

3.5 GHz spectrum award design – update

Prepared for the Ministry of Economic Affairs

February 2023

Introduction

This note sets out our suggested modifications to the proposed award design resulting from changes to spectrum availability relative to what was envisaged when developing our initial proposal. The main difference in spectrum availability is that not all spectrum will be available from the start, as 80 MHz will continue to be used by Inmarsat for a short period of time.

The proposed solution to this is to have a temporary pro-rata assignment of bandwidth until such time as Inmarsat has completely vacated the band. This means that we can continue to offer the available spectrum in homogeneous blocks for the assignment of bandwidth and then use a follow-up process for the assignment of specific frequencies.

The process for the assignment of bandwidth is unaffected by assigning only a proportion of the spectrum won for the for the period running from the award of licences up until Inmarsat's migration is complete (the 'initial period'). This means that the proposed auction design for this phase continues to be suitable and no modifications are required.

The main complication arises in relation to the assignment of scaled-down amounts of bandwidth for the initial period. Our proposal is aimed at avoiding the risk that some spectrum remains unused as a result of rounding issues during this period.

The remainder of this document is structured as follows:

- We first provide a brief overview of the developments that have taken place since we gave our initial advice.
- We then discuss the implications for the auction design in general.
- We conclude with our proposals for the assignment of scaled-down amounts of bandwidth and specific frequencies.

Background

Initial proposals

DotEcon prepared an auction design proposal for the assignment of spectrum in the 3500 MHz band in the Netherlands based on the assumption that a total of 300 MHz of clean spectrum would be available nationally. At least some of the spectrum should be offered in blocks of 10 MHz to maximise the granularity of potential

outcomes and thus the scope for an efficient allocation of spectrum. Given that there was not assumed to be any significant value difference between the different frequencies, we recommended an award design in which there would first be an assignment of bandwidth in the form of frequency-generic (abstract) blocks, followed by an assignment of specific frequencies to the winners of bandwidth.

For the reasons set out in our initial report, we recommended a two-stage approach for assigning bandwidth:

- In a first stage, three 60 MHz blocks should be offered in a sealed-bid process where bidders may bid for at most one block and winners pay the lowest winning bid;
- In a second stage the remaining spectrum, should be offered in 10 MHz blocks using a clock auction, with provisions for bidders to place exit bids linked to their demand reductions.

All bidders would be subject to a spectrum cap of 120 MHz overall, and bidders who have not participated in the first stage would be limited to at most 50 MHz in the second stage.

Modifications in light of responses

Prospective bidders protested strongly against the use of a sealed bid format for the first stage and in response we suggested to use a clock auction for the first stage also. We also suggested an increase in the amount of information available to bidders from our initial proposal of providing the size of aggregate demand (and thus the magnitude of excess demand) only after excess demand had fallen below a certain threshold to providing information about aggregate demand throughout. This change is aligned with the views expressed in the peer review of our initial proposal conducted by Prof Peter Cramton and results in an information policy that can be said to represent the international standard. We see no justification for providing more detailed information on individual bids.

Changes in spectrum availability and advisory panel advice

Subsequently, in response to a legal challenge brought by Inmarsat, a court decision confirmed Inmarsat's right to continue to use up to 126 MHz of spectrum in the middle of the band (3550 MHz – 3676 MHz) at its Burum ground station for the provision of emergency/safety communications for shipping and aviation.

In response to this decision, an Advisory Panel was set up by the Dutch government to consider options for moving forward with the award of the band for 5G services. The Panel's recommendations are based on Inmarsat reducing its requirement to 80 MHz from 1st December 2023 until its eventual relocation to Greece, which would happen as soon as possible after 1st January 2024 (and which was expected to be completed before the end of 2024). This spectrum would have to be provided as a contiguous block but could be located anywhere between 3550 MHz and 3680 MHz. This means that 220 MHz of unencumbered spectrum will be available from 1st December 2023, although there will be a restriction zone with a radius of 15 km around the Burum ground station applying to the entire band. Therefore, the Panel advised to proceed with an

auction of the full 300 MHz, of which 220 MHz would be usable from 1st December 2023 and the full 300 MHz after Inmarsat has relocated.

The spectrum should be assigned with a view to distributing the cost of the delay in accessing the 80 MHz temporarily used by Inmarsat evenly across the remaining spectrum by making temporary frequency assignments that correspond to 73.3% (220/300) of the bandwidth each bidder acquired in the auction. Because frequency assignments will be made in multiples of 10 MHz, this might lead to some loss of usable spectrum owing to rounding issues, which should ideally be minimised.

Local use in the final band plan

Further complications arose from the identification of local users with the frequency range initially envisaged for assignment (3500 – 3800 MHz) and further work was undertaken to consider the implications of the impact that such local use would have on the value of different frequencies because the homogeneity of the available spectrum was critical for the assumption that spectrum could be offered in the form of frequency-generic blocks that only differed with respect to size.

Eventually, a decision was made initially to assign frequencies in the range of 3450 – 3750 MHz, leaving 50 MHz of the band at either end for local use, which could accommodate all existing local users who could re-tune their equipment to use frequencies in the lower or upper 50 MHz.

After existing local usage rights expire, there could then be a further shift of all frequency assignments down by 30 so that the range from 3420 to 3720 MHz would be used. However, such a further shift will take place only if a thorough cost benefit analysis conducted by the Ministry finds that the change in frequency assignments creates benefits, taking account of the interests of possible local users and of the mobile operators and in any case not before 2030.

As a result, there will now be 300 MHz available for auction, all of which are unencumbered by any local use. 220 MHz will be useable from 31st December 2023 and the full 300 MHz once Inmarsat has completed its migration to Greece. We understand that operators have supported the temporary pro-rata assignment of unencumbered spectrum and have indicated that they would be happy to accept a temporary assignment of frequencies that may require them to move to a different range once the full 300 MHz becomes available.

Implications for auction design

Overall, we find that the proposed auction format continues to be appropriate and can be used with only minor modifications.

An auction model that first assigns bandwidth in the form of frequency-generic lots (potentially in multiple lot categories) and subsequently assigns specific positions within the band works well if there are no material value differences between specific frequencies.

Substantial usage restrictions on frequencies in specific parts of the band arising from incumbent use by Inmarsat could create such material value differences, even if they were of limited, but uncertain duration. A bidder might well wish to acquire more bandwidth if she expects to end up with a frequency assignment that leaves a sizeable proportion of the bandwidth that she wins subject to usage restrictions compared with the bandwidth she would acquire if she expected an assignment of only clean spectrum.

Lot categories capture value differences

In this case, bidders would want to differentiate between encumbered and unencumbered spectrum when bidding for bandwidth. This should not preclude the use of frequency-generic lot categories in principle, as encumbered and unencumbered spectrum can be offered in different lot categories. However, if the encumbered spectrum has a fixed placement or must be contiguous and bidders are allowed to bid for combinations of encumbered and unencumbered spectrum, it may then no longer be possible to guarantee a contiguous assignment of frequencies to all winners in the frequency assignment phase.

Pro-rata assignment for initial period preserves homogeneity of spectrum

The proposal of temporary pro-rata assignments circumvents these problems, albeit at the cost of:

- requiring some bidders to move their frequency assignment after Inmarsat has relocated and the full 300 MHz become available, and
- potentially leaving some spectrum unused for the period of the temporary assignment to retain alignment with the 10 MHz grid (although this issue can be addressed through more complex rules for the definition of these temporary assignments, as discussed below).

Fortunately, the flexibility regarding Inmarsat's precise location within the range from 3550 to 3680 MHz means makes it possible to guarantee contiguous temporary assignments for each winner in all auction outcomes that are compatible with the spectrum cap.

No changes to bandwidth assignment process required, but frequency assignment needs to be modified

Given that the spectrum offered will continue to be homogenous, the auction model proposed under the assumption that the full band would be available will continue to be appropriate in relation to the assignment of frequency-generic lots (subject to potentially introducing a requirement that explicitly prevents bidders from winning single 10 MHz blocks, as discussed below).

However, there will need to be some changes to the rules for the assignment phase, which we will discuss next.

Proposal for frequency assignment

Pro-rata assignments and scaling down

As noted, operators support the proposed temporary pro-rata assignment of bandwidth for the period in which Inmarsat continues to use 80 MHz placed somewhere in the range from 3550 to 3680 MHz. This means that each assignment option entails a temporary assignment of a scaled-down amount of bandwidth and a final assignment corresponding to the full bandwidth won.

As this means assigning temporarily 220 instead of 300 MHz, the bandwidth won in the first two stages needs to be scaled down by a factor of 220/300, or 73.3%.

Applying this scaling factor to the amounts of bandwidth won will obviously not result in amounts of bandwidth that are multiples of 10 MHz. We understand that the Ministry wishes to maintain temporary assignments of spectrum in multiples of 10 MHz, which requires rounding (and specifically: rounding down¹) the resulting scaled-down bandwidths to multiples of 10 MHz.² However, because of rounding-down, less than the available 220 MHz would be assigned in the initial period. This can easily be seen when looking at an outcome with three winners of 100 MHz each, as each winner would receive a scaled down amount of 73.3 MHz, i.e. 70 MHz, totalling 210 MHz, and 10 MHz would remain unassigned until Inmarsat has completed its migration).

Recognising that any rounding down will always leave at least 10 MHz out of the temporary assignment, we can improve somewhat on outcomes by subtracting 10 MHz from Inmarsat's spectrum requirement, applying a scale-down factor of 230/300, i.e. 76.7% and then add the otherwise unused 10 MHz back to Inmarsat's endowment. For example, if we have three winners with

¹ The reason that we cannot generally apply normal rounding rules is because this could result in temporary assignments that total more than 220 MHz of spectrum. In the case of three winners, this would happen with two bidders winning 90 MHz and a third bidder winning 120 MHz, which on normal rounding would result in temporary assignments of 70, 70 and 90 MHz – 230 MHz in total. Although one might consider to address this special case by stipulating that the temporary assignment for the winner of 120 MHz will be rounded down, it is not generally possible to devise a relatively simple rule that addresses the need for having to round against normal rounding rules for particular bidders, not least because cases where normal rounding would assign more than the bandwidth that is temporarily available become more frequent with a larger number of winners.

² We note that the rounding of temporary assignments may affect marginal block values. This is because winning an additional 10 MHz may not result in a greater temporary assignment owing to rounding. However, it is not clear that marginal block values are materially affected by whether the additional block also provides an additional block during the temporary assignment phase. In any case, this effect is somewhat mitigated by our proposal to allow bidders to include the spectrum that would otherwise remain unsold into their assignment bids, i.e. essentially bid for being 'rounded up'.

80, 100 and 120 MHz respectively, 73.3% of these bandwidths rounded down to the nearest multiple of 10 MHz would yield 50, 70 and 80 MHz respectively, giving a total of 200 MHz (leaving 20 MHz unassigned in the period running from the award of licences up until Inmarsat's migration is complete). If we instead were to apply a scale-down factor of 76.7%, we would assign 60, 70 and 90 MHz (giving a total of 220 MHz) in this period, so no spectrum would remain unassigned.

However, this will not eliminate all instances in which spectrum might remain temporarily unused because of rounding (and the scope for this to happen increases with the number of winners).

Creating assignment options that include otherwise unused spectrum

Therefore, we propose to create, for each winner of bandwidth, all assignment options in which she would obtain exactly the rounded-down amount and in addition all assignment options in which she obtains one additional 10 MHz block out of the spectrum that would otherwise remain unused. This allows bidders in the assignment stage to express their preferences for having a slightly larger temporary assignment and therefore compete for the additional spectrum.³ In line with the provisions limiting bidders to at most 40% of the band, the option to bid for otherwise unused spectrum might be limited to bidders who receive less than 90 MHz in their temporary assignment.⁴

As an illustration, consider the case where we have three winners of 100 MHz each, so that each bidder would temporarily receive 70 MHz, leaving 10 MHz unused during the initial period.

In terms of possible band plans, each bidder could be either at the bottom of the band (B), at the top of the band (T), or in the middle (M), where this means below Inmarsat's spectrum, which must be placed between 3550 and 3680 MHz.

If we were simply to place the unused spectrum next to Inmarsat's assignment, each bidder would have three assignment options for the temporary assignment, namely:

³ Notice that in some cases the scaling down of temporary assignments may leave more than one additional 10 MHz block available for temporary assignment. However, the proposed method does not contemplate providing assignment options where bidders obtain more than one additional 10 MHz lot. This reduces the number of potential band plans, and is aligned with a more even distribution of the cost of the delay across winners.

⁴ This means that bidding on otherwise unused spectrum will provide bidders with at most 90 MHz out of the available 220, i.e. 40.9%, which is only slightly above the cap. Note that in the case of some spectrum remaining unsold, a bidder may receive more than 90 MHz after scaling down the amount of bandwidth won. We do not suggest that such bidders should be required to leave some of the spectrum they could utilise during the initial period unused, which would obviously be inefficient.

Option	Frequency range
B	3450 – 3520 MHz
M	3520 – 3590 MHz
T	3680 – 3750 MHz

If we allow each bidder to bid for the otherwise unused 10 MHz, each bidder will now have the following assignment options, depending on whether it receives the additional 10 MHz and in the latter case whether these go the bidder placed below for a bidder in the middle position:

Option	Frequency range	Comment
B1	3450 – 3520 MHz	
B2	3450 – 3530 MHz	Bidder obtains additional 10 MHz
M1	3520 – 3590 MHz	
M2	3520 – 3600 MHz	Bidder obtains additional 10 MHz
M3	3530 – 3600 MHz	Bidder below obtains additional 10 MHz
T1	3670 – 3750 MHz	
T2	3680 – 3750 MHz	

Through her assignment bids, the bidder can then express not only her preference for the placement within the band, but also for receiving a larger temporary assignment.

The corresponding band plans and the specific assignment options for this scenario as well as other cases with more winners with asymmetric winnings where only some bidders are allowed to bid for the otherwise unused spectrum are listed in the Annex.

Rules for generating temporary assignment options

On this basis, we would propose the following rules for the generation of candidate band plans and resultant assignment options for the temporary assignment:

Let q_i be the amount of bandwidth won by bidder i in the first two stages, and $u = 300 - \sum_i q_i$ the amount of unsold spectrum (if any).

We can then distinguish three cases:

- Case 1: $0 \leq u < 70$. In this case, each bidder receives a temporary assignment of $q'_i = q_i \times \frac{230}{300-u}$, rounded down to the nearest multiple of 10 MHz, with the possibility of an additional 10 MHz for some specific assignment options.
- Case 2: $u = 70$. In this case, the scaling rule implies that no scaling is needed, which would then obviously result in temporarily assigning more spectrum than is available. Therefore, in this specific case each bidder will be guaranteed 10 MHz less than the amount of bandwidth won (which would be the same as scaling by 220/230 and then rounding down to the nearest multiple of 10 MHz).

- Case 3: $u \geq 80$. In this case, each bidder receives a temporary assignment that is equal to the amount of spectrum won.

In cases 1 and 2, any spectrum that is left over as a result of rounding will be divided into 10 MHz blocks and each bidder will have the option to bid for assignment options that include only their scaled down temporary assignment established through the rules above as well as those that also include an additional 10 MHz, provided that this does not result in the bidder obtaining more than 90 MHz in the initial period.

In case 3, the unsold spectrum will be retained as a contiguous block and placed in the band so that it comprises at least 80 MHz within the range required for Inmarsat.

Assignment options are generated by considering all possible placements that a bidder could obtain, given the potential amounts of bandwidths that could be assigned to other bidders, and eliminating assignment options that would not permit placing Inmarsat within the range of 3550 – 3680 MHz.

The winner determination and pricing process can then be conducted as set out in the original proposal.

Final assignments

In addition, we need to establish a rule for the placement of bidders within the band after Inmarsat migration has been completed and bidders will have access to the full bandwidth they have won for cases 1 and 2 (in case 3, temporary assignments can simply be carried over). There are two principal options.

Option 1: separate placements for the initial period and the final period

Under the first option, we would offer separate assignment options for the period after Inmarsat has vacated the band, allowing bidders to choose different placements in the initial period and the final licence period. Bidding for temporary and final assignments could in principle be simultaneous or sequential, so that bidders already know their final assignment before bidding for their temporary assignment, or vice versa.

Sequential bidding allows bidders to act upon their preferences for having the temporary and the final assignment closely overlapping, although with limited flexibility: if a bidder values having closely overlapping temporary and final assignments, then the outcome of the first bidding process limits the bidder's flexibility in the second one. Bidders will only be able fully to express their preferences for positions in the band and the overlap of temporary and final assignments if they are allowed to bid on combinations of assignment options for the temporary placement and the final placement. This will however substantially increase the number of potential options on which bidders can place bids as the number of options that need to be considered is the product of the number of temporary and final assignment options.

By way of illustration, assume that we have three winners (A, B and C) with 110, 100 and 90 MHz respectively. In this case, A will have seven, and B and C will have eight assignment options for the

temporary assignment (see the Annex for more detail). Each bidder has four options for the final assignment, so offering combined assignment options means that A will be faced with 28 options and B and C with 36 options. With a higher number of winners, the number can grow dramatically.

Option 2: linking temporary and final assignments

Alternatively, the final assignments could be derived from the temporary assignments by simply retaining the relative position of bidders but extending their respective bandwidths from the temporary assignment to the full amount of bandwidth won. Specifically, we would extend and shift the temporary assignments in the following manner:

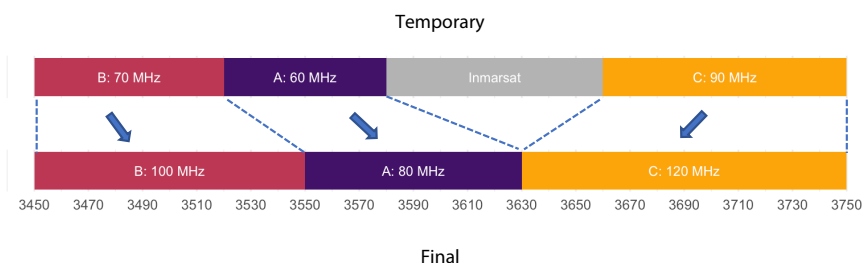
- Bidders placed at the bottom of the band will have the additional spectrum they receive in the final assignment added at the top of their holding.
- Bidders placed at the top of the band will have the additional spectrum they receive added at the bottom of their holding.
- Bidders displaced because of these two rules will then simply be shifted up or down within the band, depending on whether they need to move because of the bidder below or above will be assigned some of the frequencies they held in their temporary assignment.

This means that:

- Any unsold spectrum will end up somewhere in the range previously used by Inmarsat;
- Bidders further from the bottom/top end of the band will be exposed to greater shifts of their assignments, but this is known at the time of bidding for assignment options.

For example, consider the case of three winners (say A, B and C) with 80, 100 and 120 MHz respectively and corresponding temporary assignments of 60, 70 and 90 MHz.

Assume that the winning assignment options yield a band plan with B at the bottom of the band and C at the top. Then the expansion from the temporary to the final assignments will look as follows:



Comparing the options

We consider that the second option is preferable if bidders can be assumed to want their temporary and post-relocation assignments to be as similar as possible. This is because it ties the temporary and the final assignments together and keeps the number of assignment options available to bidders relatively small.

However, generating the final assignments by ‘growing’ the bandwidth assignments from their position during the initial period only works if every bidder has a position in the initial period. This is not necessarily the case for a bidder who wins only 10 MHz. Such a bidder would not be guaranteed any spectrum during the initial period (though she may be able to bid on a block that is available because of rounding) and may therefore not have a position in the band from which the final assignment could be expanded.

To retain the ability to ‘grow’ final assignments from temporary assignments (should this be preferable), one would have to:

- add additional provisions for the placement of bidders who have not been assigned any bandwidth during the initial period; or
- add a restriction in the first phase that prevents outcomes in which a bidder wins only 10 MHz (e.g. by disallowing bidders who have not already won spectrum in the first stage to bid on single blocks in the second stage).

As winning a single 10 MHz block is unlikely to be a realistic target for any bidder and would in any case result in undesirable fragmentation of spectrum, we would consider the second approach to be reasonable.

The first approach would in practice require a rule that allow bidders without a temporary assignment to be placed anywhere within the gap that remains after the assignments of other bidders have been expanded following the completion of the Inmarsat migration. For example, consider that there are three bidders who have won 10 MHz each with the remaining 270 MHz shared between three other bidders. Each of the winners of 90 MHz is guaranteed 60 MHz during the temporary assignment and can bid on assignments comprising 70 MHz. This means that one of the winners of 10 MHz is guaranteed to have 10 MHz initially and thus a position in the band, but the other two may not. Assume that this is the case and that one of the large bidder acquires the assignment of 70 MHz at the top of the band. In this case, following completion of Inmarsat’s move and the expansion of temporary holdings, there will be a gap of 20 MHz, between 3640 and 3660 MHz, which can be assigned to the two winners who have not received any temporary assignments. One bidder would randomly be assigned 3640 – 3650 MHz and the other the remaining block. Unlike the bidder who has obtained a temporary assignment of 10 MHz, these bidders have no control over where they will eventually end up in the band.

Conclusions

The proposed temporary pro-rata assignment of frequencies in combination with the applicable spectrum cap and the flexibility of Inmarsat to shift position within 130 MHz frequency range means that the homogeneity of the spectrum can be retained. Therefore,

the auction model suggested previously continues to be appropriate.

There should be no impact on the performance of the auction model in relation of the underlying objectives.

The rules needed to prevent an outcome in which some spectrum will remain unused until Inmarsat has relocated implies a greater number of assignment options and a more complex assignment stage. However, this seems to be manageable and preferable to leaving spectrum unassigned for the relocation period.

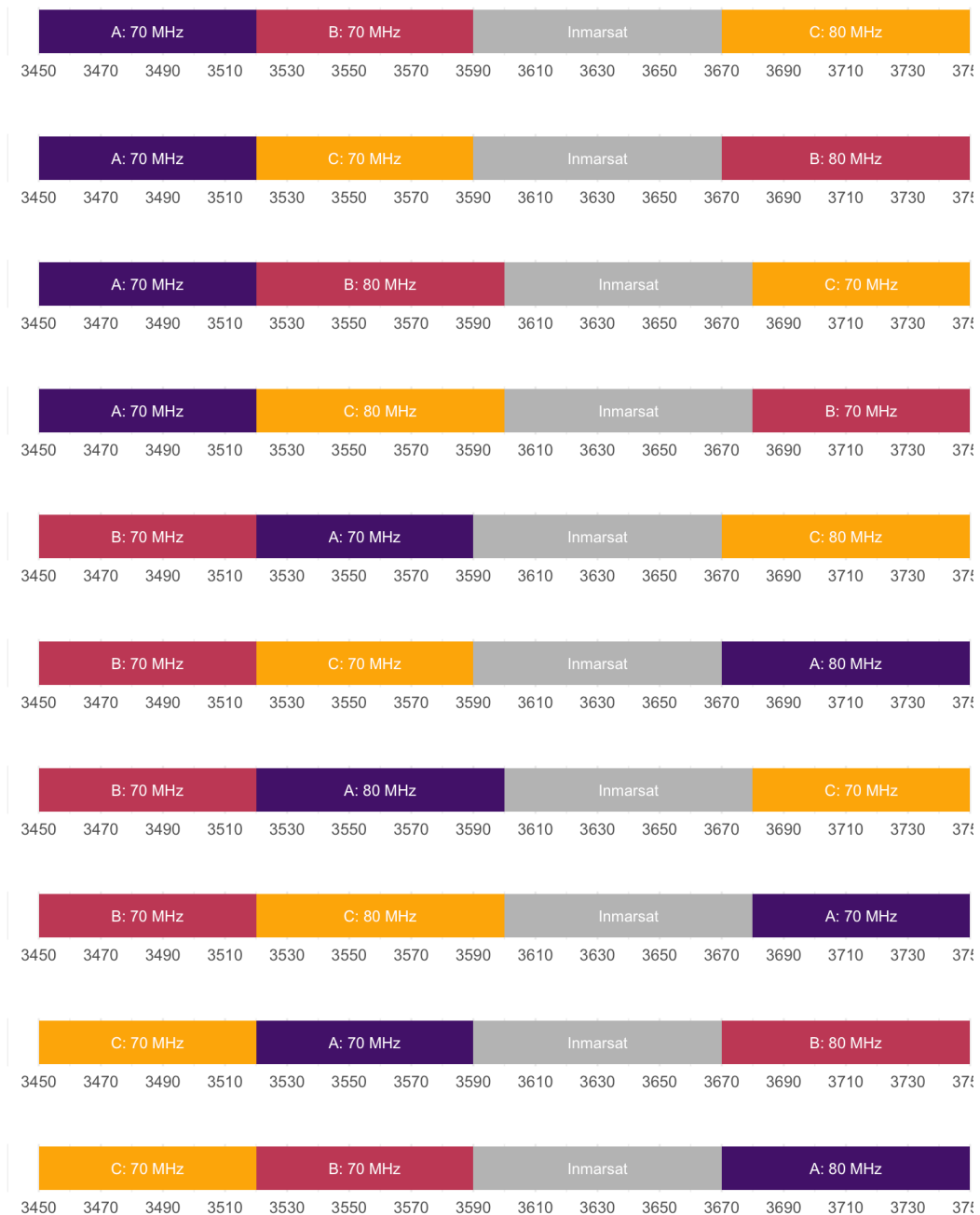
Annex: Illustrative band plans

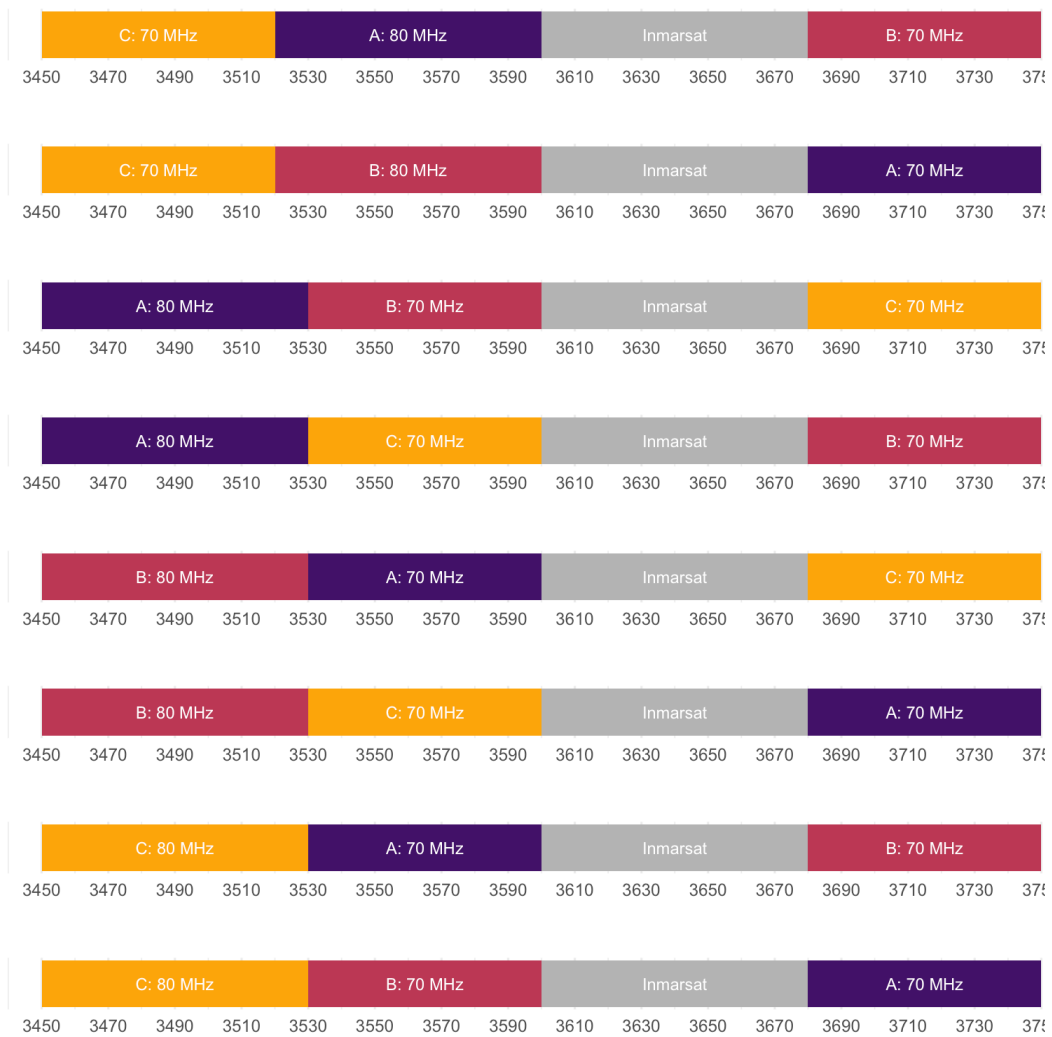
This annex illustrates band plans for the initial period and corresponding assignment options for different scenarios.

Three winners of 100 MHz each

Assume that we have three winners (A, B and C) of 100 MHz each, so each winner is guaranteed at least 70 MHz in the initial period but also can bid on options including another 10 MHz.

The possible band plans for the assignments in the initial phase are as follows:





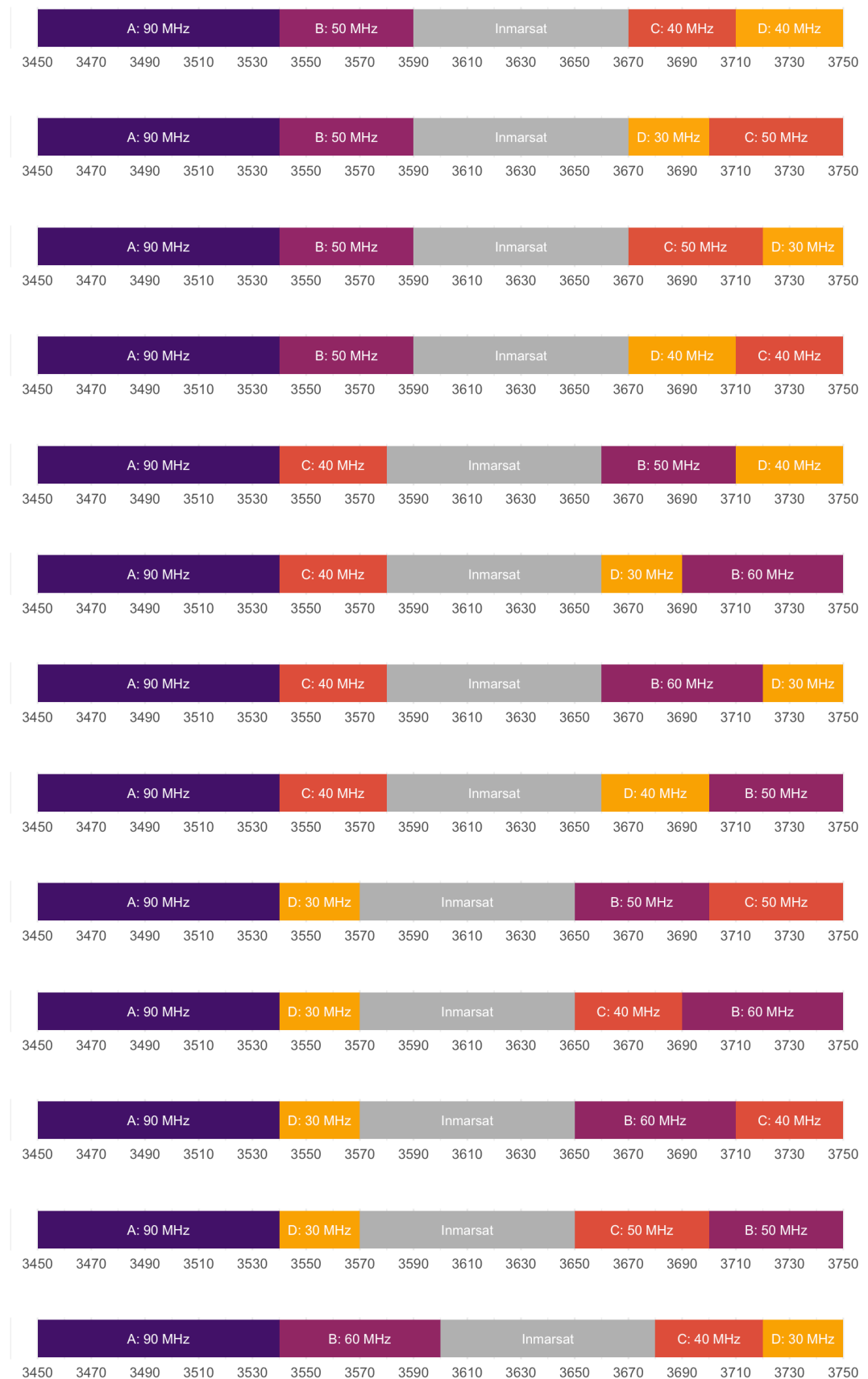
The corresponding assignment options for each bidder (which are symmetric) are as follows:

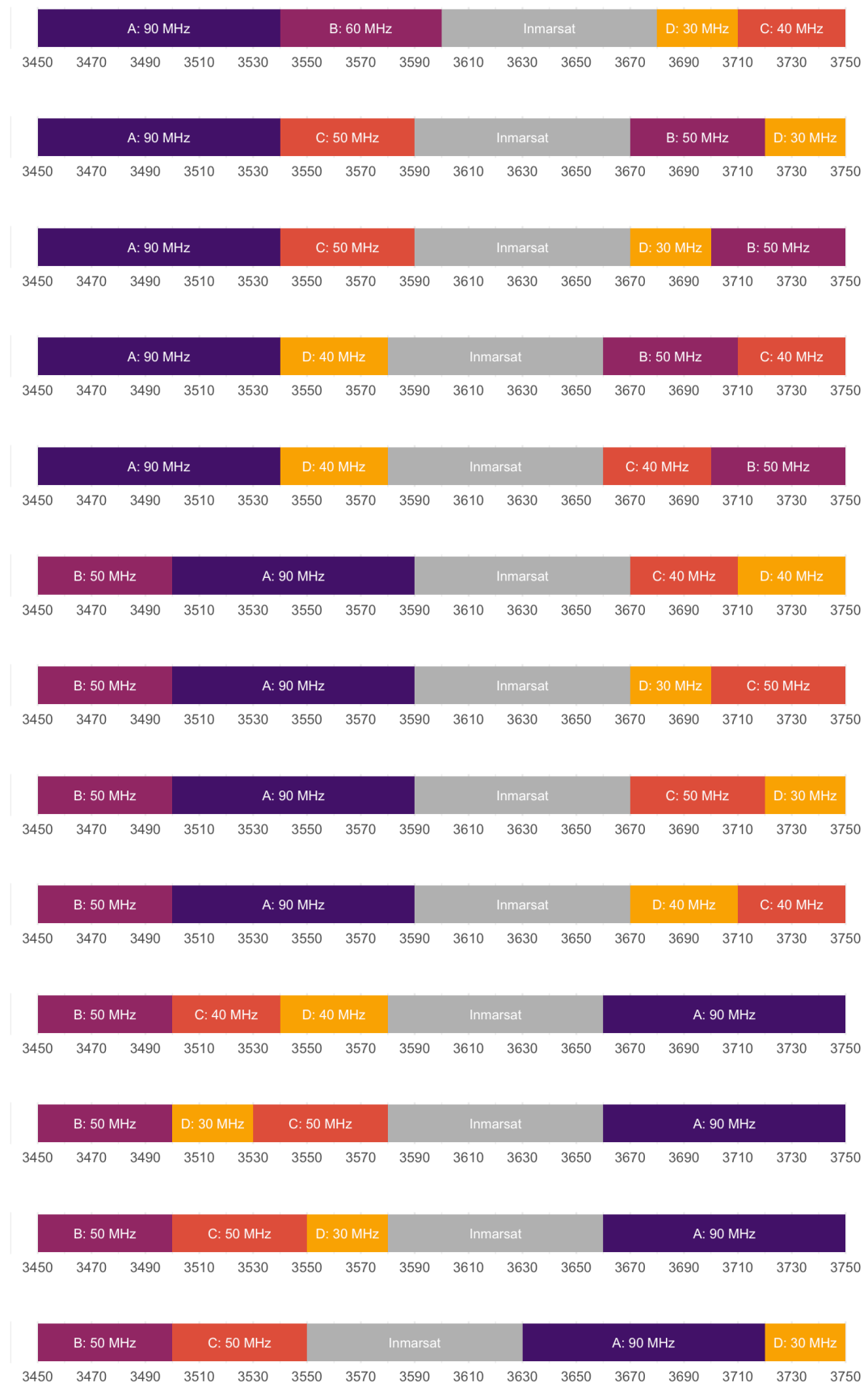
Bidder	Start	End
A/B/C	3450	3520
A/B/C	3450	3530
A/B/C	3520	3590
A/B/C	3520	3600
A/B/C	3530	3600
A/B/C	3670	3750
A/B/C	3680	3750

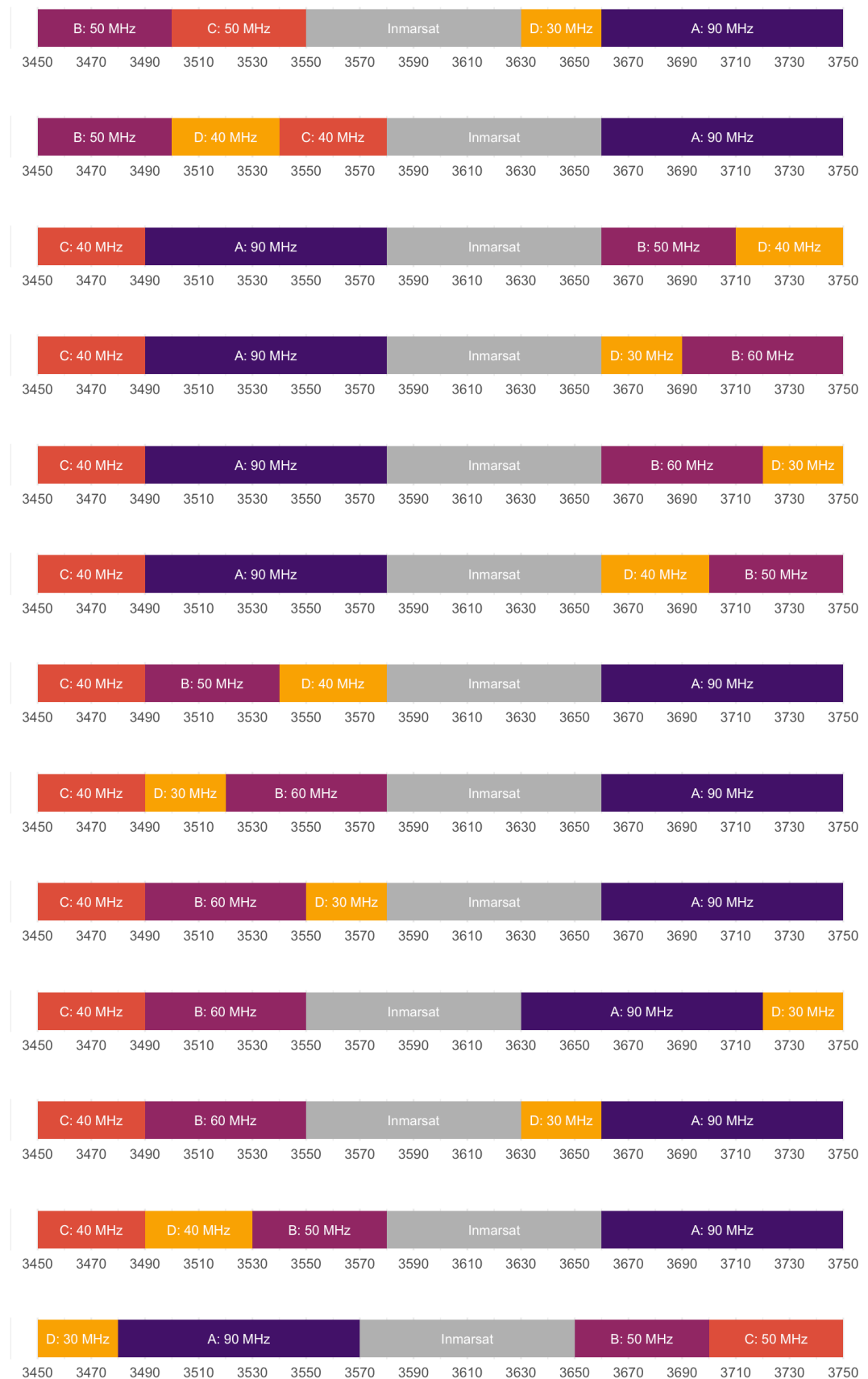
Four winners with 120/70/60/50 MHz

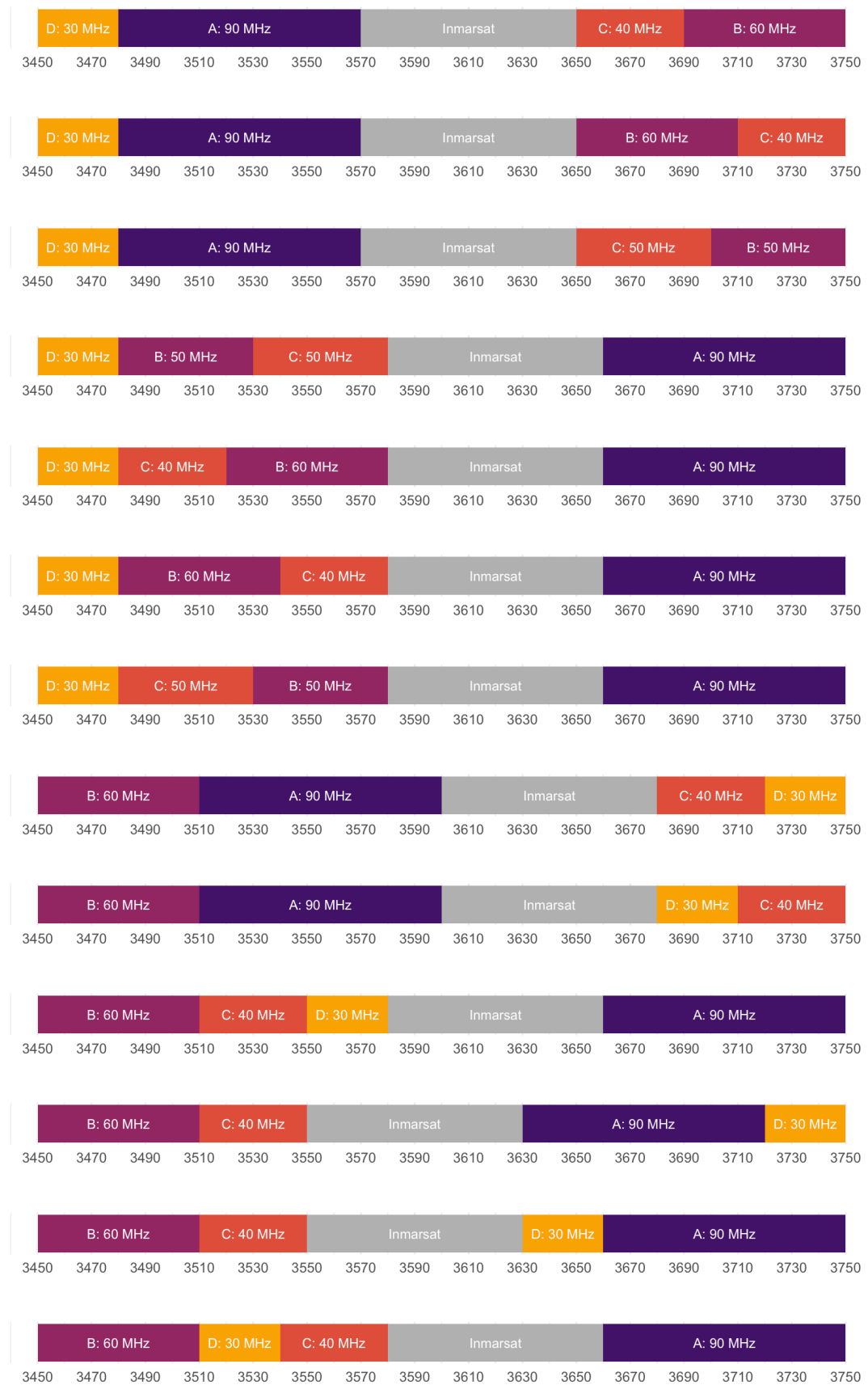
Assume that we have four winners A, B, C and D winning 120/70/60/50 MHz respectively. They are guaranteed at 90/50/40/30 MHz in the initial period. B, C and D can bid on the additional 10 MHz.

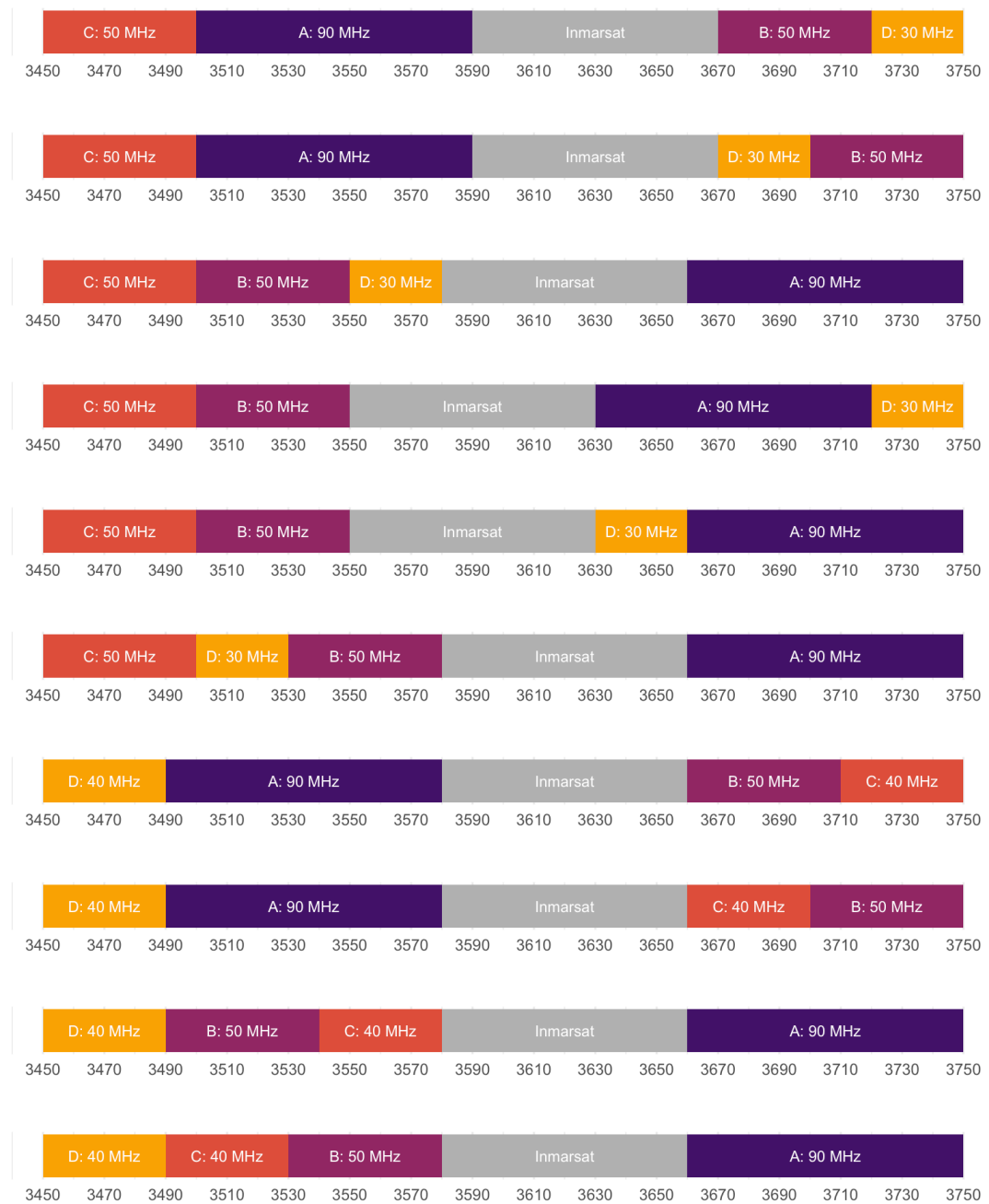
The possible band plans for the assignments in the initial phase are then as follows:











The corresponding assignment options for each bidder are as follows:

Bidder	Start	End
A	3450	3540
A	3480	3570
A	3490	3580
A	3500	3590
A	3510	3600
A	3630	3720
A	3660	3750
B	3450	3500

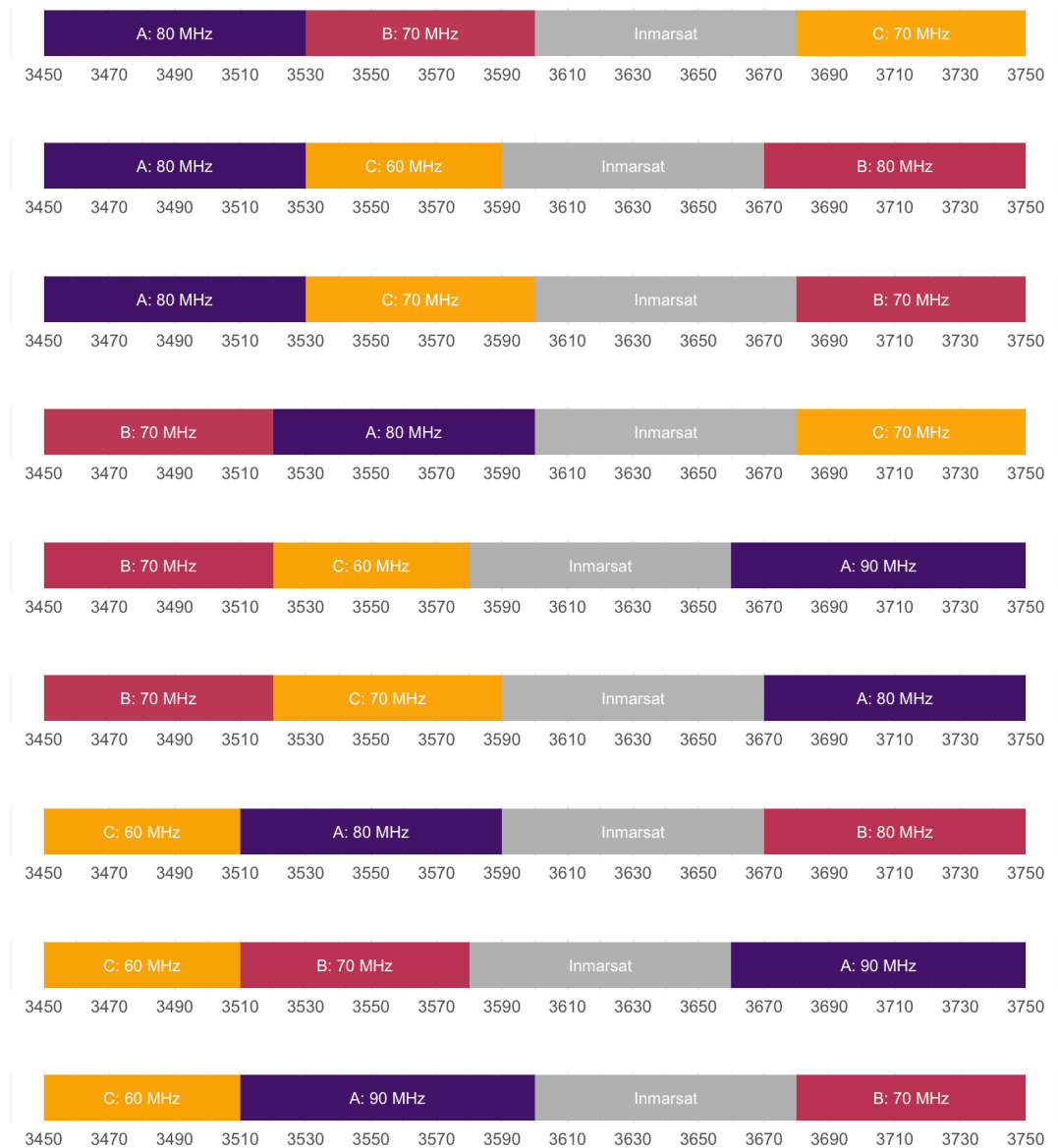
B	3450	3510
B	3480	3530
B	3480	3540
B	3490	3540
B	3490	3550
B	3500	3550
B	3520	3580
B	3530	3580
B	3540	3590
B	3540	3600
B	3650	3700
B	3650	3710
B	3660	3710
B	3660	3720
B	3670	3720
B	3690	3750
B	3700	3750
C	3450	3490
C	3450	3500
C	3480	3520
C	3480	3530
C	3490	3530
C	3500	3540
C	3500	3550
C	3510	3550
C	3530	3580
C	3540	3580
C	3540	3590
C	3650	3690
C	3650	3700
C	3660	3700
C	3670	3710
C	3670	3720
C	3680	3720
C	3700	3750
C	3710	3750
D	3450	3480
D	3450	3490
D	3490	3520
D	3490	3530
D	3500	3530
D	3500	3540
D	3510	3540
D	3540	3570
D	3540	3580
D	3550	3580

D	3630	3660
D	3660	3690
D	3660	3700
D	3670	3700
D	3670	3710
D	3680	3710
D	3710	3750
D	3720	3750

Three winners with 110/100/90 MHz

Assume that we have three winners A, B and C winning 110/100/90 MHz respectively. They are guaranteed at 80/70/60 MHz in the initial period.

The possible band plans for the assignments in the initial phase are then as follows:





The corresponding assignment options are as follows:

Bidder	Start	End
A	3450	3530
A	3450	3540
A	3510	3590
A	3510	3600
A	3520	3600
A	3660	3750
A	3670	3750
B	3450	3520
B	3450	3530
B	3510	3580
B	3510	3590
B	3520	3590
B	3530	3600
B	3670	3750
B	3680	3750
C	3450	3510
C	3450	3520
C	3520	3580
C	3520	3590
C	3530	3590
C	3530	3600
C	3540	3600
C	3680	3750

Band plans for final assignment are:



Assignment options are:

Bidder	Start	End
A	3450	3560
A	3540	3650
A	3550	3660
A	3640	3750
B	3450	3550
B	3540	3640
B	3560	3660
B	3650	3750
C	3450	3540
C	3550	3640
C	3560	3650
C	3660	3750