Cloudy day won't rain on laser communications

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Just as clouds block the sun, they interfere with laser communications systems, but Penn State researchers are using a combination of computational methods to find the silver lining and punch through the clouds.

"Radio frequency communications are generally reliable and well understood, but cannot support emerging data rate needs unless they use a large portion of the radio spectrum," says Mohsen Kavehrad, the W. L. Weiss professor of electrical engineering and director, Penn State Center for Information and Communications Technology Research. "Free space optical communications offer enormous data rates but operate much more at the mercy of the environment."

Laser light used in communications systems can carry large amounts of information, but, the dust, dirt, water vapor and gases in a fluffy cumulus cloud, scatter the light and create echoes. The loss of some light to scattering is less important than those parts of the beam that are deflected and yet reach their target, because then, various parts of the beam reach the endpoint at different times.

"All of the laser beam photons travel at the speed of light, but different paths make them arrive at different times," says Kavehrad. "The Air Force, which is funding this project through the Defense Advanced Research Projects Agency, would like us to deliver close to 3 gigabytes per second of data over a distance of 6 to 8 miles through the atmosphere."

That 6 to 8 miles is sufficient to cause an overlap of arriving data of hundreds of symbols, which causes echoes. The information arrives, but then it arrives again because the signal is distributed throughout the laser beam. In essence, the message is continuously being stepped on.

Kavehrad and Sangwoo Lee, graduate student in electrical engineering, presented their solutions to the echo problem at the recent IEEE Military Communications Conference in Wash., D.C.

"In the past, laser communications systems have been designed to depend on optical signal processing and optical apparatus," says Kavehrad. "We coupled state-of-the-art digital signal processing methods to a wireless laser communications system to obtain a reliable, high capacity optical link through the clouds."

The researchers developed an approach called free-space optical communications that not only can improve air-to-air communications, but also ground-to-air links. Because their approach provides fiber optic quality signals, it is also a solution for extending fiber optic systems to rural areas without laying cable and may eventually expand the Internet in a third dimension allowing airplane passengers a clear, continuous signal.

Using a computer simulation called the atmospheric channel model developed by Penn State's CICTR, the researchers first process the signal to shorten the overlapping data and reduce the number of overlaps. Then the system processes the remaining signal, picking out parts of the signal to make a whole and eliminate the remaining echoes. This process must be continuous with overlap shortening and then filtering so that a high-quality, fiber optic caliber message arrives at the destination. All this, while one or both of the sender and receiver are moving.

"We modeled the system using cumulus clouds, the dense fluffy ones, because they cause the most scattering and the largest echo," says Kavehrad. "Our model is also being used by Army contractors to investigate communications through smoke and gases and it does a very good job with those as well."

The computer modeled about a half-mile traverse of a cumulus cloud. While the researchers admit that they could simply process the signal to remove all echoes, the trade-offs would degrade the system in other ways, such as distance and time. Using a two-step process provides the most reliable, high-quality data transfer.

The system also uses commercially available off-the-shelf equipment and proven digital signal processing techniques.

Source: Penn State