

# OS-Gemini Non-Line-of-Sight Operation

Orthogon Systems

Ref: N.J.R King  
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## 1 INTRODUCTION

Only 14% of properties that are 500 meters apart have an optical Line-of-Sight (LOS) path between their roofs. At higher ranges and in low-rise rural environments this percentage is even lower. These factors are leading to an increasing demand for Non-Line-of-Sight (NLOS) wireless Ethernet bridges. The cost and delay of non-wireless methods of connection are very high and there is increasing interest in unlicensed bands where the speed of connection can be measured in hours rather than months.

Many products have been coming onto the market that claim NLOS operation (in the 2.4 and 5.8 GHz frequency bands) when in fact only one or perhaps two of the required features have been included. The actual requirement is for a comprehensive range of features to deliver full NLOS performance. This white paper describes issues affecting NLOS application performance and the features required to fully address them.

The radio applications that are enabled by this performance are described in Section 4. The network applications are described in Section 5.

The figures in this white paper apply to the USA.

## 2 WHY 5.8 GHZ IS THE OPTIMUM TECHNOLOGY

There are various methods of connecting buildings together, which include:

- Leased line
- Trenching or overhanging wires
- Licensed Point-to-Point (PTP)
- Unlicensed PTP
- Optical PTP

Of these, the lowest overall cost is usually the unlicensed point-to-point link. That is because the cost of equipment is generally lower. If, however, the equipment does not have sufficient ability to connect directly between the two buildings, then the link must go via an intermediate point. In this case, there will be additional equipment, rental and maintenance costs. There will also be reduced reliability and security, and increased into-service time.

It is highly desirable to have a direct link in an unlicensed band, removing the need for spectrum license fees. 5.8 GHz is the lowest frequency that fulfills the requirements of bandwidth availability and yet is not overused by other services. 5.8 GHz regulations also allow sufficient link budget to diffract around large obstacles.

*Table 1* (next page) shows the losses associated with certain obstacles in various environments. As can be seen, these losses are much greater for infrared and W-band radio than they are for 5.8 GHz radio. The cost of generating power at these higher frequencies is also greater and thus the way in which they have been made to work over long ranges is to restrict the beam-width of the radiators. This narrowing of the width brings problems in the stability of the mounting point. Laser devices often need to be self-adjusting for the movement of tall buildings in the wind.

### 3 NLOS RADIO PROPAGATION REQUIREMENTS

There are a number of requirements for a radio system that is intended to operate in a non-line-of-sight manner. These are:

- Sufficient power budget
- Demodulator with sufficient dispersion mitigation
- Fading mitigation
- Adaptive link characteristics

Obstacle	Infrared light (765nm)	W-band radio (60 GHz)	5.8 GHz radio
Clear, still air	-1 dB/km	-15 dB/km	-0.1 dB/km
Scintillation	0 to -3 dB/km	0 dB/km	0 dB/km
Birds or foliage	Impenetrable	0 to -20 dB/km	0 to -2 dB/km
Window (double-glazed)	-3 dB/km	-1 dB/km	-0.5 dB/km
Light mist (visibility 400m)	-25 dB/km	-1 dB/km	0 dB/km
Medium fog (visibility 100m)	-120 dB/km	-1 dB/km	0 dB/km
Light rain (25mm/hour)	-10 dB/km	-10 dB/km	0 dB/km
Heavy rain (150mm/hour)	-25 dB/km	-40 dB/km	-1 dB/km

Table 1: Typical signal losses depend on the environment.

**Power Budget** In Orthogon Systems' case, creating sufficient power budget involves transmitting as much power as the regulations in any particular country allow (of course there is also Transmit Power control to ensure that unnecessary power is not transmitted). On the receive side, the budget is optimized by large antenna gain, low noise figure and low system loss (relative to Shannon).

**Dispersion** Dispersion in the type of NLOS channels that are being used can be as much as 5  $\mu$ s. Equalizing a 10MHz bandwidth channel with this much dispersion can be a challenge for single-carrier systems. Orthogon Systems uses a variety of Orthogonal Frequency Division Modulation (OFDM), which has equalization pilots giving the exact dispersion characteristics. This, in conjunction with forward error correction in the frequency domain, ensures perfect demodulation in any channel.

**Fading** In non-line-of-sight paths, multipath fading is significantly accentuated. Extensive testing has shown that the graph in Figure 1 applies. Using multi-beam space time coding, Orthogon Systems is the first vendor of 5.8 GHz products to address this problem. Figure 1 shows that, for 99.99% link availability, a conventional system requires 40 dB fade margin for NLOS paths. With space time coding, this requirement is reduced to just 10 dB, giving a performance benefit of 30dB. Another way of viewing this, is given that only 10 dB is available for fade margin, a conventional system-deployed NLOS will only achieve 90% link availability while the Orthogon space time coded system would achieve 99.99% link availability.

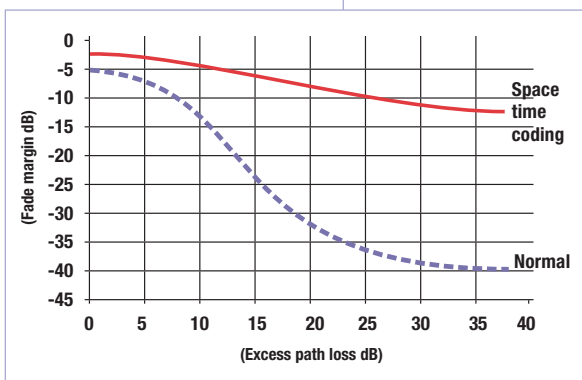


Figure 1: Conventional systems require a 40dB fade margin to operate successfully in paths that require only 10dB fade margin for multi-beam space time coding.

Fade rates are variable by path, and depend upon the movement of objects in and around the path. Trees are often the dominant source of fast fading and when the wind is high the fade rate bandwidth can be up to 4 Hz. In still conditions, the path loss through trees becomes stationary at any random point in the fade cycle. Urban paths above tree level often exhibit very slow fading and it becomes very difficult to determine the effective mean signal level (and thus the fade margin required) for the site being installed at the time of installation.

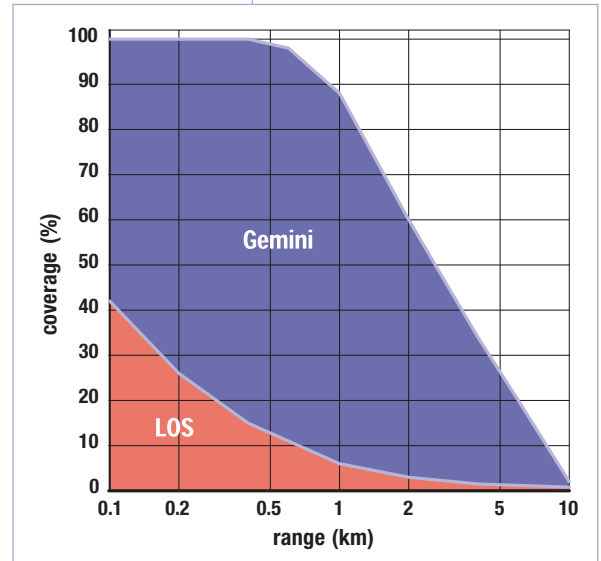
**Adaptive Modulation** Adaptive modulation, often used to increase the capacity of Point to Multipoint systems, is also applicable to PTP systems. In this technique, the radio modulation and bandwidth can be modified according to the signal level received. Since the channel often varies in intensity on a sub-second basis, transmitting the maximum amount of data possible means that such a system must be rapidly optimizing itself to the channel conditions. The effect is to increase the data rate capability and to improve the reliability of the system.

## 4 APPLICATION DATA

The result of applying this design method is that Orthogon Systems is able to increase by a very large percentage the probability of being able to install and operate a link. To give some concrete examples, Orthogon Systems has used the ATDI ICS Telecom tool to survey Paris and generate average probabilities of connecting two typical buildings in an urban environment. For illustration, the coverage around some common obstacles is also presented: propagation around a building, propagation over a hill and propagation through trees.

All of the following results have been confirmed by trials of the equipment apart from the statistical nature of the heights of equipment in the Paris model.

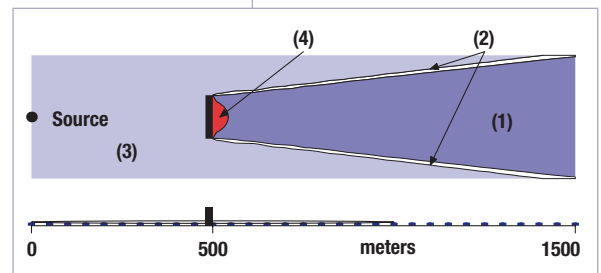
**Detailed Survey of Paris** In the detailed survey of the center of Paris a Digital Elevation Model (DEM) with 4-meter resolution was used to position 9000 PTP links. The propagation was taken from the highest point in a 10-meter radius around the property entrance. The probability of LOS or NLOS coverage was then computed, as shown in *Figure 2*.



*Figure 2: Over a range of up to 10 km in an urban setting (Paris), Gemini greatly increases the probability of signal coverage.*

This figure shows that the probability of connecting a device that is capable of reliable NLOS operation is substantially more than a device that only has LOS capability. The ATDI tool used for this analysis used P.526-7 for the detailed propagation model.

**Propagation Around a Building** *Figure 3* shows the coverage behind a substantial building. The deployment is in a flat area with the normal two-story building height of 8 meters upon which the normal installations must take place. There is an “office block” standing 37 meters high and 120 meters wide. The office block represents a 12-story building in this case. In the lower part of the figure, this stands well above the Fresnel zone. The PTP links are installed on the two 2-story buildings, two meters above the roof.

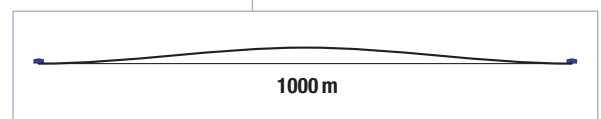


*Figure 3: Gemini greatly increases the coverage area behind a large building.*

Coverage in the shadow of the building is displayed with the dark blue area (1) showing where the normal data rate is typically at maximum with occasional deviations down to the lowest data rate in moments of extreme fading. The white area (2) is where the OS-Gemini always works at the maximum data rate. The pale blue area (3) is where an LOS system can be deployed.

The area of red (4) where the OS-Gemini system cannot be installed (without mounting a relay station) is very small and is in the immediate shadow of the building.

**Propagation over a Hill** In the case of hills, the propagation depends very much upon the shape of the hill being traversed. Reference [1] (see page 4) shows that the hill drawn in *Figure 4* can only be 18 meters high. In practice this is a worst case because any roughness in the path improves the propagation. Buildings that can be seen by both parties improve the propagation further.



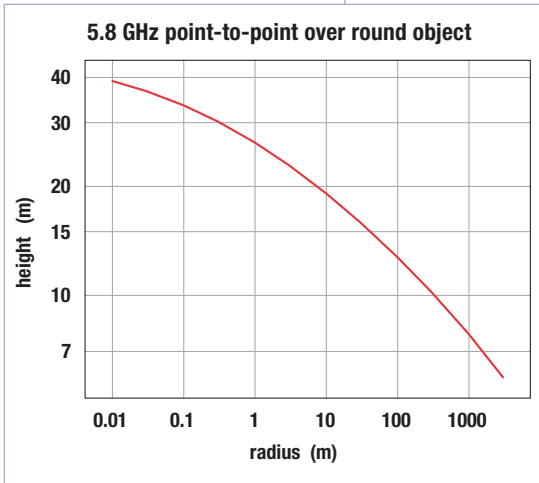
*Figure 4: In the worst-case scenario, a hill only 18 meters high can block successful signal propagation (shown here between two points 1000 meters apart).*

System performance in this area will mostly be at the full data rate with occasional fades into the lower data rate. This is similar to the performance in the dark blue area of *Figure 3*.

*Figure 5* shows the maximum height of a smooth hill with a given radius above the optical line-of-sight path of 1 km. Rough hills should normally give better propagation.

**Propagation Through Trees** There is a high degree of variability in the loss associated with trees. The loss varies with the size, thickness, type and wetness and there is an annual component with the cycling of the leaves. Trees are also a very common obstruction in provincial and rural settings. In the case of a single tree, which can be traversed at a loss of about 25 dB, this means that the range is restricted to 8 km if a single tree is the multipoint obstruction.

## 5 NETWORK APPLICATIONS



**Figure 5: A combination of height and size determines an object's impact on propagation success.**

None of the foregoing radio performance would be any use without providing for network applications. The OS-Gemini provides up to 23 Mbps aggregate data rate as an Ethernet bridge. Under particularly stressful radio conditions, this may drop to 2.5 Mbps. Typically this will be used to connect together two Ethernet LANs. The device is so inexpensive that it can be efficiently used as a backup for leased line or optical links. If very high reliability is required, one can use two links in parallel with the additional advantage of 28 Mbps aggregate data rate. Further applications include:

- Upgrades to existing analogue or slower digital links
- Very long distance wireless links via staging points giving 40 km or more range
- Backhaul for mobile cellular networks

## 6 ABOUT ORTHOGON SYSTEMS

Founded in 2000 and based in the United Kingdom, the Orthogon Systems team members are pioneers in the development of advanced radio techniques.

Reference: [1] (2002). RECOMMENDATION ITU-R P.526-7 - Propagation by diffraction. Recommendation P.526, International Telecommunications Union.

### HEADQUARTERS

Orthogon Systems  
Unit A1, Linhay Business Park  
Eastern Road, Ashburton  
Devon, TQ13 7UP, UK

tel +44 (0)1364 655500

fax +44 (0)1364 654625

### USA OFFICE

Orthogon Systems LLC  
890 Winter Street, Suite 320  
Waltham, MA 02451

toll-free 877 515 0400

[www.orthogonsystems.com](http://www.orthogonsystems.com)

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