RTT TECHNOLOGY TOPIC
May 2023

Space Optical Link Budgets

Over eleven months (through to November 2023) we are making our way through the eleven chapters of our latest book, 5G and Satellite RF and Optical Integration, highlighting industry announcements that consolidate the narrative of an emerging market for 5G services from space coupled to increasing use of optical free space technology for inter satellite, inter constellation and earth to space/space to earth links.

Chapter 1 covers 5G radio spectrum including RF C Band, RF link budgets and active and passive device efficiency.
Chapter 2 Optical C Band link budgets and active and passive device efficiency
Chapter 3 RF over Fiber- link budgets and network architectures
Chapter 4 Space RF Link Budgets
Chapter 5 Optical Inter Satellite Links (OISL)
Chapter 6 Deep Space and Near Space technologies
Chapter 7 Ground Station and Earth Station Hardware and Software
Chapter 8 Low Altitude Platforms
Chapter 9 High Altitude Platforms
Chapter 10 RF and Optical Technology Enablers
Chapter 11 Technology Economics of RF and Fiber for terrestrial and space networks.
For more information and to order go to
https://uk.artechhouse.com/5G-and-Satellite-RF-and-Optical-Integration-P2194.aspx
Hard and soft copies of the two previous books in the Series can be ordered here
https://uk.artechhouse.com/5G-and-Satellite-Spectrum-Standards-and-Scale-P1935.aspx
https://uk.artechhouse.com/5G-Spectrum-and-Standards-P1805.aspx

If you are interested in writing a book for Artech House or have research work you would like included in future 5G and 6G satellite RF and optical titles then email **geoff@rttonline.com** who will put you in touch with the Artech commissioning team.

We are also running a workshop on LEO, MEO, GSO, LEO, 5G, RF and optical integration in Prague next month (12th to 16th June 2023)
More information here
www.cei.se/continuing-education-institute/satellite-communications.html

Space Optical Link Budgets (Chapter 5)
Last month's (April) Technology Topic, Space RF Link budgets (Chapter 4 of the book) looked at the advantages and disadvantages of using RF in space for inter satellite links. This month (May 2023) we study optical rather than RF transceivers and optical link budgets rather than RF link budgets.

In an RF transceiver, radio waves arrive at an antenna which acts as a resonant device to produce a varying voltage that represents the simple or complex input signal waveform. The low level signal is filtered and amplified so that wanted energy is separated from unwanted signal energy to produce a sufficient signal to noise ratio to allow the carrier to be demodulated. The incoming signal is either mixed with a signal at the same frequency with a 180 degree offset (Direct Conversion or Homodyne Receiver) so that phase modulation can be extracted from the radio carrier or mixed with a different frequency to produce an Intermediate Frequency (IF) to make downstream processing easier. This is generally known as a Superhet. On the transmit path, a varying voltage carrying any mix of phase, frequency and amplitude information is band pass filtered, amplified and transmitted usually but not always via the same antenna to the target receiver.

In an optical transceiver, a light path arrives in the front end of the receiver. Instead of a metal antenna, the light passes through a lens which captures and concentrates the light path or wanted photonic signal energy. As with a radio receiver it also captures unwanted signal energy and the job of the system designer is to ensure that enough of wanted rather than unwanted photons arrive at a photodetector/photodiode where the energy can be turned back into a continuously varying (analog) voltage from which the frequency domain, phase and time domain can be extracted. In a beacon channel the light path will be arriving at a CMOS or CCCD detector array and the same design principles apply. As with RF, there can be additional polarisation separation. Separation of the wanted from unwanted signal is achieved by filtering.

In a **coherent optical transceiver** (as opposed to simple on off keying or intensity modulation), the incoming signal can be mixed with a signal at the same frequency with a 180 degree off set so that phase modulation can be extracted from the optical carrier, the equivalent of the RF Direct Conversion or Homodyne receiver, or mixed with a different frequency to produce an Intermediate Frequency (IF) to make downstream processing easier (the equivalent of the RF Superhet).

A third option is to keep the frequency difference between the local oscillator laser and the signal within the bandwidth of the detectors but not phase locked. These are known as **Intradyne** or **Integrated Coherent Receivers** and can be effective in higher data rate OISL. On the transmit path, a varying voltage carrying any mix of phase, frequency and amplitude information is band pass filtered, amplified and transmitted usually but not always through the same optical front end to the target receiver. As a general rule and all other things being equal, which is not always the case, a coherent receiver will deliver between 4 and 6 dB of gain compared to direct detection and will be better at rejecting background light. Coherent detection is used in terrestrial fiber to support data rates of hundreds of Gbps scaling to Terabits and there is an intrinsic assumption that it would be useful to replicate these data rates over free space links in space. OISL links are also increasingly coupled into (normally single mode) fiber on satellites to support an on board optical rather than copper data bus. Pointing accuracy (alignment of the optical beam coupling into the fiber) is critical.

The OISL story turns out to be a story of stability at a macro and micro level. At macro level, it is relatively easy to establish a link between GSO satellites because they stay positionally stable to one another. Generally they are large satellites with relatively large amounts of on board power, large aperture optical receivers and high gain optical transmit paths that already support inter GSO links at tens and hundreds of Gbps with the potential to scale to terabits by reusing terrestrial fiber DWDM technologies from terrestrial fibre optical C Band.

By comparison, at micro level in a LEO constellation there is positioning and pointing uncertainty due to the need for station keeping and altitude and attitude adjustments. LEO satellites are moving at different speeds depending on their orbit altitudes and sometimes in opposite directions and these processes introduce vibration and jitter and a need to accommodate Doppler shift. Vibration is easier to deal with than jitter but together they compromise pointing acquisition and tracking systems and introduce point ahead errors that become dominant in the OISL link budget. There is no link budget if the link is lost in space. MEO satellites have the same issues though the relative dynamics are generally easier to deal with. Doppler shift turns out to be problematic due to the broadening effect on the link in the frequency domain which is a challenge for filter designers.

These problems pale into significance when we look at the challenges of Deep Space Communication, the subject of next month's Technology Topic.

Ends

RTT Technology Topics reflect areas of research that we are presently working on. We aim to introduce new terminology and new ideas to help inform present and future technology, engineering, market and business decisions.

The first technology topic (on GPRS design) was produced in August 1998. 25 years on there are over 270 technology topics **archived on the RTT web site**.

Do pass these Technology Topics and related links on to your colleagues, encourage them to join our **Subscriber List** and respond with comments.

Contact RTT

RTT, and **Niche Markets Asia** are presently working on research and forecasting projects in the mobile broadband, public safety radio, satellite and broadcasting industry and related copper, cable and fibre delivery options.

If you would like more information on this work then please contact **geoff@rttonline.com**
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