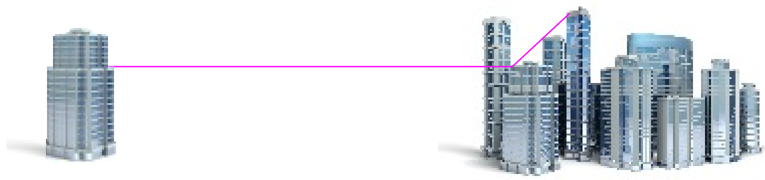

Advantages of the 60 GHz frequency band and new 60 GHz backhaul radios

White Paper

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LIGHTPOINTE™ WIRELESS

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Executive Summary

The use of the 60-GHz (V-Band) goes back to 2001, when the US regulator (FCC) adopted rules for unlicensed operations in the 57 to 64GHz band for commercial and public use. This very wide frequency band, with over a 7-GHz of continuous spectrum, makes the band very desirable for applications requiring high transmission bandwidth. Applications include indoor and outdoor point-to-point (P2P) fixed wireless bridging/backhaul. This White Paper will review technical issues and the 60 GHz regulatory background. In addition, an overview of the Lightpointe AireLink 60 system is provided.

Regulatory Background

In 2001 the US regulatory authority, the Federal Communications Commission (FCC), allocated 7 GHz in the 57-66 GHz band for unlicensed use in the United States. This unprecedented action to release a vast amount of continuous spectrum was driven by the goal to facilitate the commercialization of the millimeter wave spectrum and with the overall objective to boost the availability of spectrum for use in broadband applications. The FCC regulation 15.255, for devices operating in the 60 GHz band, initially specified EIRP up to a maximum average power level of +40dBmi. In August 2013, a ruling by the FCC extended the EIRP for outdoor use between fixed points to as much as +82dBmi, depending on antenna gain. The maximum antenna gain is specified at +51 dBi, however, the US regulation allows for a trade-off of antenna gain and conducted power.

The Canadian 60 GHz regulation, which is enforced by Industry Canada Spectrum Management and Telecommunications (IC-SMT), is harmonized with the existing US regulation.

The Australian Communications and Media Authority (ACMA) opened the frequency band from 59-63 GHz for unlicensed outdoor point-to-point operation. However, the EIRP power is restricted to a maximum of 150W (51.7 dBm).

In Europe, the European Telecommunication Standards Institute (ETSI) and the European Conference of Postal and Telecommunication (CEPT) adopted some general recommendations for operation of devices in the 57-66 GHz band. The CEPT recommendation REC (09)01, which was supplemented by ETSI EN 302 217 harmonized standard, calls for a maximum EIRP power level of +55 dBmi, but typically limits maximum conducted power to +10 dBm and the minimum antenna gain to +30dBi. This approach does not allow the trade-off of antenna gain and power in the way that the more flexible U.S. standard does.

In 2010 the UK Office of Communications (OFCOM) approved the unlicensed use of the 57...64 GHz spectrum. Although the spectrum allocation follows the FCC standard (maximum EIRP of +55 dBm), the maximum conducted power of +10 dBm and the +30 dBi minimum antenna gain is modelled after the European ETSI standard.

The European ETSI regulations provide some general guidelines with the goal to establish a harmonized standard that is binding for all member countries. However, and unlike the US for example that has a central regulatory authority, each European country has its own regulatory authority dealing with national aspects of telecommunication regulation. For the most part, this is for historic reasons, where every country had its own set of rules and spectrum allocations. As a result, the actual standards can vary from country to country and the national standards are typically a subset of the ETSI regulation. For example, many years ago Germany, Austria, and Switzerland had allocated the frequency band from 57-59 GHz for licensed operation. Consequently, this part of the ETSI allocated frequency band from 57-66 GHz is blocked and the unlicensed spectrum in these countries cover only the frequency range from 59-63 GHz. Other European countries, Slovenia for example, have even slightly different frequency allocations in the 60 GHz band. Vendors have to be aware of these differences and manufacture equipment accordingly.

In summary, the 60 GHz frequency band is open for unlicensed operation in many countries around the world, however, it is important to understand that the national frequency regulations within the 57-66 GHz frequency band can vary substantially.

Technology Background

The frequency band between 57-66 GHz, also commonly referred to as V-Band, is located in the millimeter- wave (MMW) section of the electromagnetic spectrum. It is located next to the microwave spectrum which has been used for commercial wireless deployment for decades.

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No Spectrum Shortage and High Capacity

Until recently, the 60 GHz millimeter-wave portion of the RF spectrum has been largely unexploited for commercial wireless applications. With the need for high speed connectivity growing dramatically, available microwave spectrum being used up and saturated in particular in last mile access networks, and a number of manufacturers producing MMW products, using millimeter-wave radio links has become more common. The amount of spectrum available in the millimeter-wave wave bands is by far exceeding the allocated spectrum in commonly used microwave bands and, consequently, millimeter-wave solutions can be used to dramatically increase high speed wireless connectivity in the enterprise, metro carrier, and mobile wireless backhaul market. With an unprecedented amount of spectrum available in the 60 GHz millimeter wave band, radio links exceeding GigE/GbE capacity can be implemented without using complex and very high order modulation codes that are susceptible to interference, increased latency, and require an extremely high signal-to-noise ratio (SNR) .

High Security and Interference Resistance

In addition to the high-data rates that can be accomplished in this spectrum, the 60 GHz band has some unique propagation characteristics that provides an excellent mechanism to combat interference and ensures high security. And, very importantly, the spectrum can be re-used in dense deployment scenarios.

Before commercial point-to-point radio links became an attractive option for high speed wireless communications, 60 GHz radios have been used for many years in applications requiring a highly secure communications channel, such Satellite-to-Satellite communications systems. The interest of the security/intelligence community in this frequency band was in particular triggered by the high amount of electromagnetic energy absorption in the 60 GHz transmission spectrum, caused by oxygen molecules (O2). This absorption shows as a “resonance peak” in the electromagnetic spectrum, and it is several orders of magnitude higher at 60 GHz when compared to lower microwave frequencies used for wireless communications. In Figure 1 the absorption peak is illustrated by a green vertical line. Attenuation values slightly vary with frequency, and the peak value at 60 GHz can be as high as 16 dB/km at sea level. This natural oxygen absorption attenuates the 60 GHz signals, and the longer it travels the more the signal is attenuated. In other words, and unlike with lower frequency microwave signals, the information encoded into the signal cannot travel far beyond the intended receiving station. This is the reason why 60 GHz communication is an excellent choice for covert communications as required, for example, in satellite-to-satellite communications, because the earth's atmosphere creates an "absorption shield" that prevents eavesdropping from earth based stations. This security feature also applies to terrestrial point-to-point communication links. Any "stray radiation" that is not caught by the receiving antenna is quickly absorbed by surrounding oxygen.

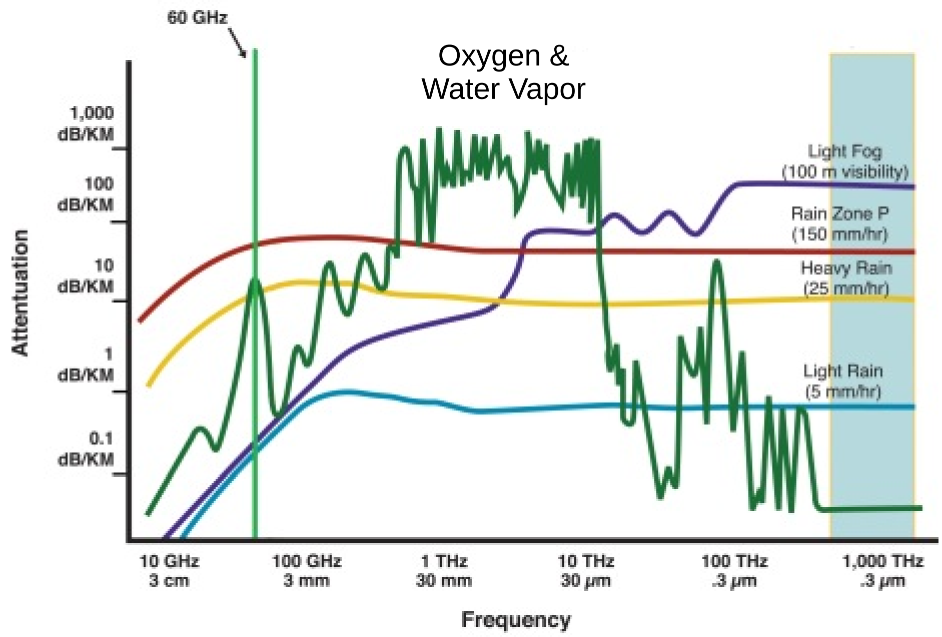


Figure 1: Atmospheric and molecular absorption at various frequencies

Ultra High Gain and Small Size Antennas

Another advantage of using high frequency transmission systems is related to the fact that the antenna gain increases with frequency and smaller, more lightweight antennas are easier to handle/install. Higher antenna gain typically translates into longer distance performance. With transmission frequency doubling, the gain quadruples for a given antenna size. It should be noted that the antenna gain impacts both the transmit power, as well as the received power at the same time. Figure 2 shows this relationship for three different antenna sizes with diameters of 15 cm (6 inches), 30 cm (12 inches), and 60 cm (24 inches), and at 60 GHz the antenna gain factors are 36 dBi, 42 dBi and 48 dBi, respectively.

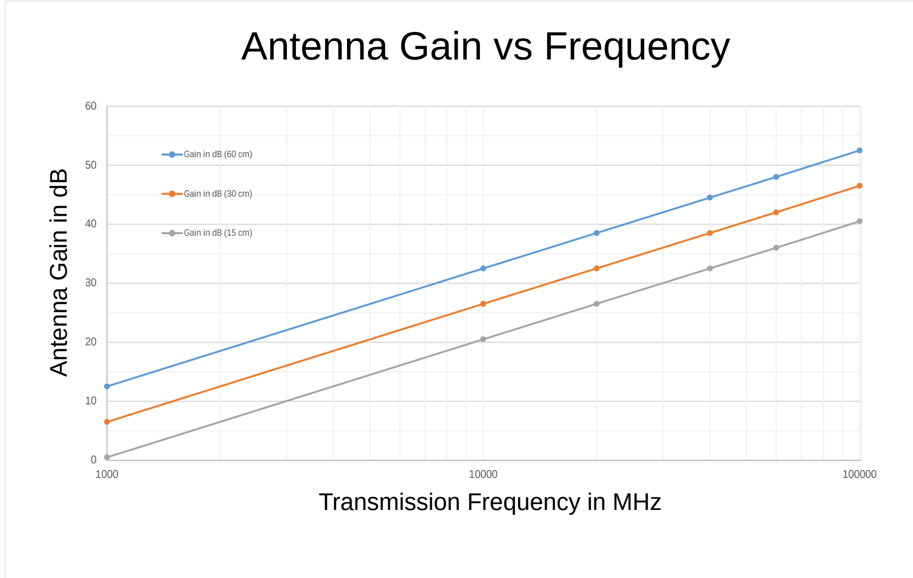
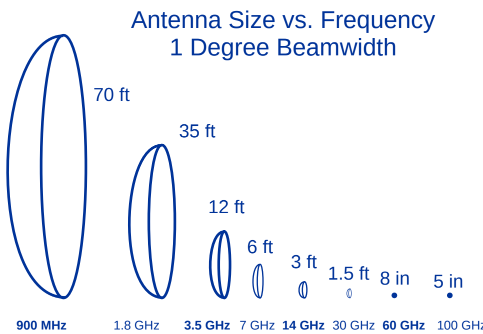


Figure 2: Antenna gain versus transmission frequency for 3 different antenna sizes

Narrow Beam Directional Antennas

Besides higher antenna gain, the antennas operating in the higher frequency bands have another advantage when it comes to minimizing potential interference risk and improved transmission security. With increased frequency the antenna beam divergence decreases, meaning the antenna beam is more directive/focused. Antenna directivity is limited by the physical principle of diffraction, meaning that the beam width is inversely proportional to the operating frequency (see figure below). To achieve, for example, a narrow antenna beam of 1 degree full width half maximum (FWHM), a 60 GHz parabolic antenna is only about 20 cm (8 inches) in diameter. To achieve such a narrow beam divergence using an antenna operating in the commonly used 5.8 GHz frequency band, the antenna would have a diameter of roughly 300 cm (10 feet)!



In particular for shorter and medium distance point-to-point wireless connections requiring a high level of security and interference resiliency, the 60 GHz frequency range is far superior when compared to alternative 2.4, 5.8, and 24 GHz frequency ranges. Figure 3 visualizes the spreading of the antenna radiation patterns at various distances to illustrate this behavior.

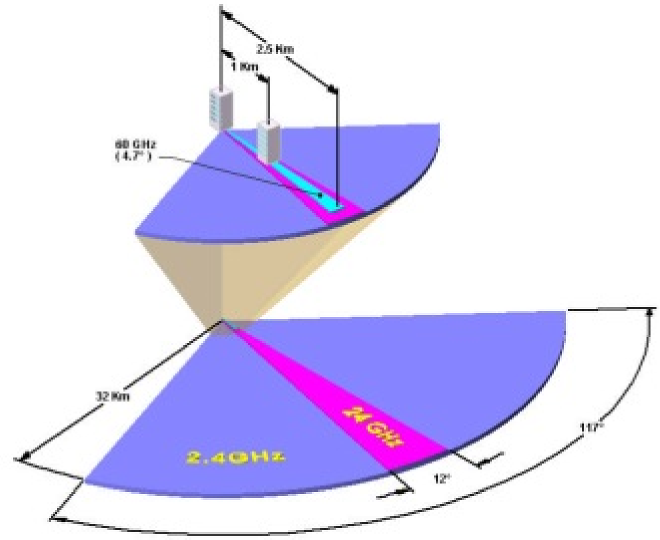


Figure 3: Typical antenna radiation pattern for the 2.4, 24 and 60 GHz frequency band

The LightPointe AireLink 60 Solution

This section will focus on the LightPointe AireLink 60 wireless point-to-point product line and outline some of the product highlights. The product was designed from the ground up using latest generation and advanced 60 GHz RF chips, modem technologies, and multiple antenna options that allow users to configure the system for specific deployment scenarios.

Real GigE Throughput

When it comes to speed/throughput performance it is important to understand how vendors present these numbers. Some vendors (Vendor A, in Figure 4) multiply the throughput rate by a factor of two because the system operates in full duplex mode, meaning the system is capable to send and receive data at the same time. Another group of vendors (Vendor B, in Figure 4) is even more aggressive by advertising the "over the air" data rate and including all standard Ethernet encoding overhead, error correction overhead, and more. This is very confusing and customers that are not really familiar with all these specifics are often mislead when seeing claims like 1.7 Gbps throughput, which is far from reality when it comes to real LAN data throughput.

Yet another group of vendors sell simplex TDD systems (vendor C, in Figure 4) that cannot transmit and receive data at the same time and claim real Ethernet speed. There are also vendors selling 802.11 radios (Vendor D, in Figure 4) claiming throughput rates of 400 Mbps and beyond while the actual LAN throughput is just a fraction of it.

LightPointe's throughput rates are the actual LAN throughput rates. The AireLink 60 transmits data at real Gigabit Ethernet LAN throughput (1000 Mbps) and in full duplex mode of operation. Also, the system can transport jumbo frames up to 10k frame size.

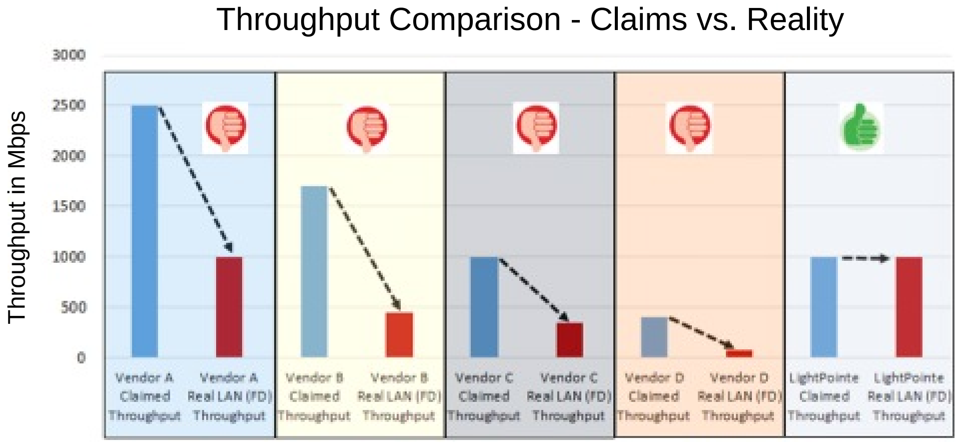


Figure 4: Radio link throughput comparison. Claim throughput versus real LAN throughput

First in Class Modem Technology

Earlier and first generation 60 GHz radio implementations used simple modulation schemes like BPSK or BFSK. Some of the second generation radios used a limited number of additional modulations like QPSK combined with Adaptive Coding and Modulation (ACM) technology, which allows the system to seamlessly switch from a higher to a lower modulation scheme. ACM provides the means to trade off overall system availability and throughput when difficult weather conditions shut down the connection. By automatically switching to a lower modulation scheme, the overall system margin to combat difficult weather conditions is improved, and consequently the system keeps operating.

The AireLink 60 modem uses an advanced 9 levels/stages of Adaptive Coding and Modulation (ACM) algorithms in conjunction with a state of the art low-density parity-check (LDPC) forward error correction (FEC) coding, to combat even the most severe signal attenuation conditions. While competing 60 GHz radio solutions use at most 4 levels of coding and modulation, the 9 level ACM architecture provides the AireLink 60 with the most advanced coding scheme on the market. This allows for very gradual changes of throughput numbers when difficult weather conditions challenge the link margin of the system.

ACM Parameter	BPSK-1/2	BPSK-5/8	BPSK-3/4	QPSK-1/2	QPSK-5/8	QPSK-3/4	QPSK-13/16	16QAM-1/2	16QAM-5/8
Throughput [Mbps]	226	277	323	469	574	673	722	904	1000

Figure 5: AireLink™ 60 ACM schemes

Highest Transmission Power and EIRP for Longer Reach

Most of the current 60 GHz systems commercially available include a very small footprint antenna. This is driven by the idea that a large percentage of the outdoor 60 GHz equipment market is within the LTE and 4G/5G backhaul market segment. Anticipated distances between LTE base stations are getting smaller and in the near future it is anticipated that distances between base stations will not be more than 200 meters.

The AireLink 60 SX, with its integrated small 120 mm lens antenna, fits the profile of such a short distance communications link for the LTE backhaul market. In addition, the AireLink 60 product line is equipped with an RF front end that allows for transmitting the maximum allowable power, and when connected to a 2 foot high gain antenna, it operates at the maximum allowable EIRP level. This unique design approach opens the system for applications not only in the ultra-short distance backhaul/bridging market, but also open applications in the medium distance backhaul/bridging market with path lengths up to 1 mile.

Multiple Network Interfaces

Most radio links are equipped with a single LAN network connection. In the majority of cases, this is just a single copper RJ-45 Ethernet connection. Besides a standard RJ-45 copper connection, the AireLink 60 system is equipped with a user selectable fiber SFP interface. In addition, the system is equipped with a PoE based out-band RJ45 management port, a separate 48 Vdc power port, and a RS232 console port. The system is also equipped with a RS485 control port that is reserved for future expansion.

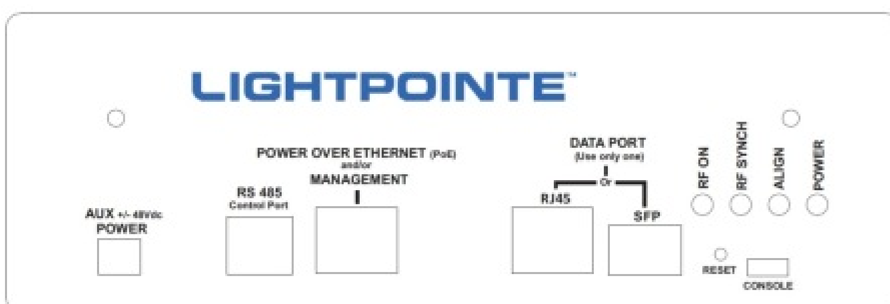


Figure 6: AireLink™ back panel connections

Multiple Antenna Options

The AireLink 60 is the only 60 GHz solution on the market that offers a small integrated and high performance lens antenna, as well as options to use external 1 foot and 2 foot antennas for longer distance operation. The external antennas are attached to an AireLink™ 60 ODU via a slip-ring mount mechanism. It also allows for easily changing the radio polarization by turning the linear polarized antenna by 90 degrees.

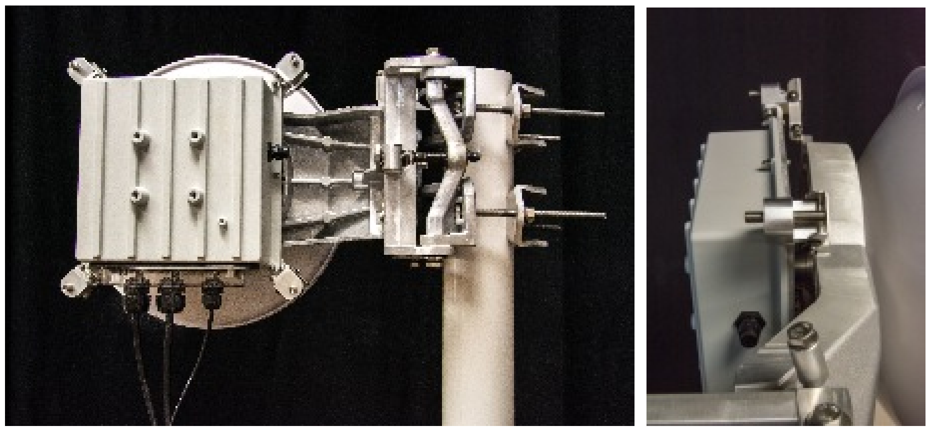


Figure 7: AireLink™ 60 with attached 1 foot antenna

Innovative design

The AireLink 60 design is driven by industrial design, robustness, longevity, and functionality. This is reflected in the modular system design for multiple antenna options, robust antenna mounting options including stainless steel mounting brackets, as well as some more unique design features. The most recognizable feature is the transparent back panel cover lid that provides easy visible access to network port status indicators, as well as power and RF status LEDs. No other 60 GHz radio provides this capability, which is very useful during system installation and provisioning. To make cable installation easier, and to add additional spacing in case more rugged and industrial size connectors are used, the back panel is recessed inside the enclosure and the IP67 waterproofed cable glands are extruded.

Figure 8: System backpanel and transparent cover lid

Another unique feature that is very helpful during system installation is the alignment site tool. It can be easily attached to the radio enclosure and dramatically speeds up the alignment process of the narrow beam antennas. After successful alignment the alignment site tool can be moved and stored or used to align additional radio links. The tool is available for the integrated lens antenna as well as for the external 1 foot and 2 foot antennas.

Figure 9: Site Alignment Tool

Advanced Powering Features

The AireLink 60 can be powered either via an 802.3at compliant Power-over Ethernet (PoE) supply or via a direct and polarity independent +/-48 Vdc power connection. For power redundancy purposes, both power lines can be connected at the same time. In case one power supply fails, the other one will pick up immediately without power interruption. With only 23 watts of total power consumption, the AireLink 60 is among one of the most energy efficient 60 GHz radio solutions.

Multiple Monitoring and Management Options

The AireLink 60 system comes standard with multiple monitoring and management options. For easy access, the system can be monitored using a standard web browser. Also included with the system is a SNMP v1/2c compliant MIB file that can be compiled into any standard SNMP management system. A TELNET based Command Line Interface (CLI) allows for settings and monitoring system parameters by entering simple command line instructions.

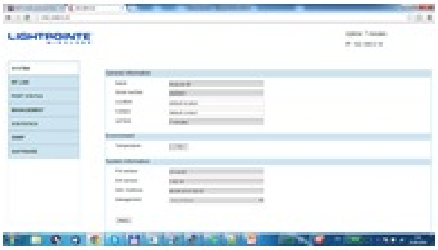


Figure 10: Web browser interface

Besides Ethernet based management options, the system is also equipped with a USB based RS232 interface for initial setup or system settings recovery.

About the Author

Dr. Heinz A. Willebrand is widely regarded as being among key driving visionary forces behind the Free-Space Optics (FSO) and millimeter wave wireless bridge movement, and is an inductee into EE Times list of *"Forty Innovators Building the Foundation of the Next-Gen Electronics Industry."* Well known and recognized for his contributions in the advancement of FSO, Heinz regularly speaks at national and international conferences on technical and business related aspects of FSO and Millimeter-Wave (MMW) technology. Heinz obtained his Ph.D in Applied Physics at the University of Muenster/Germany and has held research and teaching positions with the University of Muenster and the University of Colorado in Boulder. He holds more than 10 patents on fiber-optics and wireless technologies.

About LightPointe

LightPointe, an ISO 9001:2008 certified company, is the number one manufacturer of Gigabit capacity all-weather hybrid wireless bridges, 4th generation Free Space Optics links, and the world's fastest Ultra Low Latency (ULL) 60 and 70/80 GHz point-to-point radios. Since 1998, LightPointe has deployed over 16,000 systems with Enterprises, 4G/LTE Carriers, High Frequency Trading (HFT) networks, Government Agencies, Defense/Military Departments, and Security organizations.

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