OFFICE OF COMMUNICATIONS

Proposed modification to cap on basic supplementary bids in Principal Stage of auction of 2.6 GHz and 2010 MHz bands

Notice of proposal to make regulations

Publication date: 17 October 2008

Closing Date for Representations: 18 November 2008

Contents

Section 1

Summary

Proposed change to cap on basic supplementary bids

1.1 This document gives notice of a proposed modification to the cap on basic supplementary bids as set out in regulation 19 of the draft 2.6GHz auction regulations (relating to the award of 2500-2690 MHz and 2010-2025 MHz), as published for consultation on 4 April 2008.[1] It provides formal notice to stakeholders of Ofcom's proposal to make regulations which will incorporate the proposed modification set out in this document. The general effect of the proposed modification is set out in section 2.

1.2 In summary, we are proposing to replace the existing absolute cap on basic supplementary bids with a relative cap. This should have the effect of encouraging bidders to reduce demand in the primary bid rounds of the auction in line with their marginal valuation of the spectrum. We explain this more fully in Section 2. The change to the text of the relevant regulation is set out in annex 1, and some worked examples of the effect of the proposed change are set out at annexes 2, 3 and 4.

1.3 We remain satisfied that the draft auction regulations published for consultation on 4 April 2008 set out an efficient auction design which meets our statutory duties in particular to secure the optimal use of the spectrum.

1.4 However, since the timing of the auction has effectively been delayed as a result of the ongoing litigation brought by T-Mobile and O2 in respect of the award of the 2.6GHz spectrum, we consider that it is appropriate to propose this modification now. In particular, as it is now unlikely that we will be able to hold the auction before the end of this year at the earliest, we will be in a position to make a decision on this proposal in advance of the earliest likely starting date for the auction. The auction timetable therefore is unaffected by this proposed modification.

1.5 We believe that the proposed modification has a number of benefits, in that it:

1.5.1 would address a concern raised by one stakeholder that the UK auction could oblige bidders to reveal information on their spectrum valuations that might then put them at a disadvantage in subsequent 2.6GHz spectrum auctions elsewhere in Europe; and

1.5.2 has a number of other advantages which flow from the fact that the outcome of the Principal Stage of the auction would likely be closer to the position at the end of the primary bid rounds than would be the case under the absolute cap. In particular, it should make the auction results more readily understandable.

1.6 We plan to hold a seminar on the proposed change to the cap on supplementary bids on Wednesday 5 November 2008, at Riverside House from 10 am. We plan to then hold a mock auction over the internet, using the proposed relative cap on Tuesday 11 November. If you would like to attend the seminar and/or take part in the mock auction, you should inform us by Friday 31 October by sending an email explaining which event(s) you would like to participate in to 2GHzawardsconsult@ofcom.org.uk.

[1] http://www.ofcom.org.uk/consult/condocs/2ghzregsnotice/

1.7 Hard copies of the proposed modification to the regulations can be obtained from:

Brice Le Cannu
Ofcom
Floor 3
Spectrum Policy Group
Riverside House
2a Southwark Bridge Road
London SE1 9HA

E-mail: 2GHzawardsconsult@ofcom.org.uk
Tel: 020 7783 4503

1.8 We are inviting representations on the proposed modification to the cap on supplementary bids by 18 November 2008.

1.9 Representations should either be emailed to: 2GHzawardsconsult@ofcom.org.uk in Microsoft Word format, or may alternatively be posted or faxed to Brice Le Cannu at the above address.

1.10 We usually publish representations made to us on our website, www.ofcom.org.uk. If you consider that your representations should be kept confidential, please specify what part or whether all of your response should be kept confidential, and specify why. Please also place such parts in a separate annex.

1.11 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and will try to respect this. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

1.12 Please also note that copyright and all other intellectual property in representations will be assumed to be licensed to Ofcom to use. Ofcom's approach on intellectual property rights is explained further on its website at http://www.ofcom.org.uk/about/accoun/disclaimer/.

Section 2

Proposed modification to cap on basic supplementary bids

2.1 The proposed modification to the cap on basic supplementary bids needs to be viewed within the context of the overall auction design which was described in section 7 of our Statement published on 4th April 2008. The auction is divided into two main stages:

- a Principal Stage in which generic paired lots and generic unpaired lots in the 2.6 GHz band, together with the 2010 MHz band, are assigned to winning bidders; and
- an Assignment Stage in which these generic paired and unpaired lots are converted into specific frequency assignments in the 2.6 GHz band.

2.2 The Principal Stage has a combinatorial clock phase (the "primary bid rounds") during which bidders indicate a package of lots that they would be prepared to buy at the prices announced in each round ("round prices"), with these prices being raised from one round to the next until there is no longer excess demand. The bids made during the course of the primary bid rounds constitute the bidders' "primary bids". Once the primary bid rounds have come to an end, bidders can submit supplementary bids that differ from their primary bids in terms of their bid amount and / or in terms of the package of lots which are the subject of the bid. The outcome of the Principal Stage of the auction is determined by taking the combination of bids (that can fit into the available spectrum) for which the highest aggregate amount has been bid, selected from all of the bids submitted, whether these are primary bids or supplementary bids.

2.3 The detailed auction rules were set out in the draft regulations on which we consulted when we published the Statement on 4th April 2008. Draft regulation 19 defined a cap on the amount of each basic supplementary bid. In summary, this draft regulation had the effect of capping the amount that could be bid for packages which were of larger size (in terms of eligibility points[2]) than the package bid on in the final primary bid round (which we refer to as the "final primary round package"). The draft regulation did not impose a cap on basic supplementary bids made for packages that were the same size as, or smaller than, the size of the final primary round package. We refer to this cap as the "absolute cap" since the cap is independent of the amount of any other supplementary bids that a bidder might make.

[2] The "size" of package is defined by reference to the number of eligibility points that attach to that package (see Table 7, p. 167 of the Statement). So, for example:

- a package containing four paired 2.6GHz lots (2x20MHz) has 8 eligibility points associated with it;
- a package containing seven contiguous unpaired 2.6GHz band lots (35MHz) and the 2010MHz lot also has 8 eligibility points associated with it – and so is of the "same size" as the package above;
- a package containing 6 paired lots, or 2x30MHz, has 12 eligibility points associated with it – and so is "larger" than the packages above; and
- a package containing seven contiguous unpaired 2.6GHz lots (35MHz) only has 6 eligibility points associated with it – and so is "smaller" than the packages above.

2.4 The modification that we are now proposing relates solely to the specification of this cap on basic supplementary bids[3]. It does not affect the definition of the cap on additional supplementary bids set out in regulation 20 of the draft regulations published on 4th April 2008; these bids remain capped by the amount of their corresponding basic supplementary bids.[4]

2.5 Specifically, we are proposing a modified specification which we refer to as a "relative cap". We use the term "relative" because the modified cap would, in general, make the cap on the amount of the supplementary bid for one package dependent on the amount of the supplementary bid for an associated package in a manner described below.

2.6 The proposed modification does not change the auction design which we set out in the Statement. Similarly, it does not change the Winner Determination rules (and the winner and price determination software that we published on 26th September[5] remains equally valid).

2.7 This section now sets out:

- a reminder of the absolute cap as specified in the draft regulations published on 4th April 2008;
- a description of the proposed modification to the cap;
- an explanation of the impact of the relative cap on bidding incentives during the primary bid rounds; and
- an explanation of the reasons for proposing this modification to the cap on supplementary bids.

The absolute cap on basic supplementary bids

2.8 In order to explain how the modification proposed below relates to the absolute cap set out in the draft regulations published on 4th April 2008, it is helpful to describe the operation of the absolute cap on supplementary bids in the following terms:

- supplementary bids for packages which are of the same size as, or smaller than, the final primary round package, would be uncapped; but
- supplementary bids for larger packages would be subject to the following cap, where "SB" represents the amount of the supplementary bid for a given package.

$$SB \leq RP$$

2.9 In order to explain the term "*RP*" we use two concepts: the "constraining round" and the "constraining round prices".

[3] A basic supplementary bid (which can be referred to, colloquially, as an "unsplit" bid) is one in which any unpaired 2.6GHz lots included in the package are for a single range of contiguous lots. This is different from an additional supplementary bid (referred to as a "split bid") which is made for a package in which unpaired 2.6GHz lots are for two ranges of contiguous lots, one in the upper part of the band and one in the lower part of the band.

[4] References in this document to "supplementary bids" therefore refer only to basic supplementary bids.

[5] http://www.ofcom.org.uk/radiocomms/spectrumawards/awardspending/award_2010/wdpsoft2609/

"Constraining round"

2.10 Each supplementary bid has a "constraining round" associated with it; this is the last primary bid round in which the bidder had enough eligibility[6] to have submitted a primary bid on the package for which it now wishes to submit a supplementary bid.

2.11 For example, if a bidder reduced its demand from a package of 6 paired lots (which corresponds to 12 eligibility points) in round 16, say, to a package of 4 paired lots (which corresponds to 8 eligibility points) in round 17, then the constraining round for a supplementary bid on any package that has between 12 and 9 eligibility points associated with it would be Round 17 (e.g. round 17 would be the constraining round for a supplementary bid on a package of 6 paired lots or on a package of 5 paired lots or, indeed, for a package combining 3 paired lots and 4 unpaired lots, should the bidder wish to make such a bid).

2.12 The point is that the bidder would have been able to submit a primary bid for any of these packages in Round 17 if they had wanted to, but chose not to do so; and from Round 18 onwards it is no longer allowed to submit a primary bid on these packages.

"Constraining round prices"

2.13 We refer to the round prices that applied in the constraining round as the "constraining round prices".

"RP"

2.14 *RP* is then the total price of the basic supplementary bid at the constraining round prices that applied in its associated constraining round.

2.15 In other words, under the absolute cap, a supplementary bid is capped by the highest amount that the bidder could have placed on the package of lots included in that supplementary bid, when it was last eligible to make a primary bid for that package (i.e. at the constraining round prices).

Proposed modification to regulation 19 - relative cap on basic supplementary bids

2.16 The proposed relative cap on basic supplementary bids is defined in the modified draft of regulation 19 attached at annex 4. The essential changes from the absolute cap are as follows.

- The *only* supplementary bid which is now uncapped is the supplementary bid made on the final primary round package.
- Supplementary bids for *all other* packages are capped in accordance with the formula:

$$SB \leq RP + B - P$$

[6] i.e. in the previous round the bidder had bid on a package of lots to which sufficient eligibility points attached.

"Constraining package", *P* and *B*

2.17 The term *RP* is the same as in the case of the absolute cap (i.e. the total price of the package at the round prices when the bidder was last eligible to bid on that package).

2.18 We now introduce the term "constraining package" to refer to the package actually bid on in the relevant constraining round. The terms *P* and *B* both relate to this constraining package.

2.19 *P* is the amount that the bidder actually bid on this constraining package in the constraining round.

2.20 *B* is the highest bid that the bidder submits for this constraining package at any point in the auction. In most, if not all, cases this will be its supplementary bid for the constraining package. But if the bidder did not submit such a supplementary bid, then *B* would be the amount of the bid made in the last primary bid round in which the bidder chose to bid on this constraining package.

Operation of cap

2.21 In the case of packages that are larger than the final primary round package,[7] the effect of the modified specification is to adjust the cap by an amount equal to *B – P*. This adjustment represents the amount by which the bidder ultimately *increased* its bid for the constraining package, over and above the amount that it bid for this constraining package in the constraining round itself.

2.22 In the case of supplementary bids for packages that are of the same size as, or are smaller than, the final primary round package, the effect of the modified specification is to introduce a cap where there was none previously. The operation of the cap for packages that are the same size or smaller than the final primary round package can be understood by noting that:

- the constraining round is the final primary bid round, the constraining round prices are the prices in the final primary bid round and the constraining package is the final primary round package;
- *RP* is the total price of the supplementary bid package at the round prices that prevailed in the final primary bid round;
- *B – P* is the amount by which the bidder increases its bid for the final primary round package in its supplementary bid (over and above the amount for this package in the final primary bid round itself).

2.23 Annex 5 includes a simple example of how to calculate the relative cap.

Effect of proposed modification on bidding incentives in the primary bid rounds

2.24 Although the proposed modification relates to the cap on supplementary bids, the main change in incentives relates to bidding during the primary bid rounds. The paragraphs below consider the incentives under each version of the cap from the point of view of a bidder that wishes to submit full value bids on all the packages in which it is potentially interested (thereby maximising its chances of winning a

[7] This means all packages in the case of a bidder that dropped out before the final primary round.

package that it would be happy to win). For this bidder the "safe bidding strategy" is one that ensures that it is able to reflect its full spectrum valuation in all its bids.

Absolute cap

2.25 For those packages which are subject to the absolute cap, a supplementary bid can not exceed the total price (*RP*) that would attach to this package at the round prices in its associated constraining round. Consequently, if the value to the bidder of this package were higher than *RP* then the absolute cap would prevent the bidder from submitting a full value supplementary bid on this package. The only way to avoid this happening is for the bidder not to bid for a smaller package in a round whilst there is a still a larger package which remains profitable at the round prices. In other words, the safe bidding strategy is to bid on the *largest profitable* package[8].

Relative cap

2.26 Under the relative cap the safe bidding strategy is to bid in each primary bid round on the package which is *most profitable* at the prices announced in that round. The rationale for this is explained below but can be summarised as follows.

- If a bidder bids on the most profitable package in the final primary bid round, then it can be sure of being able to submit full value supplementary bids on packages that are *smaller* than (or the same size as) the final primary round package. However, since bidders do not know in advance of a round whether it will turn out to be the final primary bid round, the safe bidding strategy from this perspective is to bid on the most profitable package in all rounds (see paragraphs 2.29 and 2.30).

- A strategy of bidding on the most profitable package in each round is equivalent to dropping demand through the primary bid rounds in line with the bidder's marginal valuation of lots (see paragraphs 2.31 and 2.32).

- If the bidder drops demand in line with its marginal valuation of lots (or, more specifically, so long as it does not drop demand at a faster rate than this) then it will also be able to submit full value supplementary bids on packages which are *larger* than its final primary round package (see paragraphs 2.33 to 2.35).

2.27 In consequence, if the bidder adopts a strategy of bidding on the most profitable package in each round, then it will be able to submit a complete set of full value supplementary bids for all packages, whether these packages are smaller than, the same size as, or larger than the final primary round package. Meanwhile, the bidder is able to submit a full value bid for the final primary round package itself since this bid is uncapped.

2.28 In order to explain why this is so, it is helpful to reconsider the formula for the relative cap on the amount of the supplementary bid, "*SB*" which is, as set out above:

$$SB \leq RP + B - P$$

2.29 Consider first the effect of this constraint on supplementary bids for packages that are smaller than the final primary round package. The constraining round for this

[8] For packages that are the same size or smaller than the final primary round package it will clearly be possible to submit full value supplementary bid since these are not subject to a cap.

category of supplementary bids is the final primary bid round itself. The above formula can be re-expressed as:

$$(SB - RP) \leq (B - P).$$

2.30 Both terms on the right hand side relate to the final primary round package; on the basis that the bidder submits a full value supplementary bid for this package, then the term *(B – P)* is equal to the profitability of the final primary round package at the final primary bid round prices. Both terms on the left hand side relate to the supplementary bid package; if the bidder is able to submit a full value bid for *SB*, and does so, then the term *(SB – RP)* is equal to the profitability of the supplementary bid package at the final primary bid round prices. However, the above constraint indicates that this is only possible if *(B – P)* is greater than, or equal to, *(SB – RP)*. In other words, the bidder will only be able to submit a full value bid for the smaller package if the profitability of the final primary round package is greater than, or equal to, the profitability of this smaller supplementary bid package, when assessed at the prices that prevail in the final primary bid round[9].

2.31 More generally, the bidder can ensure that it retains maximum headroom for its supplementary bids on smaller packages by ensuring that the size of *(B – P)* is maximised. By definition, this can be ensured by bidding on the package that is most profitable in each primary bid round in case that round turns out to be the final primary bid round.

2.32 Bidding on the most profitable package in each primary bid round is equivalent to dropping demand in line with the marginal value of lots as prices rise from round to round. This can be understood by observing that when round prices rise above the marginal value for incremental lots then these incremental lots will, by definition, become loss-making. Therefore, continuing to include these loss making lots will reduce the profitability of a package which includes them. Similarly, if the round prices are below the marginal value of incremental lots then these incremental lots will, by definition, be profitable. Accordingly, it would reduce the profitability were these incremental lots to be excluded from the package bid on.

2.33 The position in respect of packages that are larger than the final primary round package can be understood by a further reordering the terms in the above formula as follows:

$$SB \leq B + (RP - P).$$

2.34 This relationship can be understood by recognising that the package for which the supplementary bid is being submitted can be broken down into two components: a core component which contains the same lots as included in the associated constraining package and to which the term *B* relates; and an incremental component which contains the lots which are included in the supplementary bid package, but are excluded from the associated constraining package, to which the term *(RP-P)* relates.

2.35 The term *B* in the formula represents the highest bid actually made for the constraining package; provided that the bidder submits a full value bid for this package, then the equivalent amount can be included for the core component within *SB*. The question is then whether the bidder can also reflect its full value for the

[9] And provided the bidder submits a full value supplementary bid for the final primary round package, which will be the case for a bidder that wants to submit full value bids on all packages.

incremental component in its supplementary bid. In order for it to be able to do so *(RP – P)* must exceed the bidder's valuation of this incremental component. By definition, this will happen provided that the point at which the bidder reduces its demand for the incremental component is a point when the round prices have risen above the marginal value of the lots included within the incremental component. In other words, so long as the bidder reduces demand in line with its marginal value of lots (or, rather, that it reduces demand no faster than this) then it will be able to make full value supplementary bids for all larger packages.

Summary

2.36 In summary, for a bidder that wishes to (a) submit supplementary bids on all packages in which it is interested and (b) submit full value bids on all these packages:

- the safe bidding strategy under the absolute cap would be to bid on its largest profitable package in each primary bid round (which is equivalent to dropping demand when round prices rise above the average value of lots);
- the safe bidding strategy under the relative cap would be to bid on its most profitable package in each primary bid round (which is equivalent to dropping demand when round prices rise above the marginal value of lots).

2.37 If a bidder drops demand in line with marginal value, then it will tend to reduce its demand at lower prices in the primary bid rounds than would be the case when bidding in line with average values.

2.38 The nature of the safe bidding strategy under each of the two caps on supplementary bids is further illustrated by worked examples in annex 6.

Reasons for proposing the modification

2.39 We believe that either specification of the cap on basic supplementary bids should support an efficient auction outcome. This is because:

- both approaches would allow bidders to submit supplementary bids which reflect their full valuations on all packages in which they are interested, provided that they follow a bidding strategy that is appropriate to the cap in question; and
- if all bidders do this, then the highest bid that each bidder makes for each package of interest should be the same under both approaches, and these bids would result in the same winning combination of bids and the same base prices. The only difference between the two approaches would be the sequence in which bidders submit their full set of bids.[10]

2.40 As a result, we would be content to proceed with the auction on the basis of either specification of the cap.

2.41 However, the two caps will have a different effect on the sequence in which bids are submitted. When compared with the bidding behaviour that the absolute version of

[10] Note that if a bidder decides to follow the safe bidding strategy and to bid up to its full valuations, then it could submit exactly the same set of supplementary bids for all packages under either cap. In fact, the effect of the change in cap on supplementary bids would be to change the bidding behaviour during the primary rounds and not the bids submitted in the supplementary bids round itself.

the cap would be expected to encourage, the effect of bidders reducing their demand in line with their marginal valuations of spectrum (as encouraged by the relative cap), would be to:

- cause the primary bid rounds to end at a lower level of prices, and with a combination of bids in the final primary bid round which is likely to be closer to the final outcome for the Principal Stage of the auction, assessed in terms of both the base prices and the combination of winning bids;

- allow bidders that are still bidding at the end of the primary bid rounds to better assess their position relative to all the other bidders and identify the extent to which they have to express their full valuation for spectrum in their supplementary bids (as illustrated in annex 7).

2.42 The second effect referred to above would address a concern raised by a stakeholder in its response to the consultation on the draft regulations which we published on 4th April. This stakeholder was concerned that if bidders were required to reveal their full valuation of 2.6GHz spectrum in the UK auction in order to be sure of winning, then this would be detrimental to their interests in respect of future auctions of the 2.6GHz band in other European countries. Essentially, bidders would be forced to reveal commercially sensitive information about how much they would have been prepared to pay for winning spectrum in the UK rather than the amount they actually had to pay. This would contrast with the position in a conventional SMRA auction (where the lot prices are bid up until there is no excess demand and the prices in the final SMRA round determine directly what the successful bidders pay). Annex 7 explains why the modified cap should help to address this issue, using some simple examples.

2.43 We believe that the modification would have a number of wider advantages.

- The “safe” bidding strategy encouraged by the modified cap (to bid on a bidder’s most profitable package in each primary bid round, and do so under a quantity based activity rule[11]) is likely to be more intuitive and simpler for bidders to execute.

- It should make the outcome of the auction more readily understandable (in that more of the result should be recognisable from the open, competitive process that takes place during the primary bid rounds, with the subsequent addition of supplementary bids to the pool of potential winning bids having less influence on the outcome of the auction).

- If the primary bid rounds end at a lower level of prices then this will translate into a lower deposit requirement for any given proportion of the bidders’ highest primary bid at which the deposit % is set.

[11] In theory it would be possible to use a revealed preference activity rule during the primary bid rounds, noting that this would be compatible with the adoption of a relative cap on basic supplementary bids which, itself, represents a form of revealed preference rule. However, the use of a revealed preference activity rule during the primary bid rounds could increase the complexity of bidding during the primary rounds for any bidder that contemplated a switch in demand between categories of lot. Moreover, the nature of the 2.6GHz award means that the combination of a quantity based activity rule during the primary rounds with the relative cap on supplementary bids is very unlikely to constrain legitimate switching between categories of lot in the supplementary bids round.

- It might improve the nature of price discovery if aggregate demand decreases in line with marginal valuations towards the point when demand equals supply and the primary bid rounds come to an end.

2.44 We consider that the benefits of the modified cap on supplementary bids outlined above are sufficient for us to propose its adoption in place of the cap originally set out in regulation 19 of the draft regulations published for consultation on 4 April 2008.

Question: do you agree with the proposal to modify cap on basic supplementary bids as set out in the revised draft of regulation 19 in annex 4?

Annex 1

Proposed change to regulation 19 – basic supplementary bids

A1.1 This annex sets out the proposed revised text of regulation 19 of the draft regulations which we published on 4 April 2008 to include the proposed relative cap on basic supplementary bids.

A1.2 Save for minor consequential amendments, the regulations published on 4 April 2008 remain otherwise unaffected by the proposed change.

Basic supplementary bids

19.— (1) In order to make each basic supplementary bid a bidder must, on a form provided to the bidder by OFCOM ("supplementary bids form") specify—

(a) whether it wishes the 2010–2025 MHz band to be included in a licence;

(b) in respect of the 2500–2690 MHz band—

(i) the total number of paired lots; and

(ii) the total number of individual lots,

it wishes to be included in a licence; and

(c) an amount in thousands of whole pounds that it is willing to pay for the licence.

(2) Where the bid selection specified in a basic supplementary bid includes individual lots, that selection must include at least two such individual lots.

(3) The bid selection specified in a basic supplementary bid made by a bidder must be such that the total number of eligibility points associated with the basic supplementary bid in accordance with paragraph (9) does not exceed the bidder's eligibility limit for the first primary bid round determined in accordance with regulation 26 and notified to the bidder in accordance with regulation 31(1)(c).

(4) The bid selection specified in a basic supplementary bid made by a bidder may be the same as or different from the bid selection comprised in a primary bid made by that bidder.

(5) The amount of the basic supplementary bid shall be determined by the bidder, subject to the following restrictions—

(a) the amount of the basic supplementary bid must not be less than the total amount of the round prices in the first primary bid round for the individual lots, paired lots and the 2010–2025 MHz band (as appropriate) included in the bid selection specified in that bid;

(b) where the basic supplementary bid is for a bid selection in respect of which the bidder has also made a primary bid, the amount of the basic supplementary bid must be greater than the amount of the highest primary bid made by the bidder for that bid selection;

(c) where—

(i) the bidder did not make a valid primary bid in the final primary bid round; or

(ii) the basic supplementary bid is for a selection of lots that is not the same as the selection of lots specified in the valid primary bid made by the bidder in the final primary bid round,

the amount of the basic supplementary bid must not be greater than the amount "C" determined in accordance with paragraphs (6) and (7);

(6) The amount "C"referred to in paragraph (5)(c) shall be calculated in accordance with the formula—

$$C = RP + B - P$$

where—

“ *RP* ” is the total amount of the round prices in the primary bid round referred to in paragraph (7) for the individual lots, paired lots and the 2010–2025 MHz band (as appropriate) included in the bid selection specified in the basic supplementary bid;

“ *B* ” is, where the bidder made a valid primary bid in the round referred to in paragraph (7), the amount of the highest valid principal stage bid made by the bidder for the same selection of lots as specified in that valid primary bid; otherwise zero; and

“ *P* ” is, where the bidder made a valid primary bid in the round referred to in paragraph (7) the amount of that valid primary bid; otherwise zero.

(7) The primary bid round referred to in paragraph (6) is the latest primary bid round in which a primary bid made by the bidder for the bid selection specified in the basic supplementary bid could have satisfied the restriction set out in regulation 16(6).

(8) A bidder may submit any number of basic supplementary bids in the supplementary bids round, subject to the restriction set out in paragraph (10).

(9) The number of eligibility points associated with a basic supplementary bid shall be a number equal to the total of the eligibility points associated with each individual lot, paired lot and the 2010–2025 MHz band (as appropriate) included in the bid selection specified in that bid in accordance with Schedule 7.

(10) A bidder may not submit more than one basic supplementary bid for each particular bid selection.

(11) A bidder is not required to submit a basic supplementary bid.

Annex 2

Short example of calculation of the relative cap on basic supplementary bids

A2.1 In this annex, we provide an example of how to calculate the relative cap on supplementary bids, in accordance with cap's description set out in section 2 and annex 4.

A2.2 We develop the example on the basis of a bidder that is interested primarily in unpaired lots. We also include an example of the cap calculation for a package that includes lots in all three categories.

A2.3 The bidder's profile is as per the table below.

Table 1: Bidder valuations

Size of package - Number of unpaired lots (including one restricted lot)	Size of package - Eligibility points	Total value of package to bidder (£)	Incremental value per lot of a change in package size (£ per additional lot)	Average value of lots across the package (£ per lot, rounded)
0	0	0	-	0
7	6	1,820,000	260,000	260,000
9	8	2,240,000	210,000	248,889
13	12	2,620,000	95,000	201,538
17	16	2,860,000	60,000	168,235

A2.4 Let us assume that:

a) the bidder follows a strategy of bidding on its most profitable package throughout the primary bid rounds (and only bids on unpaired lots); and

b) the final round is round 7 when prices are £95,000 for the 2010 MHz lot, £140,000 per unpaired lot and £280,000 per paired lot.

A2.5 Table 2 summarises the assumed prices and the bidder's activity in the primary bid rounds. Please note that the prices chosen in this example are purely illustrative.

Table 2: Round prices and bids in the example

Round number	Price for 2010MHz lot	Price per unpaired lot (£)	Price per paired lot	Number of unpaired lots in package bid on	Amount of primary bid	Value of package to bidder	Pay-off on package
1	100,000	50,000	100,000	17	850,000	2,860,000	2,010,000
2	110,000	70,000	140,000	13	910,000	2,620,000	1,710,000
3	119,000	98,000	196,000	9	882,000	2,240,000	1,358,000
4	127,000	107,000	214,000	9	963,000	2,240,000	1,277,000
5	134,000	117,000	234,000	9	1,053,000	2,240,000	1,187,000
6	138,000	128,000	256,000	9	1,152,000	2,240,000	1,088,000
7	145,000	140,000	280,000	9	1,260,000	2,240,000	980,000

A2.6 The bidder's bid in the final primary round is for 9 unpaired lots. The amount of its basic supplementary bid on that package is therefore uncapped and we will assume that it bids its full value of £2,240,000 for this package of 9 lots.

A2.7 We now consider an example of calculation of the relative cap for a package that is larger than the bidder's final primary round package, for example a package that includes 13 unpaired lots.

- We first identify the constraining round for this package. This is round 3 since this is the last primary bid round in which the bidder could have bid for a package of 13 unpaired lots.
- We next identify the constraining package. This is the package that the bidder bid on in the constraining round, which in this example is the package containing 9 unpaired lots.
- The bidder has now made a supplementary bid of £2,240,000 (its full value) for this constraining package of 9 unpaired lots.
- The cap on the package of 13 unpaired lots is therefore as follows.

  $C = RP + B - P$

  $C = (0,13,0)x(119\,000, 98\,000, 196\,000) + 2,240,000 - 882,000$

  $C = 2,632,000$

  - in round 3, the constraining round, the prices were
    £119,000 for the 2010MHz lot,
    £98,000 per unpaired lot, and
    £196,000 per paired lot;
  - $(0,13,0)x(119\,000, 98\,000, 196\,000) = 13 \times 98,000$ is the price of the supplementary bid package at the round price of the constraining round;
  - £2,240,000 is now its highest bid on 9 unpaired lots, i.e. the package that the bidder bid on in the constraining round in which it was last eligible to bid on 13 unpaired lots; and

- £882,000 is the amount of the primary bid in the constraining round.

A2.8 Next consider the cap on smaller packages. In this example there is only one such package which includes 7 unpaired lots. The relative cap for this smaller package is as follows.

- The constraining round for this package is the final primary bid round (round 7), and the constraining package is the final primary round package (9 unpaired lots).
- The bidder has made a supplementary bid of £2,240,000 (its full value) for this constraining package of 9 unpaired lots.

C = RP + B – P

C = (0,7,0)x(145 000, 140 000, 280 000) + 2,240,000 + – 1,260,000

C = 1,960,000

- in round 7, the constraining round, the prices were
  £145,000 for the 2010MHz lot
  £140,000 per unpaired lot; and
  £280,000 per paired lot;
- (0,7,0)x(145 000, 140 000, 280 000) = 7 x 140,000 is the price of the supplementary bid package at the round price of the constraining round;
- £2,240,000 is now its highest bid on 9 unpaired lots, i.e. the package that the bidder bid on in the constraining round; and
- £1,260,000 is the amount of the primary bid in the constraining round.

A2.9 Let us assume that the bidder also has an interest in a package that includes different types of lots.

- This package includes the 2010 MHz lot, 3 unpaired lots and 2 paired lots (the "(1,3,2) package").
- The eligibility for this package is 8, i.e. the same eligibility as in the final primary bid round for our bidder.
- The bidder's valuation for this package is £1,980,000. (Given this valuation, the bidder did not bid on this package as part of its strategy to bid on the most profitable package at the round prices in each round.)

A2.10 We can now calculate the relative cap on any supplementary bid for this (1,3,2) package.

C = RP + B – P

C = (1,3,2)x(145 000, 140 000, 280 000) + 2,240,000 – 1,260,000

C = 2,105,000

This is because

- (1,3,2)x(145 000, 140 000, 280 000) is the price of the (1,3,2) package at the round prices of the last primary bid round in which the bidder was eligible to bid on it;
- £2,240,000 is its highest bid on 9 unpaired lots, i.e. the package that the bidder bid on in the constraining round in which it was last eligible to bid on the (1,3,2) package; and
- 1,260,000 is the amount of the primary bid the bidder made in the last primary bid round when it was eligible to bid on the (1,3,2) package (the final primary bid round).

Annex 3

Illustration of the effects of different rules for the cap on basic supplementary bids on the "safe" bidding strategy

A3.1 This annex sets out some worked examples to illustrate how the relative cap and absolute cap constrain the basic supplementary bids that bidders can submit. The examples are designed to show how the choice of bidding strategy in the primary bid rounds affects the basic supplementary bids that a bidder can make as a result of the cap. They highlight that for a bidder to preserve maximum flexibility to make basic supplementary bids that are consistent with its valuations, the bidder would need to adopt different strategies depending on whether the cap is the relative cap or the absolute cap.

A3.2 However, under both caps, if the bidder adopts the right strategy, the examples show that it is able to make a supplementary bid equal to the full value of the package for every package that it is interested in.

Bidder valuations and round prices used in illustrations

A3.3 The illustrations below are based on the example of a bidder which is interested only in unpaired 2.6GHz spectrum and which has the valuations for packages of different sizes set out in Table 3.

Table 3: Bidder valuations used for the examples in annex 6

Size of package - Number of unpaired lots (including one restricted lot)	Size of package - Eligibility points	Total value of package to bidder (£)	Incremental value per lot for a change in package size (£ per additional lot)	Average value of lots across the package (£ per lot, rounded)
0	0	0	-	0
7	6	1,820,000	260,000	260,000
9	8	2,240,000	210,000	248,889
13	12	2,620,000	95,000	201,538
17	16	2,860,000	60,000	168,235

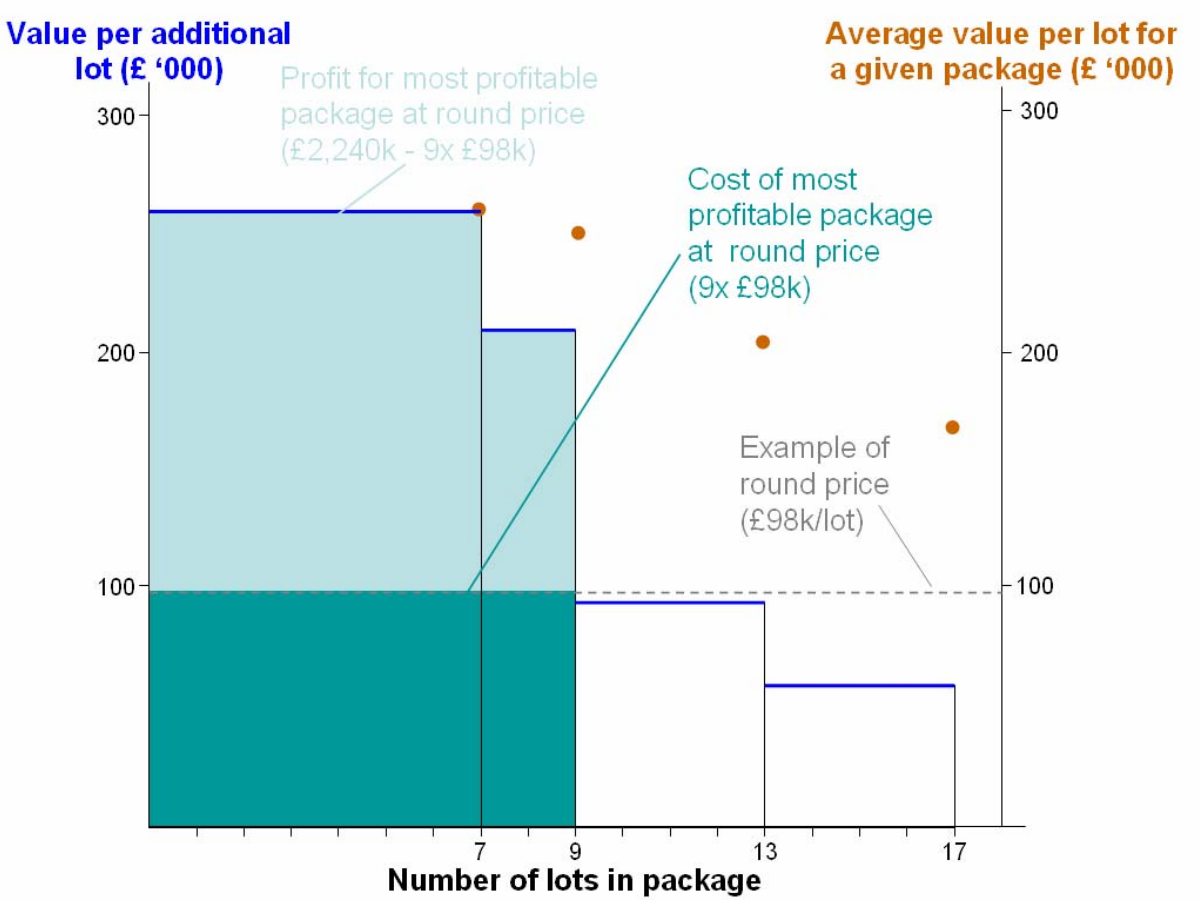
A3.4 In other words, the bidder has a minimum useful package of 7 unpaired lots (6 eligibility points) and this package is worth £1,820,000 to it. The bidder would pay up to £420,000 for an additional two lots (i.e. for a package of 9 unpaired lots as compared with a package of 7 lots), up to £380,000 to go from a package of 9 lots to 13 lots and up to £240,000 to go from a package of 13 lots to a package of 17 lots.

A3.5 These marginal (or incremental) values are shown in terms of the incremental value per lot in Table 3 above. The incremental value of the first 7 lots, which is the smallest package in which the bidder is interested in, is the same as the average value in the case of this specific package. These incremental values go from £260,000 per lot in respect of the first 7 lots in the minimum sized package, to £210,000 per lot for the next 2 lots in addition to the minimum package of interest, down to £95,000 per lot for the next four lots that bring the package to 13 lots and

down to £60,000 per lot for the last four lots that bring the package to 17 lots. The table also shows the average value per lot for each of the packages in the final column.

A3.6 The value of the packages is shown diagrammatically below in Figure 1, where the value and profitability (at a given price per lot) of a package of a given size are represented by areas. For example, at a price per unpaired lot of £98,000, the bidder's most profitable package includes 9 unpaired lots; its cost is £882,000 (the darker shaded area in Figure 1) and the associated profit is £1,358,000 (the lighter shaded area in Figure 1); the total value of the package to the bidder is £2,240,000 (the sum of both shaded areas). At this round price, a larger package of 17 lots would still be profitable given that its average value per lot for that 17 lot package is £168,235, well above the round price of £98,000.

Figure 1: Illustration of the bidder's valuations, most profitable package and profit for an example round price



A3.7 The illustrations that follow set out the bidder's bids given these valuations, for various strategies under the relative cap and under the absolute cap. We use a round price that is set at £50,000 per unpaired lot in the first primary bid round, rises by 40% in the next two rounds and then rises by approximately 10%. Please note that the prices chosen in these examples are purely illustrative, chosen only for the purpose of providing simple examples.

A3.8 Table 4 below sets out for these rounds prices the profit associated with each package that the bidder is interested in. It also highlights in each round which package is the most profitable package and which package is the largest package

that is still profitable. In rounds 1 and 11, the most profitable package and the largest profitable package are the same.

Table 4: Pay-offs at the round prices for the packages of interest to the bidder

Round number	Price per unpaired lot (£)	Package (number of unpaired lots)			
		17	13	9	7
		Pay-off for the package at the round price (£)			
1	50,000	2,010,000	1,970,000	1,790,000	1,470,000
2	70,000	1,670,000	1,710,000	1,610,000	1,330,000
3	98,000	1,194,000	1,346,000	1,358,000	1,134,000
4	107,000	1,041,000	1,229,000	1,277,000	1,071,000
5	117,000	871,000	1,099,000	1,187,000	1,001,000
6	128,000	684,000	956,000	1,088,000	924,000
7	140,000	480,000	800,000	980,000	840,000
8	154,000	242,000	618,000	854,000	742,000
9	169,000	-13,000	423,000	719,000	637,000
10	185,000	-285,000	215,000	575,000	525,000
11	203,000	-591,000	-19,000	413,000	399,000
12	223,000	-931,000	-279,000	233,000	259,000

Key

Most profitable package in that round

Largest profitable package in that round

Both most profitable and largest profitable package in that round

A3.9 We illustrate what would happen under each version of the cap when this bidder follows one of the following three bidding strategies in the primary bid rounds.

a) Bidding on the most profitable package, i.e. bidding on the package for which the difference between the value to the bidder (as per Table 3) and the cost of the package at the round prices is maximised. This is a “safe” strategy under the relative cap.

b) Bidding on the largest package that is still profitable, i.e. at the round prices, bidding the package with the highest eligibility for which the difference between the value to the bidder and the cost of the package at the round prices is greater than zero. This is a “safe” bidding strategy under the absolute cap.

c) A strategic demand reduction strategy whereby, in certain rounds, the bidder bids on packages that are smaller than the most profitable package. The goal behind such bidding strategies might typically be to hide demand, or it might be to end an auction early in the hope of paying less than otherwise for a given package.

Effect of relative cap on basic supplementary bids

A3.10 We now illustrate the implications of adopting these three different bidding strategies with the relative cap in place.

Strategy of bidding on most profitable package (reducing demand in line with marginal valuations)

A3.11 We consider first a bidding strategy in which the bidder always bids on its most profitable package. As prices rise, the bidder reduces the size of the package it is

bidding on as small packages become more profitable than larger packages. The bidder therefore reduces demand in line with marginal value to ensure that it always bids on its most profitable package. Under this strategy, the bidder will reduce demand from 17 lots to 13 unpaired lots in round 2 when the price per lot increases to £70,000 (which is therefore above the bidder's marginal value of £60,000 for each of the four lots that take the package from 13 to 17 lots); from 13 lots to 9 lots in round 3 (when the round price goes above the marginal value of £95,000 per lot for each of the 4 lots that take the package from 9 to 13 lots). The most profitable packages in each round are identified in Table 4 above and the bids are shown in Table 5 below.

A3.12 Let us suppose that the combined structure of demand across all bidders was such that the primary bid rounds ended in round 7 when the price was £140,000 per unpaired lot. In that round, given the price per unpaired lot, the most profitable package for our bidder was a package of 9 unpaired lots, with a profit of £980,000 (equal to its value for the package of £2,240,000 less the cost of the package of 9 x £140,000). All other packages that the bidder is interested in were less profitable at that price per unpaired lot. Our bidder's final primary bid was therefore for a package of 9 lots.

Table 5: Primary bids under strategy of bidding on most profitable package (example where relative cap applies)

Round number	Price per unpaired lot (£)	Number of unpaired lots in package bid on	Cost of this primary bid (£)	Value of package to bidder (£)	Bidder's pay-off on package at round prices (£)
1	50,000	17	850,000	2,860,000	2,010,000
2	70,000	13	910,000	2,620,000	1,710,000
3	98,000	9	882,000	2,240,000	1,358,000
4	107,000	9	963,000	2,240,000	1,277,000
5	117,000	9	1,053,000	2,240,000	1,187,000
6	128,000	9	1,152,000	2,240,000	1,088,000
7	140,000	9	1,260,000	2,240,000	980,000

A3.13 Consider now the effect of the relative cap on supplementary bids. In order to express its preferences as fully as possible, our bidder can do two things in the supplementary bids round:

a) increase the amount of its bids for packages it bid on during the primary bid rounds to its full value for those packages; and

b) create new bids for packages that it has not bid on during the primary bid rounds but for which it has a positive value.

A3.14 We now consider the constraints on our bidder's supplementary bids, given its activity in the primary bid rounds and the relative cap.

- As the bidder placed a bid in the final primary bid round on 9 unpaired lots, it can make a fully uncapped bid for that package. Its highest bid so far on this package in the primary bid rounds was £1,260,000 (i.e. its bid in round 7). This is below its full value of £2,240,000. It therefore makes a supplementary bid of £2,240,000 (its full value) for its final primary round package of 9 unpaired lots.

- It has made a primary bid for a package of 13 unpaired lots. It can increase the amount of its bid for that package to its full value of £2,620,000 since this falls

under the relative cap for that package. We calculate the relative cap for a package of 13 unpaired lots as follows:

£2,240,000 + 13 x £98,000 –£882,000 = £2,632,000, since

- £2,240,000 is now its highest bid on 9 unpaired lots, i.e. the package that the bidder bid on in the round in which it was last eligible to bid on 13 unpaired lots;
- £98,000 was the unpaired lot price in round 3, the latest primary bid round in which our bidder could have bid on a package of 13 unpaired lots but chose instead to reduce demand to 9 unpaired lots;
- 13 x £98,000 is the total price of the supplementary bid package at the round price of the latest primary bid round in which the bidder was eligible to bid on 13 unpaired lots; and
- £882,000 is the amount of the primary bid the bidder made in the latest round when the bidder was last eligible to bid on a package of 13 unpaired lots.

- The bidder has made a primary bid for a package of 17 unpaired lots. It can increase that bid to its full value of £2,860,000 since this falls under the relative cap for that package. We calculate the relative cap for a package of 17 unpaired lots as follows:

  £2,620,000 + 17 x £70,000 - £910,000 = £2,900,000, since

  - £2,620,000 is now the highest bid (as per the supplementary bid above) on 13 unpaired lots, i.e. the package that the bidder bid on when it was last eligible to bid on 17 unpaired lots;
  - £70,000 was the unpaired lot price in round 2, the last primary bid round when our bidder could have bid on a package of 17 unpaired lots but chose instead to reduce demand to 13 lots;
  - 17 x £70,000 is the total price of this supplementary bid package at the round price of the latest primary bid round in which the bidder was eligible to bid on this package 17 unpaired lots; and
  - £910,000 is the amount of the primary bid the bidder made in the latest round in which the bidder was eligible to bid on 17 unpaired lots.

- The bidder has not made a primary bid for a package of 7 unpaired lots. However, it has a value for that package (see Table 3). It can make a bid for a package of 7 unpaired lots of £1,820,000 (its full value) since this falls under the relative cap. For this package the relative cap is:

  £2,240,000 + 7 x £140,000 – £1,260,000 = £1,960,000, since

  - £2,240,000 is the highest bid (as per the supplementary bid above) on 9 unpaired lots, which is the bidder's final primary round

package, i.e. the package that the bidder bid on when it was last eligible to bid on 7 unpaired lots;

- £140,000 was the price in round 7, the last primary bid round when our bidder could have bid for a package of 7 unpaired lots;
- 7 x £140,000 is the total price of the supplementary bid package of 7 unpaired lots at the round prices of the latest primary bid round in which the bidder was eligible to bid on this package of 7 unpaired lots; and
- £1,260,000 is the amount of the primary bid the bidder made in the latest round in which it was eligible to bid on the supplementary bid package of 7 unpaired lots.

A3.15 In other words, as the bidder has followed a strategy of reducing demand in line with its marginal value in the primary bid rounds, the relative cap gives it the freedom to submit basic supplementary bids which reflect its full valuations for all packages in which it is interested. Its full range of preferences will therefore be considered when identifying the winning combination of bids that has the highest amount.

Strategy of bidding on largest profitable package (reducing demand in line with average valuations)

A3.16 Now consider what happens if our bidder were to express its demand by bidding on the largest package that was still profitable in each round at the given round price (i.e. the largest package for which the pay-off is greater than £0). Table 4 above identifies the bidder's pay-off at the round prices and the largest package in each round that is still profitable.

A3.17 Let us suppose that in this case the primary bid rounds finish at round 10 (i.e. later than in the above case since our bidder bids for larger packages, in accordance with this strategy) so that its final primary round package is for a package of 13 lots.

A3.18 Under this bidding strategy, our bidder's activity would be as in Table 6 below. It holds demand at 17 lots until round 9 when the price has risen to £169,000 per lot (i.e. higher than its average value of £168,235 per lot in this package). In rounds 9 and 10, it bids on the largest package that is still profitable of 13 unpaired lots.

Table 6: Primary bids under strategy of bidding on largest profitable package (example where relative cap applies)

Round number	Price per unpaired lot (£)	Number of unpaired lots in package bid on	Cost of this primary bid (£)	Value of package to bidder (£)	Bidder's pay-off on package at round prices (£)
1	50,000	17	850,000	2,860,000	2,010,000
2	70,000	17	1,190,000	2,860,000	1,670,000
3	98,000	17	1,666,000	2,860,000	1,194,000
4	107,000	17	1,819,000	2,860,000	1,041,000
5	117,000	17	1,989,000	2,860,000	871,000
6	128,000	17	2,176,000	2,860,000	684,000
7	140,000	17	2,380,000	2,860,000	480,000
8	154,000	17	2,618,000	2,860,000	242,000
9	169,000	13	2,197,000	2,620,000	423,000
10	185,000	13	2,405,000	2,620,000	215,000

A3.19 As before, our bidder wishes to reflect its full valuations in its supplementary bids in order to maximise its chance of winning a package that it wants. Now consider the possible supplementary bids under the relative cap, which include the following.

- The bidder can make an uncapped bid of £2,620,000 (its full value) for its final primary bid round package of 13 unpaired lots.
- The bidder has already made a bid for a package of 17 unpaired lots. It can increase the amount of its bid on this package to £2,860,000 (its full value) since this falls within the relative cap. For this package, this relative cap is:

  £2,620,000 + 17 x £169,000 - £2,197,000 = £3,296,000, since

  - £2,620,000 is now the highest bid (as per the supplementary bid above) on 13 unpaired lots, i.e. the package that the bidder bid on when it was last eligible to bid on 17 unpaired lots;
  - £169,000 was the round price in round 9, the last round when our bidder could have bid on a package of 17 unpaired lots but chose instead to reduce demand to 13 lots;
  - 17 x £169,000 is the total price of the supplementary bid package of 17 unpaired lots at the round prices of the latest primary bid round in which the bidder was eligible to bid on this package of 17 unpaired lots; and
  - £2,197,000 is the amount of the primary bid the bidder made in the latest round in which it was eligible to bid on the supplementary bid package of 17 unpaired lots.
- The bidder has not made a primary bid for a package of 9 unpaired lots. However, it has a value for that package (see Table 3). It can make a bid for a package of 9 unpaired lots which is now constrained to be a maximum of £1,880,000, significantly less than its full value of £2,240,000, since the relative cap is set at:

£2,620,000 + 9 x £185,000 - £2,405,000 = £1,880,000 since £185,000 was the price in the last primary bid round (when our bidder was last eligible to bid on a package of 9 lots).

- The bidder has not made a primary bid for a package of 7 unpaired lots. However, it has a value for that package (see Table 3). It can make a bid for a package of 7 unpaired lots which is now constrained to be a maximum of £1,510,000, significantly less than its full value of £1,820,000, since the relative cap is set at:

  £2,620,000 + 7 x £185,000 - £2,405,000 = £1,510,000 since £185,000 was the price in the last primary bid round (when our bidder was last eligible to bid on a package of 9 lots).

A3.20 This example highlights that the effect of this bidding strategy, under the relative cap, is to prevent our bidder from submitting full value bids for packages that are smaller than the package on which it bid in the final primary round.[12] It is therefore not able to fully express its preferences in its bids when following this strategy whereas it was able to do so under the first example where it was bidding on its most profitable package in each primary bid round.

Strategic demand reduction (reducing demand faster than marginal valuations)

A3.21 Finally, we consider what happens if our bidder were to adopt the strategy of engaging in strategic demand reduction whereby it reduces demand in the primary bid rounds *before* prices reach the bidder's full marginal value.

A3.22 An example of this bidding strategy is shown in Table 7 below where the bidder reduces its demand to 9 unpaired lots in round 2 (when the most profitable package would be 13 unpaired lots) , and from 9 to 7 unpaired lots in round 6 (when the most profitable package would still be 9 lots). The bidder then maintains its demand at 7 lots in the final primary round, as this is still a profitable package (and it is the smallest package that the bidder is interested in). In this example, we assume that the primary bid rounds end in round 7 when the price for unpaired lots is £140,000 per lot.

[12] In fact, the bidder could increase the magnitude of the relative cap on its bids for smaller packages by submitting an uncapped supplementary bid for its final primary round package that is greater than its full valuation for that package. However, that bid would be unprofitable. In this example, the bidder could increase its supplementary bid to £2,980,000 instead of its valuation of £2,620,000 so as to create the head-room to submit a full-value supplementary bid on a package of 9 lots. But, in doing so, the bidder would risk winning the package of 13 lots at a price which exceeds its value – i.e. it would risk winning a package on which it would make a loss by having to pay more than its full valuation for this package.

Table 7: Primary bids under an example of demand reduction strategy (example where relative cap applies)

Round number	Price per unpaired lot (£)	Number of unpaired lots in package bid on	Cost of this primary bid (£)	Value of package to bidder (£)	Bidder's pay-off on package at round prices (£)
1	50,000	17	850,000	2,860,000	2,010,000
2	70,000	9	630,000	2,240,000	1,610,000
3	98,000	9	882,000	2,240,000	1,358,000
4	107,000	9	963,000	2,240,000	1,277,000
5	117,000	9	1,053,000	2,240,000	1,187,000
6	128,000	7	896,000	1,820,000	924,000
7	140,000	7	980,000	1,820,000	840,000

A3.23 We now consider how the bids in the primary bid rounds constrain the bidder's ability to express its full valuations in supplementary bids. The caps on its basic supplementary bids for the packages of interest are as follows under the relative cap.

- Our bidder can make a fully uncapped bid of £1,820,000 (its full value) for its final primary round package of 7 unpaired lots.

- The bidder has already made a primary bid for package of 9 lots and can consider increasing its bid for that package to its full value. However, its bid for a package of 9 unpaired lots is now constrained to be a maximum of £2,076,000, significantly less than its full value of £2,240,000. For this package, the relative cap is:

  £1,820,000 + 9 x £128,000 – £896,000 = £2,076,000, since

  - £1,820,000 is now the highest bid (as per the supplementary bid above) on 7 unpaired lots, i.e. the package that the bidder bid on when it was last eligible to bid on 9 unpaired lots; and

  - £128,000 was the price in round 6, the last round when our bidder could have bid on a package of 9 unpaired lots but chose instead to reduce demand to 7 unpaired lots.

- The bidder has not made a primary bid for a package of 13 unpaired lots but it has a positive value for that package. Its supplementary bid for that package is now constrained to be a maximum of £2,356,000, significantly less than its full value of £2,620,000. For this package, the relative cap is:

  £2,076,000 + 13 x £70,000 – £630,000 = £2,356,000, since

  - £2,076,000 is now the highest bid (as per the supplementary bid above) on 9 unpaired lots, i.e. the package that the bidder bid on when it was last eligible to bid on 13 unpaired lots; and

  - £70,000 was the price in round 2, the last primary bid round in which our bidder could have bid on a package of 13 unpaired lots but chose instead to reduce demand to 9 lots.

- The bidder has made a primary bid for a package of 17 unpaired lots and can consider increasing this to its full value. However, its supplementary bid for that

package is now constrained to be a maximum of £2,636,000, significantly less than its full value of £2,860,000. For this package, the relative cap is:

£2,076,000 + 17 x £70,000 – £630,000 = £2,636,000, since

- £2,076,000 is now the highest bid (as per the supplementary bid above) on 9 unpaired lots, i.e. the package that the bidder bid on when it was last eligible to bid on 17 unpaired lots; and

- £70,000 was the price in round 2, the last round in which our bidder could have bid on a package of 17 unpaired lots but chose instead to reduce demand to 9 unpaired lots.

A3.24 This example demonstrates that the effect of the relative cap under this demand reduction bidding strategy is to prevent the bidder from submitting full value basic supplementary bids for packages that are larger than the package on which it bid in the final primary round.[13]

Summary of the consequences of the relative cap

A3.25 The following points provide a summary of the effect of the relative cap and the consequence it has for the choice of bidding strategy in the primary bid rounds.

a) A "safe" bidding strategy under the relative cap is for a bidder to bid on the package which is most profitable in each primary bid round given the prices in that round. This is a "safe" strategy in that, provided that the bidder has a clear view of its preferences and that these do not change during the auction, the bidder will always be able to submit supplementary bids for all packages in which it is interested, and be able to do so at amounts that reflect the full value of these packages to the bidder.

b) If bidders depart from this safe bidding strategy, then they risk being unable to submit full value supplementary bids on packages that:

   o are larger than the package they bid on in the final primary bid round, in the case where they engage in strategic demand reduction (reducing demand faster than would be required by marginal valuations);

   o are smaller than the package they bid on in the final primary bid round, in the case where they maintain demand for longer than would be required by marginal valuations (e.g. bid on the largest package that is still not loss-making as opposed to bidding on the most profitable package in a given round).

c) The effect of the relative cap is therefore to encourage bidders to reduce demand in line with their marginal valuation of lots as the prices increase from round to

[13] In fact, the bidder could increase the magnitude of the relative cap on its bids for larger packages (and incidentally smaller packages at the same time) by submitting an uncapped supplementary bid for the package of its final primary round bid that is greater than its full valuation for that package. However, that bid would be unprofitable. In this example, the bidder could increase its supplementary bid on its final package of 7 lots to £1,984,000 (instead of its full value of £1,820,000) so as to create the head-room to submit a full value supplementary bid on a package of 9 lots etc. But, in doing so, the bidder would risk winning the package of 7 unpaired lots at a price which exceeds its value – i.e. making a loss.

round. Expressed another way, it encourages bidders to bid on their most profitable package at any given set of prices.

Consequence of adopting different bidding strategies under the absolute cap

A3.26 We now illustrate the implications of adopting the same three bidding strategies with the absolute cap in place. We use the same bidder with the same valuations as set out in Table 3.

Strategy of bidding on most profitable package in each primary bid round (reducing demand in line with marginal valuations)

A3.27 We start by reconsidering the effect of a bidding strategy in which the bidder reduces demand in line with marginal value. The most profitable packages in each round will be as per Table 4.

A3.28 The bidding behaviour in each primary bid round will be the same as in Table 5 above. As before, the bidder will reduce demand from 17 unpaired lots to 13 unpaired lots in round 2 when the price per lot goes to £70,000 (which is above its marginal value of £60,000 per unpaired lot for the 4 lots that take a package from 13 to 17 unpaired lots), from 13 lots to 9 lots in round 3 (when the round price goes above its marginal value of £95,000 per unpaired lot for the 4 lots that take a package from 9 to 13 unpaired lot).

A3.29 For the purpose of this illustration, we assume that the combined structure of demand across all bidders is such that the primary bid rounds now end in round 11 when the price is £203,000 per unpaired lot. This is a later round than in the equivalent example under the relative cap above since the absolute cap will, in general, encourage other bidders to retain demand for longer, for the reasons illustrated in these examples. And where bidders retain demand for longer, the primary bid rounds of the auction will generally last for longer. The final primary bid of our example bidder was therefore for a package of 9 unpaired lots in round 11.

Table 8: Primary bids under strategy of bidding on most profitable package (example where absolute cap applies)

Round number	Price per unpaired lot (£)	Number of unpaired lots in package bid on	Cost of this primary bid (£)	Value of package to bidder (£)	Bidder's pay-off on package at round prices (£)
1	50,000	17	850,000	2,860,000	2,010,000
2	70,000	13	910,000	2,620,000	1,710,000
3	98,000	9	882,000	2,240,000	1,358,000
4	107,000	9	963,000	2,240,000	1,277,000
5	117,000	9	1,053,000	2,240,000	1,187,000
6	128,000	9	1,152,000	2,240,000	1,088,000
7	140,000	9	1,260,000	2,240,000	980,000
8	154,000	9	1,386,000	2,240,000	854,000
9	169,000	9	1,521,000	2,240,000	719,000
10	185,000	9	1,665,000	2,240,000	575,000
11	203,000	9	1,827,000	2,240,000	413,000

A3.30 Consider now the effect of the absolute cap on supplementary bids. Our bidder will wish to submit supplementary bids that reflect its full value. The following constraints apply to its supplementary bids as a result of its bidding strategy.

- As it made a bid in the final primary bid round on 9 unpaired lots, it can make an uncapped bid of £2,240,000 (its full value) for its final primary round package of 9 unpaired lots.

- It has not made a primary bid for 7 unpaired lots but it can make an uncapped supplementary bid for that package, as it is smaller than its final primary round package. It can therefore bid £1,820,000 (its full value) for a package of 7 unpaired lots.

- It has made a primary bid for a package of 13 unpaired lots. It can increase its bid for that package. However, under the absolute cap, its basic supplementary bid for a package of 13 unpaired lots is capped at £1,274,000 since the price was £98,000 per unpaired lot in the round (round 3) in which our bidder was last eligible to bid on that package (but instead chose to bid on 9 unpaired lots). This maximum bid of £1,274,000 is substantially less than its full value of £2,620,000 for this package.

- It has made a primary bid for a package of 17 unpaired lots. It can increase its bid for that package. However, under the absolute cap, its basic supplementary bid for a package of 17 unpaired lots is capped at of £1,190,000 since the price was £70,000 per unpaired lot in the round (round 2) in which our bidder was last eligible to bid on that package (but instead chose to bid on 13 unpaired lots). Again, this is very substantially less than its full valuation of £2,860,000 for this package.

A3.31 In other words, this illustration shows that a bidder who follows a strategy of bidding on its most profitable package (reducing demand in line with marginal values) under the absolute cap is unable to make basic supplementary bids that reflect its full valuations for packages larger than its final primary round package. Hence, if the bidder reduced demand during the primary bid rounds before a package becomes unprofitable at the round price (e.g. if they reduce demand in line with marginal valuations rather than average valuations), then the effect of the absolute cap is highly likely to be to prevent the bidder from submitting full value basic supplementary bids on these larger packages.

Strategy of bidding on largest profitable package (reducing demand in line with average valuations)

A3.32 Table 6 above showed how the bidder reduces demand when it bids on its largest profitable package in each primary bid round (i.e. bids in line with its average valuation). This table is reproduced below but we assume in this case that the primary bid rounds last up to round 12, again because other bidders should maintain aggregate demand for longer under the absolute cap.

Table 9: Primary bids under strategy of bidding on largest profitable package (example where absolute cap applies)

Round number	Price per unpaired lot (£)	Number of unpaired lots in package bid on	Cost of this primary bid (£)	Value of package to bidder (£)	Bidder's pay-off on package at round prices (£)
1	50,000	17	850,000	2,860,000	2,010,000
2	70,000	17	1,190,000	2,860,000	1,670,000
3	98,000	17	1,666,000	2,860,000	1,194,000
4	107,000	17	1,819,000	2,860,000	1,041,000
5	117,000	17	1,989,000	2,860,000	871,000
6	128,000	17	2,176,000	2,860,000	684,000
7	140,000	17	2,380,000	2,860,000	480,000
8	154,000	17	2,618,000	2,860,000	242,000
9	169,000	13	2,197,000	2,620,000	423,000
10	185,000	13	2,405,000	2,620,000	215,000
11	203,000	9	1,827,000	2,240,000	413,000
12	223,000	9	2,007,000	2,240,000	233,000

A3.33 Now consider the possible supplementary bids under the absolute cap. These include the following.

- The bidder can make an uncapped bid on its final primary round package of 9 unpaired lots. Therefore it makes a supplementary bid of £2,240,000 (its full value) for 9 unpaired lots.
- It can also make an uncapped bid for packages that are smaller than its final primary round package, so it bids £1,820,000 (its full value) for a package of 7 unpaired lots.
- It has already made a primary bid for a package of 13 unpaired lots. It can increase that bid with a supplementary bid that reflects its full value of £2,620,000. This is because the absolute cap for that package is £2,639,000 (£203,000 x 13 lots, since £203,000 was the price in round 11 in which the bidder could have bid on this package in the primary bid rounds but chose instead to bid on 9 unpaired lots).
- It has already made a primary bid for a package of 17 unpaired lots. It can increase that bid with a supplementary bid that reflects its full value of £2,860,000. This is because the absolute cap for that package is £2,873,000 (£169,000 x 17 lots, since £169,000 was the price in round 9 in which the bidder could have bid on this package in the primary bid rounds but chose instead to bid on 13 unpaired lots).

A3.34 In other words, the strategy of bidding on the largest profitable package in each round would be a "safe" bidding strategy under the absolute cap in the sense that this approach would allow the bidder to submit full value bids on all packages in which it is interested.

Strategic demand reduction (reducing demand faster than marginal valuations)

A3.35 Under this bidding strategy, the bidder reduces demand faster than would be implied by the marginal value bidding strategy. Table 7 provides an illustration of this strategy. Since the effect of the absolute cap is to constrain basic

supplementary bids under a bidding strategy of reducing demand in line with marginal value (see A6.31 above), it follows that the bidder would face even greater constraints on the basic supplementary bids that it can submit for packages that are larger than the package it bid on in the final primary round. It would therefore be unable to reflect its full valuations, and would only be able to make even lower supplementary bids, for these larger packages.

Summary of consequences of the absolute cap

A3.36 The following points provide a summary of the effect of the absolute cap and the consequence it has for the choice of bidding strategy in the primary bid rounds.

a) A “safe” bidding strategy under the absolute cap is for a bidder to bid on the largest package which is still profitable in each primary bid round (i.e. given the prices in that round). This is a “safe” strategy in that, provided that the bidder has a clear view of its preferences and that these do not change during the auction, the bidder will always be able to submit supplementary bids for all packages in which it is interested, and be able to do so at amounts that reflect the full value of these packages to the bidder. As part of this bidding strategy, the bidder would retain the flexibility to submit uncapped supplementary bids on all packages that are larger than the package bid on in the final primary round.

b) If bidders depart from this safe bidding strategy by reducing demand before a package becomes loss-making at the round prices, then they risk being unable to submit full value supplementary bids on packages that are larger than the package they bid on in the final primary bid round. In particular, they would face this constraint if they were to reduce demand in line with marginal values (i.e. where they bid on the most profitable package). The constraint would be tighter still if the bidder engaged in strategic demand reduction (reducing demand faster than would be required by marginal valuations).

c) The effect of the absolute cap is therefore to encourage bidders to reduce demand in line with their average valuation of lots as the prices increase from round to round. Expressed another way, it encourages bidders to bid on their largest profitable package at any given set of round prices.

Annex 4

Disclosure of valuations in supplementary bids

A4.1 In its response to our statutory consultation of 4 April 2008, one stakeholder expressed concern about the incentive on bidders to reveal their full valuations in the auction, notably through their submission of supplementary bids that are higher than their primary bids. They were concerned about the risk to their position in respect of future auctions of the 2.6GHz band in other European countries arising from the disclosure of a rich set of information through their bids in the UK auction (given the intention to publish all bids upon completion of the UK auction). In the limit, this concern could lead some bidders to bid at less than their full valuations which could, under some circumstances, create a risk to the efficiency of the auction.

A4.2 It was suggested that we address this concern by restricting the publication of information about bids to a minimum amount that is sufficient to demonstrate that the auction outcome was in accordance with the auction regulations. If this was possible, then it might not be necessary to publish the precise amount of all bids.

A4.3 We have considered very carefully whether there could be a subset of information on bids that would be sufficient for an observer to verify the auction results and whether it would be possible to achieve this without disclosing the full amount bid on some packages. However, we have concluded that it would not be possible to guarantee that interested parties would be able to verify the results without full disclosure.

A4.4 We have considered other ways in which the concern about information disclosure might be addressed, such as withholding the release of information, either indefinitely or for a significant period of time, and requiring interested parties to rely on third party verification of the auction results instead of conducting their own validation. However, we consider that it is important to allow all parties interested in the outcome of the award, including all participants in the award, to verify fully the results for themselves. Moreover, we think that it would be undesirable for Ofcom to hold what would then be confidential data of this type for a significant period of time. Our view is that none of these approaches are appropriate.

A4.5 However, we believe that the introduction of the relative cap would help to address the concern expressed above. In order to illustrate why this is so the remainder of this annex sets out two simplified examples that illustrate how the relative cap enables those bidders that are active in the final primary bid round to better assess their position, relative to other bidders, in the supplementary bids round.

A4.6 These examples take the perspective of a bidder that is still active in the final primary bid round (which we label bidder A) and that is concerned about revealing the full valuation for its desired package of 4 lots through its supplementary bid. The purpose of the examples is to illustrate how the relative cap makes it easier for bidder A to assess whether there is an upper limit on the amount that it needs to bid in the supplementary bids round in order to be confident of winning. Where this is possible, bidder A might be able to avoid revealing its full valuation, whilst at the same time not taking undue risk or otherwise affecting the outcome of the auction.

A4.7 The first example assumes that there is only one category of lot. Bidder A needs to consider the implications of another bidder which was still active in the final primary bid round reducing its level of demand in the supplementary bids round.

A4.8 The second example assumes that there are two categories of lots. Bidder A needs to consider the implications of another bidder that was still active in the final primary bid round switching its demand in the supplementary bids round into the category of lots that bidder A wants.

A4.9 In both examples, we start by illustrating the position that bidder A faces when the absolute cap on supplementary bids is in place. We then show how this position changes under the relative cap on supplementary bids.

Example of bids with a single category of lots

A4.10 We assume in this first example that there are 10 lots available and that:

a) the aggregate demand was for 16 lots in all rounds up to and including the penultimate primary bid round;

b) the aggregate demand in the final primary bid round was for 10 lots;

c) bidder A itself bid on 4 lots in both the penultimate and final primary bid rounds.

A4.11 In order to work out an upper limit on what it needs to bid in order to be confident of winning, bidder A can work out all valid combinations of possible bids and then explore the conditions under which the lowest value combination that includes its own supplementary bid will still exceed the highest value combination of bids that does not include its own supplementary bid.

A4.12 Bidder A does not have information on individual primary round bids made by other bidders; nor, of course, does it know what supplementary bids they may submit. However, the greatest threat to bidder A in this example would come from a situation in which:

- only one other bidder, bidder B, was active in the final primary bid round;
- the demand that was dropped between the penultimate primary bid round and the final primary bid round reflected another bidder, bidder C, dropping its demand from 6 lots to zero.

A4.13 Table 10 below lists (along with bidder A's own bids) the packages that bidders B and C would have bid on in the final two primary bid rounds and (a subset of) the packages for which they might make supplementary bids.

Table 10: Packages bid on in example with single lot category

	Number of lots in possible packages bid on		
	A	B	C
Penultimate primary bid round	4	6	6
Final primary bid round	4	6	0
Supplementary bids round	4	6	6
		4	

A4.14 In the explanation below, we use the notation $S_{\text{bidder name(package bid on)}}$ to represent a supplementary bid. For example, bidder B's supplementary bid for a package of 6 lots is $S_{B(6)}$. The price per lot in the final primary bid round is represented as P_F.

A4.15 If bidder A is to win its desired package of $S_{A(4)}$ then it will look to be part of a winning combination that includes its own supplementary bid for 4 lots combined with B's supplementary bid for 6 lots, which has the following combined value.

$$S_{A(4)} + S_{B(6)}$$

A4.16 The relevant competing combination is B's bid for 4 lots combined with C's bid for 6 lots which has the following combined value combined value:

$$S_{B(4)} + S_{C(6)}$$

A4.17 In the explanations below, it is helpful to represent the difference in amount between the two supplementary bids of bidder B in the form of a relationship as follows:

$$S_{B(6)} = S_{B(4)} + \delta_B$$

Consideration of bidder A's position under the absolute cap

A4.18 Under the absolute cap B's bids $S_{B(6)}$ and $S_{B(4)}$ are uncapped. C's bid for $S_{C(6)}$ is capped at $6P_F$.

A4.19 The value of the competing combination of supplementary bids, $S_{B(4)} + S_{C(6)}$ therefore has a maximum value of: $S_{B(4)} + 6P_F$

A4.20 In order for A's putative winning combination, $S_{A(4)} + S_{B(6)}$, to defeat this competing combination, the following condition must be met:

$$S_{A(4)} + S_{B(6)} > S_{B(4)} + 6P_F \quad \text{or}$$

$$S_{A(4)} + S_{B(4)} + \delta_B > S_{B(4)} + 6P_F \quad \text{which simplifies to}$$

$$S_{A(4)} > 6P_F - \delta_B$$

A4.21 It is possible that bidder B could place a very low incremental value on winning the additional 2 lots over and above its core requirement of 4 lots. In addition, the absolute cap imposes no constraint on the value of δ_B (since neither $S_{B(6)}$ nor $S_{B(4)}$ are constrained by the cap). In the limit, therefore, the value of δ_B need be no

greater than zero. Accordingly, bidder A could only be confident of defeating the competing combination if it submits a supplementary bid that meets the condition:[14]

$$S_{A(4)} > 6\ P_F$$

A4.22 In other words, bidder A would have to bid at least 50% above the price per lot in the final primary bid round in this particular example.

Consideration of bidder A's position under the relative cap

A4.23 Under the relative cap:

- B's bid on the package of 6 lots, $S_{B(6)}$, is still uncapped since this was the package that it bid on in the final primary bid round;
- B's bid on the package of 4 lots, $S_{B(4)}$, is now capped at an amount $S_{B(6)} - 2\ P_F$;
- The cap on C's supplementary bid is unchanged at $6\ P_F$.

A4.24 The maximum value of the competing combination of supplementary bids that is of greatest threat to bidder A, $S_{B(4)} + S_{C(6)}$ is now:

$$S_{B(6)} - 2\ P_F + 6\ P_F \qquad \text{which simplifies to}$$

$$S_{B(6)} + 4\ P_F$$

A4.25 In order for A's putative winning combination (which combines A's supplementary bid for 4 lots with B's supplementary bid for 6 lots) to defeat this competing combination, its supplementary bid needs to meet the following necessary and sufficient condition.

$$S_{A(4)} + S_{B(6)} > S_{B(6)} + 4P_F \qquad \text{or}$$

$$S_{B(4)} > 4P_F$$

A4.26 In other words, bidder A can now deduce that it need only increase its bid by a minimal amount above the value of $4P_F$ in order to be guaranteed of winning.[15]

A4.27 The effect of the relative cap is therefore to reduce the upper limit on the amount that bidder A has to bid in order to be confident of winning.

Example of bids with multiple categories of lots

A4.28 We now consider a variant of the above example in which there are two categories of lots available: category i and category ii. As before we assume that there are 10 lots of category i available. We assume that there is only one category ii lot

[14] In fact, it would be possible for δ_B to be negative if bidder B submitted a supplementary bid for a package of 4 lots which was higher than its bid for a package of 6 lots (something which would not be rational at face value, but could happen if bidder B was only really interested in the package of 4 lots and so did not submit a supplementary bid on the package of 6 lots). But in this case, bidder A's putative winning combination would be $S_{A(4)} + S_{B(4)}$ and the condition $S_{A(4)} > 6\ P_F$ would still apply.

[15] Although this example uses simplifying assumptions for illustrative purposes, it can be shown that the introduction of the relative cap will set an upper limit that is no more than a minimal amount above the final primary round bid in all cases where there is a simple, one-category auction (and where aggregate demand in the final primary bid round matches the number of lots available).

available and that it has the same eligibility as a category i lot (as would be the case for the 2010MHz lot and a paired 2.6GHz lot for example).

A4.29 As before, for category i lots:

a) the aggregate demand was for 16 lots in all rounds up to and including the penultimate primary bid round;

b) the aggregate demand in the final primary bid round was for 10 lots; and

c) bidder A itself bid on 4 lots in both the penultimate and final primary bid rounds.

A4.30 In respect of category ii lots, the level of aggregate demand reduced down to the one lot available by the time of the final primary bid round.

A4.31 As before, bidder A does not have information on individual primary bids made by other bidders and it does not know what supplementary bids they may submit. However, consider bidder A's evaluation of the combination of bids summarised in Table 11 below (which is one possible combination of bids that would be compatible with the aggregate demand information available to bidder A).

Table 11: Packages bid on in example with multiple lot categories

	Number of lots in possible packages bid on				
	A	B	C	D	
	cat. i	cat. i	cat. i	cat. i	cat. ii
penultimate primary round	4	6	3	3	1
final primary round	4	4	0	2	1
Supplementary bids round	4	4	3	2	1
		6		3	0
				2	0

A4.32 In this example we adapt the notification used to represent supplementary bids as follows: $S_{\text{bidder name(number of category i lots in package, number of category ii lots in package)}}$. For example, bidder B's supplementary bid for a package of 6 category i lots and no category ii lots is represented as $S_{B(6,0)}$.

A4.33 The prices per lot in the final primary bid round are represented as P_{Fi} and P_{Fii} for category i lots and category ii lots respectively.

A4.34 Taking the above set of possible bids, bidder A would look to the combination of its own supplementary bid for (4,0), B's supplementary bid for (4,0) and D's bid for (2,1) in order to be successful. This can be represented as:

$$S_{A(4,0)} + S_{B(4,0)} + S_{D(2,1)}$$

A4.35 The main threat to A's chance of winning its desired package of 4 category i lots is the competing combination comprising B's bid for (4,0), C's bid for (3,0) and D's bid for (3,0)) which has a combined value of:

$$S_{B(4,0)} + S_{C(3,0)} + S_{D(3,0)}$$

A4.36 In the explanations below, it is helpful to represent the difference in amount between the supplementary bids of bidder D in the form of the following relationship.

$$S_{D(3,0)} = S_{D(2,1)} + \delta_D$$

Consideration of bidder A's position under the absolute cap

A4.37 Under the absolute cap the bids for $S_{B(4,0)}$, $S_{D(3,0)}$ and $S_{D(2,1)}$ are uncapped. B's bid for $S_{B(6,0)}$ is capped at $6P_{Fi}$. C's bid for $S_{C(3,0)}$ is capped at $3P_{Fi}$.

A4.38 The maximum value of the competing combination, $S_{B(4,0)} + S_{C(3,0)} + S_{D(3,0)}$, is:

$$S_{B(4,0)} + 3P_{Fi} + S_{D(2,1)} + \delta_D$$

A4.39 In order for A's putative winning combination, $S_{A(4,0)} + S_{B(4,0)} + S_{D(2,1)}$, to defeat this competing combination, the following condition must be met:

$$S_{A(4,0)} + S_{B(4,0)} + S_{D(2,1)} > S_{B(4,0)} + 3P_{Fi} + S_{D(2,1)} + \delta_D \quad \text{or}$$

$$S_{A(4,0)} > 3P_{Fi} + \delta_D$$

A4.40 The challenge for bidder A is that the amount of δ_D is uncapped and it therefore can not place an upper limit on the amount of its supplementary bid, $S_{A(4,0)}$, above which it can be confident of defeating the competing combination of bids.

A4.41 Equivalent conditions can be derived in respect of all other possible competing combinations of bids. With the absolute cap, the challenge that bidder A faces in respect of competing combinations which include a switch in demand by bidder D out of the category ii lot into an additional category i lot is always that there is no limit on the size of δ_D under the absolute cap.

Consideration of bidder A's position under the relative cap

A4.42 Under the relative cap:

- The cap on B's bid for (6,0) is now $S_{B(6,0)} \leq S_{B(4,0)} + 2P_{Fi}$;
- The cap on C's supplementary bid, $Sc_{(3,0)}$, is unchanged at $3P_{Fi}$; and
- D's supplementary bids for $S_{D(3,0)}$ is no longer uncapped; instead

$$S_{D(3,0)} \leq S_{D(2,1)} + P_{Fi} - P_{Fii}$$

A4.43 The maximum value of the competing combination, $S_{B(4,0)} + S_{C(3,0)} + S_{D(3,0)}$, is:

$$S_{B(4,0)} + 3P_{Fi} + S_{D(2,1)} + P_{Fi} - P_{Fii} \quad \text{which simplifies to}$$

$$S_{B(4,0)} + S_{D(2,1)} + 4P_{Fi} - P_{Fii}$$

A4.44 The condition for bidder A's putative winning combination, $S_{A(4,0)} + S_{B(4,0)} + S_{D(2,1)}$, to defeat this competing combination is therefore that:

$$S_{A(4,0)} + S_{B(4,0)} + S_{D(2,1)} > S_{B(4,0)} + S_{D(2,1)} + 4P_{Fi} - P_{Fii} \quad \text{which simplifies to}$$

$$S_{B(4,0)} > 4P_{Fi} - P_{Fii}$$

A4.45 In other words, bidder A can now deduce a maximum bid value that it needs to place on its supplementary bid in order to meet the above condition. In this case, it only needs to increase its bid by a minimal amount above the value of $4P_{Fi}$ that it had in the final primary round. In the same manner, it can derive a full set of conditions for all the other potential competing combinations of bids.

A4.46 In summary, the effect of introducing the relative cap is that it removes the potential for another bidder that was active in the final primary bid round to place an unlimited value on a supplementary bid which switches demand into the category i lots. In particular, it places an upper limit on the value that can be attached to such a switch where this limit is related to the prices in the final primary bid round.

Summary of implications

A4.47 In these simplified examples a consequence of moving from the absolute cap to the relative cap is that bidder A is better able to work out an upper limit on the amount it might need to bid in order to be confident of being part of the winning combination of bids.

- In the first example, with only one category of lot, the issue under the absolute cap was that there was no constraint on the value of bidder B's supplementary bid for the package which was smaller than the package that B bid on in the final primary bid round. This meant that A needed its own supplementary bid to be well in excess of the prices in the final primary bid round in order to be sure of winning.

- In the second example, with two categories of lots, the potential challenge to bidder A was more severe in that it was not able to derive an upper limit on the value of its supplementary bid that would be required to ensure its success. This was because there was no limit on a supplementary bid of bidder D which included a switch from the category ii lot into the category i lot.

A4.48 By contrast, under the relative cap bidder A was able to establish an upper limit on the amount it needed to bid in order to be successful. Indeed, in these examples it only needed to increase its bid by a minimal amount above the level of its final primary round bid.

A4.49 The circumstances of the 2.6GHz award are clearly more complicated than the simplified examples given above. The fact that there are three categories of lots rather than two will increase the complexity to some extent (albeit that there is a high degree of fungibility between the two main categories, the 2.6GHz paired lot category and the 2.6GHz unpaired lot category). A further complication is that bidders may find it challenging to work out all the possible combinations of bids for unpaired lots, including bids for split allocations of unpaired lots, that can be accommodated within the 2.6GHz band plan (or rather, the number of feasible combinations that a bidder could infer might be very large). The final primary bid round may also be triggered by bidders reducing their aggregate demand to a level which is less than the available supply of lots in the 2.6GHz band. For these reasons it is very unlikely that bidders could simply infer that they would be safe to increase the amount of their bids by no more than a minimal amount from the level of their final primary round bid, as was the case in these simplified examples. Of

course, interested parties would have to consider the specific circumstances of any given auction rather than simply rely on these simplified examples to derive generalisations. Nonetheless bidders may still be able to impute an upper limit on the amount that they need to bid which may be less than the full value that they place on the packages of interest.

A4.50 This is an issue that participants in the 2.6GHz award will need to consider very carefully for themselves if they are concerned about revealing their full valuations in the auction (and so are considering bidding anything less than their full valuations in the supplementary bids round). Nevertheless, the general principles illustrated by the examples above will apply to the 2.6GHz auction. The introduction of the relative cap, in place of the absolute cap, should enable bidders to better assess their position in respect of the supplementary bids round.