Ultra Wideband

Summary and reaction to responses received to the consultation

Summary document

Issued: 20 June 2005

Section 1

1 Executive Summary

1.1 Introduction

Ofcom published its consultation document on Ultra Wideband (UWB) in January 2005, with a closing date for responses in March 2005. The UWB consultation document asked for views on our proposal that we work with European bodies to achieving a harmonised approach throughout Europe to UWB and consulted on what view we should present to these bodies. This note summarises those responses and presents our reaction to them.

1.2 Conclusions

In summary, the responses to the consultation led us to conclude that the approach that we proposed is broadly appropriate, considering that further study is underway into BFWA and the 2.5GHz band, with the following exceptions:

- The points raised in response to our technical studies require further assessment.
- It would be advantageous to find some means of mitigating interference to BFWA. Most promising appears to be detect & avoid, although this requires further study.
- Further study is needed to confirm that interference into radio astronomy can be mitigated.
- Fixed outdoor deployments should be banned.
- A tighter roll-off below 3.1GHz should be studied to understand the optimal slope.
- Some parameters should be defined, including the minimum peak to average ratios and the ability to turn devices off. Others require further study.

We should also examine the measurement process for UWB devices and clarify a number of detailed parameters around how we will confirm conformance to the mask.

1.3 Next steps

Now that we have consulted and understood better the concerns of key stakeholders, the next step is to input our preferences to CEPT such that these can be considered as part of the process of satisfying the EC mandate. We will develop a position paper setting out our preference, in line with the summary above, and input this to CEPT ECC TG3. We will then remain active within CEPT, with the aim of reaching European consensus as soon as possible, while protecting UK interests.

Section 2

2 Summary of responses

2.1 Outline of the responses

Overall 66 responses were received. The consultation document was strongly supported by around 20 respondents, broadly supported by 12 respondents and broadly criticised by 12 respondents. The remainder took a stance that was overall neutral or only addressed a sub-section of the document.

The essence of the responses was that:

- While most supported our interpretation of our duties, there were some criticisms that the interpretation was more favourable to UWB than should have been the case.
- Most supported the Masons report, but there were a few criticisms.
- A few suggested that we should consider systems not yet invented but most thought this impossible and unnecessary.
- Most agreed, as we had suggested, that there is a possibility of interference with BFWA.
- Conversely, most responses suggest that there may not be a problem with radio astronomy although further studies are needed to confirm this.
- Our assessment of the technical studies was broadly supported. However, some evidence was presented to suggest we should revise this opinion.
- Working at a European level was strongly supported.
- Many comments addressed the mask, covering the in-band power levels, the lower roll-off, the upper roll-off, the lower cut-off, the measurement process and base levels outside of the band specified.
- There were also many comments as to other parameters we might regulate.
- Concerning how to treat UWB in a spectrum framework most thought that a case-by-case approach is appropriate.

2.2 Question-by-question analysis

Q1: The key points we wish to gather opinion on are:

1. Whether it is appropriate for Ofcom to take a regulatory view on UWB.
2. Whether Ofcom has considered all the appropriate evidence and has analysed it correctly.
3. What our preference towards allowing UWB should be.

4. What our strategy should be towards influencing and co-operating with international bodies.

Are these the appropriate topics to be consulting on?

Responses: The appropriateness of these questions was supported by almost all. Some emphasised the importance of working with international bodies.

- One respondent suggested that DS-UWB and OFDM-UWB should be treated quite differently. They argued DS-UWB should be considered under EMC rules whereas OFDM-UWB should be considered under radio regulations.

- A cellular operator noted that the statement in the 3G Information Memorandum on UWB made it essential that Ofcom set out a clear position. They noted that we had not defined what constituted harmful interference and hence did not provide guidance as to when we would act to mitigate or prevent the use of UWB.

- One respondent said that these were the wrong questions and instead Ofcom should ask questions such as whether the UK should introduce UWB now.

Reaction: There were no compelling reasons to suggest that we were consulting on the wrong points. As a result, we conclude that this was an appropriate consultation and that further general consultation is not needed. Most of the specific points raised above are dealt with under the more detailed questions below.

Q2: Do you agree with this analysis of our statutory duties? Are there any important factors that have been omitted?

Responses: We asked respondents whether we had correctly interpreted our statutory duties. Most agreed that we had. Specific responses included:

- One respondent said that meeting our duties required very timely resolution of the issues around UWB. Conversely others argued that we should not proceed until all studies and European activities had concluded.

- One respondent thought we had not correctly interpreted our duties. They argued that firstly, we had not presented evidence to show that interference would not be problematic. Secondly, they judged that if UWB caused interference it could reduce competition in those sectors where it interfered. Thirdly, we had not indicated the weight of each duty and they felt that avoidance of interference should be given a much higher weight than others.

- One respondent thought that we had biased our analysis towards UWB. In particular they noted that 3G operators also created innovation, investment and competition and UWB could weaken all of those.

- One respondent noted that we had concluded that UWB effectively maximised the use of spectrum if it did not cause excessive interference, however, we had not clarified what we considered this to be, nor how we would define appropriate limits. Therefore, we could not demonstrate that we were meeting our statutory duties. They also noted that the cost-benefit work was not yet complete and that we could not draw conclusions on whether the statutory duties were met until both of these points were addressed.

- One respondent said that undue or harmful interference was not an adequate measure. Any interference reduced the data rate and reliability of a fixed satellite link.

- A number of respondents noted that allowing UWB would create innovation in UWB but if it caused interference it might reduce innovation in licensed services such as 4G. They expected the same impact on competition and investment.

- One respondent argued that any emissions by UWB must result in existing spectrum users needing additional spectrum to overcome the interference and so UWB will not result in increased availability of spectrum. (This argument is incorrect - additional infrastructure can also be used to overcome interference.)

- A number of respondents argued that we should take future potential demand for spectrum into account when considering our statutory duties and that UWB could forestall potentially valuable future uses of the spectrum.

Reaction: We accept that, in principle, the deployment of UWB, while generating innovative new applications in its own right, could potentially have a negative impact on innovation in other areas, although we expect this to be slight compared to the potential benefits of UWB. However, we disagree that we have not demonstrated that the interference will not be harmful. We provided a technical assessment that showed that in most cases it would not be harmful and we explicitly addressed the cases where it might. As discussed below, little comment was received on this technical analysis. We agree that we cannot draw final conclusions until the cost benefit analysis is complete and if the final results differ from our current assessment we will revisit our conclusions. We accept that we should take future potential demand for spectrum into account in so far as it can be predicted, and discuss this further below.

In summary, we believe that the overall balance of our duties still remains in favour of UWB.

Q3: Do you agree with the economic study? Are there other studies that Ofcom should be conducting?

Responses: Some disagreed with the study. In particular:

- One respondent noted that the study did not quantify the cost to PMSE, despite there being many PMSE bands within the main UWB frequencies. They requested further study to understand these costs.

- One respondent thought that the fixed service interference should have been calculated for UWB devices in neighbouring buildings, and so closer to the main beam of the link, rather than in the same building.

- One respondent felt that more emphasis could have been given to fixed satellite services and suggested there was an error in the assumptions used.

- One respondent noted that quality of life aspects were not taken into account, affecting areas such as amateur usage.

- One respondent noted that the study must be considered as preliminary until the additional work on BFWA was completed.

- One respondent suggested that the benefits from using UWB as a location device should also be quantified.

- One respondent suggested that the optimistic case for UWB deployment be used. While this results in greater net benefits it also shows greater cost impact on the 3G operators.

- One respondent was very dismissive of the efforts to quantify the costs for FSS and set out many criticisms and possible inaccuracies.

- A number commented on the need to study systems beyond 3G.

- A number indicated that the cost of interference to W-LANs should be taken into account, especially as W-LANs might be used to provide commercial services.

- One respondent indicated that the cost of interference to aircraft-related systems should be taken into account.

- One respondent said that the report was deficient because it does not capture the costs of BFWA and because a zero penetration option, whereby operators prepare for UWB but it does not take off, had not been considered.

- Equally, a number of respondents commented on how comprehensive, enlightening and far-sighted the study was and how it had enabled the debate to be examined on a rational and evidential basis.

- A number noted that given the conservative nature of the study, they expected benefits to be much greater than actually stated. One noted that they expected the interference from UWB to be lower in practice than feared. Another was concerned that the study was overly conservative and might therefore lead to excessively restrictive masks. Some suggested that because other noise sources were not taken into account the interference assessment was unduly pessimistic.

Reaction: The comments broadly fall into the following camps:

- *Areas that were not fully considered*. These include PMSE, FSS, W-LANs, BFWA and systems beyond 3G. PMSE and FSS were considered by Masons but judged not to suffer interference. Further study is underway for BFWA and systems beyond 3G. We decided not to quantify W-LANs because of their licence-exempt status and likely self-interference.

- *Errors in the methodology*. Concerning the suggestion as to an error in the fixed services, we believe that any differences will be small. It is unlikely that the main beam of a fixed link will point into a nearby building and so the interference will still be outside the main beam. While this scenario may increase interference slightly compared to the scenario modelled by Masons we do not believe it will materially change the conclusions. The comment on Monte Carlo simulations has previously been refuted by Masons.

- *Benefits that were not quantified*. None of these appears likely to be large.

- *Comments on the cases used*. Some suggested the best case should have been adopted, others a worse case. While we agree that these would broaden the range of cost-benefits, they would not change the central case on which we believe we should base our policy.

- These were balanced by the many respondents who felt the study was appropriate or even overstated the interference.

In summary, most of these arguments have already been raised and dismissed by Masons. Further study is underway in a number of the areas mentioned by respondents. There does not appear to be sufficient reason to revisit the initial report nor question its conclusions at this stage, bearing in mind that further work is underway in BFWA and the 2.5GHz band.

Q4: Is there a better way that future use of the spectrum could be taken into account?

Responses: Predominantly respondents agreed with our proposals in this area. The manufacturers argued that it was not necessary to take future uses into account as they would develop equipment that would work around UWB if it became a fact of life. Only a minority took the view that nothing should be done to reduce possible longer term developments in mobile, or that some forward prediction was possible.

- One respondent noted that if UWB was allowed it would alleviate the need for licensed spectrum for some of the applications envisaged for 4G. UWB would therefore reduce pressure on spectrum demand for future applications.

- Another noted that they, like many other similar companies, were involved in UWB and expected also to be involved in developing future wireless systems. It would be in their own interests, and under their control, to ensure their compatibility.

- Most simply noted that it was virtually impossible to take longer term developments into account and therefore not worth attempting. Only one took the opposite view that because they could not be quantified, but might be valuable, that UWB should not be allowed.

- Some suggested that just as UWB predictions had been made to 2020, so it should be possible to make some predictions for new systems to a similar date.

- One respondent made the point that spectrum in the 3-5GHz band was ideally suited for BFWA and should be considered differently from eg spectrum in the 6-10GHz band.

Reaction: The overall weight of opinion was that we were doing all we could in this area. Manufacturers suggested they would work around any future deployments. Taking into account our ongoing study in the 2.5GHz band which will cover foreseeable future mobile deployments we are of the view that it would not be beneficial to perform additional work in this area.

Q5: What is the most appropriate solution to the potential interference from UWB to BFWA?

Responses: Many respondents provided detailed responses to this question. Almost all agreed that there was a potential problem.

- Some manufacturers put forward proposals for mitigation including notching and detect & avoid schemes. For example, one proposed that UWB systems could use the 3.1-4.2 GHz band at the PSD limit of -41.3 dBm/MHz only if no other BFWA system is occupying that band. This could be accomplished by specifying appropriate detection requirements and avoidance criteria to ensure proper protection of BFWA systems using the 3.1-4.2 GHz band. They suggested that UWB systems could use the bands above 4.2 GHz at the PSD limit of -41.3 dBm/MHz without needing to search for and avoid BFWA systems.

- Two respondents recommended the best approach was to move UWB above 4.2GHz. In their view, frequencies above 4.2GHz would never be viable for indoor BFWA usage and so the interference impact would be less severe. Another two respondents concluded that the best approach was to move UWB emissions to 6GHz or above.

- One trade association said that if the market for UWB devices was much larger than for BFWA devices then the best approach would be to warn BFWA consumers not to use UWB equipment. They also noted that in the future devices would become better at detecting the presence of other devices and working around them appropriately.

- One respondent said that for location applications many tags would be transmit only and hence would not be able to detect BFWA devices, or create notches. To overcome this they suggest that if devices chose to have "permanent notches" in the BFWA band then they need not be dynamic.

- Another suggested limiting UWB use to low data rate applications in the lower frequency bands.

- One respondent noted that since BFWA systems would likely require careful placement in the home in any case then it was acceptable for the users to also take into account UWB transmitters when placing equipment.

Reaction: The responses clearly show that there is potential for possible interference to BFWA systems. The responses broadly agreed that:

- The guaranteed solution is to move the lower limit for UWB up in frequency to at least 4.2GHz, perhaps even as high as 6GHz.

- Notching might work and is worth further exploration.

- Techniques that required detection of a BFWA signal were a possibility but remained to be proven.

- Requiring the user to change the siting of their devices was probably not appropriate (and strongly resisted by some).

There is an on-going study into BFWA which will further inform our thinking in this area. At present, it appears that there may be mitigation techniques which would reduce the potential for a problem and we would like to see further investigation of these, perhaps through standards or international bodies.

Q6: Would it be possible to achieve sufficient isolation between radio astronomy and UWB through practical methods of physical separation?

Responses: The responses were broadly polarised between the radio astronomy community and all other respondents:

- Many thought that it would be possible to achieve sufficient isolation, given that most UWB devices would be indoors and most radio astronomy antennas would be pointing predominantly upwards. They noted that astronomy sites already protected themselves against out-of-band and spurious interference and that UWB would be little different from this. Some provided specifications showing, eg that W-LAN spurious emissions were higher than proposed UWB emissions.

- One respondent noted that in the case of MERLIN and Methanol line studies in the 6650-6675.2 MHz band, such studies are typically performed at night with narrow channel bandwidths, significantly reducing the effects of wideband or ultra wideband emissions because of pulse desensitization effects. As a result, they thought a perimeter fence restriction would be acceptable.

- One respondent recommended a small levy on each UWB device sold which would be used to provide the astronomy community with funds to mitigate the interference.

- One respondent noted that protecting astronomy at low elevation angles was probably excessive given that, somewhere in the world, there would be an observatory able to monitor the same part of the sky with a high elevation angle.

- Many noted that if the protection requirements stated were real then "radio astronomy would already be impossible" due to the spurious emissions from other devices.

- The astronomy community said that relocation would be impractical and that perimeter fences would not provide sufficient isolation. They claimed that restricting observations to night time would devalue the scientific nature of their research.

Reaction: On the balance of evidence provided there seems a strong likelihood that a means could be found whereby sufficient isolation could be achieved. This might be through the combination of a perimeter fence and a recognition that certain measurements could be performed differently in the case of interference. We will consider further studies to confirm whether this is the case.

Q7: Are there any other options that we should consider?

Responses: We asked whether there were other options we might pursue such as raising the lower frequency limit for UWB from 3.1GHz to, say, 4GHz, or 5GHz.

- Some suggested a limit of 5 or 6GHz.

- Many manufacturers indicated additional cost and delay in moving to higher bands. One said that it would "have a chilling effect" on UWB investment, another noted that propagation was lower at higher frequencies and costs were higher.

- One suggested banning fixed outdoor UWB deployments (a move the FCC have already taken).

- One respondent suggested that a system of "noise credits" could apply whereby those "polluting" had to buy credits and those being polluted sold credits (and used the money to pay for mitigation).

- Another suggested that only part of the band initially be opened up to UWB to allow evidence to be gathered. If there was no excessive interference then more of the band could be made available.

Reaction: Responses on a move to a higher frequency band were polarised. Some, both here, and elsewhere, argued for an increased lower limit. Equally, many of the device manufacturers said that this would increase costs and time to market. On balance, the evidence presented here for an increased lower limit was not compelling although this issue is discussed elsewhere. Concerning the other ideas put forward, banning fixed outdoor deployments appears a possibility. The concept of noise credits is interesting but likely difficult to implement. Opening only parts of the band suffers from the problem that the parts where there is currently equipment are also the parts where there is the greatest potential for interference.

Q8: Are there any major technical studies that we have omitted?

Responses:

- One respondent said that the case of meteorological satellite earth stations in the 7750-7850 MHz is not considered and noted that it would require a –60 dBm/MHz UWB maximum power density limit.

- One provided an additional list of documents for us to consider, which they noted were all supportive of the introduction of UWB.

- A number of respondents noted that there had been more recent studies since the consultation document was issued and argued we should review these.

- One respondent cited three reports on the use of UWB devices on board planes.

Reaction: We did not appear to have missed any substantial technical reports, although new reports have been issued since we published the consultation document.

Q9: Have we made an accurate assessment of the existing studies?

In summary, we received few specific comments in this area. Many agreed that our assessment was "fair and accurate", agreeing with our assessment that many studies were conservative. One noted that given the potentially problematic nature of

the interference, much more detailed study was required rather than what they felt were sweeping statements. Another pointed out that although spurious emissions from other services might be at a higher level, their narrowband nature and low probability of occurrence meant that they were not directly comparable with UWB as we had argued in some cases. One agreed that the studies were pessimistic but felt that this was appropriate in cases where interference might occur.

In a few cases, differences in our assessment and those performed by others resulted from a differing methodology. While many other, including international bodies, had used a criteria of the maximum increase in noise not exceeding 1% of the total acceptable interference (or -20dB), we had looked at the overall effect on the system. We discussed this difference of approach in the consultation document and raised it as a general issue as part of Question 14, discussed in more detail below. Responses to this question suggested that it would be more appropriate to consider interference issues on a case-by-case basis rather than using standard criteria such as 1%. We believe in the case of UWB that the 1% criteria will lead to conservative assessments. Hence, where the comments from respondents relate to the differences between the 1% approach and our approach we have simply noted this below but do not propose to change our assessment as a result.

Specific comments received on each of the areas were:

Fixed Services (Annex 2-1)

We said: A conservative study. In practice, Ofcom does not expect any significant degradation of P-P fixed link services to be attributed to UWB for many years, if at all. We also noted that we would have expected BFWA to have a higher potential for interference than P-P links and asked whether the adoption of a C/(N+I) measure might be a more appropriate way of performing the analysis.

Respondents said: The use of C/(N+I) was inappropriate and I/N should be used.

Reaction: Given that we treat BFWA elsewhere, and there were no other comments on our assessment then we confirm our conclusion that interference to fixed services is unlikely. The issue of the 1% criteria was also raised here.

Mobile satellite services (Annex 2-2)

We said: A conservative study; Ofcom considers that aeronautical and maritime mobile earth stations (MESs) are unlikely to suffer impairment, and no harmful interference into mobile satellite service (MSS) satellite receivers at 1.6 GHz is expected. Land based mobile earth stations are regarded as most sensitive. Ofcom regard this as a conservative assessment with mitigation options available.

Respondents said:

- One commented that the 20m separation distance assumed by Ofcom might not be valid in dense urban areas.

- Another disagreed with the conclusion that this was a conservative study, and emphasised the appropriateness of the “1%” criteria. Detailed arguments were provided.

Reaction: Much of the differences in these assessments relate to the 1% criteria, discussed above. However, we accept that there are a number of possible issues

associated with satellites (see also 2-3 and 2-11, below) and recommend further assessment in this area.

Earth exploration satellite services (Annex 2-3)

We said: This is mostly a conservative study. Passive measurements are shown to suffer some interference, radio altimeter and synthetic aperture radar operations are unlikely to suffer interference; and telemetry/data links with Earth may require the relocation of earth stations to areas with lower population (and thereby lower UWB deployment). If the suggested mitigation is not appropriate Ofcom believes that there is a risk of degradation or loss of some measurements.

Respondents said:

- One commented that the high gain nature of the antenna, while excluding noise outside the beamwidth, enhanced noise within it and so the net effect was neutral.

- Another commented that our mitigation approaches of degrading availability were not appropriate and that a maximum UWB power level of -60dBm was needed to protect satellites.

Reaction: These comments do not change our analysis that there is a risk of interference in some cases, but that in practice there are likely to be some mitigation techniques that will be appropriate. As mentioned above, we recommend further assessment of the interference potential for satellite systems.

Radio astronomy (Annex 2-4)

We said: This study finds that radio astronomy as a high-sensitivity passive service remains incompatible with UWB. Large (40 – 70dB) negative margins remain. There is a potential for interference to measurements from UWB devices operating many kilometres away. Further study is recommended on the interaction of UWB signals with actual radio astronomy measurement scenarios before firm conclusions are reached. Consideration of 'energy-per-bit' of information transferred indicates that UWB devices, with appropriate constraints, could cause less adverse effects than the spurious emissions associated with conventional communications equipment.

Respondents said:

- One considered any relocation options would be too costly.

- Another did not agree with our conclusions, noting that they showed a “lack of understanding”. However, they did not provide any basis for this assessment.

Reaction: We accept that relocation will be costly but consider (see Question 6) that the use of a perimeter fence may provide sufficient isolation.

Digital video broadcasting (Annex 2-5)

We said: This is a conservative assessment and with mitigation techniques the probability of interference is low. Ofcom is proposing using the current levels for EMC emission for UWB devices at frequencies below 1GHz and hence there is unlikely to be an overall effect, particularly where directional antennas are used. Where set-top

antennas are deployed there is an increased risk of interference but this can be mitigated by moving the UWB device or the antenna.

Respondents said:

- One said that it should not be the responsibility of the user to move equipment or otherwise reduce the impact of interference.

- Another said that:

    - Not considering receivers with integral antennas implicitly excludes DVB-H, which seems to be inconsistent with liberalising the use of broadcasting spectrum.

    - Ofcom's analysis of interference when using an internal antenna does not seem to be justified. While most UK consumers use an external antenna, a survey for the ITC in March 2003 found that around 21% of sets were connected to a set top aerial. Therefore, around 40% of households could be affected by UWB interference to DVB-T.

    - It is impractical for most viewers to mitigate interference by moving the set or antenna; this is extremely difficult because the visible effects of interference to DVB change slowly and the interference is unlikely to be constant, and this assumes that the viewer can lift the set.

Reaction: None of these comments impact our overall assessment of the probability of interference. In general, we continue to believe that if UWB emissions are at, or below, EMC levels in this band, the risk of harmful interference remains very low.

In the case of set-top antennas we accept that there is some possibility of interference, but are of the view that this will likely to be similar to that already suffered if devices like poorly-functioning hairdryers, or GSM phones, are operated close to TVs in marginal areas using set-top antennas. UWB does not differ materially from these existing sources of interference, other than its emissions are generally at a lower level, and hence we do not see the need to restrict its emissions even further.

Considering DVB-H, if included in a handheld mobile device the effects of interference might be expected to be similar to that for cellular systems like 3G, which we have demonstrated to be insignificant at these low levels.

Digital audio broadcasting (Annex 2-6)

No responses were received.

Bluetooth (Annex 2-7)

No responses were received.

Radio LANS (Annex 2-8)

We said: This is a conservative study, which concludes that the magnitude of incompatibility depends on the modulation and data rate used. In Ofcom's assessment, there might be slight fallback in data rates in a worst case. Ofcom considers that the probability of this is low and mitigation techniques such can alleviate this.

Respondents said that:

- Although individual RLAN devices operate on a non-interference non-protected basis, it does not follow that the bands in which they operate should not be protected from interference. If the usefulness of the 5GHz RLAN band for its intended purpose was significantly degraded by interference from UWB, this would be contrary to Ofcom's statutory obligation to promote the optimum use of the spectrum.

- The analysis of the effect of the UWB antenna appears to be incorrect. As the UWB emissions are specified as EIRP, the characteristics of the antenna of the UWB device should not have any impact (a distance of 36cm will be in the far field of a UWB antenna at a frequency of 5GHz).

Reaction: We do not believe that we should offer protection from interference in licence-exempt bands. Indeed, it is not possible for us to do so. No guarantees of protection against interference are offered in the 5GHz band, regardless of the use of UWB. It is quite possible for multiple R-LAN systems located in the same area to interference with each other and reduce the economic value of the band to a much greater degree than UWB interference would. Further, experience suggests that different licence-exempt devices can co-exist without significant problems. For example, at 2.4GHz, BlueTooth and W-LAN devices coexist. It is likely that the interference from BlueTooth to W-LAN would be more significant than from UWB and yet this has not prevent widespread use of the band. Although it is possible that UWB may slightly reduce the usefulness of the R-LAN band we believe this will be more than offset by the gain in value from the use of UWB.

We did not make any analysis of the effect of the UWB antenna.

IMT-2000 (Annex 2-9)

There was widespread agreement with our analysis.

Radio navigation satellite services (Annex 2-10)

We said: A conservative to reasonable case study indicating further work is required to consider detailed interactions between UWB and RNSS signals. Ofcom considers that it is likely that already-marginal operation will be degraded, though US studies indicate that better signal processing implemented in GPS receivers already increases their resilience, and all Galileo receivers can be designed to be "UWB-aware". In summary, Ofcom considers that there is some risk of loss of service at the margins of current availability.

Respondents said that the need to interwork with GPS would limit the ability to design UWB aware Galileo terminals.

Reaction: While there may be interoperability requirements, we do not see why this prevents additional receiver processing algorithms that note the presence of higher noise levels and either reduce the accuracy of the position estimation or warn the user of the noise problem. Hence, we have not changed our conclusions.

Fixed satellite services (Annex 2-11)

We said: This represents a conservative study. Ofcom considers that the real situation will not be as pessimistic as depicted in the study, however the absence of viable mitigation options for downlink protection introduces a potential risk to FSS and MSS services. The uplink studies show no significant risk of interference arising.

Respondents said:

- One concluded any relocation options would be too costly. They noted three different antenna sizes were used in the study.

- Another argued that this was an appropriate study and that accepted methodologies had been used. They disagreed with the Ofcom suggestion of errors in the methodology. They suggested that the FCC may soon need to reconsider its regulations in this area.

- Another provided detailed evidence as to why the -41.3dBm level was around 20dB too high. They rejected the analysis that this was a conservative study.

Reaction: The issue of the 1% criteria was also raised here. However, we accept, as we indicated in the consultation document, that the risk of interference remains significant and that there do not appear to be many mitigation techniques that can be used. We are supporting further studies in CEPT Task Group 3, which include:

- An impact analysis initially considering a PSD limit of -55 dBm/MHz.

- A review of FS and FSS studies to identify any additional mitigation techniques which could improve the sharing scenario.

We hope that this process will find some mechanism whereby the risk of interference can be reduced.

Amateurs (Annex 2-12)

We said: This represents a conservative analysis which concludes that there might be significant interference. Ofcom considers that with consideration of additional mitigation techniques such as building obstruction and shielding loss, the real probability of interference is low.

Respondents said:

- The assessment in the Ofcom document of the impact on Amateur stations makes some assumptions that are not explained or justified. It is claimed that amateur stations can use specialised filtering techniques to minimise received interference, but gives no indication of what these techniques may be. Amateur stations do use noise blanking techniques that work with low prf pulse noise, and these could be extended to cope with UWB with a low prf and relatively long gaps between pulses. However, much of the rest of the

consultation document focuses on using high prf to make the signal spectrum approach Gaussian noise.

- The separation requirements published in a number of studies would mean that high levels of interference could be expected in amateur bands at 3.4GHz and 5.7GHz in normal domestic environments. Intermittent use of UWB devices for applications such as downloading pictures from a camera would not pose too much of a problem, but links from TV sources to display devices will be permanently active and thus impossible to mitigate.

We accept that it is not possible to filter a signal once it becomes Gaussian-like and that continuous use of UWB in a nearby domestic environment might potentially cause some problems. However, we expect this to be a rare occurrence that can generally be mitigated by antenna placement and directivity.

Maritime (Annex 2-13)

No responses received.

Aeronautical (Annex 2-14)

We said: This is a conservative study which predicts significant interference and recommends safety margins (often combining to over 20dB) based on actual receiver sensitivities. Ofcom considers that the studies ignore actual operating conditions. International mobility and responsibilities are important considerations. Ofcom considers that there is a risk for some services - particularly primary navigation radars.

Respondents disputed the claim by Ofcom that the aeronautical studies include safety margins in excess of 20 dB. They said that study is bound to be conservative given the safety criticality of the service provided, however only one State has questioned the studies, this has resulted in changes being introduced into the Studies being conducted under ECC TG3 and ITU Task Group 1/8 since the publication of this document. The results of the studies quoted in this document are therefore out of date and should be updated.

Reaction: We accept the need for safety criticality in these applications. However, the fact that only one state has questioned the study does not in itself provide evidence that suggests we should change our conclusions. We continue to consider that there is some risk of interference with primary navigation radars and will be performing further measurements of main beam radar interference to understand this area in detail.

Meteorological radars (Annex 2-15)

We said: This study considers only meteorological radars. It is a conservative study indicating typically 20dB incompatibility with the proposed Ofcom revision to the ETSI UWB mask. The study does not specifically identify that this is largely due to the potential for UWB emitter to be located in a high-gain region of radar beam due to low operating angles of the radars, about which the NTIA study is more conclusive. It will be important to avoid main-beam interaction if UWB is to be compatible with weather radars.

Respondents said:

- One said that, with the US or UK masks, the whole meteorological systems and processes in Europe, from active or passive observations to data broadcasting is under potential threat with regards to UWB. Data presented to CEPT clearly shows that any increase of the interference compared to the radar interference criteria would seriously degrade the performance of the radars (20% loss in coverage for 1 dB noise increase) or make these radars totally unusable for higher interference value. According to the compatibility studies, the OFCOM mask proposal (-41.3 dBm/MHz) would translate in a noise increase of 10 dB that would hence result in a 90% coverage degradation that is to say an almost total loss of the coverage of the radar. Relocating radars is unfeasibly expensive and increasing the elevation angle would reduce the range, having the same effect as UWB interference. They requested maximum UWB power levels of -65dBm at 5GHz and -54dBm at 9.5GHz.

- Another, talking about radar systems in general, rejected the ability to re-site radars or for them to work with a lower elevation angle. They requested instead a 300m absolute exclusion zone and a 20km co-ordination zone where it would be possible for them to prevent specific UWB applications.

These comments underline our conclusions that it will be important to avoid main-beam interaction if UWB is to be compatible with weather radars. We will be performing actual measurement studies on radars to understand the impact in more detail.

Overall reaction

Most agreed that our assessments were accurate, and many commended us on a more realistic assessment than other organisations. However, there are clearly some cases that require further investigation according to the responses received. We will both continue to study these comments internally and also feed them into international bodies such as CEPT where the main study now appears to be taking place. We will also undertake some measurement activities as indicated above.

Q10: Do you agree that we should seek a common European framework for the introduction of UWB?

Responses: All respondents agreed with this. Some pressed for a global standard rather than a European one.

Reaction: We will continue to seek a European framework as a primary goal.

Q11: Have we proposed the most appropriate mask? Will it be possible to deliver equipment conforming to this mask?

Responses: Almost all agreed that we had selected the most appropriate mask. Specific comments were:

- A respondent suggested that while the roll-off was appropriate, there should be lower limits, perhaps 10dB down, between 3GHz and 5GHz.

- Another recommended that the same mask as proposed by ECC TG3 be adopted including a base level of -90dBm outside of the bands specified above.

- Another asked for additional protection between 5GHz and 6GHz.

- Many manufacturers thought the mask was appropriate and noted that they could manufacture equipment to this specification. Indeed, some noted that they had pre-production equipment meeting this specification. However, they noted the possible measurement difficulties in verifying the -85dBm limits. One noted that reducing the levels below -85dBm would add significant cost. Another suggested that measuring below -75dBm would not be practical.

- One respondent noted the need for a more detailed specification. They noted a preference for radiated measurements. They asked that the mask allow for a small number of narrowband spurious emissions. They questioned what measurement points would be used on the slope of the mask. Finally, they suggested a more relaxed roll-off above 10GHz to be symmetrical with the lower roll-off when viewed on a log-frequency scale.

- One respondent suggested it would not be possible to determine technically what was the most appropriate mask and instead a practical approach, avoiding litigation as far as possible, was needed. They suggested that clarifying the rights of incumbents would help in this respect.

- One respondent noted that the lower cut-off was probably extreme from a technical viewpoint but worthwhile if it enabled rapid consensus gathering.

- Some agreed with the -85dBm out-of-band limit but said it should also apply to the 2.5 - 2.7GHz band.

- One respondent noted that the mask was not well defined below 2.1GHz as EMC limits were in flux. They suggested -85dBm to 1.6GHz, -75dBm to 960MHz and CISPR 16 below that.

Some disagreed with the mask:

- One respondent thought that the power levels between 3 and 4.2GHz were too high.

- Others said it did not provide adequate protection to the 2.5-2.7GHz band, to R-LANs, to BFWA and to 4G systems. They proposed increasing the lower limit to 6GHz.

In summary, modifications suggested to the mask were:

- *Changes to the in-band power*. The manufacturers strongly resisted this, claiming (and in some cases proving) that the range would be heavily impacted. However, others suggested this as a compromise, particularly in the 3-5GHz band.

- *Base levels outside of the area shown*. A few suggested limits of either -85dBm or -90dBm outside of the areas shown.

- *Roll-off*. A few commented that the roll-off above 10GHz was overly severe. Some suggested an even steeper roll-off below 3GHz to provide -85dBm in the 2.5-2.7GHz band and some manufacturers mentioned this was viable.

- *Lower cut-off*. Various suggestions were put forwards - 4.2GHz to protect BFWA or 6GHz to protect all future mobile services. Manufacturers almost unanimously were opposed, citing lower range and higher cost at higher frequencies.

- *Notch at 5GHz*. A few suggested the need for a notch between 5GHz and 6GHz to protect W-LANs.

- *Measurement*. A few noted that measuring at -85dBm was difficult and that more details on the exact measurement process were required. Some requested that narrowband spikes above the -85dBm limit be allowed.

Reaction: Considering the points raised:

- *Changes to the in-band power*. Our view is that this is not appropriate. A lower power limit still potentially interferes with applications such as BFWA while preventing UWB achieving a useful range.

- *Base levels outside of the area shown*. We agree with the suggestion of -85dBm to 1.6GHz, -75dBm to 960MHz and CISPR 16 below that.

- *Roll-off*. We do not see a need to change the upper roll-off. Concerning the lower roll off we will discuss with manufacturers the possibility of achieving lower levels by 2.7GHz and will change our proposals if this appears feasible without significant cost.

- *Lower cut-off*. Overall, little additional evidence has been put forward since the Masons study, which concluded that changing the lower cut-off significantly reduced the benefits. By keeping the proposed lower limit but adding detect & avoid functionality it may be that the benefits are retained while avoiding interference.

- *Notch at 5GHz*. We do not currently perceive a need to protect these licence-exempt devices.

- *Measurement*. We will study this issue and provide further guidance in due course.

Q12: To what extent should we define parameters such as those listed above? What is the most appropriate definition for each of these parameters?

Responses: As well as proposing a the mask, we suggested that there are other parameters of UWB devices that, if allowed in the UK, it might be appropriate to define. We asked:

Should there be a minimum pulse repetition factor (PRF)?

- Most suggest that we adopt the same approach as the FCC that the wide-band peak in any 50MHz be limited to a value no more than -41.3dBm.

- One respondent suggested a lower limit of 1MHz as assumed by CEPT.

- Another suggested there should be a lower limit, much higher than the PRF associated with radars in the 5GHz band to prevent false triggering of the DFS system in W-LAN devices.

Should devices that are not linked with other UWB devices ("non-associated device") limit their emissions?

- Most suggest the FCC provisions be adopted.
- One respondent noted that there might be broadcast applications where non-associated devices transmitted and did not wish to see this restricted.
- Others noted that there was no need to regulate this as considerations such as battery life would ensure that it was implemented in any case.

Should there be a mandated ability to turn UWB transmitters off?

- All who responded agreed in principle.
- Some were concerned if there were an ability to switch other devices off remotely that it might be abused.
- One said there needed to be a clear "off" indicator on the device.

Should UWB devices be required to use the minimum power for the data rate and range that they are trying to achieve?

- Almost all who responded agreed and noted this could be highly effective.
- One respondent recommended that the steps in power level not be too small otherwise device costs would rise. They suggested a minimum of 1dB steps.
- Another noted that "minimum power" needed further definition. For example, it might be appropriate to always transmit beacons at full power even if the data transmission was at a lower level.
- A few thought that it would be too complex to regulate and that in practice device manufacturers would have strong incentives to implement a suitable system.

Should there be any guidance provided to UWB users?

- All who responded agreed similar guidance to the FCC should be provided.
- Some noted that while there was no harm in providing guidance, the users would be unlikely to act on it, so it should not be relied upon as a mechanism to achieve mitigation.

Should there be a minimum bandwidth for UWB?

- Some thought a minimum bandwidth was necessary but the actual limit required further study. They suggested 500MHz or perhaps 250MHz.

- Others thought that there was no need for a minimum bandwidth. One went further to note that a minimum bandwidth might result in devices unnecessarily expanding their bandwidth to meet regulation.

- Another thought that UWB had unique capabilities and that allowing narrowband devices to use the spectrum might harm those capabilities, hence a 500MHz minimum should be set.

Are there are specific applications where the potential consequences of UWB outweigh the potential benefits, e.g. replacement of monitor cables due to high data rate combined with continuous operation?

- A few thought that it might be reasonable to limit the duty cycle but not to specify applications. One suggested a maximum aggregate data rate of 40Mbits/s measured over a long time period. Another respondent suggested a maximum 20% utilisation in any 24 hour period.

- Others strongly opposed any limit in the applications.

Locational restrictions:

- One respondent recommended that UWB devices not be allowed to operate on ships or aircraft. They noted that the FCC had made this recommendation.

- Another noted that restricting devices to indoor applications would reduce the interference into meteorological systems.

- One suggested a ban on the use of fixed outdoor UWB equipment and also on UWB in remote control toys (since they might also be used out of doors).

Reaction: Firstly, in general, we would prefer minimal regulations to encourage innovation, and many respondents agreed with this. Considering each point:

- Concerning PRFs, most suggested we adopt the FCC proposals relating to minimum peak to average ratios. This seems appropriate.

- Concerning whether non-associated devices should limit their emissions, there was a mixed response. It appears there may be applications where this would be problematic and battery considerations will likely limit emissions in any case, so on balance we should not regulate this parameter.

- Concerning the ability to turn devices off, all agreed this was appropriate, although only for the user (and not via some other remote UWB device). Regulating this appears appropriate.

- Concerning a minimum power level, most thought this a good idea but cautioned that it would be difficult to regulate in practice and perhaps should be part of a device specification. More work is required to understand whether we should regulate this parameter.

- Concerning the provision of guidance, everyone felt there was no harm in doing this but it was unlikely to have an effect. Given that it will be ineffectual it seems pointless to regulate this parameter.

- Concerning a minimum bandwidth there seemed no compelling reason to set one, and indeed doing so might cause devices to unnecessarily spread their signal. Hence, we should not regulate this parameter.

- Concerning limiting applications, none thought this workable. A few suggested maximum activity ratios but it is difficult to see how this would be enforced. We should not regulate this parameter.

- A few suggested restricting UWB usage to indoors. While this would ease interference it is hard to see how this could be enforced in practice and hence will not be a useful restriction. We should not regulate location.

Q13: Is our proposed approach to international bodies appropriate?

All who responded agreed, although subject to any particular considerations they had about the mask being taken into account.

Q14: How should we best deal with the precedent potentially set by the proposed approach to UWB?

Responses:

- One respondent noted that if this precedent was applied retrospectively to international decisions, many might be overturned or modified.

- Some suggested that the existing international policy was appropriate and should not be modified.

- A number of others agreed that each case could only be considered on its merits, and that no generic guidance would be possible.

- A few suggested that the 1% limit was somewhat arbitrary and unsupportable. They agreed that an approach based on defined property rights was the best way ahead.

Reaction: We agree that a case-by-case approach is appropriate.

Q15: What should Ofcom's role be in setting and monitoring EMC standards?

Responses:

- Many noted that EMC and UWB were different and therefore declined to answer this question.

- One respondent suggested that because of the broad bandwidth of UWB it not be considered as a form of EMC but as a special case.

- Another said that Ofcom should work with those who are active in the field of EMC measurements and standards to ensure that future EMC and UWB standards are sensible, compatible and adequate.

- A number noted that clarity in this area would be very helpful.

Reaction: No clear conclusions can be drawn from these responses, and further study in this area is needed.