CCSDS Standardisation in Optical Communication

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Background: CCSDS SLS-OPT

- Consultative Committee for Space Data Systems (CCSDS) Space Link Service (SLS) area Optical Communication (OPT) Working Group standardises the following:
  - High Photon Efficiency (HPE) Optical Communication Systems
  - Low Complexity (LC) Optical Communication Systems
  - High Data Rate (HDR) Optical Communication Systems
  - Atmospheric Characterisation for Optical Communication Systems
  - Optical Link Operations based on Atmospheric Characterization and Forecasting

- Optical links can be seamlessly integrated in space and ground segments parallel to RF links due to the same protocol layering
High Photon Efficiency (HPE)

- Aiming at deep space communication scenarios, i.e. above GEO = Moon, L2, L5, Mars, Jupiter with a photon efficiency of 1 photon per bit, onboard terminals (13.5-30 cm), ground optical antennas (4-12m)
- Pulsed communication system using 1550 nm Pulse-Position Modulation (PPM) with Serially-Concatenated (SC-PPM) coding
- Modulated uplink for onboard terminal Pointing, Acquisition and Tracking using 1030-1070 nm due to kW-Power requirements
- Red Book v1 for Agency review: May 2017; Blue book v1 after 2 prototypes
- Application in NASA Psyche asteroid mission with Deep Space Optical Communication (DSOC) In-Orbit Demonstration (IOD) confirmed
- Application in ESA SSA Space Weather (SWE) L5 mission with Deep-space Optical Communication System (DOCS) proposed (heritage from AIM Optel-D preparation)
Low Complexity (LC)

• Aiming at low complexity communication scenarios, i.e. LEO to ground with small on-board terminals (< 5 cm) and small ground stations (60 cm), Mbps -> 10 Gbps
• Pulsed communication system using 1550 nm On-Off-Keying (OOK) with re-used RF coding schemes
• Modulated uplink for onboard terminal Pointing, Acquisition and Tracking using 1550 nm with eye-safe uplinks (can operate everywhere)
• Red Book v2; Blue book v2 after 2 prototypes
• Similarity in NICT SOTA flying on Socrates, DLR-IKN Osiris flying on DLR Biros; Application in ESA TAS-CH Optel-mu, IOD pending
• Potential for future LEO missions, and Inter-Satellite Links
High Data Rate (HDR) – ESA/DLR variant

• Aiming at high data rate scenarios (1.8 Gbps), i.e. LEO-GEO ISL, GEO-GEO-ISL with moderate size on-board terminals (13.5 cm)
• Bi-directional Phase Modulation, Binary Phase-Shift Keying (BPSK) using 1064 nm
• Orange Book in 2017
• Operational application in EDRS, Sentinels
• Future:
  • smaller on-board terminals for LEO
  • adding 1550 nm return link, QPSK for 3.6 and 7.2 Gbps
  • EDRS capacity increase to GlobeNet with GEO-GEO ISL
  • GEO-Ground feeder links using adaptive optics for wavefront correction, ground optical antennas ~27 cm, and erasure coding techniques
High Data Rate (HDR) – NASA variant (tbd)

- Aiming at low and high data rate scenarios (Mbps -> 10 Gbps), i.e. LEO-GEO ISL, GEO-GEO-ISL, GEO-Ground with variable size on-board terminals
- Variable slot-based bi-directional Phase Modulation, Differential Phase-Shift Keying (DPSK) using 1550 nm (tbc)
- Orange Book in 2018 (tbc)
- In-Orbit Demonstration on LCRD and ISS
Atmospheric Characterisation & Link Operation

- Atmospheric Characterisation for Optical Communication Systems
  - Aiming at the definition of atmospheric measurement techniques and associated systems for site and optical link characterisation
  - Green Book in 2017, submitted for publication

- Optical Link Operations based on Atmospheric Characterization and Forecasting
  - Aiming at operations concept for optical link operations based on weather forecasting and link handover
  - Magenta Book in preparation 2019