Visible Light Communication (VLC) Systems

VLC systems are presently being developed by scientists seeking to create ultra high-speed, high security, biologically friendly communications networks that allow the creation and expansion of seamless computing applications using very large bandwidth high-frequency pulsed light instead of radiowaves and microwaves.

Such systems use modulated light wavelengths emitted (and received) by a variety of suitably adapted standard sources, such as indoor and outdoor lighting, displays, illuminated signs, televisions, computer screens, digital cameras and digital cameras on mobile phones for communication purposes, primarily through the use of Light Emitting Diodes (LEDs).

Their use may help provide both partial and full solutions to a number of technological problems: increasingly limited availability of conventional bandwidths for electronic equipment; possible communications interference with sensitive electrical equipment; data security; and perceived negative health consequences when exposed to raised radiofrequency and microwave levels.

The incorporation of VLC components into everyday technology is being investigated by a number of universities, corporations and organisations worldwide, and has already resulted in the creation of the Japan Electronics and Information Technology Industries Association's JEITA standards (2007) for a "visible light ID system", and a Specification Standard in 2008 by the Visible Light Communications Consortium (VLCC) - as a result of its joint cooperative agreement with the Infrared Data Association (IrDA). The Institute of Electrical and Electronics Engineers (IEEE) Wireless Personal Area Networks working group 802.15.7 Task Group 7 is also developing a standard for VLC technologies that should be finalised by the end of 2010, whilst the EU-funded OMEGA project is investigating ways in which such technology can be incorporated into home networks.

VLC Research

Research in this area is being undertaken by, amongst others: Casio, Eurescom, France Telecom, NEC Corporation, Orange, Panasonic, Samsung, Sharp, Siemens AG, Telefonica, Toshiba, Universita di Roma, Universität Dortmund, Universität Ilmenau, University of Athens, University of California, and the University of Oxford.

LED (Light Emitting Diode) VLC technology

LED (Light Emitting Diode) Visible Light Communications (VLC) systems are recognised as creating a possible valuable addition to future generations of technology, which have the potential to utilise light for the purposes of advanced technological communication at ultra high speed surpassing that of current wireless systems. One of the goals of researchers is to allow 100 megabits of data transference per second (Mbps) in offices and homes by modulation of light from upgraded lighting systems.

If it is developed correctly, the possibility exists that many of the problems associated with present day infrared, radiowave and microwave communications systems (*and lighting technology*) could be at least partially resolved, and a more biologically friendly system made available to industries and the general public.

A further advantage is that VLC systems can transmit data more securely over short distances than radiofrequency/microwave communications devices whose signals can be easily detected outside the rooms and buildings they originate in.

Comparisons

RONJA

The Reasonable Optical Near Joint Access (RONJA) Free Space Optics device developed in the Czech Republic can transmit data wirelessly using beams of red visible light up to 0.87 miles (1.4 kilometres), or infrared light up to 1.25 miles (0.78 kilometres).

As with VLC systems, direct line of sight is important, with clear visibility helping to optimise data transmission rates. It has been noted that for RONJA conditions of dense fog or snow can detrimentally effect external transmissions.

Infrared (IR) Communications

Infrared devices are often used for data-transmission in devices such as notebook computers, television remote controls and even some newer mobile phones. To date the Infrared Data Association (IrDA) has standardised over 30 specifications that are widely implemented for cordless phones, printers, televisions and other devices. Its 2008 market-report indicated a prolific increase of IrDA infrared enabled devices, of which over 1 billion units have been shipped to date, and that demand for such units was likely to increase greatly, particularly with the development of IrSimple version 1.0 and technological advances used for Giga-IR.

Whilst visible light from LED systems and infrared emissions share similar frequency ranges, it is acknowledged that there are potential visual safety problems with using infrared for high rates of data transmission due to both the large energy emissions it would create and its invisibility, making suitably developed LED light data transmission a safer option for human eyes.

Radiofrequency/Microwave Communications

At present the multiple use in buildings of the three independent WLAN frequency bands can often compromise information networks. This is a problem that the adoption of VLC technologies could help resolve by providing alternative bandwidths.

Additionally, whilst the use of radiofrequency/microwave communications devices is becoming increasingly widespread, research indicates that some emissions and intensities may also interfere with sensitive electronic equipment (*such as used in hospitals, some factories and on aircraft*), cause health problems and/or biological damage.

With sufficient development, it may prove possible for VLC to avoid such problems, and become a biologically friendly environmental asset. As it appears likely that VLC will not interfere with sensitive electrical equipment it could, in principle, be used in locations where current communications technology is often prohibited and where strong data security is required. An additional incentive at present is that, whilst free usage of radiowave and microwave wireless communications is restricted by law, VLC technologies do not, as yet, require licenses.

Lighting Types and VLC

At present incandescent and fluorescent lamps are the predominant sources of artificial-lighting, with incandescent units being phased out under a strong drive by many governments worldwide to reduce energy wastage. They are generally being replaced with energy-efficient alternatives, such as fluorescent lights, compact fluorescents and LEDs.

Though the core logic behind such a policy would appear sound to most individuals, this drive has met with resistance in certain quarters due to perceived doubts about the ecological suitability of some of the proposed alternatives, particularly fluorescent and compact fluorescent lamp units - *as related to potential land contamination risk if they are disposed of incorrectly*. Potential health effects of exposures to different types of light should also be taken into account in this equation.

Doubts have been raised over the biological-friendliness of some, but not all, types of fluorescents and compact fluorescents lamp and LED units, especially towards susceptible individuals, for example those suffering from lupus and electromagnetic hypersensitivity (*as recognised by Sweden and the State of California in the USA, amongst others*). Animal-tests too have additionally revealed the need for care when specifying lighting regimes, and the benefits of optimising spectral emission profiles for specific purposes.

It appears possible to develop VLC systems with optimised spectral and frequency emission profiles in order to negate such problems and create more biologically friendly artificial-light than is presently available. As noted by the Visible Light Communications Consortium (VLCC) which was formed in Japan in 2003 (and includes amongst its members Casio, NEC Corporation, Panasonic, Samsung, Sharp and Toshiba), "*… visible light communication has characteristics to be ubiquitous, transmitted at ultra high speed and harmless for human body and electronic devices, compared to [emissions] by radio and infrared communications.*"

Such factors indicate that there is a strong need to ensure that VLC are at least as biologically friendly as the units they are designed to replace or supplement, and that they may offer a more sophisticated solution to the communications technology than is presently available. With proper development and foresight, VLC could radically reinvent the future of telecommunications industry to create a situation where everybody benefits, with technological findings also being able to be back-engineered into existing technology.

VLC Development Timeline

2010: The data transmission speeds of VLC systems are shown to be rapidly improving, with a frequency-modulated white LED being shown by Siemens researchers and the Heinrich Hertz Institute in Berlin to be capable of transmitting information over 5 meters at a rate of 500 Mbps, significantly faster than present Wi-Fi technologies (that can operate at rates of up to 150 Mbps). The same researchers were also able to demonstrate that a system using up to 5 LEDs could transfer data over greater distances at 100 Mbps with direct line of sight. Reduced levels of transmission would have occurred using diffused light from walls outside of line of sight.

VLC data transfer is generally far more secure than conventional wireless local area network (WLAN) links, as it is indicated that only photoreceptors directly within the transmitted cone of light can receive information, thereby making it apparently 'impervious to interception'.

2010: Demonstration undertaken successfully in Japan showing the combination of VLC with indoor Global Positioning System (GPS).

2010: The Center for Ubiquitous Communication by Light (UC-Light) at the University of California seeks to develop VLC technology further to allow communication between a wide variety of electronic products, such as high definition televisions, information kiosks, personal computers (PCs), personal digital assistants (PDAs) and smartphones.

2009: A result of the joint cooperative agreement between VLCC and the IrDA, VLCC issue their first Specification Standard which incorporates and expands upon core IrDA specification and defined spectrum to allow for the use of visible light wavelengths. By modifying the IrDA specification, existing IrDA optical modules can - *with only minor alteration* - be utilised for VLCC data-transmission. As a

result, this specification change will lead to reduced development costs when the IrDA specification is used widely in portable technology.

2009: Research continuing in Japan to increase viable communication distances for VLC to hundreds of meters. Such work will allow the transmission of information by light from billboards, and from new generations of traffic lights to automobiles and trains.

2009: German scientist, Dr. Stefan Spaarmann, states that the problem of light smog can be avoided through the inclusion of the transmission signals within the optical surrounding signals (as with natural sight). He stresses the importance of mimicking nature.

2008: A joint-cooperative agreement covering complimentary research and development to advance the communications technology indu stry is announced between VLCC and the international Infrared Data Association (IrDA) that is responsible for developing and establishing global specification standards for low-cost infrared technology for wireless connectivity.

That agreement allows both organisations to undertake vital complimentary research, combining widely-used mobile phone IrDA technology and new visible light communication technology, to further refine and develop existing and proposed commercial applications of the optoelectronic spectrum, using infrared and visible light frequencies, for items such as cameras, cars, indicator lights, indoor lighting, mobile phones, printers, toll booths, traffic signals and monitor displays. It is expected that such work will create a new standard of user-friendly, and potentially more biologically-friendly, technological communications.

2008: EU-funded OMEGA project seeks to develop global standards for home networks, including the use of optical wireless using infrared and VLC technology.

2007: The standardisation work undertaken by VLCC leads to the creation of the Japan Electronics and Information Technology Industries Association's JEITA standards (2007) for a "visible light ID system". VLCC is also involved in preparing and publicising proposals for safe visible light communication technology standards for a variety of applications and fields of industry.

2007: VLC developed by NEC was showcased by Fuji Television at the International Broadcast Equipment Exhibition (Inter BEE) 2007 in Japan. In that demonstration a LED-backlit LCD television operated whilst transmitting information to a PDA via light. The device also enabled the information to be sent securely to chosen individuals.

2005: Japan's Ministry of Land trials VLC communications technology to transmit information to mobile phones in the Departure Lounge of Kansai Airport. Throughput estimated at 10 Kbps from fluorescent light units and several Mbps from a light emitting diode (LED) unit.

2004: The Visible-Light Communications Consortium demonstrated at CEATEC Japan 2004 how LED-light systems can be used for high-speed transmission of data to handheld and vehicle-borne computing devices.

2003: The Visible Light Communications Consortium (VLCC) is established between major Japanese companies to develop, plan, research and standardise Japan's own visible light communication systems. Its brief is to develop, test, investigate, plan and standardise ubiquitous high-speed biologically-friendly VLC LED systems.

2002: Dr. Stefan Spaarmann develops a VLC system but cannot find a company to fund the building of a prototype.

2001: The Reasonable Optical Near Joint Access (RONJA) Free Space Optics device from the Czech Republic became the first device to transmit 10 Mbps wirelessly using beams of light. The range of the basic configuration, which can be extended, is 0.87 miles (1.4 kilometres).

1993: The Infrared Data Association (IrDA) is formed with a brief of developing low-cost, interoperable worldwide 'infrared' technology.

1931: Dr. Sergius P. Grace, of the US Bell Telephone Laboratories, discusses the potential for using light for wireless communications to prevent the danger of eavesdropping by others.

1880: The first VLC transmission (which was also the first wireless transmission in the world) was sent in Washington D.C. on 3 June 1880 by Scottish born engineer, inventor, scientist and innovator Dr. Alexander Graham Bell and his then assistant, American inventor Charles Sumner Tainter. They used a system they had developed and patented called the Photophone. Bell stated that it was his greatest achievement, surpassing even his invention of the telephone in terms of importance.

Conclusions

VLC appears to be an important potential component in expanding useable bandwidth, protecting sensitive electrical equipment and data, creating more biologically friendly communications technology, and helping develop seamless computing applications.

The lessons that can be learnt through the development of such technology may be back-engineered into existing telecommunications technology, and may also help develop hybrid systems, such as combined long distance light and radiofrequency/microwave communication systems which could use VLC technology during good weather and clear visibility, and be supplemented with more conventional (though less secure) technology where required, such as during poor weather conditions and poor visibility.

Properly developed VLC could also be used, in conjunction with other measures, to help create more equipment-friendly and biologically-friendly electromagnetic environments helping to create truly sustainable communications technology.

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For additional information, please visit the following:

LVX System http://www.lvxsystem.com , also watch video
The Visible Light Communication Consortium: http://www.vlcc.net
Oxford University http://dept106.eng.ox.ac.uk/wb/pages/home.php
Boston University http://www.bu.edu/smartlighting
Pennsylvania State University http://live.psu.edu/story/44147
University of California http://www.uclight.ucr.edu
Siemens http://w1.siemens.com/innovation
HAPCOS http://www.kn.dlr.de/freespaceoptics
Omega Home Gigabit Access project: http://www.ict-omega.eu
RONJA: http://ronja.twibright.com

The IEEE 802.15.7 Task Group 7 is chartered to write a PHY and MAC standard for Visible Light Communications (VLC).

See http://www.ieee802.org/15/pub/TG7.html