RTT TECHNOLOGY TOPIC
March 2015

5G-E Band

The four largest mobile broadband vendors are promoting the viability of launching 5G networks by 2020.

http://www.huawei.com/5gwhitepaper/
http://www.ericsson.com/news/1872291
https://www.nttdocomo.co.jp/english/info/media_center/.../0508_00.html
http://networks.nokia.com/sites/default/files/document/5g_requirements_white_paper.pdf

This is in the context of a present industry in which there is a negative coupling between increased data rates and profitability - as data rates go up, EBITDA and operator margins go down. Partly this is due to the increased maintenance and management costs that are a consequence of increasing network density.

Higher density networks also increase capital spending and reduce ROI. In the short term reduced EBITDA is being addressed by ongoing industry consolidation but in the longer term there is a requirement to achieve step function reductions in cost per delivered user bit. The present assumption that 5G should be designed as an ultra-dense network is open to question and there is a case to be made for exploring wide area large cell high capacity high data rate physical layer options.

There is a divergence of opinion as to whether 5G is a network of networks or a new physical layer but it is hard to see how 5G capacity, data rate and latency expectations can be met without significant bandwidth allocation above 4 GHz. These are bands which support military and civilian radar, military and civilian LEO, MEO and GSO satellite systems, military and civilian point to point backhaul and RF dependent sensing and communication systems including latency sensitive next generation unmanned aerial vehicle control.

Our last two technology topics, ‘Defence Spectrum – the new battleground’ and ‘Automotive Radar’ explored the viability of E band for 5G on the basis of contiguous bandwidth (two by 5 GHz bands) between 72 and 77 and 82 and 87 MHz and an additional 3 GHz between 92 and 95 GHz.

These sub bands within E band have favourable line of sight propagation (60 kilometre clear weather range) and cross industry technology and market cooperation opportunities between the mobile broadband, defence and automotive industries.(Automotive radar at 77-81 GHz).

The use of these bands would have to be formalized at the latest by WRC 2018.

The FCC has started the process of discussion on band availability above 24 GHz. This includes taking on board academic inputs that suggest that the propagation characteristics of the millimetre bands (excepting 60 GHz resonant absorption) are significantly more favourable than previously realised both in urban and rural environments.

http://nyuwireless.com/newevents/the-race-for-5g-nyu-wireless-researchers-file-comments-with-fcc-to-shape-the-future-of-wireless/

Ofcom and other European and Asian regulatory agencies have similar processes under way seeking views on spectrum preferences above 6 GHz but the process is broadly focussed and beset by a wide range of opinions and industry special interest.

In this month's technology topic we argue that this process needs to comprehend the functional relationship of 5G spectrum with 4G spectrum below 4 GHz and Wi Fi spectrum at 2.4GHz, 5 GHz and 60 GHz. The present process is likely to result in 5G being deployed in a range of random non harmonized bands anywhere between UHF and E band. This would be an economic disaster.

The only economically plausible option is for 5G to be deployed in a globally standardised band or related bands with clearly defined technical and commercial synergies with 4G and Wi Fi spectrum.

We suggest that this can be accomplished by implementing 5G as a wide area high data rate fixed and mobile network at E band complemented by 4G LTE as a wide area medium data rate sub 4 GHz network with Wi FI at 2.4, 5 and 60 GHz as the high data rate local area sandwich in between.

Read on

WRC15

Since 2007 (the US 700 MHz auction) spectrum discussions have been largely dominated by 'the battle for broadcasting bandwidth'. The US auction was followed in the UK and parts of Europe by the first digital Dividend (close down of TV in the 800 MHz band and repurposing for mobile broadband) and the ongoing Second Digital Dividend (close down of TV in the 700 MHz band and repurposing for mobile broadband). In the US there is a Third Digital Dividend process under way to close down TV in the 600 MHz band and repurpose for mobile broadband though this is being met with significant legal challenge by the broadcast community and other stakeholders.

Resolving spectrum sharing sub 1 GHz ('low band' therefore remains a priority item for WRC 2015 and includes discussion on lower UHF allocations for LTE.

Additional work items include the formalization of sub bands (bands within bands) and super bands (extension of existing bands) for 'Mid Band' and 'High Band' to support wider channel bandwidth LTE roll out. Most of these changes impose a performance cost on the user handset.

Sub 4 MHz deployment - LTE Spectrum post WRC 2018?

Bands 42 and 43 between 3400 and 3800 MHz will become available in some but not all markets. A third digital dividend would also yield additional bandwidth in the 600 MHz band with Band 31 as an outlier at 400 MHz

LTE bandwidth sub 4 GHz

	LTE spectrum sub 4 GHz (simplified and excludes some bands and some markets)									
	Low Band				Mid Band		High Band			
MHz	600MHz	700 MHz	800 MHz	900 MHZ	1800	1900	2600 FDD	2600 TDD	3400 TDD	3600 TDD
Bandwidth		APT 700	Extended Band 5		Band 3	E PCS				
Largest allocations per band	45+45?	45+45	45+45	35+35	75+75	70+70	70+70	50	200	200
	Total sub 1 GHz=270 MHz				Total mid band=280 MHz		Total high band=590 MHz			
	Theoretical total sub 4 GHz=1140 MHz – Practical total = 600 MHz									

Superficially this looks like a lot of bandwidth (over 1 GHz sub 4 GHz) however not all these bands are available in all markets. In practice any one market is unlikely to have more than 600 MHz available and rather less once spectrum for legacy standards such as HSPA is accounted for.

WRC 18 view including LTE and Wi Fi
Each subsequent radio congress takes forward work from the prior congress (with a three or four year gap between meetings) but with new items agreed for inclusion for each subsequent meeting.

The agenda items at WRC 2015 include UHF (380-470 MHz), fixed and mobile satellite (C band and KU band), IMT satellite (K band, 22-26 GHz) and automotive radar (E band 77-81 GHz).

Agenda items for WRC 2018 are as yet undetermined but can be expected to address the repurposing of the upper part of the 5GHz band for 802.11 p and potential bands above 6 GHz for 5 G deployment. This will be particularly crucial if present ambitions to introduce 5G services in 2020 are to be realized.

4G LTE band allocations are bewilderingly complex and lack regional harmonisation. Even bands that are nominally the same can have regionally specific OOB requirements, the CEPT 700 band being a recent example.

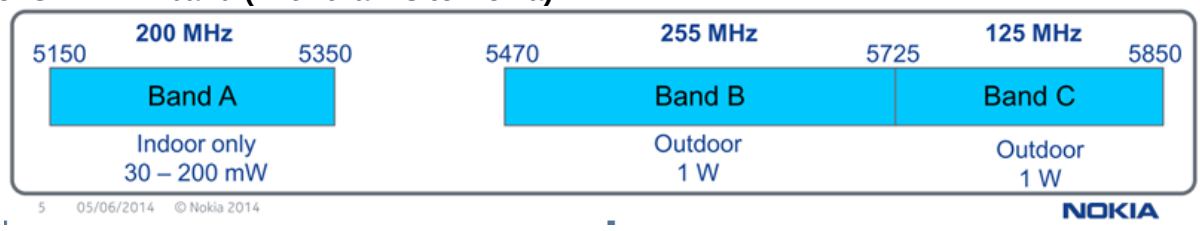
Band fragmentation and regionally specific OOB requirements introduce significant additional cost into the industry user device and base station supply chain and significant performance loss in handsets and smart phones.

By contrast Wi Fi is deployed into just two bands (three if 60 GHz is included) which by and large are globally standardized. As a direct result Wi FI can be delivered at cost levels at least an order of magnitude lower than comparable LTE devices realising the benefits of a more efficient industry supply chain.

Although 2.4 GHz Wi Fi is frequency constrained there is substantially more bandwidth at 5 GHz. Figure 7 shows the proposed addition for outdoor 5 GHz coverage. Figure 8 shows the addition of 802.11p at the top of the band for automotive connectivity.

The 5 GHz Wi Fi band is also proposed for LTE U.

5 GHz WiFi band (With thanks to Nokia)



802.11p channels above the 5 GHz WiFI band (With thanks to Rohde and Schwarz)

USA	Europe
IEEE802.11p/1609.x	CEN/ETSI EN302 663
5850 – 5925 MHz	5855 – 5925 MHz
Seven 10 MHz channels (Two 20 MHz channels formed by combining 10 MHz channels)	Seven 10 MHz channels
3 -27Mbit/s	3 - 27Mbit/s
23 - 33 dBm (EIRP)	23-33 dBm (EIRP)

http://cdn.rohde-schwarz.com/pws/dl_downloads/dl_application/application_notes/1ma152/1MA152_3e_ITS_using_802_11p.pdf

http://standards.ieee.org/findstds/standard/802.11p-2010.html

In 2002 the FCC allocated fifty megahertz of spectrum in the 4940-4990 MHz band (4.9 GHz band) for fixed and mobile public safety services though this seems unlikely to become a global allocation.

In our view the economic viability of 5G will be dependent on the identification of one group of closely related bands, specifically three sub bands 5+5+3GHz within E band between 71 and 95 GHz which can be globally deployed and integrated with legacy LTE and global Wi Fi (or LTE-U) spectrum.

This should be considered as a primary WRC 2018 objective.

This would provide a three tiered spectrum landscape post 2020 which would look something like the table below.

5G-E bands, Tri Fi Wi Fi and sub 4 GHz LTE

	5G-E bands		
	Low Band	Mid Band	High Band
	72-77 GHz	81-86 GHz	92-95 GHz
Bandwidth	5 GHz	5 GHz	3 GHz
	Wi Fi/Tri Fi/LTE-U		
	Low Band	Mid Band	High Band
	2.4 GHz	5180-5825 MHz +802.11 p 5850-5925 MHz	56-65 GHz Three or four 2.16 GHz channels
Bandwidth	80 MHz	800 MHz?	6-8 GHz
	LTE Sub 4 GHz		
	Low Band <1 GHz	Mid band/L band	High band 2 - 4 GHz
Bandwidth	300 MHz	300 MHz	300 MHz

The assumption is that with all present and possible future allocations it would be plausible in the long term (ten to 15 years from now) to have 900 MHz of LTE bandwidth per market made up of about 300 MHz in low band (<1GHz), 300 MHz in mid band (1-2 GHz L band) and 300 MHz in high

band (3<4 GHz) which would be used for medium data rate LTE including wide area (large cell) LTE.

In the middle there would be a Wi Fi/Tri Fi and/or LTE U sandwich for high data rate local area coverage with 80 MHz of bandwidth at 2.4 GHz (low band), 800 MHz of bandwidth at 5 GHz including 802.11p(mid band) and up to four 802.11ad 2.16 GHz channels between 56 and 65 GHz.

On top would be the three 5G-E band sub bands, two by 5 GHz and one by three GHz at 72-77 GHz, 81 to 86 GHz and 92-95 GHz with automotive radar between 72 and 81 GHz. The 5G-E bands would provide high data rate low latency wide area large cell coverage.

Air interface options for the 5G-E Bands

There are several candidate air interfaces proposed for 5 G most of which use orthogonal frequency, time and frequency separation to provide user selectivity and one of which (Non Orthogonal Multiple Access –NOMA) uses the power domain combined with baseband successive interference cancellation.

It would also be theoretically possible to scale the existing LTE and LTE A physical layer to E band. Note that although the frequencies are much higher, the bandwidth ratios are similar (channel bandwidth as a percentage of centre frequency). While this might not be an optimum technical choice it could be an optimum commercial choice.

DARPA support for LTE in their E band mobile hot spot development programme (see January Technology Topic) provides collateral for this approach. An alternative might be to consider a repurposing of the chirp frequency sweep waveforms used in 77 GHz automotive radar though there is no present visibility of this as a studied option.

Particular consideration needs to be given to the impact of the physical layer on RF component specification. The NOMA schemes for example will project a range of requirements on RF amplification which will be substantially different from other proposed and existing options.

Summary

Significant attention is given to discussing 5G user cases and potential physical layer and upper layer constructs. While this is a worthy and necessary process it masks the primary design aim of 5G which should be to produce a step function reduction in delivery cost per user bit.

This can only be done if large cell topologies can be supported with deployment in a single globally harmonised band.

All bands from 6 GHz to 70 GHz support existing radio systems including satellite, point to point backhaul radio, civilian and military radar, weather sensing and RF dependent weapon systems.

All of these systems will require more rather than less bandwidth over time. Modern radar systems for example are being upgraded to support wider channel bandwidths (to provide improved resolution), higher transmit power and increased selectivity (to increase range).

E band is arguably the only part of the millimetre spectrum where 5G deployment is plausible both in terms of bandwidth availability, propagation characteristics, regulation and mutual interest between consumer mobile broadband, military and automotive applications.

Automotive radar potentially opens up opportunities to translate market scale and technology innovation (chirp waveform processing and temporal and frequency and power domain spatial processing) into 5 G consumer mobile broadband applications.

E band and specifically the three E Band sub bands identified in this paper (the 5G-E bands) are therefore in our view the only economically and technically plausible candidates for 5G deployment.

RTT 'Free to attend' 5G spectrum session at GSM World Congress Barcelona
Tuesday March 3 3.30 UK TI Stand Hall 7

'From C Band to E band and beyond'

Geoff Varrall CEO RTT Programmes
It is hard how 5G capacity and data rate, latency and energy efficiency expectations can be met without significant bandwidth allocation above 4 GHz. These are bands which support existing and new generation military high power radar and radio systems including telemetry and tele command, a combination of terrestrial and sub space wide area systems supported by LEO, MEO and GSO satellite networks. Parallel investment by the automotive industry is similarly enabling RF front end innovation, for example for 77 GHz automotive radar.

In this session we review the technical and commercial challenges (including coexistence challenges) for 5G radio technologies implemented into C band (4-8 GHz), X band (8-12 GHz), the K bands (12-40 GHz), V band and W band (40 to 110 GHz) and the particular opportunities of the E band sub bands at 71-76 GHz, 81-86 GHz and 92-95 GHz. We benchmark the progress being made with RF amplifiers and RF sub systems in defence and civilian radar and radio systems and the associated energy and cost impact on 5G wide area networks deployed into these bands.

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CW TEC Technology Conference in London March 24 2015

The spectral options for 5G and associated coexistence challenges and opportunities will be discussed in the CW Technology Conference in London this March with presentations from Avanti highlighting innovations in the satellite domain and parallel presentations from EE, Qualcomm, the BBC, BskyB, Radio Design, u-blox, CSR and Samsung.

Spaces on this event are limited so it's useful to book now rather than later

http://www.cambridgewireless.co.uk/cwtec/
http://www.cambridgewireless.co.uk/cwtec/programme/

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RTT, the **Jane Zweig Group** and **The Mobile World** are presently working on a number of research and forecasting projects in the mobile broadband, two way radio, satellite and broadcasting industry.

If you would like more information on this work then please contact **geoff@rttonline.com**

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