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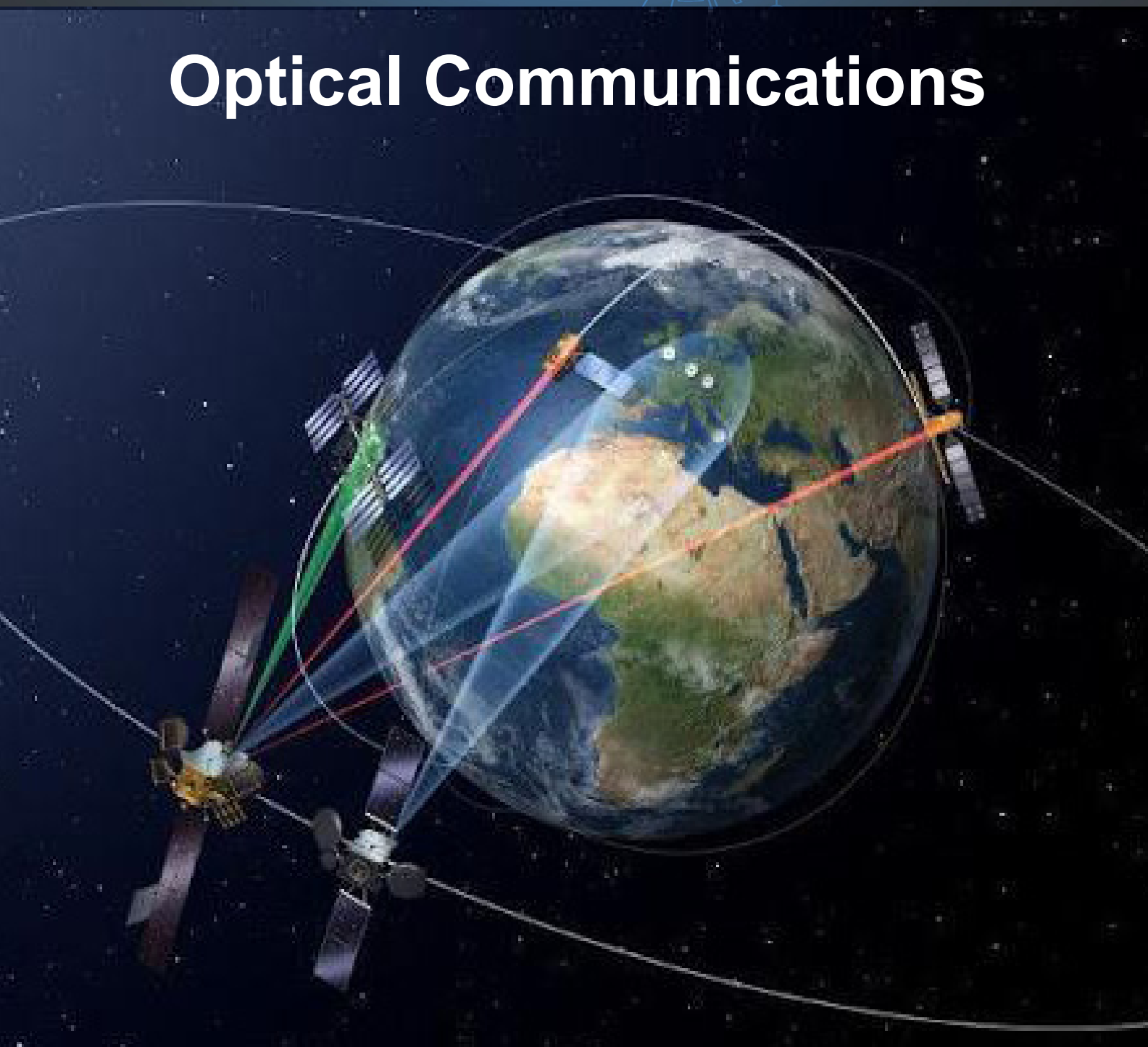
Optical Communications



Optical Communications for Satellite Applications

by Virgil Labrador

Optical communication is communication at a distance using light to carry information. Optical communication has actually existed since the advent of civilization since it encompasses communication by sight using signals or more recently by electronic means. For the purpose of this article, we will focus on optical communication using electronic devices, specifically as it applies to satellite communications.

An optical communication system uses a transmitter, which encodes a message into an optical signal, a channel, which carries the signal to its destination, and a receiver, which reproduces the message from the received optical signal. Optical networking systems using optical fiber, optical amplifiers, lasers, switches, routers, software and other related technologies. Free-space optical communication ((FSOC) use lasers to transmit signals in space, while terrestrial forms are naturally limited by geography, weather conditions and the availability of light.

image courtesy of Critical Frequency Design

Optical fiber is the most common type of channel for optical communications. The transmitters in optical fiber links are generally light-emitting diodes (LEDs) or laser diodes. Infrared light, rather than visible light is used more commonly, because optical fibers transmit infrared wavelengths with less attenuation and dispersion. The signal encoding is typically simple intensity modulation, although historically optical phase and frequency modulation have been demonstrated in the lab. The need for periodic signal regeneration was largely superseded by the commercial introduction of dense Wave Division Multiplexing (WDM) based on a dual-stage erbium-doped fiber amplifier, which extended link distances at significantly lower cost. The introduction of WDM greatly enhance the potential of optical networking.

Free-space optical communications (FSOC) systems are employed for 'last mile' telecommunications and can function over distances of several kilometers as long as there is a clear line of sight between the source and the destination, and the optical receiver can reliably decode the transmitted information. Other FSOC systems can provide high-data-rate, long-range links using small, low-mass, low-power-consumption subsystems which make them suitable for communications in space. FSOC can achieve multi-Gbps up to multi-Tbps data rates due to the wide optical spectrum.

Various planned Non Geostationary Orbits (NGSO) satellite constellations aiming to provide global broadband coverage are looking to use optical laser communication for inter-satellite links between the several hundred to thousands of satellites effectively creating a space-based optical mesh network.

In the next few years, optical communications technologies will be playing a vital role in near Earth and deep space missions. "Optical ground

stations have emerged as an effective solution for mission operators and service providers who are facing a global gridlock in optical downlinks as they provide a solution to the chicken or the egg dilemma: The lack of available ground stations has prevented the industry from developing spacecraft with optical downlinks. Due to a lack of demand, few optical ground stations have been developed," said Jorg Rockstroh, Director of Business Development and Digital Products at WORK Microwave.

Market Potential

According to NSR's recently published report "Optical Satcom Markets, 3rd Edition," the market for optical communication terminals represents a US$ 3 Billion opportunity over the next ten years. NSR forecasts more than 1,000 terminals for space-based applications to be shipped by 2025. This includes not just for satellite applications, but also for near earth applications using larger Unmanned Aircraft Systems (UAS).

According to NSR, Radio frequency communication (RF) has yet to reach the limit of its inherent capacity offer. This is, however, expected to change with the emergence of increasingly data-heavy applications which, in the long-term, will drive the adoption of Optical Satcom. Specifically, Optical laser communication may boast superior data rate speeds even if in the near to medium-term, pricing of equipment is a big impediment to compete with RF such that the upcoming cadence of demos should help drive volume and in turn, impact prices.

While SpaceX is currently producing terminals in-house, other players in the Optical Satcom market are launching over 15 in-orbit demonstrations in the next 3 years. Airbus and Xenesis, AAC Clyde' subsidiary Hyperion Technologies, the U.S. Department of Defense (DOD), and NASA are just some of the many players planning demos, according to NSR. This implies that the industry will likely see an increase in offers of various space-verified laser terminals and related necessary components. In the near-term, suppliers are scrambling to get their production lines operational as revenues mature post 2025, and lower volume terminals are expected to be brought to the market with economies of scale that will lower the price.

Key Benefits of Optical Communications

Higher Throughput--Due to the wide optical spectrum, optical communications can achieve multi-Gbps up to multi-Tbps data rates.

No interference--Unlike RF signals, optical communications are very focused using lasers where there is little opportunity for interference.

Less CAPEX, Faster Time to Market--Optical ground stations require less equipment and therefore is easier and faster to build at lower cost.

Low Latency, High Reliabilty and Security--As optical communication travels at the speed of light it has less latency and high reliability. Due to the narrow beam widths they are more secure.

Benefits

"The main strengths of optical technology for satellite applications like earth observation (EO) include higher throughput per communication window, the absence of regulatory issues and secure communication," said WORK Microwave's Rockstroh.

For remote sensing missions, optical communication has the potential to outperform RF links. That's because EO data is not real-time critical and does not depend on downloading data to a particular Earth station. Rather, it communicates with a global network. In the future, deciding whether to use optical or RF will be based on which option provides the higher throughput.

"Using an optical multi-mission receiver, operators can target up to approximately 10 Gbps with a single link and that number is likely to increase in the future. It will be difficult for RF to follow the same track for throughput growth. However, RF still provides signal robustness and, therefore, a higher service availability, which leaves room for both applications," added Rockstroh.

Challenges

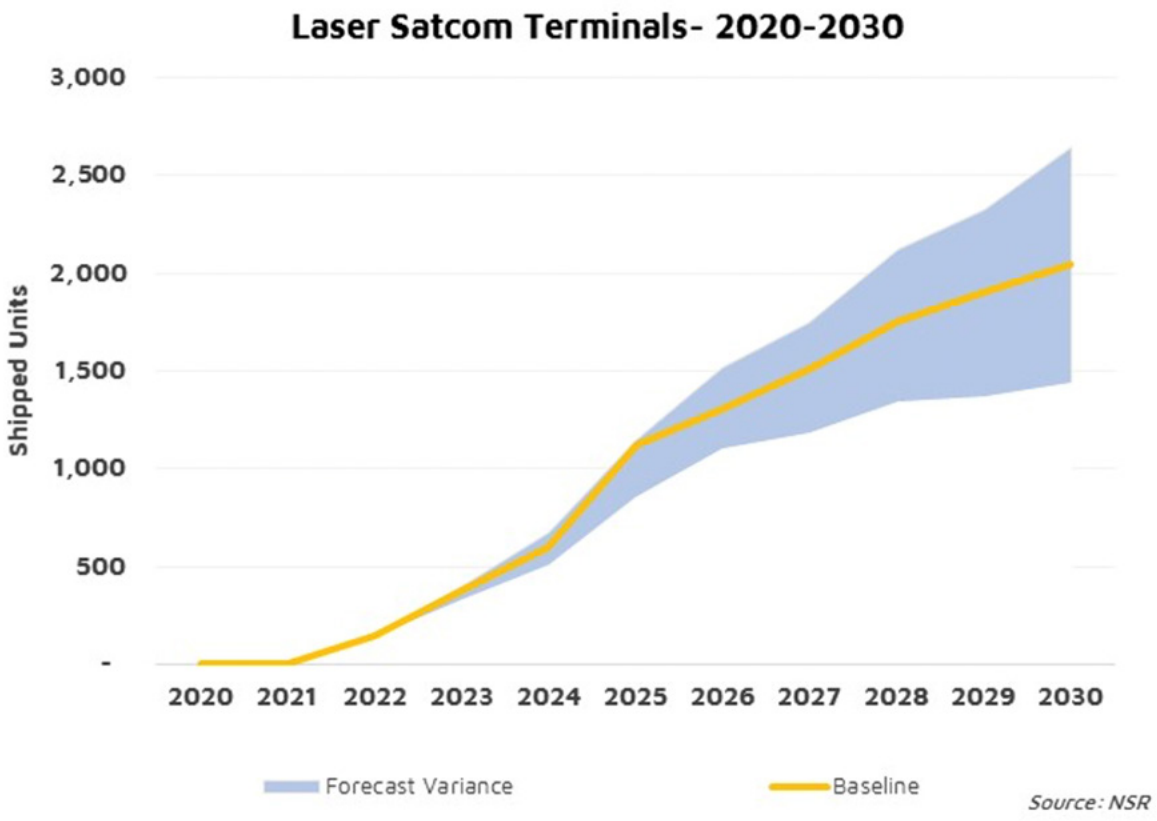
There are certain limitations to optical communications. Weather conditions can affect optical signals. For example, optical signals have some difficulty going through clouds. Therefore an optical ground station should ideally be located at a site that enjoys clear skies most of the year.

In addition, there are no established standards for signal waveforms and coding in optical communications. Standards are essential so that terminals from different providers can be interoperable. A common standard is currently being developed by the Consultative Committee for Space Data Systems (CCSDS). "For different applications, there will be different solutions. However, similar to DVB, only a widely accepted

standard can guarantee interoperability and will benefit the industry across the entire value chain," said Rockstroh.

Potential Applications

Optical communication technology presents a unique opportunity for commercial satellite and scientific missions as well as ground station service providers.



"An initial application where optical communication is expected to provide value is for the reception of remote sensing data to Earth, as the industry has more experience with the technology and commercial availability of required components. Once a wider ground station network is established, there are also communication applications on the horizon, such as uplinks and downlinks from and to gateway stations. In this scenario, the consumer end is supported by the RF Ka-band and the gateway end is optical," said Rocktroh.

Other applications for optimal communications include: backhaul, surveillance and security, tracking and monitoring, enterprise connectivity, last-mile access, research and space exploration, and telecommunications. The backhaul segment has witnessed a brisk growth as the demand for high data rate is constantly increasing due to the adoption of various advanced technologies such as M2M communication, Internet of Things, etc. which require a high gigabit capacity, according to a report by QMI. With its highly secure communicatiosn, optical communications is potentially attractive to military uses.

Optical communication can also be directly used for missions, not only payload data. If immediate access to data is not required, the mission could be completely optical and save operators significant costs. This can be especially interesting for smallsat missions that have tight budgets, as everything can be operated over a single space terminal.

The European data relay system (EDRS) is currently used mainly to transport data from scientific missions toward ground-based systems. On the EDRS, TESAT provides technology is able to establish intersatellite links and also satellite to ground communication. The work that has been done by EDRS and TESAT greatly enhanced the potential of optical satellite communications for other commercial applications.

Optical receiver ground stations can cost much less than comparable RF ground stations. One company, Kongsberg Satellite Services (KSAT) recently completed an optical ground station in Greece. The optical ground station is built by the German system integrator company Astelco Systems, but it's engineered together with KSAT. Astelco has done many projects building specialized telescope systems in the past, like robotic remote telescope stations and prototype systems for testing communications between ground-based telescopes and satellites

The station is built in the outskirts of Athens, Greece, close to the town of Nemea. KSAT already has an RF

PRODUCT SPOTLIGHT

Optical Communication Products from WORK MIcrowave

For over 35 years, WORK Microwave has been a leading developer and manufacturer of advanced satellite communications equipment and other RF electronics technologies. Known for its quality products, customized solutions, reliability, and world-class customer service, WORK Microwave sets the industry benchmark for innovation in microwave and digital signal processing technologies. All of the company's products are developed and produced in-house, leading to an unrivalled response time to customer needs.

WORK Microwave's recently developed and released solutions for optical ground segment use feature leading-edge optical technology. The future-proof solutions can transfer over a secure downlink laser when very high data throughput rates are needed.

AR-80-OPT Optical Multi-Mission Receiver

The AR-80-OPT Optical Multi-Mission Receiver is a receiver dedicated to optical direct-to-earth links. It is capable of receiving, transmitting, and processing optical communication signals. Optical On-Off-Keying (O3K) and High-Photon-Efficiency (HPE) transmissions can be processed via a common input that operates either based on hard-decision decoding or the processing of logarithmic-likelihood-ratios (LLR).

WORK Microwave's AR-80-OPT Optical Multi-Mission Receiver guarantees evolutionary extensions for the upcoming CCSDS standards on the same device, making it a no-risk solution for setting up ground stations today and supporting future applications that have yet to be defined.

An additional Soft-Decision Front-End (SDFE) device is available for bit synchronization to LLRs in combination with the AR-80-OPT. That will also allow installations of the AR-80-OPT independently from the telescope location.

Key features of the AR-80-OPT include:

- Multi-Mission support
- Hard-decision and soft-decision decoding
- Optical On-Off Keying (O3K)
- High-Photon-Efficiency (HPE) future upgradable extension
- CCSDS 141/142 support future upgradable extension
- O3K symbol rate up to 10 Gsps
- User data rate up to 10 Gbit/s
- Customizable processing infrastructure for easy integration into large communication systems
- Flexible software architecture for easy extension and future virtualization of functionality
- Teleport-grade M&C capabilities for seamless integration into professional ground station systems.

FSOD1 Free Space Optical Detector

The FSOD1 Free Space Optical Detector is a fibre-coupled optical detector for the reception of optical free space communication and is used as a perfect complement preceding optical receivers and modems. The detector features a highly responsive InGaAs avalanche photodiode (APD) with fibre coupled input. The amplified and limited output make it suitable for receiving hard decision on-off-keying signals. Built in a 19-inch rack mount housing both a frontpanel user interface and network access via SNMP and HTTP interface provide easy integration into satellite ground station infrastructures.

Key features of the FSOD1 include:

- High Sensitivity, suitable for space down-link
- Fiber-coupled input for flexible installation
- Various wavelength & bandwith options
- 19-inch rack mount unit with remote access interfaces for professional teleport environment

Kongsberg Satellite Services (KSAT) built the first commercially available optical ground station in Nemea, Greece. (image courtesy of KSAT)

ground station there, and the new optical ground station is co-located there. KSAT has chosen the Nemea station as the first site for building an optical ground station, as the site shows a clear-sky probability allowing optical space-to-ground communications of up to 95 per cent in summer.

The optical ground communication system is relatively small due to the focused laser beam. The telescope itself only measures about 50 cm, and with a foundation of around 2 meters, it is relatively modest in size and thus easy to locate. However, this groundbreaking technology will not yet replace the RF signals in the ground network operations.

"Radio frequency works through the clouds, but the optical technology provides higher data rates. We therefore see this as an add-on to the well-established RF," said Hennes Henniger, project manager at KSAT.

Conclusion

New space, old space or deep space, all missions need data links back to earth. A company at the forefront of developing optical communications technology is WORK Microwave. RF or Optical links, DVB or CCSDS standards, WORK Microwave's SpaceCom ground equipment is flexible. The modems offer proven technology platforms serving your mission requirements and bespoke application, all for an off-the-shelf price tag. With heritage in Cubesats, earth observation, satellite tele-command and control, institutional research missions and New Space approaches any data is safe through WORK Microwave's range of reliable RF and optical communication products.

"WORK Microwave's optical communication solutions will enable optical communication between space and Earth at a very high throughput rate with secure data connection. This might satisfy the growing demand for institutional, military and commercial space missions. Beyond existing solutions, WORK Microwave will develop a full-stack optical modem for multi-mission support. This will also define future technical standards in optical space-to-ground communication," said WORK Microwave CEO Thomas Fröhlich.

References

NSR report Optical Satcom Markets, 3rd Edition.

Proceedings Volume 11180, International Conference on Space Optics—ICSO 2018; 111800K (2019)

QMI report on "Optical Satellite Communication Market Size, Technical Growth Future Scope by 2028"

Wilson, K. (2000-01-04). "Recent Development in High-Data Rate Optical Communications at JPL". Jet Propulsion Laboratory. NASA Technical Reports Server.

Virgil Labrador is the Editor-in-Chief of Los Angeles, California-based Satellite Markets and Research which publishes a web portal on the satellite industry www.satellitemarkets.com, the monthly Satellite Executive Briefing magazine and occasional industry reports called MarketBriefs. Virgil is one of the few trade journalists who has a proven track record working in the commercial satellite industry. He worked as a senior executive for a teleport in Singapore, the Asia Broadcast Center, then-owned by the US broadcasting company CBS. He has co-authored two books on the history of satellite communications and satellite technology. He holds a Master's in Communications Management from the University of Southern California (USC). He can be reached at virgil@satellitemarkets.com

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A world first: Optical Modem

Lasers in space... from red light sabers to planet sized laser cannons, science fiction movies just love lasers! We like science fiction, too. But even better than that, we like turning science fiction into science fact.

At WORK Microwave we have developed the World's first Free Space Optical Laser communication link from satellites in space to the WORK Microwave optical modem on Earth at the optical ground station in Greece.

It's a big first and opens the door to space-based communication to and from earth on a scale never seen before. A big thanks to our excellent engineering team, for their dedication, enthusiasm and attention to detail!

Our team continues development of our optical modem technology, continually pushing the limits of link speed, robustness and range. But don't worry, we will leave the laser cannons to the movie makers!

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