

RESEARCH BRIEF

OPTICAL WIRELESS SYSTEMS

The potential

Optical wireless networks are suitable for “campus” networking, metropolitan communication infrastructure, rapid deployment in emergency situations, disaster recovery, and in military contexts.

We are engaged in a program of research designed to improve the performance of line-of-sight optical communication links (optical wireless) through the atmosphere along paths relatively close to the ground.

The challenge

Optical communication links must achieve high data rate and low bit-error-rate performance in the face of varying degrees of atmospheric turbulence and obscuration, such as wind, rain and fog. There are also problems with signal fading, tracking and pointing, as well as system engineering issues such as the optical design of transmitters and receivers. Important issues include wavelength of operation, spatial and temporal diversity, and the use of non-imaging receivers.

General research overview

ISR researchers, led by Dr. Christopher Davis and Dr. Stuart Milner, are developing new modulation approaches, sources, and coding schemes to deal with these challenges. They are:

- Conducting fade statistics studies on urban-based line-of-sight ranges.
- Comparing link performance at 1.3 micrometers and 1.55 micrometers.
- Studying atmospheric chirality
- Testing polarization shift keying and polarization diversity for fade resistance, and channel capacity doubling.
- Testing delayed, orthogonal channel polarization diversity for fade resistance.
- Measuring bit-error-rates at high (1Gb/s) data rates.
- Developing and testing forward error correcting codes for turbulent channels.

- Addressing systems engineering problems of transmitter/receiver design, and aperture averaging.
- Testing system concepts with an artificial turbulence generator.

Agile optical wireless transceivers

Optical wireless systems provide secure data streams because of the narrow field of view of the transceivers. An autonomic acquisition algorithm is necessary for transceivers in a pair to “find” each other and establish a link, with limited information about the precise location of the nodes involved. For mobile platforms, an additional tracking algorithm is required.



An agile transceiver with a high-performance motor.

Our goal is to develop an all-optical autonomic acquisition and tracking algorithm. The acquisition algorithm is not a three-dimensional but a six-dimensional problem. This means that before the transceivers can start to scan, coaxial pointing has to be achieved. A Fish-Eye converter (normally with FOV of 180 degree) is a good solution. Rays arriving at different angles will be imaged to different locations on a CCD imaging array. Only when the two transceivers are coaxial is the arrival ray pointed to the center. Therefore, by edge detection of the CCD image, coaxial alignment can be achieved.

Once the scanning process is complete, the system has finished its acquisition process and a link is established. During scanning we record results into a link table in order to perform the acquisition process.

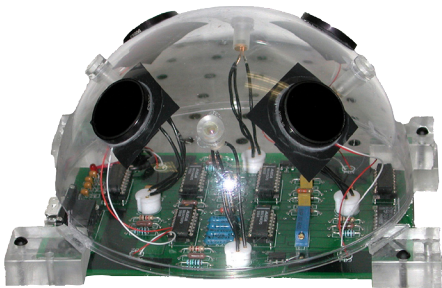
In a tracking process, motion prediction techniques will be applied. By quickly analyzing the image of a beacon on a CCD array between two continuous images, we will be able to track a moving transceiver.

Hybrid Optical/RF Links and Networks

To address a major concern for optical links, namely their failure because of atmospheric obscuration, we are studying hybrid optical/RF links in which high performance RF provides a “backup” connection in optically obscured conditions. The RF can also assist in pointing, acquisition, and tracking of the optical beams during network setup, using either RF direction finding, or the RF broadcast of the GPS locations of transceivers.

Omnidirectionality

While omnidirectionality is an important capability, in optical wireless communications, point-to-point links are generally used. We have created a prototype of an omnidirectional optical wireless system, and analyzed and characterized its performance.



A prototype of an omnidirectional optical wireless system.

The omnidirectional transceiver uses four independent transmitters and four independent receivers in a quadrant arrangement. We use special beam diverging optics in front of the laser diode-based transmitter and spatial diversity based receiver to achieve communication over moderately long distances (up to 10 meters). To obtain longer distances, higher power laser diodes are needed, which increases the complexity of the driver and controller circuits.

Special optics such as compound parabolic concentrators (CPCs) can be used to get better omnidirectionality performance in a slightly more complex arrangement.

Spatial diversity can improve receiver performance. The use of narrow field-of-view (FOV) receiver elements can improve the performance of a non-directed optical wireless link. Applying better and more complex equalization and signal processing techniques also can improve performance

A multilayer approach to topology control

The performance of optical wireless networks is highly dynamic because of changing atmospheric and platform conditions.

Topology control is a multilayered approach to providing improved network performance in adverse conditions. It is emerging as a technique for achieving survivable optical networking based on dynamic and autonomous topology reconfiguration.

With optical wireless links and networks with topology control we can provide a scalable network, in contrast to the fundamental non-scalability of broadcast RF networks.

Support

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Companies

Research on optical wireless is being carried out with two company partners: Techno-Sciences, www.technosci.com; and Lumenlink, www.lumenlink.net/.

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