BreezeACCESS VL

Beyond the Non Line of Sight

July 2003

Introduction

One of the key challenges of Access deployments is the coverage. Operators providing last mile Broadband Wireless Access (BWA) solution are facing difficulties to address all customers in a specific area thus not fully exploiting their investment, i.e. installed Base Station sites. Therefore, a major prerequisite in BWA systems is the ability to operate, while maintaining high performance, in Obstructed-Line-Of-Sight (OLOS) and Non-Line-Of-Sight (NLOS) conditions. The OFDM - Orthogonal Frequency Division Multiplexing - a multi-carrier modulation technique for transmitting large amounts of digital data over a radio wave has achieved a major breakthrough in the Broadband Wireless Access market.
The BreezeACCESS VL is an advanced OFDM system, operating in the 5GHz band and ensuring best coverage in LOS and NON LOS conditions. The VL is an expansion to Alvarion's industry leading BreezeACCESS Point-to-multipoint wireless broadband solution, incorporating a comprehensive range of access features and delivering high bit rates per CPE.
This paper focuses on three topics related to Alvarion's OFDM solution and its NLOS capabilities. First, the technical advantages of OFDM technology are introduced and it explains how OFDM operates in NLOS conditions and overcomes multi-path phenomena. Secondly, several field experiences of Alvarion's BreezeACCESS VL system operating in OLOS and NLOS environments are presented. Finally, a summary that highlights the main benefits of NLOS capabilities to operators is presented.

The role of OFDM in Fixed Wireless Access

BreezeACCESS-VL is a system designed to work in a variety of environmental 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 phenomena, 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 causes multiple echoes of the same signal to arrive at the receiver at different times. This effect is illustrated in figure 1 below.

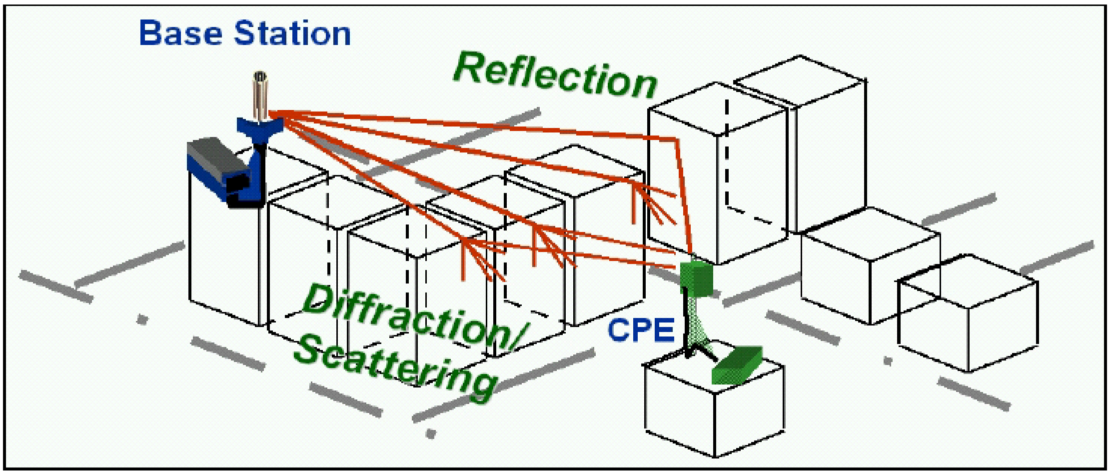

Figure 1: typical FWA scattering environment.

The effect of multipath phenomenon on wireless communication 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 using a Guard Interval (GI) period at the beginning of symbol. The Guard Interval period is actually 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 2 below.

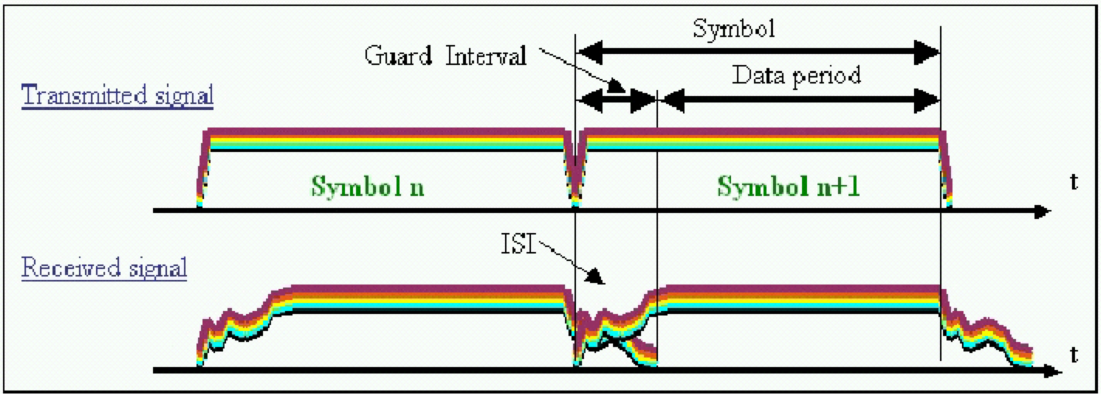

Figure 2: Illustration of OFDM symbol structure and the relation of multipath and GI.

The use of OFDM accounts for high data rates and high spectral efficiency. This is achieved by parallel transmission of multiple sub-carriers over-the-air, each capable of carrying modulated data (up to QAM 64 in BreezeACCESS VL). The sub-carriers are placed on orthogonal frequencies. Orthogonality means that the central frequency of a certain sub carrier coincides with the nulls of the other sub carriers, as illustrated in figure 3 below. The use of orthogonal frequencies avoids interference between the different sub carriers, therefore enabling usage of QAM modulation on each carrier, thus achieving very high spectral efficiency.

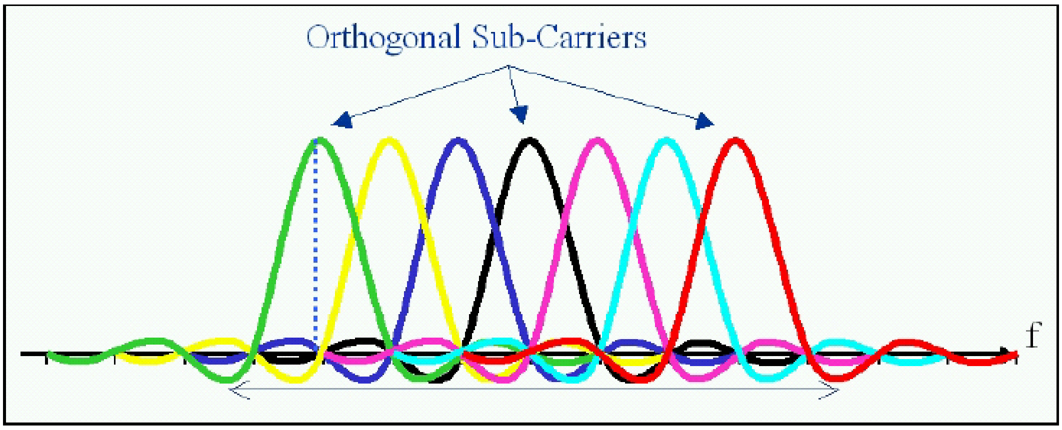

Figure 3: Illustration of orthogonal subcarriers in frequency domain.

Factors affecting coverage

The main considerations, related to the ability to operate, are the signal strength and the multipath distortion.

- Factors affecting signal strength

The key factor affecting the loss in NLOS scenarios is diffraction losses from buildings and tree lines. The main parameter is the ratio between obstruction depth and the Fresnel zone radius. The attenuation as a function of clearance is indicated below:

Fresnel zones	Attenuation
0.5 zone clear	-2 dB
0 (touching)	-6 dB
0.5 zone obstructed	-10 dB
1.0 zone obstructed	-16 dB
1.5 zone obstructed	-19.5 dB
2.0 zones obstructed	-22 dB
2.5 zones obstructed	-24 dB
3.0 zones obstructed	-25.5 dB

Note that at deeply obstructed LOS, additional factors may come in, such as the shape of the obstruction (edges of the building) or penetration through trees, in the case of tree line.

- Multipath issues

In outdoor installations the dominant source of reflections is from buildings – they are vertical and relatively flat. The main factors are the size of the building, its orientation, the roughness of the building. The polarization used also is of importance – usually vertical polarization is reflected stronger than horizontal.
Typically the BST is higher than the subscriber, and usually most of the reflections come from the vicinity of the subscriber. Exceptions exist in dense urban environment, in which high-rise buildings, far from the subscriber, can have a significant contribution.
The antenna beam acts as a spatial filter, which isolates many of the potential reflections. In this sense, 5 GHz systems are in an easier situation than lower frequency systems, since the antenna beam of the subscriber equipment is narrower.
In heavily obstructed scenarios' occasionally stronger signal can be received from a reflection than from the Base Station direction. Caution needs to be exercised not to rely too heavily on such "fortunate" occurrences. The reflected

signals tend to be less stable than direct signals, and unless the reflection is identified with a permanent, stable object it is advised not to point an antenna to it for long-term fixed wireless installation. A better strategy in such cases is to use a lower gain, broader beam antenna, which will convert several reflected signal to a multipath which subsequently be handled by the OFDM modem, rather than relying on the stability of a single reflection. The same is true for scenarios where the subscriber is on a back side of a building and is forced to work from reflections of a building across a street.

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 practically in 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 VL's capability of OFDM modem technology coupled with adaptive modulation are the key factors that enable reliable operation with high availability and high performance in NLOS. These capabilities have been demonstrated in real life links in multiple locations around the globe. The following paragraphs describe the BreezeACCESS VL OLOS and NLOS experience in Tel-Aviv, Beijing and Pennsylvania

Tel Aviv, Israel

This trial was held in Tel-Aviv area, where the Base Station was located on Alvarion building, 50 meters above ground level. The SUs were located in various distances from 350 meters to up to 1.1 km. In each site the SU was positioned in 3 heights from ground levels: 1.5 meters, 2.5 meters & 3.5 meters. In places of severely obstructed LOS, the system performed better when pointed sideways to a reflecting object, rather than directly to the base station.

Figure 4: Map of the Tel Aviv experiment area.

Site 1:

SU was positioned in an obstructed LOS location. The link was successfully established at all points, yielding 11-Mbps FTP performance, at 3.5 meters height. In this case, the preferred antenna pointing direction is 45 degrees left from the base station.

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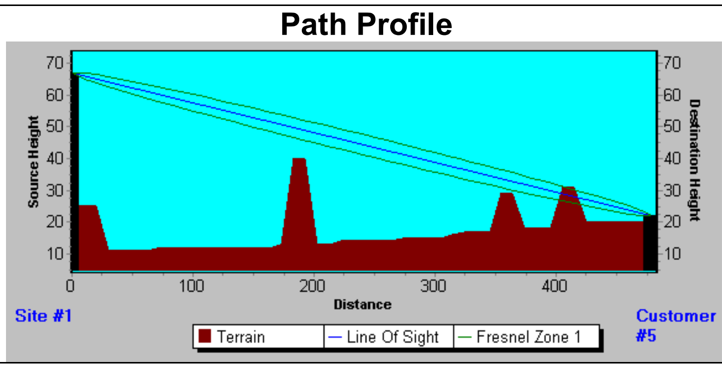
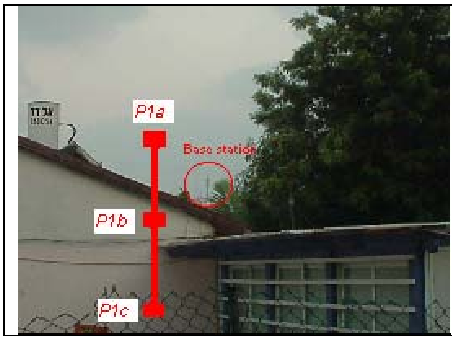
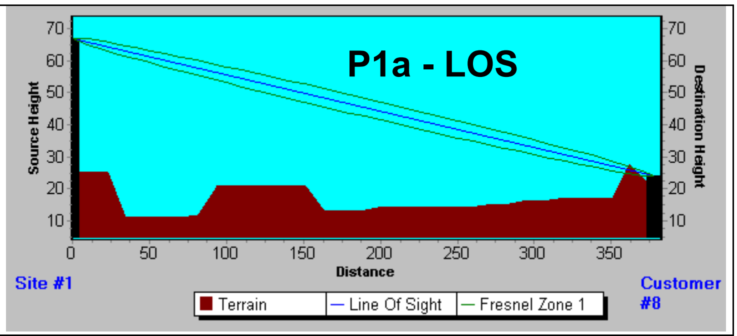


Figure 5: Tel-Aviv – SU site no. 1

Site 2:

SU was positioned in 3 heights that had either partially or completely blocked LOS. The link was successfully established at all points yielding 15Mbps FTP performance.





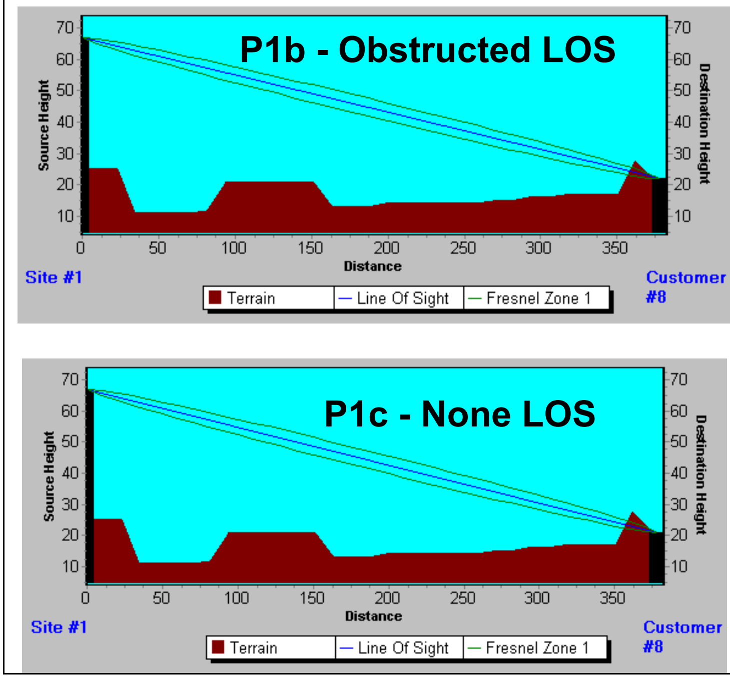


Figure 6: Tel-Aviv – SU site no. 2

Site 3:
SU was positioned in a completely blocked LOS location. The link was successfully established at 3.5meters above ground yielding 4-Mbps FTP performances.

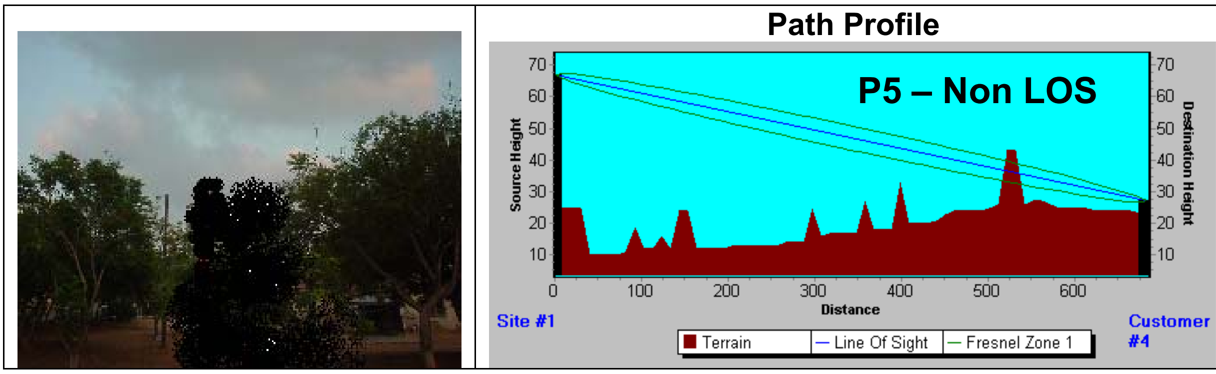


Figure 7: Tel-Aviv – SU site no. 3

Site 4:
SU was positioned in 3 heights, all with completely blocked LOS. The link was successfully established at all points, yielding 5 Mbps of FTP performances at 3.5 meters height.

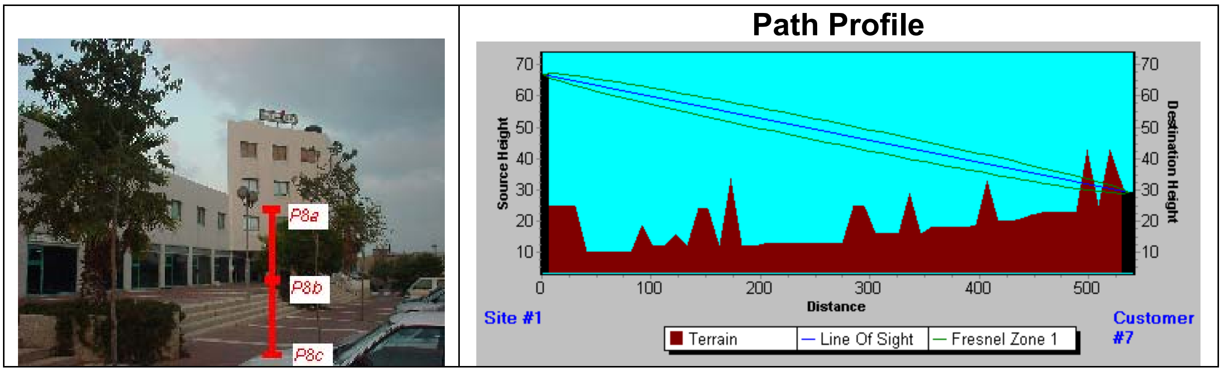


Figure 8: Tel-Aviv – SU site no. 4

Beijing, China

The Base station had been positioned on the roof of a 26-floor building as depicted in figure 9. The SUs were located in 3 sites, positioned from 1km up to 2.5 km from the AU, and with various conditions of LOS: 2 sites with 0% LOS and 1 with ~20% LOS. The SU outdoor unit was installed on a tripod approximately 1.5 meters above the ground, facing diverse obstacles. Each site was tested for performance using FTP and Video application.

Figure 9: Beijing - View from the base station building

Site 1:

The first site was located about 1 KM from the base station, with a completely blocked LOS. A large, 5-floors building, about 70 meters from the SU, was completely blocking LOS to the base station as depicted in figure 10. The ODU was pointed at another building, adjacent to the obstacle, in order to receive the signal. Link was successfully established with performance of 9.8Mbps FTP traffic and very good video quality.

Figure 10: Beijing - SU site no.1

Site 2:

The second site was located 2.5 KM from the base station, with 20% LOS. High power line, in addition to a large group of trees, were located in front of the SU, which was actually positioned under a tree, where branches obstructed LOS. Link was successfully established with performance of 13.6Mbps FTP traffic and very good video quality.

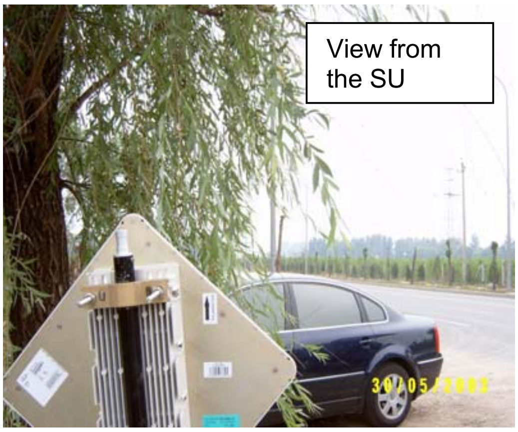


Figure 11: Beijing - SU site no. 2

Site 3:
The third site was located 2.5 KM from the base station, with a completely blocked LOS. High trees were completely blocking LOS as depicted in figure 12. Link was successfully established with performance of 10.5Mbps FTP traffic and very good video quality.

Figure 12: Beijing - SU site no. 3

Pennsylvania, USA

The Base Station was installed on a tower, while the SU was positioned on a car using pole height of 1.60 meters. The SUs were located in various distances from the AU - 5.5km up to 7.7 km.

Site 1:
The first site was located about 5.8 km from the base station, with an obstructed LOS. The link was successfully established with performance of 12Mbps FTP traffic.

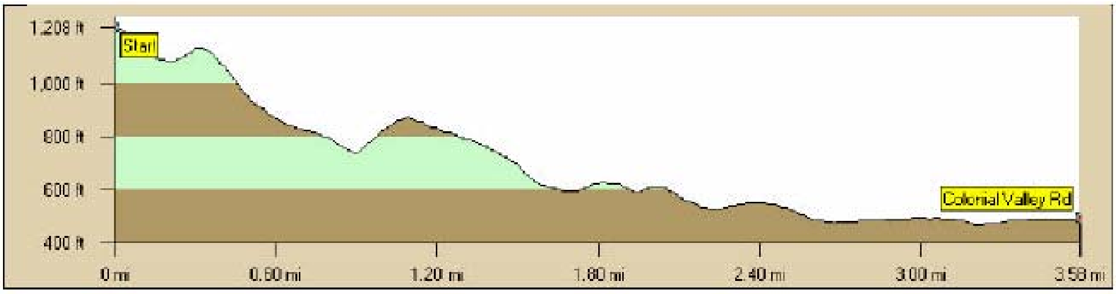


Figure 13: Pennsylvania – site no. 1

Site 2:
The second site was located 7.7 km from the base station, with an obstructed LOS. The link was successfully established with performance of 13Mbps FTP traffic.

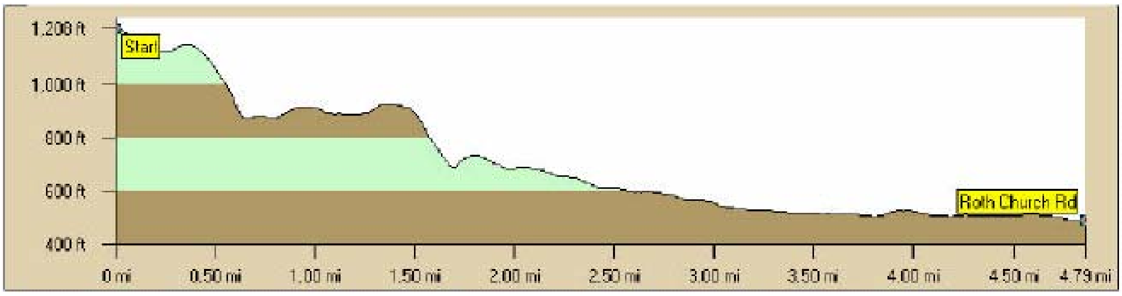


Figure 14: Pennsylvania – site no. 2

Site 3:
The second site was located 6.2 km from the base station, with a completely blocked LOS. The link was successfully established with performance of 5Mbps FTP traffic.

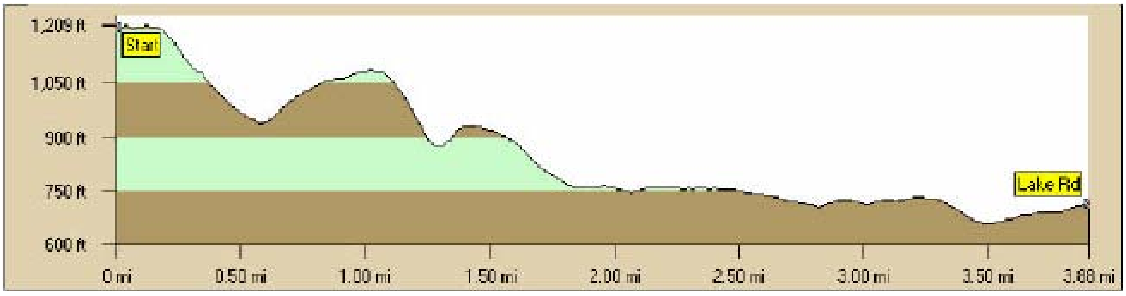


Figure 15: Pennsylvania – site no. 1

Dublin, Ireland

The CPE was located 8.8 km from the base station, separated by a high mountain, completely blocking LOS, as depicted in Figure 16. The link was successfully established with performance of 7Mbps FTP traffic!!!

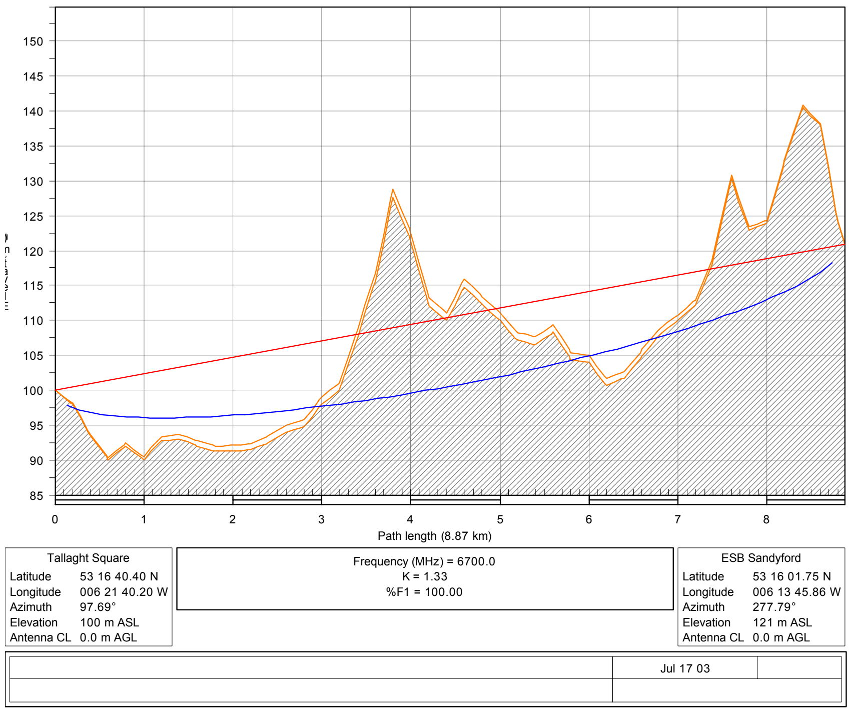


Figure 16: Dublin

Field trials conclusions

The experience from trials and Beta installations show that communication distances of 6-7 km are achievable in obstructed and even on non-LOS scenarios, depending on the topography. Aligning the antenna was the service activation was quick and straight forward using the SNR LED bar. In several cases, it was observed that the best direction for the SU was not towards the base station, but towards a reflecting object. This usually was observed at shorter distances, and with more severely obstructed LOS.

During all the experiments the adaptive modulation mechanism was activated. In all cases the data rates were adapted by the adaptive mechanism and were commensurate with the SNR. This is an indication that the parameters of the OFDM system are well adapted to the multipath environment and that no further degradation is experienced due to multipath.

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