# RTT TECHNOLOGY TOPIC
## May 2007

## RF Cost Economics for Handsets

**RF Cost Economics for Handsets**
This month's Technology Topic summarises a White Paper produced by RTT for the GSM Association researching the impact of non standard band allocations on the cost and performance of cellular handsets and by implication, the impact of RF device and design trends on spectral allocation policy.

The **White Paper** is available as a pdf document and can be read in conjunction with a more detailed and fully referenced Study. If you would like copies of these documents sent to you please e mail us or download either or both documents from our web site.

The documents are based on interviews with technical, engineering, marketing and business executives employed by silicon vendors, their RF component and service suppliers, cellular handset manufacturers, RF design houses, test equipment vendors, type approval and conformance test agencies and network operators.

In particular we were asked to use these interviews to test the validity of a number of assumptions presently influencing global spectral allocation policy.

These assumptions are as follows

**Assumptions used to justify a more flexible spectral allocation policy**
With handset production volumes approaching and exceeding one billion units per year it might be assumed that sufficient scale efficiencies are available to support a wide range of standard and non standard band allocations.

The availability of GSM quad band and GSM/WCDMA quintuplet band handsets at competitive wholesale prices would seem to suggest that design and device solutions are already available that allow additional multi band multi mode functionality to be supported with minimal cost or performance penalties.

Higher levels of device integration combined with spectrally flexible architectures using micro electronic mechanical system devices (RF MEMS) and other device innovations will deliver software defined radios that will allow additional multiple bands to be introduced using multiple radio access technologies with minimal cost or performance penalties.

Sufficient engineering effort will be available to cost and performance optimise these solutions in a timely manner.

Intuitively it might seem that frequency specific costs, the RF 'Bill of Materials' also known as the RF BOM is reducing over time as a percentage of the overall BOM of the phone.

It might also be expected that the RF BOM in a high end phone represents a smaller percentage of the overall BOM than the RF BOM in a low end or mid tier phone.

Given that most of the non RF components share economies of scale irrespective of the frequency band in which they operate, it would seem that RF costs are becoming increasingly insignificant over time.

These assumptions together support the view that there is a reducing need to harmonise spectral allocations either on a local, regional or global basis and a reducing need to mandate technology standards.

**A range of alternative assumptions**
The study draws on a wide range of industry inputs to suggest that these assumptions are largely invalid.

We identify **four cost components** in a cellular handset incurred as a result of introducing additional standard and non standard band allocations, **RF performance costs, RF component costs** (variable costs), **non recurring RF associated engineering costs** (fixed costs) **and opportunity costs**.

These costs are volume dependent and are increasing rather than decreasing over time. Because of their volume dependence, such costs for any one vendor will be influenced by the number of vendors competing in a particular market. We describe these as **'shared market costs'**

The study presents a realistic assessment of present emerging technology solutions and highlights some of the engineering effort needed to make these solutions cost and performance economic for mass market adoption. **If too much engineering effort is required to implement a solution, it cannot become economically viable.**

We highlight the impact of present industry engineering resource constraints and show how this results in 'opportunity cost multipliers' that significantly increase the real cost of spectrally non standard cellular handsets.

We show that counter intuitively, **despite halving in value over the past three years, the RF BOM has stayed remarkably constant as a cost component and continues to represent between 7% and 10% of the overall cost of the phone**.

**This ratio applies irrespective of whether the device is a low, mid or high tier handset**.

These alternative assumptions are based on industry evidence. They support the view that there is **an increasing need to harmonise spectral allocations**, locally, regionally and globally and arguably **an increasing need to mandate technology standards.**

**Present and future standard and non standard spectral allocations**

Table 1 below shows the present 'standard' spectral allocations defined by the 3GPP for present GSM and present and future UMTS deployment.

Table 1, **Band Allocations for present GSM and present and future UMTS deployment**

| Band | 3GPP | Allocation | Uplink | Duplex spacing | Downlink | Region |
|---|---|---|---|---|---|---|
| 1 | 2100 | 2x60 MHz | 1920-1980 | 190 MHz | 2110-2170 | Present UMTS |
| 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 |
| VIII | 900 | 2X35 MHz | 880-915 | 45 MHz | 925-960 | Europe and Asia |
| IX | 1700 | 2x35 MHz | 1750-1785 | 95 MHz | 1845-1880 | Japan |

Apart from the range of bands, there are also differences between bands in terms of duplex spacing and guard band spacing which have a significant impact on RF device and design implementation. Additionally, individual countries may choose to propose additional allocations.

The present Consultation Document from Ofcom in the UK, for example, proposes an auction of Band VII spectrum but with additional allocations at 2010 to 2025 and 2290 to 2300 MHz. The Consultation Document proposes that this spectrum should be allocated on a 'technology neutral' basis.

While it is possible that sufficient global market volumes may be available in Band VII to support multiple technologies, it seems unlikely that either regional or local scale efficiencies will be achieved in the 2010 to 2025 and 2290 to 2300 allocations either for single or multiple technologies.

Japan and Korea provide two examples of country specific spectrally specific technology specific network implementation, PDC and PHS in Japan and more recently, Wi Bro in Korea. These deployments may be politically expedient but are generally uneconomic.

In reality, regionally specific spectral allocations are only economic for the two largest regional markets, India and China.

**GSM market volumes and realized prices over the past ten years**
Table 2 below gives the year on year subscriber growth for GSM between 1995 and 2006.(Market statistics from The Mobile World )

Table 2, **Year on Year GSM Subscriber growth (in millions)**

| 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 est |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13.4 | 32.4 | 70.5 | 136 | 259 | 457 | 636 | 803 | 994 | 1289 | 1710 | 2033 |

The ASP of a low end GSM handset in 1995 was $250 dollars.

By 2005 prices had reduced to somewhere between $40 and $50 dollars
Over ten years there has therefore been a five fold reduction in wholesale average realized prices (ARP) equivalent to a 15% drop per year. This has largely tracked year on year reductions in component costs.

These cost reductions are a product of design improvements which result in a reduction in component count and therefore component cost. This is despite a year on year increase in radio functionality, for example the ability to support multiple band allocations and enhanced data services.

These design improvements are only realized through substantial non recurring engineering investment which needs to be recovered over substantial market volumes.

RF components do not generally fall in price as fast as mass market consumer electronics components. The reason for this is that RF functions are generally harder to integrate than digital/baseband functions and therefore do not benefit as directly from silicon geometry scaling.

**RF BOM Cost Trends and future RF functionality**
This overall ten year cost reduction trend still holds true today though some caveats apply.

Three years ago, the RF BOM for a triple band (GSM900/1800/1900) mid tier multi media handset was just over twelve dollars.

The equivalent quad band (GSM900/1800/1900/850) RF BOM today is six dollars. This suggests that year on year RF costs have decreased at 20% rather than 15% per year.

This would seem to be an alarming trend for vendors of RF components and suppliers of RF design expertise.

However substantial new application layer functionality has been added to cellular phones over this period, for example enhanced imaging and audio functionality and more recently advanced positioning capabilities. Through this process of added value, the largest of the component suppliers, design houses and handset vendors have been able to maintain profit levels.

To realise value from these advanced capabilities, network operators need to have handsets with enhanced RF physical layer functionality. This includes an ability to support higher downlink and uplink data rates and an ability to support multiple simultaneous per user variable rate data streams.

For RF component and system vendors, this is a fortuitous trend, helping to prevent further price erosion and providing opportunities to stabilise or in some instances increase RF BOM value.

Although much attention is paid to headline data rates, this is only part of the picture. Considerable design attention is now being directed towards ensuring that cellular radio functionality can co exist with other transmit/receive and receive only functions.

For example receive only functions such as digital TV or GPS, are easily desensitised by locally generated transmit power in the handset.

This implies a need for additional filter components. These will increase the recurring costs of the RF BOM. Adding a new band to a handset is therefore a significantly more complex design task which implies an increase in non recurring engineering cost and related opportunity cost.

RF BOM recurring costs might initially seem to be insignificant, about 4 dollars for a dual band GSM phone, 5 dollars for a tri band phone and 6 dollars for a quad band phone. These costs represent the additional filtering required in the receive and transmit paths of the handset.

If adding an additional non standard band to a handset only incurs a dollar or so of incremental RF BOM cost, then it would seem reasonable to assume that it would be relatively easy to ensure an adequate supply of cost competitive performance competitive handsets.

In practice however, each incremental band has a performance cost and substantial NRE and opportunity cost that taken together, invalidate many apparently viable cellular radio business plans.

These performance costs, NRE costs and opportunity costs are increasing rather than decreasing over time. In particular, these costs increase as the level of integration increases. At the same time recurring costs are decreasing.

**RF Related Software Costs**
Some vendors are presently promoting the concept of software defined radios capable of accessing a broad range of frequency bands supporting a broad range of access technologies.

In practice these technologies are not yet ready for mass market adoption and present significant integration challenges. These challenges add major NRE costs.

However there are substantial existing software costs associated with RF functionality. Present RF integrated circuits have to be designed to work with baseband IC's. These in turn have to be programmed to control and respond to changing RF channel and traffic conditions.

Thus an additional standard or non standard band allocation will require RF related hardware and software engineering effort and investment - NRE costs - that will need to be recovered over the production life of the handset.

The actual cost RF components may be a relatively small percentage of the overall BOM of the phone. However the RF costs associated with non standard band allocations come with substantial risk multipliers in terms of cellular handset performance, cellular handset functionality, cellular handset availability and unsupportable hardware cost premiums particularly for smaller markets.

**Quantifying Performance Costs for standard multi band handsets**
15 years of GSM production experience has helped develop a considerable body of knowledge of cellular phone performance including the performance costs associated with additional frequency band support.

Initial handsets were single band 900 MHz. Dual band 900/1800 handsets were introduced from 1995, tri band 900/1800/1900 from 2000 and quad band (adding in GSM850 for the US) from 2005.

From an RF design perspective, the half wave /quarter wave relationship between 900 and 1800 MHz provided opportunities to develop novel and effective RF architectures though at the time these phones still represented a significant design challenge.

Subsequent band additions have all introduced new design challenges and required optimised design solutions. All have been successfully accomplished but at considerable NRE cost.

Theoretically the additional insertion losses implicit in these multi band designs could 'cost' a dB or so per band in terms of lost sensitivity.

In practice, these potential losses have been more than balanced out by overall improvements in GSM RF performance. Handsets in 1992 struggled to meet the conformance specification of -102 dBm but on average improved by approximately 1 dB per year. By 1997, phone sensitivity could typically be measured at -107 dBm. Over the past ten years this has improved to about -110 dBm. Further improvements will be harder to achieve as GSM approaches its fundamental bandwidth/ noise limits.

These steady improvements are due to the engineering effort invested in component optimisation, design optimisation and manufacturing techniques including device self calibration.

They are also partly the result of production volume. As production volume increases, handset manufacturers can demand that their suppliers more closely control the tolerance and/or device to device batch to batch performance spread of RF components.

These effects hold true for standard band allocations provided there is sufficient market volume to fully amortise engineering design effort and sufficient market volume to achieve volume related performance gains.

**Quantifying performance costs for non standard bands**
None of the above necessarily applies for non standard band allocations.

The performance cost in terms of sensitivity loss will depend on what other bands are supported in the handset and the spectral relationship of the newly allocated bands to other bands. For example sensitivity will be dependent on the amount of guard band between the allocated band and adjacent occupied spectrum, and the duplex and diplex spacing.

Additionally low market volumes will typically not attract sufficient engineering effort to optimise the RF design of the phone including practical aspects such as antenna optimisation.

This may result in phones being 2 or 3 dB less sensitive than equivalent phones optimised for standard band allocations.

To put a dollar cost on this, a one dB loss of sensitivity equates to a need to increase network density by 10% to maintain an equivalent link budget. A loss of sensitivity will decrease downlink data rates and increase dropped call/dropped session rates.

The same principles apply on the transmit side of the cellular phone. Considerable design effort is needed to deliver acceptable error vector magnitude (EVM) and low adjacent channel power (ACPR) levels. A poorly implemented transmit chain will have a direct impact on uplink data rates.

In terms of production costs there is also the issue of RF yield.

RF yield is the percentage of handsets that pass their RF transmitter and receiver performance and functionality tests at the end of the production line.

Provided phones are at least 4 to 5 dB better than the basic conformance specification on the receive side and preferably several percentage points within the EVM specification, RF yield will be high (close to 100%).

If phones are closer to the conformance specification limit, RF yield will drop. Some phones may be able to be reworked but a substantial percentage may need to be scrapped. Note it is not just the RF components that get scrapped but possibly the whole phone so the cost impact can be dramatic particularly with higher end phones. Low production yield can also introduce time to market delay.

**Component Costs**
We have said that the direct component costs for supporting a non standard band, assuming it is additional to existing standard bands, are relatively trivial, in the order of one or two dollars per handset.

These costs are made up in GSM by additional front end switching and routing and a diplex filter. In UMTS, additional duplex filtering will be needed .There may be a requirement for a special to type antenna.

Other costs depend on what else is included in the phone. Higher end phones with Bluetooth and/or WiFi and/or DVB and/or GPS functionality may require additional filtering and reciprocal mixing to eliminate unwanted inter modulation products

This is however only part of the story. RF devices generally take a signal, do something to it (filter or amplify for example) and then pass the signal on to another device. In the process, the devices need to be power matched or noise matched - a semi black art known as conjugate matching.

So any additional RF function will usually require additional RF matching components. If these are discrete devices there will be a production cost implication - more components to place, more component variability and a harsher production test regime.

Any increase in production testing will be directly reflected in the final cost of the device. The additional component count and RF device to device variation will also reduce RF yield, adding further to costs.

**The effect of increased levels of device integration.**
One well established route to reducing component costs is to increase integration level.

In the past, previously discrete functions such as the frequency synthesiser and VCO have been 'off chip'. These are now (usually) integrated on to the RFIC.

Future plans include the use of RF MEMS to allow diplexing and duplexing functionality to be integrated together (rather ambitiously) with the RF PA into a 'single chip software definable phone'.

However as and when this happens the effect is that the RF BOM decreases but the RF NRE increases. Thus from the perspective of the manufacturer, to design a highly integrated phone, high volumes become imperative in order to recover the NRE. This makes producing for non standard bands of questionable profitability unless high volumes can be assured or the manufacturer can sell low volumes for very high prices.

Conversely a decision could be made to implement a phone for a non standard band using relatively low levels of integration. This will reduce the NRE investment but increase component count and component cost and size. With that, both the cost and the size and weight of the phone also increase.

RF performance may or may not be worse or better (a good discrete design can work rather well) but will be more variable. Higher levels of device integration will generally yield more consistent performance.

So engineering effort has to be focussed on finding optimum trade offs between device performance and device cost. SAW filter vendors differentiate their products for example on the basis of low insertion loss and/or small form factor, minimal height being a presently important metric for ultra slim handsets.

Active device vendors differentiate their products on the basis of efficiency, linearity and phase accuracy. There are hundreds of subtle but significant device and design decisions that need to be made during the development process.

These decisions are always critical but especially critical for ultra low cost handsets where performance margins may be less generous. This suggests that non recurring engineering costs may be higher for ultra low cost handsets. This suggests that it will be very challenging for vendors other than Tier 1 vendors to address this market.

**Non Recurring Costs**
Performance cost multipliers and component cost multipliers for non standard bands are important but in practice are relatively insignificant when compared with non recurring engineering costs.

Non recurring engineering costs, specifically, in the context of this study, non recurring RF engineering costs are incurred by silicon vendors and their supporting component vendors(for example SAW filter suppliers),handset vendors and operators. NRE costs include type approval testing and conformance testing. These tests alone can comfortably exceed one million dollars. Interoperability and drive testing by operators can easily equal or exceed this figure.

Typically a silicon vendor will need to spend at least three million dollars developing an RF chip set for a new standard or non standard band. This includes type approval testing.

A handset manufacturer will take this device and typically spend two million dollars on developing a working cellular phone including the internal resource needed to get the product through the conformance test process and fit for production.

A network operator should do drive testing and interoperability testing. This might be a once off process but has an unpleasant habit of becoming a semi recurring expense, particularly as network deployments evolve over time. Hence our probably conservative figure of one million dollars.

So the total NRE costs associated with a standard or non standard additional band allocation total six million dollars. In the context of an 800 million unit annual market, these figures look insignificant. However the NRE costs are insignificant compared with the opportunity cost multipliers that presently have to be applied in the industry to meet acceptable shareholder and stakeholder return on investment expectations. This is why allocation of non standard spectrum may lead to fewer and more expensive phone models than regulators (or operators on the spectrum) expect.

**Opportunity Costs**
Opportunity costs, effectively 'lost opportunity costs' were described by a number of respondents (summarised and paraphrased) as follows;

'Consider a choice which is basically to take 50 or 100 scarce and expensive engineers and put them on a cost and performance optimisation project for a mainstream product, for example a triple band GSM or quad band GSM product. I know I can ship five, ten or possibly ten or even twenty million devices per month to my major tier one customers. This is a known market with a known cost base and well documented growth history.

If that team produce a cost saving of 50 cents a phone which altruistically I share on a 50/50 basis with my customers- or 25 cents each- then I can show a direct and immediate beneficial impact on my profit, $15 million, $30 million or $60 million a year. If the team produces a cost saving of $2.0 per phone, I could profit by as much as $240 million per year. My customers and I will have consolidated our competitive position in that volume sector of my business.

I have to have that volume component otherwise I know I will be unable to match R and D investment to future market opportunity.

My alternative option is to take the same engineering team and ask them to produce a chip set and reference design for an unknown market with a non existent growth history and potential rather than proven growth prospects. It would be very unlikely that I could get an assured ten or hundred million dollars of profit.

Additionally if my competitors take the decision to cost optimise mainstream products and I don't, then I could be placed at a catastrophic market disadvantage'.

This explains why it is common particularly at silicon vendor level to use an opportunity cost multiplier of between ten and twenty times the estimated NRE costs when validating uncertain or unknown market opportunities.

Thus our figure of 6 million dollars to develop a phone for a non standard band now becomes a minimum of 60 million dollars.

**Shared market costs**
However this is a single vendor view. In practice, as most purchasing managers will agree, it is a good idea to have at least five potential suppliers competing for business of which typically two might be chosen to provide primary and secondary sourcing. This is a necessary precondition for an efficient market.
However an efficient market also has to have sufficient volume to allow for NRE recovery. Thus a single vendor has to consider the risk of other vendors dividing down the available market volume. This risk has to be expressed as a cost multiplier, the 'shared market cost.'

GSM-R provides an example of a very small market (tens of thousands of handsets). GSM-R is deployed into a 4 MHz band of spectrum below the cellular 900 MHz bands and is set aside for use by European railway companies. There are only two subsidiary vendors and one main vendor and handsets cost $1500 dollars.

TETRA, the Trans European Trunked Radio Access networks deployed in Europe in high band VHF and UHF allocations have marginally higher volumes but again a limited choice of vendors. Handsets cost between $300 and $500 dollars.

CDMA450 is another example of a sub optimum size market with limited vendor support and the additional disadvantage that handset form factor and performance expectations are directly related to other cellular networks.

**The Composite Cost Calculation for cellular handsets**

These are extreme examples but illustrate the effect of sub optimum (CDMA450), small (TETRA) or very small (GSM-R) market volumes.

In general, in more mainstream markets, network operators will be competing with entry level handsets with a wholesale cost of 40 to 50 dollars. In these markets, component vendors, handset manufacturers and network operators will need to recover NRE costs which we have established as being at least 6 million dollars.

These costs then have to be multiplied by a factor of at least 10 to account for the 'opportunity cost' of supporting a non standard band allocation.

Finally these costs have to be multiplied by the number of vendors sharing the available market volume (the shared market cost) yielding the following calculation.

NRE (6 million dollars) X10 (typical opportunity cost multiplier) X 5 (shared market cost multiplier) = 300 million dollars.

The calculated sum can then be applied to present market volumes.

For comparison purposes, the market is divided into three tiers, Global, Regional and Local.

The Tier 1 global market is 800 million units per year.

Tier 2 Large Regional Markets are in the order of 80 million units per year. China is an example. Other Tier 2 regional markets include India where year on year growth is presently faster than China. The US, Brazil and Pakistan each represent about 35 million units per year. The US and Brazil together therefore constitute a 70 million unit market however the fragmentation of technology choice in the US and Latin America arguably invalidates the possible regional scale benefits.

Tier 3 Local markets are in the order of 8 million units per year. Malaysia, Romania and Venezuela are all individual examples. Scandinavia is another example.

The 'reference product' is an ultra low cost handset at 30 dollars.

Amortising 300 million dollars of NRE, opportunity cost and shared market cost over 800 million units (the Tier 1 global market) adds less than 40 cents (37.5 cents) of real cost to the phone. The total handset cost is therefore 30.375 dollars.

The volumes are over one year. Note it would be considered imprudent to assume a return on investment over more than 12 months given that the redesign cycle is close to 18 months (possibly also reducing over time).

The same sum is then done for Tier 2 markets, for example China, at 80 million units per year and India (65 million but will soon be 80 million) and it can be seen that NRE costs are still sustainable, adding just under 4 dollars (3.75 dollars) per handset. The total handset cost is therefore 33.75 dollars.

The same sum is done for Tier 3 markets at 8 million units per year, for example Malaysia, Romania, Venezuela, with, as you would expect a cost penalty of just below 40 dollars (37.5 dollars). The total handset cost is therefore 67.5 dollars.

Costs then rise to nearly 1200 dollars per handset for markets of a quarter of a million units per year.

In practice it can be seen that only markets like India, China or equivalent regional markets can sustain a spectrally specific band allocation.

Table 3 **Amortising 300 million dollars of NRE Costs over various market volumes**

| 300 million dollars of NRE cost amortised over | 800 million units per year | 80 million units per year | 8 million units per year |
|---|---|---|---|
| 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 |
| Sold into a | Tier1 Global | Tier 2 Region India, China | Tier 3 Country Malaysia, Romania Venezuela |

**Pricing effects in Tier 2 and Tier 3 markets**

Table 4 applies the same assumptions to a cross section of Tier 2 and Tier 3 markets. A 30 dollar handset is used as the reference point. At 15 million units per year a 30 dollar handset will cost 50 dollars, at 4.28 million units per year a 30 dollar handset will cost 70 dollars, at 2.5 million units per year a 30 dollar handset will cost 150 dollars, at 1.764 million units a 30 dollar handset will cost 200 dollars, at 0.25 million units per year a 30 dollar handset will cost 1200 dollars.

Table 4, **Tier 2 and Tier 3 Market Handset Costs**

| A 30 dollar handset selling at | $50 | $100 | $150 | $200 | $1200 |
|---|---|---|---|---|---|
| Provides a per unit contribution of | $20 | $70 | $120 | $170 | $1170 |
| To recover an NRE cost of 300 million dollars requires an annual market volume of | 15 million units | 4.28 million units | 2.5 million units | 1.764 million units | 0.25 million units |
| Typical countries include | South Africa Spain | Portugal, Greece | Chile | Singapore Oman | Burundi or Chad |

| | | | | | |
|---|---|---|---|---|---|
| | Nigeria | | | | |

**The 'Broadening Spread Effect'**
Note that as cellular handset cumulative volumes increase over time, the volumes of standard handsets increase and costs decline. However the relative cost difference between handsets for standard and non standard handsets will increase.

The relative 'penalty' cost of delivering non standard regionally or locally spectrally specific products therefore increases over time.

**The impact of RF Cost economics on Spectral policy**
In summary, the impact of non standard band allocations on the cost of handsets when considered purely in terms of component cost additions seems trivial.

However on closer inspection, we find we need to factor in substantial non recurring engineering costs. Further more, these costs are increasing as integration levels increase.

Component integration is a major factor enabling ultra low cost phones. Thus NRE costs will be substantial in order to deliver equivalent phones for non standard spectrum in developing countries.

Additionally vendors need to apply rigorous opportunity cost multipliers to avoid a dangerous dissipation of design engineering resource. These are typically at least ten times the estimated baseline and are the result of realistic return on investment expectations given present engineering resource limitations and shareholder value growth expectations.

Finally this is a single vendor view. If there was a single vendor supplying the market then there would be additional NRE amortisation volume but scant incentive to provide competitive pricing.

Thus by default these are going to be multiple vendor markets and as such available volumes will be divided down by the number of competitors participating in that market.

This effectively invalidates most business models predicated on non standard band allocations.

Similar arguments could be made to show that a lack of a harmonised mandated standards policy will have an equally dramatic effect on handset technology costs.

**Conclusion**
Contrary to popular belief**, RF performance costs, non recurring RF associated engineering costs and foregone market opportunity costs are increasing rather than decreasing over time.**

In particular, **non recurring engineering costs increase as integration levels**

**increase**. This holds for high, mid, low and ultra low tier handsets. These costs are not volume dependent but their recovery is. While these costs are non recurring, they have to be recovered across significant market volume.

Present industry engineering resource constraints introduce generally **under estimated opportunity cost multipliers that significantly increase the real cost of cellular handsets intended for non standard spectrum.**

The competitive structure of the industry further increases these costs through the **'shared market effect'.**

Despite halving in value over the past three years, the **RF BOM has stayed remarkably constant as a cost component** and continues to represent **between 7% and 10% of the overall cost of a cellular phone.**

**This ratio applies irrespective of whether the device is an ultra low tier, low tier, mid tier or high tier handset.**

The **RF functionality** in the phone **directly dictates the revenues that vendors and operators can realise from the device**. These revenues in turn are **dependent on the overall RF performance of the device.**

This **performance can be seriously compromised in handsets supporting non standard band spectral allocations** unless manufacturers invest substantial engineering resources. Compromised RF performance increases cost and reduces revenue.

Overall, **non standard band allocations introduce incremental costs that in the case of specific spectral allocations in small developing countries can exceed 1000 dollars per phone.**

**These costs invalidate otherwise plausible spectral and network investment business models**. For this reason, regulators in such countries should be exceptionally careful in allocating non standard spectrum.

For a full report on the research undertaken for this White Paper download the supporting **Study.**

The White Paper and Study are based on a wide range of industry inputs some of which are anonymous for reasons of commercial sensitivity.

Our thanks to RFI Global for providing detailed information on conformance test costs for GSM and UMTS handsets. For additional detail go to Chapter 6 Section 11 in the Study Document or follow the link above to view an RFI Global Presentation on RF conformance testing.

Chapter 5 of the Study provides a detailed analysis of present cellular market dynamics and the related impact on industry costs and margins. Market statistics supplied and analysed by The Mobile World.

RTT Technology Topics reflect areas of research that we are presently working on.

We aim to introduce new terminology and new ideas to clarify present and future technology and business issues and to qualify the practical impact of RF system performance on future business models.

Do pass these Hot Topics on to your colleagues, encourage them to join our Push List and respond with comments.

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RTT, the Shosteck Group and The Mobile World are presently working on a number of research and forecasting projects in the cellular, two way radio, satellite and broadcasting industry.

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