Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title: **Crown Recognised Spectrum Access in 3400 to 3600 MHz**

To (Ofcom contact): **Cesar Gutierrez**

Name of respondent: **Stephen Truelove**

Representing (self or organisation/s): **UK Broadband**

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Name Stephen Truelove Signed (if hard copy)

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Date: 6th November 2009

Dear Mr. Gutierrez

Consultation on "Crown Recognised Spectrum Access in 3400 to 3600 MHz"

UK Broadband welcomes the opportunity to respond to this consultation (the "Consultation"). We support Ofcom's market-based approach to spectrum management and we strongly believe that the 3400 to 3600 MHz band will become increasingly important in the provision of wireless broadband services for UK citizens. It is essential that the future management of the band maximises both the social and economic benefits for the general population. UK Broadband believes the best way to achieve this is through adherence to internationally agreed channel arrangements, permitting the use of European standards based terminal products and base station equipment.

UK Broadband supports Ofcom and MOD[1] views that the spectrum currently licensed to UK Broadband should not be included in the RSA regulations at this point. UK Broadband also agrees with Ofcom's view that one of the objectives of the technical limits for the RSA grant is to avoid undue interference into the blocks of existing users, including the UK Broadband block. It is important to note that the introduction of the RSA mechanism should not compromise the rights of existing spectrum holders such as UK Broadband. Furthermore, the RSA regulations should enable the efficient and optimal use of spectrum within the 3400 to 3600 MHz band.

[1] MOD indicated in its spectrum management consultation that it does not have an intention to apply for RSA for these blocks. UK Defence Spectrum Management A Consultation on: An Implementation Plan for Reform

The key points we would like to make in response to this consultation are as follows:

1. We support the proposals to adopt base station in-block and out-of-block limits, between adjacent Broadband Wireless Access (BWA) networks derived from ECC recommendation REC (04)05, with restricted blocks between adjacent networks.

2. We also support the proposal that as specified in the EC Decision (2008/411/EC) less stringent technical parameters should be permitted if agreed between neighbouring operators.

3. We believe that the upper edge of the emergency services block should be maintained at 3475 MHz and the guard block between 3475 to 3480 MHz should be retained to allow for the efficient use of the 3480 to 3500 MHz band by protecting UK Broadband from undue interference.

4. We support an ETSI derived Block Edge Mask (BEM) for mobile terminals only. The mobile terminal BEM being derived from ETSI 302 623 for a 10 MHz channel without an offset from the block edge. i.e. “Option 3” in the Consultation but assuming a lower in-band EiRP of 28 dBm. For fixed terminals, because of their directional nature and low density of use, we believe that “Option 4” i.e. no BEM, but conformance to the relevant ETSI standard is appropriate.

In the sections below, we provide some background material which we believe to be relevant to the Consultation and support the key points made above. Furthermore, in the attached Appendix 1, we respond to the specific questions put forward in the Consultation.

Next Generation Mobile Broadband Networks

Next generation mobile network such as WiMAX 802.16e, 802.16m and LTE-Advanced require large carrier bandwidths that will be difficult to accommodate in other bands. For example the UHF band released by the Digital Dividend can only accommodate a single 20 MHz FDD link whilst in comparison the 3400 to 3600 MHz band could support more 20 MHz blocks (see section “Optimal Spectrum Utilisation”). The European commission decision 2008/411/EC permits the use of BWA (Broadband Wireless Access) in both the 3400 to 3600 MHz and 3600 to 3800 MHz ranges. As a result the whole 3 GHz band will play a pivotal role in achieving the objectives set out by the ‘Digital Britain Report’. Future IMT-Advanced technologies will require a minimum block allocation of 20 MHz. In practice operators wishing to deploy IMT-Advanced systems will require several multiples of this minimum block allocation. Fragmentation and lack of spectrum in other bands makes the 3 GHz band ideally suited for delivery of high capacity wireless broadband services. UK Broadband requests that Ofcom considers, how best to maximize the social and economic value of the 3400 to 3600

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MHz band. This can be achieved by aligning channel arrangements with continental Europe as per ECC recommendation REC (04)05 and keeping any fragmentation of the band to a minimum.

WAPECs Mandate

We request Ofcom considers the aims of the WAPECs mandate for least restrictive regulations. An emphasis on flexible use of spectrum can lead to overly complex technical requirements and regulatory restrictions; whereas a pragmatic approach will permit the deployment of future technologies using large carrier bandwidths. In Europe, several countries have auctioned the 3 GHz spectrum with 21 MHz blocks separated by 7 MHz guard bands, as permitted by recommends 4 in ECC REC(04)05[2]. This gives these operators the flexibility to deploy IMT Advanced technologies with larger carrier bandwidths, than are likely to result from Ofcom's consultation. It should be noted that EC and ECC regulations do not require a terminal BEM; in fact REC (04)05 concludes no BEM is required for fixed and nomadic terminals (complying with ETSI 302 326 assuming the use of directive antennas). For mobile terminals ECC DEC (07)02 states they *'might'* be a need for a one channel width separation to prevent terminal to terminal interference, if no other coordination measures are taken[3]. The use of a terminal BEM (in the consultation) forces the guard band to be internal, irrespective of whether interference mitigation measures are taken, or not.

Additionally ECC DEC (07)02 does not differentiate between internal or external guard bands. In the case of UK Broadband, external guard bands already exist.

The ECC decision indicates a 'one channel width' separation *'might'* be required between mobile networks to prevent terminal to terminal interference; yet the size of the separation is not mandated and left open to local interpretation. This would become impractical for WiMAX

[2] Recommends 4, Page 5 in ECC REC(04)05 - "those administrations who do not wish to follow the approach of contiguous block assignment as given in Recommends 1, should still find appropriate guidance for inter-block coexistence in annexes 1 and 3 when defining the size of external guard bands;"

[3] ECC DEC (07)02, Annex Page 7
"Technical considerations
As a starting point, the guidance given in ECC Recommendation (04)05 on technical conditions for implementation of flexible usage mode, to be set in the technology neutral BWA licence process, shall be considered.

Furthermore, the introduction of MWA usage mode will be subject to following additional requirements for deployment of mobile TS:
a. Maximum radiated power density of 25 dBm/MHz;
b. Minimum ATPC range of 15 dB;
c. When blocks are assigned contiguously (without external guard bands) care should be taken not to allow a TS transmit centre frequency closer than one channel width from the block edge <u>unless co-ordination between operators is undertaken. Co-ordination may include the application of other specific interference mitigation measures.</u> However it is understood that such a "virtual guard channel" is implicit, under normal circumstances, through application of the CS Block Edge Mask as recommended in ECC/REC(04)05."

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& LTE technologies and could lead to *50%* of the 3 GHz band becoming unusable; especially when high bandwidth carriers are contemplated for the band following WRC 2007.

UK Broadband commissioned a study from Aegis (see Appendix 2) on the impact of terminal to terminal interference. The study considered the impact of guard bands and terminal-to-terminal interference on total throughput within hotspots. The analysis shows that the impact on total cell throughput by introducing guard bands for terminals can be significantly greater than the impact of terminal-to-terminal interference. This is because guard bands deny the use of spectrum to all users on the network, whereas terminal-to-terminal interference only affects a relatively small number of users at any time. The analysis shows that the effect of terminal-to-terminal interference is significantly lowered with network coordination and when cells are small (500 meters or less and of the type typically deployed around hotspot locations i.e. where the density of terminals is high).

Maximizing total system throughput is more important in data centric networks as data services are resistant to intermittent interference and short re-transmission delays. Therefore guard bands are not required to totally eliminate mobile terminal to terminal interference (unlike traditional voice centric networks). BWA operators will choose to coordinate networks to reduce the base station filter complexity and therefore will comply with ECC DEC (07)02 without the need for the guard band to be included in the mobile terminal BEM.

The European Commission Decision on harmonization of 3400 to 3600 MHz

In May 2008, the European Commission adopted the EC decision 2008/411/EC[4] on the harmonization of the 3400 to 3800 MHz bands across the European Community adopting CEPT's recommendations as part of this decision. The EC Decision is binding in its entirety on all Member Estates and has been implemented in the UK by the 3400 to 3800 MHz Frequency Band Management regulations 2008. The key implications of the EC Decision are as follows:

<u>Creation of a single pan-European market.</u>

The EC Decision 2008/411/EC stresses some broad principles which include the creation of a single market for services based on 3400 to 3800 MHz,

> *"It is expected that the wireless broadband electronic communications services for which the 3400 – 3800 MHz band is to be designated will to a large extent be pan-European in the sense that users of such electronic communications service in one Member State could also gain access to equivalent services in any other Member State".*

[4] Commission Decision on harmonisation of the 3400-3800 frequency band for terrestrial systems capable of providing electronic communication services in the Community (May 2008)

Relaxation of limits through coordination.

The decision also specifies certain technical parameters which include limits for in-block emissions (i.e. EiRP radiated power levels) and limits for out-of block emissions (Block Edge Mask). The decision allows less stringent in-block and out-of-block emissions if there are bilateral or multilateral agreements between adjacent spectrum holders. The EC Decision does state,

> *"Less stringent technical parameters, if agreed among the operators of such networks, can also be used. Equipment operating in this band may also make use of e.i.r.p. limits other than those set out below provided that appropriate mitigation techniques are applied which comply with Directive 1999/5/EC and which offer at least an equivalent level of protection to that provided by these technical parameters".*

In-block and out-of block limits

The EiRP limits set out in both the EC Decision 2008/411/EC together with ECC DEC(07)02 are as follows:

- Central stations (i.e. base stations): +53 dBm/MHz
- Fixed outdoor terminal stations: +50 dBm/MHz
- Indoor fixed terminal stations: +42 dBm/MHz
- Mobile terminals: +25 dBm/MHz

The EC Decision and ECC recommendation state out-of-block (Block Edge Mask) limits for central stations (i.e. base stations) but not for terminals. Further ECC REC(04)05 states that out-of-block (Block Edge Mask) limits for terminal stations was not required since ECC Report 33[5] has shown that the protection requirements would be sufficiently covered by applying current harmonized ETSI standards.

ETSI Standard for Terminals in 3400 - 3600 MHz

In Jan 2009, the European Telecommunications Standards Institute (ETSI) published the report EN 302 623[6] which is aligned with the R&TTE Directive and covers mobile terminal stations in the 3400 to 3800 MHz band. The standard covers mobile terminals with a maximum radiated power density (EiRP) not exceeding 25 dBm/MHz and stipulates out-of-

[5] The analysis of the coexistence of point-to-multipoint FWS cells in the 3.4 – 3.8GHz band – (Feb 2006)
[6] EN 302 623 - Broadband Wireless Access Systems (BWA) in the 3 400 MHz to 3 800 MHz frequency band; Mobile Terminal Stations; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive (Jan 2009)

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band limits for such terminals. This ETSI standard's definition of mobile terminals is consistent with 2008/411/EC (i.e. stations not exceeding 25 dBm/MHz).

European Standards-Based Equipment

The European Commission Decision 2008/411/EC and ETSI terminal standards that have been adopted for the 3400 to 3800 MHz are now forming the basis for the emergence of a single harmonized European market for wireless services in this spectrum band which will enable:

- Economies of scale to be achieved for equipment manufacturers in the 3400 to 3800 MHz bands;
- Efficiency of markets and freedom of trade benefits which will ultimately be passed on to consumers in the form of lower prices for services and equipment and;
- Roaming of wireless devices (e.g. modems, laptops and smart phones) using common standards (such as WiMAX 802.16e) across the whole 3400 to 3800 MHz band.

It is essential that prospective and current users (such as UK Broadband) of 3400 to 3600MHz band are able to use commercially available WiMAX equipment as soon as practicable.

Band Plan for 3400 to 3600 MHz

From a regulatory perspective, there is no fixed band plan for the 3400 to 3600 MHz band. However, international bodies such as 3GPP are setting standards which will determine a de-facto band plan for equipment. For example, ECC recommendation REC (04)05 specifies a FDD pairing of 100 MHz. As a consequence of this:

- The NATO Blocks at 3400 – 3410 MHz (as referred to in the Crown Consultation) create corresponding unpaired blocks at 3500 - 3510 MHz.
- The Emergency Services and Public Safety Services blocks at 3440 - 3475 MHz also create corresponding unpaired blocks at 3540 - 3575 MHz.
- The current guard block at 3475 - 3480 MHz creates a corresponding unpaired block at 3575 – 3580 MHz.

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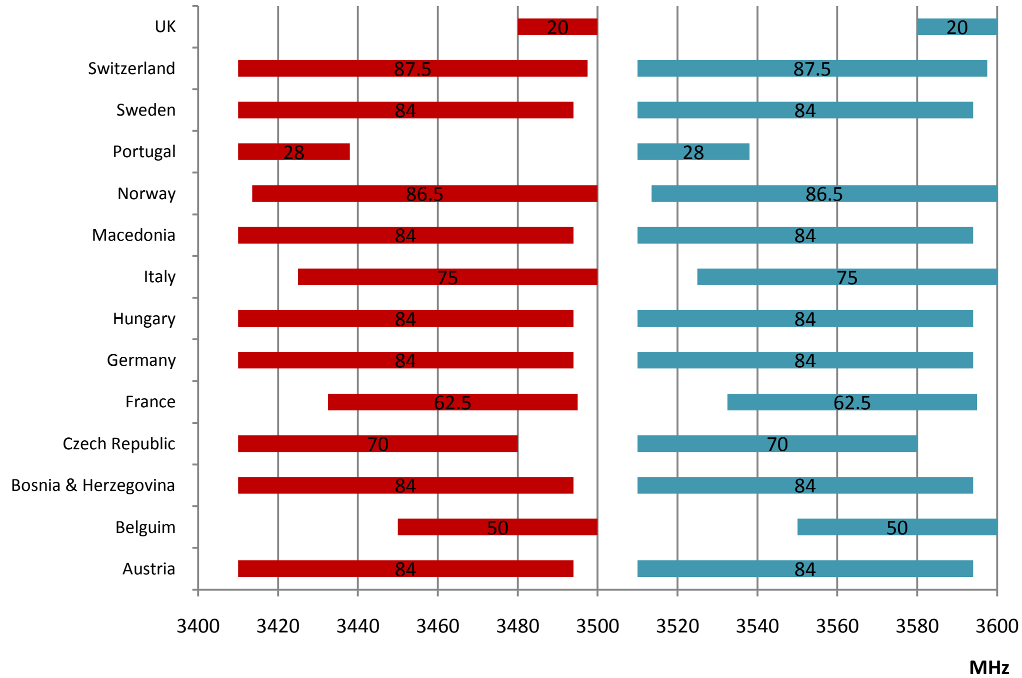

Figure 1 - CEPT country band plans for 3400 - 3600 MHz.

Analysis of significant CEPT countries where 3400 to 3600 MHz spectrum has been licensed, shows that the duplex gap falls in the 3500 - 3510 MHz (as shown in figure 1) as a consequence of the NATO blocks at 3400 – 3410 MHz.

In summary:

1. We expect the existing guard band at 3475 – 3480 MHz to be retained as specified in the original 3.5 GHz auction Information Memorandum.

   All of UK Broadband's investment has been predicated on the basis that this external guard band would be retained. UK Broadband considers that removing this external guard band would have a disproportionate impact on the ability of UK Broadband to efficiently use its spectrum allocation. Furthermore, we recognize that there could be interference issues when Emergency Services technology (Heli-Telly) operates in close proximity to a low power broadband wireless access mobile device, and to reduce the risk of this we would recommend that the 5 MHz guard band between UK Broadband's 3.4 GHz license and the emergency service band is retained to ensure that no harmful interference is experienced by UK Broadband's licensed spectrum.

   We would also like to highlight the fact that Ultra-Wideband (UWB) detect and avoid technology cannot protect broadcast services like Heli-Telly and that the ECC decision (06)12 permits the use of UWB applications with a maximum peak EiRP of 0

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dBm in 50 MHz. This is higher than the out of band power we would expect from a low power BWA mobile device complying with the harmonized ETSI standard EN 302 623. In outdoor environments, power control will further reduce any adverse effects on the operation of Heli-Telly. Vehicular applications of UWB are likely to be used to improve road safety and therefore Heli-Telly shall need to work alongside sources of interference greater than that produced from BWA mobile devices using the 3 GHz band. In addition ETSI and European regulators are considering whether to permit UWB with transmit powers 20 dB greater than currently allowed by ECC (06)12; for location tracking of emergency service personnel working in dangerous environments such as burning buildings. Location Application for Emergency Services (LAES) is likely to result in harmful interference, in the Home office band if the use of UWB and Heli-Telly isn't coordinated.

2. We expect the 3500 - 3510MHz blocks to be restricted to TDD because the NATO Blocks at 3400 – 3410 MHz (as referred to in the Crown Consultation) creates corresponding unpaired blocks at 3500 – 3510 MHz. Similarly, we expect the 3575 – 3580 MHz blocks to be restricted to TDD because the current guard block at 3475 - 3480 MHz creates a corresponding unpaired block at 3575 – 3580 MHz.

   Above and beyond the creation of these unpaired blocks, it is important to note that adjacencies between spectrum blocks need to be accommodated. In the Commission Decision EC 2008/477/EC[1] related to the harmonization of the 2500 - 2690 MHz, a clear direction is provided regarding adjacencies between licence holders,

   > *"To achieve compatibility a separation of 5 MHz is needed between the edges of spectrum blocks used for unrestricted TDD (time division duplex) and FDD operation (frequency division duplex) or in the case of two unsynchronized networks operating in TDD mode. Such separation should be achieved by either leaving these 5 MHz blocks unused as guard blocks; or through usage that complies with parameters of the restricted BEM when adjacent to an FDD (uplink) or between two TDD blocks; or through usage that complies with parameters of either restricted or unrestricted BEMs when adjacent to an FDD (downlink) block."*

   Hence, we believe that 3500 - 3505 MHz and 3575 - 3580 MHz should be restricted to synchronized TDD.

[1] Commission Decision on the harmonization of the 2500 - 2690 frequency band for terrestrial systems capable of providing electronic communications services in the community (June 2008)

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Optimal Spectrum Utilisation

Future IMT-Advanced technologies will require a minimum block allocation of 20MHz. An example channel arrangement is shown in figure 2, where the Emergency services band is paired to a TDD block. The first arrangement can accommodate one 20 MHz FDD link and two 20 MHz TDD links, excluding UK Broadband's licence and 40 MHz assumed for the Emergency services.

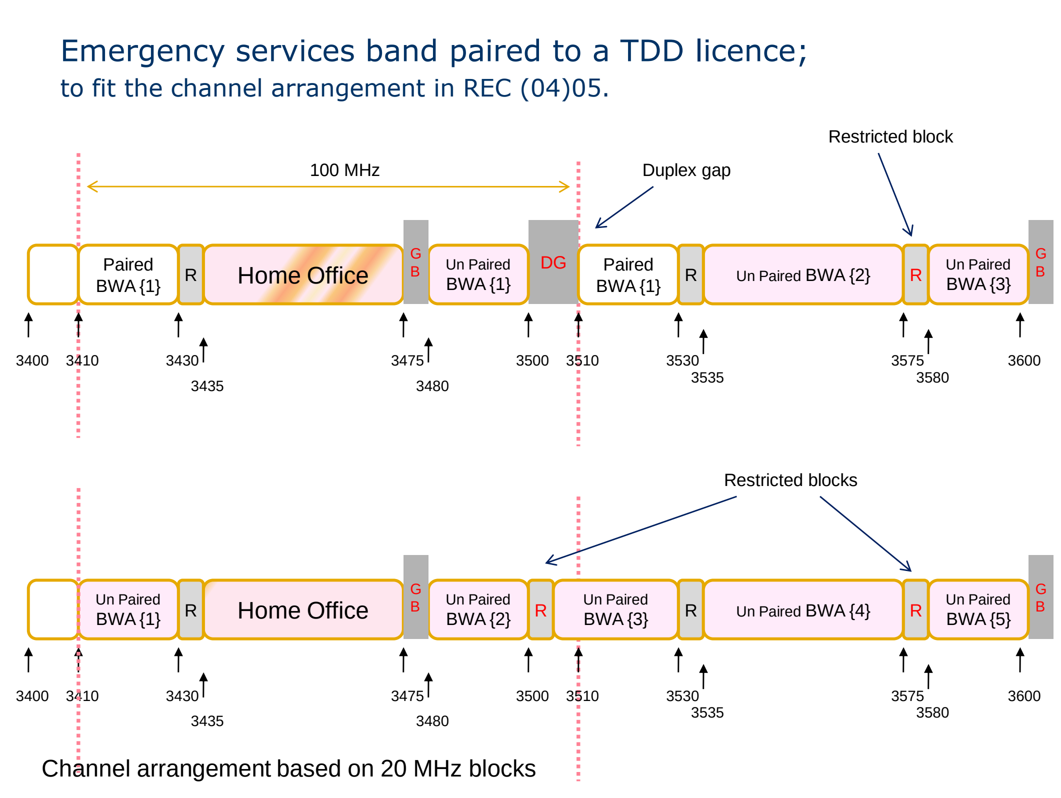

Figure 2 – Example channel arrangements, pairing the emergency services band with a TDD block.

The second arrangement permits, four 20 MHz TDD links. It should be noted that in the first example even without the guard band, restricted blocks or duplex gap, it is still only possible to have one 20 MHz FDD link and two 20 MHz TDD links. In the second arrangement synchronization can be used to increase the number of 20 MHz TDD links from four to five.

In these examples, we have increased the spectrum available to the Emergency services so that it can be paired efficiently with a corresponding TDD block (of 2 * 20 MHz).

Appropriate In-band and Out-of-band limits for Different Product Categories

UK Broadband sees a diverse range of business opportunities for wireless broadband in the United Kingdom, which require a mixture of different types of equipment (ranging from large macro base stations to mini-cell base stations) that can be deployed on street lamp posts and are small enough not to need planning permission. Customer equipment will also range from small mobile devices for portable applications, to fixed desktop modems and outdoor modems that can complement fixed line ADSL services. This range of applications cannot be accommodated by a single terminal Block Edge Mask defined in 3 GHz licences, which is fixed irrespective of equipment type, deployment environment or the likelihood of causing interference to a victim service.

Mini-cell base stations will typically be deployed on lamp posts and will be below the roofline; thus lowering the likelihood they will cause interference to neighbouring networks. In contrast macro base stations will need external filtering; because of the high PA power and antenna height. The studies which lead to the BEM in 2008/411/EC assumed heights of up to 30 meters; whereas mini-cell base stations installed on lamp posts would have a height below the roofline (approximately 12 to 8 meters).

Spectrum trading

We believe it is important that spectrum trading and flexible use of the 3400 to 3800 MHz band is encouraged; so that network operators can rapidly respond to local needs. The ability to dynamically re-assign spectrum is severely restricted by the need for external filters. Recommendation REC (04)05 was developed to permit flexible use of FDD and TDD technology; the resultant Block Edge Mask imposes the need for external filters and this limits the benefits that would come from spectrum trading. We would encourage Ofcom to take a balanced approach that reduces the technical restrictions on spectrum trading whilst permitting technology neutrality. This could be achieved by having a dynamic band plan that groups like technologies together; or agreeing network design rules to minimise the probability of interference between adjacent networks, coupled with a less restrictive Block Edge Mask.

In the future mini-cell base stations using digital pre-distortion will meet the Block Edge Mask in UK Broadband's current 3.4 GHz licence without the need for external filters. If 2008/411/EC were to be adopted without adjacent restricted blocks, this would limit the ability to re-configure channel bandwidths and carrier frequencies in response to the availability of new spectrum, or the need to meet local traffic demand.

Yours Sincerely

Stephen Truelove
UK Broadband

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Appendix 1

Question 1: do you agree that we should introduce RSA in the 3400 to 3600 MHz?

We strongly believe that the 3400 to 3600 MHz band is important in the provision of wireless broadband services to UK consumers and should be released to market.

Question 2: do you agree that we should extend the relevant regulations to allow Crown bodies to be granted and to trade RSA in the 3400 – 3480 MHz and 3500 – 3580 MHz blocks? If not, which frequency ranges do you think the RSA regulations should cover and why?

Both the bands should be made available to permit technology neutrality. Excluding one or other bands would prevent operators from deploying FDD systems. It should be noted that the presence of the Emergency service band will severely restrict FDD deployments and the only reason for the base station Block Edge Mask in the EC decision 2008/411/EC was to permit FDD and TDD systems to coexist. If the band cannot accommodate FDD systems, the benefits from adopting a stringent Block Edge Mask are very limited. Particularly, as the purpose of the EC decision 2008/411/EC was to enable the coexistence of BWA systems. It was not meant for non BWA systems.

Question 3: do you agree that there should be no minimum trading unit for the RSA grant and the WT licences arising from trade in the band?

There should be a minimum trading unit, to prevent fragmentation of the band and allow future technologies requiring high carrier bandwidths. The minimum trading block should be capable of accommodating a 20 MHz carrier.

Question 4: are there specific conditions that you consider should be included in RSA grants and WT licences arising from trading in the band?

Licences should be granted on a national basis, with the option to permit the national licence holder to sub lease the spectrum e.g. in rural areas. The RSA grant should also include coordination obligations and procedures between adjacent operators to maximise and optimise the use of spectrum.

Question 5: do you agree with the proposed in block emissions limit for base stations in the 3500 – 3580 MHz block?

UK Broadband suggests that a default in-block and out of block limits (Block Edge Mask) are derived from ECC REC (04)05, with the following provisions:

- The default base station block edge limits should be based on ECC REC (04)05, with a 20 MHz block allocation and antenna gain of 16 dBi, with the emission limits in the ECC recommendation, starting from the midpoint of adjacent restricted blocks[1]. The use of the restricted band is either through synchronisation or limiting the maximum in

[1] ECC REC (04)05, Page 13:
"The reference frequency ΔF=0 of the mask should be understood as the central division line between adjacent frequency blocks. If the blocks are immediately adjacent, then the mask reference frequency is precisely the border between the two assigned blocks and respecting the mask limits may require operators to employ appropriate guard band inside the assigned blocks. However, if an administration decides to introduce between neighbouring blocks external guard band of ~25% of the assigned blocks (see Annex 1), then the reference frequency ΔF=0 of the mask should be understood to be at the centre of guard band between neighbouring blocks."

band power permitted, similar to the European commission decision for the 2.6 GHz band 2008/477/EC[2].

- The base station Block Edge Mask limits between 0 and 2.5 MHz offset from the block edge, shall comply with ETSI EN 302 326 assuming a 20 MHz channel bandwidth and an in band EiRP of +53 dBm/MHz.

Proposed default BS BEM	
Offset from block edge {in MHz}	**Maximum mean EiRP**(in dBm/MHz}
0	+53
0 < Δf < 2.5	+22 - 4.8 * ΔF
2.5 < Δf < 6.5	+10 - 10.25 * (ΔF – 2.5)
6.5 < Δf < 9.5	-31 - 4 * (ΔF – 6.5)
≥ 9.5	-43
Note: 1). This BS BEM only applies; - when Base station EiRP is greater than 25 dBm/MHz or - the antenna height is above the roof line; or - in the absence of a bilateral agreement with the adjacent BWA operator. 2). The limits in this table are based on ECC REC (04)05 with the block edge at the centre of a 5 MHz external guard band or restricted blocks.	

Low power Pico base station equipment should be made exempt from a Block Edge Mask in the 3 GHz bands as long as the base station equipment complies with an ETSI harmonized standard.

- The in-band EiRP is no greater than 25 dBm/MHz
- Maximum outdoor antenna height is below the roof line

Question 6: do you agree with the proposed out of block emissions mask at the 3500 MHz and 3580 MHz boundaries for base stations?

The blocks 3500 – 3505 MHz and 3575 – 3580 MHz should be restricted to synchronised TDD as explained in detail in our covering letter (in the section “Band Plan for 3400 – 3600 MHz”).

[2] 2008/477/EC Commission decision of 13 June 2008 on the harmonisation of the 2 500-2 690 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community.

Question 7: do you agree that less stringent technical parameters should be permitted if agreed between neighbouring operators?

Yes we believe that this should be the case, in order to optimise the use of spectrum as we have explained in detail in our covering letter.

Question 8: should we align UK Broadband licence conditions for base stations at 3500 MHz and 3580 MHz with those in the RSA grants if and when UK Broadband requests us to do so?

Our position on base station limits are detailed in our answer to questions 5.

Question 9: do you agree with the proposed in block emissions limits for terminal stations?

UKB suggests the following:

- Mobile terminals with total radiated power less than 26 dBm to be made licence exempt.
- Fixed and nomadic terminals are licence exempt as long as total radiated power is less than 30 dBm.
- Fixed and nomadic terminals power limits as set out in 2008/411/EC, with15 dB power reduction for non directive antennas[3].

Question 10: do you agree that the block edge mask should be based on the spectrum emissions mask from ETSI EN 302 623?

Fixed and nomadic terminals should be exempt from a Block Edge Mask as long as the terminal equipment complies with ETSI 302 326[4].

The mobile terminal Block Edge Mask should be based on a 10 MHz channel complying with ETSI EN 302 623 without an offset from the block edge, thereby permitting two 10 MHz channel with no internal guard band.

Mobile Terminal BEM	
Offset from block edge {in MHz}	**Maximum mean EiRP** {dBm/MHz}.
0	+25
$0 < \Delta f < 2$	$+9.73 - 9.11 * \Delta f$

[3] ECC REC(04)05, page 14: "Out-of-block emission limits for TS. It was considered that the block edge mask for Terminal Stations was not required since Report 33 has shown that the protection requirements would be sufficiently covered by applying current harmonised ETSI standards. However, the applicability of the latter conclusion for TS limits with low gain non-directional antennas was verified for scenarios with predominant use of such terminals in indoor environment. If it is intended that the majority of a consistent population of TS with non-directional antennas will be used outdoors (e.g. on vehicles or for fixed outdoor installations), then administrations may wish to establish special radio interface requirements setting out-of-block power limits for non-directional outdoor TS, which would be up to 15 dB more stringent than noise floor limits given in ETSI EN 302 326-2, or, alternatively, limit the maximum allowed EIRP for these applications, according to the expected proportion of outdoor use.".

[4] ECC REC (04)05, Page 15: "Out-of-block emission limits for TS. It was considered that the block edge mask for Terminal Stations was not required since Report 33 has shown that the protection requirements would be sufficiently covered by applying current harmonised ETSI standards.

2 < Δf < 10	-8.5 – 0.5 * (Δf - 2)
10 < Δf < 12	-12.5 – 5 * (Δf - 10)
≥ 12	-22.5
Note: The above values are based on an in band EiRP of 28 dBm and a carrier band width of 10 MHz complying to ETSI EN 302 623.	

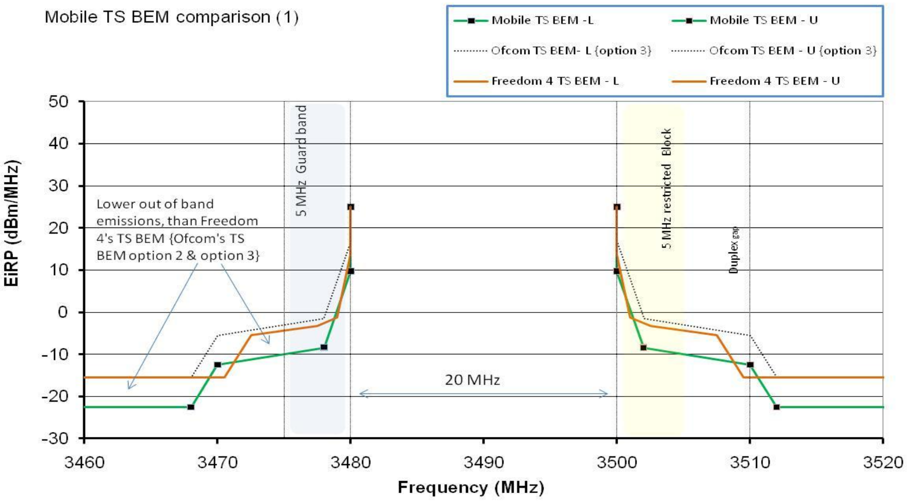

Figure 3 – Mobile terminal comparison.

- Comparison of proposed mobile terminal Block Edge Mask with Freedom 4's mobile TS BEM {option 2} & option 3.
- Proposed BEM has lower out of band emissions than option 2, even with 2.5 MHz offset.

Question 11: do you agree with our derivation of regulatory out of block limits for terminals and, if so, which of the proposed four alternative regulatory conditions do you think most appropriate?

UKB's preference is for Option 3 for mobile terminals and option 4 for fixed and nomadic terminals. However, our proposed mobile terminal BEM (see answer to question 10) has out of band emissions 7 dB lower than specified in option 3.

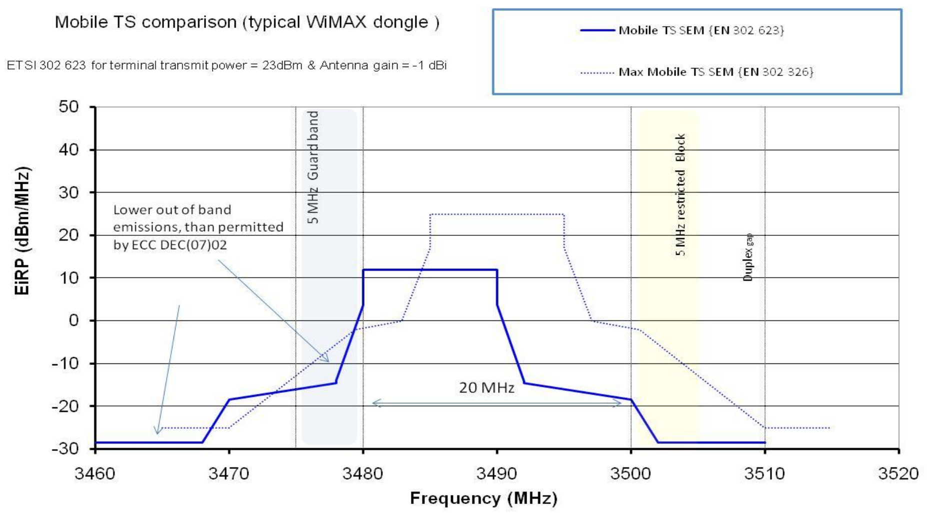

Figure 4 – typical mobile terminal emissions, compared ECC DEC(07)02 with one channel width separation. (5 MHz offset).

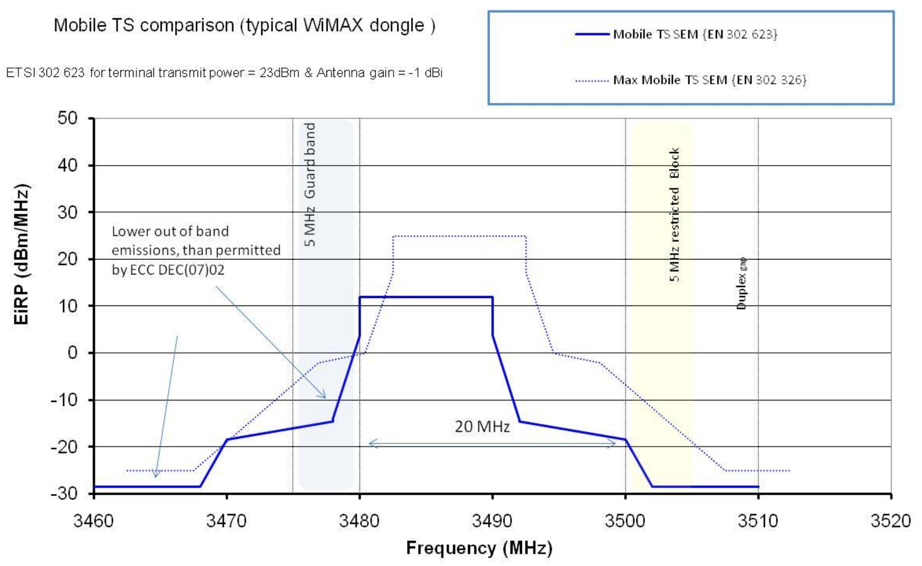

Figure 5 – typical mobile terminal emissions, compared ECC DEC(07)02 with a half channel width separation (2.5 MHz offset).

Figure 4 shows the spectrum emission mask permitted by the ECC decision, ECC DEC (07)02, with the maximum internal guard band the decision stated **'might'** be needed to prevent terminal to terminal interference. This is compared to the spectrum emissions from a typical mobile terminal (with maximum PA power of 23 dBm and -1 dBi antenna gain) without and internal guard band. It can be seen that the total out of band power from a typical mobile device is less than permitted by the decision; additionally only a moderate reduction of the internal guard band would ensure the emission mask is fully met (see figure 5 with a 2.5 MHz offset).

UKB believes that overall system throughput reduction due to an internal guard band (imposed by the terminal BEM proposed in the consultation) would be detrimental to efficient use of the 3 GHz band (see the Aegis report in the attached Appendix 2), and would prevent many types of fixed and nomadic services. We would also question how future technologies with 20 MHz carriers can make efficient use of the band, when the terminal BEM has been calculated assuming 10 MHz carriers (this issue hasn't been addressed in our proposed mobile terminal BEM).

Question 12: should out of block limits for fixed, nomadic and mobile terminals be different?

Yes, fixed and nomadic terminals should be treated differently from mobile terminals.

Fixed and nomadic terminals should be exempt from a Block Edge Mask as long as the terminal equipment complies with ETSI 302 326[5].

Question 13: should we align UK Broadband licence conditions for terminal stations at 3500 MHz and 3580 MHz with those in the RSA grants if and when UK Broadband requests us to do so?

Our position on terminal station limits are detailed in our answers to questions 9, 10, 11 and 12.

Question 14: do you agree that the technical limits at 3480 MHz should copy those at 3580 MHz when the use immediately below 3480 MHz is broadband wireless?

The technical limits at 3580 MHz should be based on the presence of a restricted block between 3575 – 3580 MHz (i.e. the block edge is at 3577.5 MHz).

The technical limits at 3480 MHz should be based on the presence of a guard band between 3475 – 3480 MHz (i.e. the block edge is at 3477.5 MHz).

Question 15: do you agree with the proposed technical limits at 3480 MHz for the scenario where the upper edge of the emergency services block does not change from the current allocation at 3475 MHz?

Yes. We have explained our position on this matter in detail in our covering letter in the section "Band Plan for 3400 to 3600 MHz".

Question 16: do you agree with the proposed technical limits at 3480 MHz for the scenario where the upper edge of the emergency services block is moved to 3480MHz?

No. We have explained our position on this matter in detail in our covering letter in the section "Band Plan for 3400 to 3600 MHz".

Question 17: do you agree that the technical conditions of the RSA grant at the 3500 MHz and 3580 MHz boundaries are the best option for the boundaries that will appear inside the 3500 – 3580 MHz block if the block is partitioned and traded into several smaller sub-blocks?

We believe networks in the 3500 - 3580 MHz range will also require restricted blocks between adjacent systems or be synchronised as described in detail in our covering letter (section "Band Plan for 3400 to 3600 MHz").

Question 18: do you think that the out of block limits for broadband wireless base stations in Figure 8.2 are sufficient to protect air-to-ground videolink receivers in an adjacent block?

Yes.

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[5] ECC REC (04)05, Page 15: "Out-of-block emission limits for TS. It was considered that the block edge mask for Terminal Stations was not required since Report 33 has shown that the protection requirements would be sufficiently covered by applying current harmonised ETSI standards.

Question 19: what are your views on the requirements for protection of air-to-ground videolink receivers from interference from broadband wireless terminals?

We believe that air to ground video links will be more prone to UWB interference, than interference from mobile BWA terminals. UWB used in vehicular applications will operate in close proximity to ground based receivers and UWB detect and avoid will not protect broadcast systems using the 3 GHz band. UWB is permitted a maximum peak EiRP of 0 dBm in 50 MHz which is equivalent to -16 dBm/MHz. This is higher than the emission floor from a mobile BWA terminal (see figure 4), when the terminal is transmitting at full output power. In practice mobile BWA terminals are unlikely to be transmitting at full power when in close proximity to video link receiver, because of power control. Metropolitan BWA networks will usually be designed to give indoor coverage and hence overcome building penetration losses. As a consequence mobile terminals operating outdoors are likely to be transmitting below the 25 dBm/MHz limit because they are in a good coverage area. Video-links will be affected by Location Application for Emergency Services (LAES), especially if permitted a maximum peak EiRP of 20 dBm in 50 MHz.

Question 20: do you think that an out of block requirement for airborne videolink transmitters of -25 dBm/MHz EIRP is sufficient to protect broadband wireless receivers?

Yes; however it should be noted that emission limits design for BWA systems do not automatically apply to non BWA systems. BWA co-existence studies have assumed a height of 30 meters; whereas Video-links used on police surveillance helicopters (Heli Tele) have line of sight to any nearby BWA base station and effective antenna height of several hundred meters.

Co-Existence of TDD & FDD Mobile WiMAX Systems in Adjacent Spectrum

Report Prepared for UK Broadband

2115/UKBB/TN2/3

12th October 2009

ÆGIS spectrum engineering

Table of Contents

1 INTRODUCTION

Aegis Systems Ltd were commissioned by UK Broadband to undertake technical modelling work focussing on the need or otherwise for guard bands between TDD & FDD Mobile WiMAX systems operating in adjacent spectrum blocks. This is to help ascertain whether an additional frequency offset (corresponding to a guard band) should be applied to the block edge mask proposed for mobile terminals operating in the 3.5 GHz band. The current assumptions about the need for guard bands are largely based on the outcome of work undertaken by Motorola and reported to CEPT in document SE19(06)70. The Motorola modelling was based on a number of mobiles connected to networks operating in adjacent spectrum blocks and located in small traffic hotspot areas of 10–20 metres radius.

The modelling assumed terminals based on the ETSI EN 302 326 standard for digital multipoint radio systems, using a 1x4x2 frequency reuse pattern (i.e. four-sectored cells and two available carrier frequencies). Various scenarios were analysed by varying guard bands and cell sizes . The results compared the impact on terminal signal to interference plus noise ratio (SINR) and spectrum efficiency (bits/s/Hz) under each scenario. The results of this modelling suggested that a guard band might be required in some cases, especially in the absence of co-ordination between adjacent block users.

Ofcom has also undertaken its own modelling of the interference situation, based on recent work by CEPT PT SE42 reported in ECC Report 131.

Our modelling approach and results are broadly consistent with the previous work: however, in addition to the impact on individual users, we have also considered the impact of guard bands and terminal-to-terminal interference on total throughput within hotspots. We believe that this approach provides a more effective comparison of the impact of guard bands on overall spectrum efficiency and is also more appropriate for packet data services where a degree of latency is acceptable to the user.

This analysis shows that the impact of introducing guard bands on total cell throughput can be significantly greater than the impact of terminal-to-terminal interference. This is because guard bands deny the use of spectrum to all users on the network, whereas terminal-to-terminal interference only affects a relatively small number of users at any time. Our analysis also shows that the effect of terminal-to-terminal interference is significantly lower for smaller cells (500 metres or less) of the type that would typically be deployed around hotspot locations.

In our analysis, we assumed that an internal guard band would only apply at the lower end of UK Broadband's two frequency blocks, i.e. at 3480 MHz and 3580 MHz, since the upper edge at 3500 MHz would be adjacent to a 5 MHz duplex gap for FDD systems and 3600 MHz already has an adjacent 5 MHz external guard band. If internal guard bands were to be deployed at both the lower and upper edges, the spectrum efficiency loss from imposing guard bands would be even greater, since a single channel guard band (removing 5 MHz at the upper and lower edges) would remove 50% of the available spectrum, rather than the 25% assumed in our analysis.

2 ANALYSIS

In this section, the methodology, assumed parameter values and analysis results are provided.

2.1 Methodology

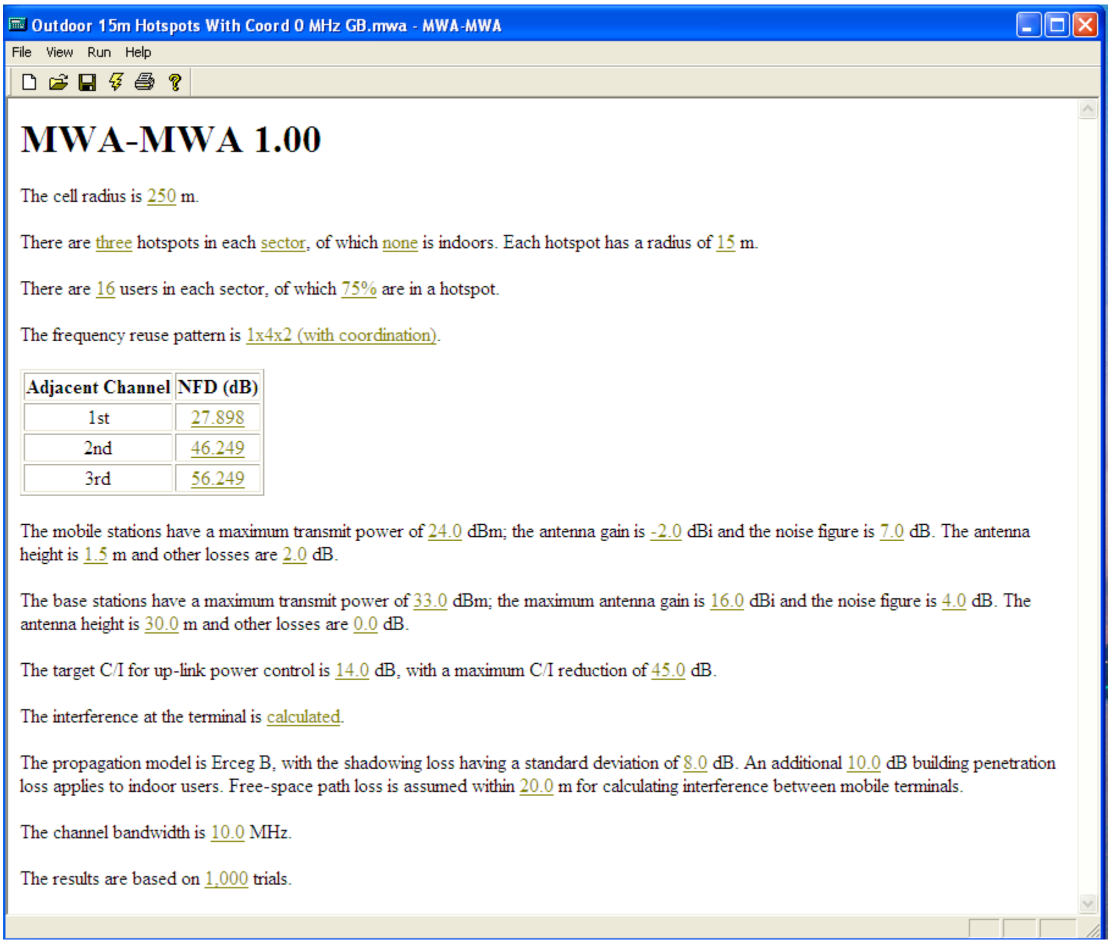
The modelling made use of our in-house Aegis Systems Spectrum Engineering Toolkit (ASSET) platform. This has been used by Aegis to implement a number of small-scale simulators, including the modelling of sharing between fixed links, UWB devices and DTH satellite receivers. The framework provides a web-style user interface, data import/ export and graph-making facilities. Our approach was to replicate as far as possible and to extend the capabilities of the existing SE19 model to provide greater flexibility.

The first part of the simulation process involves defining the locations of the cells, base stations, sectors and terminals. Terminals may be in hotspots, which may be indoors or outdoors; terminals not in hotspots are assumed to be outdoors. Uplink power control is applied to the interfering terminals. Propagation losses between base stations and terminals are calculated using the Erceg B model, whereas losses between nearby terminals are free-space (adjusted for building penetration where appropriate).

Statistics are then collected for Monte Carlo trials of terminal placement and propagation losses. Degradation in C/N+I and spectral efficiency is used to assess the impact of inter-system terminal-to-terminal interference.

As with the previous CEPT studies, the results are in the form of cumulative distribution function (CDF) curves showing the percentage of individual users that would be likely to suffer a specified level of interference. From this data it is possible to estimate the total impact on the data throughput within a hotspot. To do this, we have broken down the percentage of users into 5% bands and assumed for each band that 5% of users will suffer the degradation indicated by the CDF curves. By summing the actual throughput for each of the 5% bands the total throughput for the hotspot is then determined.

The snapshot of an example simulation scenario definition is shown below.



Outdoor 15m Hotspots With Coord 0 MHz GB.mwa - MWA-MWA

File View Run Help

MWA-MWA 1.00

The cell radius is 250 m.

There are three hotspots in each sector, of which none is indoors. Each hotspot has a radius of 15 m.

There are 16 users in each sector, of which 75% are in a hotspot.

The frequency reuse pattern is 1x4x2 (with coordination).

Adjacent Channel	NFD (dB)
1st	27.898
2nd	46.249
3rd	56.249

The mobile stations have a maximum transmit power of 24.0 dBm; the antenna gain is -2.0 dBi and the noise figure is 7.0 dB. The antenna height is 1.5 m and other losses are 2.0 dB.

The base stations have a maximum transmit power of 33.0 dBm; the maximum antenna gain is 16.0 dBi and the noise figure is 4.0 dB. The antenna height is 30.0 m and other losses are 0.0 dB.

The target C/I for up-link power control is 14.0 dB, with a maximum C/I reduction of 45.0 dB.

The interference at the terminal is calculated.

The propagation model is Erceg B, with the shadowing loss having a standard deviation of 8.0 dB. An additional 10.0 dB building penetration loss applies to indoor users. Free-space path loss is assumed within 20.0 m for calculating interference between mobile terminals.

The channel bandwidth is 10.0 MHz.

The results are based on 1,000 trials.

Figure 1: Simulation Scenario Definition

As can be seen, the simulation definition includes both simulation geometry and radio system parameters.

2.2 Assumed Parameter Values

The following table shows the system parameter values used in the modelling. These are based on typical system parameters for a mobile WiMAX network and are broadly similar to the values assumed in the Motorola modelling.

Parameter		**Value**		
Cell Radius		250, 500 & 1,000 metres		
No of Sectors in a Cell		4		
No of Hotspots in Each Sector		3		
Hotspot Radius		15 metres		
Total No of Users in Each Sector		16		
% of Total Users in Located in Hotspots		75		
Frequency Re-use		1 x 4 x 2 (i.e. four sector cells with two carriers)		
Net Filter Discrimination	*Guard band*	*0 MHz*	*5 MHz*	*10 MHz*
	First Adj Channel	27.9 dB	37.1 dB	46.3 dB
	Second Adj Channel	46.3 dB	51.3 dB	56.3 dB
	Third Adj Channel	56.3 dB	56.3 dB	56.3 dB

Parameter		**Value**
Mobile User Terminal	*Max Tx Power*	24 dBm
	Max Antenna Gain	-2 dBi
	Antenna Pattern	Omnidirectional
	Noise Figure	7 dB
	Antenna Height	1.5 metre
	Body Loss	2 dB
Base Station	*Max Tx Power*	33 dBm
	Max Antenna Gain	16 dBi
	Antenna Pattern	- min (12(θ/60)^2 , 30) dB
	Noise Figure	4 dB
	Antenna Height	30 metre
Target Uplink C/I for Power Control		14 dB
Power Control Range		45 dB
Propagation Loss	*Between BS & User Terminal*	Erceg B (with Shadowing Loss Std Dev = 8 dB)
	Between User Terminals	Free Space
Interference Radius for User Terminal Receivers		20 metre
Building Penetration Loss for Indoor Scenarios		10 dB
Channel Bandwidth		10 MHz
No Of Monte Carlo Trials		1000

Table 1: Simulation Parameters

During a simulation run, the intra-system interference from eight surrounding base station transmitters is calculated at user terminals located in the victim cell placed in the centre of a 9-cell pattern. This intra-system interference is then added to the inter-system interference from interfering user terminals located within a 20 metre interference radius of victim user terminal receivers.

The net filter discrimination values are derived from the adjacent channel leakage ratio (ACLR) and adjacent channel selectivity (ACS) values specified in ETSI EN 302 623 where mobile terminal requirements for broadband wireless access systems are defined for 3.4–3.8 GHz band deployment.

2.3 Simulation Results

The implications of different cell sizes and guard bands as well as the frequency coordination between the adjacent operators have been examined in the simulation analysis.

The 1x4x2 frequency re-use pattern is illustrated below. Both the interfering and victim systems use 2 consecutive blocks of frequency.

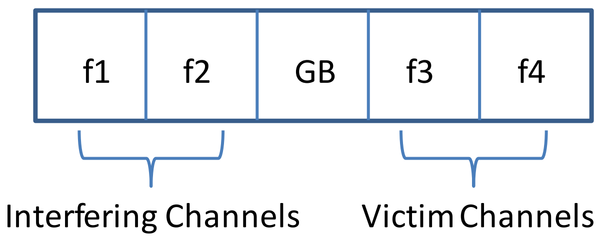


Figure 2: Frequency Plan

Scenarios have been simulated with and without frequency coordination between the two operators. This is illustrated in the following figure assuming interfering and victim system share the same station site and their sectors overlap.

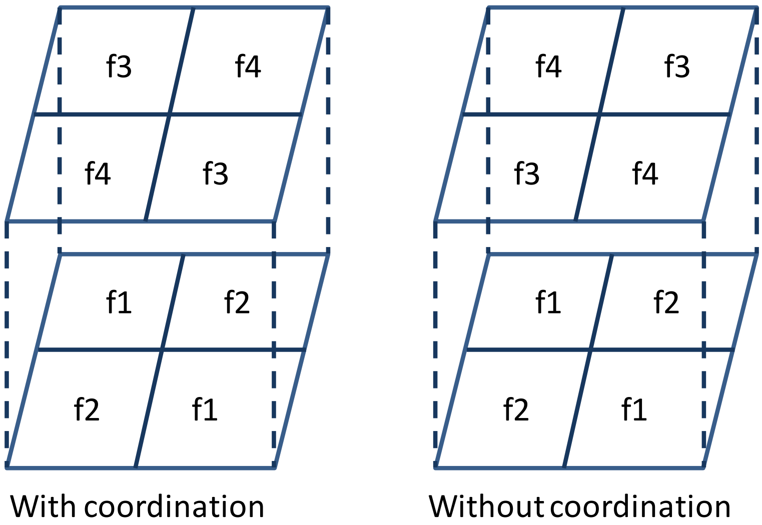


Figure 3: Coordinated and Uncoordinated Deployment

2.3.1 Interference with Frequency Coordination

The results are presented in the form of SINR and spectrum efficiency degradation (due to the additional interference from user terminals of an adjacent band operator) in hotspots and in the entire cell for different guard band options. The following figure shows the SINR degradation results for an assumed 250 metre cell radius, assuming that the adjacent frequency block networks have undertaken co-ordination to avoid adjacent frequencies being deployed in the same cell sectors.

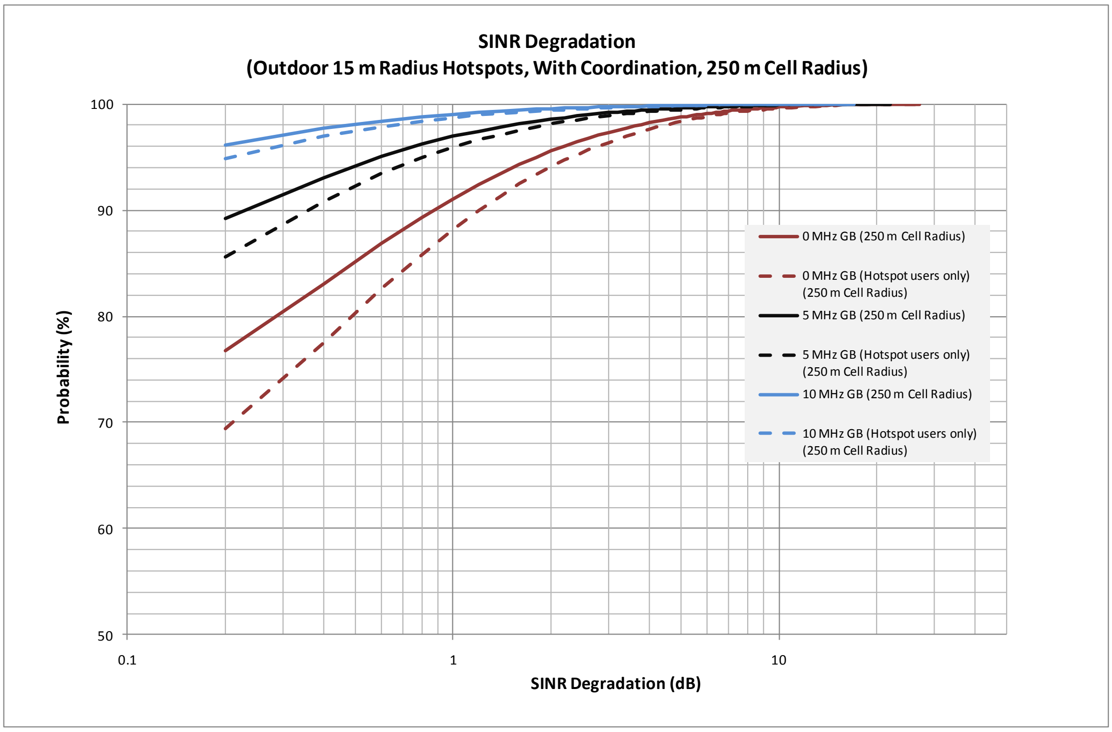


Figure 4: SINR Degradation Results for 250 metre Cell Radius (With Coordination)

As can be seen, SINR degradation is less than 1 dB for 88% of hotspot users when there is no guard band between the operators, i.e. 88% of users are unlikely to see any noticeable degradation in performance. When a 10 MHz guard band is introduced this increases to 98.7% of users. However, assuming each block is 20 MHz wide, a 10 MHz guard band equates to a 25% loss of the available spectrum (since 5 MHz of each 20 MHz block becomes a guard band) which must be balanced against the effect of interference in considering overall spectrum efficiency.

The SINR results obtained in the simulation runs can be mapped into an achievable spectrum efficiency based on the following relation.

$$\text{SpectrumEfficiency\_Bits\_Sec\_Hz} := \begin{cases} 0 & \text{if } \text{SINR} \le 5 \\ \left[0.5\left(\log_2\left(1 + 10^{\frac{\text{SINR}}{10}}\right)\right)\right] & \text{if } 5 < \text{SINR} \le 30 \\ 5 & \text{if } \text{SINR} > 30 \end{cases}$$

The degradation in the spectrum efficiency for individual users is then calculated by comparing the results with and without inter-system interference. The following figure shows the degradation CDFs for an assumed 250 metre cell radius for zero, half and one channel guard bands.

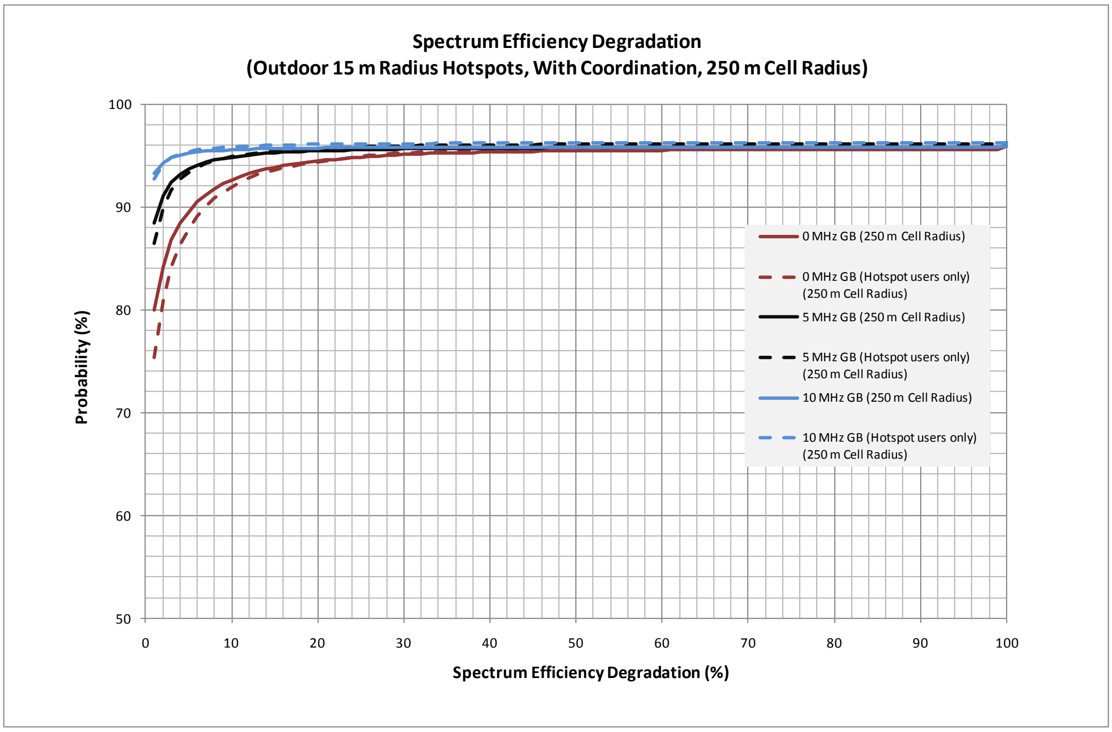


Figure 5: Spectrum Efficiency Degradation Results for 250 metre Cell Radius (With Coordination)

The results indicate that, without a guard band, 92% user terminals suffer less than 10% degradation in their spectrum efficiency (i.e. less than 10% reduction in data throughput) due to additional interference from user terminals operating in the adjacent spectrum. When a guard band of 10 MHz is introduced this percentage increases marginally to 95.8% of user terminals, but again this is at the expense of a 25% loss of available spectrum.

It should be noted that a small number of user terminals will be temporarily inoperable at any given time due to interference (i.e. C/I < 5 dB) due to the combined effects of fading and intra-system interference. Therefore, the spectrum efficiency degradation CDFs become flat at a percentage that is less than 100% (i.e. approximately 96%). This indicates that there is no degradation due to the additional inter-system interference for 4% inoperable user terminals as their spectrum efficiency is already zero.

The spectrum efficiency degradation results shown above are then used to determine the total impact of interference on the data throughput within hotspots. This is achieved by breaking the percentage of users into 5% bands and assuming that, for each 5% band, users will suffer the degradation indicated by the hotspot spectrum efficiency CDF curves. For each 5% user band, the throughput reduction is calculated by multiplying the percentage degradation with 5%. The total throughput reduction is equal to the sum of throughput reductions in each 5% band. The results are shown in the following table.

Scenario	Reduction in Throughput
No Guard Band	4%
Half Channel Guard Band	2.1%
Single Channel Guard Band	1.4%

Table 2: Total Throughput Reduction in Hotspots (With Coordination)

The results indicate that there is a gain of 2.6% in the hotspot throughput when a single channel guard band is introduced. However, the deployment of a guard band will itself reduce the throughput since the available bandwidth is reduced. Assuming 20 MHz blocks and 10 MHz channels, with a single channel guard band, the available bandwidth would be reduced by 25%, a significantly greater reduction than appears to result from the inter-system interference. As noted in the introduction, the reduction would be 50% if guard bands were applied at both ends of each frequency block.

Where a half-channel guard band is applied, the improvement in the throughput is only 1.9% relative to the no guard band scenario, compared to the 12.5% that would be lost by the imposition of the guard band (or 25% if guard bands were applied at both ends of each frequency block)..

In conclusion, it is apparent that the imposition of guard bands would result in lower overall throughput, even at hotspot locations, than would be the case if no guard bands were deployed.

It should further be noted that the impact of terminal-to-terminal interference is very dependent on the assumed cell size. It is likely that smaller cells (less than 500 metres radius) would be deployed around hotspot locations. The effect of smaller cells is to improve the link budget between terminals and base stations, resulting in higher received signal levels at the terminal and lower terminal transmit powers (due to automatic transmitter power control).

The impact of cell size on total throughput reduction is determined by repeating the simulations for cell radii of 500 and 1000 metres. The resultant spectrum efficiency degradation curves are then processed to obtain the total throughput reduction in hotspots. The results are plotted in the figure below.

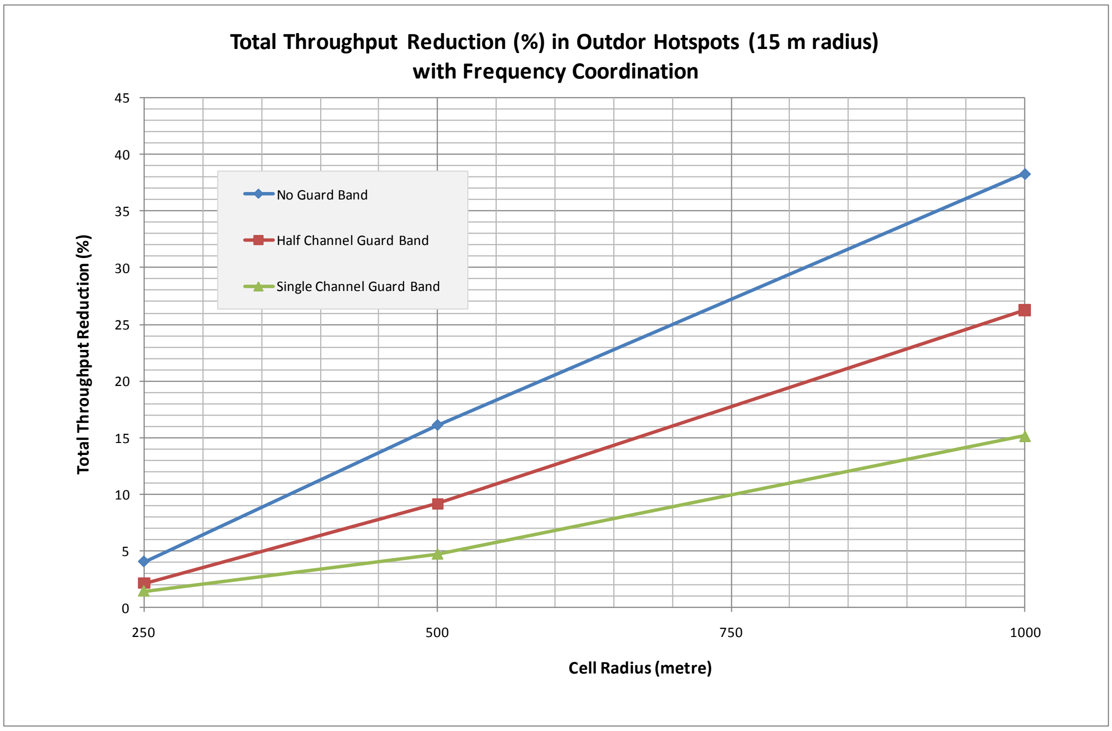


Figure 6: Overall Throughput Degradation Results for 250, 500 and 1000 metres Cell Radii (With Coordination)

In summary, for a given guard band, the total throughput reduction increases with an increasing cell size. Similarly, for a given cell radius, the reduction is decreased with an increasing guard band. However, even for a 1 km cell radius the 24% throughput improvement achieved resulting from a single channel guard band (reduction in throughput is 39% without the guard band and 15% with the guard band) is less than the 25% reduction that the guard band itself would create. For smaller cell sizes the benefit of removing the guard band becomes greater.

2.3.2 Interference without Frequency Coordination

The scenarios developed in the preceding section have been simulated assuming that the adjacent block operators have not undertaken coordination. The following figure illustrates the SINR degradation results for an assumed 250 metre cell radius.

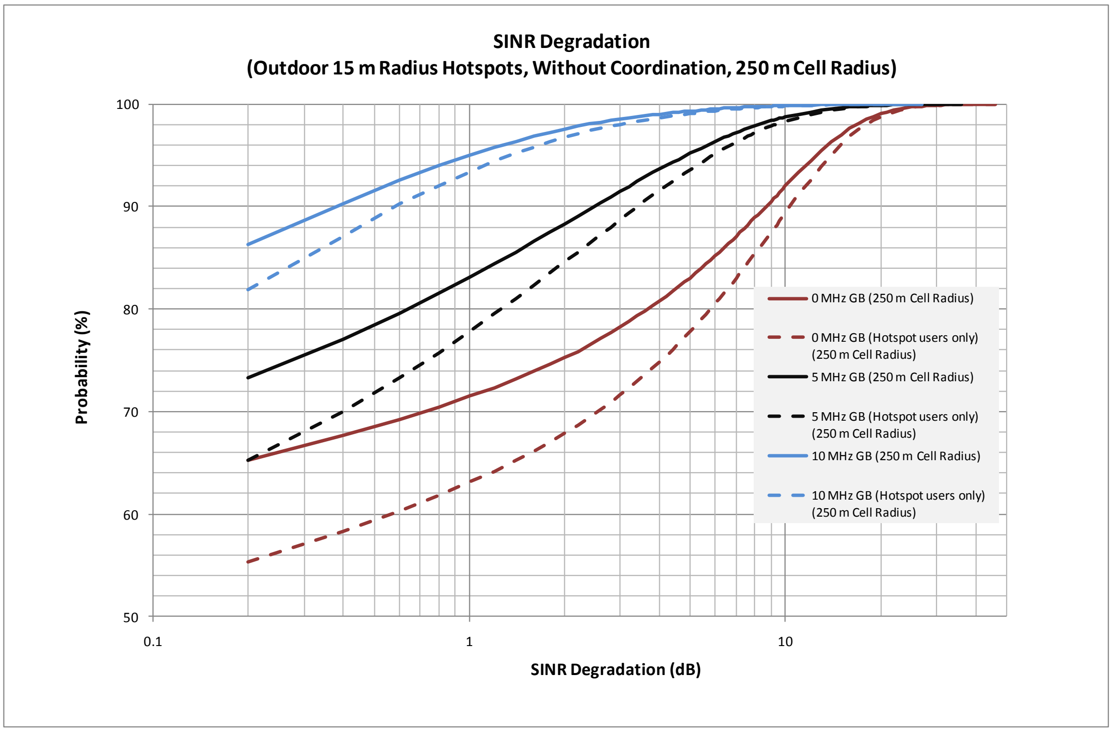


Figure 7: SINR Degradation Results for 250 metre Cell Radius (Without Coordination)

The impact of interference is more significant compared to the corresponding coordinated scenario. The SINR degradation is less than 1 dB for 63% of hotspot users when there is no guard band between the operators (note that the corresponding value is 88% in the case of coordinated deployment). When a 10 MHz guard band is introduced this increases to 93.4% of users. It should however be noted that a 10 MHz guard band implies a loss of 25% of the available spectrum.

For the same scenario, the following spectrum efficiency degradation CDFs have been calculated.

Figure 8: Spectrum Efficiency Degradation Results for 250 metre Cell Radius (Without Coordination)

Similarly, the impact of interference on spectrum efficiency degradation is more significant with an uncoordinated adjacent band deployment. The CDFs show that 72% of user terminals suffer less than 10% degradation without a guard band (note that the corresponding value is 92% with coordinated deployment). With a 10 MHz guard band, this percentage increases to 93.8% of user terminals at the expense of losing 25% of useable spectrum.

It is interesting to note that there is a sudden increase at the right end of the CDFs. This represents the user terminals that become inoperable due to the additional inter-system interference. In other words, the C/I value associated with these terminals falls below the threshold value of 5 dB hence their spectrum efficiency degradation is 100%.

The table below shows the total throughput degradation in hotspots without coordination, for a 250 metre cell radius.

Scenario	Reduction in Throughput
No Guard Band	13.7%
Half Channel Guard Band	5.8%
Single Channel Guard Band	2.3%

Table 3: Total Throughput Reduction in Hotspots (Without Coordination)

As can be seen, the total reduction figures are larger than those calculated for the coordinated case where the corresponding values are 4%, 2.1% and 1.4% for no guard band, half channel guard band and single channel guard band scenarios, respectively.

The impact of cell size on total throughput reduction is examined for the additional cell radii of 500 and 1000 metres. The results are shown in the figure below.

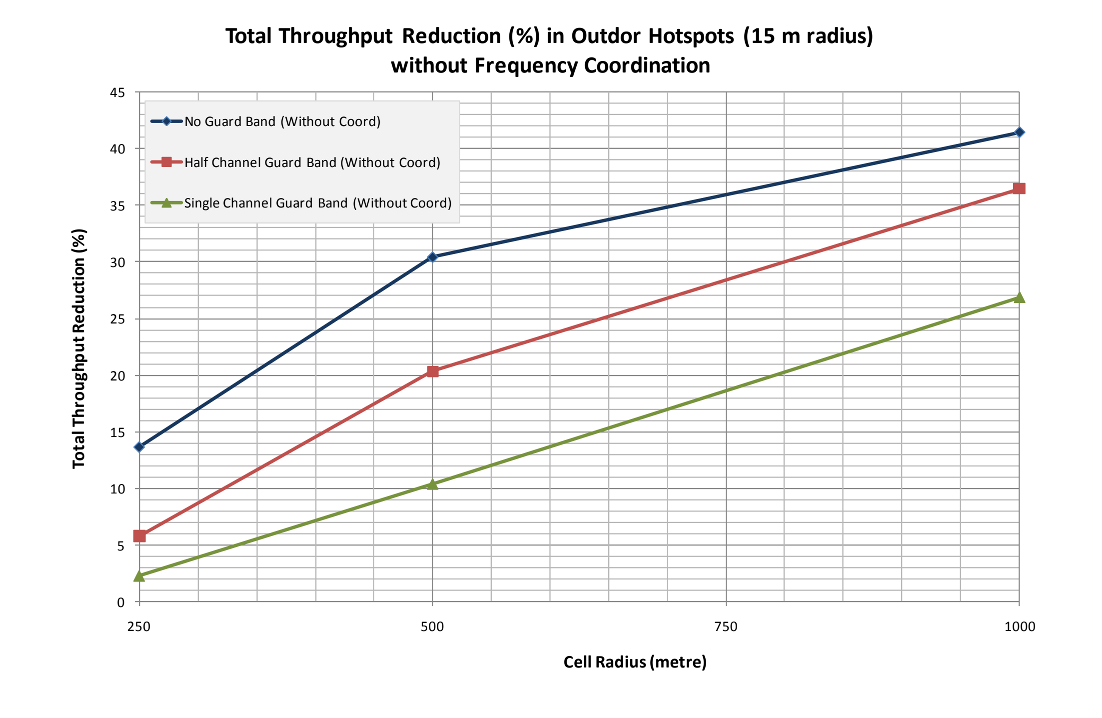


Figure 9: Overall Throughput Degradation Results for 250, 500 and 1000 metres Cell Radii (Without Coordination)

It is interesting to note that in the absence of frequency co-ordination there is a significant degradation in overall throughput even if a guard band is applied. For a 1 km cell radius, the throughput reduction improves from 42% to 27%: however, this would be offset by the additional 25% reduction in available spectrum (and hence throughput) that would result from the introduction of the guard band. For smaller cell sizes, the advantage of removing the guard band becomes progressively greater.

2.4 Analysis with Fixed Terminals

The interference scenarios have been re-analysed by assuming that the victim and interfering user terminals are fixed and use directional antennas. The antenna gain is assumed to be 20 dBi and the antenna pattern is represented by ITU-R Rec.1336. The remaining simulation parameters are the same as those used in mobile interference scenarios.

The implications of both coordinated and uncoordinated deployment have been considered. The following figures illustrate the total throughput degradation in hotspots for different guard bands and cell radii.

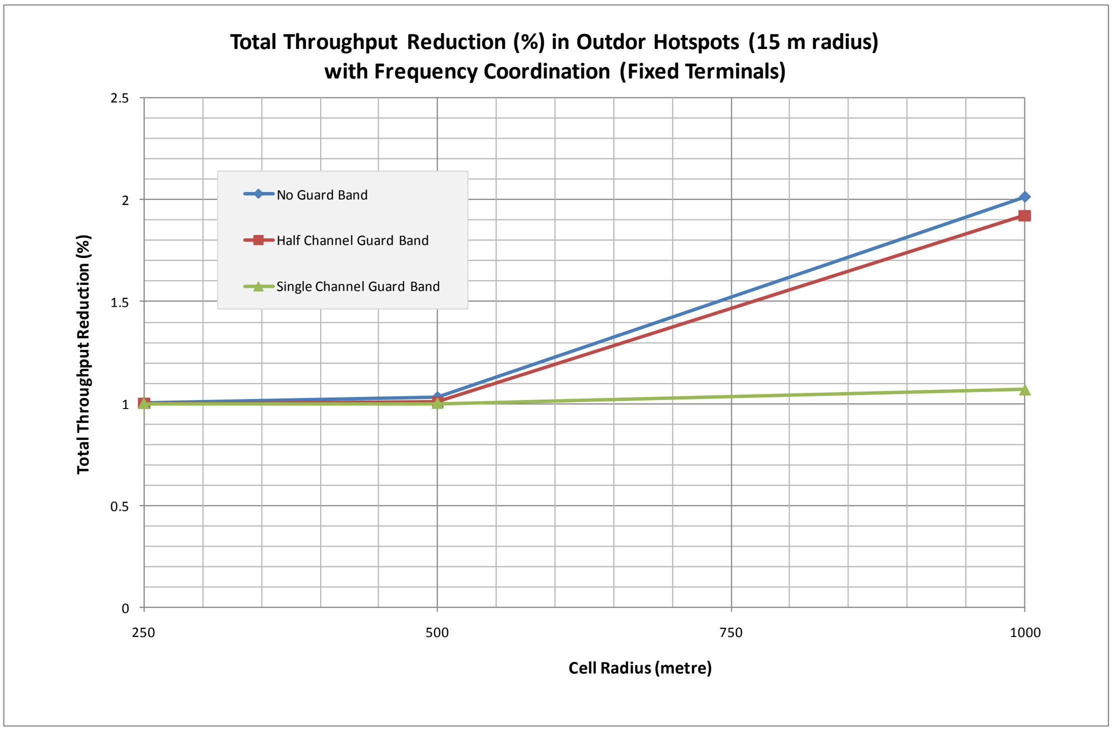


Figure 10: Overall Throughput Degradation Results for 250, 500 and 1000 metres Cell Radii (With Coordination, Fixed User Terminals)

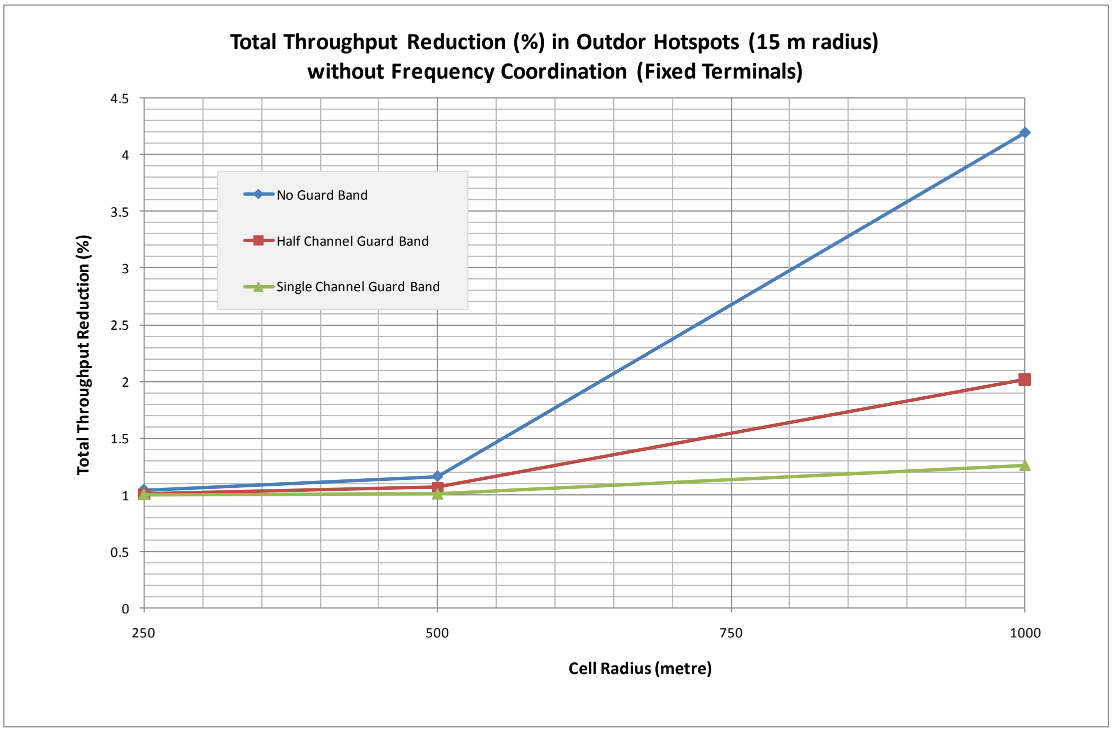


Figure 11: Overall Throughput Degradation Results for 250, 500 and 1000 metres Cell Radii (Without Coordination, Fixed User Terminals)

The results show that, for cell radii less than 0.5 km, the throughput reduction in hotspots due to inter-system interference is approximately 1% for all scenarios (i.e. with/without coordination and with/without guard band). For 1 km cells, the reduction remains less than 2% for coordinated deployment and 4.5% for uncoordinated deployment.

3 CONCLUSIONS

Our analysis suggests that the loss of overall spectrum efficiency (in terms of the total throughput likely to be supported in a hotspot area) is likely be greater if a guard band is applied between mobile terminals operating in adjacent frequency blocks than if no guard band is applied. This is because the greater terminal-to-terminal interference in the absence of a guard band only affects a limited number of users at any given time, whereas the imposition of guard bands results in a loss of spectrum to all users of the networks.

The benefit of removing the guard band becomes greater as the cell radius is reduced below 1 km and applies regardless of whether or not frequency co-ordination takes place between users. The benefit applies even where there is only one guard band in each frequency block; if a guard band is applied at both edges of each frequency block the benefit of removing the guard bands is even greater. It should also be noted that the lack of co-ordination between networks operating in adjacent blocks will have a significant impact on overall spectrum efficiency, regardless of whether a guard band is applied or not.

Further modelling results concerning interference between fixed terminals suggest that the loss of overall spectrum efficiency is much greater if a guard band is employed. In fixed terminal scenarios, the degradation due to interference is very small due to the additional antenna discrimination available at the directional user terminal antennas.

The implications of our analysis are that a mobile terminal block edge mask based on the ETSI standard EN 302 623 should not require any additional offset from the edge of the frequency block (i.e. no guard band need be assumed).