RTT TECHNOLOGY TOPIC
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Sub G 5G

In February this year, ITU-R M.2083 formalized three high level use cases for 5G, enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable/low latency communications (URLLC).

These high level use cases are intended to inform the Release 15 and Release 16 standards process. The 'new radio' work items within 3GPP are focussing initially on eMBB and URLLC and consider frequency ranges up to 52.6 GHz with over the air RF requirements defined for below 6GHZ and above 24 GHz. Release 15 is scheduled for completion by mid-2018 (RAN 80).

Release 16 is scheduled for completion by December 2019 by which time the outcome of WRC2019 will be known. Release 16 has additional work items on adaptive beam forming intended for use in Ku-band, Ka-band and E band.

Release 15 includes work on additional bandwidth above existing LTE allocations including bands up to 4.99 GHz but also interworking with 5 GHz Wi-Fi including 802.11p. It also includes study work on refarming LTE spectrum for 5G which in theory could be anywhere from Band 31 at 450 MHz (initially in Brazil) to Band 43 at 3.8 GHz.

Some countries have suggested their own 5G preferences. The UK for example has suggested 26 GHz, 3.6 GHz and 700 MHz as three pioneer bands for 5G. Europe presently seems to be favouring 26 GHz; the US favours 28 GHz, 38/39 GHz and E band.

The headline assumption for 5G eMBB is 100 MHz of bandwidth at all times which would seem to suggest an emphasis towards higher frequency shorter wavelength bands.

However countries such as India (The Telecommunications Standards Development Society) have been lobbying for larger area cell sizes to be supported for low cost rural and urban coverage and this is now reflected in **a stated requirement for low mobility large cells** and rural coverage supporting high speed vehicles.

While this would be feasible at C band and shorter wavelengths there may be economic reasons for looking at the relative economics and technical feasibility of implementing 5G in sub 1 GHz spectrum for these large cell deployments, the subject of this month's technology topic.

Read on

The vendor community, particularly the US vendor community, presents a vison of 5G based on high data rates delivered in the centimetre and millimetre band with a present implementation focus on 28 GHz, 38/39GHz and E band (the 71-76, 81-86 GHz duplex either side of the automotive radar bands).

The underlying technical logic is that smart antennas deployed at these wavelengths can potentially deliver over 40 dBi of isotropic gain, offsetting the additional free space propagation loss, non-line of sight loss and surface scatter absorption.

The underlying commercial logic is that 28 GHz and 38 GHZ and E band hardware already exists for point to point and point to multi point backhaul so in practice this is a scaling of existing RF technology platforms.

It also allows 5G to scale to ultra-dense network topologies to compete with Wi-Fi. As a rule of thumb in a present day network, 400 Wi-Fi sites provide equivalent coverage to 20 LTE cellular sites. Implementing 5G in the centimetre and millimetre bands would support Wi-Fi density but with a significantly higher link budget. The improved link budget would be delivered by using fractional beam width antennas to realize higher EIRP and improved receive sensitivity. FDD if adopted would deliver an additional sensitivity gain over TDD Wi-Fi.

However there is a counter argument that cautions against the notion of using licensed Ku and Ka-band and E band spectrum as the basis for competing with unlicensed spectrum delivered from access points where the costs are covered by other third parties. Cafes and clubs provide the basis for a no cost Wi-Fi business model against which it is foolish to compete.

The economic counter argument is further strengthened by another rule of thumb which is that at 28 GHz an additional 30 dB of downlink transmit power is needed to achieve the same user device receive power as a 900 MHz cellular network. On the uplink a similar level of selectivity gain will be required.

While this is technically possible and indeed attractive on the basis that it introduces additional complexity which translates into additional vendor value, it may not be the best option for mobile broadband operator EBITDA and intuitively not a good idea for lower ARPU markets.

A simpler 5G solution that scaled to longer wavelengths would seem to be possibly more appropriate but could that include sub 1 GHz spectrum?

Five Band Sub G 5G

The IMT2020 definition of 5G enhanced mobile broadband (eMBB) specifies that a minimum of 100 MHz of bandwidth should be available at all times - the assumed practical upper limit of LTE Advanced using aggregated carriers becomes the lower limit of 5G.

This would seem to be impractical as a sub 1 GHz deployment until you take a closer look at the sub 1 GHz band plan

Five Band Sub G 5G

450		600			700			800			900		Total
Band 31 Brazil		Band 71 US		Band	Band 28 APT		Band	E850 USA Band 26		Band	Band 8 Europe and Asia		MHz
452 457	462 467	617 652	663 698		703 748	758 803		814 849	859 894		880 915	925 960	
5	5	35	35		45	45		35	35		35	35	155+155
				12	696 716	729 746	20	791 821	832 862	US ISM	902 928		
				17 AT&T	704 716	734 746							
				13 Verizon	746 756	777 787							
				14 First Net	758 768	788 798							

The table shows the five bands available between 450 MHz and one GHz.

Theoretically if the 450 band in Brazil (Band 31) is added to Band 71 in the US (the new 600 MHz allocation following the incentive auction) together with Band 28 in Asia, the E850 band (Band 26) in the US (and parts of Asia) and Band 8 at 900 MHz (Europe and Asia) then 155+155 MHz of spectrum is available.

Practically this does not scale geographically due to the differences in allocation between the three ITU Regions but it would not be impossible to find 100 MHz of common FDD spectrum that could be potentially refarmed for 5G which could include Band 14 now earmarked for use by AT&T for the First Net (first responder) network.

This poses many implementation questions not least of which is the impact of introducing any of the five 5G candidate waveforms into spectrum supporting LTE CP-OFDM, 3G and 'narrow band' GSM .

Agilent have a video on this topic.

But also there is a present lack of ambition as to how far 5G cell sizes could or should scale. The IMT 2020 recommendations for 700 MHz suggest a cell inter site distance of 5 kilometres but this seems paltry when compared with standard GSM (35 kilometre cells) and particularly insignificant when compared to proprietary larger cell size implementations of GSM, for example in Australia where 100 kilometre radius cells are deployed in a high power high tower topology.

These larger cells come with round trip timing implications. The TDMA time slots in GSM are time advanced to compensate for the flight time difference of close in and cell edge users and in 100 kilometre cells every other time slot is left blank to provide sufficient additional time domain guard band to avoid user to user ISI. Capacity is traded against coverage.

Similar issues arise with the cyclic prefix in LTE with larger cells incurring significant time domain guard band overheads. Not all of the 5G candidate waveforms use a cyclic prefix but none of them have been expressly designed to be efficient or effective in larger radius cells suggesting that this is an area of 5G standards making that deserves additional priority.

It would also be harder to implement smart antennas at these wavelengths though not impossible, the challenge is to deliver performance gain within a 0.3m width envelope panel antenna (one column of elements) to meet weight and wind loading constraints.

Arraycomm and Quintel provide two examples of antennas available today for sub 1 GHz deployment that might not be as smart as 5G massive MIMO centimetre band and millimetre band adaptive phase arrays but still deliver useful performance gain in noise limited and interference limited networks irrespective of whether 4G or 5G technologies are deployed.

Quintel additionally position their product as a way of managing 4G and legacy technology coexistence in the same band and 4G/5G coexistence would be a relatively simple extension of the same technique.

Care has to be taken when wider bandwidth waveforms and narrow band waveforms coexist in adjacent channels within the same pass band with the wider bandwidth channels generally projecting higher OOB emissions into their narrow band neighbours but this is a well understood and manageable problem.

In terms of device front design, the additional hurdle of high bandwidth ratios has to be overcome. Designing an antenna and ground plane to work efficiently from 450 MHz to 900 MHz is a non-trivial task particularly when space is at a premium and it is a shame to throw all or some of the longer wavelength propagation gain away due to lack of aperture or compromised noise and power matching and or hand capacitance effects.

Similarly it would be prematurely ambitious to consider a multiplexing architecture that could couple these five bands together through a single transmit and receive chain. In practice there would be five pass bands each defined by an acoustic duplex filter.

Incidentally we are reliably informed that temperature compensated SAW devices based on lithium niobate (LiNbo3) or equivalent FBAR devices are now capable of supporting bandwidths of up to 6% so high bandwidth ratios (45+45 MHz for APT Band 28 for example) can now be handled by a single duplex filter - our thanks to Avago for pointing this out to us. There is also a potentially useful quarter wave/half wave relationship between the 450 and 900 MHz bands similar to the 900/1800MHz bands which may allow front end efficiencies to be realised.

Summary

It has always been our position that high data rates are a worthy ambition but the real challenge for 5G is to deliver data more cost efficiently and power efficiently than all and any of the technologies that 5G aims to replace. It also needs to deliver improved EBITDA and higher enterprise value for operators servicing developed economy markets already fully saturated with 4G networks and devices and deliver low cost IOT connectivity.

It has also been our position that for 5G to be economically viable it has to be able to scale to lower ARPU markets and to be capable of servicing vertical markets where geographic coverage is more important than demographic coverage. Verizon's announcement of a nationwide Cat 1 network for IOT at $2 dollars per month is an indication of where the operator community wants to go but IOT vertical markets need geographic rather than demographic coverage which is not what existing networks have been designed to deliver.

All of which implies that 5G has to scale to larger radius cells. It is not impossible to support large area cells in the centimetre and millimetre band. For example there are military radio systems that achieve 60 kilometre line of sight range in E band but not at consumer price points.

The present marketing obsession with network densification is understandable from a vendor perspective as it multiplies hardware sales. The sheer volume of 4G (millions of base stations now deployed) provides a starting point for further significant reductions in 4G and 5G hardware cost.

However dense networks come with irreducible capex and opex cost multipliers including site costs. These costs are not impacted by industry scale. Dense networks are also not power efficient and incur significant backhaul cost and bandwidth overheads.

Improving returns from existing spectral assets (improving returns on a per MHz basis) is always better than taking on additional spectral risk, particularly if that risk is compounded by co-existence costs of unknown magnitude, the inevitable consequence of co sharing Ku and Ka-band and E band with the satellite and radar industry.

The additional benefit of Sub G 5G is that it could be deployed from existing cell sites, improving returns on a per site basis.

Five band Sub G 5G has implementation challenges but these are not insurmountable. Given the potential mobile operator EBITDA benefits (better returns per MHz and per site) it would seem sensible to see this as a higher priority work item in 3GPP Release 15 standards.

For developing economy low ARPU markets, The Telecommunications Standards Development Society of India has done a creditable job of highlighting the need for large cell 5G but the economic benefits potentially scale equally well into high ARPU markets including vertical markets where geographic coverage is more important than demographic coverage – data reach rather than data rate could or more importantly should be a key performance metric in 5G fixed and mobile broadband.

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