# RTT TECHNOLOGY TOPIC
# October 2023

# RF and Optical Technology Enablers

Over the course of this year (January to November 2023) we have been 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 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 Technology Enablers (Chapter 10)**
In last month's (September) Technology Topic we looked at the challenges and opportunities implicit in using High Altitude Platform Stations (HAPS) as 5G base stations (known in ITU speak as HIBS with I standing for IMT).

We finished by returning to where we started, debating the likely mix of RF and optical transport in next generation terrestrial and non-terrestrial networks which in turn served to introduce this month's technology topic, RF and Optical Technology Enablers (Chapter 10).

The underlying narrative is that optical transport is increasing as a percentage of the overall technology mix. The reason for this is that the size, weight, power and cost (SWaPc) of optical devices is improving faster than the SWaPc of RF devices. This is because RF networks are operating at close to the Shannon limit whereas optical devices are relatively lightly optimised and therefore have more potential for performance improvement over time.

In our January Technology Topic we looked at the differences between 5G networks deployed below 6 GHz (Frequency Range 1/ FR1) and networks being deployed above 6 GHz (Frequency Range 2) including Ku and Ka band. In subsequent month's (and Chapters we did the same for satellite networks and for good measure went down in frequency as well as up, from VHF to V band, from Long Wave to Light.

In the RF domain channel bandwidths are increasing (100 MHz and above) and network deployments are moving to C band and Ku and Ka band. 5G advanced and 6G standards bodies are now looking at spectrum up to 950 GHz. This will presumably be called Frequency Range 3 (FR3)

The problem for RF engineers is that low cost well behaved CMOS technologies will not work at these higher frequencies. Power amplifiers therefore have to be built from more exotic semiconductor materials which cost more partly because a) the materials are exotic and b) because the production yield is lower and c) because vendors can make more money selling these devices to military customers.

Acoustic filters, Surface Acoustic Wave (SAW) and Film Bulk Acoustic Resonator (FBAR) filters, also become less efficient and less well behaved (ripple and band edge issues) as frequency increases and stop working altogether in Ku and Ka band and above and all filter options will suffer from additional insertion loss.

Although antennas get smaller, it gets harder to get a good compromise between power matching on the transmit path and noise matching on the receive path. As VSWR (reflected power) increases heat rise increases which can cause reliability issues and or frequency drift. In hand held devices, hand capacitance effects can compromise front end performance.

In our February and May Technology Topics (Chapters 2 and 5) we talked about Coherent Optical DSP which is marketing jargon for a DSP which has enough bandwidth to process optical signals in the time, phase and frequency domain (and polarisation for free space optical) as opposed to systems that just do simple on off keying or intensity modulation. Coherent DSP is fundamental, as the description implies, to all coherent communication systems irrespective of whether they are RF or optical, guided terrestrial (cable and fiber), unguided terrestrial, space based or LAPS or HAPS. We did however make the point that RF networks are already working close to the Shannon limit whereas optical networks still have a huge potential to increase throughput while maintaining high levels of power efficiency.

In communication systems there are four wave form qualities or properties that we use to get information on to an RF or optical carrier, frequency, amplitude, phase and polarisation. In the optical domain there are five dimensions available to us. Red, Blue and Green can be considered as representing three dimensions, the fourth is brightness, and the fifth is saturation. Within a pulse of light of a few milliseconds we can use these five dimensions to express any number between 1 and 1,099,511,671,776. This suggests that optical will become not only the dominant carrier in communication systems but will increasingly replace electronics in computing and storage systems.

The neatest way to harness this optical computing power is to grow a crystal in the shape of a ball. It turns out that you do not need a crystal ball to foretell the future. The crystal ball is the future.

Moving from the RF to the optical domain and from the electronic processing to optical processing (photons replacing electrons) opens up an almost infinite amount of power efficient bandwidth. The final question to answer is who will make money out of this transition. This brings us to the final technology topic in this series summarising our final Chapter (Chapter 11), the Technology Economics of RF and Fiber for terrestrial and non-terrestrial networks.

**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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