The advantages of common frequency bands for mobile handset production – technical note

Background

This is a GSM Association white paper, based on independent research. This research, by RTT[1], examined the impacts on mobile handset design and costs, of not having common frequency bands identified internationally.

The work shows that there are significant opportunity costs involved for manufacturers when they consider the need to incorporate extra frequency bands in a mobile handset. The exact amount varies and depends on assumptions made (such as the number of vendors a market needs to support). The figures assumed to provide table 1 are derived from RTT's extensive discussion with the manufacturing industry. However they do show that the impact on a $30 low end handset could be to increase its price by 50% (to $45). This is not the only impact as the inclusion of ever more frequency bands in handsets makes them bigger, and less efficient as radio receivers. This impact on radio performance of handsets can mean operators need to deploy more base stations to provide the required quality of service.

Table 1: The impact of spectrum fragmentation on handset costs

Impact on handset costs (assuming 2 vendors)	800 million units per year (Global)	80 million units per year (China)	8 million units per year (Romania, Venezuela)
Extra cost on a handset	**15 cents(US)**	**$1.5 dollars (US)**	**$15 dollars (US)**
Resulting in a $30 (US) handset costing	**$30.15 (US)**	**$31.5 (US)**	**$45 (US)**

The GSMA concludes therefore that there are significant economies of scale to be had in the production of terminals with internationally identified common frequency bands. Without the identification of common bands, handset costs could be set prohibitively high, and the effect will be a significant reduction in the take-up of any mobile service. This will harm not only consumers and industry directly, but also the benefits that mobile offers to economies as a vital infrastructure.

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[1] "The advantages of common frequency bands for handset production". See http://www.rttonline.com/home_frame.htm

Introduction – Common Bands are no longer needed?

One of the main arguments in favour of a centralised spectrum management regime was to ensure that economies of scale could arise in terms of handsets and base station equipment, and replicate the success that was seen with GSM in the early 1990's. The impact on the business case is generally considered to be the highest on handset costs. The impact of economies of scale historically can be seen in the average sale price[2] of low end GSM handsets, shown in figure 1. For example, in 1997 there were 70 million subscribers worldwide, by the year 2004 there were some 1.7 billion GSM users worldwide.

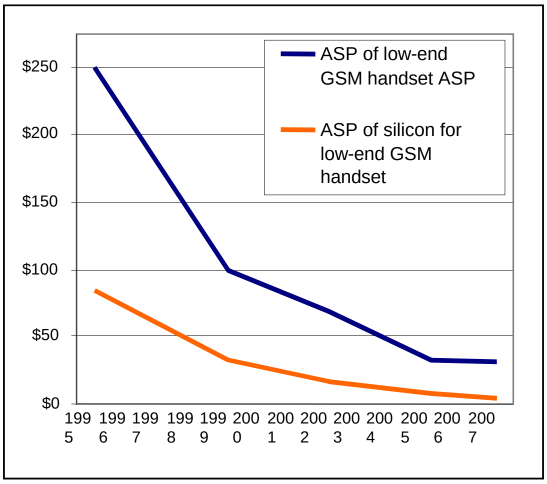

Figure 1 Average sales price (ASP) of low-end GSM handsets and their silicon chip components 1995-2007 (Incode)

This period (1997-2004) saw a drop in GSM terminal average sale price, from around $200 to less than $50.

However what was true in the 1990's may not be now. This view, on the benefits of common frequency bands, has been challenged by the huge rise in the number of mobile users, with almost a billion mobile devices sold every year. In such a huge market it is argued that economies of scale will cease to be significant. It is also pointed out that much of a mobile radio network is not frequency specific, so does not benefit from frequency harmonisation. For example switches, databases, billing platforms etc are independent of the frequency band selected.

What goes into making up the cost of a Handset (Bill of Materials)

In handsets, much of the cost of the components will be on things like batteries, memory, screens etc, that are not even common to a particular standard (ie WCDMA or CDMA2000). Indeed from RTT's research, we can see that the impact of frequency band appears to be relatively small in terms of the overall costs of a handset's bill of materials (BOM).

[2] Ie the price charges by handset manufacturers to operators or service providers – ie the wholesale price.

Looking at the bill of material for a handset, only some 7% of a handset's BOM is directly related to radio frequency components. This would seem to suggest that in terms of economies of scale, and the need for common frequency bands, there would be little benefit.

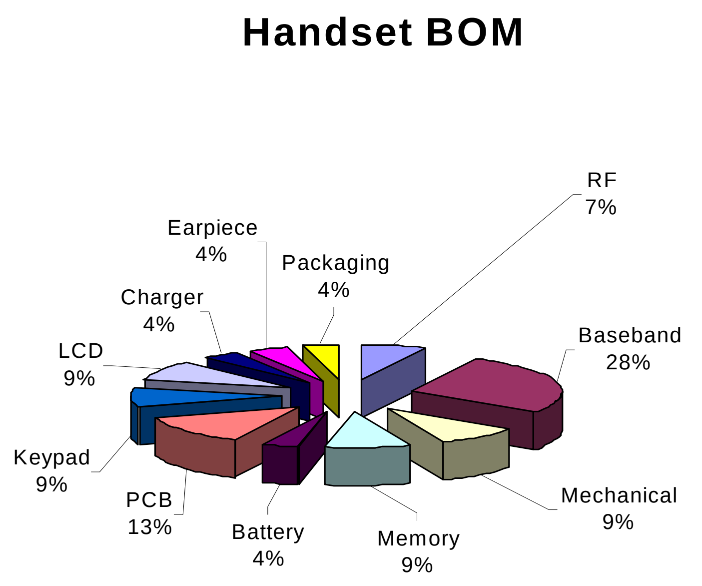

Figure 2 Handset Bill of Materials : Source RTT

The implication of the above is that there is no need to be concerned about having common frequency bands for mobile services, except perhaps to control the problems of cross-border radio interference. But if this really correct, why do handsets for niche markets cost more, for example GSM-R[3] $1200, and TETRA[4] $200 to $300, whilst GSM handsets can cost as little as $30?

Another strand to this argument is what is the impact in terms of radio frequency engineering, on handset design. With the greater move towards integrated chips, and the onset of software defined radio, can't all bands be built into handsets with little or no extra costs? When GSM started, handsets were single band (GSM900) and moved to dual band (GSM900/1800), and then to tri-band (GSM900/1800/1900) to allow roaming with North America. However it took time for these handsets to emerge, and today operators and manufacturers are faced with many more bands (see table 2) to allow GSM and UMTS terminals to operate worldwide. Add to this the need to include other radio air interfaces, such as Bluetooth, WiFi, DVB-H, GPS, etc and one can see that the RF complexity of handsets has increased hugely.

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[3] GSM used for train operators, operating in Europe primarily near the GSM900 band.
[4] The mobile standard used by emergency services in Europe, and also used for "professional" users, such as truck fleet or dispatch operators.

Table 2: Band Allocations for present GSM and present and future WCDMA deployment

Band	3GPP[5]	Allocation	Uplink	Duplex spacing	Downlink	Region
I	2100	2x60 MHz	1920-1980	190 MHz	2110-2170	Present UMTS/3G
II	1900	2x60 MHz	1850-1910	80 MHz	1930-1990	US PCS
III	1800	2x75 MHz	1710-1785	95 MHz	1805-1880	GSM Europe, Asia, Brazil
IV	1700/2100	2x45 MHz	1710-1755	400 MHz	2110-2155	New US
V	850	2x25 MHz	824-849	45 MHz	869-894	US and Asia
VI	800	2X10 MHz	830-840	45 MHz	875-885	Japan
VII	2600	2x70 MHz	2500-2570	120 MHz	2620-2690	New UMTS/3G
VIII	900	2X35 MHz	880-915	45 MHz	925-960	Europe and Asia
IX	1700	2x35 MHz	1750-1785	95 MHz	1845-1880	Japan

But if it is so easy to incorporate all these bands into handsets, why don't manufacturers simply put all bands into all handsets at the time of production? That would mean that they could be sold into all markets as they develop, indeed this would help kick-start markets, and give vendors first mover advantages. If this is simply an issue of a slightly longer design exercise, with little extra production costs, why is this not what happens now? Obviously what happens in the real world market for handsets is more complex than the simple discussion above.

How the Market works in practice

Handset prices are key to allowing bands to be exploited commercially. We can see however that large scale vendors do not want to be involved in small markets, without a significant mark-up in prices. Bespoke solutions are always possible from specialised vendors, but these can charge many thousands of $'s and are more suitable for the design of prototype or military or scientific radio devices. Perhaps the strongest counterfactual is the actual market shares of mobile devices worldwide, with GSM having nearly 70% of the market and WCDMA 10% (see figure 3 below). Also interestingly GSM quad band has around 5% of the GSM market. If economies of scale were not operating why would this be so.

Of course this may be to do with elements in networks or handsets that are not frequency specific. But the number of frequency bands for GSM is relatively few, primarily 900 and 1800 MHz, with 850/1900 MHz developing for the US market (which is both large and wealthy). GSM450 being less successful.

In fact the upfront costs associated with adding an extra band to a handset are not large, compared to the size of the market, and is around $6 million.

[5] International standardisation body responsible for GSM and WCDMA. See http://www.3gpp.org/

This includes chipset modification and handset integration, as well as testing costs. However this research by RTT has found that the issue is more complex than this, and subtle effects can multiply this cost many times.

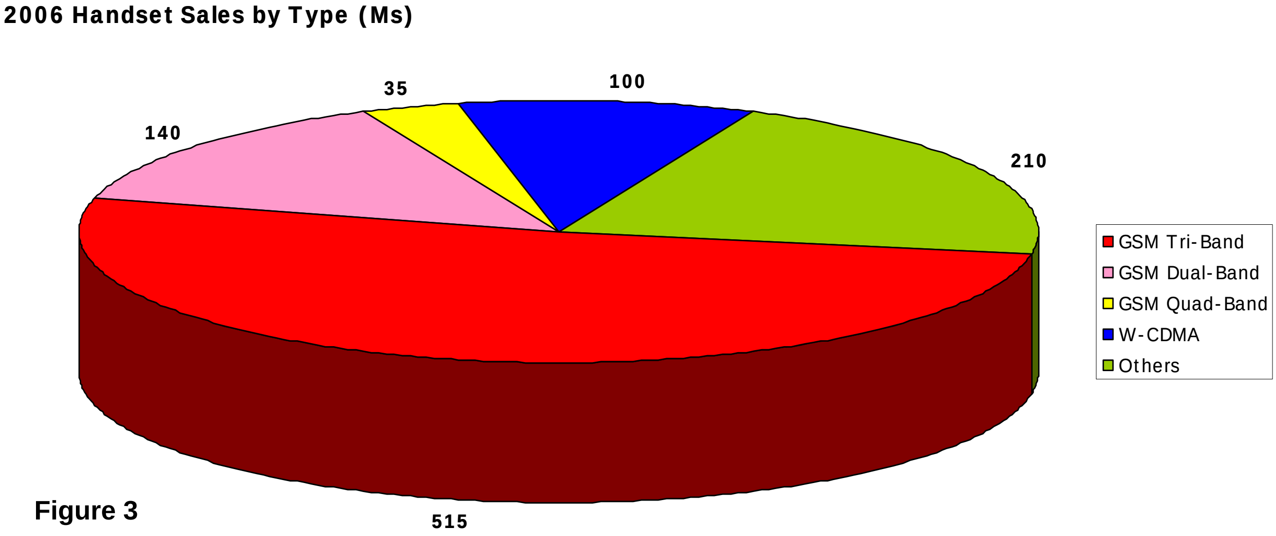

Figure 3

To understand why the above discussion does not tell the whole story one needs to better understand how handsets are made, and how the market for them works. One of the first steps in understanding this is looking at the value chain. One can think of the value chain of handsets coming in 4 parts[6], namely:

1. Component manufacturers (most important of which is the chipset vendors) ie Texas Instruments/Qualcomm etc;
2. The handset manufacturers (who integrate component, design the circuit boards, design the form factor etc) – ie Nokia/Motorola;
3. The operator or service provider (who sell the handsets to consumers on individual networks) – ie Vodafone/T-mobile; and
4. The consumers who use the phones to make calls.

Handsets require components, and someone to integrate those components, to make a commercially viable handset. All the actors in the value chain will be looking to maximise their profits and maintain their competitive advantage. This can come in a couple of ways, either from economies of scale, and closely related to that , learning better ways of producing terminals or integrating components (on chipsets say). Put another way each of the actors in the first two layers has a limited R&D (RF engineers) resource to spend each year, and will spend this limited resource in those areas that give them the most profit, and help maintain their competitive position. If they waste those efforts on small niche markets, not only do they make less money, but they fall behind other competitors who will be able to make

[6] Some manufacturers may operate at more than one level.

smaller/cheaper/better handsets in the more lucrative mass markets (100 million terminals per year, as opposed to 1 million terminals per year).

Opportunity Cost

The effect of this is that vendors will charge a premium for moving away from mainstream frequency bands. Industry research shows that this is currently a factor of around 10 (source RTT), and that the trend in this opportunity cost is growing, as the market for terminals grows. That is there is an opportunity cost, and the size of this opportunity cost depends on the difference in annual terminal volumes between the niche, and mainstream product markets. Of course it is possible that manufacturing process may change significantly in the longer term. For example the advent of software defined radio. However according to RTT's analysis this (in its current form) still relies on certain RF specific devices (such as filters). This means that software defined radios could still exhibit such scale economies in the foreseeable future. It is also not clear when such technologies will become mainstream for mobile handsets.

It is possible that some manufacturers will decide for strategic reasons to support loss leading phones in niche frequency bands. Obviously there is a risk element in this (you may not make your money back), and cannot be done indefinitely. Also, handsets is a highly competitive market where margins can be small, and we have seen some large names exit this market recently. This would tend to suggest that the scope for such strategic behaviour is limited.

It is also possible for operators or service providers to "force" vendors to provide niche handsets as part of a portfolio of terminals. For example, "make a niche band of one million terminals for me for country X, and I will give you large orders for some of my bigger markets in other countries". This is also known in the industry as a "portfolio" effect. One would expect however that vendors will in some way factor this extra cost into the overall price charged for all terminals, so ultimately the network operator is subsidising these niche handsets.

The operator or service provider also has an interest in being able to source handsets from more than one vendor. An operator would ideally like to be able to source handsets from 4 or 5 vendors. This will give them access to a wide range of terminal types that are needed in most markets (low end basic terminals, mid specification phones for basic business users, high end feature rich phones). Having the latest or "sexiest" model phone can have a significant impact on attracting high spending customers who are most profitable. The danger for an operator would be that if they have only a single supplier they may find terminals more expensive or have a less diverse range to choose from.

Impact on Radio Frequency (RF) Performance

The process of designing and making a handset is divided in three parts:

- firstly the design of components, such as RF filters etc, and the chip sets
- designing the circuit board on which these components will sit or feed into; and
- Integrating these components into a handset.

It is the interaction of the value chain and these manufacturing stages that is what drives the complexity of this market; and why it does not behave in the way that might be expected, when you consider the impact of common frequency bands. To include new bands in handsets requires that circuit boards be redesigned, and extra RF components be introduced. This means that compromises need to be made in the design of the handset each time a new band is incorporated. For example the size or form factor will increase. The handset RF sensitivity will also be diminished to combat the problem of extra bands causing interference within the handset (such as intermodulation problems[7] etc). This may also impact on the battery life, as the handset may not be as efficient at sending and receiving signals. It may also mean that the performance of the handset on a network is not as good as a handset with fewer bands. This could ultimately mean that the radio coverage area is effectively reduced. For example a 2 dB reduction in radio sensitivity might mean an operator would need about a third more base stations to keep the same geographic coverage. Such a figure (2 dB) is quite small in engineering terms. Of course with time and effort these issues can be resolved and handsets will reduce in size and get more efficient in terms of RF performance. One has seen this with GSM with the first phones just making it past some RF standards. But with time the RF performance has improved by a dB or so each year to approach theoretical limits. This is common in many manufacturing processes, first devices may find it hard to meet some parameters required in standards, latter devices easily meeting such requirements. This comes about by designing and redesigning phones, and again is linked to volumes, as this usually serves as a proxy for the effort a manufacturer will be willing to put into a design.

All these issues mean that there are performance issues and an impact on the size and complexity of phones with more and more bands, as well as cost increases from the loss of economies of scale. This does not scale in a linear manner, but becomes increasingly more difficult as the number of bands increases. This increase in complexity means that it is harder to make handsets to a given specification, so that more components will fail production quality testing. Time may improve this with learning effects but this too is linked to volumes.

[7] That is when multiple radio frequencies mix within a handset to produce frequencies that interfere with the reception or transmission of signals.

Conclusions

The impact of all these factors (handset complexity increasing with frequency bands added, learning effects, etc) means that there is a significant opportunity cost for vendors when they divert scarce R&D resource away from their main markets. This means that vendors will only do so if they are :

1. Able to charge a premium to reflect the opportunity cost (x10);
2. Have a strategic business reason to support a loss leader to grow a market; or
3. Encouraged to do so by large operators who use a “portfolio” effect.

The opportunity cost factor tied to the need to support multiple vendors, suggests that an upfront figure of $6 million might be increased to $240 or $300 million (US). That is this $6 million is x 5 for the number of vendors required in a market, and 10 for an opportunity cost. This upfront cost (as well as any incremental costs due to more components) must be added to the normal price of a phone (say $30 per terminal for ultra low cost GSM devices). Spread over a 100 million devices per year this is a $3[8] added to the cost of each and every handset. It may be however that an operator would be willing to rely on less than 4 or 5 suppliers in some situations. This might reduce the upfront cost to $120 million with only 2 vendors say, or $60 million for a single vendor.

The impact this would have on handset costs is illustrated in the table 3 below, for two scenarios. The first (in blue) is when a market needs to support 5 vendors and the opportunity cost factor of 10, which gives an effective upfront cost of $300 million upfront cost that must be recovered in 12 months. This cost is then added to the price of a low end $30 terminal to give an increase cost of the terminal to nearly $70, ie more than double the price.

In the second scenario the market needs to support 2 vendors (pink), and we can see that for a market of 8 million terminals per year, the increase in cost of $30 terminal (to recover $120 million upfront cost over 12 months), is $15. The total cost is to now $45, a 50% increase in the cost of a terminal.

[8] Assuming 5 vendors, and a payback period of one year, which was the industry view.

Table 3: The increase in costs on a $30 handset of having to accommodate new frequency bands for varying size markets

300 million dollars of NRE cost amortised over (5 vendors)	**800 million units per year (Global)**	**80 million units per year (China)**	**8 million units per year (Romania, Venezuela)**
Implies a per unit recovery of	**37.5 cents**	**3.75 dollars**	**37.5 dollars**
Resulting in a 30 dollar handset costing	**30.375 dollars**	**33.75 dollars**	**67.5 dollars**
120 million dollars of NRE cost amortised (2 vendors)			
Implies a per unit recovery of	**15 cents**	**1.5 dollars**	**15 dollars**
Resulting in a 30 dollar handset costing	**30.15 dollars**	**31.5 dollars**	**45 dollars**

This would still suggest however that there are substantial cost benefits to be had from having internationally identified common frequency bands; at least on a regional level. The conclusion of this white paper is therefore, ***that there are significant economies of scale to be had in the production of terminals with internationally identified common frequency bands.***

This impact on handset costs of internationally identified common frequency bands means that regulators should be wary of introducing country specific band plans.

Without such identification of common bands, handset costs could be set prohibitively high, and the effect will be a significant reduction in the take-up of any mobile service. This will harm not only the consumer and producer surplus directly, but also the indirect benefits that mobile offers to economies.

GSM Association
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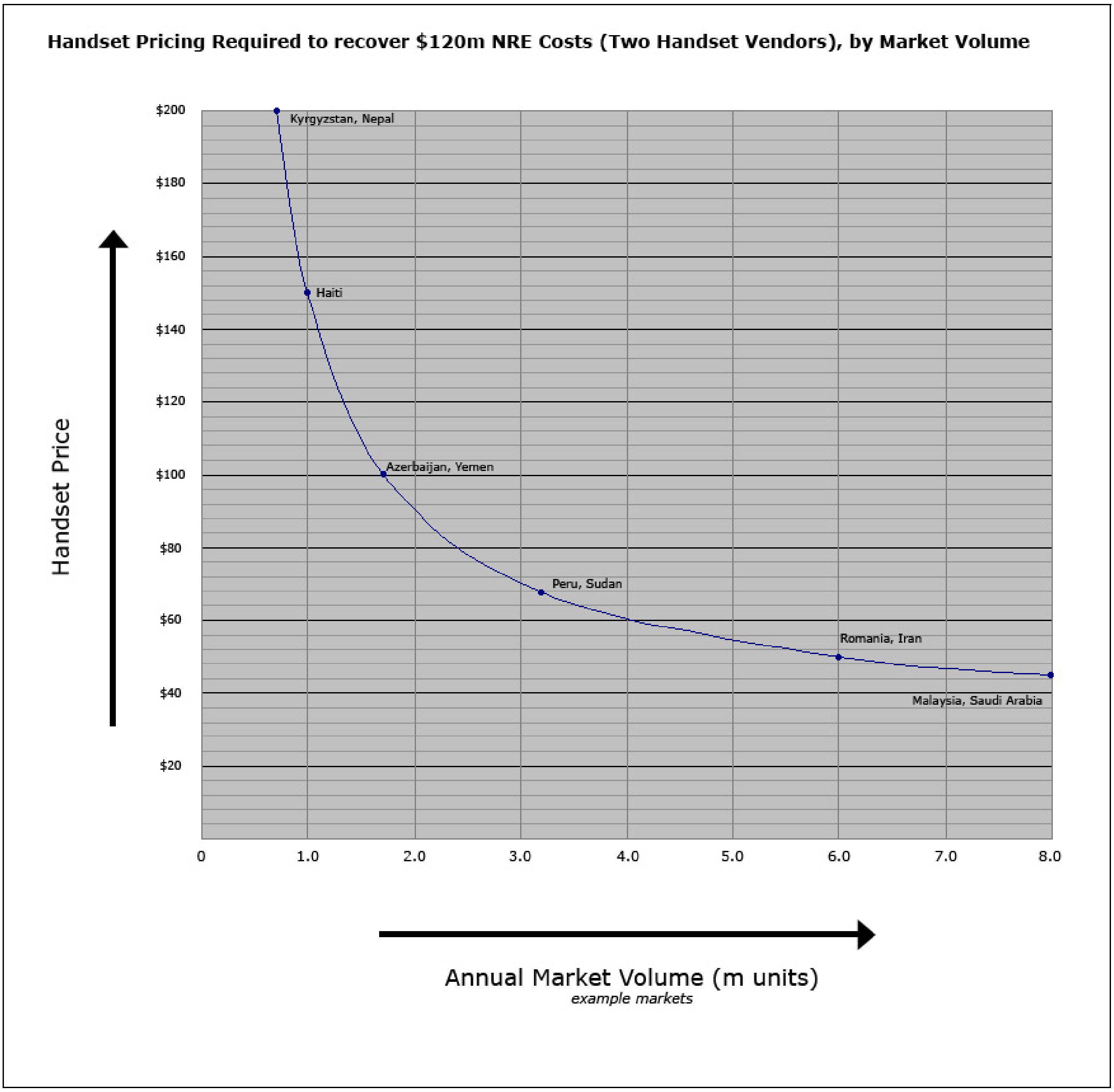
Annex 1 : Example of the impact of a new frequency band on the cost of a $30 terminal, for various market sizes (assuming 2 vendors).



country	Annual handset market volumes 2006
South Africa/Spain/Nigeria	15 million (each)
UK/Turkey/Mexico	20 million (each)
USA/Pakistan	35 million (each)
Russia	50 million
India	65 million
China	80 million

Source RTT