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Sub Orbital Value

In this month's technology topic/posting we look at sub orbital RF and optical communication systems as a complementary component to satellite and terrestrial cellular networks.

We draw on a presentation from the July 22nd Cambridge Wireless (CW) webinar on Non- Terrestrial Networks by Tim Fowler of Cambridge Consultants and a presentation by Richard Johanson of Archangel Lightworks at a CW webinar on RF and Optical Integration on October 20.

The Cambridge Consultants presentation included background on a project for Stratospheric Platforms Limited studying High Altitude Platforms (HAPS) for 4G and 5G with Deutsche Telekom as a delivery partner. The Archangel presentation reviewed the role of free space optical links for above the cloud platforms delivering broadband connectivity.

The definition of sub orbital is generally taken as any altitude beneath the Karman line at 100 kilometres but this is sub divided into the troposphere from ground level to 12 kilometres, the stratosphere from 12 kilometres to 45 kilometres, the mesosphere between 45 and 50 kilometres, and the thermosphere above 80 kilometres.

High altitude platforms (HAPS) are normally deployed in the stratosphere between 17 and 22 kilometres. This is above the height at which civil aircraft fly and generally above cloud level though night/noctilucent clouds can occasionally be found as high as 85 kilometres.

One high altitude platform (HAP) can provide coverage typically over a 140 kilometre diameter cell. If equipped with spot beam antennas this can be divided into sub cells of a similar size to terrestrial cellular systems, for example a 2 kilometre diameter cell.

LEO satellites are of the order of ten to 100 times higher. This means HAPS have an RF link budget advantage over LEOS of between 20 and 40 dB and a latency advantage of several milliseconds. (Less than one millisecond for a 20 km link compared to around 4 milliseconds for a 700 kilometer LEO link).

At a height of 20 kilometres the minimum path length (directly downwards) is 20 kilometres. The maximum path length to the edge of a 140 kilometer diameter cell is 73 kilometres. The longer path length incurs 33 dB of additional radio path loss compared to a line of sight path from a base station one kilometre away.

If Ku and Ka band frequencies are being used, there will be additional path loss if the radio signal goes through clouds and rain. The fade margin increases with rain rate and elevation and can be of the order of 10 to 12 dB. Lower radio frequencies such as S band remain largely unaffected and are the preferred choice for early deployments. Deutsche Telekom and Inmarsat as an example use Inmarsat S band spectrum immediately above Band 1 LTE for their European Aviation Network project

Path loss and blocking loss will be minimised if HAPS platforms are Nearly Overhead Nearly all the time though this implies a high density of HAPS platforms and negates the economic benefit of illuminating larger cells.

Sub orbital platforms by definition need to stay up in the sky. They can either be unpowered lighter than air, for example balloons which go where the wind takes them or powered lighter than air though speed needs to match wind speed which can be difficult due to the typical size of Lighter than Air platforms.

The Stratospheric platform is based on a light weight air frame with a wing span of sixty metres. The aircraft uses hydrogen as the power source giving flight duration of the order of seven days and a payload of 140 kg. The airframe supports a smart antenna with a diameter of three metres giving 30dB of gain to ensure flux density on the ground is similar to terrestrial cellular line of sight. When the HAP is Line of Sight and terrestrial is Non Line of Sight, the HAP should have a link budget advantage. Stratospheric claim that a power budget of 20 kilowatts is feasible equivalent to 500 terrestrial masts.

Additional challenges of working in the stratosphere include cold air temperatures and counter intuitively, heat dissipation (due to being in a near vacuum). The need to refuel once a week requires navigation through civil aviation flight paths and a risk of damage from stormy weather.

The alternative is to use solar energy as the power source to keep the aircraft up in the stratosphere for longer but solar powered aircraft are fragile and have limited payload capability, around 5 to 15 kg with a payload power budget of 100 watts to 1 kW. Solar power is also less efficient above 30 degrees latitude particularly in the winter,

The viability of large scale deployment of hydrogen powered HAPS at present remains unproven and support from terrestrial vendors such as Nokia, Ericson and Huawei would greatly increase its chance of success. High power high tower terrestrial LTE can be deployed to support low population density cells of the order of several tens of kilometers and temporary coverage can be economically served from LTE drones or LTE equipped light aircraft.

Scale economy is also an issue. Huawei build hundreds of thousands of base stations every year and very few of them leave the ground.

An alternative is to use High Altitude Platforms to support sub orbital optical networks

As with Ku and Ka band radio frequencies, laser links are affected by rain and mist and cloud. A free space optical system in clear conditions will have a loss similar to fibre, of the order of 0.2 dB per kilometre. The free space link will also have a speed advantage over fibre, 100% of the speed of light rather than 70% of the speed of light. Dense fog will increase link loss to tens of dB's of loss per kilometre. Very dense fog can increase the link loss per kilometre to over 300 dB. Free space optical systems in the atmosphere will also suffer from scattering and atmospheric turbulence including scintillation.

Getting above cloud level makes things more predictable. A 500 kilometre link between two HAPS at 20 kilometres using an intensity modulated laser at 1550 nm can typically yield a data rate of 384 Mbit/s with a Bit Error rate of 1 in 10^6 with a transmit power of 800 milliwatts. Some systems use a beacon channel at 810 nm or 976 nm for acquisition, pointing and tracking. Some of these acquisition and pointing and tracking systems use MEMS mirrors to reduce size and cost.

Above the cloud optical HAPS have the same issues as RF HAPS in terms of flight duration and it is hard to see deployment costs getting low enough for optical High HAPS to be widely deployed as a 5G network layer at least within the next ten to fifteen years.

Telesat's Light Speed Constellation however explicitly includes optical HAPS coupled to LEO optical cross connect with the HAPS optical links either going up to LEO, MEO or GSO before returning to earth or being linked to terrestrial assets including military assets such as tanks or fighter planes or drones or being cross connected to other HAPS before down linking. The optical mesh architecture is designed to be resilient to jamming and optimised for latency and throughput.

It is therefore likely that optical HAPS will become widely deployed initially in defence applications before they penetrate consumer communication markets.

In practice, the most likely outcome are HAPS that integrate RF and optical assets and are therefore part of the ongoing narrative of multi-platform RF and optical systems.

Ends

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00 44 7710 020 040