Spectrum Usage Rights

Licence verification approaches

Statement

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Section 1

Executive Summary

Context of this Statement

1.1 In December 2007 we published a statement on Spectrum Usage Rights (SURs) which set out modelling as our proposed approach to verify licensees' compliance with SUR licence terms. In that statement we provided an example of how such verification might work but indicated that other cases would need further consideration.

1.2 In January 2008 we published a consultation setting out the additional cases needed along with a proposed approach to each and inviting input as to whether the approaches were appropriate. Following from the responses, we held a number of stakeholder workshops to ensure we fully understood the issues raised by respondents and to collaboratively explore alternatives. Having done so, we are now able to issue this statement.

1.3 This Statement sets out the general outlines of the approach to be adopted where compliance with SUR terms is to be verified. We anticipate that in each particular case, for example each auction where SURs are adopted, that more specific details will be provided, for example including the propagation model to be adopted and precise details on the parameters and process to be used.

Types of modelling needed

1.4 We believe that the types of modelling needed are:

- From one downlink to another adjacent downlink.
- From one uplink to another adjacent uplink.
- From one downlink to an adjacent uplink.
- From one uplink to an adjacent downlink.

1.5 We believe that combinations of these cases can cover situations such as the use of Time Division Duplex (TDD) technology.

1.6 The first of these cases were set out in the SUR statement and is repeated in this statement for ease of reference. The other cases are discussed in this statement.

Uplink to adjacent uplink

1.7 In outline, the approach is to determine for each cell in the test area a representative number of mobiles in the cell and then assign to each a transmit power based on their distance from the base station. The approximate coverage area of the cell is then determined and mobiles distributed evenly across the cell. The total interference from all mobiles to each test point in the measurement area can then be determined using the same propagation model as adopted for the downlink to downlink interference case.

Downlink to adjacent uplink

1.8 In outline, in this case the approach is to sum the interference from each of an operator's base stations at each test point across the measurement area. Both the transmitter and receiver are assumed to be at heights typical for base stations.

Uplink to adjacent downlink

1.9 In outline, in this case the approach is to model the interference occurring at each test point within the test area. This modelling is based on assessing the density and average power of mobiles within the test point and determining the interference caused to multiple points throughout the test area using transmitter and receiver heights typical for mobiles. In practice, a simple formula can be provided such that if the density and average powers are known the interference can be quickly determined without needed to perform modelling.

Section 2

Verification approaches

Introduction

2.1 The SUR Statement set out our preference for compliance to SURs to be verified by modelling. It also gave an example of how that modelling might be performed based on an approach developed and consulted on as part of the "L-Band" award process.

2.2 This Statement extends the modelling approach to all other situations.

2.3 The approaches provided here are intended to be generic to all services and frequencies. As a result, it is not possible to specify particular parameters, such as the particular propagation model to be used. As set out in the SUR Statement, these parameters would be specified at the appropriate time such as during an auction process.

2.4 The cases of geographical interference and downlink to downlink interference have already been presented in the L-Band award consultation and SUR Statement. The text provided there is also presented in this statement for ease of reference.

Terminology

2.5 The *test area* is an area covering at least 10 transmitters. Its size is determined based on how large it needs to be in any given location in order to enclose at least 10 transmitters, as set out in the SUR Statement. Generally, it might be expected to cover many square kilometres.

2.6 *Test points* are smaller locations within the test area. Their size will be set out in the licence and will typically depend on factors such as the resolution of the underlying mapping data. For example, a typical size for a test point might be 50m x 50m. In any test area there may be hundreds or thousands of test points.

Geographical interference

2.7 To verify compliance to a geographical PFD limit, the 'victim' licensee highlights a reference point on the geographical boundary where they believe that interference is occurring. The segment(s) of the geographical boundary that occurs within a radius R[1] from the reference point is then used for assessing compliance.

2.8 The aggregate PFD is determined at test points which can be distributed, for example, on the terrain data resolution used. The test points are expected to be located along the relevant segment(s) of the boundary.

2.9 The actual transmitters of the investigated licensee to be included in the modelling will be specified in the licence terms. In the extreme, all of its transmitters causing signal levels at the boundary higher than the UWB (ultra-wideband) mask (as defined in the European Commission Decision 2007/131/EC) will be considered in the modelling.

[1] The radius R will be specified in the licence.

Downlink to downlink

2.10 To verify compliance to an in-band PFD limit due to a broadcasting or mobile downlink[2] type of service (excluding Time Division Duplex), information such as transmitter location and transmit power is requested from investigated licensees. A simulation is then run over a test area, in a location chosen by the 'victim' licensee. Only the neighbouring licensee's transmitters[3] in the test area will be considered in the modelling. At each of the test points distributed uniformly across the test area, an aggregate PFD value is calculated based on the sum of the predicted interference from each of the neighbour's transmitters at the relevant height which will typically be that of a mobile (eg around 1.5m). The PFD value is based on the transmit power specified, the antenna radiation pattern and the propagation loss as predicted by the propagation model specified within the licence.

Uplink to uplink

2.11 To verify compliance to an in-band PFD limit due to a mobile uplink[4] type of service (excluding Time Division Duplex), the first step is to approximate the number of mobiles and their transmit power. Generally, it is either not possible, or extremely difficult to determine the actual number of mobiles as this varies continuously depending on factors such as mobile location, services used (eg voice or data) and overall interference levels. Hence, we estimate at the time that the licence is written, what a typical maximum[5] number of mobiles per channel would be. For example, for a 3G system we would estimate the maximum number of voice calls that can typically be supported in a cell on a 5MHz carrier. This would be written into the licence as an assumption and no attempt would be subsequently made to verify it in practice. If, through technological progress, the number actually supported on the network increased over time, we would not automatically change the assumed number provided in the licence but might consult with all affected parties to understand whether they wished to see any change.

2.12 In some cases it may be necessary to take into account frequency reuse – ie the fact that not all frequencies are in use in all cells. We will do this by dividing the capacity per channel by an assumed frequency reuse factor. We can then make the simplification of assuming all frequencies are in use in all cells.

2.13 The next step is to determine the coverage area of each of the cells in the test area. At each test point the signal strength from each cell is predicted. If the path loss from at least one cell is less than a maximum set in the licence then the cell providing the strongest signal is taken to be the "serving cell" for that test point, otherwise the test point is considered not to have coverage. The coverage area of a cell is then the sum of all the test points in the test area where it is the serving cell.

2.14 The mobile terminals served by a cell are then evenly distributed within its coverage area. This is done by dividing the number of test points where the cell is the serving cell by the number of mobiles (eg 650 test points divided by 60 mobiles = 10.8) and taking the closest integer value termed *n* (11 in this case). Then working across the

[2] A mobile downlink refers to a case where the base station transmits and the mobile terminal is on receive mode.
[3] Indoor transmitters are excluded from the modelling.
[4] A mobile uplink refers to a case where the mobile terminal transmits and the base station is on receive mode.
[5] This is the maximum number of users that can be supported assuming a fully loaded network across the test area ie all cells in this area are at optimal load points to maximise capacity across the area.

test area in a conventional raster manner[6] a mobile is placed at the centre of every n^{th} test point. If n<1 then more than one mobile is placed at the centre of the test point as needed. For example, if there were 60 test points and 90 mobiles then alternately one and then two mobiles would be placed at the centre of each cell. Where multiple mobiles are placed they are assumed to be collocated.

2.15 Each mobile is assigned a transmit power level based on the predicted path loss to the serving cell. In the licence the assumed maximum transmit power and maximum path loss will be provided. The transmit power is then reduced by the difference between the actual path loss and the maximum path loss. For example, if the maximum transmit power was 25dBm at a path loss of 150dB then if the path loss at a test point was 130dB a mobile transmit power of 5dBm would be used.

2.16 At each test point within the test area, the aggregate PFD at the height of the base station due to the mobile terminals is calculated using an appropriate propagation model as stated in the licence. Due to reciprocity, this model can typically be the same as the one used for the downlink to downlink interference case. If there is a one or more mobiles within that test point then the distance used in the propagation model for this mobile is set to half the width of the test point resolution (eg if the test point is 50x50m resolution then the distance is set to 25m).

2.17 In practice, it is unlikely to be necessary to model the propagation from each mobile since the received signal level will be predominantly composed of the signal from a small number of nearby mobiles. Hence, approximations such as only considering the five closest mobiles could be adopted if desired by stakeholders.

2.18 To verify compliance to an out-of-band PFD limit, the out-of-band PFD can be derived from the in-band PFD according to a method specified in the licence. In some cases, if appropriate, this can be based on the Adjacent Channel Leakage Ratio (ACLR) or the transmitter spectrum mask or other attenuation mask as specified in the relevant standards or alternatively it can be based on actual measurements of a few transmitters.

Mixed downlink and uplink

2.19 There may be situations when it is necessary to consider the interference caused by neighbours operating links of different directions. For example, one operator may be using a band as a downlink while their neighbour is using their band as an uplink. Or the neighbour might be using time division duplex (TDD), effectively using their band as both an uplink and a downlink simultaneously. This section sets out proposals to model these situations to ensure compliance with SUR levels.

2.20 Note that in general significant interference can occur if uplinks and downlinks are operated close to each other in frequency terms. When deriving SURs appropriate PFD levels will be set to reflect this. For example, the PFD that an uplink user is allowed to generate into the receiver of a downlink user might be set to very low levels. As a result of this, the uplink user may create a guard band or take other action to enable them to deliver an economic service while still meeting their PFD limits.

[6] Starting in the top left corner, moving across the top row the returning to the left hand side of the second row and moving across that, etc.

2.21 We firstly consider the two cases of uplinks interfering with downlinks and downlinks interfering with uplinks. We then show how these, coupled with the downlink to downlink and uplink to uplink modelling processes can be used for the case of TDD.

Uplink to downlink

2.22 Imagine the situation where two adjacent operators, OA and OB, are both using their bands for downlink transmissions with given SUR levels. OB now decides to change their downlink to an uplink[7]. In doing so they must respect their SUR levels, ensuring that OA suffers no more interference than would be the case if their link was used as a downlink[8]. The interference mechanism relevant to operator OA is now the interference from OB's transmitting mobiles into OA's receiving mobiles.

2.23 In outline, our proposal for modelling this interference is to determine a representative distribution of OB's mobiles, assign a transmit power to each mobile and then model the interference to a set of locations. Because mobile density can vary from location to location, this process needs to be performed at multiple locations across a test area. This process is now described in more detail.

2.24 The process starts in an identical fashion to the general uplink to uplink case described above by establishing a test area. Operator OB is then requested to provide details of all their base stations within this area. As with the uplink to uplink interference process, a representative number of mobiles will be specified in the licence[9]. Then, as with the uplink to uplink case, the mobiles are distributed evenly across the coverage area of the cell and assigned a transmit power based on the modelled path loss. It is at this point that the process departs from the uplink case.

2.25 Processing then proceeds on a 1km x 1km tile basis. For each tile the number of mobiles within that tile and the average power of those mobiles are assessed. At the time that the licence is issued Ofcom will supply a formula to convert mobile numbers and power levels to PFD numbers. This can simply be used to derive the PFD limits for that tile. This completes the process that would be followed by licence holders. Some additional notes are provided below as to the reasoning that was used to develop this approach.

2.26 The first point of note is that taking the average mobile power within a given tile is a simplification. In practice, mobile power levels will vary, although the variation within a 1km grid square will be less than across larger areas. We have undertaken modelling that suggests that the error associated with taking the average mobile power compared to modelling individual mobiles with different power levels is around 4dB. However, taking average power levels allows the licence holder to make use of the pre-defined formula rather than having to simulate each grid square themselves. In our view, the difference in results is sufficiently small to make this simplification worthwhile.

2.27 The second point is that the approach that we have set out does not model the "clustering" of subscribers that can sometimes occur in a cell – for example if there is

[7] The analysis that follows also applies to an auction where there is a boundary between uplink and downlink usage.
[8] Note that in practice meeting these SUR requirements will impose severe operational restrictions on using the band as an uplink, and an operator would likely seek agreement with their neighbour for modified SURs or choose to set aside some of their band as a guard band.
[9] If this has not been specified, for example, because the licence was initially intended for downlink usage, then the licence holder OB would firstly need to request that Ofcom add this information to their licence.

a sports venue within the cell then on a few occasions a week a high mobile density might be experienced in that area. We have modelled the effect of clustering and found that if around 80% of the subscribers cluster in 20% of the cell that the PFD limits differ by around 1dB from the case of an even distribution. With a more extreme clustering of 90% of subscribers in 10% of the cell the difference only rises to 2dB. Given that clustering will not occur in all cells, and where it does occur it may only be for limited periods of time, it does not seem appropriate to increase the complexity of the modelling in order to accommodate it.

2.28 It is not necessary for a licence holder to understand the process that Ofcom will follow to determine the equation relating mobile density to PFD levels, but this process is described here in outline for completeness.

2.29 We firstly distribute the mobiles evenly across the 1km grid square. We then “walk” a measurement point across the test point in a manner uncorrelated with the mobile distribution process[10]. At a suitable number of evenly spaced points along this walk, the interference from all the mobiles in the grid square is calculated in a manner described shortly. This then gives a distribution of PFD levels. A single value is then taken from this distribution at an agreed level of probability, eg the 95% percentile point. This process is then repeated for different mobile density levels.

2.30 The mobile-to-mobile interference is calculated by determining the distance from the measurement point to each mobile in the grid square and then using an appropriate propagation model to determine the path loss. Coupled with the assumed transmit power, the interference can then be found.

2.31 For example, such a curve is shown as the solid line for one particular case[11] below. This could readily be approximated by a straight line shown as the dotted line in the figure below and the equation for this line supplied in the licence.

[10] For example, if the mobiles are distributed on a square grid then the measurement point might be walked diagonally from one corner to another.
[11] This is based on 100mW transmissions at 2.6GHz.

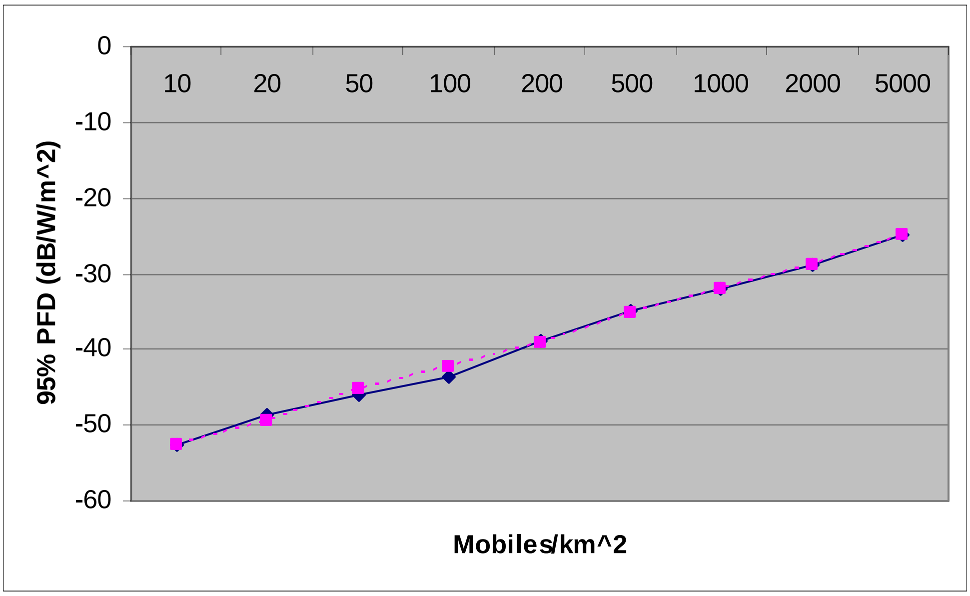

Figure 1: Solid line is modelling of PFD limits for various mobile densities with 100mW transmit power at 2.6GHz. Dashed line is best fit straight line to curve with equation $y=-62.7+10.2 \log_{10}$ (mobile density)

Downlink to uplink

2.32 Consider the situation where adjacent operators OA and OB are using their bands for uplink. Operator OB now wishes to change their use to downlink. As before, OB must not exceed its SURs and so must not cause any more interference to OA than before it made this change.

2.33 The interference mechanism of interest is now from the transmission of the base stations of operator OB into the receivers in OA's base stations. The way that we propose to model this is as follows.

2.34 As before a test area A is established. However, now operator OB is requested to provide the locations and transmit power levels of its base stations. At each test point across area A the interference from OB's base stations is established as follows.

2.35 The propagation loss from each of OB's base stations to the test point is firstly established. This would use a propagation model suitable for the situation where both ends of the link are generally above the clutter as is normal for base stations. The received signal level at each test point is then determined based on the sum of the transmit power and path loss for each base station. This process is repeated for each test point and a distribution of interference obtained from which the SUR parameters can be verified.

Changing an uplink or downlink to TDD

2.36 Now consider the case where operator OA is operating a downlink and operator OB wishes to change their downlink to a TDD link. OB can now potentially cause interference by two mechanisms. The first is downlink-downlink interference and the second is uplink-downlink interference. Both of these can be determined according to the processes set out above and then added together for each test point.

2.37 Similarly, in the case where OA is operating an uplink and OB wishes to change from an uplink to TDD then the interference is comprised of uplink-uplink interference and downlink-uplink interference. As before, both of these can be calculated for each test point and added together.

2.38 When adding the levels of interference from the downlink and uplink components of the TDD transmission the average TDD downlink-uplink ratio should be used to ensure they are added in the correct proportions. For example, if the ratio is 50:50 then both types of interference are halved (to account for the 50% duty cycle) then summed. At the start of the investigation process operators would be requested to provide a typical duty cycle for their network.

TDD adjacent to TDD

2.39 Finally there is the case of SURs for two adjacent TDD users. In this case each operator will be concerned about:

- The interference to the downlink portion of their TDD operation, which comprises downlink-downlink interference and uplink-downlink interference.

- The interference to the uplink portion of their TDD operation, which comprises uplink-uplink interference and downlink-uplink interference.

2.40 The modelling approaches set out above are sufficient to cover these cases.

Directional and adaptive antennas

2.41 There may be cases where antennas are used that do not illuminate the whole cell or sector but instead seek to direct a narrow beam at a receiver. These may be fixed in their direction and beamwidth, for example as used in fixed link systems, or they may be adaptive, changing direction and beamwidth in accordance with subscriber behaviour.

2.42 Directional antennas are also used at the receiver end, for example by rooftop TV antennas. Such an antenna will accentuate the interference received in its direction of pointing but attenuate the interference from other directions. If the interference was evenly distributed around the antenna then the overall effect in terms of interference received by such a directional antenna would be no different from that of an omni-directional antenna. Because our modelling is not sufficiently detailed to account for direction of pointing of receive antennas we therefore make the assumption that the interference is evenly distributed and hence the directionality can be ignored.

2.43 When modelling a conventional downlink the operator is requested to provide the transmitter power and also the antenna pattern of the antennas used such that the signal radiated in any direction can be determined. These antennas may actually be directive – for example they may illuminate a sector of a cell.

2.44 When modelling an adaptive antenna, the antenna is assumed, over a reasonable period of time, to provide even illumination across the sector of the cell which it is serving. The total power delivered into all the antenna elements is assumed to be radiated into this sector. Hence, an adaptive antenna is modelled as a non-adaptive sector antenna where the power radiated is determined based on the total power delivered to all antenna elements.

2.45 For such adaptive antennas the out-of-band power radiated is also determined in the same manner – namely the sum of the out-of-band powers delivered to all antenna elements.

Mobile relay

2.46 In this case a mobile network is using some mobiles to relay the signals from others. This might be, for example, mobiles out of coverage of a base station whose signal is relayed through mobiles within the coverage zone to the base station.

2.47 For simplicity, we propose to assume that the density of the transmitting mobiles outside of the coverage area is lower than that inside – if this were not the case then there would likely be insufficient relaying capacity from the mobiles at the edge of the network. Because the density is of these mobiles is lower then the transmissions from them are unlikely to affect the overall statistics materially, especially where a relatively high PFD percentage such as 95% is adopted. Therefore, we suggest that such activity is ignored for the purposes of SUR calculation. We will review this in future if mobile relaying becomes significant.

Mesh networks

2.48 An extension of the situation set out above is a pure mesh network where there are no base stations and mobile devices communicate between themselves. Our view is that such networks are unlikely to be deployed in licensed spectrum. Instead they would be deployed in licence-exempt spectrum where we do not currently propose to apply SURs. Nevertheless, we give them some consideration here.

2.49 If an operator did decide to deploy such a network it would still need to meet its SUR requirements. In a pure mesh there appears to be no easy way to control the mobile density or transmitted power. Therefore, it appears to us that an operator could not change from an existing licence to this type of deployment and still be able to demonstrate that they met their SUR requirements. However, if an operator wishes to make this change, and believes that they have appropriate mechanisms to control mobile density and transmit powers then we would be willing to work with such an operator to define an appropriate modelling approach for verifying compliance to the SURs.

Annex 1

Responses to the consultation document

Overall

A1.1 In their introductory remarks a number of respondents made general remarks about SURs such as the degree of legal certainty that they conferred. These remarks were outside the scope of this consultation and have, in most cases, been addressed during other SUR consultations. However, where appropriate, we have discussed these issues further with those that raised them in order to understand their concerns in detail and discuss what might be done to address them.

A1.2 There was also a widespread feeling that the issues raised in the consultation were complex and would benefit from more discussion and cooperative study. Based on this we held a series of workshops with respondents to discuss technical issues raised and explore the merit of different possible solutions. The proposals set out in the statement are a result of these workshops.

A1.3 A general concern raised by the broadcasting community was that if there were a licence stated in SUR terms adjacent to an existing service with a more conventional licence this may not afford sufficient protection to the existing service. In particular, they suggested this might be an issue at the boundary of DVB-T transmission and the cleared DDR spectrum in the UHF band. We accept that DVB-T transmission is a special case due to the coverage obligations placed upon the broadcasters and the nature of the service itself and are exploring the need for additional protection to these services as part of the DDR project.

A1.4 One respondent was also concerned that it appeared that requirements were being placed on mobiles that might conflict with other legal requirements such as the R&TTE directive. We think such conflict unlikely. As discussed in more detail below we only wish to establish nominal mobile performance as part of a stage in the calculation process, we will not be conducting measurements to establish whether mobiles conform to these parameters.

Answers to specific questions

Q1: Are there any situations not covered by the modelling approaches suggested here?

A1.5 Respondents did not suggest any completely new situations that had not been covered by the consultation document. However, they did highlight a number of areas within the categories proposed that might need further attention.

A1.6 One thread raised both in this, and some subsequent questions was whether SURs should be applied to indoor transmitters. In previous consultations we had discussed the application of SURs to indoor base stations and concluded that it was impractical to add these into the measurement approach because of the difficultly in modelling indoor propagation. We also noted that none of the existing licensing types such as block edge masks (BEMs) confer any protection from indoor transmitters (other than limiting their maximum power levels to no more than the outdoor transmitters, which is of little value since indoor transmitters are invariably of lower power than the maximum levels allowed for outdoor transmitters). Hence, on balance we concluded that modelling for verification processes should not be applied to indoor base stations and no additional evidence was presented either in response to the consultation or in the subsequent workshops to suggest we change this approach.

A1.7 Slightly different is the approach to indoor mobiles. The approach suggested for the uplink cases simply considers the maximum number of mobiles and their likely density without differentiating between indoor and outdoor mobiles. The sum of the power from the mobiles in each test point as received at the base station is then deduced. This is appropriate because, in principle, when a mobile is using power control, if it is indoors and communicating to an outdoor base station then it will raise its transmit power by an amount equal to the building penetration loss when compared with an outdoor mobile. The interference levels experienced by others will therefore be unaffected, except for those mobiles also in the same building. For this reason, and due to the difficulties in indoor modelling explained above, we also do not propose to take indoor mobiles into account.

A1.8 Another general point raised was whether fixed receivers had been correctly modelled, particularly for the downlink cases. Such fixed receivers might include rooftop TV antennas. This issue is considered specifically in the case of question 3, below.

A1.9 Finally, there were some comments questioning the manner in which out-of-band (OOB) limits could be derived from in-band performance. We generally propose using relevant standards which provide masks from which the out-of-band emissions relative to the in-band emissions can be deduced. Some noted that practical performance can often be materially better than the specification and hence the PFD limits might be unnecessarily restrictive. However, we note that all such numbers are subject to consultation at the time that the SURs are set at which point stakeholders can guide us if they feel that different values should apply.

Q2: Is this proposed methodology appropriate for modelling the uplink-uplink case?

Mobile numbers and power levels

A1.10 There was some concern raised over the concept that operators would supply the maximum number of simultaneous users and their average power levels. Some noted that, for example, 3G systems do not have a set number of simultaneous users, but divide the capacity of a cell between a variable number of users. Also they noted that there is no direct way to determine the average power of a terminal because in a closed loop power control arrangement there is no need for a terminal to report its absolute power to the network. This led to two concerns around firstly how the value of these parameters could be determined and secondly how Ofcom would validate them.

A1.11 We appreciate these difficulties. As a result, we have changed our proposals in this area as discussed in the Statement such that an assumed number of mobiles and transmit power levels are set in the licence and operators are not requested to supply this information.

A1.12 Relevant to this discussion is the comment by one respondent that maximum rather than average mobile power should be used. As the discussion above shows, the maximum power is being adopted – but this is the maximum power that can be allowed per cell rather than the maximum power per mobile. To adopt the maximum mobile power would be to substantially overstate the possible interference that could be caused on the uplink since it would be most unusual for all mobiles in a cell to be transmitting on maximum power. Hence, such an approach would not be appropriate.

A1.13 A final relevant comment made was that the very high density situations such as airports need to be allowed for. If these areas are served by outdoors base stations then our methodology does indeed accommodate them since it would take account of the high base station density needed to serve the mobiles and allocate a correspondingly high mobile density. If these areas are served by indoors base stations, then, as discussed earlier, they will not be accounted for and we see no obvious mechanism within a modelling approach to enable this. We do not see this as a serious shortcoming. Our modelling suggests that if the mobile density increases by an order of magnitude then the PFD levels will rise by just over 10dB. However, indoor cells are characterised by relatively short distances between mobiles and base stations. If power control is used then a 10dB difference equates to a mobile being 100m away from a cell indoors compared to 200m out of doors. On this basis, we expect PFD levels in dense indoor situations to be similar to those in outdoor environments.

Other sources of interference

A1.14 One respondent commented that SUR limits needed to also allow for other sources of interference such as UWB. This is indeed the case, and these “noise” sources need to be allowed for when setting the SUR limits. These can be relatively simply factored into the analysis and will rarely make any significant difference.

Cell coverage areas

A1.15 In our methodology, it is of some importance to approximate the cell coverage area. If, for example, all cells were assumed to cover the same area then this would result in a lower assumed mobile density in areas where there were multiple small cells. In the consultation we suggested that circular coverage areas be assumed based on signal strength models. Some respondents questioned whether this would give a sufficiently accurate result. One suggested that within the test area we assign each test point to the base station providing the highest signal strength. This would then form more accurate coverage areas for each base station. This appears to us to be a superior approach and has been adopted within the Statement.

A1.16 Another respondent commented that sectored cells needed to be accounted for. They are indeed accounted for in our proposal as discussed further in Question 8.

Q3: Is this proposed methodology appropriate for modelling the uplink-downlink case?

A1.17 Many comments were repeated from earlier questions and will not be discussed again here.

A1.18 One respondent suggested that the approach was overly complex, but others thought that it was straightforward, particularly given the ability to pre-calculate the curves. We remain of the view that it is not overly complex and can be readily automated within planning tools or similar.

A1.19 Broadcasters were concerned as to whether fixed receivers were correctly captured. The differences with fixed receivers compared to, eg mobiles are firstly that they are often mounted at a different height such as 10m and secondly that they often make use of directional antennas. A further issue is that with mobile receivers interference can often be transitory while the receiver moves through a high-interference zone whereas with fixed receivers the interference can be longer term.

A1.20 It is first worth noting that the operator suffering the interference (termed "OA" in our consultation) must not suffer any worse interference as a result of the change of use of OB. If, say, OA was a TV broadcaster then the interference that OB could cause would already be specified at an appropriate height and PFD level. Hence, the difference in height is accommodated for when the "random walk" process is followed by using appropriate factors within the propagation model. The directionality in receive antennas is discussed in more detail in Q8, below, but in essence could be included within the random walk process.

A1.21 The difference between interference into fixed and mobile devices is discussed in more detail in Question 5. This is part of a broader discussion as to the impact of different forms of interference of the same average power levels on a range of systems. For example, two forms of interference could be envisaged – one that was constant and another that was "bursty", providing relatively high power levels for say 25ms and then not transmitting for 75ms. If averaged over a relatively long time period (we have previously suggested 3 minutes) then both types of interference might lead to the same PFD values. However, the bursty interference might have a very different effect. For a system with powerful error correction it might be that the burst could be corrected and this type of interference became less problematic than constant interference. For a system with weaker power correction it might be that the burst disrupted a complete frame sufficient for retransmission to be required and that on retransmission the effect was the same such that the communications capability of the channel became worse than for the constant interference.

A1.22 Understanding the impact of different types of interference can often be highly complex due to the interactions between various elements in communications networks such as power control, error correction, variable modulation levels and more. It will tend to be specific both to the technology being used and the technology causing the interference. It is very difficult, therefore, to treat in a technology-neutral manner.

A1.23 As a result of this, our approach to SURs to date has been to consider the interference when averaged over a period long enough to remove aspects such as data bursts but short enough to capture peak traffic levels. It would be possible to add additional conditions to the PFD limits so that as well as average data rates, burstiness could be limited, or variation over longer time periods, such as might be caused by mobiles moving through the environment, could be specified. Clearly there are balances to be struck here – the more items that are specified the greater the protection to neighbouring users but the greater the restrictions to licence holders. Also, there would be a greater burden of modelling or verification needed. This is something that could be consulted on for each specific case with additional limits added where there were heightened interference concerns.

Q4: Is ITU P1411-2 a suitable model to use for this purpose where its frequency range is valid?

A1.24 Respondents were generally of the view that models should be specified on a case-by-case basis and hence it was inappropriate to determine in advance the model that should always be used for mobile-mobile (or more exactly uplink-downlink) interference. We accept this and will suggest models on a case-by-case basis, consulting on the best model where appropriate. One respondent suggested that in some cases much simpler models such as the Hata Model could be adopted. We agree that in many situations this may be adequate.

Q5: Is this proposed methodology appropriate for modelling the downlink-uplink case?

A1.25 A wide range of responses were made to the proposals in this area.

A1.26 One respondent was concerned that base stations may cluster in a given area and that a change of use might have an undue impact while still complying with the SUR. We do not believe this to be the case – any change of use must still result in the same PFD levels at the same percentage of locations and clustering is taken into account in the modelling we are proposing.

A1.27 Another respondent suggested that maximum transmit powers be used. We believe that the maximum transmit powers in terms of the maximum average power delivered during the busiest period should be used, but to use the momentary peak powers over shorter periods could substantively overstate the interference caused.

A1.28 Another respondent suggested that antenna factors such as downtilt should be considered. We agree, and believe these to all be part of the antenna patterns considered in Question 8.

A1.29 One respondent noted that the effect of the interference could be different in that interference caused by mobiles could be transitory whereas interference caused by base stations could be fixed. Simplistically, there might be a change from a situation where most base stations were affected but for short intermittent periods to one where a few base stations were affected but for much longer periods. They suggested that some quality of service (QoS) metric needed to be introduced into the process.

A1.30 This is similar to the discussion in the previous section – the metrics we are currently proposing for SURs do not differentiate between different interference patterns, only absolute levels. If this change in interference type were a serious concern then it would be possible to define additional PFD-related parameters to control it. We also note that, as mentioned in the consultation, changes of use from say and uplink to a downlink are highly unlikely without a change in SUR parameters. This is because the PFD levels applying to, say, a downlink would be so restrictive when applied to an uplink that it would be difficult to offer a viable service. Hence, a licence holder wishing to make this change would typically enter into negotiation with their neighbour over the possibility of changing limits. The impact of any difference in the form of interference could be assessed then.

A1.31 One respondent asked whether operator OA would need to change their calculation method as a result of changes by OB. This is not the case - only the operator that changed their usage would need to change their calculation method. It is worth noting that in this case OA would have been calculating their out-of-band SURs as for uplink usage – ie they would apply at the base station height of OB. Because OB has now moved to a downlink the SURs of OA are now at the “wrong receiver height” for it. However, it cannot expect OA to have to change its calculation method. Instead, if it is important for OB that OA does change its method then it needs to negotiate this change with OA.

Q6: Is this proposed methodology appropriate for modelling the TDD to uplink and downlink cases?

A1.32 One of the key responses here was to ask for more detail on how the interference would be summed. In this case two sets of interference parameters would be calculated for the TDD operator, one relevant to their downlink usage and the other to their uplink usage as discussed in the consultation. These would be calculated at the relevant heights (eg if their neighbour was a mobile downlink user then they would be calculated at 1.5m). They would then be reduced according to the activity factor – so if the downlink:uplink factor was 50:50 each value would be reduced by half (3dB). The factors would then simply be added together. This clarification has been added to the Statement.

Q7: Is this proposed methodology appropriate for modelling the TDD case?

A1.33 Broadly the same issues as for previous questions were raised here. In addition a respondent suggested that different limits might apply if adjacent operators decided to synchronise their networks. Our general approach with SURs has been to assume that adjacent operators do not cooperate but to suggest that if they do that they might wish to agree to modify their SURs to take this into account.

Q8: Is this an appropriate way to model directional and adaptive antennas?

In band

A1.34 Vodafone suggested that the concept of an average beamwidth was not always applicable to some adaptive antennas and that instead an approach based on the total power delivered to each of the elements in the antenna array should be used, averaged over the width of “sector” across which the antenna array was considered to operate. This seems to us to be a sensible approach and we have changed our proposal to reflect this.

A1.35 For all approaches, the antenna pattern in both the horizontal and vertical plain and factors such as downtilt need to be taken into account when supplying the relevant information for each cell.

Out of band

A1.36 A few respondents noted that the out-of-band radiation pattern of an adaptive antenna might not be well aligned with the in-band radiation pattern. We suggest therefore that the same approach as above be adopted, namely that the total out-of-band power fed to the antenna array be averaged over the width of the sector.

Mobiles

A1.37 One respondent noted that it was inappropriate to ignore directional antennas on receivers, for example TV receiver antennas are directional. The effect of a directional receive antenna will be to accentuate the sources of interference within the main lobe of the antenna and reduce the effect of other interferers. Averaged over a number of locations and assuming randomly distributed sources of interference the interference levels seen as a result will be the same regardless of whether a directional or omni-directional antenna is used, however, the variation of interference levels will be greater for the directional case. On the basis that SURs are generally derived to control average interference levels then we believe that in general the use of directional antennas at receivers does not need to be factored into SURs. However, there may be special cases where existing services need particularly high levels of protection and such an average approach might not deliver this. Additional measures or modelling may be required in these cases.

Q9: Is it appropriate not to have a specific approach to modelling the mobile relay case?

A1.38 Respondents suggested that it was appropriate not to have a specific approach at present and that this could be reviewed in future as understanding of relay networks increased.

Q10: Is this an appropriate approach to pure mesh networks?

A1.39 As above, respondents agree that an approach to mesh networks was not needed at this time.