



Free-space optical transmission improves land-mobile communications

Technology that is widely used in static environments for wireless transmission, is being adapted to achieve high data rates in a mobile application.

10 January 2007 Hennes Henniger and Bernhard Epple

The increasing emergence of data services for mobile applications requires high-speed connection technologies able to support mobile ad-hoc networks. To this end, free-space optical (FSO) communications technology has the potential to outperform that at radio frequency (RF) in terms of data rate, size, mass, and power consumption of network terminals. Furthermore, narrow optical beams have the inherent advantage of being nearly undetectable—and therefore more secure—than RF signals.

Unfortunately, the narrow beams create difficult constraints for the pointing and tracking abilities of the communication terminals. In land-mobile systems—for example, transmissions between moving vehicles—where objects such as trees or buildings can frequently block the line of sight (LoS), fast re-acquisition is necessary in order to reduce link outages.

For a terminal to acquire a communication partner, the position of the counter terminal must be known. This information can be communicated using a low-rate nondirectional RF signaling link. Using this technique combined with FSO technology, we have demonstrated that it is possible to implement a high data rate land-mobile optical communication system that is difficult to detect and capable of handling link blockings.

The setup used for our demonstration consists of an optical free-space communication terminal mounted on an arbitrary moving vehicle, and a fixed optical ground station (OGS). The distance between the moving vehicle and the ground station varies between 1300m and 1900m. A high definition camcorder serves as a data source, producing a 1.5Gbps synchronous data-stream that is transmitted from the mobile terminal (MT) to the OGS. The optical communication system operates with intensity modulation at a wavelength of 1550nm. To demonstrate the reacquisition process, some obstacles temporarily block the LoS while the vehicle is moving with a velocity of up to 30km/h. In the case of short-term blockings, the terminal can keep the pointing accurate enough to immediately resume communication after the LoS is cleared.¹

The transmission beam on the MT is also used as its own beacon. With a low transmission power of just 180mW, the terminal operates eye-safe. Both terminals, MT and OGS, are built with widely available and cost-effective off-the-shelf components. (Figures 1 and 2 show the designs of the MT and OGS, respectively).

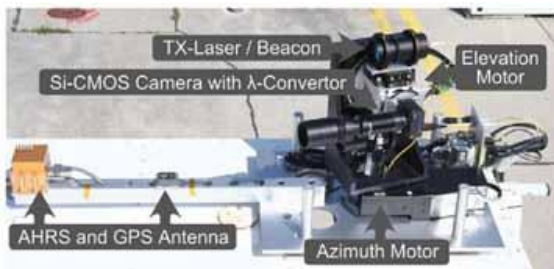


Figure 1. The mobile terminal includes a laser/ beacon telescope and tracking camera positioned on an azimuth/elevation mount. The altitude and heading reference system (AHRS) is aided by a global positioning system (GPS) to track the terminal's location. The λ -converter is used to observe the 1550nm beacon with a standard silicon camera. TX: Transmitter.



Figure 2. The optical ground station includes a 500mW beacon, InGaAs tracking camera and 200mm telescope positioned on an azimuth/elevation mount. The wide field of view (WFOV) camera is only used for demonstration purposes. RX: Receiver.

In the demonstration scenario, the OGS is fixed at a known position, with its orientation measured in advance. The MT, however, remains mobile throughout the demonstration, and its position and orientation are not predetermined. The MT is equipped with a global positioning system (GPS)-aided attitude and heading reference system (AHRS). To broadcast its current position, the MT uses a 9.6kbps RF transmitter operating at 868MHz.² The OGS receives the MT's position signal and points its beacon towards the MT to set up a connection. The MT knows the predefined location of the OGS, and points its optical head permanently towards it. When both terminals light each other with their beacons, they can switch to former mode and begin data transmission. The fine-pointing is accomplished via optical tracking using the installed cameras (see Figure 3) and blob extraction algorithms. To ensure that the terminals would be capable of detecting each other on the camera images, the field of view of the cameras and the divergence angles of the beacons were designed to compensate for errors in the coarse-pointing process.^{1,3}



Figure 3. Successful mobile optical data transmission was achieved over 1900m at 1.5Gbps. The image shows the transmitted stream from the high definition television (HDTV) camcorder (right), the moving van with an 800nm test-beacon shown by the wide field of view camera (lower left) and the eye-pattern of the received signal (upper left).

We have shown that it is possible to build land-mobile optical communication terminals using solely off-the-shelf components. The demonstrated automatic pointing, acquisition, and tracking system reduces the impact of obstructions to a minimum and enables high-quality FSO data communications in a mobile environment.

A future point of research will be to optimize the terminals for more agile and accurate pointing, extending the field of applications to cross-country environments and enhancing link distances. Further error-correction coding will be developed in order to address short link outages.⁴

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Hennes Henniger received his Dipl.-Ing. degree from the University of Applied Sciences, Munich, in 2002, and his Master of Science degree in 2004. He joined the optical communications group of the Institute for Communications and Navigation in 2001. His current research interests include techniques for fading mitigation, such as diversity concepts and forward error correction coding. Henniger is also serving as a program committee member for the SPIE's conference on free-space laser communications at the Optics & Photonics symposium in 2007.

Bernhard Eppler received a Dipl.-Inf. degree in computer science from Ludwig-Maximilians-Universität, Munich in 2004. Since then he has been with German Aerospace Center (DLR) in Oberpfaffenhofen, Germany, as part of the optical free-space communications group. His current research interests include efficient algorithms for mobile optical system communication and multiple communication partners.

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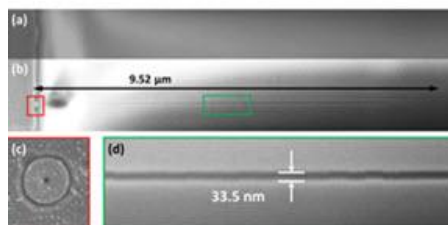
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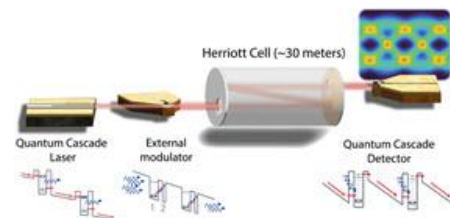
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