

ANALYSIS OF THE WORLD-WIDE LICENSING AND USAGE OF IMT SPECTRUM



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Executive Summary

Mobile operators around the world are facing the challenge of delivering the capacity to meet the growth in demand for data services. It is well documented that there are three methods by which operators can expand their capacity:

- More spectrally efficient technology can be deployed.
- Offloading traffic from mobile networks to alternatives such as Wi-Fi.
- More infrastructure (cell sites) can be built.
- More spectrum can be used.

Operators will naturally try and adopt the approach which yields the lowest cost solution. Using new, more spectrally efficient technology requires both an investment in new network equipment (on existing cell sites) but requires that an existing service is interrupted or reduced to make way for the new one. WiFi, though increasingly ubiquitous, often does not offer the quality of service that operators would wish to deliver, especially as hotspots become more congested. Simply increasing the amount of infrastructure can become costly, especially where new sites are difficult to obtain, an increasing problem as the public kick-back against the apparent proliferation of cell sites. Deploying more spectrum also usually requires new network equipment on existing cell sites but such equipment is typically the newest technology and thus already spectrally efficient and does not interrupt existing services. Thus, operators will tend to deploy new spectrum in preference to new technology or more infrastructure, and this is the lowest cost approach to meeting the capacity demands.

Given the above, operators are continually pressing for more spectrum to be made available for mobile networks. At present, the ITU identifies over 1000 MHz of spectrum for commercial mobile (IMT) services, and in a recent report, claims that almost 2000 MHz of spectrum will be required for such services by 2020.

This paper examines the extent to which the spectrum that is already identified for IMT services is licensed and in-use.

Our findings are surprising.

- On average, around the world, less than two-thirds of the spectrum that *should* have been made available for IMT services is licensed. Less than half of that which *could* be made available is licensed.
- In every country examined, there was potential scope for making more spectrum (at least 150 MHz and in many cases significantly more) available for IMT services without additional allocations. TDD spectrum is particularly underlicensed.
- Compared to the ITU's forecast for IMT spectrum demand in 2015 (just one year hence) the amount of spectrum licensed today is at best only 50% of that forecast.
- Though it is harder to ascertain, evidence from a number of regulators indicates only 70 to 80% of spectrum licensed to mobile operators today is actually deployed and in use.

Overall it is clear that operators need to work more closely with regulators to get spectrum already identified for IMT services licensed and to put this spectrum in-use before seeking to identify new bands in which to operate.

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1 Introduction

Agenda Item 1.1 of the next World Radiocommunications Conference in 2015 (WRC-15) will require delegates to:

“consider additional spectrum allocations to the mobile service on a primary basis and identification of additional frequency bands for International Mobile Telecommunications (IMT) and related regulatory provisions, to facilitate the development of terrestrial mobile broadband applications, in accordance with Resolution 233 (WRC-12)”

Resolution 233 recognises that:

“many countries have not yet made available spectrum already identified in the Radio Regulations for IMT, for various reasons, including the use of this spectrum by other systems and services”

Whilst there is clearly growth in demand for mobile data services and a need to find solutions to deliver these, spectrum is not the only option. The use of more spectrally efficient mobile technology, offloading traffic, and the deployment of additional network infrastructure (cell sites) provide gains in capacity that could deal with much of the growth in demand. On the other hand, operators often prefer to use new spectrum as it is a lower cost option than replacement or renewal of technology, or rolling out new sites. But before new spectrum is made available, it would be prudent to ensure that all of the existing spectrum identified for IMT spectrum was licensed by regulators for use by mobile operators, and that those mobile operators were using the spectrum to deliver services.

To this end, this paper examines licensing data for over 90 countries to determine whether the spectrum that should and could be used for IMT services has been made available, and further examines the results of a survey of 20 regulators to assess whether the spectrum that has been licensed is actually in use.

2 IMT Spectrum Availability

Before considering the extent of licensing and, it is important to define which bands should or could be used in each ITU region. There are a number of bands which are designated for use for IMT services around the World. The actual bands used differ from region to region and whilst there are norms in each of the ITU's three regions, there is significant divergence from these norms in some countries. In order to assess the extent to which spectrum for IMT is licensed and in use, it is first necessary to identify the set of bands that would be expected to be licensed in each region, to form the baseline against which actual usage is measured.

The ITU has formally identified between 981 and 1181 MHz of spectrum for IMT services, however this spectrum includes guard bands and duplex gaps which are not used by operators themselves but are instead there to provide protection against interference between different services and bands.

There are bands that could generally be recognised as being harmonised in particular regions. For example, in the European Union, there are Directives of the European Commission which mandate the availability of specific bands for IMT services. However, due to the use of bands in one ITU region or area that are essentially bands which are normally used in a different region, it is possible for a country to licence spectrum that exceeds 100% of that which is notionally harmonised for its region. For example, in Nicaragua, a country in ITU Region 2, mobile networks are licensed in the 900 MHz band, which is not a band commonly associated with Region 2. Similarly, in many Asian countries, the 850 and 1900 MHz bands (typically associated with Region 2) are in use alongside the 900 and 1800 MHz bands (typically associated with Region 1). When comparing the amount of spectrum licensed or in use, it is therefore informative to consider how this relates to the harmonised spectrum and how it relates to the total potential IMT spectrum. Licensed spectrum should be near 100% of that which is harmonised and could be higher, up to a limit set by the potential availability of spectrum for IMT in that region..

As such, in setting the baseline for each region, those bands which are both notionally harmonised for that region, in addition to those which can be used in part, or in whole, alongside those harmonised bands have been identified. The tables below show which bands have been assumed to be available in each region.

Band	Notionally Harmonised?	Uplink	Downlink	Available Spectrum	Notes
FDD					
450 MHz		452.5 - 457.5	462.5 - 467.5	10	
700 MHz		703 - 733	758 - 788	60	
800 MHz	Yes	791 - 821	832 - 862	60	
850 MHz		824 - 849	869 - 894	10	Overlaps with 800 and 900 MHz bands
900 MHz	Yes	880 - 925	935 - 960	70	
1800 MHz	Yes	1710 - 1785	1805 - 1880	150	
1900 MHz		1850 - 1910	1930 - 1990	20	Overlaps with 1800 and 2100 MHz bands
2100 MHz	Yes	1920 - 1980	2110 - 2170	120	
2600 MHz	Yes	2500 - 2570	2620 - 2690	140	
Total				640	
TDD					
1400 MHz		1452 - 1492		40	
1900 MHz	Yes	1900 - 1920		20	
2000 MHz	Yes	2010 - 2025		15	
2300 MHz		2300 - 2400		100	
2600 MHz	Yes	2570 - 2620		50	
3400 MHz	Yes	3400 - 3600		200	
Total				425	

Table 2-1: IMT bands available in ITU Region 1 (Europe/Africa/Middle East)

In ITU Region 1 there is a total of 1025 MHz of spectrum that could be used for IMT services, of which 825 MHz is notionally harmonised (that is to say that it is in common usage across the majority of countries). Note that the 3400 MHz band is harmonised up to 3800 MHz in European Union countries however at the ITU level only 3400 – 3600 MHz is identified for IMT.

For the purposes of analysis, countries in the European Union¹ where directives which affect the allocation of spectrum for IMT apply, have been separated from those in the rest of Region 1. This gives finer granularity and provides a more direct like-for-like comparison between countries which have been impacted by the EU directives and those which have not.

¹ And those in the European Economic Area which implement EU Directives

Band	Notionally Harmonised?	Uplink	Downlink	Available Spectrum	Notes
FDD					
450 MHz		452.5 - 457.5	462.5 - 467.5	10	
700 MHz	Yes	703 - 748	758 - 803	90	
850 MHz	Yes	824 - 849	869 - 894	50	
900 MHz		880 - 925	935 - 960	40	Overlaps with 850 MHz band
1700 MHz	Yes	1710 - 1755	2110 - 2155	90	
1800 MHz		1710 - 1785	1805 - 1880	0	Overlaps with 1700 MHz band
1900 MHz	Yes	1850 - 1910	1930 - 1990	120	
2100 MHz		1920 - 1980	2110 - 2170	0	Overlaps with 1700 and 1900 MHz band
2600 MHz	Yes	2500 - 2570	2620 - 2690	140	
Total				540	
TDD					
1400 MHz		1452 - 1492		40	
1900 MHz		1900 - 1920		10	Overlaps with 1900 MHz band
2000 MHz		2010 - 2025		15	
2300 MHz		2300 - 2400		100	
2600 MHz	Yes	2570 - 2620		50	
3400 MHz		3400 - 3600		200	
Total				415	

Table 2-2: IMT bands available in ITU Region 2 (The Americas and Caribbean)

In ITU Region 2, there is a total of 955 MHz of spectrum potentially available for IMT services. Of this, 540 MHz is notionally harmonised. Note that the 3400 MHz band can extend from as low as 3300 MHz to as high as 3700 MHz in some jurisdictions but has been limited to 3400 – 3600 MHz as this is the formal ITU identification.

Band	Notionally Harmonised?	Uplink	Downlink	Available Spectrum	Notes
FDD					
450 MHz		452.5 - 457.5	462.5 - 467.5	10	
700 MHz	Yes	703 - 748	758 - 803	90	
800 MHz		791 - 821	832 - 862	30	Overlaps with 700 and 850 MHz bands
850 MHz		824 - 849	869 - 894	10	Overlaps with 800 and 900 MHz bands
900 MHz	Yes	880 - 925	935 - 960	70	
1800 MHz	Yes	1710 - 1785	1805 - 1880	150	
1900 MHz		1850 - 1910	1930 - 1990	20	Overlaps with 1800 and 2100 MHz bands
2100 MHz	Yes	1920 - 1980	2110 - 2170	120	
2600 MHz	Yes	2500 - 2570	2620 - 2690	140	
Total				640	
TDD					
1400 MHz		1452 - 1492		40	
1900 MHz	Yes	1900 - 1920		20	
2000 MHz	Yes	2010 - 2025		15	
2300 MHz		2300 - 2400		100	
2600 MHz	Yes	2570 - 2620		50	
3400 MHz		3400 - 3600		200	
Total				425	

Table 2-3: IMT bands available in ITU Region 3 (Asia/Pacific)

In ITU Region 3, there is a total of 1025 MHz of spectrum potentially available for IMT services, of which 655 MHz is notionally harmonised. Again the extent of the 3400 MHz band can vary widely but has been left as 3400 – 3600 MHz for compatibility with other regions.

The situation in the 700 – 900 MHz region is complicated in Region 3 because of the common use of the 850 MHz band which clashes with the allocation for the 800 MHz band. In making the assumptions concerning total spectrum availability above, a band-plan such as that illustrated in the figure below has been assumed (note that in order to expand the detail around 800 MHz, the totality of the 900 MHz band is not shown).

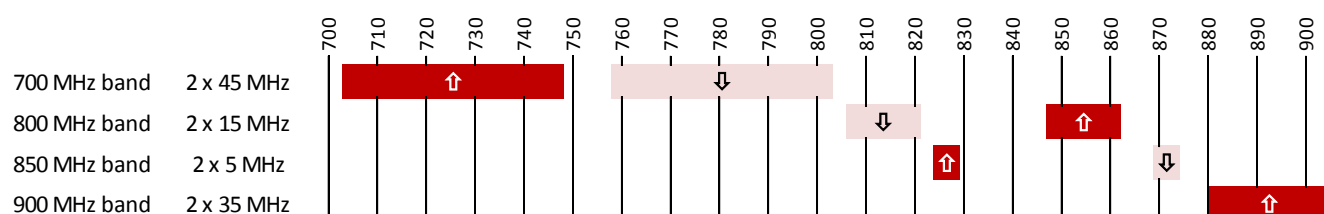


Figure 2-1: One possible arrangement for 700 – 900 MHz area in Region 3

It would be possible to use more of the 850 MHz band, at the expense of a reduction in the amount of 800 MHz (and also the 900 MHz) band that is available, however total spectrum availability would remain largely unchanged.

The table below therefore summarises the amount of spectrum that has been taken to be available in notionally harmonised bands and in totality for each of the ITU regions. In addition, the amount of

spectrum that the ITU forecasts² show as being necessary for IMT service by 2015 (just one year hence) has also been shown.

Region	Area	Notionally Harmonised Spectrum Available	Total IMT Spectrum Potentially Available	ITU Forecast IMT Spectrum Demand in 2015
1	Europe, Africa and the Middle East	825 MHz	1025 MHz	1300 MHz
2	The Americas and Caribbean	540 MHz	955 MHz	1300 MHz
3	Asia/Pacific	655 MHz	1025 MHz	1300 MHz

Table 2-4: IMT spectrum availability in different ITU regions

The figures for the total potential amount of spectrum available are lower than those identified by the ITU for IMT services because the analysis above excludes guard bands and other parts of the spectrum which are identified for IMT by the ITU but are not used for this purpose. As an example, the ITU recognise the range 1710 – 2025 MHz as being for IMT services, however in Region 1 the frequency range 1880 – 1900 MHz is commonly used for wireless DECT cordless phones, and the arrangement of bands in Region 1/3 and Region 2 means that different parts of the spectrum are required as guard bands, or are in use for other services.

² As identified in Report ITU-R M.2078. The same value is identified for both high and low market settings.

3 Overall Analysis of Licence Data

Information concerning the amount of spectrum licensed to IMT operators in different countries around the world has been gathered from a number of public sources, in particular the outcomes of the many spectrum auctions that have taken place. Whilst this data does not provide a full set of information for every country in each region, it does provide a snapshot of the results in a number of countries and allow an assessment of the extent to which available spectrum has been licensed.

It may be worth noting that just because a particular band has not yet been licensed, it does not mean that it is available for IMT services. For instance, the IMT bands which rely on the switch-over from analogue to digital broadcasting (the ‘digital dividend’ bands) may not be available until such time as the switch-over is complete. A country that does not have 100% of the harmonised spectrum available may not therefore represent a case of regulatory sloth in making the assignments, but may be as a result of ongoing re-farming. That said, indicating that the spectrum is not yet licensed for IMT use does continue to imply that it could be made available in the future and thus represents an opportunity for additional spectrum licensing without the need to find new allocations.

The results of these analyses are presented below.

Region	Countries Included	Average IMT Spectrum Licensed	Compared to Harmonised Total	Compared to Potential Availability	Compared to ITU Forecast
European Union	32	628 MHz	76%	61%	48%
Region 1 outside EU	24	348 MHz	42%	34%	25%
Region 2	14	409 MHz	76%	43%	31%
Region 3	22	442 MHz	68%	43%	34%

Table 3-1: IMT spectrum licensed in different regions of the world

Note that these values are likely to marginally under-estimate of the amount of spectrum licensed. This is because there may be new licenses for which no published information is yet available. Nonetheless, we believe that these values are within 5% of the true values as in many cases we are aware that the data for specific countries is fully identified.

These results are illustrated graphically below.

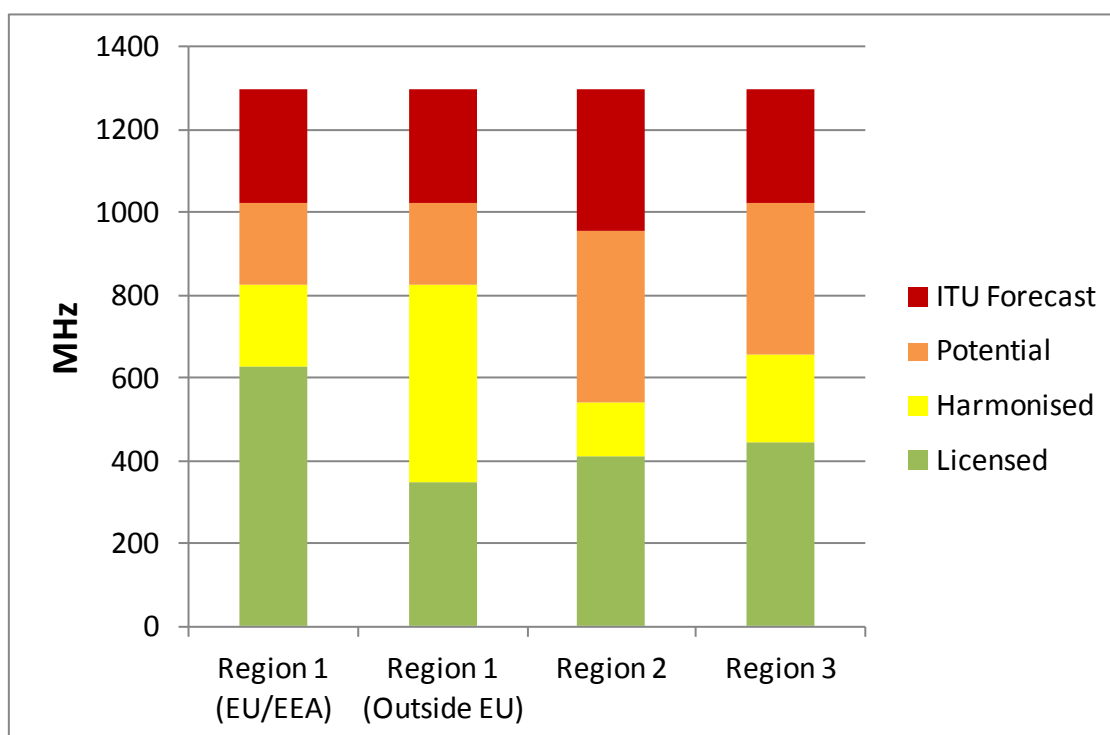


Figure 3-1: IMT spectrum licensed in different regions of the world

The table below shows the lowest and highest values of spectrum licensed in each region.

Region	Lowest Amount of Spectrum Licensed	Compared to Harmonised Total	Highest Amount of Spectrum Licensed	Compared to Harmonised Total	Compared to Potential Availability
Region 1 (EU/EEA)	161 MHz	20%	880 MHz	107%	86%
Region 1 (Outside EU)	124 MHz	15%	647 MHz	78%	63%
Region 2	154 MHz	29%	694 MHz	128%	73%
Region 3	152 MHz	24%	800 MHz	122%	78%

Table 3-2: Lowest and Highest amount of IMT spectrum licensed in different regions of the world

With the exception of countries in Region 1 but outside of the EU, the maximum amount of spectrum licensed exceeds the harmonised value, showing that some countries must have licensed spectrum in bands beyond those which are notionally harmonised. In the case of the countries where the lowest amount of spectrum is licensed, some of these are very small nations (e.g. Turks and Caicos Islands) where there may not be a high demand for spectrum. Nonetheless, there are larger countries amongst those with small levels of licensed spectrum.

Even in countries where high amounts of spectrum are licensed, the total spectrum licensed is still below the maximum which is potentially available, and is far below the ITU's forecasts. In every country analysed, there is typically at least another 150 MHz of potentially available spectrum which could be licensed for IMT use and in many cases significantly more.

4 Country-by-Country Analysis

The following charts show the amount of spectrum licensed for IMT services on a country-by-country basis for those countries analysed. In addition to showing the amount licensed, the amount of spectrum notionally harmonised, the potential availability and the ITU's forecasts are also shown for comparison.

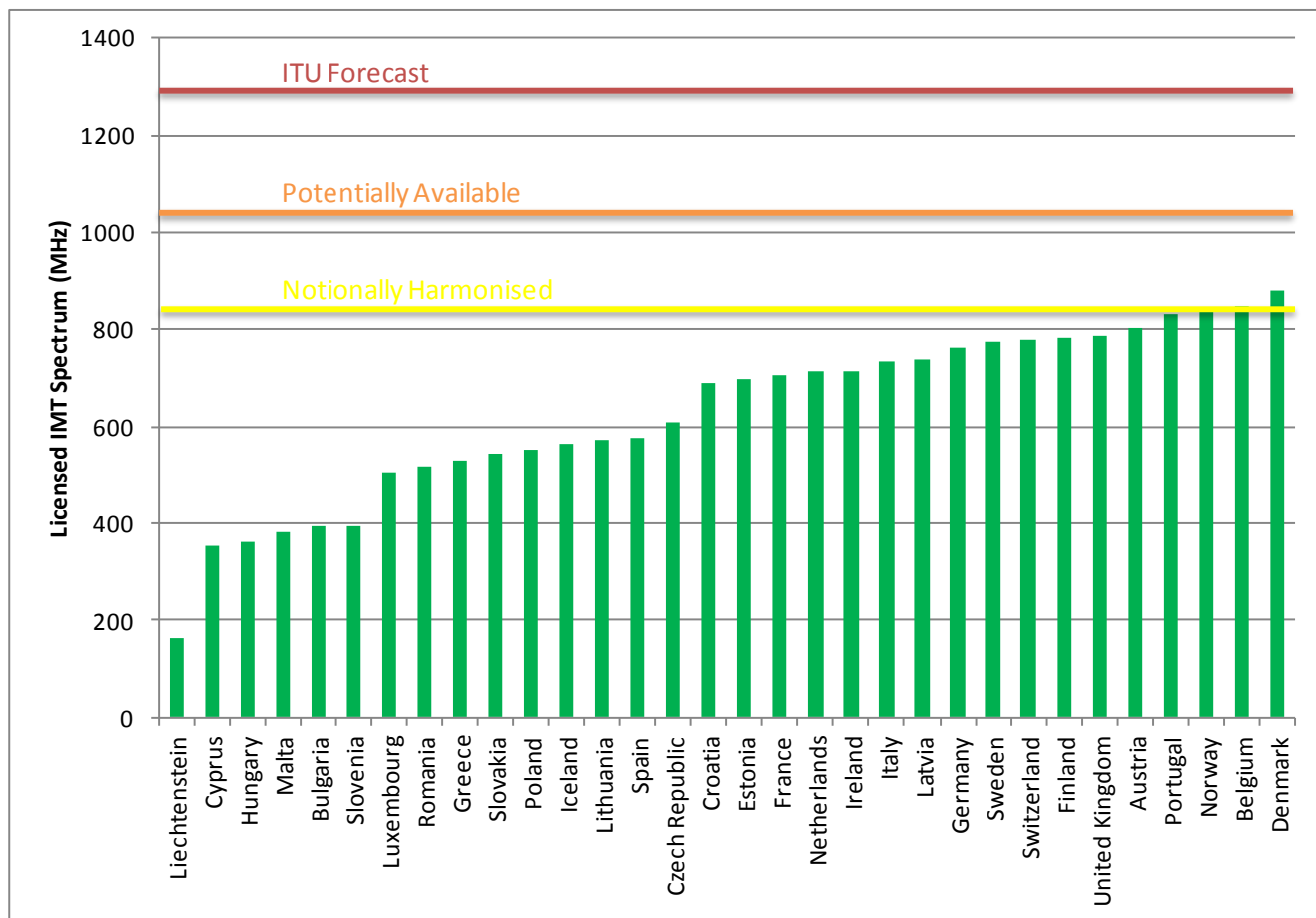


Figure 4-1: IMT spectrum licensed in the European Union (and EEA)

In The European Union, many countries are still in the process of licensing the 800 MHz digital dividend band and the 2600 MHz bands meaning that many still fall below the amount of spectrum notionally harmonised. There is a varying degree of use of the 3500 MHz band which also contributes to some countries indicating low amounts of licensed spectrum compared with others.

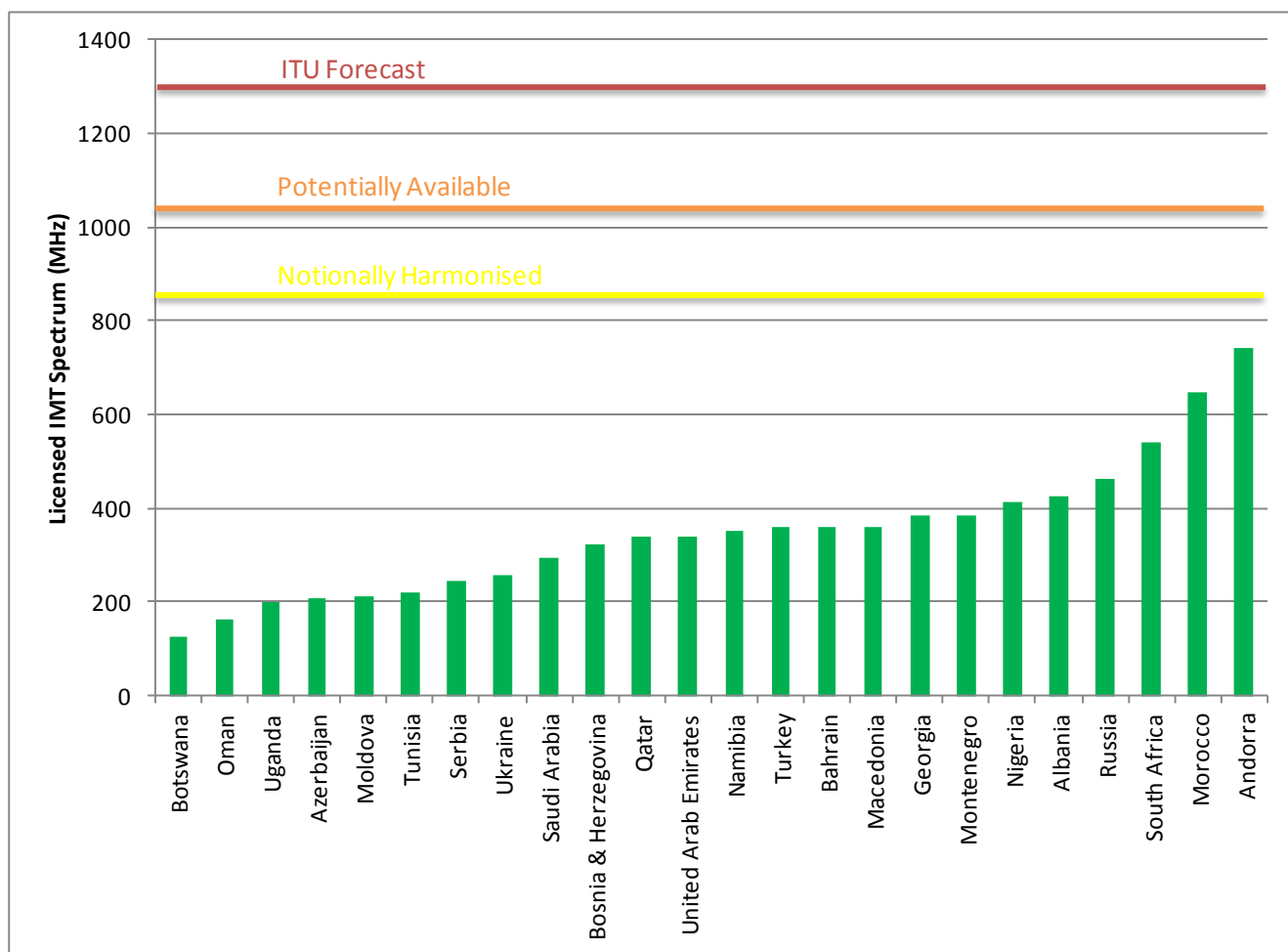


Figure 4-2: IMT spectrum licensed in Region 1 (excluding the EU/EEA)

The situation in Region 1 but outside of the European Union is notably different. Typically the 900, 1800 and 2100 MHz bands may have been licensed (amounting to just 340 MHz of licensed spectrum) but there is little further licensing beyond these bands. Many of these countries are yet to complete the switch to digital broadcasting meaning that the 700 and 800 MHz bands are not available, and similarly many use the 2600 MHz bands for other services such as wireless cable.

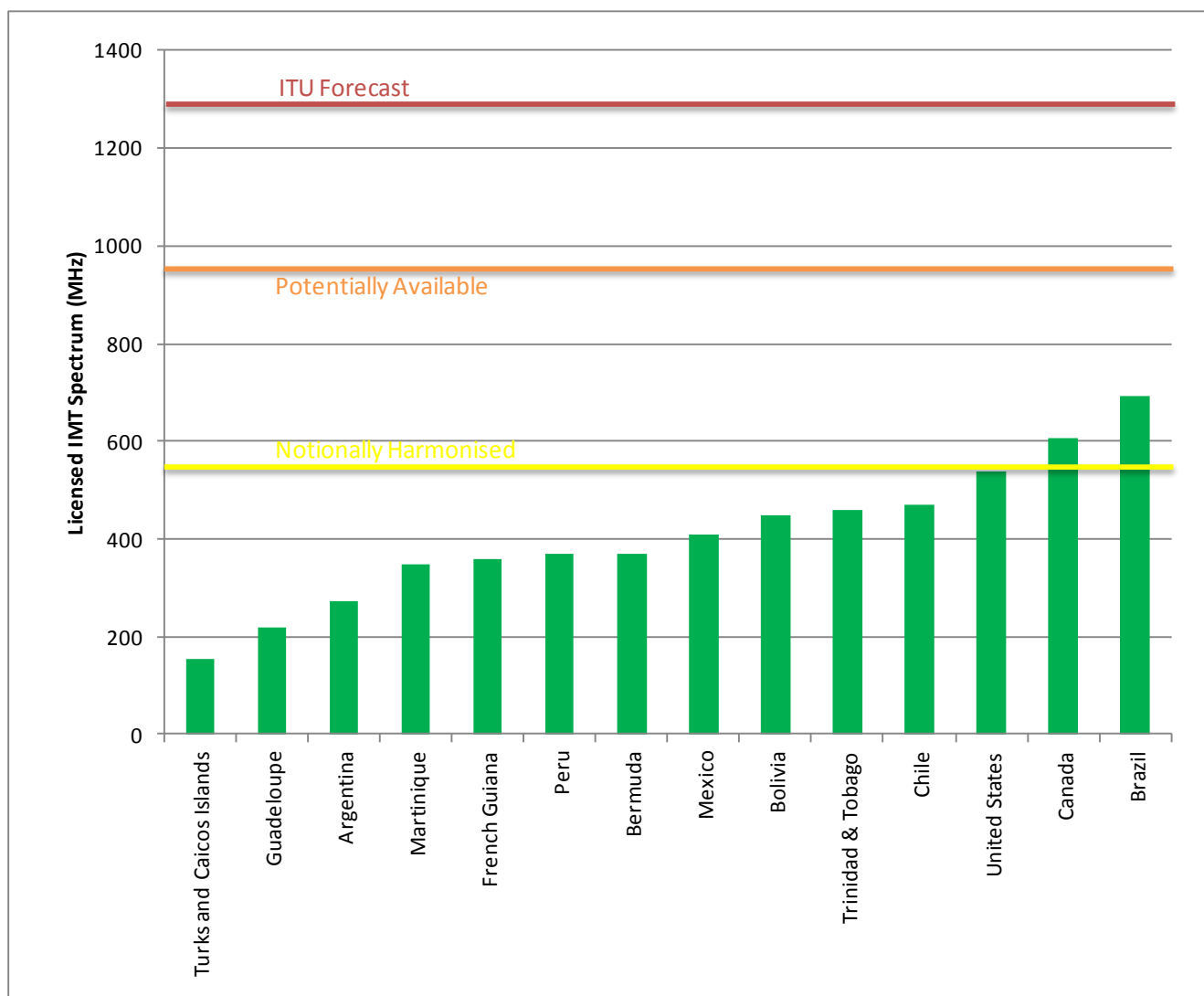


Figure 4-3: IMT spectrum licensed in Region 2

Many Region 2 countries are yet to complete the switch to digital broadcasting and thus do not have the 700 MHz band available. Many are yet to open up the AWS band, and many of the higher frequency bands (such as 2500 and 3500 MHz) are currently used for other services.

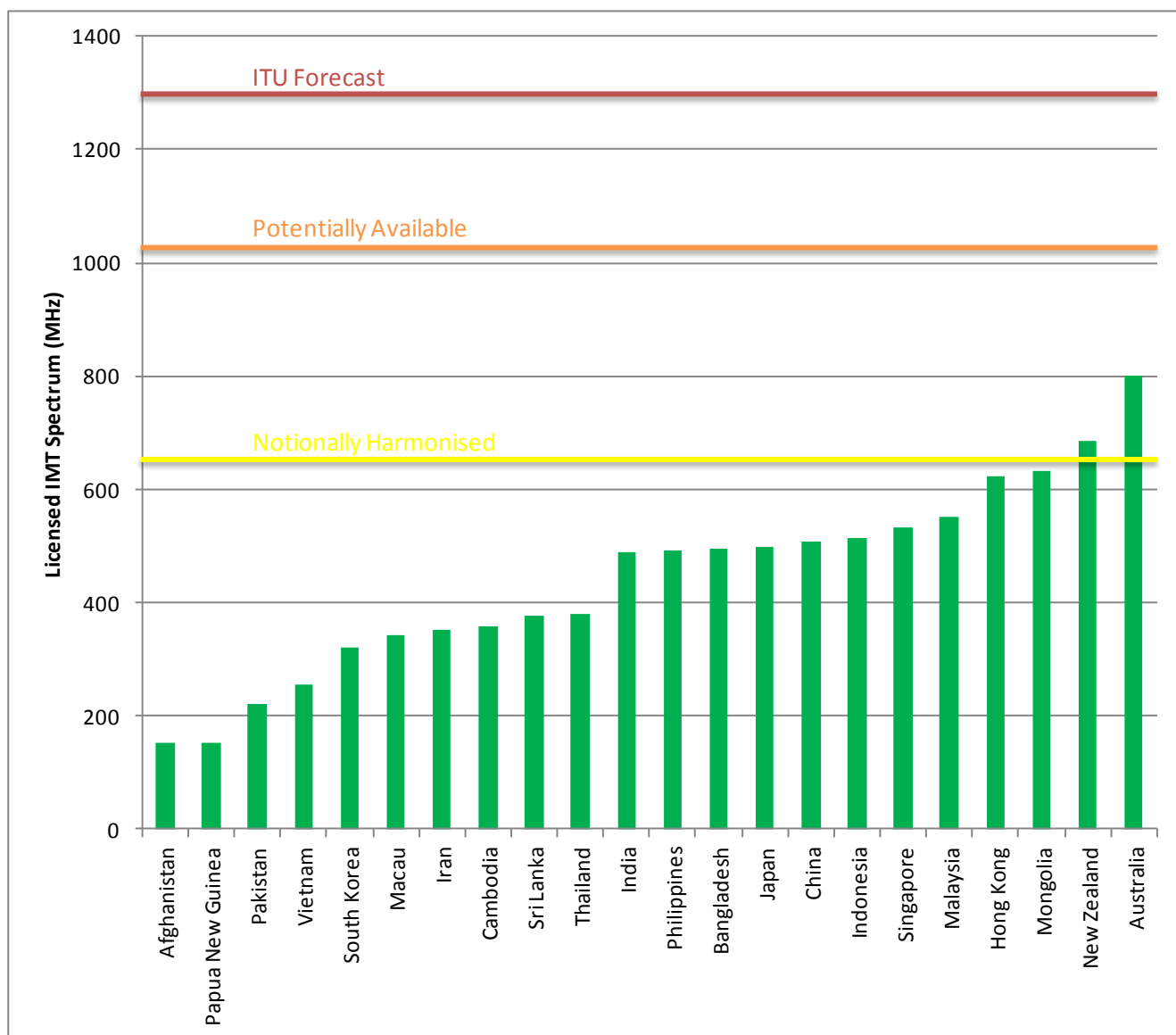


Figure 4-4: IMT spectrum licensed in Region 3

Many Region 3 countries are yet to complete the switch to digital broadcasting, however many already use the 850 MHz band in addition to the 900 MHz band meaning that the 800 MHz band will never become available, and it may require further re-farming of broadcast services to clear the 700 MHz band. Many countries also currently use the higher frequency bands such as 2600 and 3500 MHz for other services.

5 Band-by-Band Analysis

The following charts show the extent to which the potentially licensable frequency division duplex bands are licensed in each of the regions analysed. A value of 100% means that the band is licensed in all of the countries examined. For clarity, TDD spectrum has been shaded a different colour.

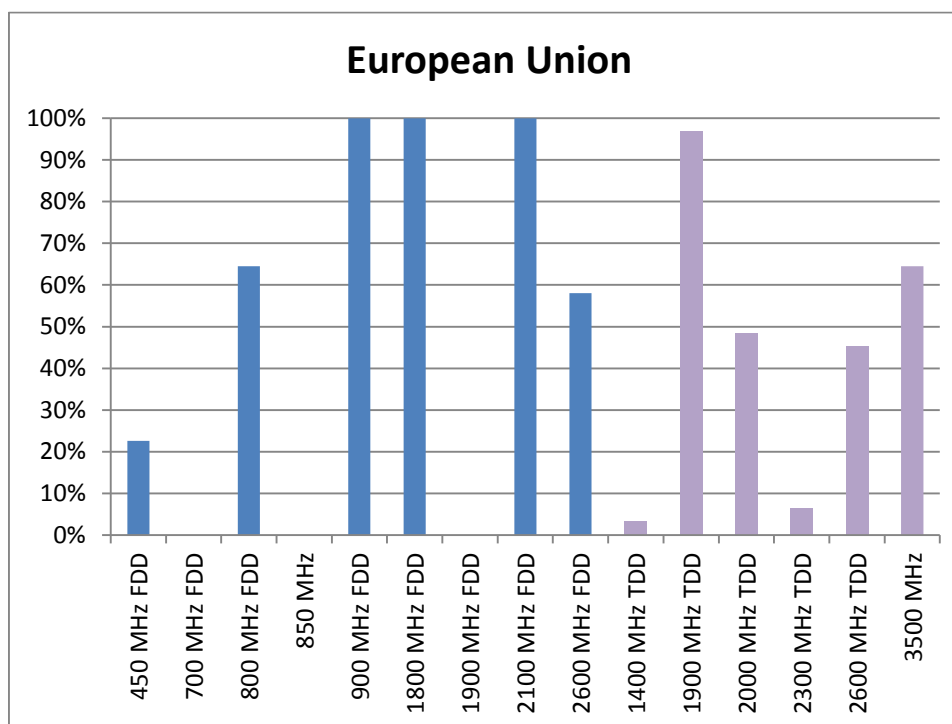


Figure 5-1: Extent of band licensing in European Union (and EEA) countries

It is worth noting that, in this area:

- The 450 MHz band is not available in all countries, as it is often used for PMR instead of IMT services, hence the low value of around 20% probably represents a relatively high proportion of those countries where it is available.
- No country has yet licensed the 700 MHz band. Current expectations are that this is unlikely to become available until at least 2017 in many countries due to the need for additional re-farming of television services.
- Around two-thirds of countries have licensed the 800 MHz band, and there is a continuing programme of auctions in many of the remaining countries. It is expected that this band will be fully licensed within the next 3 years.
- The 900, 1800 and 2100 MHz bands are licensed in all countries.
- No country has licensed the 1900 MHz band (but this would not provide much additional spectrum and may preclude other services).
- Just over 50% of countries have so far licensed the 2.6 GHz FDD band and slightly fewer the 2.6 GHz TDD band. This band is often licensed concurrently with the 800 MHz band and so it is expected that the level of licensing will increase over the next 3 years.
- The 1900 MHz TDD band is licensed in most countries.

- Very few countries have yet been able to licence the 2.3 GHz TDD band.
- Around 50% of countries have licensed the 3.5 GHz band.

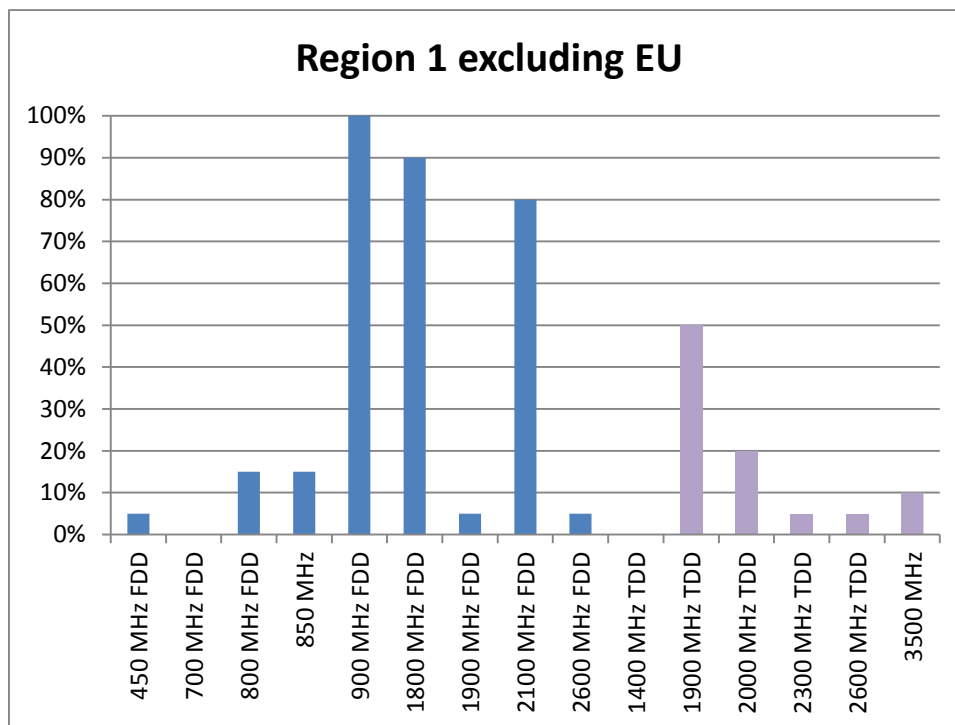


Figure 5-2: Extent of band licensing in Region 1 excluding European Union (and EEA) countries

The only band that is fully licensed in every Region 1 country (both inside and outside the EU) is the 900 MHz band. The 1800 MHz band is almost completely licensed, and the 2.1 GHz band is also 80% licensed. The situation in other bands is much lower in this part of Region 1, with the 800 and 2.6 GHz bands hardly licensed at all. There are a few countries using the 450, 850 and 1900 MHz bands and so far none have licensed the use of the 700 MHz band.

Far fewer countries have licensed TDD spectrum in these countries compared to the rest of Region 1.

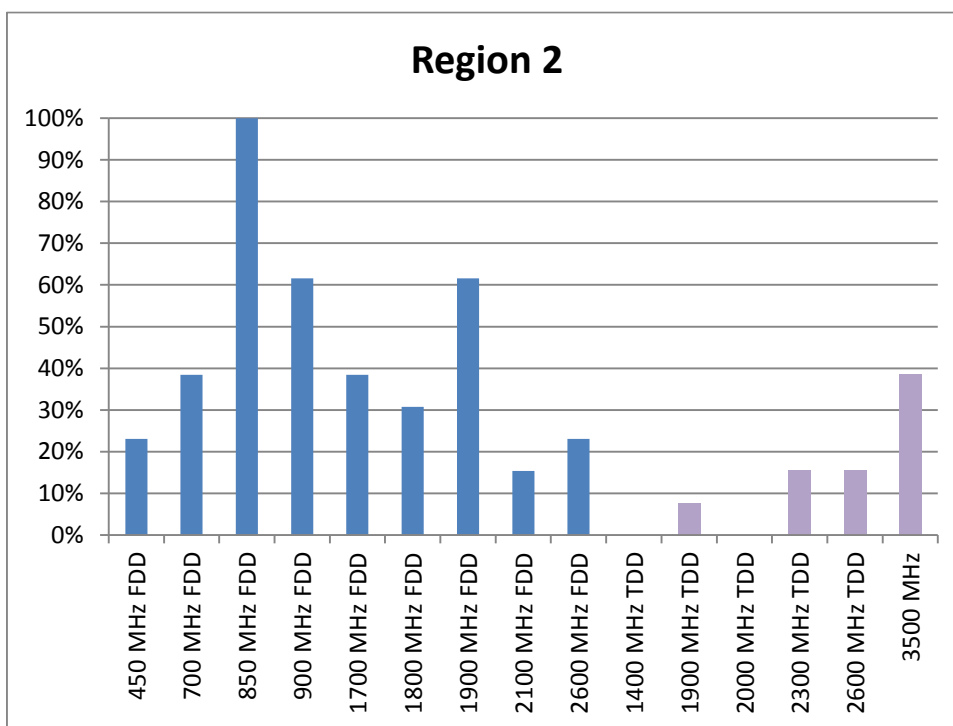


Figure 5-3: Extent of band licensing in Region 2

The only band that is licensed in every country in Region 2 is 850 MHz. The 900 and 1900 MHz bands are licensed in around two-thirds of countries, with the various other bands licensed in around 20% to 40% of countries. Licensing of TDD spectrum is generally very low.

There is clearly still a long way to go in this ITU Region before all of the available bands are exhausted.

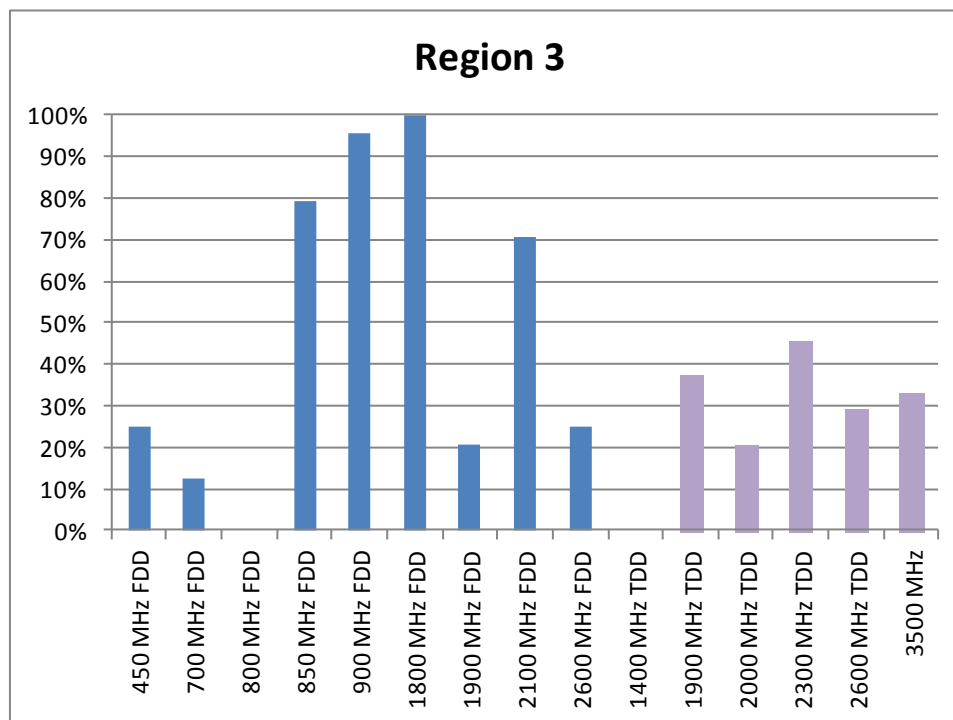


Figure 5-4: Extent of band licensing in Region 3

The Region 3 situation closely reflects that of Region 1 with respect to the 900, 1800 and 2100 MHz bands, in that these are licensed in almost every country. The 850 MHz band is also licensed in many of the countries in this Region which would, together with the widespread future adoption of the 700 MHz APT band, explains why no countries have yet licensed the 800 MHz band.

The 2.3 GHz TDD band is licensed in over 50% of the countries analysed in Region 3, this may be led by China and India who have used the band for TDD services for some time. Other TDD bands show a similarly low level of licensing as in other ITU regions.

6 Use of Licensed Spectrum

A survey was conducted between June and July 2014. Over 90 regulators were invited to participate and 20 responses were received. These came from a representative set of regulators across all ITU regions, from countries ranging from small to large, and from developed to developing. Whilst this represents a relatively small proportion of countries world-wide, it does provide useful and valid information on the use of spectrum. Regulators were asked to identify:

- Which bands are licensed in their country;
- How many licenses have been awarded in each of those bands;
- How many of those licensees have active services in those bands.

These relatively simple questions reveal a significant amount of information on whether licensed spectrum is in use.

The results of the survey are shown in the table below.

Type of IMT Spectrum	Number of licenses awarded	Number of active licenses	Percentage of licenses in-use
FDD	207	180	87%
TDD	85	47	55%
Total	292	227	78%

Table 6-1: Use of licensed FDD and TDD spectrum

Of those FDD licenses not in active use, the majority were for bands which have only recently been licensed (such as the 800 and 2600 MHz bands). Only one FDD band was in use in every country in which it had been licensed, and that was the 850 MHz band. Of the TDD licenses not in use, these varied across all of the TDD bands. None of the licensed TDD bands were in full use in every country.

Of the countries which responded, only 5 (25%) reported that all of the licences on issue were in-use.

7 Conclusions

We have analysed the licensing data of over 90 countries, and the responses by 20 regulators to a survey on the use of licensed IMT spectrum. This data has been compared to the amount of spectrum which should be easily licensed, as it is notionally harmonised, and that which could be licensed if all of the spectrum identified for IMT was put to use. We have also compared this with the amount of spectrum which the ITU forecasts would be required for IMT services by 2015 (next year).

Our findings are:

- Most regions of the world have licensed around 70% of spectrum that should be easily available for IMT services.
- Most countries should be able to find at least another 150 MHz of IMT spectrum from within that which is regionally harmonised.
- Almost every country should be able to find at least a further 200 MHz of spectrum that has been identified for IMT but is not necessarily fully harmonised.
- The 700 MHz still remains to be licensed in many parts of the world.
- With the exception of the European Union, the 2600 MHz bands, which represent nearly 200 MHz of IMT spectrum, remains to be licensed.
- The European Union has by far the greatest amount of spectrum licensed for IMT services, however this is still only around two-thirds of that which is identified for IMT and could potentially be licensed. Despite having the largest amount of spectrum licensed for IMT, it is still less than 50% of that which the ITU predicted would be required by 2015.
- In the rest of the world, the amount of spectrum licensed for IMT services is below 50% of that which could potentially be made available.
- Whilst nearly 80% of licensed spectrum is in use by those operators to which it is licensed, the use of licensed TDD spectrum is only around 50%.

There is therefore clearly a need for regulators to push forward with the licensing of remaining IMT spectrum, and for operators to put all of their licensed spectrum into use before further spectrum is identified for IMT services.