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Communications Regulation

Multi Band Spectrum Award

**DotEcon Report – Benchmarking
Update**

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MBSA2 benchmarking update

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1 Introduction

1.1 Previous publications

In June 2019, ComReg published a report prepared by DotEcon¹ that:

- set out the results of a benchmarking exercise which examined prices at which similar spectrum to the frequencies available in the forthcoming award of spectrum in the 700 MHz, 2.1 GHz, 2.3 GHz and 2.6 GHz bands in Ireland ('MBSA2') had been awarded in other countries; and
- using the benchmarking results as input, provided recommendations to ComReg on suitable minimum prices for the lots to be made available in the MBSA2.

The initial benchmarking and recommendations on minimum prices were based on the assumption that new licences would be awarded with a 15-year term (split across two time slices for the spectrum above 1 GHz) and, for the purpose of discounting, a nominal WACC estimate for mobile network operators of 8.63% per annum was applied.

Following a public consultation on the initial proposals and comments from stakeholders, ComReg decided to increase the licence duration to 20 years (again split across two time slices for the higher frequencies²). The draft Information Memorandum (the 'Draft IM')³ for the award, published in May 2020, included updated minimum prices which were based on the initial recommendations but adjusted to account for the longer licence term. No other changes were made to the minimum prices other than to reflect this change in licence duration.

¹ ComReg document 19/59b

² Rights of use for the 2.1 GHz, 2.3 GHz and 2.6 GHz bands will be awarded for two consecutive time periods ('time slices'). For the 2.3 GHz and 2.6 GHz bands, the total duration of the two time slices will be 20 years. New 2.1 GHz licences will begin later (due to the need for existing rights of use licensed to the three MNOs to expire first) but will have a common expiry date with all other licences awarded, so the total duration of 2.1 GHz licences will be less than 20 years. The 700 MHz spectrum will be awarded for just a single time slice spanning the full 20-year term (i.e. the same period as time slices 1 and 2 together). Further details on the time slices and licence terms can be found in ComReg documents 19/59R, 19/59a, 19/124, 19/124a, 20/122 and 20/122a.

³ ComReg document 20/32

Subsequently, in October 2020, ComReg adopted a new nominal WACC estimate for mobile network operators of 5.85% per annum.⁴ Indicative minimum prices were then provided in ComReg documents 20/122 (ComReg's 'Decision') and 20/122a (DotEcon's associated report), taking into account this new lower WACC when adjusting the original minimum prices for the longer 20-year licence term and determining the annual Spectrum Usage Fees (SUFs).

These minimum prices comprise a reserve price (i.e. the starting value for the round price in the auction and the lowest possible level of the Spectrum Access Fee (SAFs) payable by winners) and annual SUFs. Table 1 below reproduces these as set out in the Decision.

Table 1: Minimum prices set out in ComReg document 20/122

Band	Time slice	Lot size	Reserve price per lot (€)	Annual SUF per lot (€)
700 MHz	NA	2x5 MHz	9,158,000	998,931
2.1 GHz	1	2x5 MHz	1,327,000	525,753
2.1 GHz	2	2x5 MHz	2,849,000	525,753
2.3 GHz (2300 - 2390 MHz)	1	5 MHz	197,000	52,575
2.3 GHz (2300 - 2390 MHz)	2	5 MHz	285,000	52,575
2.3 GHz (2390 - 2400 MHz)	1	10 MHz	197,000	52,575
2.3 GHz (2390 - 2400 MHz)	2	10 MHz	285,000	52,575
2.6 GHz FDD	1	2x5 MHz	394,000	105,151
2.6 GHz FDD	2	2x5 MHz	570,000	105,151
2.6 GHz TDD	1	5 MHz	197,000	52,575
2.6 GHz TDD	2	5 MHz	285,000	52,575
2.6 GHz TDD Guard Bands	1	5 MHz	25,000	5,000
2.6 GHz TDD Guard Bands	2	5 MHz	35,000	5,000

⁴ <https://www.comreg.ie/publication/the-cost-of-capital-for-the-irish-communications-sector-final-report>

The minimum prices in the Decision also reflected ComReg's decision to reduce the minimum prices for the fixed frequency lots in the 2.3 GHz band and the 2.6 GHz TDD band. Previously in the Draft IM these had been set equal to the minimum prices for frequency-generic lots in their respective bands. However, given uncertainty over the value of the fixed frequency lots in light of the power restrictions that will apply to the use of those frequencies, ComReg considered it prudent to set the minimum prices at a significantly lower level.

1.2 Updated data and assumptions

The initial minimum price recommendations, and subsequent updates in the Draft IM and ComReg's Decision, are all based on the original benchmarking data and estimates of price/MHz/pop derived from this data. Since then, further awards for spectrum similar to the bands included in the MBSA2 have taken place in other countries. There has also been updates to the economic indicators data (Consumer Price Index (CPI), purchasing power parity (PPP) and population) used to standardise the benchmark data.

It is also the case that previously published minimum prices assumed a (provisional) start date of 12 December 2020 for all licences other than for the 2.1 GHz band. Clearly that is no longer applicable, and the final minimum prices need to be based on the licence terms provided in the final IM.

The purpose of this report is to set out our final recommendations to ComReg on minimum prices (including the breakdown of minimum prices between the SAFs and SUFs) based on the most up-to-date information.

We first set out an update to the benchmarking exercise by including relevant awards completed after the initial benchmarking and improvements to the data stored for pre-existing awards. This update also takes into account the longer licence durations, the new Irish mobile WACC and up-to-date economic indicators.

We then provide updated recommendations on the final minimum prices (including the breakdown into SAFs and SUFs), based on the updated benchmarking and the final licence durations to be set out in the final IM.

We have clearly stated in our previous benchmarking reports that estimates of spectrum prices are subject to uncertainty and that there is significant variation in prices across awards, even once standardised for known differences. For this reason, particular weight has been given in the benchmarking exercise to the geometric mean of the observed prices, as this is intrinsically conservative, giving less weight to higher prices. Given this

uncertainty, we must expect some movement in the new benchmark figures relative to those produced in 2019.

Given that there has already been significant consultation on the minimum prices, and with stakeholders' expectations on likely reserve prices for the award having already been informed by the Draft IM and the Decision, there is merit in keeping the minimum prices close to those most recently set out in ComReg's Decision document wherever possible. Therefore, whilst we update our analysis using the most recently available data, there would need to be sufficient evidence to warrant modifying the minimum prices at this point in the overall award process.

1.3 Summary

We set out our findings and recommendations below. In summary, the revised benchmarking does not suggest a sufficiently large change in the estimated market price of spectrum in any of the bands to justify any amendments to the level of the minimum prices (for 20-year licences) relative to those most recently proposed by ComReg in its Decision. However, some minor adjustments in minimum prices will be needed to account for the revised licence durations and the corresponding need for a redistribution of the minimum prices for full 20-year licences between the time slice 1 and time slice 2 lots.

2 Benchmarking

In this Section we set out the updates to the benchmarking exercise.

For the avoidance of doubt, we have not made any changes to the benchmarking methodology, details of which can be found in ComReg document 19/59b. The adjustments required for this update relate only to the award data included in the analysis, updated economic indicators, the licence durations, and the new mobile WACC in Ireland.

In particular, this updated benchmarking exercise:

- includes relevant awards that were completed after the initial benchmarking and that provide additional information about the likely current market value of the spectrum;
- includes adjustments to the information stored in DotEcon's spectrum awards database where additional (previously unknown) data has been added for pre-existing awards and improvements to the way in which awards are identified as competitive – this has allowed us to include more data points as competitive awards⁵ (as some awards that were previously not identified as competitive due to insufficient information are now considered competitive), which in turn helps to reduce uncertainty around the benchmarking output;
- uses a revised nominal WACC of 5.85% per annum for calculating the net present value (NPV) of deferred licence fees and when adjusting prices to standardise the licence duration;
- normalises licences to have a common duration of 20 years (rather than 15 years, as before), again to put prices in comparable terms and in line with the proposed duration of licences available in the MBSA2⁶; and
- uses up-to-date economic indicators data, in particular the CPI, PPP and population data, to put observations in 2021 terms rather than in 2019 terms as before.

Details of the awards included in the benchmarking for each band considered can be found in Annex A.

⁵ Competitive awards are defined as awards which use an auction mechanism and in which the price of at least one licence exceeds its reserve price.

⁶ The 2.1 GHz licences will not be available for the full 20 years given the expiry dates of existing rights of use. This will be accounted for after obtaining a price point for 20-year licences, which would be adjusted accordingly based on the actual licence duration.

2.1 Samples

As with the initial benchmarking, even with the addition of new awards, the number of 700 MHz and 2.3 GHz awards is relatively small. For each of these bands, we take the same approach used in our previous benchmarking reports of producing averages for the bands individually, before pooling with data for similar frequencies to provide a larger sample size. In particular, for the 700 MHz band we also consider awards for 800 MHz and 900 MHz spectrum, and for the 2.3 GHz band we look at a larger sample that also includes observations for the 2.6 GHz band.

For each sample, outliers are identified as observations for which the adjusted average price per MHz per capita:

- lies more than three standard deviations away from the sample arithmetic mean; and/or
- lies beyond the outer fence (the outer fence is defined as three times the interquartile range from the first and third quartiles respectively) from the median.

Outliers are then removed before producing the summary statistics for the sample.

For each of the samples considered for each band, as before we also calculate summary statistics for the following nested sub-samples:

- **all awards** – uses all of the suitable data available in our database corresponding to the relevant band(s);
- **competitive auctions** – a subsample which includes only observations from awards which use an auction mechanism and in which the price of at least one licence exceeds its reserve price;
- **competitive auctions in the last 10 years** – a sub-sample that includes only competitive auctions (as above) completed in 2010 or later; and
- **competitive auctions in the last 10 years in Europe** – a subsample that includes only competitive auctions within the last 10 years (as above) in European countries – note that because of the shift in the period covered by ‘the last 10 years’ since the original benchmarking, some awards that were included in this subsample previously will no longer meet the criteria as they are now too old.

In the analysis below, for each band (or combination of bands) under consideration, we provide charts plotting the available observations (for both the adjusted price per MHz per capita for these awards and its logarithm) over time. These charts use the following legend:

- competitive auctions are marked as a dot;
- awards which are not competitive auctions are marked with a cross (x);

- where the chart plots awards for multiple different bands, the markers are colour-coded according to the applicable band;
- outliers (according to the definition above) are circled in red;
- European awards are circled in purple.

2.2 Current indicative minimum prices

The main reason for conducting this update to the benchmarking is to determine whether there is any reason to doubt that minimum prices set out in the Decision would not serve their function of being high enough to discourage any potential speculative bidding behaviour and tacit collusion, yet low enough to avoid choking off efficient demand.

The Decision set out minimum SAFs (reserve prices) and SUFs in Table 1 above. To put these figures into comparable terms with the new benchmarking output, we calculate the corresponding price/MHz/pop for 20-year licences⁷ for a 5 MHz or 2x5 MHz block in each band based on:

- the sum of the relevant SAF and discounted stream of SUFs (to give a total minimum price); and
- the most recent 2021 population data provided by the Central Statistics Office⁸.

Table 2: Current minimum prices in the Decision expressed as €/MHz/Pop

Band	Lot size	€/MHz/Pop
700 MHz	2x5 MHz	0.460
2.1 GHz	2x5 MHz	0.242
2.3 GHz	5 MHz	0.048
2.6 GHz FDD	2x5 MHz	0.048
2.6 GHz TDD	5 MHz	0.048

⁷ For this comparison we ignore the split of the overall licence term across time slices and the shorter total duration of 2.1 GHz licences as the benchmarking output is in terms of 20-year licences. The relevant adjustments for the time slice split, shorter 2.1 GHz licences, and the lower prices required for power restricted fixed frequency lots are carried out when generating the recommended SAFs and SUFs.

⁸

<https://www.cso.ie/en/releasesandpublications/er/pme/populationandmigrationestimatesapril2020/>

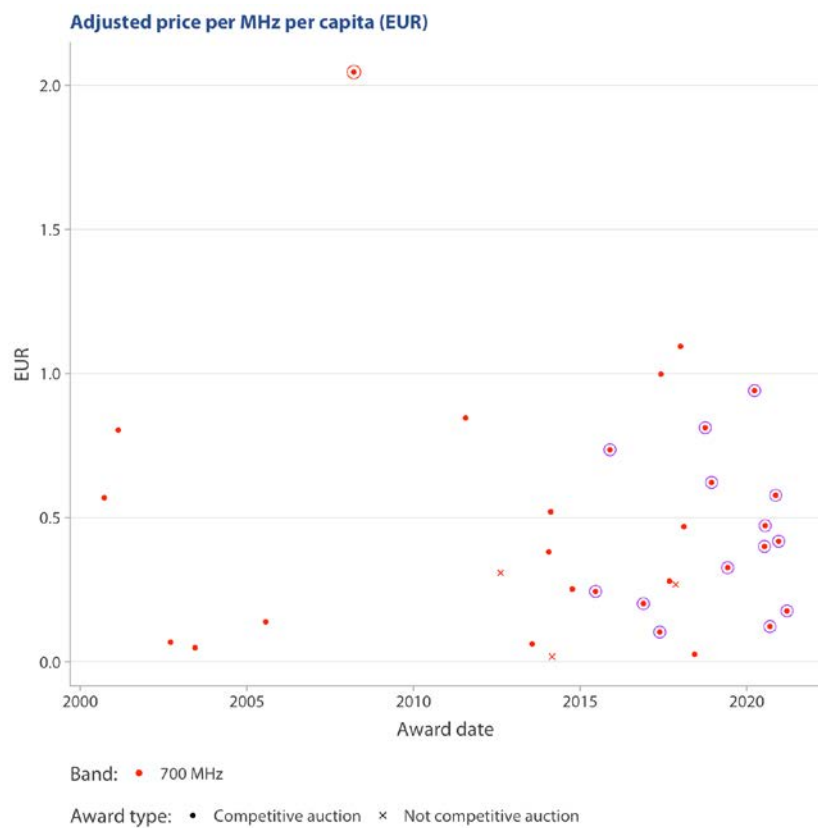
Below, we refer to the figures in Table 2 as the 'current minimum prices'.

2.3 The 700 MHz band

For the 700 MHz band, we have identified eight awards that have been completed since the previous benchmarking exercise, and these are included in the updated analysis.

Figure 1 plots the observations available at the time of this update (both the adjusted price per MHz per capita for these awards and its log) over time. There is only one outlier identified (the US).

Figure 1: Observations from 700 MHz licences



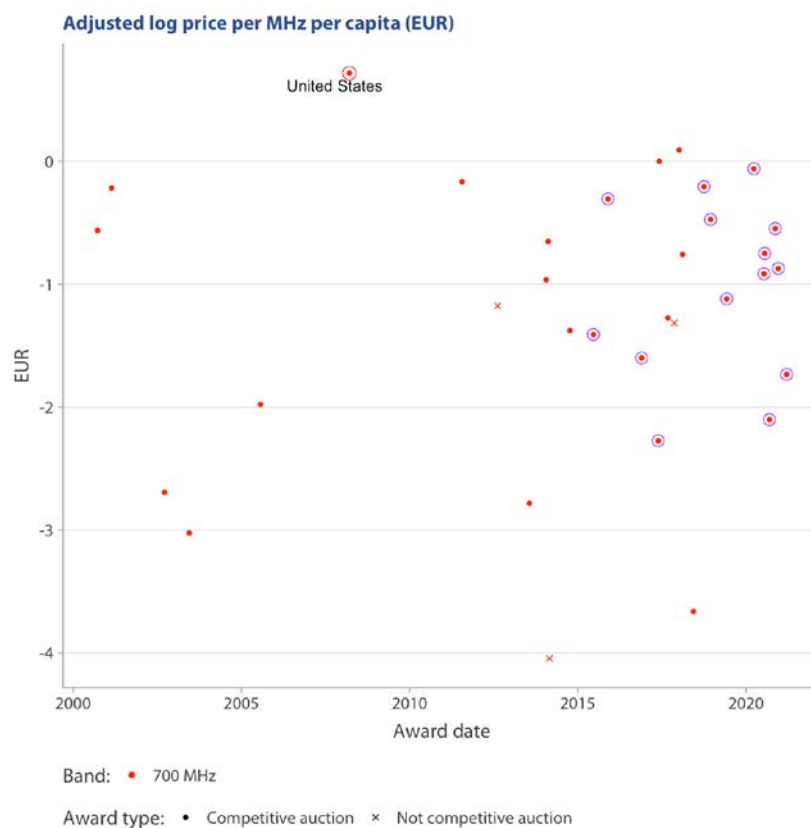


Table 3 reports summary statistics of the adjusted price (Euro per MHz per capita) for the full sample and each of the subsamples considered.

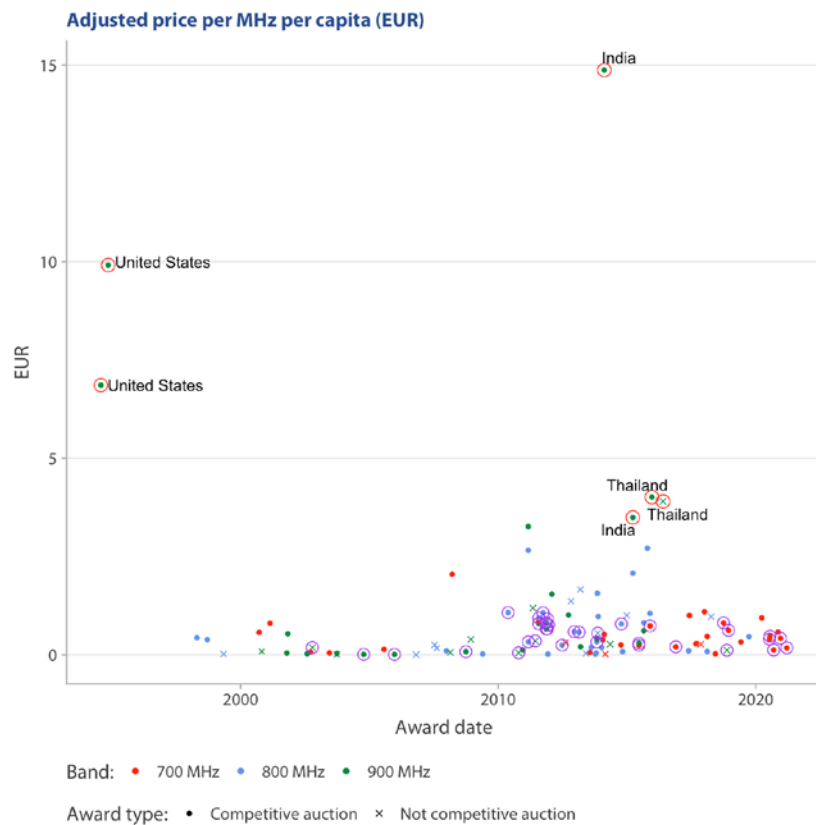
Table 3: Summary statistics for 700 MHz observations (excluding outliers)

Sub-sample	Num. obs.	Arithmetic mean	Std. dev.	Geometric mean	First quartile	Median	Third quartile
All	32	0.416	0.309	0.278	0.167	0.354	0.589
Competitive	29	0.438	0.313	0.305	0.176	0.400	0.622
Competitive last 10 years	24	0.462	0.310	0.339	0.233	0.409	0.650
Competitive last 10 years European	14	0.439	0.267	0.358	0.212	0.409	0.611

When pooling the 700 MHz, 800 MHz and 900 MHz bands⁹, the overall sample size is increased to 110, with six outliers identified.

Figure 2 plots the 700 MHz, 800 MHz and 900 MHz observations (both the adjusted price per MHz per capita for these awards and its log) over time. The specific band to which an observation belongs is represented by the colour of the corresponding marker (red for 700 MHz, blue for 800 MHz and green for 900 MHz).

Figure 2: Observations from 700 MHz, 800 MHz and 900 MHz licences



⁹ To verify the appropriateness of pooling the three sets of observations, we have run Wilcoxon rank sum tests to check for structural differences between the 700 MHz and 800 MHz observations, and separately between the 700 MHz and 900 MHz observations. The probability that our 700 MHz observations have been drawn from the same distribution as our 800 MHz and 900 MHz observations is 0.4 and 0.7 respectively, allowing us to reject the hypothesis that the observations belong to different distributions even at the 10% significance level.

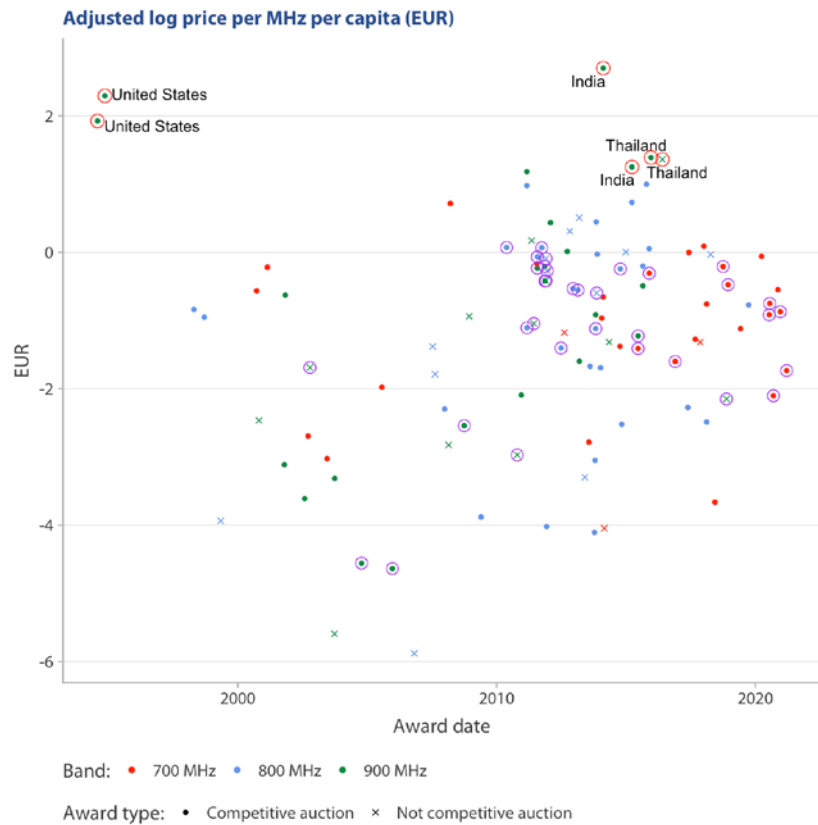


Table 4: Summary statistics for 700 MHz, 800 MHz and 900 MHz observations (excluding outliers)

Sub-sample	Num. obs.	Arithmetic mean	Std. dev.	Geometric mean	First quartile	Median	Third quartile
All	104	0.555	0.609	0.264	0.103	0.384	0.812
Competitive	78	0.590	0.647	0.299	0.122	0.409	0.813
Competitive last 10 years	61	0.667	0.664	0.399	0.202	0.472	0.929
Competitive last 10 years European	39	0.628	0.522	0.429	0.245	0.574	0.874

As before, both the geometric mean and the arithmetic mean are greater when using the pooled data than when looking at 700 MHz observations independently. However, the distribution of observations in the charts does not suggest that prices for the 800 MHz and 900 MHz licences are systematically higher (reinforced by the results of the non-parametric tests), and the new 700 MHz data points appear to be in line with data from previous awards.

Focussing on the subsample with competitive auctions in the last 10 years in Europe, we observe that the geometric mean is close to the current minimum price for the band of €0.46, so the current minimum price is reasonably aligned with the typical market price (as conservatively measured by the geometric mean). This is consistent with our initial recommendations, where the proposed minimum price was set to be very close to the geometric mean for the subsample containing competitive European awards in the previous 10 years. Furthermore, the arithmetic mean of €0.63 suggests that the expected price of 700 MHz lots in a competitive European award is substantially higher than the current minimum price.

Given that the geometric mean is expected to provide a conservative estimate of the market price, and that the arithmetic mean suggests a higher price could be expected, the current minimum price for the 700 MHz lots is set at a reasonable level. There is no compelling evidence from the updated benchmarking to suggest that the current minimum price is set either too high or too low.

2.4 The 2.1 GHz band

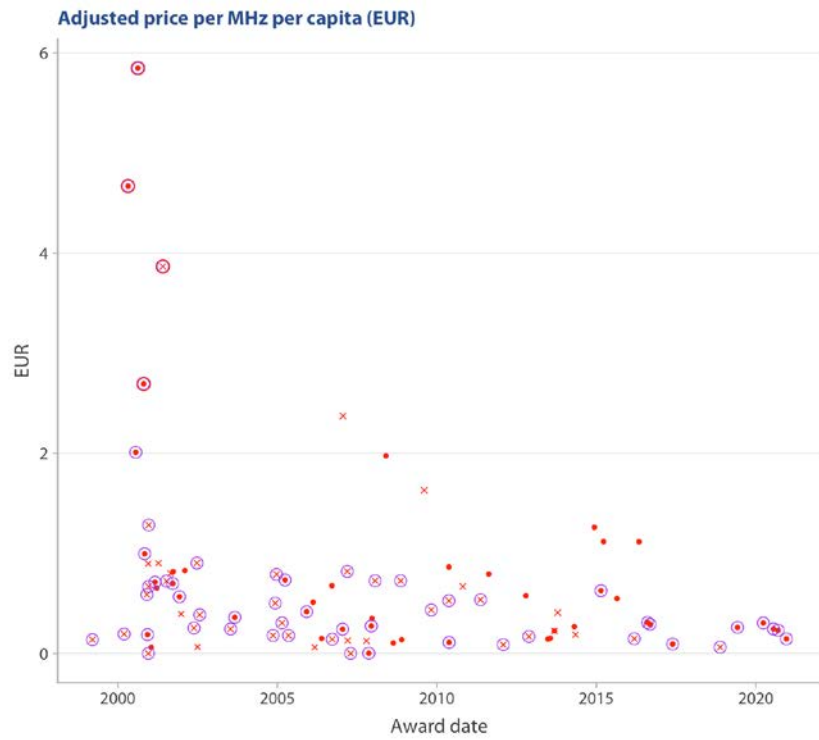
For the 2.1 GHz band, we have a total of 90 observations, including six from awards completed after the initial benchmarking, and two that have been identified following adjustments to the information stored in the spectrum awards database¹⁰. Four of the observations are identified as outliers.¹¹

The observations are plotted in Figure 3, using the same legend as in earlier figures.

¹⁰ The 2016 award of 1800 and 2100 MHz spectrum in Slovenia, and an award of 2100 MHz and 2.6 GHz spectrum in Albania, also completed in 2016.

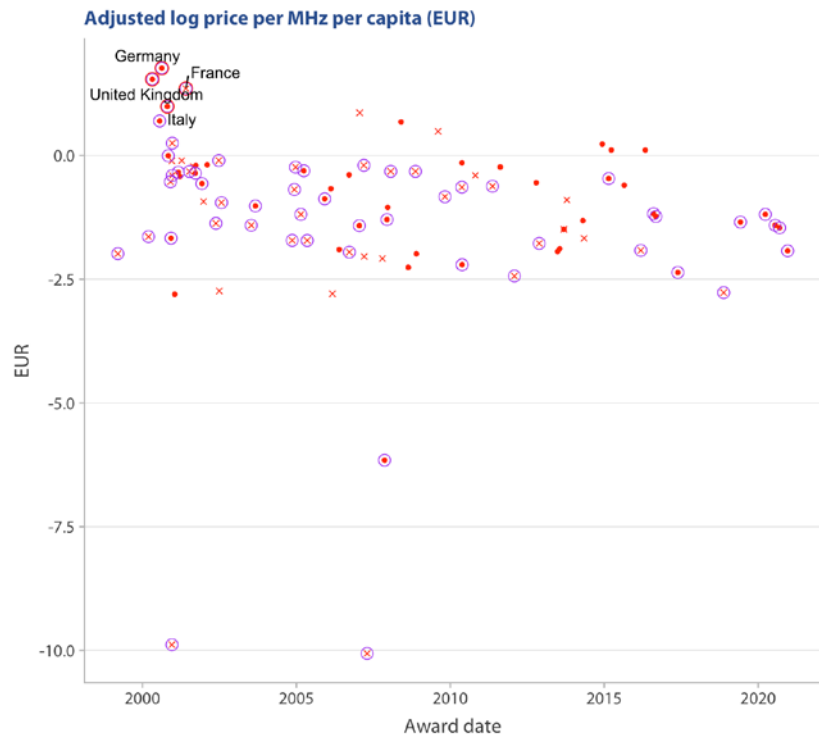
¹¹ These outliers are related to some of the early 3G spectrum awards (in the UK, Germany, France and Italy)

Figure 3: Observations from 2.1 GHz licences



Band: • 2.1 GHz

Award type: • Competitive auction × Not competitive auction



Band: • 2.1 GHz

Award type: • Competitive auction × Not competitive auction

Table 5: Summary statistics for 2.1 GHz observations (excluding outliers)

Sub-sample	Num. obs.	Arithmetic mean	Std. dev.	Geometric mean	First quartile	Median	Third quartile
All	86	0.509	0.460	0.282	0.172	0.373	0.726
Competitive	44	0.526	0.455	0.344	0.216	0.356	0.718
Competitive last 10 years	21	0.461	0.366	0.343	0.225	0.292	0.628
Competitive last 10 years European	10	0.262	0.151	0.228	0.167	0.253	0.301

Looking first at the subsample including competitive auctions in Europe within the last 10 years, the current minimum price of €0.24 lies between the geometric mean and the arithmetic mean. This is in line with the approach taken following the original benchmarking. Moreover, although we have a number of new 2.1 GHz observations, the number of competitive European awards in the last 10 years is still relatively low, and there is merit in looking at the wider picture. When expanding the subsample, both the geometric mean and the arithmetic mean increase significantly. Even just looking at competitive auctions in the last 10 years without restricting to Europe, the geometric mean is €0.34 and the arithmetic mean is €0.46, both of which are significantly higher than the current minimum price, and these figures are higher still for the subsample of all competitive awards.

In summary, there is no convincing evidence from the updated benchmarking to suggest that the current minimum price is set too high or too low.

2.5 The 2.3 GHz and 2.6 GHz bands

For the 2.3 GHz band, there are fairly few observations. In particular, we have only 15 observations in total, six of which (excluding outliers) were competitive and in the last 10 years, and only two of those were in Europe. This is a small improvement compared to the 2019 sample, where we had a total of 13 awards (5 competitive in the previous 10 years and one of those in Europe). Since then, we have added a newly completed 2.3 GHz award (a Swedish award in completed in January 2021) as well as data for an award completed in Australia in 2017.

Given the small sample size for the 2.3 GHz band alone, as in the previous benchmarking exercise we pool the 2.3 GHz observations

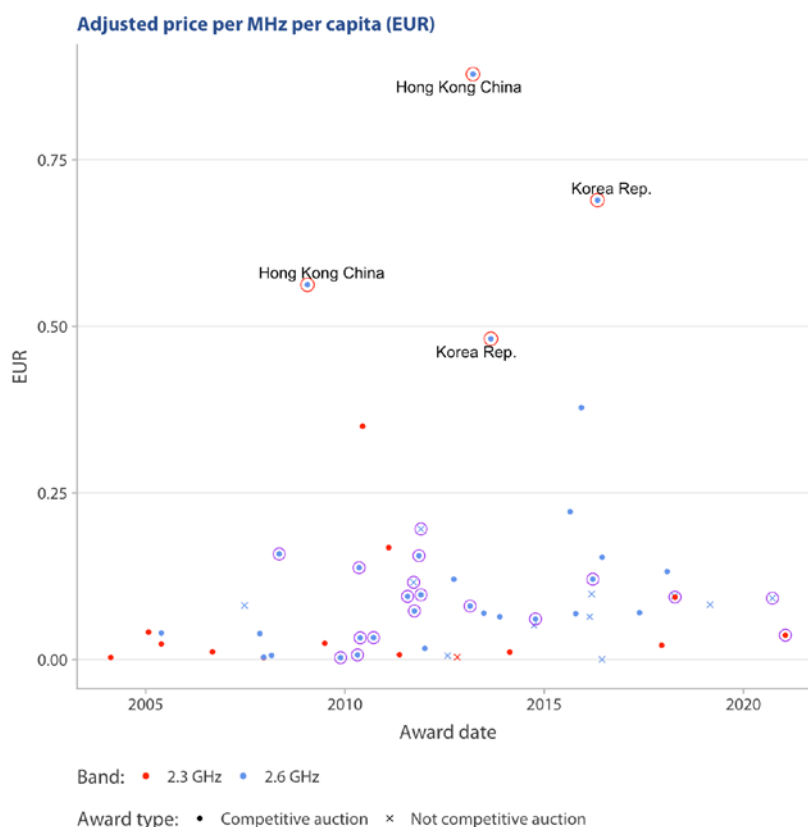
with observations from 2.6 GHz awards to form a single price estimate, on the premise that the two bands have similar characteristics and usage possibilities and can be expected to be substitutable.

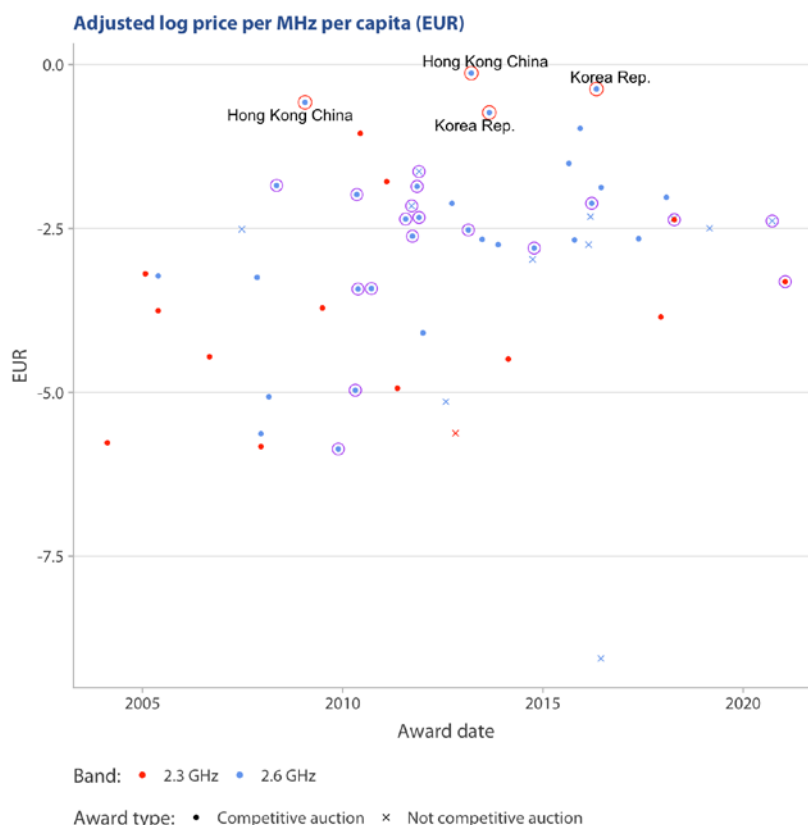
For the 2.6 GHz band, we have 42 observations. This includes three awards not covered in the original benchmarking, in particular awards in Croatia (2019) and Belgium (2020) that had not been completed at the time, and a 2016 award in Albania that was added to the spectrum awards database (although none of these have been identified as competitive).

When pooling the data across the two bands, there is a total of 57 observations, four of which (two in Hong Kong and two in Korea) are identified as outliers within the pooled data set.

The 2.3 GHz and 2.6 GHz observations are plotted in Figure 3, with 2.3 GHz awards shown with red markers and 2.6 GHz awards shown with blue markers.

Figure 4: Observations from 2.3 GHz and 2.6 GHz licences





As with the output from the original 2019 benchmarking, non-parametric tests suggest that we cannot rule out that there are structural differences between the 2.3 GHz and 2.6 GHz observations.¹² However, as discussed in the 2019 benchmarking report, this might be due to the fact that most of the (small number of) 2.3 GHz observations are for licences that would have been awarded before there was a clear expectation that the band might be used for IMT, whilst many of the observations for 2.6 GHz licences are from a time where the band had been clearly designated for IMT (and thus achieved higher prices). On this basis, we conjectured that structural differences between the two samples therefore might not reflect any intrinsic difference across the bands, but rather the higher value of spectrum in these bands once they have been designated and can be used for IMT. We were also of the view that the price of 2.3 GHz is likely to be closer to the price estimate we obtain when using the pooled sample than the price estimate we would obtain when using the small number of available 2.3 GHz band observations (which are older and therefore less relevant).

The updated benchmarking only includes two additional awards for the 2.3 GHz band, which is insufficient to change the fact that overall we still have just a small number of 2.3 GHz observations, most of

¹² We have run Wilcoxon rank sum tests to check the probability that the observations are from the same distribution or not, and the probability that our 2.3 GHz observations have been drawn from the same distribution as our 2.6 GHz observations is 0.007.

which are relatively old. Therefore, our previous concerns about the reliability of using 2.3 GHz data alone remain and we consider that it is more appropriate to pool the 2.3 GHz and 2.6 GHz observations, in particular as these bands are likely to become more substitutable in the long run.

Table 4 reports summary statistics of the adjusted price (Euro per MHz per capita) for this pooled sample.

Table 6: Summary statistics for 2.3 GHz and 2.6 GHz observations (excluding outliers)

Sub-sample	Num. obs.	Arithmetic mean	Std. dev.	Geometric mean	First quartile	Median	Third quartile
All	53	0.078	0.080	0.038	0.017	0.064	0.098
Competitive	41	0.079	0.086	0.040	0.017	0.061	0.120
Competitive last 10 years	29	0.100	0.092	0.063	0.033	0.073	0.132
Competitive last 10 years European	20	0.082	0.045	0.066	0.055	0.077	0.120

The current minimum price for both the 2.3 GHz band and the 2.6 GHz band is €0.048. This is well below the geometric mean and the arithmetic mean for both subsamples containing competitive awards in the last 10 years. This would strongly suggest that the current minimum price for these bands is not too high, and indicates that there may in fact be little risk to increasing it. Whilst there is some headroom to increase this minimum price without creating a risk of lots going inefficiently unsold, equally the benefit in terms of additionally supporting the efficiency of the award process is modest. Given the merit of maintaining the minimum price already set out in the Decision (in the absence of compelling evidence to the contrary), we believe that the current minimum price for the 2.3 GHz and 2.6 GHz fixed frequency lots remains appropriate.

3 Recommendations on minimum prices

3.1 Conclusions from benchmarking

Based on the updated benchmarking detailed above, we have not identified any evidence to suggest that the minimum prices set out in the Decision document are inappropriate and need to be revised (either up or down).

For all bands, the level of the current minimum prices is consistent with our approach when proposing minimum prices in 2019 (in terms of where they lie in relation to both the geometric and arithmetic means for the relevant subsamples).

For the 2.6 GHz band, the benchmarking output suggests that there is even likely to be scope for increasing the minimum prices relative to those proposed. However, as discussed above, we would only suggest making such a change if there were a sufficient reason to do so. In this case the difference between the benchmarks and the current minimum prices is not sufficient to suggest that there would be any problem or risk from not increasing them, and we therefore do not recommend making any changes in that regard.

3.2 Other relevant adjustments

The 2.1 GHz, 2.3 GHz and 2.6 GHz bands are to be awarded in two time slices, where each band/time slice combination is a separate lot category with its own associated minimum price.

The total duration of the time slices for the 2.3 GHz and 2.6 GHz bands is 20 years, and is a little shorter for the 2.1 GHz band where new licences will start later but have an end date common with new licences for all other bands. For each band, the minimum prices for time slice 1 lots and time slice 2 lots are set according to the relative duration and start dates of the time slices for that band.

For the minimum prices previously published, the working assumption was that the first time slice would begin on 1 December 2020. This clearly is no longer feasible, and ComReg has since established revised planned start dates for 700 MHz, 2.3 GHz and 2.6 GHz licences of 14 February 2022. However, since the end date of the first time slice is fixed to be 11 March 2027 (to align with the expiry date of Eir's current 2.1 GHz licence), and the total duration of the time slices is fixed at 20 years, the relative durations of the two time slices will change relative to previous assumptions. This change

needs to be reflected in the relative minimum prices across the two time slices.

Under ComReg's current planned licence terms, for the 2.3 GHz and 2.6 GHz bands:

- time slice 1 will run from 14 February 2022 to 11 March 2027; and
- time slice 2 will run from 12 March 2027 to 13 February 2042.

For the 2.1 GHz band:

- time slice 1 will run from 16 October 2022 to 11 March 2027; and
- time slice 2 will run from 12 March 2027 to 13 February 2042.

New licences for the 700 MHz band will be awarded for a single time period running from 14 February 2022 to 13 February 2042.

A further consideration for the final minimum prices is ComReg's decision to set significantly lower minimum prices for the fixed frequency lots in the 2.3 GHz and 2.6 GHz TDD bands than for the frequency-generic lots in the corresponding band. In particular, ComReg specified in its Decision that to account for uncertainty over the value of the fixed frequency lots due to the power restrictions that will apply:

- the reserve price of the 2.6 GHz TDD guard band blocks would be reduced to €25,000 for the first time slice and €35,000 for the second time slice, and the SUFs would be set at €5,000; and
- for the upper 2.3 GHz frequency-specific lot (2390 – 2400 MHz) the reserve price would be reduced to €197,000 for the first time slice and €285,000 for the second time slice, and the SUFs would be reduced to €52,575.

3.3 Recommended minimum prices

Table 7 below sets out our recommendations for final minimum prices, and the split between the SAFs and SUFs. These take into account the relative durations of the two time slices, the later start date of new 2.1 GHz licences compared with licences in other bands, and the reduction in minimum prices for the fixed frequency lots.

Table 7: Recommended SAFs and SUFs

Band	Time slice	Lot size	Reserve price per lot (€)	Annual SUF per lot (€)
700 MHz	NA	2x5 MHz	9,158,000	998,931
2.1 GHz	1	2x5 MHz	1,398,000	525,753
2.1 GHz	2	2x5 MHz	3,188,000	525,753
2.3 GHz (2300 - 2390 MHz)	1	5 MHz	163,000	52,575
2.3 GHz (2300 - 2390 MHz)	2	5 MHz	319,000	52,575
2.3 GHz (2390 - 2400 MHz)	1	10 MHz	197,000	52,575
2.3 GHz (2390 - 2400 MHz)	2	10 MHz	285,000	52,575
2.6 GHz FDD	1	2x5 MHz	326,000	105,151
2.6 GHz FDD	2	2x5 MHz	638,000	105,151
2.6 GHz TDD	1	5 MHz	163,000	52,575
2.6 GHz TDD	2	5 MHz	319,000	52,575
2.6 GHz TDD Guard Bands	1	5 MHz	25,000	5,000
2.6 GHz TDD Guard Bands	2	5 MHz	35,000	5,000

For the avoidance of doubt, these minimum prices are based on the licence start dates as planned at the time of publication of this report and which we understand are expected to be final. However, it is possible, and allowed within the rules of the award, for ComReg to set an alternative start date, in which case further adjustments to the relative minimum prices will be required to account for the impact on relative durations of the time slices.

Annex A Observations included in our analysis

This Annex provides the list of observations included for band used for our analysis.

A.1.1 700 MHz

Table 8: 700 MHz awards

Country	Award	Year
United States	Auction 33 - Upper 700 MHz Guard Bands	2000
United States	Auction 38 - Upper Guard Bands	2001
United States	Auction 44 - Lower 700 MHz Band	2002
United States	Auction 49 - Lower 700 MHz Band	2003
United States	Auction 60 - Lower 700 MHz Band Auction	2005
United States	Auction 73- 700MHz	2008
United States	USA Auction 92 - 700 MHz band	2011
Bahamas	Bahamas 4G	2012
Fiji	Fiji multiband	2013
New Zealand	New Zealand 700MHz	2014
Canada	Canada 700MHz	2014
Chile	Chile 700MHz	2014
Brazil	Brazil 700MHz	2014
Germany	Germany 700MHz, 900MHz, 1500MHz and 1800MHz	2015
France	France 700MHz	2015
Finland	Finland 700 MHz	2016
Iceland	Iceland Multi-band Award	2017
Saudi Arabia	Saudi Arabia 700 MHz and 1800 MHz auction	2017
Uruguay	700 MHz & 1700/2100 MHz auction	2017
Panama	700 MHz auction	2017
Paraguay	700 MHz auction	2018
Saudi Arabia	Saudi 700 MHz, 800 MHz and 1800 MHz auction	2018
Tanzania	700 MHz auction	2018
Italy	Italy 5G Auction	2018
Sweden	700 MHz auction	2018
Norway	700 MHz and 2.1 GHz Award	2019
Hungary	Hungary 5G	2020
Luxembourg	Luxembourg 700MHz and 3600 Mhz award	2020
Netherlands	Dutch Multiband award 2020	2020
Austria	Austria 700 MHz, 1500 MHz, and 2100 MHz	2020
Czech Republic	Czech 5G	2020
Greece	Greece 5G	2020
United Kingdom	Award of the 700 MHz and 3.6-3.8 GHz spectrum bands	2021

A.1.2 800 MHz

Table 9: 800 MHz awards

Country	Award	Year
Australia	PCS 800MHz-1800MHz auction	1998
Australia	PCS 800MHz-1800MHz 2nd auction	1998
Australia	PCS 3rd auction 800MHz	1999
Macao China	3G	2006
Nigeria	Nigeria 800MHz Spectrum Auction	2007
Hong Kong China	Hong Kong CDMA	2007
Brazil	2G Licences	2007
Canada	Auction of spectrum for air-ground services	2009
Germany	Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	2010
Hong Kong China	850MHz, 900MHz and 2GHz bands auction	2011
Sweden	800MHz	2011
Spain	Spain 800MHz, 900MHz and 2.6GHz bands	2011
Korea Rep.	Korean 800MHz,1800MHz & 2.1GHz	2011
Italy	Italian 4G Auction	2011
Portugal	Portuguese 4G Multiband Auction	2011
Brazil	Brazil leftover 800 MHz,1800MHz	2011
France	French 4G auction (800MHz)	2011
Denmark	800MHz auction	2012
Croatia	Croatia 800MHz auction	2012
Netherlands	Dutch Multiband	2012
United Kingdom	UK 4G Auction	2013
India	India 800MHz	2013
Estonia	Estonia 800MHz - first block	2013
Estonia	Estonia 800MHz - second block	2013
Lithuania	Lithuanian 800MHz auction	2013
Latvia	Latvia 800MHz auction	2013
Finland	Finland 800MHz	2013
Croatia	Croatia remaining 800MHz auction	2013
Belgium	Belgian 800MHz auction	2013
Czech Republic	Czech 4G Auction 800MHz 1800MHz and 2.6GHz	2013
Estonia	Estonia 800MHz - third block	2014
Greece	Greece 800MHz and 2.6GHz	2014
Argentina	Argentina 3G,4G	2014
Georgia	Georgia 800MHz	2014
India	India 800MHz, 900MHz, 1800MHz and 2100MHz	2015
Turkey	Turkey 4.5G (4G) Auction	2015
Poland	Poland 800MHz and 2.6GHz	2015
Serbia	Serbia 800MHz	2015
Iceland	Iceland Multi-band Award	2017
Saudi Arabia	Saudi 700 MHz, 800 MHz and 1800 MHz auction	2018
Malta	Malta 800 and 2600 MHz	2018
Albania	Albania 800 MHz (A1 & A3)	2019

900 MHz

Table 10: 900 MHz awards

Country	Award	Year
United States	Auction 1 - Nationwide Narrowband (PCS)	1994
United States	Auction 3 - Regional Narrowband (PCS)	1994
Switzerland	Additional GSM 900MHz frequencies	2000
United States	Auction 41 Narrowband PCS	2001
Norway	E-GSM Auction	2001
New Zealand	Auction 5 WLL and LMP and Cellular	2002
Austria	GSM 2002 Auction	2002
United States	Auction 51 Regional Narrowband PCS	2003
United States	Auction 50 Narrowband PCS	2003
Austria	GSM 2004 Auction	2004
Ireland	WDM Auction	2005
Singapore	Public Cellular Mobile Telecommunications Services Auction	2008
Austria	900 MHz Auction	2008
Poland	E-GSM	2008
Denmark	900MHz	2010
Brazil	Brazil 1900/2100MHz and leftover 800MHz, 900MHz, 1800MHz	2010
Hong Kong China	850MHz, 900MHz and 2GHz bands auction	2011
Malta	Malta 900MHz and 1800MHz	2011
Spain	Spain beauty contest	2011
Spain	Spain 800MHz, 900MHz and 2.6GHz bands	2011
Spain	Spanish 4G second auction	2011
Greece	Greek 900 and 1800	2011
Portugal	Portuguese 4G Multiband Auction	2011
Hungary	Hungarian 900MHz Auction	2012
Romania	Romania 4G 800 MHz, 900 MHz, 1800 MHz and 2600 MHz band auction	2012
Uruguay	Uruguay 900MHz, 1900MHz, AWS	2013
Taiwan	Taiwan multiband auction	2013
India	India 900MHz & 1800MHz	2014
Dominican Republic	Dominican Republic 900 and 2100MHz	2014
India	India 800MHz, 900MHz, 1800MHz and 2100MHz	2015
Germany	Germany 700MHz, 900MHz, 1500MHz and 1800MHz	2015
Turkey	Turkey 4.5G (4G) Auction	2015
Thailand	Thai 900MHz auction	2015
Thailand	Thai 900MHz re-auction	2016
France	France 900 MHz, 1800 MHz and 2100 MHz	2018

2.1 GHz

Table 11: 2.1 GHz awards

Country	Award	Year
Finland	3G	1999
Spain	3G	2000
United Kingdom	3G Auction	2000
Netherlands	3G Auction	2000
Germany	3G Auction	2000
Italy	3G Auction	2000
Austria	3G Auction	2000
Norway	3G	2000
Switzerland	3G Auction	2000
Korea Rep.	3G	2000
Sweden	3G	2000
Portugal	3G	2000
Poland	3G	2000
New Zealand	Auction 3: 1710 - 2300 MHz	2001
Belgium	3G Auction	2001
Australia	3G Auction	2001
Singapore	3G Auction	2001
France	3G	2001
Greece	3G Auction	2001
Korea Rep.	Second 3G award	2001
Denmark	3G Auction	2001
Hong Kong	3G Auction	2001
China		
Czech Republic	3G Auction	2001
Israel	2G/3G Auction	2001
Taiwan	3G Auction	2002
Luxembourg	3G Award	2002
Ireland	3G	2002
Malaysia	3G	2002
France	3G 2nd Award	2002
Luxembourg	3G Award 2	2003
Norway	3G Auction 2	2003
Romania	3G	2004
Hungary	GSM and 3G	2004
Croatia	2G and 3G	2004
Czech Republic	3G Auction 2	2005
Bulgaria	3G Auction	2005
Poland	3G	2005
Denmark	3G Auction 2	2005
Indonesia	3G auction	2006
Malaysia	Malaysia 3G round 2	2006
Georgia	3G Auction	2006
United States	Auction 66 - Advanced Wireless Services	2006
Slovenia	3G tender 2	2006
Estonia	3G Tender	2007
Egypt	3G licence upgrade	2007
Ireland	2nd 3G	2007
Nigeria	3G Auction	2007
Russian Federation	3G	2007
Kenya	Kenya 3G licence	2007
Norway	2.6 GHz	2007
Norway	3G 4th licence	2007

Brazil	3G	2007
Macedonia FYR	3G	2008
Canada	AWS auction	2008
United States	Auction 78 - AWS1	2008
Macedonia FYR	3G 2	2008
Turkey	3G	2008
Jordan	First 3G licence	2009
France	Fourth 3G licence	2009
France	Remaining mobile 3G France	2010
India	3G auction	2010
Germany	Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	2010
Singapore	3G Spectrum Rights	2010
Belgium	3G Auction	2011
Korea Rep.	Korean 800MHz,1800MHz & 2.1GHz	2011
Hungary	Fixed price spectrum for entrant in Hungarian 900MHz auction	2012
Thailand	Thailand 3G	2012
Norway	2GHz auction	2012
Colombia	Columbia 4G	2013
Peru	Peru AWS	2013
Bangladesh	Bangladesh 3G auction	2013
Bangladesh	Bangladesh admin award at 3G auction price	2013
Algeria	Algeria 3G	2013
Pakistan	Pakistan 3G&4G	2014
Dominican Republic	Dominican Republic 900 and 2100MHz	2014
Hong Kong	Hong Kong 2.1GHz	2014
China		
Ukraine	Ukraine 2100MHz	2015
India	India 800MHz, 900MHz, 1800MHz and 2100MHz	2015
Turkey	Turkey 4.5G (4G) Auction	2015
Albania	Albania 2100 MHz, 2.6 GHz	2016
Korea Rep.	Korean multi-band	2016
Slovenia	Slovenia 1800 MHz & 2100 MHz	2016
Slovenia	Slovenia remaining 1800 MHz and 2100 MHz	2016
Iceland	Iceland Multi-band Award	2017
France	France 900 MHz, 1800 MHz and 2100 MHz	2018
Norway	700 MHz and 2.1 GHz Award	2019
Hungary	Hungary 5G	2020
Netherlands	Dutch Multiband award 2020	2020
Austria	Austria 700 MHz, 1500 MHz, and 2100 MHz	2020
Greece	Greece 5G	2020

2.3 GHz

Table 12: 2.3 GHz awards

Country	Award	Year
Canada	2300 & 3500 MHz Auction	2004
Canada	Residual 2300 & 3500 MHz Auction	2005
Singapore	Wireless Broadband Auction	2005
Norway	2.3 GHz Auction	2006
New Zealand	2.3 and 2.5 GHz auction	2007
Canada	Residual Spectrum Licences in the 2300MHz and 3500MHz bands	2009
India	BWA Auction	2010
Hong Kong	2.3GHz Auction	2011
China		
Australia	Australia residual 2.3GHz auction	2011
Latvia	Latvia 2.3GHz	2012
Nigeria	Nigeria 2.3GHz	2014
Nigeria	Nigeria 2.3GHz	2014
Australia	Multiband residual lots auction 2017	2017
United Kingdom	2.3 and 3.4 GHz award	2018
Sweden	PTS 2.3 GHz and 3.5 GHz	2021

2.6 GHz

Country	Award	Year
Singapore	Wireless Broadband Auction	2005
Taiwan	Wimax auction	2007
Norway	2.6 GHz	2007
New Zealand	2.3 and 2.5 GHz auction	2007
Norway	Residual 2.6GHz	2008
Sweden	2.6GHz	2008
Hong Kong China	BWA Auction	2009
Finland	2.6GHz	2009
Netherlands	2.6 GHz band	2010
Denmark	2.5GHz auction	2010
Germany	Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	2010
Austria	2.6GHz auction	2010
Spain	Spain 800MHz, 900MHz and 2.6GHz bands	2011
France	French 4G auction (2.6 GHz)	2011
Italy	Italian 4G Auction	2011
Spain	Spanish 4G second auction	2011
Portugal	Portuguese 4G Multiband Auction	2011
Belgium	Belgian 4G Auction	2011
Latvia	Latvia 2.6GHZ	2012
Chile	Chile 4G	2012
Romania	Romania 4G 800 MHz, 900 MHz, 1800 MHz and 2600 MHz band auction	2012
United Kingdom	UK 4G Auction	2013
Hong Kong China	Hong Kong 4G	2013
Colombia	Columbia 4G	2013
Korea Rep.	Korea 1800MHz & 2.6GHz	2013
Czech Republic	Czech 4G Auction 800MHz 1800MHz and 2.6GHz	2013
Hungary	Hungary 800, 900, 1800MHz, 2.6 and 26GHz	2014
Greece	Greece 800MHz and 2.6GHz	2014
Turkey	Turkey 4.5G (4G) Auction	2015
Poland	Poland 800MHz and 2.6GHz	2015
Taiwan	Taiwan 2.6GHz	2015
Russian Federation	Russia 2.6GHz	2016
Albania	Albania 2100 MHz, 2.6 GHz	2016
Spain	Spain 2.6 GHz and 3.5 GHz	2016
Korea Rep.	Korean multi-band	2016
Nigeria	Nigeria 2.6GHz	2016
Czech Republic	Czech remaining 1800MHz and 2.6GHz	2016
Iceland	Iceland Multi-band Award	2017
Ukraine	Ukraine 2600 MHz	2018
Malta	Malta 800 and 2600 MHz	2018
Croatia	Croatia 2.6 GHz	2019
Belgium	Belgium 2.6 GHz leftover spectrum	2020