

# Award of the 700 MHz and 3.6-3.8 GHz spectrum bands

## Bidding example using relaxed activity rules for the principal stage

- A1.1 We present a worked example to demonstrate the mechanics of the principal stage, including the primary bid rounds and the supplementary bids round. The worked example assumes that the auction design proposed in the December 2018 consultation is implemented. This document is intended as a complement to the draft Auction Regulations. We show how a hypothetical bidder that has pre-determined its valuations for certain packages could bid straightforwardly throughout the auction. For these purposes, we have assumed purely illustrative reserve prices, bidder valuations, cost of coverage obligation and bids. This document is entirely illustrative and should not be taken as advice to potential participants about how they should bid.
- A1.2 In the primary bid (or clock) rounds<sup>1</sup>, the example shows how:
- The bidder switches between packages within its current eligibility;
  - The bidder submits relaxed bids, which in this case require also submitting chain bids; and
  - The prices of packages are subject to a minimum of £0.001m.
- A1.3 The example follows a bidder who makes these bids in the clock rounds:
- Round 1: Standard bid on 12 lots of 3.6<sup>2</sup> GHz
  - Round 2: Standard bid on 2 lots of 700 MHz with a coverage obligation, which reduces the bidders' eligibility limit
  - Round 3: Relaxed bid on 12 lots of 3.6 GHz with a coverage obligation
  - Round 4: Relaxed bid on 12 lots of 3.6 GHz with a coverage obligation
  - Round 5: Standard bid on 2 lots of 700 MHz with a coverage obligation
- A1.4 The example then illustrates how the bidder bids in the supplementary bids round, given the constraints that arise from its bids in the primary bid rounds.

## Lot categories and bidder valuations

- A1.5 For simplicity, we have restricted the number of lot categories to three in this example: 700 MHz FDD, 3.6 GHz and coverage lots. Table A1.1 below shows the relevant information about each lot category, including starting (or reserve) prices that set the clock prices for the first round. For the purpose of the worked example, the reserve prices are assumed to

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<sup>1</sup> In this document, we refer interchangeably to 'primary bid rounds' and 'clock rounds'.

<sup>2</sup> In this document when we refer to 3.6 GHz lots we are referring to lots in the 3.6-3.8 GHz range

be the mid-points of the ranges in our consultation “Award of the 700 MHz and 3.6-3.8 GHz spectrum bands”, published 18 December 2018 (the “December 2018 consultation”).<sup>3</sup>

**Table A1.1: Information about each lot, including reserve prices<sup>4</sup>**

Lot category	MHz in a lot	Supply	Starting price of lot (£m)	Eligibility points
700 MHz	10	6	170	4
3.6 GHz	5	24	20	1
C	0	2	-350	0

A1.6 For the purpose of this example, we have constructed a hypothetical bidder who is interested in packages that include selections of one or two lot categories from the three available categories and has the following valuations for four packages. For simplicity, there is only one spectrum lot category in each package.

**Table A1.2: Assumed valuations for the 4 packages the bidder is interested in**

Package name	Number of 700 MHz lots	Number of 3.6 GHz lots	Number of C lots	Bidder's valuation (£m)	Activity of package
1	0	12	0	420	12
2	2	0	0	480	8
3	0	12	1	80	12
4	2	0	1	140	8

A1.7 These valuations are such that:

- The bidder is interested in either 60 MHz of 3.6 GHz (Packages 1 and 3) or 2x10 MHz of 700 MHz (Packages 2 and 4). On a per MHz basis, the bidder values 700 MHz above 3.6 GHz.
- Packages 3 and 4 include the coverage obligation, while Packages 1 and 2 exclude the coverage obligation (i.e. the “C” lot category).
- The total cost of the coverage obligation is £340m for this bidder (as the valuation for a package including the coverage obligation is reduced by this amount relative to the corresponding package without the coverage obligation).<sup>5</sup>

<sup>3</sup> [https://www.ofcom.org.uk/data/assets/pdf\\_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrum-bands.pdf](https://www.ofcom.org.uk/data/assets/pdf_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrum-bands.pdf)

<sup>4</sup> Note that the draft regulations refer to the maximum discount for the two coverage obligations as a positive amount that is subtracted from the spectrum price (subject to the amount bid being at least £0.001m) and that reduces if there are more than two bids on the obligations. This is equivalent to each coverage obligation having a ‘negative’ reserve price that increases (i.e. gets closer to zero) if there is excess demand. For the purposes of this example, the coverage obligation discount is shown as having a ‘negative’ round price.

<sup>5</sup> For the purposes of this example, we have used the upper value of the coverage obligation cost range £170m-£340m (when a private discount rate of 7.6% is used), which we are consulting on. We have used the higher obligation value to demonstrate how the positive price constraint caused the prices of packages to be converted to £0.001m. The obligation

- A1.8 In the example, we assume that the bidder starts with 12 eligibility points, which would be calculated based on its initial deposit. The bidder is able to make bids on all the packages it is interested in (i.e. it is not prevented from doing so by any spectrum caps).
- A1.9 For the purpose of this example, we assume the bidder bids straightforwardly by making bids that maximise the surplus (i.e. profit) it expects to make on each package in each round in isolation. The surplus is the difference between a bidder's valuation for a package and its bid amount for that package (which in the primary bid rounds is the clock price).<sup>6</sup> For example, if the bidder bids £240m for Package 1 (the reserve price), for which its valuation is £420m, its surplus is £180m.
- A1.10 We assume that the bidder behaves in the following way:
- It would not bid for a package when the surplus from that package is negative. This would create the possibility that the price ultimately paid for the package is higher than the bidder's valuation, and if so, the bidder would be better off submitting a zero bid.<sup>7</sup>
  - When there are multiple packages with a positive surplus, the bidder would prefer to bid on the package with the highest surplus.

## Primary bid rounds

### Round 1 – bidder submits a standard primary bid

- A1.11 Based on the starting prices of each category, the bidder can calculate the surplus associated with each of the four packages the bidder is interested in. The bidder's surplus for each package in the first round is shown in the table below; this is the difference between its valuation of each package and the price.
- A1.12 Due to the positive price constraint, the round price of Packages 3 and 4 is not calculated simply by adding together the clock prices of the lots within the package. This is because this would give a price for Package 3 of -£110m (12 lots of 3.6 GHz at £20m each and a coverage obligation at -£350m) and for Package 4 a price of -£10m (2 lots of 700 MHz at £170m each and a coverage obligation at -£350m). Since Ofcom does not have the power to accept negative bids, the prices for these packages are instead the smallest positive bid amount of £0.001m, which (for simplicity) we have rounded to £0m in the table below.<sup>8</sup>

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cost range is described in further detail in Annex 14, Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, [https://www.ofcom.org.uk/\\_data/assets/pdf\\_file/0021/130737/Annexes-5-18-supporting-information.pdf](https://www.ofcom.org.uk/_data/assets/pdf_file/0021/130737/Annexes-5-18-supporting-information.pdf).

<sup>6</sup> In practice this is the minimum surplus, given that the bidder is likely to pay a lower base price than its bid amount for its winning package.

<sup>7</sup> A zero bid is a bid that contains no spectrum lots and no coverage obligation, which necessarily must be at a bid amount of £0.

<sup>8</sup> See from paragraph 7.96 in our December 2018 consultation for more detail on the positive price constraint.

**Table A1.3: Highest bidder surplus from Package 1, based on Round 1 prices**

Package name	Number of 700 MHz lots	Number of 3.6 GHz lots	Number of C lots	Bidder's valuation (£m)	Price of package (£m)	Bidder's surplus (£m)	Activity of package
1	0	12	0	420	240	180	12
2	2	0	0	480	340	140	8
3	0	12	1	80	0	80	12
4	2	0	1	140	0	140	8

A1.13 The table above gives the bidder's surplus for each package at the starting prices, with the highest highlighted in purple. In the first round, the package with the highest surplus is Package 1, which has a surplus of £180m. The bidder therefore wishes to bid in Round 1 for 12 lots of 3.6 GHz spectrum at the bid amount of £240m.

A1.14 Package 1 has 12 eligibility points associated with it. The bidder has an initial eligibility of 12 points, which means that it is allowed to submit its bid for Package 1 at a bid amount of £240m.

A1.15 At the end of Round 1, Ofcom, via the Electronic Auction System (EAS), would calculate the aggregate demand in each lot category across all bidders.<sup>9</sup> Ofcom would then increase the price of the lot categories that have excess demand in the next round.<sup>10</sup>

A1.16 Table A1.4 illustrates whether there was excess demand in each of the lot categories. For Round 1, there was excess demand in both spectrum lot categories, which leads to price increases in the 700 MHz and 3.6 GHz lots for Round 2. There was no excess demand on the coverage lots, so the coverage lot price remains the same for Round 2. Note that we have used unrealistically large clock price increments purely in the interests of having fewer rounds in the example. In practice, we currently expect to set price increments for spectrum lots of no greater than 20% of the previous clock price from one round to the next.

**Table A1.4: Price increases for 700 MHz and 3.6 GHz in Round 2 due to excess demand**

Lot category	Round 1 price (£m)	Excess demand	Round 2 price (£m)
700 MHz	170	Yes	190
3.6 GHz	20	Yes	30
C	-350	No	-350

A1.17 The bidder's eligibility for Round 2 will be the lower of its eligibility limit at the start of Round 1 (i.e. 12 points) and its activity in Round 1 (i.e. also 12 points). The bidder therefore starts Round 2 with 12 eligibility points.

<sup>9</sup> The aggregate demand is the sum of the demand from all bidders in that primary bid round, which excludes any demand resulting from chain bids.

<sup>10</sup> Excess demand is when the aggregate demand is greater than the lots available.

## Round 2 – bidder submits an eligibility reducing bid

A1.18 In Round 2, the bidder again calculates the surplus it expects from each package, based on its valuations and round prices. We set out the bidder’s surplus in a slightly altered format below, which will be useful for the discussion of later rounds in this worked example. In this table, we show the package price and the surplus for each package for the current round and also for all previous rounds.

**Table A1.5: Highest bidder surplus from Package 4, based on Round 2 prices**

Round	Price per lot			Package 1 (0,12,0)		Package 2 (2,0,0)		Package 3 (0,12,1)		Package 4 (2,0,1)		Activity rules		
	700	3.6	C	Price	Surplus	Price	Surplus	Price	Surplus	Price	Surplus	Eligibility	Activity	Type of bid
1	170	20	-350	240	180	340	140	0	80	0	140	12	12	Standard
2	190	30	-350	360	60	380	100	10	70	30	110	12	8	Standard

A1.19 The clock prices of 700 MHz and 3.6 GHz lots have increased, causing the round price of Package 1 to increase by £120m, but the round price for Package 4 (consisting of 700 MHz lots and a coverage obligation) to increase by only £30m. As a result the bidder would achieve the highest surplus with Package 4, so it switches from Package 1 to Package 4. Package 4 has 8 eligibility points associated with it (2 lots of 700 MHz, each at 4 eligibility points). Since the bidder started the round with 12 eligibility points, the bidder is allowed to submit this bid as a standard primary bid. However, bidding for this package leads to a reduction in the bidder’s eligibility points for the following round. Round 2 is therefore an eligibility reducing round. Eligibility reducing rounds are first described in regulation 37 of the draft regulations.

A1.20 The outcome of Round 2 is shown in the table below. Again, there is excess demand for both spectrum categories, so the clock prices of these categories increases.

**Table A1.6: Price increases for 700 MHz and 3.6 GHz in Round 3 due to excess demand**

Lot category	Round 2 price (£m)	Excess demand	Round 3 price (£m)
700 MHz	190	Yes	225
3.6 GHz	30	Yes	32
C	-350	No	-350

A1.21 The bidder’s eligibility for Round 3 will be the lower of its eligibility limit at the start of Round 2 (i.e. 12 points) and its activity in Round 2 (i.e. 8 points). In Round 3, the bidder will therefore begin the round with 8 eligibility points.

## Round 3 – bidder submits a relaxed bid with a chain bid

**Table A1.7: Highest bidder surplus from Package 3, based on Round 3 prices**

Round	Price per lot			Package 1 (0,12,0)		Package 2 (2,0,0)		Package 3 (0,12,1)		Package 4 (2,0,1)		Activity rules		
	700	3.6	C	Price	Surplus	Price	Surplus	Price	Surplus	Price	Surplus	Eligibility	Activity	Type of bid
1	170	20	-350	240	180	340	140	0	80	0	140	12	12	Standard
2	190	30	-350	360	60	380	100	10	70	30	110	12	8	Standard
3	225	32	-350	384	36	450	30	34	46	100	40	8	12	Relaxed

- A1.22 In Round 3, the clock price increases for the 700 MHz lots by a larger amount than the 3.6 GHz lots. Consequently, the packages that include 3.6 GHz lots have become relatively more profitable. Furthermore, the clock price of the 3.6 GHz spectrum has now risen high enough that the full coverage discount is in effect for Package 3, which causes the bidder to prefer the 3.6 GHz package that includes coverage. Therefore, Package 3 is now the package that gives the bidder the highest surplus. Since Package 3 requires 12 eligibility points and the bidder only has 8 eligibility points, the bidder is not able to place a standard primary bid on Package 3. However, the bidder may be able to place a relaxed primary bid on Package 3. Relaxed bids are described in regulations 23, 24, 37-43 of the draft regulations.
- A1.23 For the bidder to be permitted to make this relaxed primary bid, two conditions need to be satisfied. As Package 3 has an associated eligibility that exceeds the bidder’s current eligibility, any bids that the bidder may make for this package are subject to a relative cap, based on the bidder’s choice and the prevailing round prices in the last round in which the bidder had enough eligibility points to submit a standard primary bid on Package 3. Therefore, the first step to check whether the bidder can make a relaxed primary bid for Package 3 is to identify the relative cap that applies to its bids for this package.
- A1.24 The relative caps are based on revealed preference, and require that the bidder’s bids must be consistent with the preferences it expressed in the last round in which the bidder had enough eligibility points to submit a standard primary bid on Package 3, which was Round 2. In Round 2, the bidder started Round 2 with 12 eligibility points (which would allow the bidder to submit standard primary bids for Package 3), but its activity in the round was 8 eligibility points, leading to a reduction in its eligibility for the following round to 8 (which is insufficient for the bidder to submit standard primary bids for Package 3). As a result of this eligibility reduction, the bidder does not have sufficient eligibility to submit standard primary bids for Package 3. Furthermore, the bidder’s choice in Round 2 gave rise to a relative cap on its bids for packages with an associated eligibility greater than 8 and no greater than 12, including Package 3.
- A1.25 In Round 2 the bidder revealed a preference for Package 4 over Package 3 at the prevailing round prices. For this relative cap, Package 4 is the ‘constraining’ package and Package 3 is the ‘constrained’ package, because the bidder could have bid for Package 3 in Round 2 but

decided to bid for Package 4 instead.<sup>11</sup> In Round 2, the round price of Package 3 was £10m and the round price of Package 4 was £30m. Therefore, the bidder chose Package 4 despite it being £20m more expensive, which would be consistent with the bidder valuing Package 4 at least £20m more than Package 3. The relative cap, based on this revealed preference, requires that any further bids must be consistent with the bidder valuing Package 3 at no more than its value for Package 4 less £20m. This has two implications:

- the bidder will not be permitted to choose Package 3 in preference to Package 4 if Package 4 costs less than £20m more than Package 3; and
- at any time during the auction, the highest bid that the bidder submits for Package 3 cannot exceed its highest bid for Package 4 plus £20m.

A1.26 The conditions for a relaxed primary bid for Package 3 to be permitted follow from the implications above. The first condition is that the difference in price between Package 3 and Package 4 at Round 3 prices must not exceed the price difference between the packages at Round 2 prices. In other words, the first condition requires that Package 3 has not become relatively more expensive compared with Package 4 than in the round in which the bidder chose Package 4, even though the absolute price of both packages has increased. If this condition were not satisfied, then bidding for Package 3 in Round 3 would be inconsistent with the bidder's revealed preference to bid for Package 4 in Round 2. This condition is satisfied:

- In Round 2, the price of Package 3 was £10m and the price of Package 4 was £30m. The difference (i.e. the constrained Package 3 price minus the constraining Package 4 price) was -£20m.
- In Round 3, the price of Package 3 is £34m and the price of Package 4 is £100m. The difference in price has fallen to -£66m, making Package 3 cheaper relative to Package 4 than in Round 2
- Since -£66m is less than -£20m, the condition is satisfied. Package 3 has become relatively cheaper compared to Package 4. Therefore, a bid in Round 3 for Package 3 would be consistent with the preference revealed by the bidder's bid in Round 2.

A1.27 The second condition requires that the difference between the relaxed primary bid for Package 3 in Round 3 (i.e. the round price of Package 3 in Round 3) and the highest bid submitted for Package 4 must not exceed the difference in price of the two Packages at Round 3 prices. This condition ensures that the constraining package, Package 4, has a high enough bid to maintain the relative preference to the constrained package, Package 3, expressed in Round 2. To check this second condition we first consider the highest bid that the bidder has submitted for Package 4 in previous rounds. If this bid is already sufficient to satisfy the condition, then the bidder is permitted to submit the relaxed primary bid. However, if this is not the case, this does not mean that a relaxed primary bid for Package 3 is necessarily prohibited, but rather that the bidder might be required to submit a 'chain

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<sup>11</sup> In the draft regulations, the 'constraining package' is the package chosen by the bidder in the most recent eligibility reducing round in which the bidder could have chosen the relaxed bid selection as a standard bid (referred in the draft regulations as the *connected eligibility reducing round* – connecting the relaxed bid with a particular eligibility reducing round) and the 'constrained package' is referred to as the package selection in the bidder's relaxed bid.

bid' (described below) on Package 4 alongside the relaxed primary bid on Package 3 in Round 3 in order to satisfy the second condition.

A1.28 We first check if the second condition is already satisfied with the bids submitted by the bidder in earlier rounds. In this example we have a situation whereby:

- The round price of Package 3 in Round 3 is £34m.
- The highest bid amount submitted so far by the bidder for Package 4 is £30m, which was submitted in Round 2.
- The difference between these two amounts is £4m.
- In Round 2, the round price of Package 3 was £10m and the round price of Package 4 was £30m. The difference in round prices was -£20m.
- Since the £4m is greater than -£20m the second condition is not already satisfied with the bids that the bidder has already submitted for Package 4.

A1.29 We therefore check whether the bidder would be able to satisfy the second condition if it submitted a chain bid on Package 4. A chain bid is a bid on a constraining package (in this case, Package 4) at the smallest amount that is high enough to satisfy the second condition for the submission of a relaxed primary bid. Chain bids would need to be submitted alongside the relaxed primary bid. In this case, the chain bid on Package 4 would need to be £54m. This is the difference between the relaxed primary bid for Package 3 in round 3 (£34m) minus the difference between the highest bid for Package 3 and the highest bid for Package 4 required by the relative cap, i.e. the difference between the round prices of these packages in Round 2 (-£20m). However, chain bids cannot exceed the current round price on the corresponding package (because that would be inconsistent with the bidder's revealed preference not to bid for that corresponding package in the current round). We therefore also need to check whether this chain bid would be allowed in this round given the current clock prices. The chain bid of £54m is smaller than the round price of Package 4 in the current round, which is £100m. As this is satisfied, the chain bid is allowed.

A1.30 We then check whether there have been any further eligibility reductions after Round 2, to see if any further chain bids would be required for the submission of the chain bid identified above. Since there have been no further eligibility reducing rounds, there is no possibility of further chain bids being required.<sup>12</sup>

A1.31 Therefore, the bidder may submit a relaxed primary bid for Package 3 in Round 3, at £34m, provided that it also submits a chain bid on Package 4, at £54m.<sup>13</sup> The table below shows that, given its assumed valuations, the bidder is content to make the relaxed primary bid and the corresponding chain bid, given that both bids would be below valuation and yield a

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<sup>12</sup> There could be situations where multiple chain bids are required. For example, the bidder could place standard bids on packages with 12, 10 and 8 eligibility points in early clock rounds. The bidder could then place a relaxed bid on a package with 12 eligibility points, which could require chain bids on the packages it previously bid on with 10 and 8 eligibility points. An example where multiple chain bids is described is in Annex 5 of the Irish 3.6 GHz auction, specifically in Round 5. 3.6 GHz Band Spectrum Award, Information Memorandum, ComReg, <https://www.comreg.ie/publication/3-6-ghz-band-spectrum-award-information-memorandum/>.

<sup>13</sup> In this example, a chain bid was required in order to place a relaxed bid. However, it would be possible to construct a scenario where a relaxed bid could be placed without requiring any chain bids.

positive surplus. In particular, the bidder is happy to make the chain bid, as it would yield a greater surplus than the relaxed primary bid in question.

**Table A1.8: Bidder has positive surplus from both the relaxed primary bid on Package 3 and the chain bid on Package 4.**

Package name	Number of 700 MHz lots	Number of 3.6 GHz lots	Number of C lots	Bidder's valuation (£m)	Bid amount (£m)	Bidder's surplus (£m)	Activity of package
3	0	12	1	80	34	46	12
4	2	0	1	140	54	86	8

A1.32 In summary, in Round 4 the bidder makes the following bids:

- a) A relaxed primary bid on Package 3 (the constrained package) at Round 4 prices (£34m)
- b) A chain bid on Package 4 (the constraining package) with a bid amount of £54m.

A1.33 As the bidder has previously indicated it is interested in Package 3, the EAS would have indicated to the bidder that the relaxed primary bid on Package 3 was possible in Round 3. The EAS would have also calculated the necessary chain bid associated with this relaxed primary bid. Bidders would not have discretion over the amount of a chain bid; this would automatically be set at the lowest possible amount needed to ensure that the relaxed primary bid is permitted.

A1.34 The outcome of Round 3 is shown in the table below. Again there is excess demand for both spectrum categories, but there is also now excess demand for coverage. The clock prices of all three categories will increase in the next round.

**Table A1.9: Price increases for all spectrum lot categories and the coverage obligations in Round 4 due to excess demand**

Lot category	Round 3 price (£m)	Excess demand	Round 4 price (£m)
700 MHz	225	Yes	235
3.6 GHz	32	Yes	34
C	-350	Yes	-345

A1.35 The bidder's eligibility for Round 4 will be the lower of its eligibility limit at the start of Round 3 (i.e. 8) and its activity in Round 3 (i.e. 12). Therefore, the bidder will have 8 eligibility points at the start of Round 4. Even though the bidder had activity of 12 in Round 3 due to its relaxed primary bid, its eligibility is not increased to 12 for Round 4. The bidder's eligibility can only remain the same or decrease from one round to the next, as set out in regulation 36.

## Round 4 – bidder submits another relaxed bid with a chain bid

**Table A1.10: Highest bidder surplus from Package 3, based on Round 4 prices**

Round	Price per lot			Package 1 (0,12,0)		Package 2 (2,0,0)		Package 3 (0,12,1)		Package 4 (2,0,1)		Activity rules		
	700	3.6	C	Price	Surplus	Price	Surplus	Price	Surplus	Price	Surplus	Eligibility	Activity	Type of bid
1	170	20	-350	240	180	340	140	0	80	0	140	12	12	Standard
2	190	30	-350	360	60	380	100	10	70	30	110	12	8	Standard
3	225	32	-350	384	36	450	30	34	46	100	40	8	12	Relaxed
4	235	34	-345	408	12	470	10	63	17	125	15	8	12	Relaxed

- A1.36 In Round 4, Package 3 is still the package that gives the bidder the highest surplus. Since Package 3 requires 12 eligibility points and the bidder only has 8 eligibility points, the bidder is not able to place a standard primary bid on Package 3. However, as before, the bidder may be able to place a relaxed primary bid on Package 3.
- A1.37 To assess this, we check two conditions to ensure that the relaxed primary bid is permitted. As identified before, the last round in which the bidder had enough eligibility points to submit a standard primary bid on Package 3 was Round 2, where the bidder had 12 eligibility points and could have bid on Package 3, but chose instead to bid on Package 4, which has 8 eligibility points. Therefore, as for the previous round, Package 3 is the ‘constrained’ package and Package 4 is the ‘constraining’ package.
- A1.38 For a relaxed primary bid for Package 3 to be allowed in Round 4, the first condition is that the difference between the round price of the constrained Package 3 and the round price for the constraining Package 4 in Round 4 must not exceed that in Round 2.
- In Round 2, the round price of Package 3 was £10m and the round price of Package 4 was £30m. The difference in round prices was -£20m.
  - In Round 4, the round price of Package 3 is £63m and the round price of Package 4 is £125m. The difference in round prices is -£62m.
  - Since -£62m is less than -£20m, the condition is satisfied. Submitting a primary bid for Package 3 in Round 4 and a primary bid for Package 4 in Round 2 is consistent with the bidder’s expressed preferences.
- A1.39 The second condition is that the difference between the round price of Package 3 in Round 4 and the highest bid amount submitted for Package 4 must not exceed the difference in the round price of the two Packages in Round 2. We first check if this is satisfied with the bids submitted by the bidder so far:
- In Round 4, the round price of Package 3 is £63m.
  - The highest bid amount submitted for Package 4 so far is £53m, which was submitted in Round 3 as a chain bid.
  - The difference between these two amounts is £10m.
  - In Round 2, the round price of Package 3 was £10m and the price of Package 4 was £30m. The difference in price was -£20m
  - Since £10m is greater than -£20m, the condition is not satisfied.

A1.40 We now check whether the bidder could submit a chain bid for Package 4 to satisfy this second condition (chain bids in primary bid rounds are described in regulations 40-43 in the draft regulations). The chain bid on Package 4 needs to be at the lowest amount that is sufficient to satisfy the second condition. In this case, the chain bid on Package 4 needs to be £83m. This is the round price of Package 3 in round 4 (£63m) minus the difference in round prices between Package 3 and Package 4 in Round 2 (-£20m). We also need to check whether this chain bid would be allowed given the current clock prices. The chain bid of £83m is smaller than the round price of Package 4 in the current round, which is £165m. As this is satisfied, the chain bid is allowed.

A1.41 Since there have been no further eligibility reducing rounds, there is no possibility of further chain bids being required.

A1.42 Therefore, to be permitted to make the relaxed primary bid of £63m for Package 3 in Round 4, the bidder needs to also make a chain bid of £83m on Package 4. The table below shows that the bidder is content to make the necessary relaxed primary bid and chain bid, given that both packages would yield a positive surplus. As before, the bidder is happy to make the chain bid, given that it would yield a greater surplus than the relaxed primary bid in question.

**Table A1.11: Bidder has positive surplus from both the relaxed primary bid on Package 3 and the chain bid on Package 4.**

Package name	Number of 700 MHz lots	Number of 3.6 GHz lots	Number of C lots	Bidder's valuation (£m)	Bid amount (£m)	Bidder's surplus (£m)	Activity of package
3	0	12	1	80	63	17	12
4	2	0	1	140	83	57	8

A1.43 In summary, in Round 4 the bidder makes the following bids:

- a) A relaxed primary bid on Package 3 (the constrained package) at Round 4 prices (£63m)
- b) A chain bid on Package 4 (the constraining package) with bid amount £83m.

A1.44 The outcome of Round 4 is shown in the table below. There is only excess demand for the 3.6 GHz category.

**Table A1.12: Price increases for 3.6 GHz in Round 5 due to excess demand**

Lot category	Round 4 price (£m)	Excess demand	Round 5 price (£m)
700 MHz	235	No	235
3.6 GHz	34	Yes	36
C	-345	No	-345

A1.45 The bidder would start Round 5 with eligibility of 8, which is the lower of its eligibility limit at the start of Round 4 (i.e. 8) and its activity in Round 4 (i.e. 12).

## Round 5 – bidder submits a standard bid

**Table A1.13: Highest bidder surplus from Package 4, based on Round 5 prices**

Round	Price per lot			Package 1 (0,12,0)		Package 2 (2,0,0)		Package 3 (0,12,1)		Package 4 (2,0,1)		Activity rules		
	700	3.6	C	Price	Surplus	Price	Surplus	Price	Surplus	Price	Surplus	Eligibility	Activity	Type of bid
1	170	20	-350	240	180	340	140	0	80	0	140	12	12	Standard
2	190	30	-350	360	60	380	100	10	70	30	110	12	8	Standard
3	225	32	-350	384	36	450	30	34	46	100	40	8	12	Relaxed
4	235	34	-345	408	12	470	10	63	17	125	15	8	12	Relaxed
5	235	36	-345	432	-12	470	10	87	-7	125	15	8	8	Standard

A1.46 In Round 5, the price of 3.6 GHz lots increases, causing 700 MHz lots to be relatively more profitable for the bidder. The bidder obtains the most surplus by bidding again on Package 4. Package 4 requires 8 eligibility points and the bidder started the round with 8 eligibility points. The bidder would therefore be allowed to place a standard primary bid on Package 4.

A1.47 The bidder places a bid of £125m on Package 4 in Round 5.

A1.48 The outcome of Round 5 is shown in the table below. Since there is no excess demand in any category, Round 5 is the final primary bid round. The auction therefore moves to the next stage, which is the supplementary bids round.

**Table A1.14: No excess demand in any lot category**

Lot category	Round 5 price (£m)	Excess demand
700 MHz	235	No
3.6 GHz	36	No
C	-345	No

## Supplementary bids round

A1.49 In the draft regulations, the regulations governing the rules in the supplementary round are 44-58. After the end of the clock rounds there is a supplementary bids round in which bidders would be able to:

- increase the bid amount for any non-zero packages bid on during the clock rounds; and
- add additional packages with corresponding bid amounts.

A1.50 All bids, including standard primary bids, relaxed primary bids and chain bids, are binding. This means that every package bid for in the clock rounds is submitted as supplementary bids at the highest bid amount specified for that package in either the clock rounds or the supplementary bids round. The EAS would automatically add these packages to the bidder's list of supplementary bids.

A1.51 The package bid for in the final clock round (the 'final clock package') is not subject to a final price cap. The bidder could increase the bid amount for the final clock package by any amount, unless its final clock round bid is a zero bid. If the bidder made a relaxed primary

bid for its final clock package, then it will be subject to a relative cap and it may also be necessary to increase bid amounts for a constraining package as well (and possibly other packages that constrain that constraining package). We give an example of this specific situation below.

A1.52 Supplementary bids for all other packages are subject to caps on the bid amount. All supplementary bids, other than for the final clock package, are subject to a final price cap. The final price cap is referred to in the draft regulations as the ‘supplementary cap rule’ and is described in regulation 50. Additionally, all supplementary bids for packages with eligibility larger than the bidder’s eligibility at the start of the final primary bid round are subject to relative caps; which are described in the draft regulations from regulation 51 to 57.

A1.53 This section demonstrates the supplementary bid cap rules under three different scenarios, using variants of the example of the primary bid rounds above:

- i) Case 1: the primary bid round history is exactly as set out in the example above, where the bidder’s final clock round bid is a standard primary bid (i.e. bid is within its eligibility and non-zero).
- ii) Case 2: the primary bid rounds ended after Round 4, so that the bidder’s final clock round was a relaxed primary bid.
- iii) Case 3: we assume an additional round in which the bidder submitted a zero bid.

A1.54 In all three variants, we assume the bidder’s valuations to be the same as above. For ease, we show these valuations again below:

**Table A1.15: Valuations for the 4 packages a bidder is interested in**

Package name	Number of 700 MHz lots	Number of 3.6 GHz lots	Number of C lots	Bidder's valuation (£m)	Activity of package
1	0	12	0	420	12
2	2	0	0	480	8
3	0	12	1	80	12
4	2	0	1	140	8

A1.55 In each case, the bidder has been able to place supplementary bids at its valuation for all the packages that it is interested in. This is because the bidder’s valuations did not change during the course of the bidding and the bidder bid consistently with its valuations in every clock round.

### Case 1: Final primary bid is a standard bid

A1.56 The bidder submitted the following set of bids during the primary bid rounds.

**Table A1.16: All bids submitted in the clock rounds**

Round	Package	Bid amount (£m)	Type of bid
1	1	240	Standard
2	4	30	Standard
3	3	34	Relaxed
3	4	54	Chain
4	3	63	Relaxed
4	4	83	Chain
5	4	125	Standard

A1.57 Since we are only interested in the highest bid for each package, these bids can be collapsed down to those in the table below.

**Table A1.17: Highest bid on each package submitted in the clock rounds**

Round	Package	Bid amount (£m)	Type of bid
1	1	240	Standard
4	3	63	Relaxed
5	4	125	Standard

A1.58 These bids will be automatically submitted in the supplementary bids round, unless higher bids for the respective packages are submitted during the supplementary bids round.

A1.59 We assume that the bidder wishes to maximise its chances of winning a package and, were it able to win different packages, to win the package that maximises its surplus. In order to do this, the bidder wishes to submit bids on each of the packages it is interested in at its valuation or, if that is not possible, as close to its valuation as possible.

A1.60 For the final clock package (Package 4) there are no restrictions imposed by the final price cap. Package 4 also has no relative cap restrictions as the bidder had enough eligibility in the round to place a standard primary bid. The bidder may therefore submit any bid amount for Package 4, as long as it is greater than its previous highest bid of £125m. The bidder is therefore able to bid its value of £140m for Package 4, raising its final clock package bid by £15m.

### Final price cap

A1.61 For all packages other than Package 4, there are restrictions on the bid amount due to the final price cap. The final price cap restricts a bid to the final round price of that package, plus the amount by which the final clock package had been raised in the supplementary bids round relative to its price in the final clock round. The final price cap sets the following limits:

- **Package 1:** £432m (final clock round price) + £15m (amount final clock package was raised by in a supplementary bid) = £447m
- **Package 2:** £470m + £15m = £485m

- **Package 3:** £87m + £15m = £102m

### Relative cap

- A1.62 The relative cap ensures that bids made in the supplementary bids round reflect the preferences a bidder expressed in the primary bid rounds. Relative caps only apply to packages which have higher eligibility associated with them than the bidders' eligibility limit at the start of the final clock round.
- A1.63 There may therefore be a relative cap on Packages 1, 2 and 3. We examine them in increasing order of eligibility as there may be relative caps that link the packages together. This means it may be necessary to raise the bid amount of lower eligibility packages, which are the constraining packages, in order to be able to raise the bid amount of larger constrained packages. We therefore consider Package 2 next, which has 8 eligibility points.
- A1.64 Package 2 has the same number of eligibility points as the final clock package; it therefore does not have a relative cap, and the only constraint on the amount the bidder can bid on Package 2 is therefore the final price cap. The bidder has a valuation of £480m for Package 2, which is below the final price cap of £485m. The bidder can therefore bid its valuation of £480m for Package 2.
- A1.65 Package 3 has a higher number of eligibility points than the final clock package; it is therefore subject to a relative cap on its bid amount. In order to calculate the relative cap restriction, we need to identify the last round in which the bidder had sufficient eligibility to submit a standard primary bid for Package 3, which was Round 2. In Round 2 the bidder chose to submit a primary bid on Package 4, which is the relevant constraining package. The relative cap ensures that the bidder maintains the relative preference it expressed for Package 4 over Package 3 at Round 2 prices. The relative cap for Package 3 is therefore:
- The highest bid submitted for Package 4 (the constraining package), which is £140m submitted in the supplementary bids round (see above); plus
  - The round price difference between Package 3 (the constrained package) and Package 4 (the constraining package) in Round 2 (£10m - £30m = -£20m).
- A1.66 This imposes the relative cap of £120m on Package 3, which is less binding than the final price cap of £102m. The bidder is therefore able to bid at its valuation for Package 3 as this is £80m (i.e. it satisfies both the final price cap and the relative cap).
- A1.67 Package 1 has a higher number of eligibility points than the final clock package; it therefore is also subject to a relative cap. To calculate the relative cap restriction, we identify the last round in which the bidder could have submitted a standard primary bid on Package 1, which is Round 2. In Round 2 the bidder chose to bid on Package 4, so this is the constraining package. The relative cap ensures that the bidder maintains the relative preference it expressed for Package 4 over Package 1 at Round 2 prices. The relative cap for Package 1 is therefore:
- The highest bid submitted for Package 4, which is £140m submitted in the supplementary bids round (see above); plus

- The difference between the price of Package 1 and the price of Package 4 in Round 2 (£360m - £30m = £330m).

A1.68 This imposes the relative cap of £470m on Package 1, which is less binding than the final price cap of £447m. The bidder is able to submit its valuation for Package 1 as this is £420m.

### Summary of supplementary bids

A1.69 The table below summarises the bids made in the supplementary Bids Round and the applicable caps for the first variant.

**Table A1.18: Summary of the final price cap, relative cap and bid amount on each package**

Package name	Number of 700 MHz lots	Number of 3.6 GHz lots	Number of C lots	Final Price Cap (£m)	Relative Cap (£m)	Bid amount (£m)
1	0	12	0	447	470	420
2	2	0	0	485	-	480
3	0	12	1	102	120	80
4	2	0	1	-	-	140

### Case 2: Final primary bid is a relaxed primary bid

A1.70 In this variation, we imagine that the clock rounds had been different. In particular, that the primary bid rounds had ended after round 4 due to no excess demand, instead of round 5. We do this to examine the situation where a relaxed primary bid was placed in the final clock round, which causes there to be a relative cap on the final clock round package.

A1.71 Below is a table that shows the bidding until the end of Round 4, excluding chain bids.

**Table A1.19: Bid history of the clock rounds for Case 2**

Round	Price per lot			Package 1 (0,12,0)		Package 2 (2,0,0)		Package 3 (0,12,1)		Package 4 (2,0,1)		Activity rules		
	700	3.6	C	Price	Surplus	Price	Surplus	Price	Surplus	Price	Surplus	Eligibility	Activity	Type of bid
1	170	20	-350	240	180	340	140	0	80	0	140	12	12	Standard
2	190	30	-350	360	60	380	100	10	70	30	110	12	8	Standard
3	225	32	-350	384	36	450	30	34	46	100	40	8	12	Relaxed
4	235	34	-345	408	12	470	10	63	17	125	15	8	12	Relaxed

A1.72 The bidder's highest bids on each of its packages in the clock rounds are detailed below.

**Table A1.20: Highest bid on each package submitted in the clock rounds**

Round	Package	Bid amount (£m)	Type of bid
1	1	240	Standard
4	3	63	Relaxed
4	4	83	Chain

A1.73 The bidder wishes to raise its bids on each of these packages to its valuation for each package. The bidder also wishes to bid on Package 2, for which it did not submit any bids during the primary bids rounds. Below we examine whether this is possible, given the final price cap and the relative caps.

### Final price cap

A1.74 The final price cap applies to each package other than the final clock package (i.e. Package 3). As in the first variant set out above, the final price cap restricts bids to the final round price of that package, plus the amount by which the final clock package is raised. This would impose the following caps on the packages, where Z is the amount by which the final clock package is raised:

- £408m + £Zm on Package 1
- £470m + £Zm on Package 2
- £125m + £Zm on Package 4

### Relative cap

A1.75 We examine the packages in order of increasing eligibility. The packages with the lowest eligibility are Packages 2 and 4, which require 8 eligibility points. Since the bidder had enough eligibility points to bid on these packages in the final clock round, there are no relative caps on these packages. The bidder has a valuation of £480m for Package 2 and £140m for Package 4. The bidder is therefore unable to place bids on these packages at their valuations unless it raises its final clock package by a sufficient amount – at least £10m to be able to bid at valuation on Package 2 and at least £15m to bid at valuation on Package 4.

A1.76 Next, we examine whether the bidder can put in a bid of £80m on Package 3, which is its valuation for that package. Since Package 3 was the final primary bid, there is no final price cap restriction on Package 3. However, because Package 3 requires more eligibility points than the bidder had at the start of the final clock round, Package 3 is subject to a relative cap.

A1.77 In order to calculate the relative cap, we identify the last round in which the bidder had enough eligibility points to submit a standard primary bid on Package 3, which is Round 2. In Round 2 the bidder chose to bid on Package 4, which is therefore the constraining package. The relative cap ensures that the bidder maintains the relative preference it expressed for Package 4 over Package 3 at Round 2 prices. The relative cap for Package 3 is therefore:

- The highest bid submitted for the constraining Package 4, which is £83m submitted in the Round 4 as a chain bid; plus
- The difference between the round prices of Package 3 (the constrained package) and Package 4 (the constraining package) in Round 2 (£10m - £30m = -£20m).

A1.78 This means that the relative cap on Package 3 is currently £63m, which would not allow a bid of £80m for Package 3. The bidder would have to raise its bid for Package 4 by at least £17m in order to be able to increase its bid on Package 3 by £17m to £80m.

### Interactions between the final price cap and the relative cap

- A1.79 The bidder therefore has a restriction on Package 3 that depends on Package 4, and vice versa. The bidder would like to increase its bid on:
- Package 3 by £17m to £80m, but requires Package 4 to be raised by at least £17m
  - Package 4 by £57m to £140m, but requires Package 3 to be raised by at least £15m
- A1.80 The bidder is therefore able to submit its preferred bids on Packages 3 and 4, which will satisfy the restriction on each of the packages. The bidder therefore submits bids of £80m on Package 3 and £140m on Package 4.
- A1.81 The restriction on Package 2 is just the final price cap. The bidder is also able to submit its preferred bid of £480m on Package 2, since the bid on the final clock package (Package 3) was raised by £17m. The final price cap on Package 2 was less restrictive, at £487m.
- A1.82 Both the final price cap and a relative cap apply to Package 1. The final price cap for Package 1 is £425m. Package 1 requires a higher number of eligibility points than the bidder has at the start of the final clock round. This results in a relative cap of £470m on Package 1 (the calculation is the same as case 1 paragraph A1.63), which is less binding than the final price cap of £425m. The bidder is able to submit its valuation for Package 3, as this is £420m.

### Summary of supplementary bids

- A1.83 The table below summarises the bids and caps that were applicable in the supplementary bids round.

**Table A1.21: Summary of the final price cap, relative cap and bid amount on each package**

Package name	Number of 700 MHz lots	Number of 3.6 GHz lots	Number of C lots	Final Price Cap (£m)	Relative Cap (£m)	Bid amount (£m)
1	0	12	0	425	470	420
2	2	0	0	487	-	480
3	0	12	1	-	120	80
4	2	0	1	142	-	140

### Case 3: Final clock round bid is a zero-bid

- A1.84 In our third variant, instead of the clock rounds ending with Round 5, there is a further clock round where the bidder submits a zero bid. This is to show how there would be a final price cap on every package that would limit the bid amount to the price of each package in the final clock round.
- A1.85 In Round 6, the prices for all the lot categories increases, such that the bidder finds it unprofitable to bid on any package. Below is a table that shows the bidding until the end of Round 6.

**Table A1.22: Bid history of the clock rounds for Case 3**

Round	Price per lot			Package 1 (0,12,0)		Package 2 (2,0,0)		Package 3 (0,12,1)		Package 4 (2,0,1)		Activity rules		
	700	3.6	C	Price	Surplus	Price	Surplus	Price	Surplus	Price	Surplus	Eligibility	Activity	Type of bid
1	170	20	-350	240	180	340	140	0	80	0	140	12	12	Standard
2	190	30	-350	360	60	380	100	10	70	30	110	12	8	Standard
3	225	32	-350	384	36	450	30	34	46	100	40	8	12	Relaxed
4	235	34	-345	408	12	470	10	63	17	125	15	8	12	Relaxed
5	235	36	-345	432	-12	470	10	87	-7	125	15	8	8	Standard
6	250	36	-335	432	-12	500	-20	97	-17	165	-25	8	0	Zero bid

A1.86 The clock rounds end after Round 6 due to no excess demand and the auction progresses to the supplementary bids round. The bidder's highest bids on each of its packages in the clock rounds are detailed below.

**Table A1.23: Highest bid on each package submitted in the clock rounds**

Round	Package	Bid amount (£m)	Type of bid
1	1	240	Standard
4	3	63	Relaxed
5	4	125	Standard

A1.87 The bidder wishes to raise its bids on each of its packages to its valuation of each package. Below we examine whether this is possible, given the final price cap and the relative caps.

### Final price cap

A1.88 Since the bidder submitted a zero bid in the final clock round, the final price cap applies to every package the bidder is interested in. The final price cap restricts bids to the final round price of that package, plus the amount by which the final clock price package is raised, which is necessarily £0m in this case as it is not permitted to increase the zero bid. This means that in this case the final price cap restricts the amount the bidder can bid on any package to the round price of that package in the final clock round. It therefore imposes the following final price cap restrictions:

- £432m on Package 1
- £500m on Package 2
- £97m on Package 3
- £165m on Package 4

### Relative cap

A1.89 As the bidder had enough eligibility points to submit a standard primary bid on Packages 2 and 4 at the start of the final clock round, there is therefore no relative cap restriction on these packages. The bidder is able to submit bids of £480m on Package 2 and £140m on Package 4, given that these bid amounts are below the final price cap restrictions.

A1.90 Package 3 requires a higher number of eligibility points than the bidder has at the start of the final clock round. This results in a relative cap of £120m on Package 3 (the calculation is

the same as case 1 paragraph A1.61), which is less binding than the final price cap of £97m. The bidder is able to submit its valuation for Package 3 as this is £80m.

A1.91 Package 1 requires a higher number of eligibility points than the bidder has at the start of the final clock round. This results in a relative cap of £470m on Package 1 (the calculation is same as case 1 paragraph A1.63), which is less binding than the final price cap of £432m. The bidder is able to submit its valuation for Package 3 as this is £420m.

### Summary of supplementary bids

A1.92 The table below summarises the bids and caps that were applicable in the supplementary bids round.

**Table A1.24: Summary of the final price cap, relative cap and bid amount on each package**

Package name	Number of 700 MHz lots	Number of 3.6 GHz lots	Number of C lots	Final Price Cap (£m)	Relative Cap (£m)	Bid amount (£m)
1	0	12	0	432	470	420
2	2	0	0	500	-	480
3	0	12	1	97	120	80
4	2	0	1	165	-	140

### Implications of the positive price constraint on the final price cap

A1.93 The final price cap restricts bids to the final round price of that package, plus the amount by which the final clock package is raised. An implication of the positive price constraint (that bid amounts must be at least £0.001m) is that certain packages may have a looser final price cap relative to the case where all final round prices are positive. Specifically, this would apply to a package that has a round price of £0.001m in the final clock round, due to the sum of the 'underlying' clock price being less than this amount.

A1.94 For the packages that were converted to £0.001m, the final price cap would restrict bids to £0.001m plus the amount by which the the final clock package is raised. An example of this would be:

- Suppose that the underlying clock price of a Package X in the final clock round is -£30m (calculated by simply adding together the clock prices of each spectrum lot and coverage obligation in the package). This would be converted to £0.001m.
- The bidder does not bid on Package X, which results in a final price cap restriction on Package X.
- In the supplementary bids round, the final clock package bid amount is raised by £40m.
- The bidder can submit a bid up to £40.001m (£0.001m + £40m) on Package X in the supplementary bids round. This is higher than if the final price cap applied to the underlying clock price, which would result in a final price cap of £10m (-£30m + £40m).

A1.95 An implication of the bidder being able to bid above the underlying final clock round prices in the supplementary bids round is that some of the effects of the final price cap are altered. For example, when there are no unallocated lots in the final clock round, it might

still be possible for the allocation to change due to the bids made in the supplementary bids round.