Webinar "Wireless Laser Communication: Don't let clouds get in the way of success!"

Q&A

Answers by Reuniwatt and Airbus

FSOC

Q. Do you think FSOC will replace RF communication?

A. Airbus: Just like we have heterogeneous networks on the ground, we can expect to see them regarding the deployment of free space optical communications. For example, the major links up to aircraft or satellites could be provided by optical communication and supplemented by different types of RF technology.

Q. Will FSOC be the base of space-to-Earth communication in the future?

A. Airbus: Historically, that was one of the areas which pushed the development of FSOC technology forward. Wireless Lasercom offers two advantages: It needs little energy supply while providing high data rates, which makes it very attractive for space missions, e.g. it allows for the use of much smaller telescopes to be able to transmit a certain amount of data back from Mars to us, and has expanded the data transmission boundaries for space missions beyond the earlier standards.

Q. Which key advances in optical components will support inter-satellite FSOC?

A. Airbus: We see improvements in technology happening in mirror designs, fiber amplifiers and positioning technologies. Latter are mature from a capability perspective, but still relatively expensive. From the optical antenna and back-end electronics perspective, it is important for improving communication payload to rely on optical communication as long as possible: For this purpose photonic integrated circuits were developed, which allow for higher efficiency in the areas of multiplexing, demultiplexing, managing channels etc. Bringing these technologies into orbit and installing them on satellites is essential to counteract potential bottlenecks inside the spacecraft and update the state-of-the-art of onboard payload communication. In short: The communication onboard the satellite must support the communication to/from it.

Q. Which wavelengths are most often used for FSO links?

A. Airbus: The Consultative Committee for Space Data Systems (CCSDS) is a multi-national forum for the development of communications & data systems standards for spaceflight which is setting the standards in this question. Currently, the standardly used wavelengths are 1064nm and 1550nm. 1064nm has been traditionally used for optical links based on the availability of hardware components early in the development of FSOC, but suffered from constraints regarding the export and import of the relevant hardware. 1550nm has now become a standard wavelength for the

telcom industry and hardware is widely available. For this reason, and because it favours a good transmittance through the atmosphere, it is now being standardly used for FSOC.

Q. What are current FSOC related activities of your company?

A. Airbus: Airbus is a world leader in optical communications. Regarding satcom, we have a lot of operational experience. One notable project is the Space Data Highway, a public-private partnership between ESA and Airbus. One focus of airbus lies in closing the hardware compatibility gap between LEO and GEO satellites and the terrestrial networks.

A. Reuniwatt: Since years, Reuniwatt has been working together with the Saint-Exupery Technological Research Institute IRT. Together with them, we have been working on the BroadBand Satellite Access project ALBS (2014-2020). Currently, we are on board the 4-year research project ANAtOLIA funded by ESA, aiming to overcome cloud cover, aerosols and turbulence in FSOC.

Q. Do you think FSOC will enable 24/7 connectivity and how far from that point are we?

A. Airbus: I think research is going in the direction of prevention rather than reaction regarding the cloud cover over a particular ground station. This will eventually lead to telecommunications operators building a system intelligent and autonomous enough that the open question will not be whether 24/7 connectivity is possible, but rather what is the appropriate balance to achieve the level of operations that makes sense for an end customer.

A. Reuniwatt: From a cloud forecasting perspective, we have worldwide experience, especially regarding solar power forecasts. We're able to make a good site survey to select appropriate locations for reliable ground stations for 24/7 connectivity via FSOC. There are already some preliminary studies which show that it's possible, and the ongoing project ANAtOLIA will also provide a deeper insight into atmospheric monitoring for optical ground stations.

Q. In your opinion, what will be the next important advances in FSOC?

A. Airbus: For satellite-to-ground links, they are not widespread enough to get a real commercial sense of what customers are looking for. Without the direct customer feedback, it is hard to know what key technologies and key components need to be advanced. The work that Airbus and Reuniwatt are doing together is focusing on one of the major issues of FSOC: We are trying to make the cloud question obsolete, so standard and existing optical communications technology can be used to start building up a system, which can later be adapted to the need of the customers.

Another important topic for customers is cost-efficiency. Traditionally the FSOC community focused on the smallest possible number of ground stations at the best locations. Really high availability comes at a price. We are trying to establish a balanced approach looking to find good sites for a sufficient number of ground stations, respecting cloud cover statistics, availability and weather prediction as well as existing telecommunications infrastructure and overall costs. The work of Reuniwatt is a very critical component for answering those questions.

Q. Who could be the typical customer for FSOC systems?

A. Airbus: Of course, ground station and satellite systems operators are typical customers. But wireless lasercom allows us to bring optical fibre capacity to places where there is no fibre. Remote

offgrid power plants at locations suitable from cloud cover perspective could use laser links to connect to other areas via FSOC.

Q. Do you think we can overcome atmospheric turbulence by using adaptive optics?

A. Airbus: It is important to realize that there are weather complications even with RF systems. Major rain will cause signal degradation – possible rain outages require rain prediction. Satellite ground station operators are familiar with this issue and handle it – and analogous processes need to be defined for optical communications.

A. Reuniwatt: There have been many improvements in the recent years, but the technology – just as cloud forecasting – has to step up from test systems into real life FSOC systems, because operational challenges are always different from what you see in research.

Q. What do you think would be the optimal constellation for commercial FSOC systems?

A. Airbus: The market is driven by the LEO constellation segment. They are marketed as having lower latency, better connectivity and cheaper access. It will allow for deployments of FSOC systems. However, GEO satellites have much larger coverage and LEO constellations might be supplemented by them. Also, the type of service will play a role in whether the constellation involves LEO satellites, GEO satellites or both.

FORECASTING

Q. What is the range of the Sky InSight™ sky imager?

A. Reuniwatt: The range of a sky imager mainly depends on the cloud base height. If you have very low clouds, the field of view will be reduced. For high clouds, such as cirrus clouds, the field of view can be up to a radius of 50km around the camera. The range can be extended by using a stereoscopic approach and installing multiple sky imagers, and satellite images used in combination with the skycam will also improve the range of the forecasts.

Q. Does the sky imager work at night?

A. Reuniwatt: Because we are using an infrared thermal camera, the sky imager will see the clouds during the day and at night with the same sensibility.

Q. Is there enough good data available to use NWP for cloud forecasting?

A. Reuniwatt: NWP are powerful tools for weather forecasting and have improved over the last years along with higher computing power. However, they are better suited for day-ahead forecasts (from 6 hours to several days ahead). For short-term forecasting, computing processes are to slow. So even if all available data was high quality data, computing power is simply not sufficient to provide short-term forecasts. The image processing approach is better and more efficient.

Regarding forecast precision, the best results can be delivered by a synergy of the adequate tools. For forecasts 1min ahead up to 15min ahead, the best tools are all-sky imagers. From 15min ahead

up to 6 hours ahead, satellite-based forecasts should be used in addition, and beyond 6 hours, NWP will provide the best results.

Q. What's the precision of your forecasts? How to best evaluate the forecast errors of the sky camera? How does forecast precision change with prediction time?

A. Reuniwatt: The question of precision is a real scientific issue, still much debated in the forecasting community. What is important to remember is that performance can be described along three axes:

- The **weather sensitivity** for the location: For the French overseas islands, it is mainly the tropical climate, to which must be added the extremely important concept of microclimates. For example, on the 2500 km² of Reunion Island, there are no less than 200 microclimates! We must also add the notion of seasonality. In tropical climates, the summer is generally very hot. With the sea nearby, this will create a favourable ground for evaporation and therefore for cloud formation. In winter, evaporation being weaker, we will mainly see clouds moving. Thus, the meteorological phenomena to be taken into account vary according to the location and will directly influence performance.

- The **quality of input data**: Reuniwatt aggregates a lot of data from different sources, such as measurements from pyranometers in real time. This input data is then used to calibrate our forecasts, which means that there is a real O&M (Operations & Maintenance) challenge to work on over time so that this quality monitoring system remains effective.

- The **metrics**: How do we evaluate the precision of a forecast? The most commonly used scientific metric is the nMAE ("normalized Mean Absolute Error"). Climatological analyses to identify the meteorological phenomena at the sky imager location or "backtests" (forecasts made under real conditions but on past data sets) can help estimate forecast performance. It should also be noted that forecast performance will improve with time.

The forecast accuracy will decrease with the forecasting horizon, so a combination with satellite-based forecasts and NWP is necessary for longer forecasting horizons.

Q. Are you also measuring index turbulence as a limitation of pointing accuracy?

A. Reuniwatt: Turbulence is another key parameter for FSOC. While cloud observation is the most important, because clouds can completely block the signal, turbulence monitoring devices are available and Reuniwatt can offer an integrated solution.

Q. Which NWP models do you use?

A. Reuniwatt: We use different global numerical weather models, e.g. GFS and ECMWF. Besides that, Reuniwatt also uses a regional model, the WRF model. Each model has its strengths and weaknesses, and you do have to combine different models to get the best possible result.

OTHER QUESTIONS

Q. I would like to contact you.

A. If you have questions concerning the content of this webinar you can contact our speakers Kevin Shortt (Airbus), Olivier Liandrat (Reuniwatt) and Lola Courtillat (Systematic Optics & Photonics Hub) directly – we are happy to answer your questions ! For any other questions, be sure you will be forwarded to the right counterpart when contacting us here:

Airbus: https://www.airbus.com/

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