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The Benefits of 60 GHz Unlicensed Wireless Communications

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Introduction

In 2001, the Federal Communications Commission (FCC) set aside a continuous block of 7 gigahertz (GHz) of spectrum between 57 and 64 GHz for wireless communications. A major factor in this allocation with commercial ramifications is that the spectrum is “unlicensed” – in other words, an operator does not have to buy a license from the FCC before operating equipment in that spectrum. The licensing process typically is very expensive and time-consuming. Up until then, less than 0.3 GHz of bandwidth had been made available at lower frequency bands for unlicensed communications. See Figure 1.

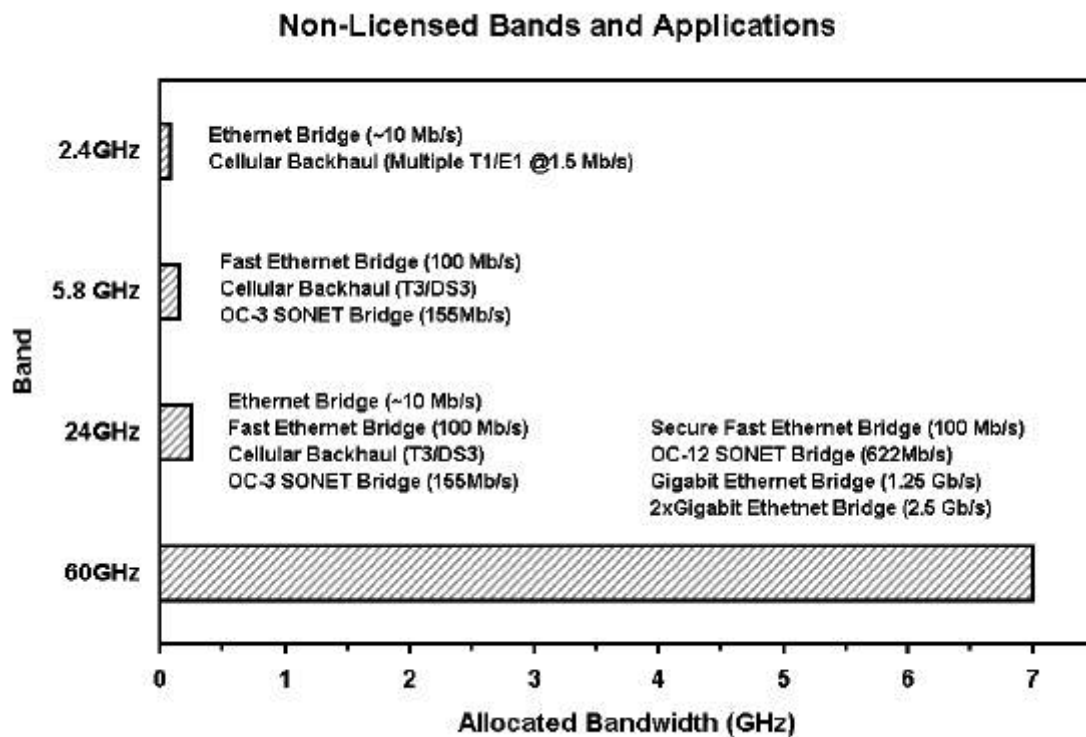


Figure 1 - Non-Licensed Bands and Typical Applications

The 57-64 GHz band is located in the *millimeter-wave* portion of the electromagnetic spectrum, where the wavelength varies from ten millimeters (30 GHz) down to one millimeter (300 GHz). The millimeter-wave portion of the RF spectrum has been largely unexploited for commercial wireless applications. That is now changing. YDI Wireless has used its well-established expertise in millimeter-wave products and technologies to develop wireless products operating in that spectrum that enable two-way wireless communications at data rates that previously could only be accomplished with fiber optic cable.

In addition to the high-data rates that can be accomplished in this spectrum, energy propagation in the 60 GHz band has unique characteristics that make possible many other benefits such as excellent immunity to interference, high security, and frequency re-use. In this paper, we will discuss in detail the benefits of wireless communications in the 57 to 64 GHz band.

Oxygen Absorption

Point-to-point wireless systems operating at 60 GHz have been used for many years by the intelligence community for high security communications and by the military for satellite-to-satellite communications. Their interest in this frequency band stems from a phenomenon of nature: the oxygen molecule (O_2) absorbs electromagnetic energy at 60 GHz like a piece of food in a microwave oven (see Figure 2). This absorption occurs to a much higher degree at 60 GHz than at lower frequencies typically used for wireless communications. This absorption weakens (attenuates) 60 GHz signals over distance, so that signals cannot travel far beyond their intended recipient. For this reason, 60 GHz is an excellent choice for covert satellite-to-satellite communications because the earth's atmosphere acts like a shield preventing earth-based eavesdropping. Because of the rich legacy of applications in this band, a wide variety of components and subassemblies for 60 GHz products are available today.

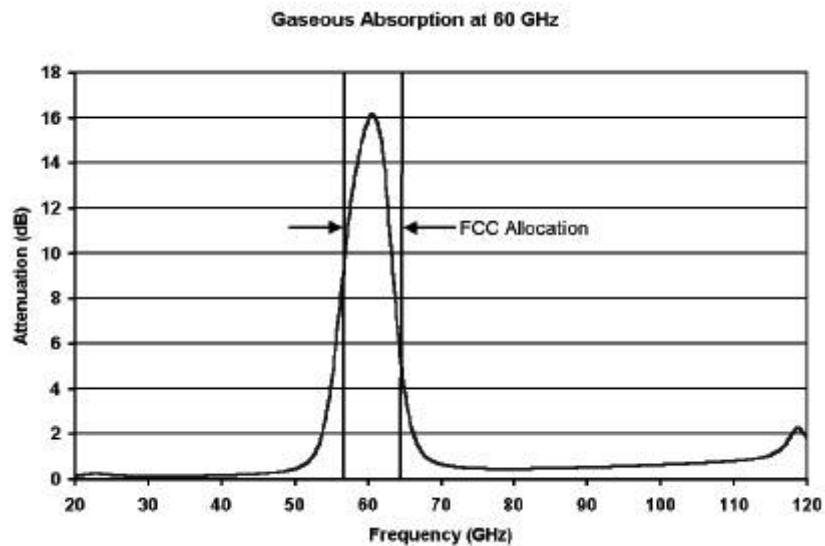


Figure 2 – O_2 attenuation versus frequency

Another consequence of O₂ absorption is that radiation from one particular 60 GHz radio link is quickly reduced to a level that will not interfere with other 60 GHz links operating in the same geographic vicinity. This reduction enables higher “frequency reuse” – the ability for more 60 GHz links to operate in the same geographic area than links with longer ranges. As an example, let’s compare two different links, one operating near 60 GHz and the other at a frequency that is less affected by O₂ absorption. The second link could be operating at another unlicensed frequency such as 2.4 GHz or 24 GHz. Consider a typical operating scenario where both links are operating over a distance of one kilometer with the transmitter’s power output adjusted such that the signal level at the receiver is 30 decibels (dB) above the background noise. Figure 3 shows how the signal level drops with distance beyond the receiver in the two cases. For the link unaffected by O₂ absorption, it takes 32 kilometers (km) for the transmitted signal to drop down to the background noise level. In other words, that signal would interfere with any other signal at that same frequency for more than 30 kilometers beyond its original recipient. That reduces the number of links at that frequency that can be installed in a fairly large area. Also, this means that the lower-frequency signal could be intercepted up to more than 30 kilometers beyond its intended recipient. In contrast, the transmitted signal at 60 GHz drops down to the noise level in a mere 2.5 km. Consequently, more 60 GHz links can be used in the same area without worrying about interference. Also, the 60 GHz links are far more secure given their limited range.

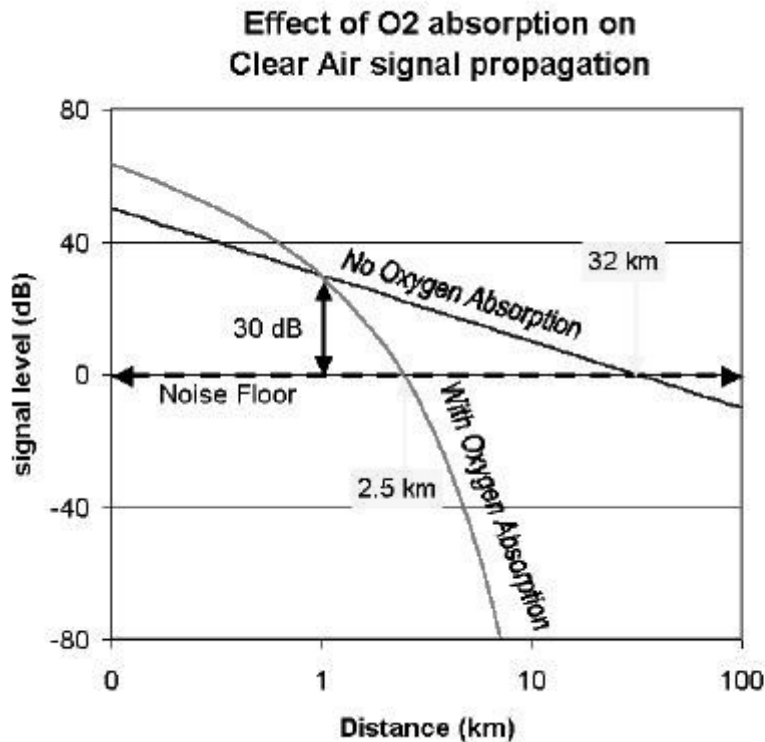


Figure 3 – Radiation Limiting by O₂ Absorption

Antenna Focus

Directivity is a measure of how well an antenna focuses its energy in an intended direction. Point-to-point radios should have highly directional antennas as the goal is to connect to end points of a link. Ideally, all the transmitted energy is directed just at the intended recipient. Highly focused antennas minimize the possibility of interference between links in the same geographic area, minimize the risk that the transmission will be intercepted, and maximize performance.

Operating at higher frequencies inherently results in a more focused antenna. Antenna directivity is limited by the physical principle of *diffraction* that states that the beam width is inversely proportional to the operating frequency. Therefore at 60 GHz, the beam width is far narrower than at the lower frequency unlicensed bands. Table 1 shows the beam width for several unlicensed frequency bands. These results are shown graphically in the next section.

Frequency	99.9% Beam Width
2.4 GHz	117 degrees
24 GHz	12 degrees
60 GHz	4.7 degrees

Table 1 – Beam Width for Several Unlicensed Frequency Bands
For 1-foot diameter antennas

Radiation Limiting at 60 GHz

The combined effects of O₂ absorption and narrow beam spread result in high security, high frequency re-use, and low interference for 60 GHz links. Figure 4 shows two buildings that are 1 km apart. The wedges show the radiation pattern from 2.4, 24 and 60 GHz links operating with the same performance at 1 km. The links have equivalent 1-foot diameter antennas. The three wedges show the locations where the radiation at each frequency remains high. The largest wedge represents the radiation pattern from a 2.4 GHz link. The 60 GHz link has the narrowest and shortest wedge and can be barely be seen except in the blow-up. The wedges for 2.4 and 24 GHz links are substantially larger than the 60 GHz link, even though their operational link distance is the same (1 km).

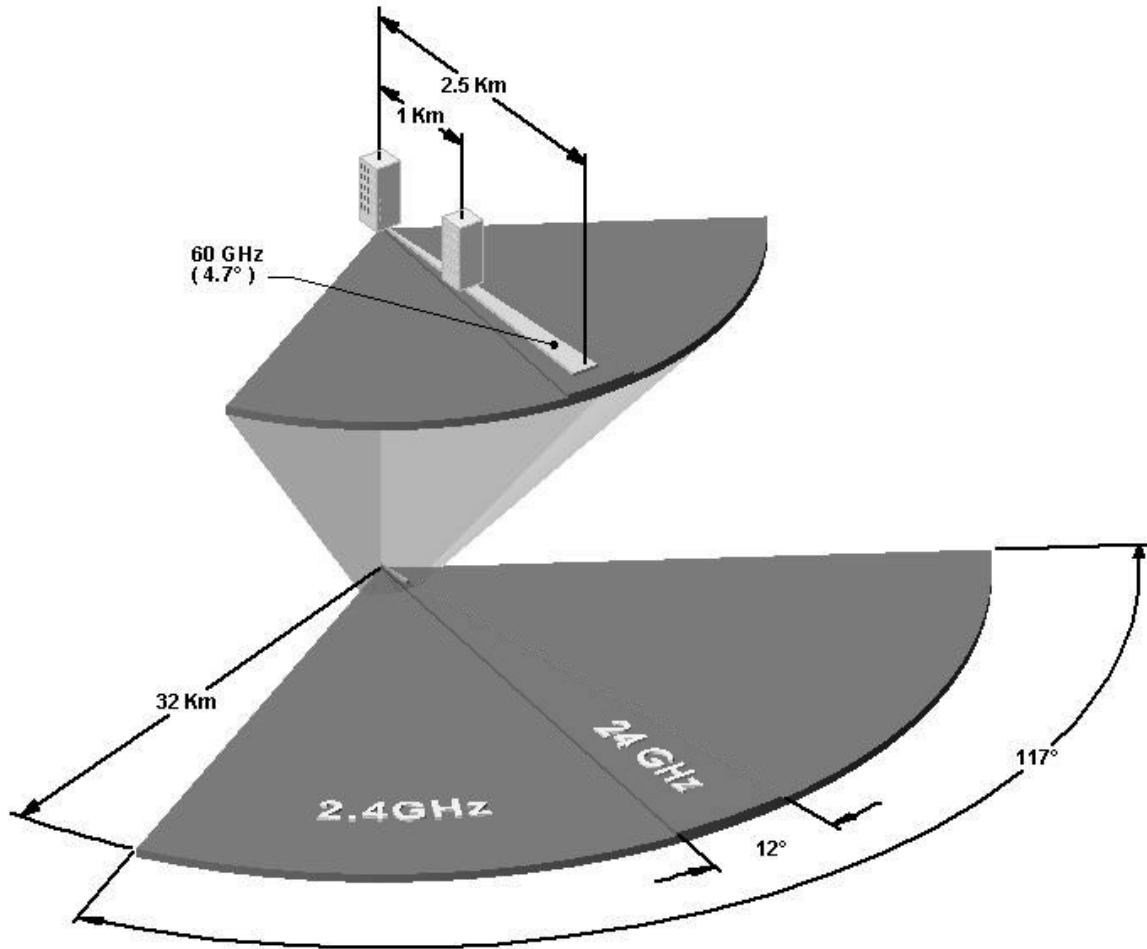


Figure 4 – Radiation maps for 2.4, 24 and 60 GHz Links.

The practical implications of these graphics are obvious. A 60 GHz link can only be intercepted in the tiny wedge and will only interfere with another 60 GHz link in that wedge. A 24 GHz link has interference and interception risks over a much longer and somewhat broader wedge, while a 2.4 GHz link has interference and interception risks over a very large area, both in distance and in breadth.

O₂ versus Rain

But, a potential user might ask, doesn't O₂ absorption limit the maximum link range? The short answer is that it does, with the resulting benefits described above. However, link distances of millimeter-wave radios operating in the real world are limited primarily by rain. Users of these products typically want the links to provide robust communication capability, such as the "five nines" of availability demanded by most carriers. In this application, the rainfall rates where the product is used will typically be more of a limiting factor than O₂ absorption.

60 GHz radio links are engineered to overcome the effects of rain attenuation. To simplify, the maximum operating link distance is a function of level of availability desired (for example, 99.999% or 99.99%) and rainfall rates in the geographic area of intended use. Again to simplify, link distance increases as level of availability and rainfall rates decrease. Rainfall statistics are so well known for locations around the globe that range and availability can be accurately predicted. Figure 5 shows the attenuation due to rain (solid line) compared to O₂ absorption (dashed line).

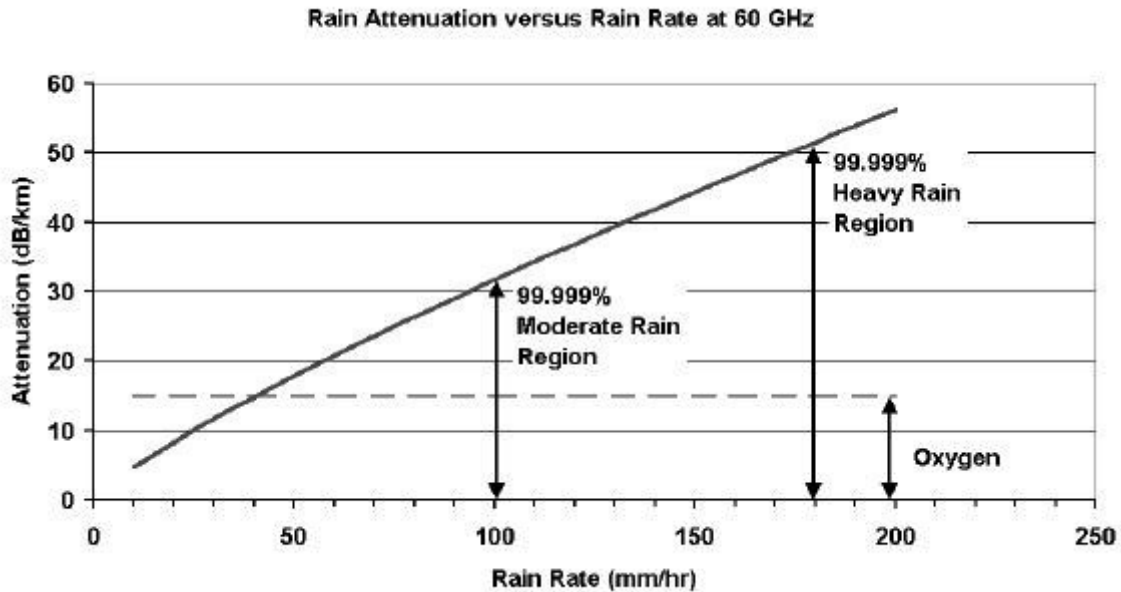


Figure 5 – Attenuation versus Rain Rate

In moderate rain regions, the rain attenuation is about twice the oxygen attenuation, and in heavy rain regions, the rain attenuation is more than three times the oxygen attenuation. Therefore, in designing a 60 GHz link to provide robust communication capability in the real world, rain attenuation is a larger factor than oxygen absorption.

So, this combination of oxygen absorption and robust engineering enables 60 GHz links to provide the best of both worlds. The oxygen absorption limits the distance of a transmission in providing for security and frequency re-use even in the best weather. Engineering for rain attenuation enables carrier-class service even in the worst weather conditions.

Conclusions

The 60 GHz band is an excellent choice for high-speed Internet, data, and voice communications offering the following key benefits:

- Unlicensed operation – no need to spend significant time and money to obtain a license from FCC
- Highly secure operation – resulting from short transmission distances due to oxygen absorption and narrow antenna beam width
- Virtually interference-free operation – resulting from short transmission distances due to oxygen absorption, narrow antenna beam width, and limited use of 60 GHz spectrum
- High level of frequency re-use enabled – communication needs of multiple customers within a small geographic region can be satisfied
- Fiber optic data transmission speeds possible – 7 GHz of continuous bandwidth available compared to <0.3 GHz at the other unlicensed bands
- Mature technology – long history of this spectrum being used for secure communications
- Carrier-class communication links enabled – 60 GHz links can be engineered to deliver “five nines” of availability if desired

YDI Wireless has 60 GHz FCC approved products available *now* for Gigabit Ethernet and OC-3/OC-12 SONET connections. For information on the product line, visit:

<http://www.ydi.com/products/fiberleap.php>