Free-space optical communication

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In telecommunications, **Free Space Optics** (FSO) is an optical communication technology that uses light propagating in free space to transmit data between two points. The technology is useful where the physical connections by the means of fibre optic cables are impractical due to high costs or other considerations.

An 8-beam free space optics laser link, rated for 1 Gbit/s at a distance of approximately 2 km. The receptor is the large disc in the middle, the transmitters the smaller ones. To the top and right side a monocular for assisting the alignment of the two heads.

Contents

History

Optical communications, in various forms, have been used for thousands of years. The Ancient Greeks polished their shields to send signals during battle. In the modern era, semaphores and wireless solar telegraphs called heliographs were developed, using coded signals to communicate with their recipients.

In 1880 Alexander Graham Bell and his then-assistant Charles Sumner Tainter created the photophone, at Bell's newly establish Volta Laboratory in Washington, D.C. Bell considered it his most important invention. The device allowed for the transmission of sound on a beam of light. On June 3, 1880, Bell conducted the world's first wireless telephone transmission between two buildings, some 213 meters apart.[1] Its first practical use came in military communication systems many decades later.

Carl Zeiss Jena developed the *Lichtsprechgerät 80* (direct translation: light speaking device) that the German army used in their World War II anti-aircraft defense units.[2]

The invention of lasers in the 1960s revolutionized free space optics. Military organizations were particularly interested and boosted their development. However the technology lost market momentum when the installation of optical fiber networks for civilian uses was at its peak.

Usage and technologies

Free-space optical links can be implemented using infrared laser light, although low-data-rate communication over short distances is possible using LEDs. IrDA is a very simple form of free-space optical communications. Free Space Optics are additionally used for communications between spacecraft. Maximum range for terrestrial links is in the order of 2 to 3 km (1.2 to 1.9 mi),[3] but the stability and quality of the link is highly dependent on atmospheric factors such as rain, fog, dust and heat. Amateur radio operators have achieved significantly farther distances (173 miles in at least one occasion) using incoherent sources of light from high-intensity LEDs. [4] However, the low-grade equipment used limited bandwidths to about 4 kHz. In outer space, the communication range of free-space optical communication is currently in the order of several thousand kilometers[5], but has the potential to bridge interplanetary distances of millions of kilometers, using optical telescopes as beam expanders[6].

Secure free-space optical communications have been proposed using a laser N-slit interferometer where the laser signal takes the form of an interferometric pattern. Any attempt to intercept the signal causes the collapse of the interferometric pattern.[7] Although this method has only been demonstrated at laboratory distances, in principle it could be applied over large distances in space.

Applications

Typically scenarios for use are:

Two solar-powered satellites communicating optically in space via lasers.

- LAN-to-LAN connections on campuses at Fast Ethernet or Gigabit Ethernet speeds.
- LAN-to-LAN connections in a city. *example, Metropolitan area network*.
- To cross a public road or other barriers which the sender and receiver do not own.
- Speedy service delivery of high-bandwidth access to optical fiber networks.
- Converged Voice-Data-Connection.
- Temporary network installation (for events or other purposes).
- Reestablish high-speed connection quickly (disaster recovery).
- As an alternative or upgrade add-on to existing wireless technologies.
- As a safety add-on for important fiber connections (redundancy).
- For communications between spacecraft, including elements of a satellite constellation.
- For inter- and intra[8]-chip communication.

The light beam can be very narrow, which makes FSO hard to intercept, improving security. In any case, it is comparatively easy to encrypt any data traveling across the FSO connection for additional security. FSO provides vastly improved EMI behavior using light instead of microwaves.

Advantages

- Ease of deployment
- License-free long-range operation (in contrast with radio communication)
- High bit rates

- Low bit error rates
- Immunity to electromagnetic interference
- Full duplex operation
- Protocol transparency
- Very secure due to the high directionality and narrowness of the beam(s)
- No Fresnel zone necessary

RONJA is a free implementation of FSO utilizing high-intensity LEDs.

Disadvantages

For terrestrial applications, the principal limiting factors are:

- Beam dispersion
- Atmospheric absorption
- Rain
- Fog (10..~100 dB/km attenuation)
- Snow
- Scintillation
- Background light
- Shadowing
- Pointing stability in wind
- Pollution / smog
- If the sun goes exactly behind the transmitter, it can swamp the signal.

These factors cause an attenuated receiver signal and lead to higher bit error ratio (BER). To overcome these issues, vendors found some solutions, like multi-beam or multi-path architectures, which use more than one sender and more than one receiver. Some state-of-the-art devices also have larger fade margin (extra power, reserved for rain, smog, fog). To keep an eye-safe environment, good FSO systems have a limited laser power density and support laser classes 1 or 1M. Atmospheric and fog attenuation, which are exponential in nature, limit practical range of FSO devices to several kilometres.

See also

- Applications of atomic line filters in laser tracking and communication
- Extremely high frequency
- IrDA
- Laser safety
- Mie scattering
- Modulating retro-reflector
- Optical telegraph for the early history of optical communication, including semaphores
- Optical window
- Photophone
- Radio window
- Rayleigh scattering
- Smoke signals
- Visible Light Communications

References

Notes

1. ^ Carson 2007, pg.76-78
2. ^ "GERMAN, WWII, WW2, Lichtsprechgerät 80/80" (http://www.laud.no/ww2/lispr/lispr2.htm) . http://www.laud.no/ww2/lispr/lispr2.htm. Retrieved 29 March 2010.
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External links

- Harvard Broadband Communications Laboratory: Free-Space Optical Communications (http://www.seas.harvard.edu/hbbcl/fsoc.html)
- Analysis of Free Space Optics as a Transmission Technology, U.S. Army Information Systems Engineering Command (http://web.archive.org/web/20070613000248/http://www.hqisec.army.mil/isec/publications/Analy (archived)
- Free Space Optics on COST297 for HAPs (http://www.hapcos.org/DOCS/wg2/wg2_home.php)
- Explanation of Fresnel zones in microwave and optical links (http://ronja.twibright.com/fresnel.php)
- Lichtsprechgerät 80/80 (http://www.laud.no/ww2/lispr/lispr2.htm) - technical details and images
- video showing Lichtsprechgerät 80 in use (http://www.youtube.com/watch?v=vR4N6MTx_vw) at YouTube

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RONJA

From Wikipedia, the free encyclopedia

Single high-brightness LED with a cheap loupe lens creates a bright narrow beam that can stream DVD-quality video over neighbourhoods. A few steps aside and the narrow beam becomes invisible.

RONJA (**Reasonable Optical Near Joint Access**) is a Free Space Optics device originating in the Czech Republic. It transmits data wirelessly using beams of light. Ronja can be used to create a 10 Mbit/s full duplex Ethernet point-to-point link.

The range of the basic configuration is 1.4 km (0.9 miles). The device consists of a receiver and transmitter pipe (optical head) mounted on a sturdy adjustable holder. Two coaxial cables are used to connect the rooftop installation with a protocol translator installed in the house near a computer or switch. The range can be extended to 1.9 km (1.2 miles) by doubling or tripling the transmitter pipe.

Building instructions, blueprints, and schematics are published under the GNU Free Documentation Licence. Only free software tools are used in the development. The author calls this level of freedom "User Controlled Technology". Ronja is a project of Twibright Labs.

Three bolts preloaded with pink rubber blocks facilitate fine adjustment of the optical head direction with a gear ratio 1:300. The bolt on the right side is a part of a rough adjustment mechanism which allows pointing the optical head in virtually any direction.

Contents

Manufacture

The building instructions are written with an inexperienced builder in mind. Basic operations like drilling, soldering etc, are explained. Several techniques - drilling templates, detailed checks after soldering, testing procedures - are employed to minimize errors at critical places and help to speed up work. Printed circuit boards are downloadable ready for manufacture, with instructions for the fabhouse. People with no previous experience with building electronics have reported on the mailing list that the device ran on the first try.

Artificially enhanced picture of a situation, where a Ronja link stops working because of heavy fog.

Around 153 installations worldwide have been registered into a gallery.

Models

- **Ronja Tetrapolis**: Range of 1.4 km (0.87 miles), red visible light. Connect with RJ45 connector into a network card or switch.
- **Ronja 10M Metropolis**: Range of 1.4 km (0.87 miles), red visible light. Connects to Attachment Unit Interface.
- **Ronja Inferno**: Range of 1.25 km (0.78 miles), invisible infrared light.
- **Ronja Benchpress**: A measurement device for developers for physical measurement of lens/LED combination gain and calculation of range from that

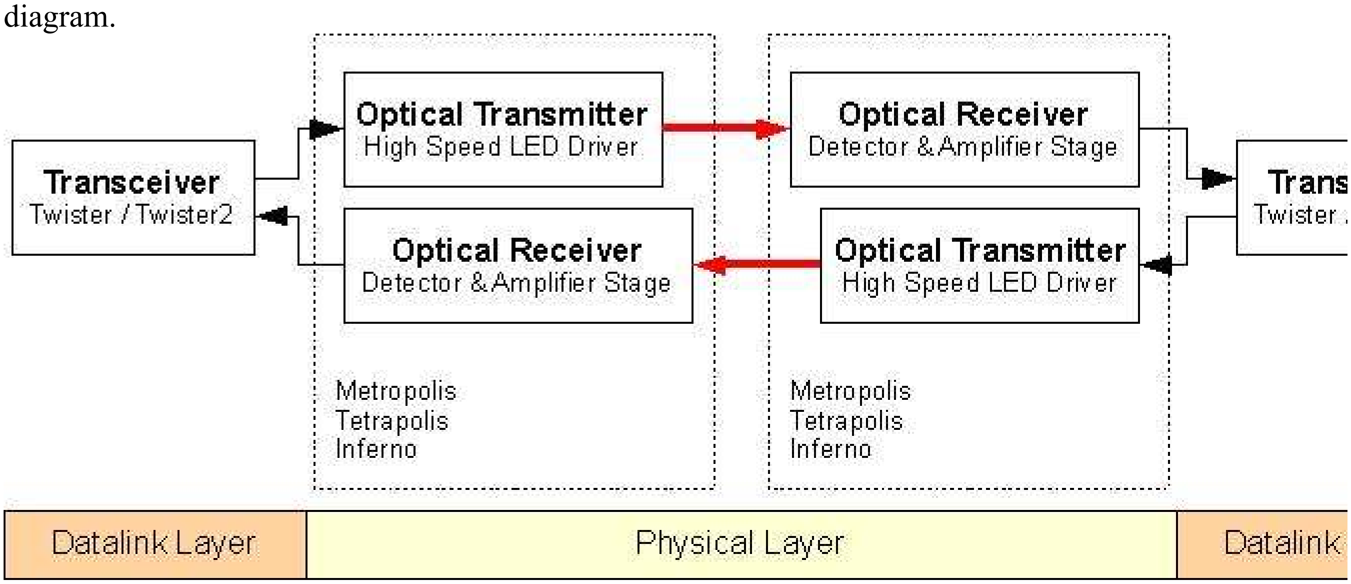
Limitations

By definition, clear visibility between the transmitter and receiver are essential. If the beam is obscured in any way, the link will stop working. Typically, problems may occur during conditions of dense fog, or snow. A Star network (of the type used in a wireless LAN) is not possible.

Technology

System Overview

A complete RONJA system is made up of 2 transceivers: 2 optical transmitters and 2 optical receivers. They are assembled individually or as a combination. The complete system layout is shown in the block diagram.



Optical Receiver - Preamplifier stage

Map showing the distribution of the 153 registered installations of RONJA as of 1 October 2007. Based on data found at the official RONJA website (http://ronja.twibright.com/installatio

The usual approach in FSO (Free Space Optics) preamplifiers is to employ a transimpedance amplifier. A transimpedance amplifier is a very sensitive broadband high-speed device featuring a feedback loop. This fact means the layout is plagued with stability problems and special compensation of PIN diode capacitance must be performed, therefore this doesn't allow selection of a wide range of cheap PIN photodiodes with varying capacitances.

Ronja however uses a feedbackless design where the PIN has a high working electrical resistance (100 kilohms) which together with the total input capacitance (roughly 7 pF, 5 pF PIN and 2 pF input MOSFET cascode) makes the device operate with a passband on a 6 dB/oct slope of low pass formed by PIN working resistance and total input capacitance. The signal is then immediately amplified to remove the danger of contamination by signal noise, and then a compensation of the 6 dB/oct slope is done by derivator element on the programming pins of an NE592 video amplifier. A surprisingly flat characteristic is obtained. If the PIN diode is equipped with 3 kΩ working resistor to operate in flat band mode, the range is reduced to about 30% due to thermal noise from the 3 kΩ resistor.

Optical Transmitter - Nebulus infrared LED driver

The HSDL4220 infrared LED is originally unsuitable for 10 Mbit/s operation. It has a bandwidth of 9 MHz, where 10 Mbit/s Manchester-modulated systems need bandwidth of around 16 MHz. Operation in a usual circuit with current drive would lead to substantial signal corruption and range reduction. Therefore Twibright Labs developed a special driving technique consisting of driving the LED directly with 15-fold 74AC04 gate output in parallel without any current limitation. As the voltage to keep the nominal LED average current (100mA) varies with temperature and other component characteristic, an AC-bypassed current sense resistor is put in series with the LED. A feedback loop measures voltage on this resistor and keeps it at a preset level by varying supply voltage of the 74AC04 gates. Therefore the 74AC04 is operating as a structured power CMOS switch completely in analog mode.

This way the LED junction is flooded and cleared of carriers as quickly as possible, basically by short circuit discharge. This pushes the speed of the LED to maximum, which makes the output optical signal fast enough so that the range/power ratio is the same as with the faster red HPWT-BD00-F4000 LED. The side effects of this brutal driving technique are: 1) the LED overshoots at the beginning of longer (5 MHz/1 MHz) impulses to about 2x brightness. This was measured to have no adverse effect on range. 2) A blocking ceramic capacitor bank backing up the 74AC04 switching array is crucial for correct operation, because charging and discharging the LED is done by short circuit. Under dimensioning this bank causes the leading and trailing edges of the optical output to grow longer.

Transceiver - Ronja Twister

Ronja Twister is an electronic interface for free space optical datalink based on counter and shift register chips. It is a part of the Ronja design. It is effectively an optical Ethernet transceiver without the optical drive part.[1]

The original design has been superseded with Twister2, however the logic circuit remained the same.[2]

Organization

The whole toolchain is strictly built upon free tools and the source files are provided for free under the GPL. This allows anyone to enter the development, start manufacture or invest into the technology without entry costs. Such costs normally can include software licence costs, time investment into resolution of compatibility issues between proprietary applications, or costs of intellectual property licence negotiations. The decision to conceive the project this way was inspired by observed organizational efficiency of Free Software.

In Christmas 2001, Ronja became the world's first 10 Mbit/s Free Space Optics device with free sources.

Examples of tools used in development:

- gEDA gschem (Schematic capture)[3]
- QCad
- BRL-CAD
- The PCB program[4]
- Sodipodi for Vector graphics

See also

- Wireless community network
- Visible Light Communications
- List of device bandwidths

References

1. ^ Ronja Twister (http://ronja.twibright.com/twister/)
2. ^ Ronja Twister2 (http://ronja.twibright.com/twister2/)
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4. ^ *PCB* (http://pcb.sourceforge.net/) , Sourceforge, http://pcb.sourceforge.net/

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- Unstrung: Da Doo Ron RONJA (http://www.unstrung.com/document.asp?doc_id=18416)
- Ronja talk at WSFII London 2005 (http://www.archive.org/details/Ronja_WSFII_London) (archive.org)
- Hack a Day: Ronja (http://www.hackaday.com/2005/06/13/ronja-optical-data-link/)
- A user testimonial (http://hansmi.ch/articles/ronja)

External links

- ronja.twibright.com (http://ronja.twibright.com) — Ronja Homepage
- Gallery of Registered Installations (http://ronja.twibright.com/installations.php)
- RONJA Adaptation for Underwater (http://www.ece.ncsu.edu/seniordesign/projects_new.php?id=463)

- British council project - Promotion of ronja in community networks in UK 2004 (http://charon.hkfree.org/ronja/)

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