RTT TECHNOLOGY TOPIC
June 2017

K-SATS

The successful launch from New Zealand of the first Rocket lab space vehicle at the end of May marks another step in developing low cost access to space, carbon composite construction, oxygen/kerosene pump fed engine, FPGA programmable hardware and 3D printed engine parts. Book your payload on line https://www.rocketlabusa.com/electron/

The launch is further validation that space economics are changing faster than most terrestrial operators realize suggesting that satellites can and should be factored into 5G business modelling.

In last month's technology topic, Dot.space - Above the Cloud Computing we debated the technical and commercial rationale for putting servers into space.

We suggested that the combination of upgraded Ka-band High Throughput (HTS) geostationary satellites coupled with new generation Ka-band MEO and LEO HTS constellations will provide a cost economic and power efficient mechanism for delivering mobile and fixed broadband wide area terrestrial connectivity in the centimetre and millimetre bands. We used a beach in Bournemouth as an application example, coincidentally one of the towns with the worst 4G coverage in Britain.

From a technical perspective the nearly always nearly overhead (NANO) line of sight link budget available from high satellite count mixed constellations provides a flux density equivalent to terrestrial line of sight and can be significantly better than Ka-band terrestrial non line of sight where most of the RF uplink and downlink power will be absorbed by surface scatter loss.

Nearly always nearly overhead connectivity increases active phase array flat conformal antenna efficiency and/or enables lower cost power efficient passive flat panel antennas. If the connectivity is coupled to satellite based server bandwidth then significant latency gain can be achieved.

The commercial benefits of space based connectivity and server bandwidth include multiple pay load cost amortisation, free energy for twenty years and no site costs. This is coupled to launch innovation, satellite hardware innovation and production innovation which together are realizing step function reductions in delivery cost.

Satellite Ka-band plans have already been covered in our August 2016 Technology Topic, Satellite Spectrum and Standards. In this month's Technology Topic, we take a closer look at the regulatory and competition policy issues that are emerging as the 5G and satellite industry begins to consider the risks and opportunities of Ka-band, K and Ku band shared access and the underlying technical and commercial arguments for maintaining satellite primary access rights to centimetre band and millimetre band spectrum (including V and W and E band). This will inevitably be a dominant and divisive issue at WRC 2019.

The significance of the 'new space' satellite industry in 5G business modelling is under appreciated and the lobbying power of satellite stakeholders is underestimated. More pragmatically, satellites can potentially play a major role in improving the EBITDA and enterprise value of the 5G mobile operator community and associated vendor supply chain. This changes or should change the nature of the spectrum debate and the positioning of regulatory and competition policy.

Read on

First a reminder of the ‘core’ satellite bands defined in terms of the IEEE 521-1984 standard radar bands. These are summarized in Table 1 together with the present licensing regime. There are also constellations in the VHF band; the Orbcomm satellites for IOT are an example.

Table 1 Core satellite bands

L band	S Band	C Band	X Band	Ku-Band	K-Band	Ka-Band	V Band	W Band
1-2 GHz	2-4 GHz	4-8 GHz	8-12 GHz	12-18 GHz	18-27 GHz	27-40 GHz	40-75GHz	75-110GHz
GPS	MSS	TV	Military	Commercial	Military	Commercial	Automotive radar	
Licensed	Licensed	Licensed	Licensed	Licensed	Licensed	Licensed	Unlicensed	

The three most used orbits are summarized in Table 2

Table 2 Satellite orbits

Low Earth Orbits	Medium Earth Orbits	Geostationary Orbits
160 km - 2000 km	2000 - 36,000 km	36,000 kilometres
99 miles-1200 miles	1200 miles- 22,000 miles	22,000 miles

The cost and performance trade-offs of these orbits are rehearsed intensively in the industry literature but can be summarized as lower latency for closer earth. Geostationary have the advantage of staying more or less in the same place in the sky. High count LEO and MEO constellations have the advantage of being more or less directly overhead for most of the time.

The three sizes of satellites are summarised in Table 3

Table 3 Satellite size

Pico satellites	Nano satellites	Micro satellites	Macro Satellites
< 1 kg	<10 kg	< 500 kg	➢ 500 kg

The relative advantages of Pico Sats, Nano Sats, Micro Sats and Macro Sats can be summarised in terms of available RF power and capability. Smaller satellites are useful for sensing and imaging applications; larger satellites are more suitable for supporting multiple transponders and complex and adaptive antenna arrays which support cell radius scaling from 2 to 1200 kilometres. New generation GSOs, for example third generation Ka-band Viasat satellites, have a throughput per satellite of 1000 gbps, three times the throughput of previous generation macro GSO satellites.

Any of the K bands (Ku, K and Ka-band) are capable of supporting the 3.5 GHZ+3.5 GHz pass bands that are the basic building block of high throughput satellites typically on a 250 MHz channel raster. These in turn could scale to the 5GHz + 5 GHz FDD pass band in E band (71-76, 81-86 GHz) either side of the automotive radar bands.

So there is plenty of bandwidth available and the combination of new generation high power GSO and high count LEO and MEO constellations delivers plenty of power but how good are the cost economics?

As discussed in last month’s Technology Topic, a number of technology innovations are helping to reduce the cost of launching space assets and keeping them in orbit including reusable rockets (courtesy of Mr Musk) and electric satellites (lighter launch weight and longer life). Improvements in solar cells and RF power amplifier efficiency are increasing the amount of RF power available and this power can be adaptively focused on areas of demand using adaptive fractional beam width antennas. Terrestrial flat panel array adaptive beam tracking conformal antennas or optimised passive flat panel antennas deliver additional uplink and downlink gain. These improvements increase the value of space assets and the spectral assets associated with those space assets.

Space asset, spectral asset and orbital asset value

Space asset value can be calculated on the basis of the amount of allocated spectrum, the quality and characteristics of the spectrum including the spectrum band plan, the mix of transponders on board the space asset, the level of interference to which the satellite might be exposed and for geostationary satellites, the orbital position and number of allocated slots. There may be some associated negative value in terms of debris damage risk and debris management cost - an emerging issue for high count LEO constellations.

A satellite may have a mix of C band, X band, Ku, K and Ka-band transponders supporting a mix of broadcast and bi-directional traffic. The level of interference within each band is a function of frequency reuse ratios and orbital separation.

For example, a 3 degree longitude separation produces 120 possible orbital slot positions; a two degree longitude separation produces (unsurprisingly) 180 satellite slots. A two degree separation is equivalent to a spacing distance of 1470 kilometres. The total satellite count in geostationary orbit is of the order of 1800 satellites. This includes satellites that are co-located, defined as appearing to be at the same position when viewed from earth via a satellite dish or flat panel array. Two Astra satellites at a longitude of 19.2 degrees east have a longitude separation of 0.0014575 degrees equivalent to a distance separation of one kilometre which in space terms is cosy.

Theoretically LEO and MEO satellites could also be co-located with coordinated station keeping maintaining space separation. This would double the RF bandwidth and double the RF power. Effectively this is angular power concentration as opposed to angular power separation. Simultaneous connectivity could also be supported from multiple satellites.

GSO Slot value is a function of the coverage footprint available in terms of the sea mass and land mass illuminated from the satellite. Space asset value is also a function of the capacity and RF power available from the satellite.

The rationale for installing Ka band transponders for example is to increase capacity and throughput relative to equivalent K and Ku-band transponders. These satellites are generically known as High Throughput (HTS) satellites (though see earlier comments, K and Ku band HTS constellations are also feasible and cost economic).

High throughput satellites are of course only useful if the capacity can be absorbed. This is described as fill rate. A fill rate of over 70% is considered as economic. Lower fill rates become progressively less attractive.

Interference is also managed by implementing band plans with FDD separation. As an example, Inmarsat have an FDD band plan at 28 GHz (Ka band) with four 250 MHz uplink channels between 28.35 GHz and 30 GHz paired with a downlink between 17.7 (Ku-band) and 21.2 GHz (K-band). This is combined with a military transponder at 30 to 31 GHz (Ka-band) with a downlink at 20.2 to 21.2 GHz (K band).

Note that it is going to be easier to coordinate coexistence between satellite and 5G terrestrial networks if 5G networks are also FDD – a detail not always appreciated by present 3GPP Release 15 work groups. Note also that much of the coordination will need to be resolved spatially rather than geographically.

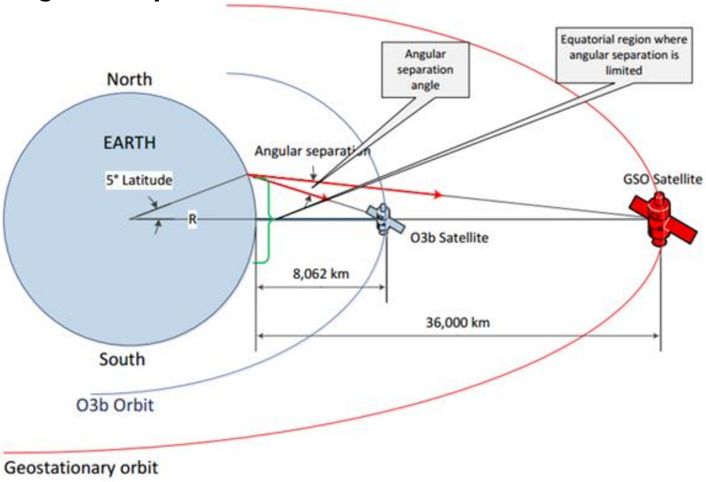
O3B provide an example of space spectrum spatial separation. O3B's band plan for their Medium Earth Orbit constellation at 8062 kilometres is based on a Ka-band downlink at 17.7- 20.20 GHz and an uplink at 27.5 - 30 GHz.

Because there are military GSO users in the downlink band, the ITU define stringent EPFD (equivalent power flux density) limits. 03B are however able to demonstrate that the angular separation between their MEO satellites and GSO satellites in the same frequency band confines any potential interference to a narrow range of equatorial latitudes, within approximately 5 degrees of the equator.

However this also means that it should be possible to deliver simultaneous coverage from an integrated MEO and GSO constellation with the MEO managing critical latency traffic and the GSO providing cost effective capacity. O3B and SES are in a persuasively good technical and commercial position to realise joint value from this spectral and space asset combination.

OneWeb and Space X and Dish Networks also all claim to have proprietary techniques for managing angular power separation. This is a critical enabler for 5G terrestrial systems where the satellite industry has prior art experience.

Inherent Angular Separation of 03B Orbit from GSO



Regulatory and competition policy implications

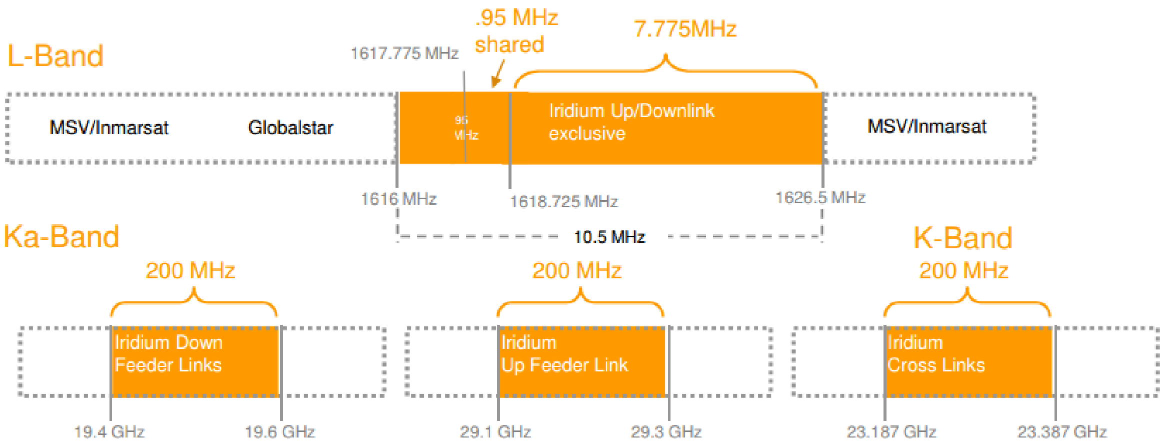
The satellite industry and mobile broadband industry have similar but different competition policy and regulatory regimes. For example regulators impose 'use it or lose it' license obligations on satellite operators to discourage paper satellites – satellites that only exist on paper as a construct for denying spectrum and orbital slots to potential competitors. Similar things happen in the mobile broadband industry with mobile operators buying spectrum so that competitors are unable to realize viable subscriber numbers.

Regulators are responsible for setting emission limits in the satellite industry to allow interference disputes to be resolved. Regulators have also intervened in cases where there has been a perceived risk of interference to space assets from terrestrial networks, Light Squared to GPS interference being a recent example. These interference risks tend to be over stated by the incumbent parties either deliberately for commercial reasons or due to cautious engineering assumptions. TV and mobile broadband coexistence arguments over the past ten years in the UHF band demonstrate the financial costs of these spectral disputes.

As the 03B example illustrates, system to system interference in the satellite sector is increasingly being managed in the spatial domain on the basis of angular power separation. This will also be the case in 5G terrestrial networks. However this on its own is not a justification for changing the access rights to allow 5G priority to Ka-band (or K, Ku and E band) spectrum particularly if the economic benefits of this are questionable.

There is the additional opportunity for existing LEO constellations to re-use their K-band and Ka band feeder and cross link spectrum for terrestrial HTS. A change in regulatory policy to allow this would transform the enterprise value of the 'legacy LEOS' (see graphic below).

Figure 1 Repurposing of K band and Ka band uplink and downlink feeder links



There is of course competition for capacity for military satellite systems across all of these bands (Ka, K, Ku and X band in particular) but there are equally strong technical arguments for moving more of these military systems to E band (60-90 GHz) releasing more HTS spectrum for commercial civilian (and consumer) applications.

Last but not least, high count LEO and MEO satellite constellations will require a new regulatory regime to address issues of debris management, collision avoidance and end of life deorbiting.

Summary

Over the next two years leading up to WRC2019 we can expect intense lobbying and debate over 5G and satellite coexistence issues, real or imagined in Ka-band and to a lesser extent in all other satellite bands.

While this might be understandable, it is regrettable and will slow the pace of 5G and satellite Ka-band HTS LEO, MEO and GSO adoption and constellation upgrades. More importantly it will reduce the potential added value to be realized from a closer integration between the mobile broadband industry, the satellite industry and their respective industry supply chains.

There is a strong technical and commercial argument that it will often be more cost economic to provide wide area terrestrial connectivity from a mix of GSO and LEO and MEO satellite Ka, K and Ku- band satellites rather than from terrestrial networks.

If this is the case, the enterprise value of the 5G mobile operator and satellite operator community would be mutually enhanced if the satellite industry maintained their primary access rights to Ka-band and K and Ku-band spectrum with initial 5G terrestrial deployment concentrated on sub 6 GHz spectral assets.

Ends

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