

Performance Characteristics of 60-GHz Communication Systems

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TERABEAM[®]

The Shift in Wireless Communication

Since the viability of long-haul radio-frequency wireless communication was demonstrated over 100 years ago, the use of radio waves to broadcast information over long distances has become quite common, as evidenced by the proliferation of satellites orbiting the earth and the number of microwave dishes and broadcast towers that dot the landscape. Despite this rapid growth, however, available radio-frequency spectrum was limited, and the ever-increasing demand for bandwidth (i.e., increased data throughput) led the push to develop more sophisticated equipment. As a result, satellite- and land-based microwave systems were replaced by fiber; and for a time, the continued expansion of the physical fiber backbone seemed to provide the ideal solution to replace inadequate long-haul microwave segments.

Today, most large cities have installed fiber trunks that are capable of transporting large amounts of digital voice, video, and data traffic, but this infrastructure seldom supports a broadband connection to the end user. The reasons are varied. Installation is costly, lead-times are significant, and the necessary right of way is often unavailable – issues collectively referred to as the last-mile problem. As a result, the past few years have witnessed another shift in wireless communication and the emergence of a number of wireless point-to-point technologies that offer fiber data rates and can support dense deployment architectures. These new technologies can generally be characterized as satisfying the following set of new criteria:

- Short links
- High data rates
- Low cost
- High densities
- High security
- Low transmit power
- Small profile

Terabeam Corporation develops and manufactures two wireless communication systems that meet the above criteria: the Elliptica™, a free-space optics (FSO) communication system; and the Gigalink™, a millimeter wave (MMW) communication system. These technologies use the infrared and millimeter portions of the electromagnetic spectrum, respectively, to provide point-to-point, line-of-sight connectivity. Both FSO and MMW have specific strengths and weaknesses that define their appropriateness for a given application. This document focuses on MMW systems.

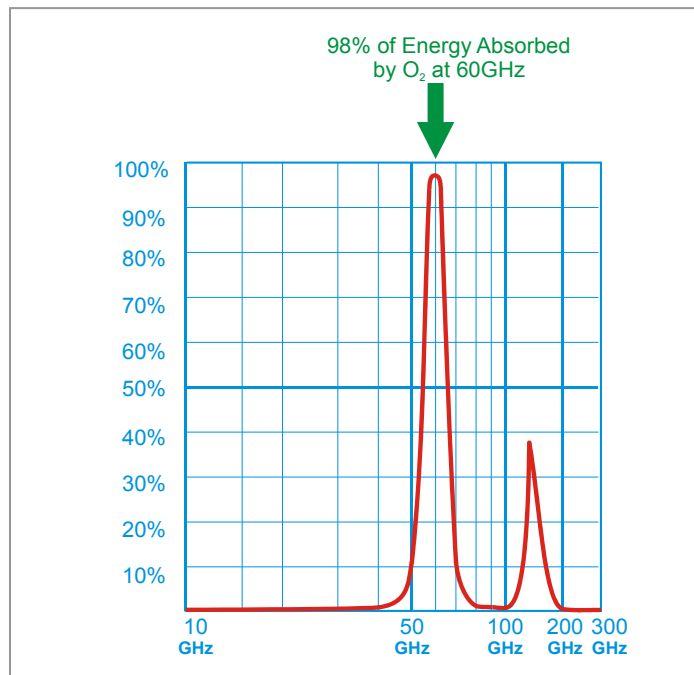
The Rediscovery of the Radio Wave

Traditionally, wireless telecommunication services have been confined to regulated spectrum allocations in the range of 2 to 30 GHz. Frequency “slices” within this range, typically around 50 MHz wide, were adequate for data transmission capacities of up to 155 Mbps. However, the exploding demand for bandwidth combined with the limitations of the fiber-based data transport backbone has demonstrated the inadequacy of the traditional microwave frequency allocations. Given the scarcity of the available unlicensed spectrum and the need for interference-free channel separation, the wireless industry began to focus on higher, previously unallocated portions of the spectrum. The MMW frequency region, from 30 GHz to 300 GHz, became the logical solution to meet this need.

Radio Interference and the Benefits of Atmospheric Absorption

The 60-GHz MMW region of the electromagnetic spectrum is characterized by high levels of atmospheric radio frequency (RF) energy absorption. This means that transmitted energy is quickly absorbed by oxygen molecules in the atmosphere over long distances. The atmospheric absorption for MMW frequencies is shown in Figure 1.

Figure 1
**Atmospheric
Absorption for
Millimeter Wave
Frequencies
over a 1-km Path**

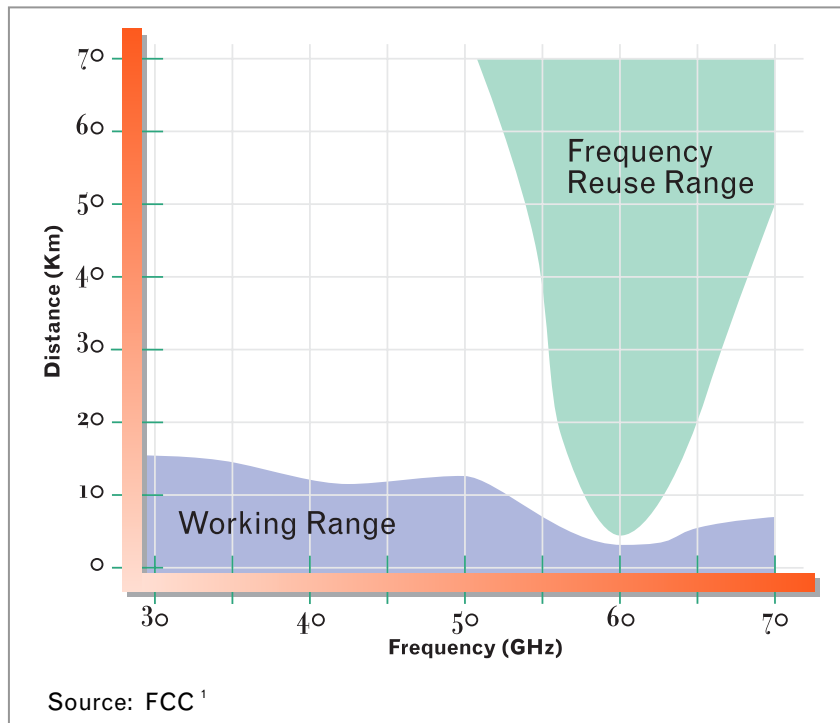


In the past, these high levels of atmospheric absorption and the resulting range limitations were viewed as rendering MMW technologies unsuitable for long-haul wireless applications. However, the newly identified criteria – including the need for short-distance transmission and high-security transmission paths – make MMW technologies, and 60-GHz MMW systems in particular, an ideal solution to the last-mile problem.

Frequency Reuse

In addition, the 60-GHz wavelength allows for the ability to reuse the same frequency in a localized region of air space, as shown in Figure 2. Therefore, operation in the 60-GHz MMW region of the electromagnetic spectrum makes it possible to deploy numerous radio terminals that operate on the same frequency in very dense configurations, while virtually eliminating the probability of interference, all within a 1.2-km link range – thus satisfying another of the new criteria.

Figure 2
Frequency
Reuse

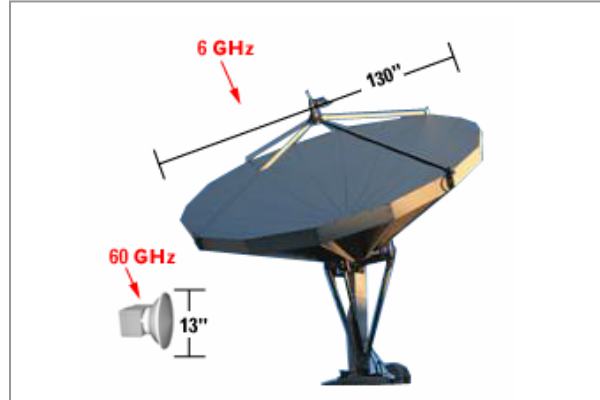


Wavelength and Antenna Size

Another benefit of the MMW frequency is the fundamental relationship between signal wavelength and antenna size. To overcome the effects of atmospheric absorption and maintain reliability, radio links in the MMW region must use highly focused, or higher-gain, antennas in order to focus as much of the transmitted signal as possible onto the receiving antenna. As RF frequency increases, signal wavelength becomes shorter, making it possible for smaller antennas to produce the required gain. The benefit of the relationship between wavelength and antenna size is clearly illustrated in Figure 3. The antenna size necessary for an MMW terminal with 40-dBi gain and a 1.0° beam is one-tenth the size of a 6-GHz microwave antenna with the same capability. Thus, at 60 GHz, a very compact, low-cost antenna can achieve a highly focused beam.

¹ Federal Communications Commission (FCC). 1997. Millimeter Wave Propagation: Spectrum Management Implications. Bulletin No. 70. Office of Engineering and Technology, New Technology Development Division. July 1997.

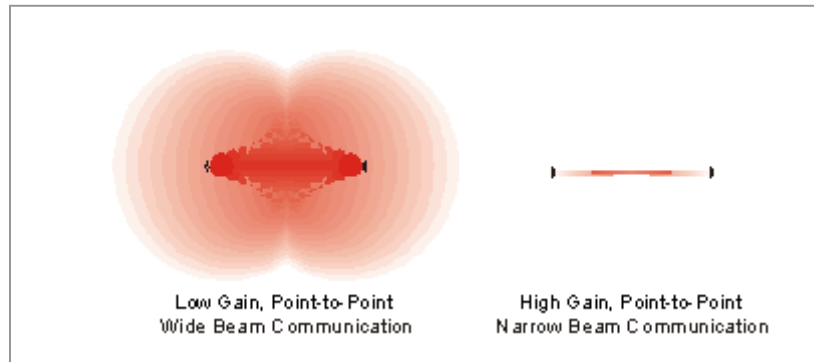
Figure 3
**Comparison of
Microwave and
Millimeter Wave
Antennas**



Interference Immunity

Emissions from an MMW system with a high-gain/narrow beam antenna occupy a minimum of the surrounding air space, as shown in Figure 4. A signal transmitted with a narrow beam is less likely to interfere with unintended receivers. Conversely, a high-gain/narrow-beam antenna will only receive energy from the same direction in which it is transmitting, thus reducing the probability of receiving an unwanted signal.

Figure 4
**Space Occupied
by Emissions
from Low-Gain
and High-Gain
Antennas**



Two-dimensional statistical modeling of randomly placed terminals has been performed. It shows that by using narrow-beam antennas, Terabeam can deploy two to three times as many randomly installed MMW terminals on the same frequency without interference from each other as compared to lower-gain antennas.

Safety

Terabeam's 60-GHz MMW systems are among the safest RF communication systems ever designed. Due to their combination of low power emissions and high operation frequency, the Gigalink can be safely installed in any location.

The Gigalink is certified as a FCC Part 15 device, placing it in the same category as controllers for garage door openers. Under this certification, the Gigalink is allowed to transmit a maximum average power of $9 \mu\text{W}/\text{cm}^2$. This threshold represents less than 1 percent of the power limits established by standards organizations and the federal government for the general public's safe exposure to 60 GHz and similar radio systems.

In addition to the very low power levels discussed above, 60 GHz systems do not penetrate the human body. High-frequency emissions such as 60 GHz are absorbed by the moisture in the human body and are thereby prevented from penetrating beyond the outer layers of the skin. As a result, exposure to 60 GHz is very similar to the exposure to sunlight – but at 1/10,000 of the energy. Lower-frequency emissions penetrate and may even pass completely through the human body. The minimal penetration of 60-GHz energy sets it apart from the debate that currently surrounds the safety of other RF communication systems.

By way of comparison, the $1 \text{ mW}/\text{cm}^2$ energy level at 60 GHz is similar to the exposure level of a Class 1 FSO system at 1550 nm, where the limit is $2 \text{ mW}/\text{cm}^2$. Both Gigalink and Elliptica operate well below these limits and can therefore be installed in unrestricted locations.

Conclusion

Terabeam's 60-GHz MMW systems provide an excellent solution to the last-mile problem. The scientists and engineers at Terabeam have combined their expertise in MMW and signal processing technology to achieve a higher-speed radio communication system by blending traditional analog and digital technology with MMW science. This unique approach has enabled the creation of a high-speed digital wireless system that is reliable, safe, secure, and easy to deploy.