RTT TECHNOLOGY TOPIC
October 2021

RF and Optical Device Integration

The last two technology topics (Smart Servers from Space and RF and Optical Network Integration) and this month's topic (RF and Optical Device Integration) look at how the integration of RF and optical technology is changing the relative delivery and storage economics of terrestrial and non-terrestrial networks.

The three topics together provide background to a Cambridge Wireless Webinar being presented on the afternoon of Wednesday October 20th

Information on the webinar can be found here.
https://www.cambridgewireless.co.uk/events/rf-and-optical-integration/

It is a chargeable event for non-Cambridge Wireless members but you can book a free ticket by going to register here and quoting **'CWGV21'** when prompted.

We look forward to you joining us at this event.

Read on

Telecommunication networks by definition are a combination of components which together determine delivery cost including through life cost and energy consumption.

The passive and active components in the radio front end of a smart phone determine the sensitivity, selectivity and stability of the network which in turn determine the capacity and coverage available to subscribers. The back end of the smart phone, the base band processor, brings together voice, audio and video inputs and outputs to create user value including value from the multiple cameras now more or less ubiquitous in higher end devices.

The efficiency of optical networks is similarly defined by the sensitivity, selectivity and stability of the optical components. In free space and fibre this includes the lasers and optical amplifiers used at either end of the link. In fibre this includes multiplexers and active repeater and relay components together with multiplexers and filters.

As device cost has reduced, fibre has moved closer to users with fibre to the desk now becoming increasingly viable.

At network level, free space optical links of up to 30 Gigabits over 15 kilometres provide an alternative to Ku, Ka band or V band radio links.

As with RF engineering, fibre optic engineers and device developers need to work in the transmission windows where losses are relatively low though losses over short distances are less of an issue. In free space, link budgets are dominated by atmospheric losses up to high altitude. In free space intersatellite links, pointing loss becomes dominant particularly with LEO and MEO cross connect. Just as with RF, optical signals have to be matched, for example when a free space link is coupled to a fibre link. Transpedance amplifier efficiency is therefore an additional part of the end to end link budget.

In radio systems, engineers have a choice of modulation techniques ranging from simple on off keying though to complex higher order modulation in which frequency, phase and amplitude are all used as an information carrier.

The same choices are available in the optical world. LED transmitters can be on off keyed or intensity modulated, typically at two or four levels. LED light sources are low cost but relatively wide band with channel bandwidths typically between 30 and 60 nanometres (8-16 THz)

The source is non-coherent, not particularly directional and only couples to multi-mode fibre which means that overall efficiency is low with a throughput limit of around 100 M/bit/s over a kilometre. LED's are however ideal for low cost local Li Fi domestic and industrial optical networks

They are also used in Cube SATS for size, weight and cost reasons.

Where more efficiency (greater range and throughput) is needed the default options are laser diodes, Vertical Cavity Surface Emitting Lasers or Distributed Feedback devices

All of these are based on the principle of bouncing electrons backwards and forward or up and down or side to side until they are sufficiently excited to become photons at which point they spill out of the device in the desired direction either because the device is a diode, or in DFB devices, due to differences in reflectivity between mirrors at either end of the device

The laser diode was patented by Robert Hall of General Electric in 1962.

A laser diode replaces the silicon used as a semiconductor in an LED with aluminium or gallium arsenide. In a conventional laser, concentrated light is produced by 'pumping' the light emitted from excited atoms repeatedly between two mirrors. A laser diode performs the same function by bouncing photons backwards and forwards in a microscopic junction typically one micrometre wide between the slices of a p-type and n type semiconductor known as a Fabry Perot resonant cavity, a fine example of an old technique put to modern use (Jean-Baptiste Alfred Perot and his colleague Charles Fabry produced their first interferometer in 1899).

The emission wavelength of the laser diode is determined by the composition of the light emitting semiconductor material based on work originally done by Lawrence Bragg and his Dad in 1913 investigating why and how crystalline solids produced surprising patterns of reflected x rays. A Bragg reflector uses materials with different refractive indices, with the thickness of the materials chosen to produce a quarter wavelength reflection of a particular wavelength. A Distributed Bragg Reflector uses one or two Bragg gratings as end reflectors in a short Fabry-Perot Cavity so both the French and the British can claim bragging rights for these inventions.

Laser diodes cost more than LED sources but produce coherent light which means more complex modulation can be used. Laser diodes also exhibit better coupling efficiency and can be used with single mode fibre for longer distance communication but they are temperature and life limited.

A vertical cavity surface emitting laser (VCSEL) produces less power than a laser diode (typically 1-10 milliwatts rather than 100 milliwatts) but is power efficient drawing 15 milliamps compared to 60 milliamps for a distributed feedback laser.

A VCSEL has top and bottom mirrors separated by a laser cavity with oxide layers either side which act as a gain region. The low cost and lower output power of these devices relative to Distributed Feedback lasers makes them a good choice for systems operating close to visible light (315-384 THz/950 to 780 nanometre) where there is a risk of eye damage in free space systems

For long distance high capacity fibre, Distributed Feedback Laser Diodes are a default option. Good stability means they can support wavelength multiplexing down to 25 GHz channel spacing, they can be matched well and provide a well behaved source of coherent light. In free space terrestrial and non-terrestrial networks, DFB devices can be matched to high quality optics to provide a well matched source with good collimation characteristics. Just as a reminder, collimation is the opposite of focusing a light beam, the object being to make the laser have the same diameter for as long a distance as possible. Collimation can be considered conceptually as creating a fibre like connection in free space.

The optical component industry does not have a direct equivalent to the smart phone. The RF component industry has the benefit of an addressable market of a billion smart phones a year at a relatively high consumer price point. The close coupling of RF front end efficiency to network economics has placed a modest but useful premium on RF front end components that deliver an efficiency benefit, FBAR filters and gallium arsenide amplifiers are two examples.

Performance and price premium opportunities do however exist in the optical domain with useful component commonality between fibre and free space applications and between terrestrial and non-terrestrial optical markets. In the relatively near future, fibre to the home will become more or less ubiquitous and fibre to the desk (and TV and cinema systems) will add additional volume and value.

RF component vendors have not had an easy time over the past thirty years but those that have invested intensively in new material and manufacturing processes have enjoyed a generous return. Similar gains can be expected in the optical component sector.

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