Benefits of 60 GHz

Right Frequency, Right Time

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Introduction

Radios operating in the license-free 60 GHz band have unique characteristics that make them significantly different than radios operating in the traditional 2.4 and 5 GHz license-free bands. These qualities give 60 GHz millimeter wave band radios operational advantages not found in other wireless systems.

This paper provides an overview of these advantages and why 60 GHz millimeter wave radio technology presents the optimal opportunity to achieve orders of magnitude higher link budgets than IEEE 802.11n and Ultra Wideband (UWB) systems, which translates into reliable and affordable gigabit-plus wireless connections. Specifically, this paper addresses the advantages listed below and how they translate into benefits:

- Spectral availability to achieve gigabit-plus data rates
- High allowable transmit power for solid signal strength and range
- Worldwide availability and acceptance
- License exempt operation
- Narrow beam width and oxygen absorption for interference immunity and highly secure operation

Shannon's Law Rules

Large bandwidth coupled with high allowable transmit power equals high possible data rates. For the first time, sufficient spectrum has been allocated in the 60 GHz band to make possible multi-gigabit wireless links. In 2001, the Federal Communications Commission (FCC) set aside an unprecedented continuous block of 7 GHz of license exempt spectrum between 57 ~ 64 GHz. The majority of the globe has done the same at varying points between 57 ~ 66 GHz. This compares to <0.67 GHz (~660 MHz) for all possible 802.11n channels, and an effective 1.5 GHz for UWB.

In addition to this total available spectrum, 60 GHz enjoys 2,500 MHz of spectrum per channel, also referred to as bandwidth, while UWB has just 520 MHz and 802.11n has only 40 MHz.

Partly because of oxygen's absorption characteristics at 60 GHz, various regulators across Asia, Europe, and the Americas allow for 10's to 100's of Watts of Equivalent Isotropic Radiated Power (EIRP) for wireless transmissions in this band. The wide bandwidth and high allowable transmit power enable multi-gigabit wireless transmissions.

Shannon's Law states that the maximum possible data rate is given by:

Shannon Capacity = Channel Bandwidth * log (Power/Noise).

More simply stated, the maximum possible data rate increases with increasing channel bandwidth and effective transmit power. Referring to Figure 1, 60 GHz is able to achieve 80 times the maximum possible data rate of 802.11n and 200 times that of UWB.

	Channel Bandwidth	Effective Transmit Power	Max possible data rate
UWB	520 MHz	0.4 mW	80 Mbps
802.11n	40 MHz	160 mW	1,100 Mbps
60 GHz	2,500 MHz	8,000 mW	25,000 Mbps

Figure 1

Another advantage that arises from this capacity is the fact that 60 GHz radios will require less complex modulation for lower cost system designs. For example, since 60 GHz has 2,500 MHz of bandwidth, the bps/Hz required to achieve 1 gigabit per second is only 0.4 in order while 802.11n would be required to support 25 bps/Hz. As the required bps/Hz increases, so does the difficulty and cost of the design.

Worldwide Availability and License Exempt

As previously stated, majority of the globe has allocated 7 GHz of continuous unlicensed spectrum at varying points between 57 ~ 66 GHz. Within these points, the countries have 5 GHz of continuous spectrum in common. Therefore, products that operate in this frequency will not encounter regulatory problems, country by country. A major factor, that has commercial ramifications, is that the spectrum is unlicensed. In other words, a customer does not have to buy a license from the FCC or another country agency before operating equipment in this spectrum. 60 GHz links can be deployed without expensive permits, paperwork, public notices or license fees. This makes it easier for companies to launch worldwide products requiring minimal homologation. All of these factors allow companies to maintain operational efficiencies while delivering high performance wireless products.

Interference-Free and Highly Secure

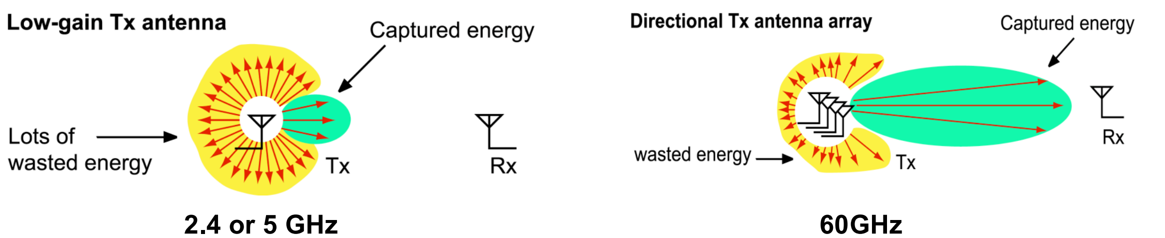
Oxygen attenuates 60 GHz signals that travel over large distances, meaning that oxygen absorbs radio emissions, a property that is unique to the 60 GHz spectrum. This absorption weakens the 60 GHz signals over distance, so that signals cannot travel far beyond their intended recipient. While this limits distances that they can cover, it also offers interference and security advantages when compared to other wireless technologies.

Another consequence of oxygen 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 vicinity. This reduction enables the ability for more 60 GHz radio-enabled devices to successfully operate within one location.

In addition, radios that operate at this frequency at this high power are typically very directional, unlike a 2.4 or 5 GHz radio, which are more omni-directional. Directivity is a measure of how well an antenna focuses its energy in an intended direction. Operating at the higher 60 GHz radio frequency results in a more focused antenna with a narrower beam width for a fixed size antenna. Narrow beam sizes make these links highly immune to interference from other 60 GHz signals. Another link in the immediate vicinity will not interfere beyond the intended target. In order to intercept the signal, one would have to locate a receiver lined up on the exact same trajectory *and* in the immediate locale of the targeted transmitter – nothing simple. These characteristics combined render the 60 GHz frequency more secure than the lower 2.4 and 5 GHz unlicensed frequency bands.

Friis' Law – Penetrates Walls

The high antenna gains typical for 60 GHz systems come in part from the Friis Equation for Path Loss. This equation, also known as Friis' Law, literally holds that as the frequency of operation changes, the effective area of any particular antenna decreases proportionately to the frequency squared. Put another way, this means that the gain possible from an antenna of any given size increases by the frequency squared. This means that an antenna with an area of one square inch will have a gain of approximately 25 dBi at 60 GHz versus a gain of approximately 3dBi at 5 GHz. This advantage is a key method by which 60 GHz or millimeter wave systems deliver much faster and higher power links than systems operating at other unlicensed bands and enables 60 GHz antennas to penetrate walls, even with associated attenuation.



With constant antenna area, max received power increases as the frequency squared!

Friis' Law: $$P_r = P_t \lambda^2 \frac{G_r G_t}{(4\pi r)^2}$$

Conclusion

The 60 GHz band is an excellent choice for wireless applications requiring gigabit-plus data rates especially considering the large bandwidth and high allowable transmit power. Out of all the currently available wireless technologies, millimeter wave brings the world closer to the promise of gigabit and multi-gigabit wireless speeds at longer range required for bandwidth intensive applications. The cost and ease of bringing this to market is minimized since the spectrum is license exempt and there are no regulatory issues that would prevent worldwide approvals.

	Spectral Availability	Channel Bandwidth	Allowable Tx Power	Max Possible Data Rate	Bit/Hz req'd to get to 1 Gbps	WW Availability
60 GHz	7 GHz	2,500 MHz	8,000 mW (39 dBm)	25,000 Mbps	0.4 bps/Hz	Y
802.11n	0.67 GHz	40 MHz	160 mW (22 dBm)	1,100 Mbps	25.0 bps/Hz	Y
UWB	1.5 GHz	520 MHz	0.4 mW (-4 dBm)	80 Mbps	2 bps/Hz	N

Figure 2

SiBEAM technologists are exploiting the unlicensed block of 57 ~ 66 GHz spectra that allows very high EIRP levels or transmit power, and are combining this with smart antenna systems to deliver high-speed wireless performance at an affordable price.