Webinar "No Clouds on the Horizon: The Future Looks Bright for FSOC"

Q&A

Answers by Mynaric and Reuniwatt

FSOC TECHNOLOGY

Q. Are the detectors (receivers), assumingly APDs/photodiodes, based on a single diode or an array of diodes (like an image sensor)?

A. Mynaric: Coherent transceivers usually used balanced PIN diode as detectors to ensure that only the beat signal between the received light and the oscillator will be amplified. Avalanche photodiodes are typically used for OOK at "lower" data rates or when using single photon detection as with pulse position modulation.

Q. How can higher data rates be achieved using modulating retro reflectors on aerial/space platforms for FSO links?

A. Mynaric: The link budget is not very favorable for modulating retro reflectors, these concepts are usually only considered when power on one site is abundantly available, while on the other side it is at a premium, also the modulating frequency is not high enough to achieve Tbit/s performance (or even Mbit/s in most cases). Also consider that e.g. NASA's TBIRD CubeSat has demonstrated 200G data rates from space to ground , so modulating retroreflectors are more for certain niche 'extremely low power on the far side' applications.

Q. What is the footprint and aperture diameter of your ground terminal?

A. Mynaric: The RHINO Mk1 has an aperture diameter of 400mm, while the next generation ground station (currently under development) will increase this substantially. However, both are still fitting into a moderately sized dome for protection from the elements, i.e. still fits into a cargo container for shipping and transporting.

Q. Does Mynaric develop transceivers by themselves, or do you use it from the available fiber telecom players?

A. Mynaric: These are co-engineered with some of the big names in the telecom world as technology partners in order to work in the harsher aerospace and space environment as the usual COTS part would not work here "as is".

Q. How can the sporadic atmospheric fading be countered using COTS CFP2-DCO modules as they contain only SD-FEC?

A. Mynaric: These modules work well as long as "enough" light is available, i.e. links through the atmosphere would usually be operated at considerable link margin, so that fades that would actually effect the link to the point that the signal drops below the FEC threshold are statistically rare. There are also options to run additional interleavers around the data stream, so that even if

short fades would corrupt the data beyond recovery without them, the gap can be recovered. However, these interleavers would add to latency, so that standards as the one from the SDA actually require an Automatic Repeat reQuest (ARQ) to be implemented with the data being buffered for a short time in case an ARQ occurs.

Q. What adaptive optics techniques should be used for fine tracking PAT in mobile FSO systems?

A. Mynaric: Fine tracking should be robust enough to not require adaptive optics per se. That said, adaptive optics absolutely is a must have for the ground segment when using fiber coupled receivers and especially when using multiple carriers and/or coherent receivers for the data itself.

Q. How much Doppler Shift (in GHz/nm) can be compensated using the tunable Tx and LO lasers present in the CFP2-DCO modules?

A. Mynaric: At 1550 nm about +/- 8 to 10 GHz should be sufficient for almost all link scenarios, when also considering the thermal drift of the seed (TX) laser and local oscillator, which is almost in the range of what COTS telecom transceivers can cover out of the box.

Q. Is there any development or integration of adaptive optics into the Mynaric OGS?

A. Mynaric: Yes

OGS SITE SELECTION AND CLOUD OBSERVATION

Q. How many years of data do you require for a site survey?

A. Reuniwatt: It's always interesting to have at least one year to observe seasonality. Several years is even better.

Q. Are there datasets for covering time series variations for polar regions for OGS site assessments?

A. Reuniwatt: Data from geostationary satellites are only valid for latitudes < 65°. For polar sites, other options are available depending on location. Obviously, a measurement campaign will give the best results. Get in touch with us and we'll suggest the best options for your sites of interest.

Q. Up to how many LEO satellites can you predict simultaneously regarding the cloud coverage when we are performing a satellite tracking run?

A. Reuniwatt: There is no absolute limits in the number of LEO satellites forecast we can provide.

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

A. Reuniwatt: The range of the Sky InSight™ will depend on the Cloud Base Height. The worst-case scenario would be fog: the range is a few meters. Generally, the range is between tens to hundreds of kilometers.

Q. How does your sensor compare to others on the market?

A. Reuniwatt: Most sky imagers use visible sensors, which limits operations to daytime only. Furthermore, although some thermal imagers are described in scientific literature, our camera is the only one with such industrial experience: our Sky InSights™ have been operating all over the world for over 10 years, under all types of climates.

Q. What other hardware do you offer besides Sky InSight™?

A. Reuniwatt: We also manufacture visible-range sky imagers. This visible –range imager is called Sky Cam Vision™.

Q. Are you working on the next generation of Sky InSight™?

A. Reuniwatt: Our R&D team continuously works on improving the robustness of the imager, and developing new features associated with the equipment. This involves monitoring new sensors to increase resolution and sensitivity, as well as working on the validation of our algorithms.

Q. How about using flash LiDAR for cloud observation?

A. Reuniwatt: LIDARs are obviously a good complement to wide-angle cameras. We already have some experience in data fusion. If you'd like to try out new approaches with us, please don't hesitate to contact us.

Q. How can a ground station join the ANAtOLIA network?

A. Reuniwatt: Please contact us for this question. We'll put you in touch with the consortium. You can contact us at teammarketing@reuniwatt.com.

OUTLOOK

Q. Which key technologies will allow for the large deployment of free space optical communications?

A. Mynaric: Design for manufacturing, assembly, integration, and test (MAIT) is key to make optical communications scalable enough and affordable enough for large deployments. For this reason, especially for larger constellations, also Design-to-cost and delivery on time are key factors.

A. Reuniwatt: We may be advocating for our cause… but a key technology undoubtedly lies in mastering the uncertainty associated with clouds through reliable observation and forecasting of cloud optical thickness!

Q. Will purely electronic beam steering be possible in the foreseeable future?

A. Mynaric: There have been some interesting developments in the past years, but reducing the losses in the non-mechanical beam steering device has so far been limiting the power levels that can be used with these devices before their performance starts to degrade. However, this is likely something that can be overcome in one way or another in the foreseeable future. The next limiting factor would then be scaling the technology up to the desired beam sizes.

Q. How about blue/green lasers to help reduce cloud & precipitation fade, so networks don't have to move ground stations, or a UAV at higher altitude (above clouds) to retransmit at rf/mmw to avoid complete signal loss?

A. Mynaric: At blue wavelengths atmospheric scattering could become prohibitive in attenuation. Also note that shorter wavelengths will make the impact of wavefront error and point stability more severe and could be detrimental to actual real-life performance and certainly cost. This was already seen to be the case for 1064 nm, despite some aspects of the system being far more favorable in terms of performance (optical amplifiers and availability of extremely stable lasers, with very low intensity and phase noise and extremely small linewidths). Most of these impairments have been overcome by design and clever engineering for the 1550 nm C-band, which is why these wavelengths are currently the sweet spot for overall system performance.

GENERAL QUESTIONS

Q. What opportunities for students/interns do you have?

A. Mynaric: Lots. We are always looking for students who are interested in working with us in the lab on software, hardware, as well as test and measurement setups, and even gaining experience in design, simulation, etc. Some of our best engineers started as students or interns and were hired for permanent positions after they finished their degree.
https://mynaric.com/careers/working-students/

A. Reuniwatt: Reuniwatt offers student internships in meteorology, machine learning and related topics. To find out more, take a look at our internship page: https://reuniwatt.com/en/master-student-internships-data-science-for-renewables/

Q. How can I contact you?

A. For any other questions, be sure you will be forwarded to the right counterpart when contacting us here:

Mynaric	https://mynaric.com/company/contact-us/
Reuniwatt	https://reuniwatt.com/en/contact-us/
Fraunhofer IOSB	https://www.iosb.fraunhofer.de/de/kontakt.html