RTT TECHNOLOGY TOPIC
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5G and Satellite Spectrum, Scale and Supply Cost

This month we continue with a narrative previously covered in our August 2016 Technology Topic, Satellite Spectrum and Standards which highlighted the developing inter dependency of the 5G and satellite industry in terms of technology innovation, technology standardisation and spectrum but this time with more attention on the need to achieve cross amortisation across RF hardware platforms including point to point backhaul.

RF hardware commonality is a function of spectrum allocation. Spectrum allocation is determined by a mix of macro-economic and political factors. However allocation and auction policy also needs to comprehend the bandwidth requirements of the technologies being deployed. This includes the channel bandwidth and pass band, the guard bands (determined by protection ratios) and, in FDD band plans, the duplex gap.

Auction policy is also influenced by competition policy. In mobile broadband terrestrial networks this has meant that a mix of narrower band (200 KHz) and wider band (5 MHz and 10 MHz) channels supporting five operators in a market requires a sub 1 GHz pass band of at least 35 by 35 MHz.

At 900 MHz, a 35 MHz pass band has a bandwidth ratio of 3.8%, comfortably within the limits of acoustic filters. The 35 MHz band allocated in the recent US incentive 600 MHz auction has a bandwidth ratio of 5.8%. This is outside the comfortable performance limit of an acoustic filter. A need to co-exist with adjacent high power TV will also incur additional filter loss in user devices.

The 45 MHz pass band in the APT band (Band 28 at 700 MHz) has similar challenges. Wider pass bands incur performance loss due to the degradation of filter Q and noise matching and power matching loss and require more dynamic range to avoid desensitisation. Performance will also vary across the band. This at least partly explains the relatively low prices achieved for the 600 MHz auction.

LTE Advanced introduces wider bandwidth requirements with an aggregated channel bandwidth of up to 100 MHz, requiring multiple channels or multiple pass bands to be supported simultaneously.

The multiplexing needed for **inter band channel aggregation** results in significant user device performance loss when operating on a single duplex pair so performance gain in terms of peak data rate is traded against a reduction in range and a reduction in capacity and lower power efficiency.

The peak to average envelope variation for **intra band channel aggregation** inflicts additional PA efficiency loss. Envelope tracking and digital pre distortion used to reduce this loss adds noise into the receive path. This performance loss compromises range (data reach), capacity and battery life.

5G deployed as a mobile or fixed access network has maximum data rates that require channel bandwidths of the order of 250 MHz. On the basis of multiple operators continuing to own and control their own spectrum this implies a pass band of 1 GHz.

The Release 15 standards process is assuming that 5G can and should be deployed in sub 6 GHz spectrum but it is hard to see how 250 MHz channels can ever be supported power efficiently at these longer wavelengths. The combination of extreme bandwidth ratios and antenna and matching inefficiencies will impact significantly on the link budget.

The Achilles heel of all existing cellular networks is that they send most of their RF power in the wrong direction, sideways or backwards. This can be resolved more efficiently by moving to the centimetre and millimetre bands.

However, the centimetre and millimetre bands will only be economically sustainable if deployed globally with harmonised spectrum and standards to allow the potential scale benefits of mobile and fixed broadband, backhaul and satellite access integration to be realized.

In this month's technology topic, '5G and Satellite Spectrum, Scale and Supply Cost', we take a look at how the FCC is approaching 5G spectrum allocation at 28 and 38 GHz in the US and the potential for common RF hardware across mobile and fixed access, backhaul, satellite and radar systems in this shorter wavelength spectrum.

Read on

To be sustainable, 5G has to deliver a cost and performance gain over present and future 4G and legacy wide area mobile broadband systems. This is dependent on delivering isotropic gain from centimetre band and millimetre band fractional beam width antenna arrays but is equally dependent on realising cost reduction by building on existing RF hardware platforms.

The bands proposed by the FCC and the ITU for 5G directly overlap existing point to point microwave band allocations, satellite and space allocations and civilian and military radar.

With the exception of the 28 GHz band, proposed by the FCC as a core band and excluded from study by the ITU, there is reasonable commonality between the FCC and ITU on preferred candidate bands which means that global economies of scale can potentially be achieved.

The companies best placed to deliver cost competitive 5G products are the companies already delivering point to point hardware, satellite RF hardware and radar RF hardware into these bands.

This includes some but not all of the existing LTE vendor community and a mix of other large and small (and some very small) suppliers who are presently less obvious as potential 5G hardware suppliers.

Table 1 shows the 5G candidate bands proposed for study at WRC 2019 for K-band, Ka-band, V band and W band (the IEEE 521-1984 designated radar bands) and the parallel FCC proposals set out in the Spectrum Frontiers Ruling in July 2016 and the Future Notice of Proposed Rule Making.

The ITU has identified 33.8 GHz of centimetre band and millimetre band spectrum to be studied as potential 5G spectrum for discussion at the next World Radio Congress (WRC 2019). With the exception of the 28 GHz band, the FCC proposals are similar though not identical (different pass bands for example).

There is also a present lack of clarity as to how the potential bands at 70 and 80 GHz either side of the automotive radar bands might be allocated and managed. The FCC are proposing an extension of the 60 GHz unlicensed band from 57 to 71 GHz but a licensed or shared access or lightly licensed regime for 71-76 GHz and 81 to 86 GHz remains as an option.

It would be useful to have the same bands, pass bands and regulatory and licensing regime in the US and Rest of the World but this seems presently unlikely.

Table 1 ITU and FCC Proposed 5G Candidate Bands for study

[ITU WARC 2019](#) Bands agreed for study for 5G														
	K-Band		Ka-Band				V Band						W-Band	Total
GHz	24.25 27.5		31.8 33.4	37 40.5		40.5 42.5	42.5 43.5	45.5 47	47 47.2	47.2 50.2	50.4 52.6	66 76	81 86	
GHz	3.25		1.6	3.5		2	1	1.5	200 MHz	3	2.2	10	5	**33.8 GHz**
[FCC Upper Microwave Flexible Use](#)														
GHz			27.5 28.35	37 38.6	38.6 40									
GHz			850 MHz	1.6	1.4							64 71		
			Licensed	Licensed *								7 GHz Unlicensed		
GHz				FCC ITU										**10.85 GHz**
Summary	**33.8GHz of ITU spectrum for study at WRC2019,** **10.85 GHz of FCC UMFU spectrum for study of which 3 GHz is common (37-40 GHz)** **FCC proposed lower band at 28 GHz not included as an ITU WRC 2019 study band though adjacent to ITU study band** *** 600 MHz of FCC spectrum from 37 to 37.6 GHz proposed as shared use commercial/federal**													
[FCC Future notice of proposed rule making](#)														
GHz	24.25 24.45	25.5 25.25	31.8 33.4				42 42.5			47.2 50.2	50.4 52.6	71 76	81 86	
GHz	200 MHz	200 MHz	1600 MHz				500 MHz			3 GHz	2.2 GHz	5 GHz	5 GHz	**17.7 GHz**
	FCC/ ITU						**FCC/ITU**			**FCC/ITU**	**FCC/ITU**			
GHz														
Summary	**17.7 GHz of FCC spectrum for study of which 17.7 GHz is common to ITU and FCC (24 GHz, 25 GHz, 32 GHz, 42, 47-50, 50-52 GHz, 71-76 81-86 GHz)**													
IEEE 521-1984 radar bands - X Band 12-18 GHz, Ku Band 12-18 GHz, K-Band 18-27 GHz, Ka- band 27-40 GHz, V band 40-75 GHz, W-Band 75-110 GHz														

Many of these bands are used by the satellite industry. Inmarsat Global Express high throughput (HTS) satellites for example have a commercial uplink at 27.5 GHz to 31 GHz with a paired downlink at 17.7 GHz to 21.2 GHz and a military uplink at 30 GHz to 31 GHz paired to a downlink at 20.2 GHz to 21.2 GHz.

For point to point terrestrial backhaul there are large regional variations both in terms of the ratio of microwave to fibre and the frequencies used for microwave.

38 GHz is presently one of the most highly utilised bands and likely to remain a core band for the foreseeable future, 26 GHz is also popular and utilisation of the 28 and 32 GHz bands is increasing. These new bands are needed for wider channels, for example 56 MHz and 112 MHz, to support gigabit link rates.

Emerging bands also include 40 GHz, sometimes described as Q band (the WR22 waveguide designation) and E band (from the WR12 waveguide designation) at 71-76 GHz and 81-86 GHz

Q band and E band Backhaul Hardware

Table 2 below shows an example of existing Q band and E band hardware with typical link budgets and the isotropic gain available from fractional beamwidth antennas, in this example, a two foot cassegrain with radome.

Table 2 Q and E Band Backhaul Point to Point Microwave- with thanks to RF Com

The cassegrain delivers 44 dB of gain from a 0.7 degree antenna at 40 GHz and 51 dB from a 0.35 degree antenna at 70/80 GHz. The additional 7 dB of gain is equivalent to 14 dB assuming the same antennas either end of the link.

This more than off sets the additional propagation loss in clear sky conditions. Note some of the gain of the narrower beam width antenna may be off-set by pointing loss.

Table 2 Q and E Band Backhaul Point to Point Microwave- with thanks to RF Com

Band	Q Band				E Band		
Frequency	40.5-43.5 GHz				71-76/81-86 GHz		
Throughput	Up to 10 Gbps full duplex						
Channel Bandwidths	250/500/750/1000/1250/1500/2000 MHz						
Modulation	QPSK to 256 QAM						
Max distance with 2 ft antennas in clear sky	Up to 20 km (12 miles)						
Antennas – gain and beam width	Cassegrain with radome						
2 foot	44 dB/0.7 degree Q band 40 GHz				51 dB/0.35 degree E band 70/80 GHz		
QPSK Link budget by channel bandwidth	183 dB at 250 MHz 180 dB at 500 MHz 178 dB at 750 MHz 177 dB at 1000 MHz 176 dB at 1250 MHz				197 dB at 250 MHz 194 dB at 500 MHz 192 dB at 750 MHz 191 dB at 1000 MHz 190 dB at 1250 MHz 189 dB at 1500 MHz 188 dB at 2000 MHz		
Max Throughput Q and E band	250 MHz	500 MHz	750 MHz	1000 MHz	1250 MHz	1500 MHz	2000 MHz
Mbps	1750	3540	5290	7045	7430	8940	10 GBps

Mast or roof mounted RF point to point backhaul hardware is not the same as a compact low cost 5G Node B and a handheld 5G user device will never have the gain achievable from a dish antenna but they are getting more similar over time particularly if 5G is considered essentially as a progressive point to point network topology (5G PPP E band?)

At a minimum, the RF hardware exists as a basis for 5G product and network development. Common RF transceiver hardware could also provide the basis for moving terrestrial and satellite backhaul in band.

The one lesson that should have been learnt from 3G and 4G is that escalating development costs coupled with fragmented spectrum and standards make it harder to realize the product and network costs needed to service low ARPU markets. Although hard to address, these are the markets with the highest growth potential.

The ability for 5G to build on already proven and part or fully amortized RF hardware built around harmonized spectrum and standards would help break this ultimately unsustainable model.

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