RTT TECHNOLOGY TOPIC
January 2015

Defence Spectrum – the new battleground?

In this month's technology topic we look at contemporary military radio developments, the integration of LTE user devices into defence communication systems, the relevance of military research to 5 G deployment efficiency and related spectral utilisation and regulatory issues.

Defence communication systems are deployed across the whole radio spectrum from long wave to light. This includes mobile communication systems at VHF and UHF and L Band and S band, LEO, MEO and GSO satellite systems (VHF to E band) and mobile and fixed radar (VHF to E band).

Legacy defence systems are being upgraded to provide additional functionality. This requires more rather than less spectrum. Increased radar resolution requires wider channel bandwidths; longer range requires more power and improved sensitivity. Improved sensitivity increases the risk of inter system interference. Emerging application requirements including unmanned aerial vehicles require a mix of additional terrestrial, satellite and radar bandwidth. These requirements are geographically and spectrally diverse rather than battlefield and spectrally specific.

The assumption in many markets is that the defence industry will be willing and able to surrender spectrum for mobile broadband consumer and civilian use. The AWS 3 auction in the US is a contemporary example with a $5 billion transition budget to cover legacy military system decommissioning in the DOD coordination zone between 1755 and 1780 MHz

This transition strategy assumes an increased use of LTE network hardware and user hardware in battlefield systems. While this might imply an opportunity for closer coordination and cooperation between the mobile broadband and defence community it seems likely that an increase in the amount of defence bandwidth needed to support a broadening range of RF dependent systems could be a problematic component in the global spectral allocation and auction process.

This is not dissimilar to the issues emerging from the 600 MHz Incentive Auction in the US which has been complicated by the recognition by the TV broadcast community that more rather than less bandwidth is required to remain competitive with other increasingly high definition content delivery options. The auction is therefore not a spectrum sale but a compensation process. Given that the bids for AWS 3 spectrum have exceeded $38 billion dollars it is likely that the compensation cost expectations of the defence community will become significantly higher.

To date LTE has (more or less) happily coexisted with existing defence radio and radar and satellite VHF and UHF systems. There have however been co-existence issues between air traffic control radar and LTE deployment in Band 7 and Band 38 (2.6 GHz) which suggest that scheduled auctions at 2.3 and 3.4 GHz may have mixed use challenges that will become more significant over time
http://www.microwavejournal.com/articles/22740-co-existence-tests-for-s-band-radar-and-lte-networks.
http://media.ofcom.org.uk/news/2014/new-spectrum-auction/

Future military mobile communication systems can and probably will make good use of LTE hardware in bands between 700 MHz and 4GHz, establishing a common interest which should facilitate the resolution of spectrum allocation, sharing and valuation issues. The bigger challenge may be scaling this **mutual interest model** to the higher bands needed for 5G deployment.

Read on

5 G spectrum requirements

Definitions of 5G are many and various with an increasing emphasis on cloud and core technology but beneath the market fluff there is an assumption that a more effective and efficient physical layer will be required. The design brief/performance expectations for 5G have been summarized as

1000 X increase in mobile data volume,
10 to 100 X increase in connected devices
5X lower latency
10X-100X increase in peak data rate
10X battery life extension for low power devices

http://www.ericsson.com/res/docs/2014/5g-what-is-it.pdf
https://gsmaintelligence.com/files/analysis/?file=141208-5g.pdf

It is hard to see how these capacity and data rate 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, a combination of terrestrial and sub space systems supported by LEO, MEO and GSO satellite networks.

The ITU Radio band designations describing these higher bands originated in a CCIR (Consultative Committee for International Radio) meeting in 1937 and were approved at the International Radio Conference in Atlantic City in 1947. Each band was given a number (nine band numbers in total) which is the logarithm of the approximate geometric mean of the upper and lower band limits in Hz.[1]

Symbol	Description	Band	Frequency	Wavelength
VLF	Very Low Frequency	4	3-30 kHz	10 -100 km
LF	Low Frequency	5	30-300 kHz	1-10 km
MF	Medium Frequency	6	300-3000 kHz	100 -1000 m
HF	High Frequency	7	3-30 MHz	10 -100 m
VHF	Very High Frequency	8	30-300 MHz	1-10 m
UHF	Ultra High Frequency	9	300-3000 MHz	10 – 100 cm
SHF	Super High Frequency	10	3-30 GHz	1 – 10 cm
EHF	Extremely High Frequency	11	30-300 GHz	1 – 10 mm
THF	Terahertz (or terrifically!) High Frequency	12	300-3000 GHz	0.1 – 1 mm

In 2008, the US military, NATO and the European Union agreed on a naming protocol for bands into which electronic counter measure (ECM) RF systems are deployed

Band	Frequency	Wavelength
A	<250 MHz	<1.2m
B	250-500 MHz	1.2m- 600 cm
C	500 MHz-1 GHz	600 cm-300 cm
D	1-2 GHz	300 cm-150 cm
E	2-3 GHz	150 cm-100 cm
F	3-4 GHz	100 cm- 75 cm
G	4-6 GHz	75cm-5 cm
H	6-8 GHz	5 cm-3.75 cm
I	8-10 GHz	3.75 cm-3 cm
J	10-20 GHz	3 cm- 1.5 cm
K	20-40 GHz	1.5 cm- 750 mm
L	40-60 GHz	750 mm-500 mm
M	60-100 GHz	500 mm-300 mm

[1] Proposed by BC Fleming Williams – Letter to the Wireless Engineer 1942

http://en.citizendium.org/wiki/EU-NATO-US_frequency_bands
https://www.ncia.nato.int/BMD/Pages/Where-we%27re-headed.aspx
http://www.erodocdb.dk/docs/doc98/official/pdf/ERCRep025.pdf

However IEEE descriptions are still generally used for radar and RF dependent weapon and communication spectrum. This naming system had its origins in the Second World War when it was classified. It was regularized in a 1984 IEEE standard.

L band stood for long wave, S band for short wave, C band for **c**ompromise between S and X band, X band was used for fire control with the X being the cross hair in a trigger. It is now used for NATO and US Electronic Counter Measure systems. K**U** band was from **K**urz (German for short) **U**nder with K band in the middle and K**A** band **K**urz **A**bove.

V and W were added later.

Radar Frequency Bands IEEE Standard 521-1984	
Band	Frequency (GHz)
L Band	1-2
S Band	2-4
C Band	4-8
X Band	8-12
KU Band	12-18
K Band	18-27
KA Band	27-40
V Band	40-75
W Band	75-110

Within V and W Band there are three bands allocated for fixed (but potentially mobile) services, two 5 GHz bands at 71- 76 and 81 - 86 GHz and a 3 GHz band at 92-95 GHz.

These are known collectively as E band from the waveguide naming regime for 60 to 90 GHz

http://www.microwaves101.com/encyclopedias/rectangular-waveguide-dimensions

E band was formally established by the ITU at the WARC 1979 World Radio Communication Conference but mostly ignored until 2005 when the FCC issued a light licensing scheme that permitted E band radios to operate at up to 3 watts. This is 25 dB higher than the 10 mw limit at 60 GHz. A 30 cm parabolic antenna at this frequency delivers a gain of the order of 44 to 45 dBi, 24 dB more than a comparable 18 GHz antenna of the same size.

This combination of wide channel bandwidth (3 or 5 GHz) and relatively high ERP means that full duplex rates of 10 gbps are supportable, enough to support five 5G operators each with 2 gbps of fixed and mobile wireless connectivity.

DARPA have a Mobile Hotspot E band system development project based on gigabit air to ground and ground to air links implemented in E Band between 71 and 76 MHz and 81 to 86 MHz integrated with voice and data support for LTE smart phones.

Power Amplifier efficiency at E band of 25% is claimed with similarly impressive LNA noise floors. The E band antennas deliver 40 dB of gain with a 2 degree beam width providing a clear weather range of 60 km.

The network is self-configuring and designed to minimise signalling overheads and routing delay and delay variability. It is claimed to be possible to provide Hot Spot coverage of 1000 square kilometres within a few hours using unmanned aerial vehicles as the delivery platform. By any definition this is not a local area system.

http://www.microwavejournal.com/articles/23121-darpas-mobile-hotspot-program-drives-e-band-performance-benchmarks

Can the Mutual Interest Model scale to E Band?

On the basis of the E band proposal the answer is yes, at least for LTE deployment.

There has always been a close coupling between military communication technology and civilian radio systems with technology flowing in both directions. Advances in military radio communication in the First World War translated into the post war radio broadcasting revolution, TV receiver technologies in the 1930's translated into Second World War radar and combat radios, the cold war facilitated solid state technologies that provided the basis for mass market transistor radios.

The launch of the Russian Sputnik satellite in 1957 prompted the formation of the NASA space agency and the Defence Advanced Research Projects Agency.

http://www.darpa.mil/default.aspx.

Over the next fifty years the need to develop communication and guidance and imaging systems that could work efficiently at microwave and millimetre wavelengths produced significant materials innovation.

Some of these innovations became crucially useful for cellular radio, gallium arsenide for microwave power amplification being one example.

Military systems are increasingly looking to leverage the scale advantage of consumer markets in terms of user device functionality. This has motivated military and public protection communication procurement agencies to mandate support for LTE smart phones and where possible to use standard LTE UHF, L band and S band network hardware.

The process has been accelerated by the introduction of smart phones that are designed for clumsy consumers.

http://www.extremetech.com/computing/190698-apples-iphone-6-is-more-durable-less-breakable-than-galaxy-s5-and-one-m8

But the mutual interest model extends beyond iPhones for soldiers and iPads for tanks

Defence budgets and telecommunications spending are similar in scale. US military spending peaked in the Cold War at 5.5% of GDP. The present day budget is $627 billion, 3.4% of GDP.

The world spends $1.6 trillion dollars per year on defence. The US accounts for about 40% of this. US and Allied budgets together account for about two thirds of global spending. An increasing percentage of this budget is being spent on high data rate long range wide area connectivity.

The numbers for the telecommunications industry are similar. Telecommunications spend in the US is between 3% and 4% of GDP. South Korea is greater than 5%.

http://www.statista.com/statistics/270565/ict-share-of-telecommunications-expenditures-in-the-gdp/

LTE user device and network hardware development is however not inexpensive.

Qualcomm has invested $14 billion dollars in LTE baseband development over the past 4 years, Apple's annual spend is of the order of $5 billion, Samsung well over $10 billion and Intel is about $10 billion. Huawei is spending over $5 billion per year.

Not all of this is directly related to LTE but a lot of it is and we haven't even started to count other related LTE investment at component and sub system level. It would be conservative to say that LTE global physical layer development investment comfortably exceeds $50 billion dollars per year.

Even in military terms this is significant money focused on a specific outcome with a market volume that provides a cost base several orders of magnitude below the cost base of equivalent US or Chinese or Russian military radio hardware.

In the other direction there are areas of military research that could potentially reduce 4G and 5 G delivery cost and improve existing and future network efficiency.

For example delivery cost to the 'middle earth' markets either side of the equator would be substantially reduced as and when servicing and in-flight refuelling of geostationary satellites becomes feasible, a priority DARPA project.

http://www.darpa.mil/Our_Work/TTO/Programs/Phoenix.aspx

User device costs and network RF hardware costs will be reduced and performance improved by replacing RF components with silicon. DARPA is presently working to develop digital CMOS amplifiers that can work efficiently at 90 GHz

http://www.darpa.mil/NewsEvents/Releases/2014/06/30.aspx.

Network efficiency gains and latency control are dependent on improved timing accuracy and the capability to distribute highly accurate and stable time references over large distances. This is an emerging problem in high data rate wide area networks and addressed by the DARPA Pulse Programme.

http://www.darpa.mil/Our_Work/DSO/Programs/Program_in_Ultrafast_Laser_Science_and_Engineering_%28PULSE%29.aspx

Emerging military/commercial cooperative business models applied in the satellite sector could have a broader terrestrial remit.

http://www.defense.gov/home/features/2011/0111_nsss/docs/NationalSecuritySpaceStrategyUnclassifiedSummary_Jan2011.pdf

Research into competitive and cooperative spectrum sharing could help resolve potential co-existence issues.

http://www.darpa.mil/Our_Work/I2O/Programs/Spectrum_Challenge.aspx

Last but not least there are techniques needed to analyse frequency agile wide bandwidth radar and electronic warfare systems including time and frequency analysis of complex pulsed signal waveforms which will become increasingly useful if, as and when 5G radio systems are deployed into the K bands and or E band spectrum.

https://www.keysight.com/main/editorial.jspx?cc=GB&lc=eng&ckey=2510838&id=2510838&cmpid=47318

Summary – 4 G matters to the military, military matters for 5G

Every generation of cellular has directly and indirectly benefited from military research. Materials and component innovation has been particularly important and will remain important as the industry moves to realize efficient and effective networks at millimetre wavelengths.

4G is proving to be a useful adjunct to existing defence radio systems with military procurement focused on leveraging the scale economics of the consumer mobile broadband industry both in terms of network nodes (terrestrial LTE base stations) and user devices. User devices are being ruggedized in order to meet consumer expectations of robustness that are not dissimilar to day to day military requirements.

Conversely 4G and 5G systems can benefit from RF innovation in radar and satellite systems including advances in amplifier and antenna design, dynamic beam steering and interference resilience.

These innovations could translate into a much needed step function improvement in delivery and energy economics.

The Long Term Evolution of military communication is therefore of specific interest to the 5 G community and 5G technology ambitions have considerable relevance to the military procurement community. A closely coupled cooperation would produce clear economic benefits to both parties and their related user communities – **the mutual interest model.**

The same can be said of the terrestrial broadcast industry and mobile broadband industry but cooperation between these entities has been frustrated by an adversarial spectral auction process. Developing successful mixed use models for military spectrum could prove equally challenging.

Co-existence issues between LTE and military and radar and radio systems have to date been managed effectively and efficiently at least up to C band.

Populating 5G into higher bands including the K bands and E band will require co-ordination with next generation RF dependent defence systems including high capacity mobile and point to point/multipoint connectivity, high performance wide channel bandwidth radar and satellite systems and UAV telemetry and telecontrol. This will be more easily achieved if defence agencies clearly perceive that 5G has a useful role to play in battlefield communication. This implies an ability to support high data rate extended range large cell topologies – not presently a priority within the 5G development community.

New book from Elsevier Academic Press, HSPA Evolution, Fundamentals for Mobile Broadband

The rate of 5 G deployment will be crucially dependent on the return on investment realized from existing network technologies – this new book from Elsevier addresses 3 G optimization options and emerging opportunities to address the economic challenges of servicing widely varying minimum coupling loss. Copies available via the RTT book store.

http://www.rttonline.com/bookshop.html

CW TEC Technology Conference in London March 24 2015

The translation of military technologies to commercial LTE and commercial LTE to military technology transfer will be discussed in the CW Technology Conference in London next March with presentations from Avanti highlighting innovations being implemented 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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