

The massive MIMO effect: has the 3.4-3.8 GHz TDD spectrum become more valuable than 800 MHz (and 700 MHz) FDD?

Paradigm change in mobile technology leads to paradigm change in spectrum valuations (observation after the UK auction)

Rewheel public research note, 12th April 2018.

On the 5th of April 2018 Ofcom, the UK telecom regulator, announced¹ the completion of the principal stage of the 2.3 and 3.4 GHz TDD spectrum auction. Ofcom's table below summarises the outcome after the end of the principal stage (before the assignment stage). Four out of the five bidders (i.e. the four UK mobile network operators) won the 40 and 150 MHz available in the 2.3 and 3.4 GHz bands for a staggering 1.36 billion GBP. Telefonica-O2 acquired 40 MHz in the 2.3 GHz band and as well 40 MHz in the 3.4 GHz band, Vodafone acquired 50 MHz in the 3.4 GHz band while EE and Hutchison-3 acquired 40 and 20 MHz respectively in the 3.4 GHz band.

Award of the 2.3 and 3.4 GHz spectrum bands – Publication under regulation 58 of the Wireless Telegraphy (Licence Award) Regulations 2018 of the results of the Principal Stage of the auction

Bidder	Lot type	Lots won	Base price A (per lot) ¹	Base price A (total)	Base price B (per lot)	Base price B (total)
EE Limited	2.3 GHz	0	£0	£0	£0	£0
	3.4 GHz	8	£37,824,000	£302,592,000	£0	£0
Hutchison 3G UK Limited	2.3 GHz	0	£0	£0	£0	£0
	3.4 GHz	4	£37,824,000	£151,296,000	£0	£0
Telefónica UK Limited	2.3 GHz	4	£51,474,000	£205,896,000	£0	£0
	3.4 GHz	8	£39,715,000	£317,720,000	£0	£0
Vodafone Limited	2.3 GHz	0	£0	£0	£0	£0
	3.4 GHz	10	£37,824,000	£378,240,000	£0	£0

Number of 2.3 GHz lots not won by any bidder	0
Number of 3.4 GHz lots not won by any bidder	0

In this research note our main focus is the 3.4-3.8 GHz TDD band but the observations and conclusions are to a large extent also valid for the 2.3 GHz and 2.6 GHz European TDD bands.

Historically, low frequency (sub 1GHz) spectrum was widely considered much more valuable than higher frequency spectrum due to its superior propagation and indoor penetration properties. Does this paradigm still hold true in the unlimited mobile broadband era where the bottleneck is no longer the reach of mobile networks (4G population coverage is higher than 95% in most markets) but their capacity?

A year back, in March 2017, in a research study² titled "*Capacity utilization and fixed-to-mobile broadband substitution potential – A study of 64 European operators*" we asserted that Massive MIMO is a very promising technology that will dramatically increase the spectral efficiency and sector capacity of the macro site layer, primarily in the high frequency, TDD bands. We questioned the conventional wisdom of sub-1GHz still being the *beach-front* of spectrum and concluded that fixed-to-mobile broadband substitution (i.e. unlimited mobile data) will be the main driver of 5G spectrum valuations.

Few months later, in September 2017 in a research study titled³ "*Unlimited mobile data and near zero marginal cost – a paradigm shift in telco business models*" we asserted that we are witnessing a paradigm shift in the industry driven by the availability of new high frequency radio spectrum bands, massive MIMO's '*unlimited*'⁴ capacity and near-zero marginal mobile data cost. This paradigm shift has profound implications on fixed-to-mobile broadband substitution strategies and they way operators value spectrum.

¹<https://www.ofcom.org.uk/about-ofcom/latest/features-and-news/results-auction-mobile-airwaves>

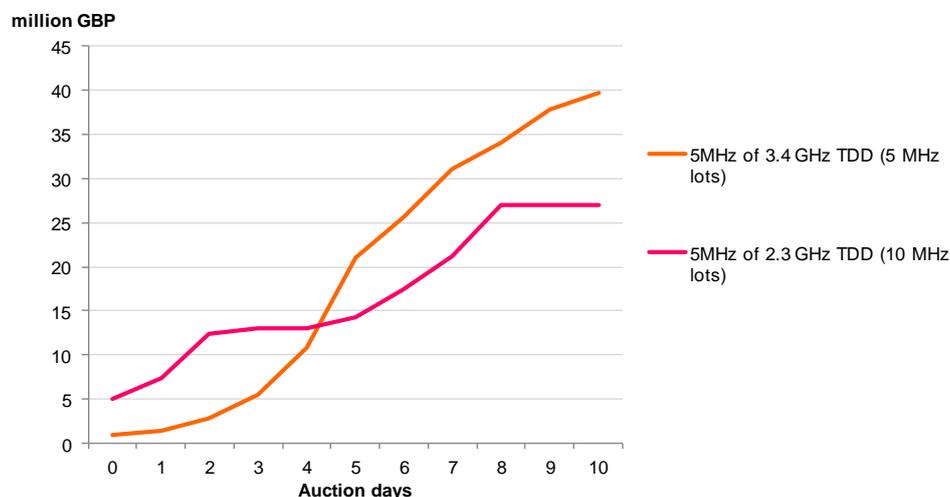
²http://research.rewheel.fi/insights/2017_mar_pro_network_utilisation_mimo/

³http://research.rewheel.fi/insights/2017_sep_pro_near_zero_marginal_cost/

⁴<https://www.sciencedaily.com/releases/2018/03/180312115501.htm>

The UK 2.3 and 3.4 GHz TDD spectrum auction outcome is a prelude to what lies ahead.

The eye watering 1.19 billion GBP that the four UK operators paid for just 150 MHz in the 3.4 GHz band (the EU harmonised 3.4–3.8 GHz bands comprise of 400 MHz of spectrum) exceeded the level that many analysts had predicted and raised many eyebrows⁵ in the industry.



Source: Rewheel analysis

Is the EU-harmonised 3.4-3.8 GHz TDD band double as valuable as the EU-harmonised 800 MHz FDD band?

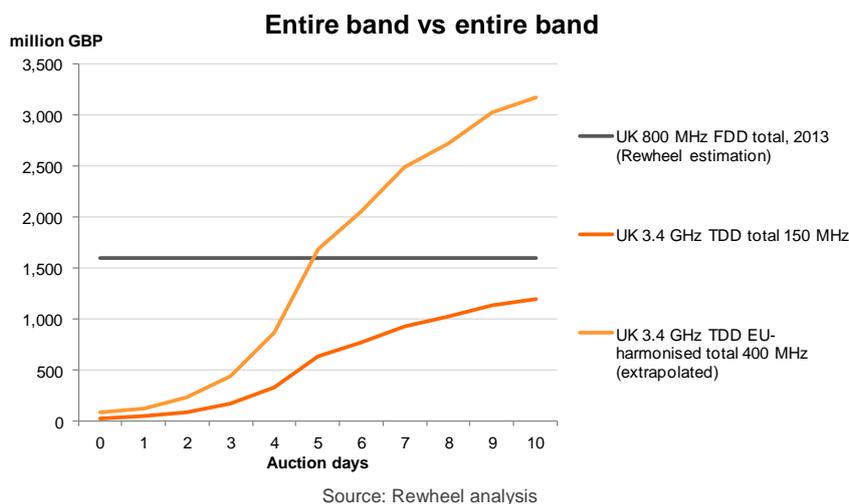
The prices paid in the UK spectrum auction for the 3.4 GHz TDD band indicate that as a *whole*, the 400 MHz of the 3.4-3.8 GHz TDD EU-harmonised band may be more valuable than the 2x30 MHz of EU-harmonised 800 MHz FDD band.

The table above shows that while on a per MHz basis the 800 MHz FDD spectrum in the UK was over 3 times more expensive than the 3.4 GHz TDD spectrum, in total operators offered 1.19 million GBP (prior to the assignment round) for 150 MHz in the 3.4 GHz TDD band versus roughly 1.6 billion for the entire 800 MHz FDD band. However, Ofcom auctioned only less than half of the total EU harmonised (and 5G designated) 3.4-3.8 GHz range (150 MHz of the 400 MHz). Extrapolating the 3.4 GHz TDD prices to the full 400 MHz of EU-harmonised bandwidth we get 3.2 million GBP. That is double as much as paid for the entire EU-harmonised 800 MHz FDD band in 2013!

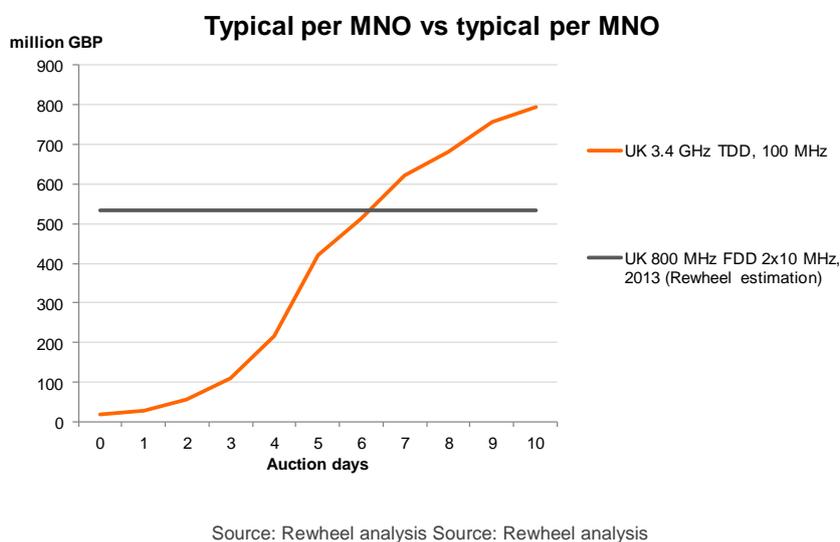
	Bandwidth (MHz)	Price (million GBP)
UK 3.4 GHz auction 2018		
Auction lot	5	40
per 1 MHz	1	8
UK 2018 auction total band	150	1,191
EU-harmonized total band, extrapolated	400	3,177
Typical desired 3.4 GHz bandwidth for 5G per MNO	100	794
UK 800 + 2600 MHz auction 2013		
Total band size, 800FDD+2600FDD+2600TDD	245	2,341
of which price allocated to 800FDD (Rewheel estimation)	60	1,600
per 1 MHz of 800 FDD	1	27
Typical bandwidth for 800FDD LTE per MNO	20	533

Source: Rewheel analysis

⁵<https://www.totaltele.com/499792/Orange-Overcharging-for-spectrum-could-lead-to-disastrous-consequences>



Is 100 MHz in 3.4-3.8 GHz TDD 50% more valuable than 2x10 MHz in 800 MHz FDD



In the UK auction – where the total amount was limited to 150 MHz and four participants won spectrum – the maximum acquired by a single operator was 50 MHz (Vodafone). However, in this band the vendors and operators are aiming typically for 100 MHz. In contrast, in the 800 MHz FDD band European operators typically bought and deployed only 2x10 MHz of bandwidth.

If we compare the prices for the bandwidth required by a typical MNO in the two bands (2x10 MHz for 800 FDD and 100 MHz for 3.4-3.8 GHz TDD) then we can see that the ideal per-operator holding in the 3.4-3.8 GHz TDD band would be actually 50% more expensive (794 million GBP vs 533 million GBP) than the typical per-operator 800 MHz FDD holding was in 2013.

Why is the 3.4-3.8 GHz band so interesting and valuable for mobile operators?

TDD-based massive MIMO technology leads to a paradigm change in mobile data network capacity and reliability.

The sub 6GHz (*'cmWave'*) band is ideal for deploying massive MIMO on the existing macro site grid, providing very high aggregate sector spectral efficiency and capacity. According to vendors, it can also create similar coverage as provided by traditional *'High Band'* LTE frequencies, such as 1800 MHz FDD. The 3.4-3.8 GHz frequency range is high enough so that the wavelength is short enough to be able to squeeze high number (e.g. 64) of antenna elements into practical form factors. *'Low Band'* frequencies such as 700, 800, 900 MHz in Europe would require clearly impractical antenna sizes. The 3.4-3.8 GHz EU-harmonised band offers very high bandwidth per operator (about 100 MHz) multiplied by very high aggregate sector spectral

efficiency (b/s/Hz), which can be increased by increasing the number of the antenna elements in the antenna array. Researchers refer to this as 'unlimited capacity'⁶ property.



The 5G-oriented antenna deployment solution in Telefónica

Photo: macro site antenna solution developed by Telefonica Germany and Huawei.

The antenna box on the top combines all '*traditional*' FDD bands (700, 800, 900, 1400SDL, 1800, 2100 and 2600 MHz), reserving antenna space for the 3.6 GHz massive MIMO active antenna (the square box on the bottom-right).

Photo source: Daily Mirror <http://www.dailymirror.lk/article/Huawei-and-Telef%C3%B3nica-Deutschland-launch-world-s-first-G-oriented-antenna-deployment-solution-139031.html>

While many vendors advertise their FDD-based '*massive MIMO*' technology, the spatial multiplexing gains using FDD (e.g. in '*High Band*' 1800, 2100, 2600 FDD frequencies in Europe) is limited, only TDD-based '*real*' massive MIMO has the '*unlimited capacity*' properties.

Another important property of TDD massive MIMO is '*channel hardening*': the technology dramatically improves link reliability and user throughputs near the cell edges, in weaker radio conditions.

Good macro site grid based coverage properties, very high sector spectral efficiency, large bandwidth and the channel hardening property makes the 3.4-3.8 GHz TDD spectrum band and massive MIMO technology a very interesting combination in the unlimited mobile broadband era. The mid-term business case driver for acquiring 3.4-3.8 GHz TDD spectrum is fixed-to-mobile broadband substitution in suburban and rural areas. This case is especially relevant for mobile telcos that haven't yet deployed fibre based fixed broadband and need to rely on outdated DSL-based or expensive fibre wholesale access to attack the home broadband (and TV) markets in suburban and rural regions.

⁶Unlimited capacity in wireless networks with massive MIMO <https://www.sciencedaily.com/releases/2018/03/180312115501.htm>



Photo: Elisa Finland deploying Huawei 3.6 GHz TDD 5G NR massive MIMO (100 MHz bandwidth) in February 2018 for Helsinki field trial. Stable 700 Mbit/s single user throughput was achieved about 500 meters from the antenna, using Huawei pre-production 5G FMS modem (CPE).

The 3.4-3.8 GHz spectrum auction in Finland is planned to be held in 2018, the three MNOs are aiming to secure 100 MHz each. According to the Finnish regulator in the second half of 2017 average monthly consumption of mobile data was almost 26 gigabytes per person. Mobile broadband subscribers consumed 37 gigabyte per month on average while smartphone subscribers consumed 10 gigabyte per month on average. Over 35% of Finnish households were mobile broadband only households in February 2017 according to Eurostat.

Photo source: Helsingin Sanomat <https://www.hs.fi/kaupunki/art-2000005572103.html>

Is 700 MHz “essential”?

700 MHz FDD (as well as 700SDL and 1400SDL) spectrum bands are also being auctioned in Europe, sometimes in combined multi band auctions with 3.4-3.8 GHz. If the (country specific) auction rules ensure that all MNOs can get a fair amount of additional ‘Low Band’ spectrum (e.g. 2x10 MHz in 700) on attractive reserve prices, then it is a no brainer to buy it, since it can be used to increase the capacity and user speeds outside the reach of the ‘High Band’ grid (e.g. rural areas, geo-coverage, deep indoor in cities). However, in situations, where demand exceeds supply (e.g. in 4-MNO markets, such as the UK, only three MNOs could get the desired 2x10 MHz), the answer is more complicated.

While 800 MHz FDD spectrum used to be regarded as essential in order to deploy country-wide LTE coverage, for those operators that already have the ‘Low Band’ LTE coverage, 700 MHz plays only a capacity role (900 MHz is also planned to be reframed by many operators for LTE in the next few years). However, compared to the dramatic capacity increase that can be achieved by 3.4-3.8 GHz TDD and massive MIMO, the capacity improvement potential of new ‘Low Band’ FDD spectrum is marginal. For the type of reliable, high speed fixed-to-mobile broadband substitution play (that the 3.4-3.8 GHz TDD and massive MIMO can enable) the typical ‘Low Band-only coverage areas’ user throughputs will be too low, even by combining 700, 800 and 900 band (e.g. 2x30 MHz FDD).

As the CFO of Sprint, the US challenger operator put it, ‘Low Band’ (600 MHz in this particular US case) is “*spectrum of the past, as the world is moving toward high-capacity wireless data networks*”⁷. Verizon’s Chief Network Officer said⁸ 600 MHz spectrum just isn’t that much use to a carrier that already has a hefty amount of low band spectrum holdings (Verizon in 2017 had 43 MHz Low Band Spectrum on average⁹, equivalent of e.g. 2x10 MHz in 800 MHz + 2x11.5 MHz 900 MHz for a typical European operator prior to the 700 MHz auctions). Sprint and Verizon didn’t participate in the 2017 600 MHz auction, AT&T bought some holdings but sold it shortly afterwards. T-Mobile was the only national MNO in the US that bought and kept (unlike AT&T) significant bandwidth of 600 MHz and now they have similar bandwidth of Low Band spectrum (41 MHz) as Verizon (that didn’t buy in 600 MHz).

The 3.4-3.8 GHz band, the game changing properties of massive MIMO and the fixed-to-mobile broadband substitution potential have taken centre stage in our spectrum strategy and valuation modelling consulting engagements in 2016 and 2017 (e.g. 700, 1400SDL, 3.4-3.8 GHz auction preparations, advocacy development, multi band valuation models).

⁷ <https://www.fiercewireless.com/wireless/sprint-cfo-robbiati-600-mhz-spectrum-past>

⁸ <https://www.wirelessweek.com/news/2017/05/verizon-fcc-auction-we-didnt-bid-because-we-dont-need-spectrum>

⁹ <https://www.fiercewireless.com/wireless/2017-how-much-low-mid-and-high-band-spectrum-do-verizon-at-t-mobile-sprint-and-dish-own>

About Rewheel

*New radio spectrum bands, 4.5G and 5G technology, unlimited mobile data plans and the Internet of Things radically change mobile network operators' cost, revenue and profitability dynamics. **Rewheel's mission is to help prepare for the paradigm shift in network and spectrum strategy, spectrum valuation, network sharing, M&A, MVNO economics and mobile data pricing.***

Founded in 2009, Rewheel is a Finland based boutique management consultancy. Our clients are mainly European mobile network operators, telco groups, MVNO groups, sector regulators, governments, global internet firms, mobile data-centric start ups, PE and VC investors.

We delivered management consultancy work for clients in the United Kingdom, United States, Ireland, Switzerland, Finland, Sweden, Belgium, Greece, Poland, Slovenia, Hungary, Russia, Romania. Buyers of our research reports and related strategic workshops include many companies and authorities across Europe and worldwide.

Since 2010 we have been supporting a number of European challenger mobile operators in multiband (700, 700 SDL, 800, 900, 1400 SDL, 1800, 2600, 3.5 GHz) auctions with impartial spectrum valuation modelling and strategic advisory services.

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