Tri Band Networks

The coupled auction debate
There is presently an ongoing regulatory debate as to how spectrum at 700 and 800 MHz and spectrum at 2.6 GHz should be allocated and auctioned.

In the UK for example, it has been suggested that coupling an 800 MHz auction with a 2.6 GHz auction could provide a mechanism for maximising future economic value both for the treasury and the operator community.

The theory is that a dual band auction would deliver a spectral pairing that would combine the benefits of low band (low cost rural coverage and good in building penetration) with the benefits of high band (high capacity and high peak data rates).

In the US, the 700 MHz auction could be regarded as a success in terms of returns to the treasury but is proving problematic for operators in terms of practical deployment due to the challenges of producing technically and commercially competitive user and network RF hardware.

This underlines the point that efficient auctions can have the unintended consequence of reducing spectral economic efficiency and decreasing spectral economic value. This is particularly true if the rules of physics are ignored by the bidding parties.

Additional costs include indirect opportunity costs. For example, the US 700 MHz band plan is presently absorbing RF engineering resource which would be more profitably focused on cellular band plans that more closely obey the rules of efficient radio roll out.

On this basis, it seems sensible to take a step back and revisit spectral policy in terms of what makes sense from an engineering perspective.

Unsurprisingly, **maximising spectral engineering efficiency maximises spectral economic efficiency and by implication longer term spectral economic value.** It also places a premium on the ability to reconfigure radio network topologies and band plans.

The Dual Band Network Legacy
The idea of coupling the 800 MHz auction and 2.6 GHz auction in some or possibly all European and some Asian markets has prompted a wider debate as to what constitutes a 'fair' allocation of lower band and higher band spectrum.

Many countries deploying cellular networks in the 1980's started off with a national incumbent operator with some countries introducing a second operator in order to create a competitive market.

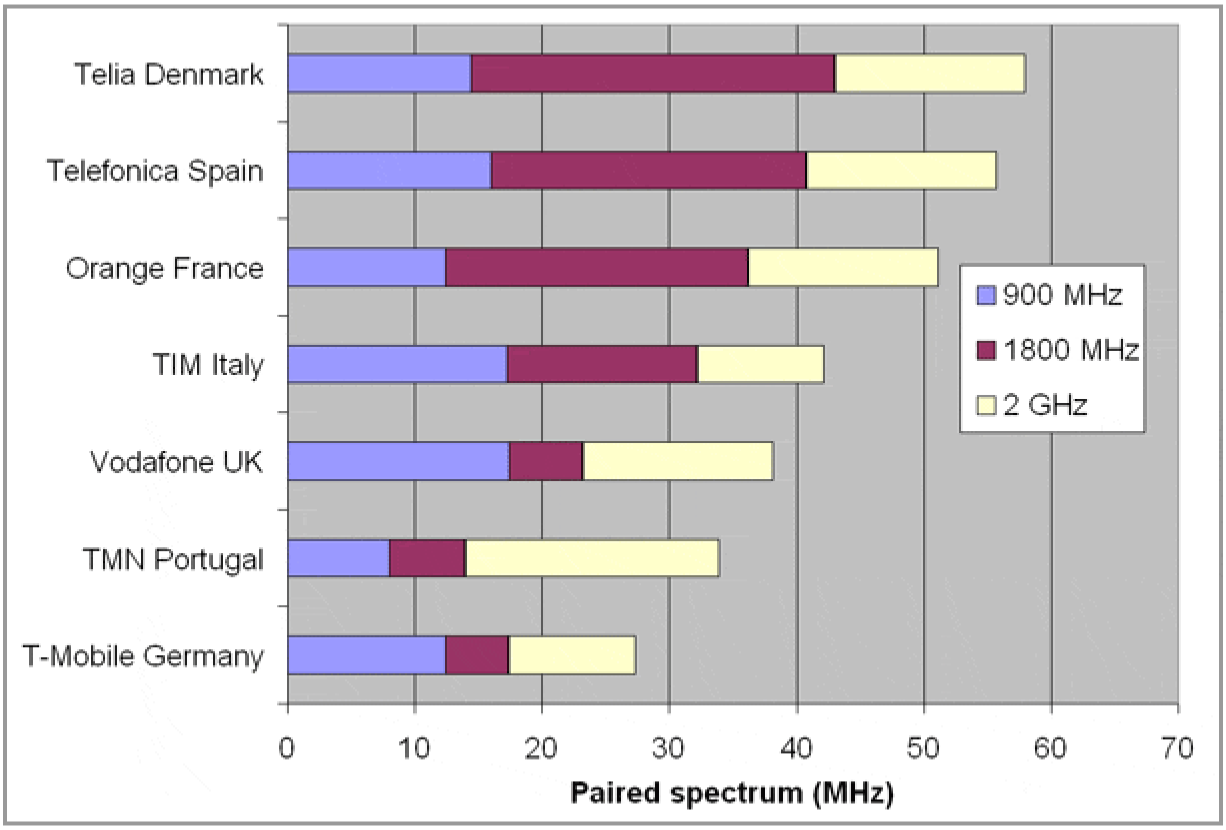
This was the position in the UK with Vodafone (Racal Vodafone) and Cellnet (now O2 Telefonica) each having half of the allocated spectrum at 900 MHz.

Later market entrants were allocated spectrum at 1800 MHz. This band incurs higher coverage costs but lower capacity costs due to the wider bandwidth available. Dual band licences, which became the norm in most countries, enabled networks to be optimised for both coverage and capacity at the lowest cost.

Tthe half wave/quarter wave relationship between 900 and 1800 MHz also allowed for some innovative base station and handset RF design solutions.

A mix of existing European operators and new operators then bid for Band One 3G spectrum at 1/9/2.1 GHz.

Present spectrum distribution
The result is that different operators hold different amounts of spectrum in different bands. The table below compares seven European operators.



Present 900/1800/2000 spectral allocations - with thanks to Aegis Systems

Newer operators with less 900 MHz spectrum have argued that they are economically disadvantaged and that future allocations should be altered to redress this imbalance.

Incumbent operators not unsurprisingly contest this position and suggest that splitting the relatively narrow operational bands at 900 MHz would be inefficient and ineffective although feasible if 1.4 MHz or 3 MHz LTE channels were deployed.

The Tri Band Network Option
The table above from Aegis Systems shows three discrete bands of spectrum, 900 MHz, 1800 MHz and Band 1 UMTS (1.9/2.1 GHZ).

Assuming LTE is successfully deployed into the 850 band in Australia and the US and will be used in the 700 and 800 MHz bands then there is an argument that LTE would also sensibly be deployed into the 900 MHz band.

In parallel most markets seem likely to deploy LTE at 2.6 GHz.

This would then suggest the 1800 and 1900 bands would follow suit.

The 850, 900, 1800 and 1900 (US PCS) bands will need to support legacy users on GSM or CDMA for a number of years but in the longer term these technology transitions, at whatever rate they occur, imply an opportunity to develop a new kind of tri band network.

It has been relatively rare historically for operators to do inter band handovers even if they own spectrum in multiple bands within a country.

Vodafone and O2 in the UK can hand over from a 900 MHz channel pair to an 1800 MHz channel pair or from a 3G channel pair as would any of the operators listed in the table but optimizing inter RAT handovers is complex and ideally requires that handsets measure each band. A mid session inter band handover that was invisible at the application layer would be ambitious.

There is no technical impediment to this as phones have to be capable of working at 900 MHz and 1.8 GHz (and 850 and 1900 MHz in the US). 3G phones also have to work at 1.9 and 2.1 GHz, the basis for a modern quintuple band handset.

However forcing a phone to continuously measure three bands rather than one, with different channel measurement procedures (UMTS on Band 1, GSM at 900 and 1800 MHz) consumes time and energy. Channel quality measurements then have to be compared somewhere in a network, in a node B or enhanced node B for example, then acted upon. This would be simplified if the same channel quality measurements were used in all bands which would be the case if LTE were universally deployed. Even so, a phone being asked to scan all channels in all bands implies significant battery drain and a risk of variable application latency.

The addition of UHF TV spectrum and the 2.6 GHz extension band however open up additional handover opportunities based on a low, mid and high band plan. We suggest this could yield capacity, coverage, cost and DC power drain advantage.

The core international band plan would be as below

Low Band	Mid Band	High Band
700/800/850/900 MHz	1800/1900/2100	2.4, 2.6GHz

RF handset design teams, responding to operator requests to add in 700 and 800 MHz and 2.6 GHz to an existing five band phone presently start from the point of adding two or three additional transceiver functions to the existing architecture of the phone.

This results in loss of sensitivity and selectivity, an increase in power drain and additional weight and cost.

The alternative is to consider low band, mid band and high band as three discrete design tasks, each with its own unique optimization opportunities. A similar approach can potentially be adopted in RF base station design. At network level handover algoritms could potentially be made more efficient if intra band and inter band handovers were more actively managed.

Delivering an efficient handset particularly if three or four sub bands need supporting in each of thebands remains an issue and handover algorithm optimisation would be non trivial but could yield significant benefits. These can be summarised as follows;

Tri Band Network Added Value
If an operator can exploit a **balanced** mix of low band, mid band and high band channels and match channel availability to application requirement then it should be possible to produce a more optimum mix of coverage and capacity. There should be a significant gain in trunking and multiplexing efficiency and a significant gain in **average** data throughput per user.

Average data rates may be higher in low band for example where link budgets will tend to be more favourable as a result of better in building penetration and or lower rural propagation loss. For example a 1.4 MHz or 3 MHz LTE channel at 900 MHz could yield a higher average data throughput than a wider band (5,10, 15 or 20 MHz) channel at mid band or high band.

Although channel multiplexing gain would be lower with a narrow band channel this could be more than off set by a more robust link budget though this would be dependent on interference levels.

Multiplexing gain could be achieved by intra band or inter band load distribution rather than from high contention ratios on a single wide band channel.

The gain would be particularly significant if all operators in a market could share all available channels within each band.

Additionally it would be reasonable to anticipate that each band could deliver significant service differentiation in terms of end user experience.

Low band offers opportunities to integrate terrestrial TV with wide area cellular service and or two way radio public safety and business radio, mid band provides a common core compromise mix of coverage and capacity and high band could support enhanced peak rate data throughput capabilities.

Low band would arguably be best suited for **macrocells** and generally a better option for high mobility users as cell sizes will be larger thus reducing handover signalling overheads.

Mid band would arguably be best suited for **micro cells.**

The **2.6 GHz band** would be best suited to **pico cell and femtocell deployment** and would allow for integration of LTE wth WiFI at 2.4 GHz , probably a necessary pre condition for the mass market acceptance of Femtocell products in the home or office.

In some ways this is similar in concept to the user experience differentiation achieved between long wave, medium wave, short wave and VHF FM radio broadcasting. The propagation characteristics influence the choice of content - cricket on long wave and music on FM VHF being one example.

However a cellular network has the advantage of knowing where a subscriber is, where they are going and how fast they are getting there and potentially also knows what they are likely to need and or expect in terms of cellular connectivity.

More active use of this knowledge opens up the possibility of handover algorithms that use context to predict and decide whether low band, mid band or high band access would be most appropriate at a given time or place for a particular user for a particular application.

Handovers would typically be within band, for example to another low band or mid band or high band channel and handover from low to mid to high would only be triggered by a significant change in session access requirement, minimising signalling and measurement overhead.

Tri Band networks and a Universal Broadband Service Obligation

Our contention is that such an approach would provide the basis for a significant gain in spectral economic efficiency. Critically such a gain in efficiency would be a necessary precursor to any commitment by cellular operators to a universal broadband service obligation.

The impact of tri band on engineering added value

However a transition to low band macro cells, mid band microcells and high band pico cells and femtocells would imply a radical change to existing RF network configuration.

This means that vendors who have a balanced presence in handset design and RFnetwork infrastructure provision and operators with a developed understanding of these processes are likely to be best placed technically to provide an optimized connectivity experience. This will translate directly into a tangibly better more consistent more predictable session experience.

Some aspects of cellular network provision may be becoming commoditized but it would be a mistake to think that this implies a wholesale destruction of RF hardware added value or that traditional network and RF engineering skills are no longer needed.

Expectations of broadband connectivity will increase rather than decrease engineering value in the industry. The successful technical and commercial exploitation of tri band networks could provide an early example of this trend. A regulatory framework that encouraged tri band deployment would further hasten the process.

Summary

As data traffic increases, the present allocation of spectrum may become increasingly inappropriate.

Cellular operators will not be able to deliver wide area broadband connectivity cost effectively. An inconsistent connectivity experience will undermine user value.

Band plans as presently constructed are economically inefficient. Any attempts to base a universal broadband service obligation on present spectral allocations would be fiscally risky.

Re organizing band plans into low band macro, mid band micro and high band pico and femto hierarchical cell structures could significantly increase spectral economic efficiency at network level and could provide significant opportunities for engineering optimization which would translate directly into a better more consistent user experience and increased user value.

In general it would be wrong to assume that RF and network engineering skills are becoming less relevant in an era of commoditized network hardware.

The opposite is true and vendors and operators who have retained strong network engineering and RF capability combined with radio access algorithmic expertise are likely to be well placed to profit from future engineering added value.

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