Science on the ISS_Lasers

In space-to-ground communications, radio is on the way out. It's old technology. It's doesn't cut the mustard anymore. It's *Oh, how quaint, you still use radio…* The problem is that it's slooow… Well, of course radio travels at the speed of light, so maybe slow isn't quite the right word, but radio's information-carrying capacity is a bit ordinary.

Transmitting data via electromagnetic radiation requires modulation of the radiation's waveforms (at the transmission end) so that someone (at the receiving end) can decode those modulations into a meaningful message. In the case of radio, you can certainly encode data into the waveform, but it's a bit like using a blunt stick to carve a message into wet sand. With the finer wavelength of optical light it's more like writing on fine paper with a ballpoint pen. So even though both radio and optical light move at the same speed, you can move a lot more information per unit time when you use optical light.

Optical light wave modulation, for the purpose of carrying information, was demonstrated by Alexander Graham Bell in 1880, using his patented Photophone. Bell regarded the Photophone as a much more important achievement than his moderately-successful Telephone and the world's first-ever wireless phone call was made with the Photophone on the 3rd of June 1880, between two buildings separated by about 200 metres.

The Photophone essentially involved someone shouting at a flexible mirror while it was reflecting sunlight. The mirror's geometry was slightly disturbed by the sound waves striking it and those slight geometric disturbances modulated the waveforms of the sunlight being reflected off the mirror.

The beam of reflected sunlight carried that embedded modulation to a receiver made of selenium, which then passed a current to a speaker system. Selenium physically reacts to transmitted light and the way that it reacts will be modified if the light it absorbs has been modulated – which will affect the way that it passes current to a speaker system.

So the nett result is that an audio speaker at the receiving end mimics the way the mirror at the transmission end was disturbed by being shouted at – and voila you have yourself a Photophone. Bell was so pleased with the outcome he became determined to name his newly-born daughter *Photophone*. But fortunately his wife thought differently. One imagines that particular conversation did not take place over any type of phone.

In any case, the Photophone never took off in a big way, since its signal was easily disrupted by atmospheric disturbances, which could be anything from light rain to heat haze. It could also be disrupted by material objects, like passing birds and of course buildings. While radio's information-carrying capacity may be limited, it is wonderfully unperturbed by such things. You can pick up radio inside a log cabin, in the middle of nowhere, while a thunderstorm is raging about you.

Of course, these days we use optical fibre to transmit information by optical light pretty much anywhere we want on Earth – but we can't very well run a cable up to the ISS. Fortunately, the vacuum of space is an excellent environment for laser transmission. Down on Earth we can only send a 'free air optical communication' across a distance of 2 to 3 kilometres before atmospheric disturbance degrades the signal too much. But in a vacuum, we can send optical light messages between planets.

In the vacuum of space, the distance record for a successful handshake by laser light is about 24 million kilometres, using a 'lasercomm' system that was mounted on the Messenger spacecraft, while it was preparing for its long distance journey to Mercury.

More recent projects have trialled sending real data. For example, the lasercomm experiment aboard the recent LADEE mission to the Moon successfully transferred a complete digital image of the Mona Lisa. Even more recently in 2014, the ISS has trialed OPALS, the Optical Payload for Lasercomm Science, a lasercomm system launched aboard a Space X resupply mission in April 2014 and then installed on the outside of the ISS. In June 2014, it successfully downloaded a 20 megabyte video file, entitled 'hello world', to the ground in 3.5 seconds – something that would have taken about 10 minutes via radio.

Managing a lasercomm connection from the ISS to the ground is complicated by the fact that the station is moving at nearly 8 kilometres a second relative to the ground. To maintain a link the laser emitter had to swivel to stay locked on its ground target and even then its ground target was only in line of sight for a minute or two.

Now, this might start you thinking how the heck the ISS manages to stay in radio contact with the ground at all, when a space-to-ground connection site is only in line of sight for a minute or two. The ISS is linked by radio to the Tracking and Data Relay Satellite, or TDRS, network – which is a fleet of around seven satellites sitting in geostationary orbit. The ISS can link to whatever TDRS unit happens to be in line of sight at any time and that signal is then relayed around all the TDRSs until it reaches the one above White Sands, New Mexico, which is linked to a server on the ground. This means that despite moving at 8 kilometres a second and orbiting the planet every 92 minutes, the ISS can stay in regular radio contact with Earth and because of this it can also access our ground-based internet.

They say the station's internet speed is nearly as good as your average household connection, except it has all the usual latency issues associated with satellite-mediated internet. So, you can post a twitter message or download a file, but a cumulative lag becomes noticeable during any back and forth data transactions, because you are connecting via geostationary satellites that sit at 36,000 km altitude. So, due to this latency problem, you can forget about on-line gaming.

But with lasercomm, you probably could manage online gaming from the ISS, *if* you could set up laser connections (instead of radio) between a fleet of geostationary satellites like the TDRSs. And, in fact, there is a plan for the next generation of TDRSs to have both radio and laser relay capability.

But NASA aren't doing this just so the astronauts can play online games. With a laser-enabled relay network, Earth could also receive laser comm signals from deep space, that is from our own spacecraft that are out there exploring the Solar System.

With radio, it can take about an hour to download a 10 megabyte data file from Mars, so we have to be very conservative about how much data we collect and how much we send back. Laser comm will increase data transfer speed and hence daily data transfer volumes from space, by at least ten times and as much as a hundred times under the right conditions. That means we'd get a lot more science data from Mars, once we start sending hardware with laser comm capabilities. Indeed, that would be more efficient in all sorts of ways, since a laser transmitter is smaller, lighter and needs less power than a radio transmitter does.

Now that the ISS has successfully trialled OPALS the next big step will be the LCRD, the Laser Communications Relay Demonstration, which is planned for launch in 2017. This will be a laser-relay enabled Earth-orbiting satellite.

But laser-enabled relay satellites face an extra problem that doesn’t affect the current radio-enabled TDRS units.

Unlike radio, laser light can’t penetrate clouds, so a global network of laser-enabled geostationary satellites will need to have multiple connections with the ground, so that there’s always at least one satellite with clear weather below to make the space-to-ground link. That’s a whole new level of complexity we’ve never have had to worry about before, which is why we are taking it slow, seeing if one thing works before we take the next step.

Anyhow, the ISS OPALS trial was a success, so now we are taking a next cautious step with the LCRD laser-enabled geostationary satellite. If it all works, the astronauts might then be able to indulge in a little online gaming. After all, even they sometimes need a break from doing all that science on the ISS.