Qualcomm Europe Inc.

Qualcomm's response to Ofcom Consultation "Award of the 2.3 and 3.4 GHz spectrum bands. Competition issues and auction regulations"

January 2017

Introduction

Qualcomm welcomes the opportunity to respond to the Ofcom consultation on the "Award of the 2.3 and 3.4 GHz spectrum bands"

An EU Commission study[1] forecasting the socio-economic benefits of 5G, estimates that in 2025 benefits from the introduction of 5G capabilities could reach €113.1 billion per year in four key sectors that will also be using 5G connectivity: automotive, health, transport and energy. Investments of approximately €56.6 billion will be likely to create 2.3 million jobs in Europe. The European Commission has identified early introduction of 5G as being a key priority for Europe's communication industries.

5G connectivity will create new services, new industries and devices, and empower brand new user experiences transforming societies and industries to an even greater extent than previous service generations. 5G will empower brand new user experiences via support of ultra-low latency, ultra-low power, ultra-high reliability and ultra-high security devices with flawless connectivity. 5G will be scalable and adaptable across extreme variations in requirements and will be a unified design across all spectrum bands and types (licensed, shared and unlicensed) from below 1 GHz for wide area

[1] *"Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe" (SMART 2014/0008)*

coverage deployments to higher bands up to 6 GHz for more capacity focused deployments, to above 6 GHz and mmWave for extreme bandwidth and more targeted capacity deployments.

With large commercial introduction of 5G networks taking place by 2020, it is expected that the early introduction of 5G in Europe will benefit from trials and pilots of new 5G networks taking place well before this. Mobile operators and manufacturers have already begun to invest in research on 5G technology, as well as carrying out initial trials. These trials are expected to increase in scale and number over the coming twelve months as European policies encouraging the development of 5G (such as proposed in the 5G Action Plan) are further developed.

5G is the biggest opportunity ever for our industries. We need to make sure there is one global standard in order to not fragment terminal ecosystem. 5G needs to benefit from the global scale that we have become used to with LTE.

3.4 – 3.8 GHz: the primary band for 5G

Availability of spectrum is a key requirement to enable development, testing and early deployment of 5G before 2020 and we do believe that the 3400-3800 MHz will be the primary band in the spectrum between 1 GHz and 6 GHz for the introduction of 5G in Europe before 2020, as recommended by the Radio Spectrum Policy Group and in the EC Action plan:

- In its 'Opinion on spectrum related aspects for next-generation wireless systems (5G)', the RSPG "…considers the 3400-3800 MHz band to be the primary band suitable for the introduction of 5G use in Europe even before 2020, noting that this band is already harmonized for mobile networks, and consists of up to 400 MHz of continuous spectrum enabling wide channel bandwidth. This band has the possibility to put Europe at the forefront of the 5G deployment."

- In its Action Plan, the European Commission states: "….the 3.5 GHz band seems to offer high potential to become a strategic band for 5G launch in Europe."

Making spectrum in 3400-3600 MHz band available in 2017 timeframe would allow the UK to be ahead for 5G roll-out and this would enable also the country reap the benefits of a leading country advantage. Qualcomm believe that there is a trend towards mobile use of the 3.4-3.8 GHz band.

Furthermore,

- In June 2016 ECC established a new Work Item and invited ECC PT1 to assess the suitability of the harmonized technical conditions of ECC Decision (11)06[2] to 5G.
- In December 2016, the EC RSCOM (Radio Spectrum Committee) issued a mandate to CEPT to develop harmonized technical conditions for spectrum use in support of the introduction of next-generation (5G) terrestrial wireless systems in the Union and in particular to review by June 2018 the harmonised technical conditions applicable to the 3.4-3.8 GHz ('3.6 GHz') frequency band, as a 5G pioneer band, with view to their suitability for 5G terrestrial wireless systems and amend these, if necessary.
- This band is being considered for early trials and introduction of 5G services in a number of countries/regions in the world including China, Japan and Korea.
- In Europe, Germany and France have recently signaled in their public consultation their willingness to auction this spectrum for 5G. In Ireland, ComReg published the Information Memorandum for the forthcoming award of spectrum rights of use for the 3.4 – 3.8 GHz frequency band. In Italy, the

[2] ECC Decision (11)06 : "Harmonised frequency arrangements for mobile/fixed communications networks (MFCN) operating in the bands 3400-3600 MHz and 3600-3800 MHz" - http://www.erodocdb.dk/docs/doc98/official/pdf/ECCDec1106.pdf

telecom regulator has published their proposed auction rule for the 3.6 – 3.8 GHz band and in Spain the regulator has provided information on their refarming activity regarding the 3.6 – 3.8 GHz band and their intention to tender it for MFCN according to market and operators' needs.

The proximity of this band to existing bands used for mobile, the potential reuse of existing infrastructure in areas where dense networks are deployed, bandwidths considerably wider (in the order of 100 of MHz) than those of today that can assist to address 5G use cases in the short/medium term providing a combination of capacity and coverage making the 3400 – 3800 MHz range very attractive for 5G.

By design, 5G NR (New Radio) will optimally support wideband operation, allowing operators to fully take advantage of larger allocations of contiguous spectrum to increase peak rates and user experience, with manageable terminal complexity and minimal power consumption. Ongoing standardization for the 5G NR new air interface in 3GPP is considering bandwidth in the order of 100MHz.

5G-NR specification will provide a full set of new features that will allow leveraging large bandwidths in a differentiating way compared to latest releases of LTE Advanced Pro, thus providing better average performances or better capacities at equivalent bandwidth and proportionally amplified by the use of large channel bandwidth.

- Enhanced active multi-element antenna systems leveraging latest High Order MIMO, with beamforming capabilities on both DL and UL will be delivered by design when using mmW frequencies for 5G-NR and will also be available to 3.4-3.8 GHz 5G-NR. These new generation of 2-dimensional antenna arrays allow better control of interference through directional transmissions to users and minimisation of transmitted power and additional capacity enhancements.
- In particular, the 5G NR slot structure is being designed to have a more flexible TDD integrated subframe design with the efficient embedding of uplink reference signal transmissions to enable massive multiuser MIMO based on channel reciprocity (i.e.

the ability to estimate the channel without relaying large amounts of channel estimation side information). Compared to LTE MIMO, these 5G NR shorter latency wideband sounding signals enable robustness to channel variability.

- Qualcomm is currently working on new simulations to highlight the benefits of using these new active antennas solutions together with wideband channels and 5G-NR.
- As an example, massive MIMO at 3.6GHz allows re-use of existing macro sites at same transmit power to obtain a significant throughput gain at cell edge. Simulations have been carried out using the following characteristics:

    - macro cell deployment with inter-site distance of 1.7 km,
    - 46dBm transmit power at base stations,
    - 10 users per cell and
    - 24 column antenna array per cell and 4 antennas per UE at 4 GHz using an 80 MHz channel.

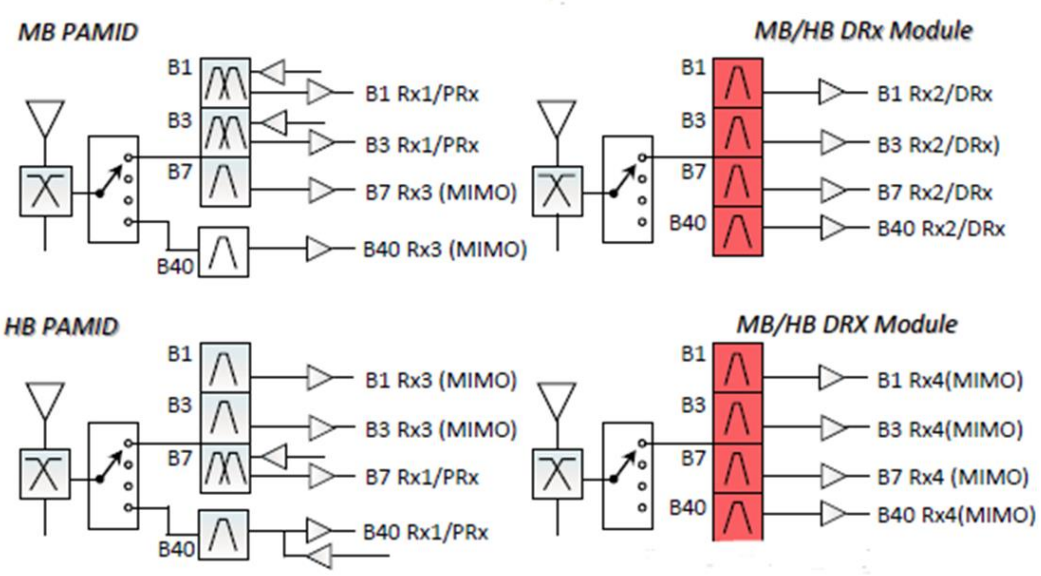
  This provides 3.9x to 4.1x gains for cell edge and median users, respectively, compared to 2 x 4 MIMO using the same 80 MHz bandwidth at 4 GHz and delivers an average cell throughput of 808 Mbps.

- The massive MIMO designs enable MU-MIMO (Multi-User MIMO) to be able to simultaneously serve multiple users in the same spectrum and cell at the same time based on the increased level of directional transmission to separate users. Applied to large bandwidths, the absolute gains become significantly attractive to cope with new usages related to eMBB.

- It is therefore important to highlight that key element for successful deployment of massive MIMO and active antennas is the availability of large contiguous bandwidths. Considering channel reciprocity, the highest gains are expected in TDD deployments which allow the 5G NR system to leverage channel information without the need for large amounts of channel state information transfer between terminals and cell sites. The enhanced spatial directivity from Massive Multiuser

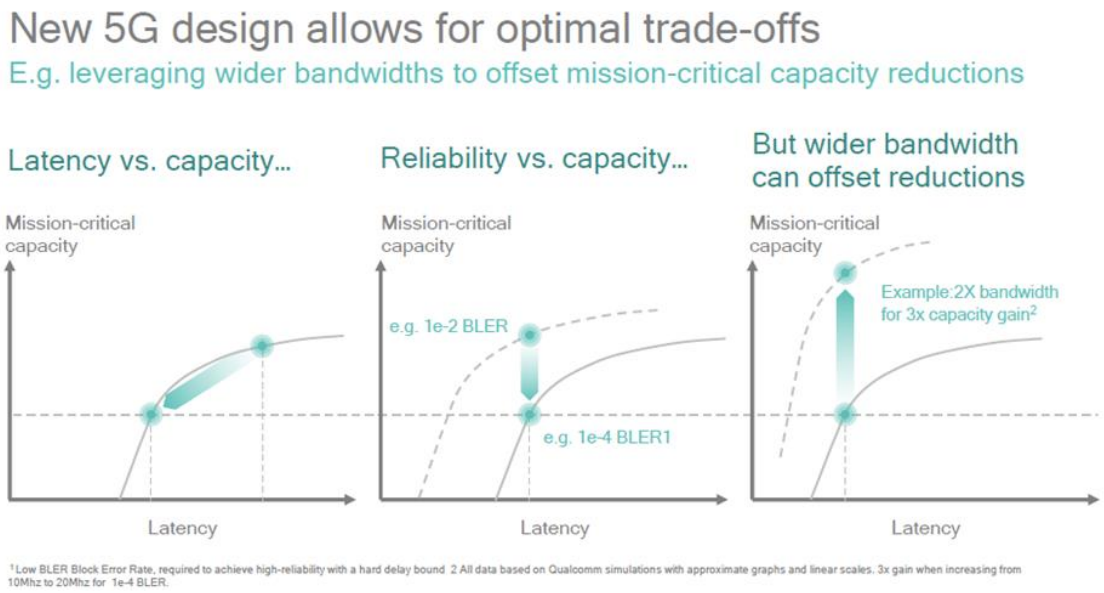
MIMO at the 3.4-3.8 GHz band causes less interference to other users and cells which translates into a capacity gain as well as energy consumption savings on the network side since the signal is effectively steered to each of the desired users vs being transmitted in a broader spatial area.

- 5G-NR on large bandwidths will reduce terminal front end complexity and power consumption compared to LTE using multiple 5 to 20 MHz carrier aggregations to exploit a similar large bandwidth.
    - By being able to work on wideband carriers and by using flexibility in sub-carrier spacing, 5G-NR enables efficient RF front end and baseband processing to have improved power consumption per Mbps and per MHz.



Example : Mid-Band (MB) / High-band (HB) RF front-end with 4x4 MIMO for B1-B3-B7-B40

- 5G-NR on large bandwidths allow to improve access to ultra-reliable services by offsetting mission critical capacity needs and access to new generation of services by bringing native forward compatibility for straight forward launches with limited impact on legacy services.



LTE can use Carrier Aggregation to aggregate multiple 20MHz channels, but as described above, as the number of channels to be aggregated increases, LTE will become less inefficient than an 5G NR system designed to inherently leverage wideband TDD deployments and massive MIMO

By delivering improved link budget, better spectrum efficiency in higher bands such as 3.4-3.6 GHz, 5G-NR will improve peak and average data rates experienced in similar channel bandwidths The following table provides theoretical 5G data rate per channel BW.

RF channel Bandwidth (MHz)	Peak data rates[3]	Average data rates[4]	5th percentile data rates[5]

[3] *Peak spectral efficiency (SE) of NR: 30 bit/s/Hz in DL (from draft New Report IMT-2020.TECH PERF REQ in ITU-R WP 5D). Peak data rate in IMT-2020.TECH PERF REQ is 20 Gbit/s in DL (roughly equivalent to a total of 667 MHz with the considered SE).*
[4] *Average SE of NR: 7.8 bit/s/Hz in DL for Dense Urban scenario (3 x SE of IMT-Advanced, also considered in IMT-2020.TECH PERF REQ)*
[5] *5th percentile SE of NR: 0.225 bit/s/Hz in DL for Dense Urban scenario (3 x SE of IMT-Advanced, also considered in IMT-2020.TECH PERF REQ). User experience data rate in IMT-2020.TECH PERF REQ is 100 Mbit/s in DL (roughly equivalent to a total of 444 MHz with the considered SE). Studies in ITU-R*

40	1.2 Gb/s	0.312 Gb/s	9 Mb/s
100	3 Gb/s	0.78 Gb/s	22.5 Mb/s
200	6 Gb/s	1.56 Gb/s	45 Mb/s
400	12 Gb/s	3.12 Gb/s	90 Mb/s

5G-NR will also bring the ability to "multiplex" new forward compatible services with limited impact on eMBB capacity needs and the ability to deliver simultaneous wireless backhauling and fronthauling capabilities to gNBs (5G-NR base station). Wide bandwidths channel will significantly facilitate the use of these capabilities and therefore contribute to the acceleration of new services introduction.

To sum-up, it can be said that 5G NR is being designed to inherently incorporate advanced wireless techniques across a wide range of requirements that take full benefit of wideband channels to deliver improved spectral efficiency, better capacities and user experiences

Conclusions

Qualcomm:

- believe that spectrum in the 3.4 – 3.6 GHz band should be auctioned in 2017 to allow 5G trials spanning eMBB and mission critical services paving the way for eMBB commercial rollout before 2020.
- agrees with OFCOM proposal for an auction design based on 5 MHz blocks with the possibility for operators to purchase contiguous blocks without a cap in this band. This is important to allow operators, which wish so, to get access to wider contiguous spectrum of at least 80 MHz and ideally 100 MHz, which is required for MNOs to reap the full benefits of this frequency band for 5G.

are still ongoing regarding these numbers also in the context of the spectrum needs of IMT-2020 above 24 GHz.

- believe that following the award of the spectrum in the 3.4 – 3.6 GHz band in 2017, Ofcom should consider releasing also at least additional 100 MHz of spectrum in the 3.6 – 3.8 GHz band in a timely manner and ideally in 2018.