RTT TECHNOLOGY TOPIC
November 2023

Technology Economics of RF and Fiber for terrestrial and Space Networks

Over the course of this year (January to November 2023) we have summarized the eleven chapters of our most recent book, 5G and Satellite RF and Optical Integration, consolidating 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.
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 optical 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 LEO, MEO and GSO workshop presented in association with the Continuing Education Institute in Sweden will be held in Barcelona from 11th to 15th December - details via the link.

https://www.cei.se/course-820-leo-meo-and-gso-system-and-service-integration-group.html

If you would like an in house presentation of this course then CEI would be happy to arrange this for you. The workshop includes background on 6G, satellite and space RF and optical technologies. Contact CEI Europe

RF and Optical Terrestrial and Space Economics (Chapter 11)
In last month's (October) Technology Topic, RF and Fiber Technology Enablers, we looked at how and why optical transport is increasing as a percentage of the overall technology mix in terrestrial and space telecom networks. This month (November 2023) we look at who will make money from this transition or perhaps more accurately what we need to worry about if we want to avoid Chapter 11. It is not a coincidence that in most of our books, Chapter 11 is about Chapter 11.

Throughout the book we argue that the (RF or optical) link budget should always be the start point of every telecoms business plan. If the link budget doesn't close, the business will. It is also a good idea to make sure that the technology behind the Business Plan obeys the laws of physics, a surprising number don't.

We are interested in RF versus optical value but we are also interested in the relative value of terrestrial RF and optical networks and space based RF and optical networks. Will investors get a better dollar return from space investment than they will get from terrestrial investment? Will investors get a better dollar return from optical investment than they will get from investing in yet more radio spectrum?

From an income perspective, we hope we have made an adequate case that space value is based on more than communications value. Satellites can take pictures of deep space and the earth, trilaterate radio signals, count cars in car parks and tanks on a road. They are a super accurate clock source which means they can provide exquisitely accurate and robust positioning and location. Satellites can do Air Traffic Management from space and can talk to HAPS and other objects that float or fly in the sky and to objects that float on or under the sea and they can do all that from VHF to V Band and from long wave to light. Space based radio and optical telescopes help us to understand how the Universe began and how our neighbourhood solar system works. This might not have immediate commercial value but the mechanics of getting good pictures of space from space (pointing stability and vibration management) are directly deployable across a wide range of wireless platforms.

We made the argument that power in space is free and there are no rental costs or rates to pay.

The cost of getting to space is reducing and there will be some law that expresses how fast this is happening, we may as well call it Musk's Law. Cost per kilogram is halving over some as yet to be determined time frame. If it is every 18 months then it will soon be cheaper to send base stations into space rather than put them on a truck. It will often also be faster. Never knowingly understated, Mr Musk claims that his reusable rockets will deliver 150 tonnes of hardware into space for $1.5 million dollars which is $10 dollars per kilogram and even argues that his new Raptor Rockets are environmentally friendly.

The cost of staying in space is reducing partly because alternatives to hydrazine are being introduced which are more size, weight and volume efficient but also it is now possible to refuel and repair satellites including GSO satellites. Being able to extend the life of a big GSO satellite for an additional 10 or 15 years will transform the economics of the geostationary and geosynchronous satellite sector. Small cube SATs are also being placed in GSO and GEO orbits. Thousands of optical satellites could be deployed into geostationary orbit with no co-interference.

Last but not least, **BIG SPACE is about to GET BIGGER**. Many lessons have been learnt from building and operating the International Base Station and a new generation of even larger structures are being designed and built and launched mainly by commercial entities. Designing huge structures that fold up into tiny spaces, a game of Orbital Origami has the potential to put extravagant amounts of link budget receiver gain and RF and optical power into space.

All this space generated value has to be brought back to earth. The space to earth and earth to space RF path is problematic. Not a lot of RF bandwidth and a lot of RF interference which will increase rather than decrease over time. Whatever happens with earth to space and space to earth RF, it is clear that an increasing amount of data will flow to and from optical ground stations.

Optical storage and optical computing will mean that it is economic to put servers into space. This will increase the demand for optical bandwidth both for Optical Inter Space Links and uplinks and downlinks. Inter satellite optical links and dark path and dry path (and ideally dust free) routing are crucial to orbital optical economics.

Standards are the great achievement of the cellular industry, written by thousands of engineers from Europe, China and the USA. The satellite industry is by definition a global industry but geopolitics and space defence considerations are a barrier to global cooperation. 6G could be the answer to this problem. At time of writing, interest from the mobile operator community has increased and work items on 5G and 6G Terrestrial and Non Terrestrial Integration are ongoing though real progress would require buy in from the 5G network vendor supply chain. This is not presently evident though emerging semiconductor support suggests this is changing.

It also has to be said that no existing standards adequately address RF and optical integration. This is partly because RF engineers know about RF Technology and optical engineers know about Optical Technology and they rarely get together to have a beer let alone write a technical standard. The problem is compounded by a lack of integration of RF and optical engineering in Universities and or post graduate research institutions.

This is a pity because bossing photons around is much the same as bossing electrons around. Designing a homodyne, heterodyne or intradyne optical transceiver is similar to designing an RF transceiver. Both involve, amplifiers, filters, mixing and matching. The dark art of RF design turns out to be equally applicable to the dark art of optical design. At network level, closing an RF link budget is more or less identical to closing an optical link budget and all the basic bandwidth ratios and noise and gain calculations apply.

These are resonant networks and therefore behave and misbehave in more or less the same way. As RF engineers are tasked with exploring the sub millimeter bands (initially up to 950 GHz), the similarities become stronger and the moment they are asked to design and build an integrated RF and optical antenna coupled to an integrated RF and optical transceiver will mark the moment when RF and optical engineering begins to be regarded as an integrated design discipline.

Our guess is that this will happen just about when the first 6G standards are published in 2028 and provides the working title for one of our future books, 6G and Satellite RF and Optical Spectrum, Standards and Scale.

In the meantime please keep reading these Monthly Technology Topics and keep us posted on any and all new technologies in this ever expanding RF and optical universe.

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**
00 44 7710 020 040