Km between the base station and CPE. The link operated at a data rate of 8 Mbps corresponding to QAM 16 modulation. The channel response recording of this link is also illustrated. It shows how the OFDM signal is received at the subscriber end and provides better understanding of the multi-path conditions experienced in this specific link.

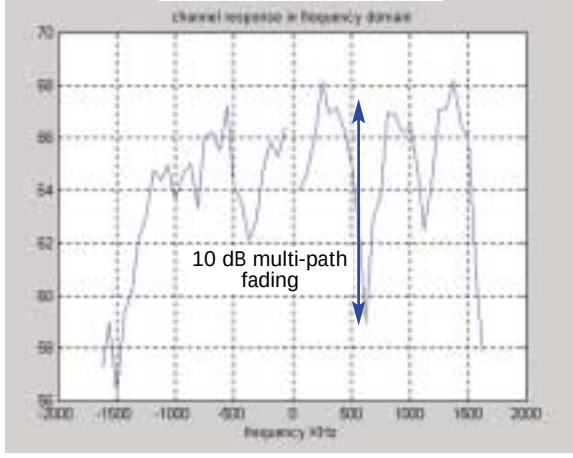
Figure Description	Figure/Diagram
View from BreezeACCESS OFDM base station towards direction of the subscriber unit located 3 Km in Non-Line-Of-Sight conditions. The building marked by the red circle is obstructing the path between the Subscriber Unit and the Base-station.	
This graph shows the channel response recording of the received signal in the frequency domain. It shows that the link is experiencing strong multi-path fading, expressed by the strong notches of up to 10dB in part of the OFDM sub-carriers across the 3.5MHz channel bandwidth.	

Figure 7 - NLOS link example in Latin America

2 OFDM, Multi-path and Spectral Efficiency

BreezeACCESS OFDM is a system designed to work in a variety of envorinmental link conditions, from Line-Of-Sight (LOS) to Obstructed Line-Of-Sight (OLOS) and Non-Line-Of-Sight (NLOS). This results from the inherent capability of Orthogonal Frequency Division Multiplexing (OFDM) technology to overcome multipath phenoma, which is typical for NLOS links. Multipath appears when obstacles exist between the Base Station and Subscriber location. In such conditions the transmitted signal experiences reflection, diffraction and scattering which cause multiple echoes of the same signal to arrive at the receiver at different times. This effect is illustrated in figure 8 below.

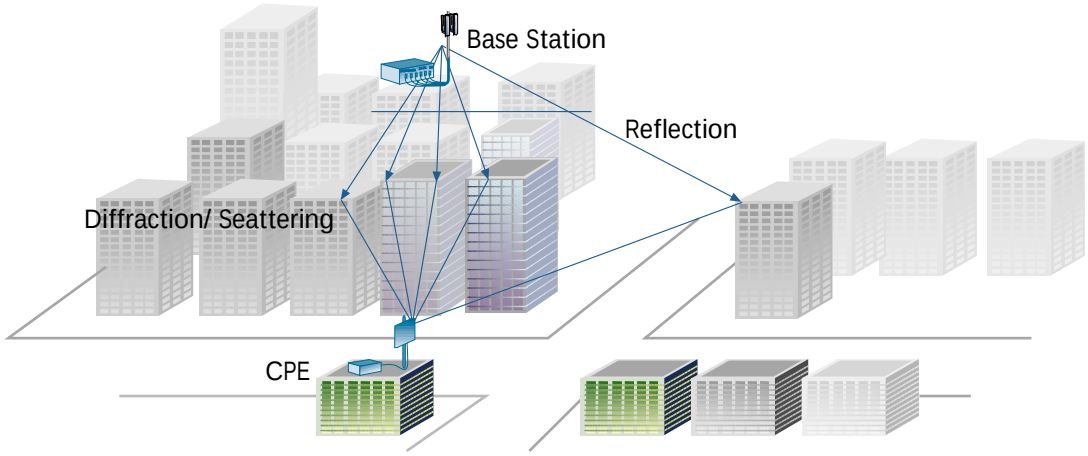


Figure 8- Multipath in NLOS link conditions

The effect of multipath phenomenon on wireless communicatin is ISI - Inter Symbol Interference. The echoes of a certain symbol (namely symbol n) resulting from the multi path nature of an NLOS link are seen as interference to the subsequent symbol (namely symbol N+1). OFDM technology overcomes the ISI problem by use of a Guard Interval (GI) period at the beginning of symbol. The Guard Interval period accounts for the part of the symbol that is corrupted by the ISI. The data period that follows the Guard Interval carries the data payload. This concept is demonstrated in figure 9 below.

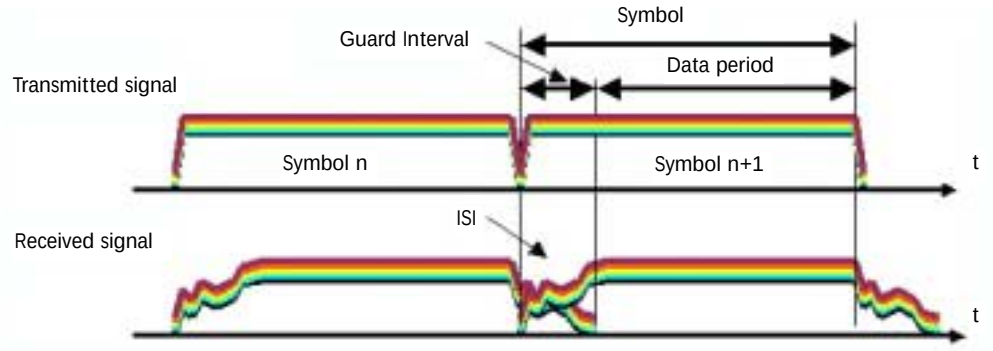


Figure 9 - OFDM Symbol Structure, ISI and Guard Interval

The use of OFDM accounts for high data rates and high spectral efficiency. This is achieved by transmission in parallel of multiple subcarriers over-the-air, each capable of carrying modulated data (up to QAM 64 in BreezeACCESS OFDM). The sub-carriers are placed on orthogonal frequencies. Orthogonality means that the central frequency of a certain subcarrier coincides with the nulls of the other subcarriers as illustrated in figure 10 below. The use of orthogonal frequencies avoids interference between the different subcarriers while enabling high density positioning of subcarriers in the frequency domain, thus achieving very high spectral efficiency.

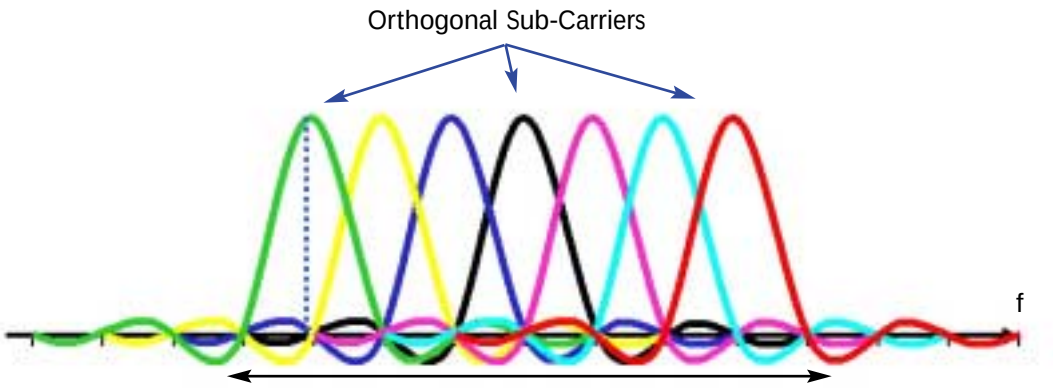


Figure 10 - OFDM Sub-Carrier Orthogonality in Frequency Domain

3 Summary

The ability to operate in Obstructed-Line-Of-Sight (OLOS) and Non-Line-Of-Sight (NLOS) conditions is crucial to the future use of BWA as an access technology. Understandably, operators need to know that BWA can be deployed anywhere, and can overcome obstacles such as mountains and trees in rural areas, and buildings in suburban and dense urban areas. 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 broadband access market with a single BWA system.

The benefits of having BWA systems with NLOS capabilities are:

- Better coverage and penetration, which enables the provision of BWA services to previously unserved 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 LOS conditions and may save the need to install additional accessory equipment such as high masts, etc.

As detailed throughout this paper, BreezeACCESS OFDM provides excellent broadband connectivity in NLOS conditions. Combined with its rich and mature feature set which comes from Alvarion's vast BWA deployment experience with the BreezeACCESS product line, BreezeACCESS OFDM is the ideal solution for Carriers, Operators and Service Providers who want to deploy profitable broadband networks.

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