RTT TECHNOLOGY TOPIC
April 2023

Space RF Link Budgets

Last month's (March) Technology Topic, RF over Fiber summarised the evolving technology economics of RF over Fiber, This month's (April) Technology Topic, Space RF Link budgets, looks at the advantages and disadvantages of using RF in space for inter satellite links and summarises topics covered in Chapter 4 of our new book 5G and Satellite RF and Optical Integration.

The good news for RF inter satellite links is that there is no atmosphere in space which means that the rain fade margins needed for mobile and point to point terrestrial links disappear from the link budget. Links can also be established to and from High Altitude Platforms (HAPS). Atmospheric loss at an altitude of 20 kilometers, comfortably above the maximum height of most clouds (60,000 feet), is less than 0.002dB/km which means that links from space can be cross connected between HAPS platforms with minimum loss. Stated simply once you are above the clouds, any radio (or optical) signal has minimal (HAPS above 20 Kilometers)) or no (space above 100 kilometers) atmospheric loss.

The bad news for RF (and optical) inter satellite links is that there is no atmosphere in space which means that RF and baseband hardware can be damaged by radiation. RF and electronic components including pointing and tracking systems also have to work across a wide temperature range with fast changes in temperature and there is no air to dissipate heat generated by active devices.

There is also no mains electricity in space so power has to come from solar panels or radio isotope sources, used more traditionally in deep space exploration. Solar panels have become more efficient over time with silicon germanium conversion efficiency now better than 40%. It is also sunnier in space (1400 watts per square meter rather than 1000 watts per square meter at ground level) but solar panels can suffer from fogging and surface abrasion.

Some of the solar arrays in space generate upwards of 15 kilowatts at the beginning of their service life but this will fall back to 13 kilowatts or less as the satellite ages. GSO satellites presently under construction[i] with a launch mass of 4,500 kg have a payload power of more than 25 kW. A 3U Cube SAT, (0.1mX0.1mx0.3m) weighing 3 Kg will have a power budget closer to 10 watts. Most of the rest are somewhere in between. The comms budget is only part of the payload power budget but is important irrespective of satellite size both in terms of the RF power amplifier and gain and therefore size of the antenna.

As we move to the higher end of the millimeter band (E band, V and W Band), radio waves begin to behave in a similar way to light which means that optical techniques can be used to beam form and beam shape and collimate. This means that we can span long link lengths in space with data rates that are high when compared to present RF benchmarks. The problem with RF hardware is that noise increases with frequency and gain decreases. High volume demand for RF components for 5G Ku and Ka band networks will help to focus R and D on performance improvements and 5G market volume will reduce cost suggesting that there are many evolving opportunities to reuse 5G RF hardware in space. The use of RF components not specifically designed for space might be considered to be a through life risk but this risk reduces as it becomes easier and less costly to replace satellites that have suffered RF hardware degradation or failure.

On the other hand, optical links are becoming more power efficient than radio links particularly on a per bit basis and can have a significant space and weight and throughput advantage over RF

system alternatives. This brings us conveniently to the subject of next Month's Technology Topic, Space Optical Inter Satellite link budgets.

Over the next eleven months (January to November 2023) we are making our way through the eleven chapters of our new book, 5G and Satellite RF and Optical Integration, highlighting industry announcements that hopefully help to consolidate the underlying 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.
As a reminder,
Chapter 1 covers 5G radio spectrum including RF C Band, RF link budgets and active and passive device efficiency.
Topics addressed in the rest of the book include
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.

Our next five day workshop on LEO, MEO, GSO, LEO, 5G, RF and optical integration is in Prague 12 to 16th June 2023

For more information and to book go to
www.cei.se/continuing-education-institute/satellite-communications.html
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.**

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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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