Ofcom

2500-2690MHz, 2010-2025MHz and 2290-2302MHz Spectrum Awards – Engineering Study (Phase 2)

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2500-2690MHZ, 2010-2025MHZ AND 2290-2302MHZ SPECTRUM AWARDS - ENGINEERING STUDY (PHASE 2)

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This technical study ("Technical Study") has been prepared for Ofcom, in connection with the award of wireless telegraphy licences to use the three spectrum bands at 2500-2690 MHz, 2010MHz -2025MHz and 2290-2300MHz (the “Spectrum Bands”). It is referred to in the Consultation Document on Ofcom’s proposals for the grant of wireless telegraphy licences to use the Spectrum Bands and the method for their allocation

This Technical Study is intended for information purposes only. This Technical Study is not intended to form any part of the basis of any investment decision or other evaluation or any decision to participate in the award process for the Spectrum Bands, and should not be considered as a recommendation by Ofcom or its advisers to any recipient of this Technical Study to participate in the award process for the Spectrum Bands. Each recipient of this Technical Study must make its own independent assessment of the potential value of a licence after making such investigation as it may deem necessary in order to determine whether to participate in the award process for the Spectrum Bands. All information contained in this Technical Study is subject to updating and amendment.

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APPENDICES

1. EXECUTIVE SUMMARY

This report has been prepared by Mason Communications (Mason) on behalf of the Office of Communication (Ofcom) as the Final Report of the second phase of our engineering study of the options for allocating spectrum within the 2500-2690MHz, 2010-2025MHz and 2290-2302MHz bands. The second phase of the study involved detailed compatibility assessment to consider the potential for adjacent channel interference (ACI) both within the bands (arising from different technologies being deployed in neighbouring spectrum blocks) and at band edges (with adjacent bands allocated to other services).

The first phase of the study was reported to Ofcom in a separate report.

Mason's sister company, Analysys Consulting Limited (Analysys), with DotEcon Limited (DotEcon), is conducting a corresponding economic study in parallel with the engineering study, to investigate demand for the three bands, and conditions for potential award of licences.

This is the final report of the Phase 2 Engineering Study.

Study Objectives

The overall objective of the Engineering Study was to assist Ofcom in advising on boundary conditions between different applications and technologies that might realistically use spectrum within the three bands, and to determine appropriate technical conditions to manage co-existence between different uses and to protect services operating in adjacent spectrum.

Phase 1 of the engineering and economic studies identified three possible types of compatibility relationship that have an influence on the interference environment in the three bands under study:

(1) **International coordination** – compatibility between systems deployed in a band in the UK and systems deployed in the same spectrum in neighbouring countries (Belgium, France and Ireland)

(2) **Adjacent UK bands** – compatibility between technologies deployed in each of the three bands and existing services using adjacent spectrum at the upper or lower end of each of the bands

(3) **Co-existence** – compatibility between same and/or different technologies deployed in adjacent spectrum packages within the three bands.

Based on discussion with Ofcom, analysis of (1) was not required within the current study and, hence, this is not considered further in this report.

The compatibility assessment conducted for this study, therefore, addresses issues (2) and (3) as set out above.

Approach

We undertook a two-stage approach within Phase 2:

- **Detailed sharing and compatibility assessment** – this considers the potential for adjacent channel interference (ACI) between different systems that might use the three bands, and between those systems and existing services operating in adjacent spectrum
- **Spectrum packaging and technical usage conditions analysis** – this considers technical usage conditions for the various bands to manage ACI effects identified from our compatibility assessment, and considers the implications of these on the feasibility of different spectrum packaging options.

Modelling was based on FDD and TDD technologies as follows:

- FDD: UTRA WCDMA, as specified by 3GPP
- TDD: 802.16d/e (WiMAX Revisions d and e), as specified by the IEEE.

The approach, levels of interference calculated and mitigation techniques considered are equally applicable to 3GPP TDD and other similar technologies. This is because first order FDD/TDD co-existence effects are largely due to the duplex method employed (e.g. TDD or FDD), whilst differences in the air interface technology (e.g. WCDMA or OFDM) have only a second order effect.

Our analysis assumed a 5MHz channel width for both FDD and TDD systems. It is noted that 802.16 systems and 3GPP LTE may use 10MHz channels. An 802.16e system with a bandwidth greater than 5MHz, sharing a frequency band with a 5MHz WCDMA system, would typically result in **less** interference to WCDMA, but **more** interference from WCDMA to 802.16 than is presented in our analysis.

FDD/TDD and TDD/TDD Co-existence

We have modelled FDD/TDD and TDD/TDD co-existence using input parameters based on the 3GPP UMTS FDD[1] and IEEE802.16d and e TDD specifications[2]. Adjacent channel interference was first modelled using a worst-case analysis, and then assuming appropriate interference mitigation (e.g. antenna techniques, filtering, site placement etc.) was applied.

The results of the worst-case analysis demonstrated that FDD/TDD (and TDD/TDD) co-existence is not feasible at a 5MHz offset (equivalent to operation of a FDD or TDD system adjacent to another TDD system, each with 5MHz channel spacing, with no guard band). The worst-case interference mode is base station to base station (BS-BS), for which a separation distance of significantly greater than 1km was predicted to be required between base stations to avoid interference.

[1] TS25.104 and TS24.101
[2] IEEE802.16d and e parameters based on material submitted to the ITU from the WiMAX Forum

Interference between a UMTS FDD base station and a WiMAX ‘fixed subscriber station’ (e.g. the subscriber end of a system using the IEEE802.16d-2004 version of the WiMAX standard) is also an issue, with separation distances in excess of 1km required.

Interference between mobiles (FDD and TDD or TDD and TDD) was excessive in all scenarios modelled, for short propagation paths (10 metres or less). The interference between mobiles reduces significantly as the distance between devices increases, due to the low power of the devices and the power/distance relationship.

The results of the worst-case analysis demonstrated that FDD/TDD, and TDD/TDD, co-existence is not feasible at either 10 or 15MHz offset without suitable interference mitigation. At 10MHz and 15MHz offset, the separation distance between base stations in the BS-BS interference scenario is, again, in excess of 1km, with excessive interference also occurring between mobiles (though less than the 5MHz offset case).

This suggests that operation of FDD and TDD systems in adjacent frequency blocks in the same frequency band is not feasible without consideration of suitable interference mitigation techniques.

Various mitigation techniques were considered. The application of suitable mitigation at the base station suggests that co-existence between FDD/TDD and TDD/TDD is feasible at 10MHz and 15MHz offsets assuming standard operation (e.g. typical macro site EIRP). The 5MHz-offset case is still not feasible, due to limitations on filtering at this offset. This channel will require restricted technical usage conditions for system deployment (e.g. limiting its use to low power base stations or pico-cells) to avoid interference.

Although suitable interference mitigation techniques can be applied at the base stations of FDD and TDD systems at offsets greater than 10MHz between carrier frequencies, interference still exists between mobiles since mitigation (other than power control) is not practical in consumer mobile handsets. The results of our analysis suggest that interference will be noticeable when the distance between mobiles is less than 10 metres.

However, it is noted that a number of other factors affect the probability of MS-MS interference occurring, namely:

- The MS transmission power depends on its position within the cell and the load on the system
- If an MS is operating close to its own BS, the BS can increase its power to overcome interference.

Thus, the probability of the predicted worst-case scenario interference occurring is low.

The results concluded that FDD/TDD co-existence at 5MHz offset (i.e. operation in an adjacent channel) is not feasible for macro cellular deployment, but is feasible at 10MHz and 15MHz offset, with the use of appropriate mitigation techniques at base stations. This suggests that technical usage conditions governing FDD and TDD use of the 2.6GHz band may have to define two alternative 'masks':

- A standard operation mask, appropriate to FDD and TDD macro base stations
- A restricted operation mask, limiting the transmitter power, for use in channels between FDD and TDD deployments. This effectively limits the use of one channel between an FDD and a TDD system to pico-cellular or indoor systems only.

Inbound and Outbound Interference to/from Cellular and Mobile Broadband FDD/TDD systems and Programme Making and Special Events (PMSE)

Localised interference occurred between PMSE systems and FDD/TDD systems in all deployment scenarios considered, unless appropriate interference mitigation (e.g. band edge filtering) is applied. Interference can occur in both directions, i.e. from PMSE to FDD/TDD systems, and vice versa.

The addition of suitable mitigation should result in PMSE operation being feasible adjacent to an FDD/TDD system (without a guard band). The addition of frequency separation (e.g. from 10MHz to 20MHz separation in our analysis) does not significantly improve the co-existence results (due to the wide band spectrum mask of the video link).

Our results suggest that:

- Localised interference could occur from all types of PMSE links to TDD and FDD base station receivers (and from FDD and TDD base station transmitters to PMSE). The interfering distances for different types of base station are: within 200 metres of a macro base station, within 100 metres of a micro base station and within 75 metres of a pico base station. Due to the wideband nature of the PMSE system, interference will affect both the top channel at each band edge plus the next adjacent channel (2015-2020MHz)
- In future, coordination may be required between PMSE links and cellular/mobile broadband base stations, to avoid the interfering distances defined above
- The worst-case outbound interference scenario we predicted was if a cellular or mobile broadband base station is transmitting in a channel adjacent to the PMSE band. Due to the location of PMSE bands relative to the three bands considered in this study, this only occurs if TDD is located at certain band edges (since if used for FDD, the relevant band edges would be adjacent to the FDD uplink band).

FDD/TDD System Interference to Mobile Satellite Service (MSS)

The 2483.5-2500MHz band is allocated to the Mobile Satellite Service (MSS) on a global basis and used by the Globalstar system. The 2483.5-2500MHz band provides the Space-Earth link for this system.

The Earth Station providing Globalstar coverage to the UK is located within central Europe and hence is not considered further in this report. We focused on the potential for FDD/TDD systems operating in the 2.6GHz band to cause adjacent channel interference to Globalstar terminals in the UK.

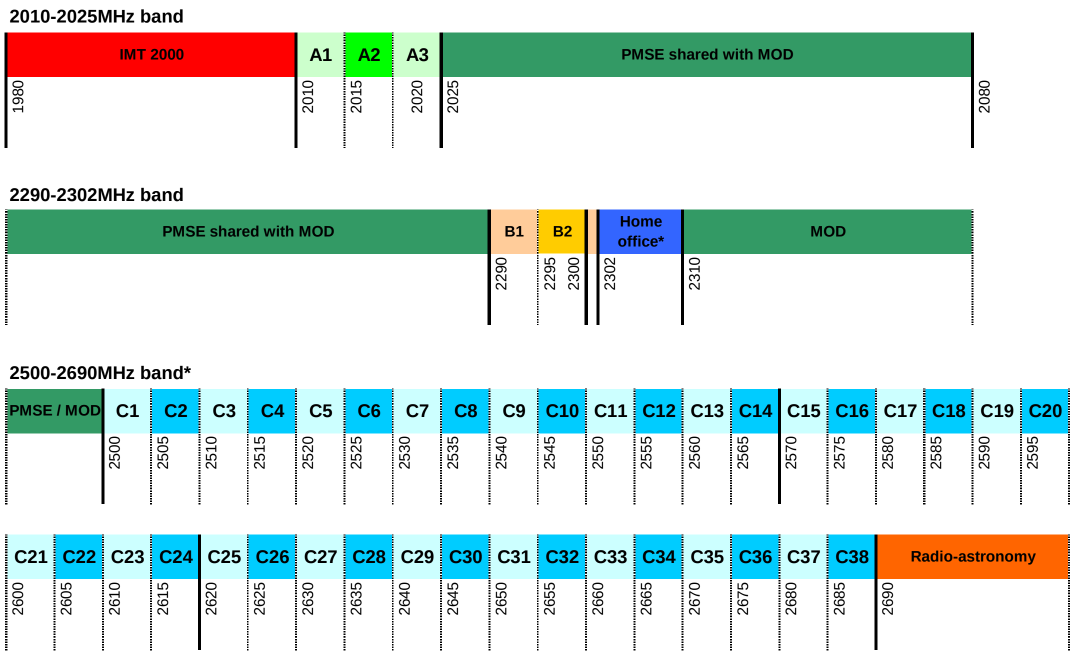
The results of our analysis illustrated that the 'worst case' interference to Globalstar terminals is from FDD/TDD base stations causing interference to mobile reception. This worst-case interference will occur if the lower channels of the 2.6GHz band are used for TDD systems, in which case both TDD base stations and fixed subscriber stations (e.g. of an IEEE802.16d system deployment) will interfere with Globalstar mobile terminal reception.

If the lower channels of the 2.6GHz band are used for FDD, this worst-case scenario is avoided since the FDD base stations will transmit in the upper duplex pair. However, localised interference could occur between FDD and Globalstar mobiles.

The probability of mobile-mobile interference occurring in practice is dependent on a number of factors including the likelihood of devices being co-incident within the interfering range (less than 10 metres), the FDD or TDD MS transmission power (depending on its location within the cell) and other factors.

Spectrum Packaging Implications

Based on the following reference band plan, we have drawn the following conclusions from the ACI analysis.



*Under the CEPT plan, blocks C1-C14 paired with C25-C40 are specified for UMTS FDD, uplink and downlink respectively; blocks C15-C24 are specified for UMTS TDD. However, Ofcom is no obliged to conform to this plan.

Table 1.1: Reference Band Plans (Source: DotEcon)

2010-2025MHz

Results of our ACI analysis for the 2010-2025MHz band suggests the following impact on packaging of spectrum in this band:

- At band edge with A1 (2010MHz): 500kHz guard band recommended in ECC (06) 01 to reduce outbound interference from TDD base stations to MSS satellites (in accordance with ECC Decision (06) 01. We have not validated the CEPT analysis leading to this recommendation in our report
- At the band edge with A3 (2025MHz): Mitigation required to protect PMSE from outbound interference (e.g. use of filtering). In addition, A2 and A3 suffer inbound interference from PMSE
- At the band edge with A3 (2025MHz): 300kHz guard band recommended in ECC Decision (06) 01 to provide protection to Space Science Services in 2025-2110 MHz[3]..

2290-2302MHz

Results of our ACI analysis for the 2290-2302MHz band suggest the following impact on packaging of spectrum in this band:

- At boundary with B1 (2290MHz) – no guard band with PMSE recommended but mitigation required to reduce the impact of localised interference. However, if B1 and B2 are used for PMSE, mitigation may not be required, since the channels can be incorporated in to the existing PMSE band plan in the adjacent band
- At boundary with B2 (2302MHz) – no mitigation or other restrictions required.

2500-2690MHz

Results of our analysis of internal and external adjacent channel interference affecting the 2500-2690MHz band suggests the following:

- Base stations and mobiles of networks operating in channels close to the band edge with 2500MHz (channels C1 and C2) will be affected by incoming and outgoing interference to/from PMSE. This affects both FDD and TDD systems but outgoing interference is worse if TDD systems are deployed in C1 (since TDD base stations will transmit in C1)
- TDD base stations operating in channels close to the band edge with 2500MHz (if channel C1 is used for TDD) may require restricted technical usage conditions to limit interference to MSS terminals. This restriction is not necessary if C1 is used for FDD systems, since base stations will transmit in the upper frequency pair of the FDD band. The mobile/mobile model interference between FDD/TDD mobiles and MSS terminals is limited to short propagation paths

[3] It needs to be confirmed whether this guard band is required in the UK plan

- Coordination between FDD and TDD systems will be required at each FDD/TDD boundary within the 2.6GHz band:
  - ♦ For FDD/TDD operating at 5MHz offset (i.e. adjacent channel), co-existence is not achievable without restricted technical usage conditions applying (e.g. limiting base station transmitter power to that of pico-cell deployments only)
  - ♦ For FDD/TDD operating at 10MHz offset (i.e. second adjacent channel) – our view is that site coordination will be required if systems are to be co-located, plus use of band stop filtering on base station transmitters
  - ♦ For TDD/TDD operating at 5MHz and 10MHz offset – synchronisation of systems will avoid ACI occurring. However, this also requires detailed coordination of usage between operators (e.g. equivalent up/down timeslot allocations). Without synchronisation, interference will occur, which will require site coordination and base station transmitter and receiver filtering to overcome.

Glossary of Terms

3GPP	Third Generation Partnership Project
ACI	Adjacent Channel Interference
ACP	Adjacent Channel Power
ANSI	American National Standards Institute
CAA	Civil Aviation Authority
CCI	Co Channel Interference
CDMA	Code Division Multiple Access
CEPT	Committee on European Postal and Telecommunications Regulation
CGC	Complementary Ground Component
DL	Downlink e.g. in a mobile system, the link from a base station to a mobile, and in a satellite system, the downlink is the link from a satellite down to one or more ground stations or receivers
DMB	Digital Multimedia Broadcasting
DVB-H	Digital Video Broadcasting: Handhelds
DVB-T	Digital Video Broadcasting: Terrestrial
ECC	Electronic Communication Committee (of the CEPT)
EIRP	Effective Isotropic Radiated Power
FCS	Federation of Communication Services
FDD	Frequency Division Duplex
GHz	Giga Hertz
HC-SDMA	High Capacity Spatial Division Multiple Access
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access, collective term for HSDPA+HSUPA
HSUPA	High Speed Uplink Packet Access
IEEE	Institute of Electrical and Electronic Engineers
IMT (2000)	International Mobile Telecommunications
ITU	International Telecommunications Union
LTE	Long Term Evolution (of UTRA)
MBMS	(3G) Multimedia Broadcast Multicast Service
MHz	Mega Hertz
MMDS	Multi-channel Multipoint Distribution Service
MoD	Ministry of Defence
MSS	Mobile Satellite Service
OFDM	Orthogonal Frequency Division Multiplexing
PMSE	Programme Making and Special Events
RSA	Recognised Spectrum Access
RX	Receive
TD-CDMA	Time Division CDMA
TDD	Time Division Duplex
TX	Transmit
UL	Uplink e.g. in a mobile system, the uplink is the link from a mobile to a base station, and in a satellite system, the uplink is the link from a ground station up to a satellite
UMTS	Universal Mobile Telecommunications System
UTRA(N)	UMTS Terrestrial Radio Access (Network)
WCDMA	Wideband Code Division Multiple Access
WiBro	Wireless Broadband
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

2. INTRODUCTION

This report has been prepared by Mason Communications (Mason) on behalf of the UK Office of Communications (Ofcom) as a summary of results of the second phase of the engineering study of the options for allocating spectrum within the 2500-2690MHz, 2010-2025MHz and 2290-2302MHz bands.

Mason's sister company, Analysys Consulting Limited (Analysys), with DotEcon Limited (DotEcon), is conducting a corresponding economic study in parallel with the engineering study, to investigate demand for the three bands, and conditions for potential award of licences.

The engineering study has been conducted in two phases, coordinated with the economic study:

- **Phase 1** - to assess potential users, applications and technologies that could make use of the bands and to review existing studies (completed and underway) in relevant international forum relating to relevant adjacent channel interference issues (including co-existence between different technologies within the bands)
- **Phase 2** - to define, in detail, the technical provisions of spectrum licences, taking account of adjacent channel interference constraints and necessary boundary conditions.

This is the final report covering the results of Phase 2 of the study. A separate report was prepared for Ofcom in June 2006 summarising results of Phase 1.

2.1 Background

The study is concerned with the award of spectrum in three bands:

- The 2500-2690MHz band was identified at the World Radio Communications Conference in 2000 (WRC-2000) as additional spectrum for IMT-2000 technologies, over and above spectrum at 2GHz, which is now being used for 3G services in many countries worldwide. The intention was that the 2500-2690MHz band could be used to provide additional capacity for 3G services deployed in the 2GHz band – however, the demand for 3G services is not as advanced as predicted in forecasts made at the time of the WRC-2000 and in the meantime, other technologies have been developed for which this spectrum may be of value. The 2500-2690MHz band is currently used for TV outside broadcasting in the UK (Programme Making and Special Events – PMSE), but the PMSE industry have been given notice by Ofcom that new spectrum licences are to be awarded in this band, and that their licences will be subject to a rolling three-month notice period from 01 January 2007 onwards
- The 2010-2025MHz band is part of the spectrum originally identified for IMT-2000 at the World Administrative Radio Conference in 1992 (WARC-92). The 2010-2020MHz sub-band was previously reserved for self-coordinating 3G Time Division Duplex (TDD) systems, as part of ERC Decision (99) 25. Though in the UK, the entire 2010-2025MHz band was reserved for self co-

ordinating 3G systems at the time of the UK 3G auction in 2000. However, demand for such systems has not materialised and hence the CEPT has revised the original decision to remove the self-coordinating designation. According to the new ECC Decision (06) 01, the entire band 2010-2025MHz is potentially available for licensed TDD systems (which do not require paired spectrum), or alternatively for potential pairing with another band (e.g. part of 2500-2690MHz) for FDD systems
- The 2290-2302MHz band is spectrum released from the Ministry of Defence (MoD) and could potentially be used for either TDD systems, which do not required paired spectrum, or for potential pairing with another band for FDD systems.

An initial study looking at possible allocation options for the three bands was conducted by DotEcon, Analysys and Mason in the second half of 2004-2005. A number of developments since this time prompted Ofcom to commission further study in preparation for award of the three bands. Two studies have been commissioned:

- An economic study, to assess demand for the spectrum and the implications of this on spectrum packaging and auction design
- An engineering study, to assess how different candidate uses and technologies would use the spectrum, and to define technical conditions of spectrum usage rights to be offered.

Ofcom, therefore, commissioned this engineering study in parallel with the economic study being conducted by Analysys and DotEcon. The objective of the engineering study is to examine in detail the interference issues associated with different uses and technologies being deployed within the three bands, and to make recommendations in relation to the feasibility of different spectrum packaging options and resulting technical usage conditions for the award of the three bands.

2.2 Objectives of the Study

The overall objective of the Engineering Study is to assist Ofcom in advising on boundary conditions between different applications and technologies that might realistically use spectrum within the bands, and to determine appropriate technical conditions to manage co-existence between different uses within the bands and to protect services operating in adjacent spectrum.

During Phase 1 of the engineering study, we reviewed a comprehensive set of technical literature and previous studies relating to the 2500-2690MHz, 2010-2025MHz and 2290-2302MHz bands, including studies conducted in CEPT, 3GPP, WiMAX Forum and ITU-R. During this phase of the study, we also undertook an extensive industry consultation to understand demand for the spectrum, likely uses and applications. This was coordinated with the economic study being conducted in parallel by Analysys and DotEcon.

An objective of the first phase was to determine where existing studies have resolved Adjacent Channel Interference (ACI) issues, and where additional modelling was required to conclude on spectrum packaging issues for the bands under study.

Based on this, objectives of Phase 2 of the engineering study were agreed with Ofcom as being to:

- Conduct additional detailed sharing and compatibility analysis to study the impact of co-existence issues within the 2500-2690MHz and related bands between different systems that might use those bands. Based on results of Phase 1 of the engineering and economic studies, possible uses of the band have been identified to be: cellular telephony services, broadband wireless access (BWA) services, programme making and special events (PMSE) and mobile multimedia
- Conduct additional detailed compatibility analysis to study the potential for inbound and outbound interference between different uses of the three bands and services using adjacent bands
- Assess specific spectrum packaging options and identify technically viable options (assisting the Economic Study to resolve spectrum packaging issues and auction design issues)
- Assist with the definition of technical usage conditions to avoid harmful interference both within the bands and with adjacent users.

In order to achieve this, we have undertaken a two-stage approach to Phase 2 of the study:

- **Detailed sharing and compatibility assessment –** this encompasses consideration of adjacent channel interference (ACI) between different systems that might use the three bands, and between those systems and existing services operating in adjacent spectrum
- **Spectrum packaging and technical usage conditions –** this encompasses the consideration of appropriate technical usage conditions to manage ACI effects identified through the detailed sharing and compatibility assessment, and recommendations on the feasibility of different spectrum packaging options for the bands under study.

2.3 Structure of this Document

The remainder of this report is structured as summarised in Table 2.1 below.

Section	Description
Section 3	Summarises results of Phase 1
Section 4	Describes the approach to the study
Section 5	Provides the ACI scenarios considered for the 2500-2690MHz band and examines the potential for interference within this band and with adjacent services
Section 6	Provides the ACI scenarios considered for the 2010-2025MHz band and examines the potential for interference within this band and with adjacent services
Section 7	Provides the ACI scenarios considered for the 2290-2302MHz band and examines the potential for interference within this band and with adjacent services
Section 8	Develops recommendations for technical usage conditions and spectrum packaging in the three available bands
Section 9	Discusses the cost to potential users of the three available bands to reduce the predicted ACI through use of appropriate filtering
ANNEXES	
Annex A	Interference Analysis: Co-Existence of Different 2.6GHz systems (UMTS FDD, UMTS TDD, WiMAX TDD)
Annex B	Interference Analysis: Inbound and outbound interference between PMSE and UMTS/WiMAX
Annex C	Interference Analysis: Outbound interference to MSS (Globalstar) terminals receiving in 2483.5-2500MHz

Table 2.1: Structure of Document

2.4 Acknowledgements

Within both phases of this study, discussions were held with a number of interested parties within the radio industry to provide input to our market analysis on use of the three bands and to validate technical assumptions used in our ACI analysis. This included equipment vendors, filter manufacturers, existing and potential spectrum users as well as experts within Ofcom.

Mason would like to acknowledge the time and information provided by the representatives of the various organisations that we have approached as part of this study and thank them for their contributions.

3. SUMMARY OF RESULTS OF PHASE 1 ENGINEERING STUDY

Our approach to the second phase of the engineering study, as described in this report, was influenced by the results of the first phase of the study, which were presented to Ofcom in June 2006.

A summary of findings from the first phase of the study is provided below. A detailed account of the first phase of the study is contained in Mason's Phase 1 Report to Ofcom.

3.1 Uses and Applications

During the first phase of the study, we conducted a series of one to one interviews within the wireless industry (operators, vendors and trade associations) to identify the range of services and technologies that might be deployed in the available spectrum bands. This investigation was coordinated between the engineering and the economic studies on award of the three bands to provide a consistent viewpoint.

A key reason for investigating likely uses of the bands, from the perspective of the engineering study, was to confirm the spectrum requirements and required frequency arrangements of those technologies that might use the available bands, which were then used to define interference scenarios for our ACI assessment within the second phase of the study.

Table 3.1 summarises the spectrum requirements of the different services and technologies that we identified during Phase 1 that could be deployed in the available spectrum bands.

Service/Technology	Paired or Unpaired?	Potential Spectrum Requirement	Band Preferences
3G cellular mobile	Paired	Multiple blocks of 2 x 5MHz (possible requirement for 2 x 10MHz for 3GPP LTE)	2500-2570MHz paired with 2620-2690MHz
MDMS/Mobile Multimedia	Unpaired	Unpaired blocks of 5MHz	2010-2025MHz or 2570-2620MHz
UMTS TDD	Unpaired	Unpaired blocks of 5MHz	2010-2025MHz or 2500-2690MHz
WiMAX	Unpaired	Multiple blocks of 10MHz	2500-2690MHz
PMSE	Unpaired	(For Digital Systems) Blocks of 10MHz	All three bands, adjacent to existing PMSE use

Table 3.1: Summary of Spectrum Requirements of Different Services and Technologies that could be deployed in the Available Bands

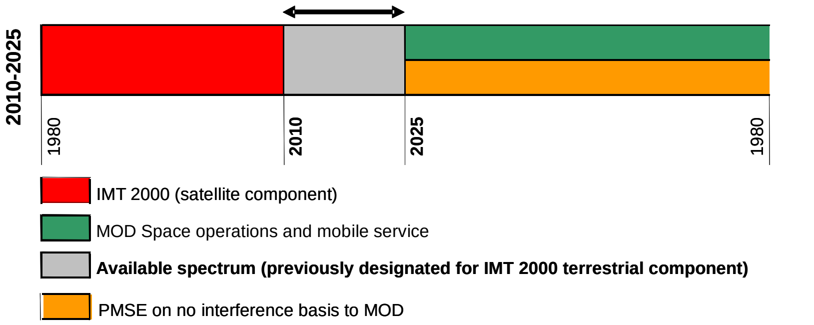
The Phase 1 results confirmed that a number of alternative technologies might feasibly use the three bands, which include both FDD and TDD technologies.

Based on the assumption that the technical usage conditions granted in this band should not preclude any feasible technology, this identified that compatibility issues might be created within the three available bands between:

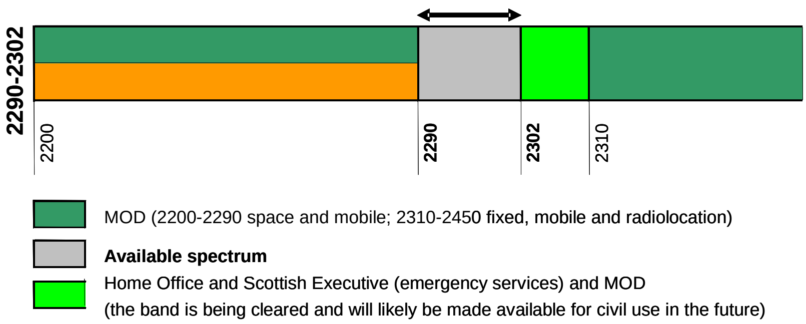
- Mobile/broadband FDD and TDD systems deployed in adjacent spectrum
- Adjacent mobile/broadband TDD systems if not synchronised and/or used for different services
- Mobile/broadband FDD and TDD systems and PMSE.

3.2 Adjacent Services and Adjacent Channel Interference Scenarios

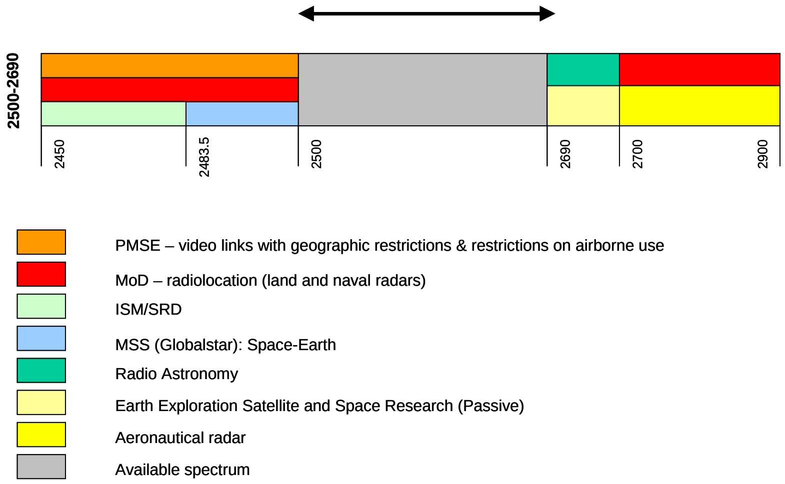
During the first phase of work, we identified services operating in spectrum bordering the three bands under study, which might suffer interference from systems deployed within 2010-2025MHz, 2290-2302MHz and 2500-2690MHz. The relevant adjacent services are illustrated in Figure 3.1.



2010-2025MHz band and neighbouring uses



2290-2302MHz band and neighbouring uses



2500-2690MHz band and neighbouring uses

Figure 3.1: Services Adjacent to the Bands Under Study

Based on the range of systems and technologies identified that could use the available spectrum, and the services operating in adjacent bands, we then considered the adjacent channel interference (ACI) issues requiring further consideration during the second phase of the study.

These are summarised below.

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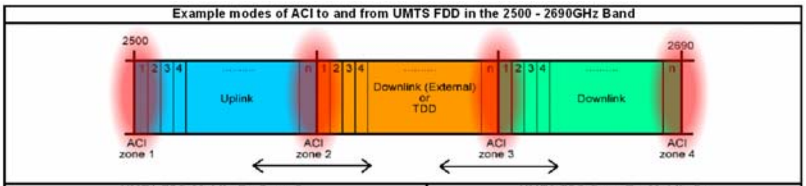
3.2.1 2500-2690MHz

Figure 3.2 summarises the ACI issues that we identified associated with the 2.6GHz band.



	UMTS FDD Mobile Tx, Base Rx		UMTS FDD Base Tx, Mobile Rx	
ACI Class	ACI Zone 1	ACI Zone 2	ACI Zone 3	ACI Zone 4
Base to Base		UMTS FDD(ext) to UMTS FDD UMTS TDD to UMTS FDD WiMAX TDD to UMTS FDD	UMTS FDD to UMTS TDD UMTS FDD to WiMAX TDD	UMTS FDD to CAA Radar UMTS FDD to Radio Astronomy
Mobile to Mobile	UMTS FDD to Satellite Phone	UMTS FDD to UMTS FDD(ext) UMTS FDD to UMTS TDD UMTS FDD to WiMax TDD	UMTS TDD to UMTS FDD WiMAX TDD to UMTS FDD	
Mobile to Base	ISM (WiFi etc.) to UMTS FDD	UMTS FDD to UMTS TDD UMTS FDD to WiMax TDD UMTS TDD to UMTS FDD WiMax TDD to UMTS FDD		
Base to Mobile			UMTS FDD to UMTS TDD UMTS FDD to WiMax TDD UMTS TDD to UMTS FDD WiMAX TDD to UMTS FDD	CAA Radar to UMTS FDD

Figure 3.2: ACI Summary 2.6GHz

Whilst the illustration in Figure 3.2 above arises from the CEPT ECC(05) 05 Decision for the 2.6GHz band, it was noted during the first phase of the study that Ofcom could implement a band plan for the 2.6GHz band other than this. A range of alternative plans could be considered that would still retain the key features for handset implementation (e.g. 120MHz duplex spacing for FDD).

Figure 3.3 below provides examples of alternative band plans that could be considered for the 2.6GHz band. The ACI modes of interference for alternative plans are similar to those indicated in Figure 3.2, with the main difference being that ACI effects may occur in different portions of the band depending on where the boundary(s) between FDD and TDD use lies. The exception is the 'all TDD' plan, which introduces different ACI modes at the boundaries of the 2.6GHz band with adjacent services (e.g. TDD base station interference to PMSE in ACI Zone 1).

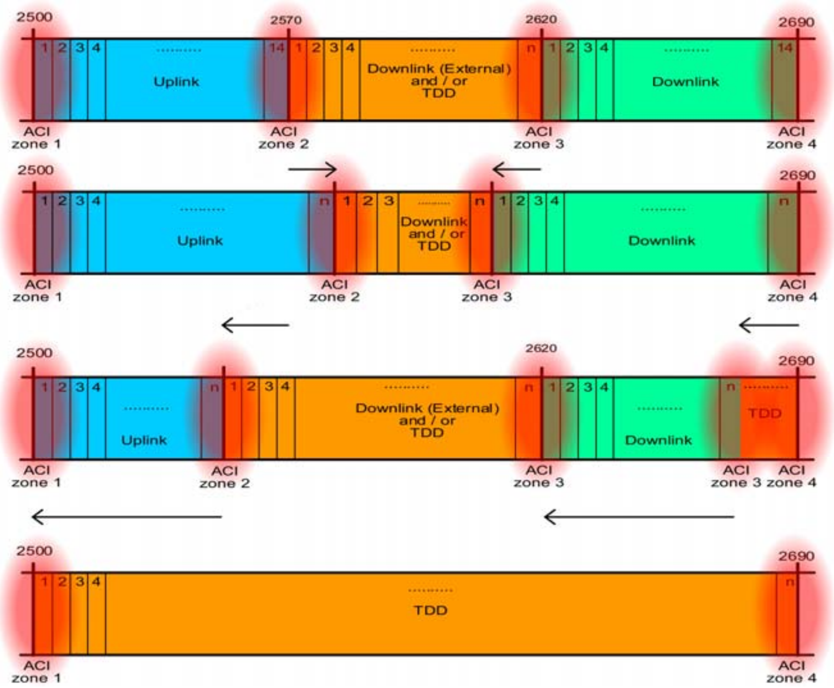
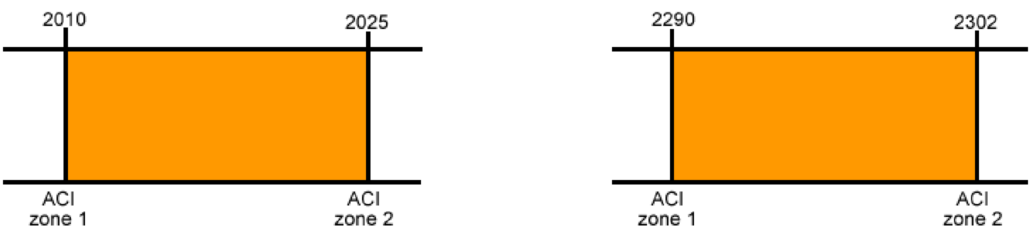


Figure 3.3: Alternative Band Plan Options for 2.6GHz Band

3.3 2010-2025MHz and 2290-2302MHz

Figure 3.4 illustrates the adjacent service boundaries in the 2010-2025MHz and 2290-2302MHz bands. Internal system boundaries may also occur within these bands (depending on how the spectrum is packaged), however, given the limited bandwidth of the two bands, mixed use of these bands may create unacceptable inefficiencies (which is to be confirmed through the second phase of the study).



ACI Class	2010-2025 MHz ACI Zone 1	2010-2025 MHz ACI Zone 2	2290-2302 MHz ACI Zone 1	2290-2302 MHz ACI Zone 2
Base to Base	UMTS TDD or WiMAX to MSS satellite	UMTS TDD or WiMAX to PMSE PMSE to UMTS TDD or WiMAX	UMTS TDD or WiMAX to PMSE PMSE to UMTS TDD or WiMAX	MoD to UMTS TDD or WiMAX
Mobile to Mobile	MSS (MS) to UMTS TDD or WiMAX	PMSE to UMTS TDD or WiMAX UMTS TDD or WiMAX to PMSE	UMTS TDD or WiMAX to PMSE PMSE to UMTS TDD or WiMAX	
Mobile to Base	UMTS TDD or WiMAX to MSS satellite	UMTS TDD or WiMAX to PMSE PMSE to UMTS TDD or WiMAX	UMTS TDD or WiMAX to PMSE PMSE to UMTS TDD or WiMAX	
Base to Mobile		UMTS TDD or WiMAX to PMSE PMSE to UMTS TDD or WiMAX	UMTS TDD or WiMAX to PMSE PMSE to UMTS TDD or WiMAX	MoD to UMTS TDD or WiMAX

Figure 3.4: Adjacent Channel Interference: 2010-2025MHz and 2290-2302MHz

The issues identified relevant to the 2010-2025MHz and 2290-2302MHz bands are summarised as follows:

- 2010MHz ACI Zone 1 – the relevant adjacent services are satellite uplinks in the 1980-2010MHz band for satellite personal communications services (ERC/DEC/(97) 03)[4]
- 2025 MHz ACI Zone 2 – the relevant adjacent services are MoD space operations (earth to space), PMSE and space research (earth to space). PMSE use of the 2025-2110MHz band is on a co-ordinated basis with the MoD at present. Both incoming and outgoing interference may be an issue to the upper channel within the 2010-2025MHz band at the 2025MHz boundary
- 2290MHz ACI Zone 1 – the relevant adjacent services are PMSE and MoD. Both incoming and outgoing interferences may be an issue to the lower channel at the 2290MHz boundary
- 2302MHz ACI Zone 2 – the relevant adjacent services are MoD (from 2310MHz) and fixed links (although we understand that these are being phased out and hence were not considered further during Phase 2 of the study).

3.4 Phase 1 Recommendations

It was identified during Phase 1 that a number of existing studies had previously assessed ACI issues for some interference scenarios relevant to the three bands:

- CEPT conducted extensive studies on compatibility issues associated with the 2010-2025MHz band as part of ERC Report 65 (2000)
- CEPT has also studied some compatibility issues associated with the 2500-2690MHz band in ECC Report 45 (2004), however, results were not fully applicable with the envisaged range of uses that we identified for the 2.6GHz band in Phase 1 of the study
- ITU-R is undertaking a range of ongoing studies within Working Party 8F relevant to UMTS/WiMAX compatibility in the 2.6GHz band, however, as with the CEPT study, these are not fully representative of the range of uses for the 2.6GHz band.

This suggested further detailed sharing and compatibility analysis being required in the following key area in order to achieve the objectives of Phase 2 of our study:

- Detailed modelling of adjacent channel co-existence effects between UTRA (FDD and TDD) systems and WiMAX IEEE802.16d-2004 and IEEE802.16e-2005 systems, to validate ongoing analysis within ITU-R and other studies that are also studying co-existence between these systems

[4] It is understood that this Decision is under review within CEPT

- Modelling of adjacent channel co-existence effects between UTRA FDD and TDD and/or WiMAX and PMSE users within adjacent spectrum bands (noting that PMSE in the UK uses the bands 2025-2110MHz, 2200-2290MHz and 2390-2500MHz, which have adjacencies with each of the bands under consideration within our study)
- Modelling of outbound adjacent channel interference from UTRA FDD and TDD and/or WiMAX systems to Globalstar satellite terminals operating in the 2483.5-2500MHz band.

4. OVERVIEW OF OUR APPROACH

Phase 2 of the engineering study consisted of two parts: detailed sharing and compatibility assessment, and consideration of the impact of the sharing and compatibility results on spectrum packaging and usage rights.

Table 4.1 summarises our overall approach:

Sharing and Compatibility Assessment	Spectrum Packaging and Usage Rights
Task 1: Technologies and Services • Identify spectrum usage characteristics of technologies that might be deployed within the three bands (based on the market demand assessment conducted in Phase 1 of the Study) relevant to ACI analysis • Confirm services operating in adjacent spectrum and their characteristics • Define ACI scenarios for modelling	**Task 3: Spectrum Packaging** • Assess the feasibility of high level packaging options defined in Phase 1 of the study • Recommend possible band plans to minimise unacceptable ACI
Task 2: Sharing and Compatibility Analysis • Model ACI effects for each scenario • Where ACI effects are unacceptable, identify possible interference mitigation measures and model the effect they have in reducing ACI • Estimate the cost of applying appropriate mitigation techniques to users of the affected band(s)	**Task 4: Usage Conditions** • Identify required system characteristics to minimise ACI, defined in terms of appropriate EIRP mask(s) • Consider possible deployment scenarios and identify parameters to be used in determination of aggregate power flux density (PFD) or other appropriate technical usage conditions

Table 4.1: Summary of Approach

Sections 4.1 and 4.2 describe our approach in more detail.

4.1 Sharing and Compatibility Assessment

Phase 1 of the study identified three possible types of compatibility relationship that have an influence on the interference environment in the three bands under study:

(1) International coordination – compatibility between systems deployed in a band in the UK and systems deployed in the same spectrum in neighbouring countries (Belgium, France and Ireland)

(2) Adjacent UK bands – compatibility between technologies deployed in each of the three bands and existing services using adjacent spectrum at the upper or lower end of each of the bands

(3) Co-existence – compatibility between same and/or different technologies deployed in adjacent spectrum packages within the three bands.

Based on discussion with Ofcom, analysis of (1) was not required within the current study and, hence, this is not considered further in this report.

The compatibility assessment conducted for this study, therefore, addresses issues (2) and (3) as set out above.

The first task in the sharing and compatibility assessment was to identify relevant spectrum usage characteristics of technologies that might be deployed within the three bands, and those of existing services in adjacent spectrum, relevant to our ACI analysis.

Within the analysis conducted, we have focused on interference that may arise as a result of out-of-band (adjacent channel) interference. We have not modelled the effect of in-band interference from co-channel use of the same spectrum across geographic boundaries, since it has been assumed that licences offered within the award process for the three available bands be UK-wide national licences (in line with conclusions drawn from the spectrum usage and demand assessment conducted in the first phase of the engineering and economic studies).

Since out-of-band interference is determined by the adjacent channel performance of the interfering transmitter and victim receiver, the first task was to compile relevant transmitter and receiver parameters of each system to be modelled.

Using definitions from ITU-R and CEPT studies, the level of adjacent channel interference received depends on the spectral 'leakage' of the interferer's transmitter and the adjacent channel blocking performance of the receiver.

For the transmitter, the spectral leakage is characterised by the **Adjacent Channel Leakage Ratio** (ACLR), which is defined as:

"*The ratio of the transmitted power to the power measured in the adjacent radio frequency (RF) channel at the output of a receiver filter.*"

Similarly, the adjacent channel performance of the receiver is characterised by the **Adjacent Channel Selectivity** (ACS), which is defined as:

"The ratio of the power level of unwanted ACI to the power level of co-channel interference that produces the same bit error ratio (BER) performance in the receiver."

Figure 4.1 below illustrates the interference mechanisms.

The out-of-band power from the interferer that falls within the pass band of the victim is controlled by the ACLR. The main transmit signal power from the interferer is out-of-band and is attenuated by the ACS.

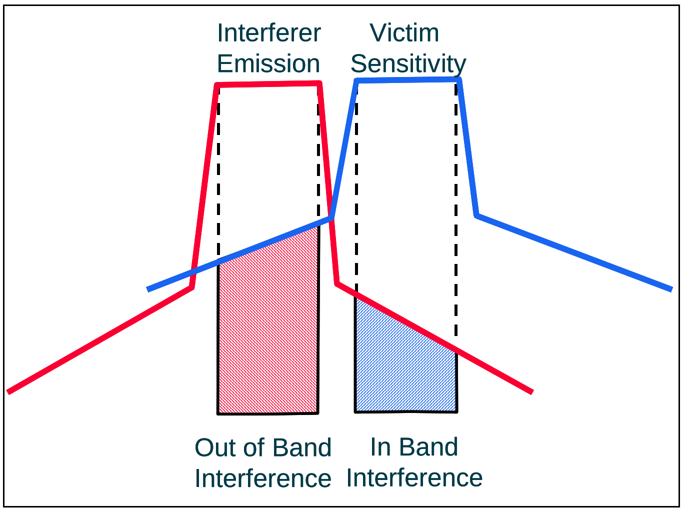


Figure 4.1: Interference Mechanism Considered

The ACLR of the interferer and ASC of the victim can be combined to give ACIR using the formula below:

$$ACIR = \frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}}.$$

Assuming an appropriate propagation model for the interference scenario being considered enabled us to calculate path loss between the interferer and the victim.

The additional isolation required to prevent ACI was then calculated using the formulae in Table 4.2.

Co-Location Additional Isolation (dB)	*Non Co-located Additional Isolation (dB)*
Additional isolation = TX power – antenna coupling loss – ACIR – interference limit	*Additional isolation = TX power + TX gain + RX gain – propagation loss – ACIR – interference limit*

Table 4.2: Additional Isolation to Prevent ACI

Required parameters for the various ACI assessments were, therefore:

- Transmitter power
- Antenna gain
- Antenna height
- Interference threshold
- Adjacent channel leakage radio at 5 and 10MHz offsets from the carrier frequency
- Adjacent channel selectivity and 5 and 10MHz offsets from the carrier frequency.

Relevant RF parameters for both interfering and interfered systems were compiled from a mixture of sources (ETSI specifications, ITU-R Recommendations, industry studies, vendor information). A full summary of parameters used in our analysis is provided in Appendix A. Where required RF parameters were unavailable, or deployment assumptions were required, these were estimated by Mason using knowledge of typical deployment for the systems under consideration.

To identify ‘victim’ adjacent services that may suffer interference, or cause interference to, systems operating within the three available bands, Ofcom provided information on services currently using adjacent spectrum above and below the three bands under study, and the relevant protection criteria for those services.

A list of interference scenarios was then drawn up for each frequency band, defining all potential inbound and outbound ACI paths between different systems within the band and services in adjacent bands.

A shortlist of technologies that might be deployed within the 2500-2690MHz, 2010-2025MHz and 2290-2302MHz bands was developed as part of Phase 1 of the study. A wide range of alternative technologies were considered during the first phase of work, from which the following shortlist of ‘most likely’ technologies was developed for the purposes of the detailed compatibility analysis:

- 3GPP/UMTS (FDD)
- 3GPP/UMTS (TDD)
- IEEE802.16d and IEEE802.16e WiMAX (TDD)

- PMSE (radio cameras, portable/mobile links, temporary video links and air to ground vide links) based on DVB-T digital technology.

It is noted that other CDMA or OFDM technologies might also use the available bands; however, it was agreed to base the ACI analysis on characteristics of the above systems.

4.2 Spectrum Packaging and Technical Usage Conditions

The objective of this task was to first identify (from various packaging options identified during the first phase of the study), the feasibility of different options based on the results of the sharing and compatibility assessment, and then to define technical usage conditions.

Spectrum requirements for the various potential uses of the three bands were identified during the first phase of the study. These included:

- Required configuration – whether systems require paired spectrum or not
- Bandwidth/channel width
- Duplex spacing and duplex direction (for paired systems).

These requirements were used to develop a series of high-level spectrum packaging options during the first phase of the study.

Drawing on the results of the compatibility analysis described in this report, we reviewed the packaging options identified and provided further analysis of:

- The extent of constraints that might apply to particular channel(s) at the lower and upper ends of the three available bands, due to the need to protect existing services operating in adjacent spectrum
- The extent of constraints that might apply on specific channels to avoid ACI between different technologies deployed within the same band, e.g. at spectrum boundaries between FDD and TDD systems.

A series of recommendations were then drawn up to illustrate where constraints might apply, to form an input to the Phase 2 of the economic study being conducted by Analysys and DotEcon.

The results of the compatibility analysis were also used to make recommendations on appropriate characteristics for spectrum masks to define technical usage conditions. Alongside technical spectrum masks, we have also considered deployment examples upon which Ofcom could base further detailed Spectrum Usage Right (SUR) derivation (e.g. of aggregated PFD limits).

4.3 Scenarios

Our Phase 1 results confirmed the following internal and external interference modes for further investigation during the second phase of the study.

2.6GHz Interference Scenarios – Internal
UMTS and WiMAX BS to BS interference: • UMTS TDD/UMTS FDD • UMTS FDD/WiMAX TDD • UMTS TDD/WiMAX TDD • UMTS/PMSE • WiMAX/PMSE
UMTS and WiMAX MS to MS Interference: • UMTS TDD-UMTS FDD • WiMAX TDD-UMTS FDD • WiMAX TDD-UMTS TDD
UMTS and WiMAX MS to BS Interference • UMTS TDD-UMTS FDD • WiMAX TDD-UMTS FDD • WiMAX TDD-UMTS TDD
UMTS and WiMAX BS to MS Interference • UMTS TDD-UMTS FDD • WiMAX TDD-UMTS FDD • WiMAX TDD-UMTS TDD
2.6GHz Interference Scenarios – External
Adjacent Services: UMTS (FDD and TDD) and/or WiMAX in 2010-2025MHz, 2290-2302MHz and 2500-2690MHz with PMSE and MSS • Outbound interference to MSS satellite terminals in 2483.5-2500MHz • Inbound and outbound interference effects between UMTS, WiMAX and PMSE

Table 4.3: Interference Scenarios

5. ADJACENT CHANNEL INTERFERENCE (ACI) ANALYSIS 2500-2690MHZ

This section summarises the results of our modelling to investigate internal and external ACI effects for the 2500-2690MHz band. This is in three parts:

- Internal adjacent channel interference effects – co-existence of UMTS FDD, UMTS TDD and WiMAX TDD systems that might be deployed in the available spectrum and the effect of adjacent channel interference
- Internal blocking effects between FDD and TDD systems
- External adjacent channel effects – adjacent channel interference to/from UMTS FDD, UMTS TDD and WiMAX TDD and existing services operating in spectrum adjacent to the 2.6GHz band.

5.1 Internal Adjacent Channel Interference: FDD and TDD Co-Existence within the 2.6GHz Band

This section summarises the results of our FDD and TDD co-existence modelling. The aim of this modelling was to calculate the additional isolation required to avoid adjacent channel interference between systems operating in neighbouring spectrum blocks (considered at 5MHz, 10MHz and 15MHz offsets between the centre frequency of the interfering system and the interfered (victim) system), for various deployment scenarios (co-located systems and systems with some distance isolation between them). Based on the additional isolation calculated, we then considered appropriate interference mitigation techniques that could be employed, and their effect on the potential for interference.

Input parameters to the modelling presented in this section are based on FDD and TDD technologies as follows:

- FDD: 3GPP UTRA WCDMA
- TDD: IEEE 802.16d/e (WiMAX Revisions d and e).

The approach, levels of interference calculated and mitigation techniques considered are equally applicable to 3GPP TDD and other similar technologies. This is because the first order FDD/TDD co-existence effects are due to the duplexer method employed (e.g. TDD or FDD) whilst differences in the air interface technology (e.g. WCDMA or OFDM) have only a second order effect.

A 5MHz channel width has been modelled for both FDD and TDD systems in this analysis. It is noted that 802.16 systems may use 10MHz channels for improved network performance. An 802.16 system with a bandwidth greater than 5MHz, sharing a frequency band with WCDMA, would typically result in less interference to WCDMA, but more interference from WCDMA to 802.16 than is presented in our analysis.

A full description of assumptions and input parameters for this modelling, and full results, are provided in Appendix A of this report.

5.1.1 Co-Existence without Mitigation

The additional isolation required to prevent ACI for the various FDD/TDD interference modes is summarised in Table 5.1 below, corresponding to 5MHz, 10MHz and 15MHz offsets respectively from the carrier frequency.

Where the result is negative, the value represents the margin that exists between interferer and victim. Red is used to highlight a requirement for additional isolation and green indicates a margin for safety. (For base-base interference, the 10-metre separation case is shown in black, since this was not considered to be a typical separation based on typical site configuration/separations.)

Since these results represent the interference potential without mitigation (i.e. the worst case), in the case of directional antennas, both antennas of victim and interferer are modelled as pointing directly at each other and with no down tilt. In the case of devices with power control, the interferer is assumed to be transmitting at full power.

Interference Path			Additional Isolation or Margin at 5MHz Offset (dB)					
Class	Interferer	Victim	Co-lo [1]	10	50	100	500	1000
Base to Base	FDD Macro Base Station	TDD Base Station	78.0		68.3	62.3	48.3	42.3
	TDD Base Station	FDD Macro Base Station	69.7		60.0	54.0	40.0	34.0
	FDD Micro Base Station	TDD Base Station	26.0		39.1	27.3	0.0	-11.7
	TDD Base Station	FDD Micro Base Station	22.7		35.8	24.0	-3.3	-15.0
	FDD Pico Base Station	TDD Base Station	0.0		7.6	-4.4	-32.4	-44.4
	TDD Base Station	FDD Pico Base Station	10.7		18.3	6.3	-21.7	-33.7
	TDD Base Station	TDD Base Station	62.6		53.9	47.9	33.9	27.9
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	46.8	76.5	62.5	56.5	42.5	36.5
	FDD Micro Base Station	TDD Fixed Sub	61.7	60.6	33.3	21.5	-5.8	-17.5
	FDD Pico Base Station	TDD Fixed Sub	16.2	29.7	1.8	-10.3	-38.2	-50.3
	TDD Base Station	TDD Fixed Sub	66.5	70.6	43.3	31.5	4.2	-7.5
Base to Mobile	TDD Base Station	FDD Mobile	34.6	66.4	39.1	27.3	0.0	-11.7
	FDD Macro Base Station	TDD Mobile	42.8	73.6	46.3	34.5	7.2	-4.5
	FDD Micro Base Station	TDD Mobile	34.8	56.6	29.3	17.5	-9.8	-21.5
	FDD Pico Base Station	TDD Mobile	56.5	37.6	10.3	-1.5	-28.8	-40.5
	TDD Base Station	TDD Mobile	31.8	66.6	39.3	27.5	0.2	-11.5
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	31.1	61.9	34.6	22.8	-4.5	-16.2
	TDD Fixed Sub	FDD Micro Base Station	51.0	49.9	22.6	10.8	-16.5	-28.2
	TDD Fixed Sub	FDD Pico Base Station	63.8	44.9	17.6	5.8	-21.5	-33.2
	TDD Fixed Sub	TDD Base Station	31.6	63.4	36.1	24.3	-3.0	-14.7
Mobile to Base	TDD Mobile	FDD Macro Base Station	25.8	56.6	29.3	17.5	-9.8	-21.5
	TDD Mobile	FDD Micro Base Station	45.7	44.6	17.3	5.5	-21.8	-33.5
	TDD Mobile	FDD Pico Base Station	58.5	39.6	12.3	0.5	-26.8	-38.5
	FDD Mobile	TDD Base Station	24.6	56.4	29.1	17.3	-10.0	-21.7
	TDD Mobile	TDD Base Station	23.6	58.4	31.1	19.3	-8.0	-19.7
Mobile to Mobile	TDD Mobile	FDD Mobile	54.3	37.3	-32.0	-45.0	-77.0	-85.0
	FDD Mobile	TDD Mobile	57.1	40.1	-29.2	-42.2	-74.2	-82.2
	TDD Mobile	TDD Mobile	56.1	42.1	-27.2	-40.2	-72.2	-80.2
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	56.8	45.9	18.6	6.8	-20.5	-32.2
	TDD Fixed Sub	TDD Mobile	60.8	52.9	25.6	13.8	-13.5	-25.2
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	56.1	45.2	17.9	6.1	-21.2	-32.9
	TDD Mobile	TDD Fixed Sub	55.1	47.2	19.9	8.1	-19.2	-30.9
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	56.1	52.0	38.0	32.0	18.0	12.0

Interference Path			Additional Isolation or Margin at 10MHz Offset (dB)					
Class	Interferer	Victim	Co-lo [1]	10	50	100	500	1000
Base to Base	FDD Macro Base Station	TDD Base Station	73.0		63.3	57.3	43.3	37.3
	TDD Base Station	FDD Macro Base Station	57.6		47.9	41.9	27.9	21.9
	FDD Micro Base Station	TDD Base Station	21.0		34.1	22.3	-5.0	-16.7
	TDD Base Station	FDD Micro Base Station	10.6		23.7	11.9	-15.4	-27.1
	FDD Pico Base Station	TDD Base Station	-5.0		2.6	-9.4	-37.4	-49.4
	TDD Base Station	FDD Pico Base Station	-1.4		6.2	-5.8	-33.8	-45.8
	TDD Base Station	TDD Base Station	51.5		42.7	36.7	22.7	16.7
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	36.1	65.8	51.8	45.8	31.8	25.8
	FDD Micro Base Station	TDD Fixed Sub	51.0	49.9	22.6	10.8	-16.5	-28.2
	FDD Pico Base Station	TDD Fixed Sub	5.5	19.1	-8.9	-20.9	-48.9	-60.9
	TDD Base Station	TDD Fixed Sub	48.1	52.2	24.9	13.1	-14.2	-25.9
Base to Mobile	TDD Base Station	FDD Mobile	24.6	56.4	29.1	17.3	-10.0	-21.7
	FDD Macro Base Station	TDD Mobile	32.1	62.9	35.6	23.8	-3.5	-15.2
	FDD Micro Base Station	TDD Mobile	24.1	45.9	18.6	6.8	-20.5	-32.2
	FDD Pico Base Station	TDD Mobile	45.8	26.9	-0.4	-12.2	-39.5	-51.2
	TDD Base Station	TDD Mobile	13.4	48.2	20.9	9.1	-18.2	-29.9
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	17.4	48.2	20.9	9.1	-18.2	-29.9
	TDD Fixed Sub	FDD Micro Base Station	37.3	36.2	8.9	-2.9	-30.2	-41.9
	TDD Fixed Sub	FDD Pico Base Station	50.1	31.2	3.9	-7.9	-35.2	-46.9
	TDD Fixed Sub	TDD Base Station	17.7	49.5	22.2	10.4	-16.9	-28.6
Mobile to Base	TDD Mobile	FDD Macro Base Station	8.4	39.2	11.9	0.1	-27.2	-38.9
	TDD Mobile	FDD Micro Base Station	28.3	27.2	-0.1	-11.9	-39.2	-50.9
	TDD Mobile	FDD Pico Base Station	41.1	22.2	-5.1	-16.9	-44.2	-55.9
	FDD Mobile	TDD Base Station	14.6	46.4	19.1	7.3	-20.0	-31.7
	TDD Mobile	TDD Base Station	5.7	40.5	13.2	1.4	-25.9	-37.6
Mobile to Mobile	TDD Mobile	FDD Mobile	41.9	24.9	-44.4	-57.4	-89.4	-97.4
	FDD Mobile	TDD Mobile	46.4	29.4	-39.9	-52.9	-84.9	-92.9
	TDD Mobile	TDD Mobile	37.9	23.9	-45.4	-58.4	-90.4	-98.4
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	45.9	35.0	7.7	-4.1	-31.4	-43.1
	TDD Fixed Sub	TDD Mobile	49.9	42.0	14.7	2.9	-24.4	-36.1
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	45.4	34.5	7.2	-4.6	-31.9	-43.6
	TDD Mobile	TDD Fixed Sub	36.9	29.0	1.7	-10.1	-37.4	-49.1
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	40.9	36.9	22.9	16.9	2.9	-3.1

Interference Path			Additional Isolation or Margin at 15MHz Offset (dB)					
Class	Interferer	Victim	Co-lo [1]	10	50	100	500	1000
Base to Base	FDD Macro Base Station	TDD Base Station	57.8		48.0	42.0	28.0	22.0
	TDD Base Station	FDD Macro Base Station	50.5		40.7	34.7	20.7	14.7
	FDD Micro Base Station	TDD Base Station	5.8		18.9	7.1	-20.2	-31.9
	TDD Base Station	FDD Micro Base Station	3.5		16.6	4.8	-22.5	-34.2
	FDD Pico Base Station	TDD Base Station	-20.2		-12.6	-24.7	-52.6	-64.7
	TDD Base Station	FDD Pico Base Station	-8.5		-1.0	-13.0	-41.0	-53.0
	TDD Base Station	TDD Base Station	49.0		40.3	34.3	20.3	14.3
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	22.1	51.8	37.8	31.8	17.8	11.8
	FDD Micro Base Station	TDD Fixed Sub	37.0	35.9	8.6	-3.2	-30.5	-42.2
	FDD Pico Base Station	TDD Fixed Sub	-8.5	5.1	-22.9	-34.9	-62.9	-74.9
	TDD Base Station	TDD Fixed Sub	41.8	45.9	18.6	6.8	-20.5	-32.2
Base to Mobile	TDD Base Station	FDD Mobile	18.7	50.5	23.2	11.4	-15.9	-27.6
	FDD Macro Base Station	TDD Mobile	18.1	48.9	21.6	9.8	-17.5	-29.2
	FDD Micro Base Station	TDD Mobile	10.1	31.9	4.6	-7.2	-34.5	-46.2
	FDD Pico Base Station	TDD Mobile	31.8	12.9	-14.4	-26.2	-53.5	-65.2
	TDD Base Station	TDD Mobile	7.1	41.9	14.6	2.8	-24.5	-36.2
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	13.8	44.6	17.3	5.5	-21.8	-33.5
	TDD Fixed Sub	FDD Micro Base Station	33.7	32.6	5.3	-6.5	-33.8	-45.5
	TDD Fixed Sub	FDD Pico Base Station	46.5	27.6	0.3	-11.5	-38.8	-50.5
	TDD Fixed Sub	TDD Base Station	14.6	46.4	19.1	7.3	-20.0	-31.7
Mobile to Base	TDD Mobile	FDD Macro Base Station	4.8	35.6	8.3	-3.5	-30.8	-42.5
	TDD Mobile	FDD Micro Base Station	24.7	23.6	-3.7	-15.5	-42.8	-54.5
	TDD Mobile	FDD Pico Base Station	37.5	18.6	-8.7	-20.5	-47.8	-59.5
	FDD Mobile	TDD Base Station	0.2	32.0	4.7	-7.1	-34.4	-46.1
	TDD Mobile	TDD Base Station	2.6	37.4	10.1	-1.7	-29.0	-40.7
Mobile to Mobile	TDD Mobile	FDD Mobile	36.5	19.5	-49.8	-62.8	-94.8	-102.8
	FDD Mobile	TDD Mobile	32.3	15.2	-54.0	-67.0	-99.0	-107.0
	TDD Mobile	TDD Mobile	34.5	20.4	-48.8	-61.8	-93.8	-101.8
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	40.5	29.6	2.3	-9.5	-36.8	-48.5
	TDD Fixed Sub	TDD Mobile	44.5	36.6	9.3	-2.5	-29.8	-41.5
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	31.3	20.4	-6.9	-18.7	-46.0	-57.7
	TDD Mobile	TDD Fixed Sub	33.5	25.6	-1.7	-13.5	-40.8	-52.5
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	37.5	33.4	19.5	13.4	-0.5	-6.6

Table 5.1: Additional Isolation or Margin at 5MHz, 10MHz and 15MHz Offsets (Worst Case)

The results of the worst-case analysis demonstrate that FDD/TDD (and TDD/TDD) co-existence is not feasible at a 5MHz offset (equivalent to operation of a FDD or TDD system adjacent to another TDD system, each with 5MHz channel spacing, with no guard band). The worst-case interference mode is BS-BS, for which a separation distance of significantly greater than 1km would be required between base stations to avoid interference.

Interference between a UMTS FDD base station and a WiMAX ‘fixed subscriber station’ using the 802.16d standard is also an issue, with separation distances in excess of 1km required.

Interference between mobiles (FDD and TDD or TDD and TDD) is also predicted to occur in all scenarios modelled, at short range (10 metres or less between devices). The interference between mobiles reduces significantly at increasing distances due to the low power of the devices and the power decay/distance relationship.

The results of the worst-case analysis also demonstrate that FDD/TDD, and TDD/TDD, co-existence is also not feasible at either 10 or 15MHz offsets, since the additional isolation figures are unacceptable. At 10MHz and 15MHz offsets, the separation distance between base stations in the BS-BS interference scenario is again in excess of 1km, with excessive interference also between mobiles, though less than the 5MHz offset case.

This suggests that operation of FDD and TDD systems in adjacent frequency blocks in the same frequency band is not feasible without consideration of suitable interference mitigation techniques.

This is considered in the next section.

5.1.2 Co-Existence with Mitigation

We considered the impact of a number of alternative mitigation techniques, described in more detail in Appendix A.

A summary of mitigation techniques considered is as follows:

- Site placement (for macro/micro scenarios) – typically resulting in 17dB additional isolation where macro and micro sites are rooftop and street level respectively
- Antenna separation (separating antennas vertically, horizontally or back to back) – typically 10-15dB additional isolation over and above the standard 30dB isolation assumed for macro-macro co-location
- Antenna polarization – providing a few dB improvement by having antennas orthogonally polarized to each other
- Adaptive antennas – little impact on ‘peak’ interference but can significantly reduce the probability of interference

- Transmitter/receiver filtering – depending on the frequency offset, can add around 15dB improvement at 5MHz offset, 60dB at 10MHz offset (based on ITU-R Recommendation M.2045)
- Power amplifier linearization techniques – 18dB at 5MHz offset, 13dB at 10MHz offset
- TDD power control – can significantly reduce the probability of interference
- TDD external synchronisation- synchronisation of neighbouring TDD systems can completely remove TDD-TDD co-existence issues, as it removes the up/down link transmission clash such that transmission and reception do not occur simultaneously in adjacent channels. However, there are significant operational issues associated with synchronising networks, since it means that technologies in adjacent spectrum must be the same or similar, and also that services are the same (to coordinate the length of uplink and downlink timeslots)
- Reduce transmission power – to achieve the same coverage with less power, more base stations may be required, alternatively, low power systems may be able to utilise channels unsuitable for 'full' power use.

Our analysis of the most appropriate mitigation techniques, and their impact, is summarised in Table 5.2 below, for 10 and 15MHz offset (at 5MHz, there is insufficient frequency separation for mitigation such as filtering to be feasible).

Interference Path			Mitigation at 10MHz or 15MHz Offset (dB)					
Class	Interferer	Victim	Site Placement	Site Eng.	Tx /Rx Filter	Antenna Azimuth	Co Lo Total	Separate Total
Base to Base	FDD Macro Base Station	TDD Base Station		15	60	5	75	65
	TDD Base Station	FDD Macro Base Station		15	60	5	80	65
	FDD Micro Base Station	TDD Base Station	12		50		62	62
	TDD Base Station	FDD Micro Base Station	12		50		62	62
	FDD Pico Base Station	TDD Base Station	17		30		47	47
	TDD Base Station	FDD Pico Base Station	17		30		47	47
	TDD Base Station	TDD Base Station		15	50		65	50
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub			60	5	65	65
	FDD Micro Base Station	TDD Fixed Sub			55	5	60	60
	FDD Pico Base Station	TDD Fixed Sub			40	5	45	45
	TDD Base Station	TDD Fixed Sub			60	5	65	65
Base to Mobile	TDD Base Station	FDD Mobile			60		60	60
	FDD Macro Base Station	TDD Mobile			60		60	60
	FDD Micro Base Station	TDD Mobile			55		55	55
	FDD Pico Base Station	TDD Mobile			40		40	40
	TDD Base Station	TDD Mobile			60		60	60
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station			60	5	65	65
	TDD Fixed Sub	FDD Micro Base Station			55	5	60	60
	TDD Fixed Sub	FDD Pico Base Station			40	5	45	45
	TDD Fixed Sub	TDD Base Station			60	5	65	65
Mobile to Base	TDD Mobile	FDD Macro Base Station			60		60	60
	TDD Mobile	FDD Micro Base Station			55		55	55
	TDD Mobile	FDD Pico Base Station			40		40	40
	FDD Mobile	TDD Base Station			60		60	60
	TDD Mobile	TDD Base Station			60		60	60
Mobile to Mobile	TDD Mobile	FDD Mobile					0	0
	FDD Mobile	TDD Mobile					0	0
	TDD Mobile	TDD Mobile					0	0
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile					0	0
	TDD Fixed Sub	FDD Mobile					0	0
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub					0	0
	TDD Mobile	TDD Mobile					0	0
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub				10	10	10

Table 5.2: Effect of Mitigation at 10MHz and 15MHz Offsets

Applying this mitigation, Figure 5.3 summarises the impact on the isolation requirements previously calculated for the 10MHz and 15MHz offset cases.

Interference Path			Additional Isolation or Margin at 10MHz Offset (dB)					
Class	Interferer	Victim	Co-lo [1]	10	50	100	500	1000
Base to Base	FDD Macro Base Station	TDD Base Station	-2.0	12.3	-1.7	-7.7	-21.7	-27.7
	TDD Base Station	FDD Macro Base Station	-22.4	-3.1	-17.1	-23.1	-37.1	-43.1
	FDD Micro Base Station	TDD Base Station	-41.0	-0.6	-27.9	-39.7	-67.0	-78.7
	TDD Base Station	FDD Micro Base Station	-51.4	-11.0	-38.3	-50.1	-77.4	-89.1
	FDD Pico Base Station	TDD Base Station	-52.0	-16.4	-44.4	-56.4	-84.4	-96.4
	TDD Base Station	FDD Pico Base Station	-48.4	-12.8	-40.8	-52.8	-80.8	-92.8
	TDD Base Station	TDD Base Station	-13.5	6.7	-7.3	-13.3	-27.3	-33.3
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	-28.9	0.8	-13.2	-19.2	-33.2	-39.2
	FDD Micro Base Station	TDD Fixed Sub	-9.0	-10.1	-37.4	-49.2	-76.5	-88.2
	FDD Pico Base Station	TDD Fixed Sub	-39.5	-25.9	-53.9	-65.9	-93.9	-105.9
	TDD Base Station	TDD Fixed Sub	-16.9	-12.8	-40.1	-51.9	-79.2	-90.9
Base to Mobile	TDD Base Station	FDD Mobile	-35.4	-3.6	-30.9	-42.7	-70.0	-81.7
	FDD Macro Base Station	TDD Mobile	-27.9	2.9	-24.4	-36.2	-63.5	-75.2
	FDD Micro Base Station	TDD Mobile	-30.9	-9.1	-36.4	-48.2	-75.5	-87.2
	FDD Pico Base Station	TDD Mobile	5.8	-13.1	-40.4	-52.2	-79.5	-91.2
	TDD Base Station	TDD Mobile	-46.6	-11.8	-39.1	-50.9	-78.2	-89.9
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	-47.6	-16.8	-44.1	-55.9	-83.2	-94.9
	TDD Fixed Sub	FDD Micro Base Station	-22.7	-23.8	-51.1	-62.9	-90.2	-101.9
	TDD Fixed Sub	FDD Pico Base Station	5.1	-13.8	-41.1	-52.9	-80.2	-91.9
	TDD Fixed Sub	TDD Base Station	-47.3	-15.5	-42.8	-54.6	-81.9	-93.6
Mobile to Base	TDD Mobile	FDD Macro Base Station	-51.6	-20.8	-48.1	-59.9	-87.2	-98.9
	TDD Mobile	FDD Micro Base Station	-26.7	-27.8	-55.1	-66.9	-94.2	-105.9
	TDD Mobile	FDD Pico Base Station	1.1	-17.8	-45.1	-56.9	-84.2	-95.9
	FDD Mobile	TDD Base Station	-45.4	-13.6	-40.9	-52.7	-80.0	-91.7
	TDD Mobile	TDD Base Station	-54.3	-19.5	-46.8	-58.6	-85.9	-97.6
Mobile to Mobile	TDD Mobile	FDD Mobile	41.9	24.9	-44.4	-57.4	-89.4	-97.4
	FDD Mobile	TDD Mobile	46.4	29.4	-39.9	-52.9	-84.9	-92.9
	TDD Mobile	TDD Mobile	37.9	23.9	-45.4	-58.4	-90.4	-98.4
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	45.9	35.0	7.7	-4.1	-31.4	-43.1
	TDD Fixed Sub	TDD Mobile	49.9	42.0	14.7	2.9	-24.4	-36.1
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	45.4	34.5	7.2	-4.6	-31.9	-43.6
	TDD Mobile	TDD Fixed Sub	36.9	29.0	1.7	-10.1	-37.4	-49.1
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	30.9	26.9	12.9	6.9	-7.1	-13.1

Interference Path			Additional Isolation or Margin at 15MHz Offset (dB)					
Class	Interferer	Victim	Co-lo [1]	10	50	100	500	1000
Base to Base	FDD Macro Base Station	TDD Base Station	-17.2	-13.0	-27.0	-33.0	-47.0	-53.0
	TDD Base Station	FDD Macro Base Station	-29.5	-25.3	-39.3	-45.3	-59.3	-65.3
	FDD Micro Base Station	TDD Base Station	-56.2	-15.8	-43.1	-54.9	-82.2	-93.9
	TDD Base Station	FDD Micro Base Station	-58.5	-18.1	-45.4	-57.2	-84.5	-96.2
	FDD Pico Base Station	TDD Base Station	-67.2	-31.7	-59.6	-71.7	-99.6	-111.7
	TDD Base Station	FDD Pico Base Station	-55.5	-20.0	-48.0	-60.0	-88.0	-100.0
	TDD Base Station	TDD Base Station	-16.0	-10.7	-24.7	-30.7	-44.7	-50.7
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	-42.9	-13.2	-27.2	-33.2	-47.2	-53.2
	FDD Micro Base Station	TDD Fixed Sub	-23.0	-24.1	-51.4	-63.2	-90.5	-102.2
	FDD Pico Base Station	TDD Fixed Sub	-53.5	-39.9	-67.9	-79.9	-107.9	-119.9
	TDD Base Station	TDD Fixed Sub	-23.2	-19.1	-46.4	-58.2	-85.5	-97.2
Base to Mobile	TDD Base Station	FDD Mobile	-41.3	-9.5	-36.8	-48.6	-75.9	-87.6
	FDD Macro Base Station	TDD Mobile	-41.9	-11.1	-38.4	-50.2	-77.5	-89.2
	FDD Micro Base Station	TDD Mobile	-44.9	-23.1	-50.4	-62.2	-89.5	-101.2
	FDD Pico Base Station	TDD Mobile	-8.2	-27.1	-54.4	-66.2	-93.5	-105.2
	TDD Base Station	TDD Mobile	-52.9	-18.1	-45.4	-57.2	-84.5	-96.2
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	-51.2	-20.4	-47.7	-59.5	-86.8	-98.5
	TDD Fixed Sub	FDD Micro Base Station	-26.3	-27.4	-54.7	-66.5	-93.8	-105.5
	TDD Fixed Sub	FDD Pico Base Station	1.5	-17.4	-44.7	-56.5	-83.8	-95.5
	TDD Fixed Sub	TDD Base Station	-50.4	-18.6	-45.9	-57.7	-85.0	-96.7
Mobile to Base	TDD Mobile	FDD Macro Base Station	-55.2	-24.4	-51.7	-63.5	-90.8	-102.5
	TDD Mobile	FDD Micro Base Station	-30.3	-31.4	-58.7	-70.5	-97.8	-109.5
	TDD Mobile	FDD Pico Base Station	-2.5	-21.4	-48.7	-60.5	-87.8	-99.5
	FDD Mobile	TDD Base Station	-59.8	-28.0	-55.3	-67.1	-94.4	-106.1
	TDD Mobile	TDD Base Station	-57.4	-22.6	-49.9	-61.7	-89.0	-100.7
Mobile to Mobile	TDD Mobile	FDD Mobile	36.5	19.5	-49.8	-62.8	-94.8	-102.8
	FDD Mobile	TDD Mobile	32.3	15.2	-54.0	-67.0	-99.0	-107.0
	TDD Mobile	TDD Mobile	34.5	20.4	-48.8	-61.8	-93.8	-101.8
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	40.5	29.6	2.3	-9.5	-36.8	-48.5
	TDD Fixed Sub	TDD Mobile	44.5	36.6	9.3	-2.5	-29.8	-41.5
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	31.3	20.4	-6.9	-18.7	-46.0	-57.7
	TDD Mobile	TDD Fixed Sub	33.5	25.6	-1.7	-13.5	-40.8	-52.5
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	27.5	23.4	9.5	3.4	-10.5	-16.6

Table 5.3: Additional Isolation Required at 10 and 15MHz with Mitigation

As indicated by the results in Table 5.3, the application of suitable mitigation techniques at the base station suggests that co-existence between FDD/TDD and TDD/TDD is feasible at 10MHz and 15MHz offset assuming standard cellular/mobile broadband (e.g. typical macro site EIRP). Results suggest that the 5MHz offset is still not feasible, due to limitations on filtering at this offset.

Although suitable interference mitigation techniques can be applied at the base stations of FDD and TDD systems, interference still exists between mobiles since mitigation (other than power control) is not practical in consumer mobile handsets. The results of our analysis suggest that interference will be noticeable when the distance between mobiles is small (less than 10 metres).

However, it is noted that a number of other factors affect the probability of MS-MS interference occurring, namely:

- The MS transmission power depends on its position within the cell and the load on the system
- If an MS is operating close to its own BS, the BS can increase power to overcome interference.

Taking this in to account, we performed a high level probabilistic assessment (covered in Appendix A), the results of which suggest that 1.9% of mobile devices in high user density areas might suffer effects of 2.6GHz MS-MS interference, for 1.4 % of the time. Our conclusion is that this probability is sufficiently small to enable FDD and TDD co-existence at 10 and 15MHz offsets assuming standard mobile network deployments.

The results suggest that FDD/TDD co-existence at 5MHz offset (i.e. operation in an adjacent channel) is not feasible for macro cellular deployment. This suggests that technical usage conditions governing FDD and TDD use of the 2.6GHz band may have to be based on two alternative spectrum masks:

- A standard operation mask, appropriate to FDD and TDD macro base stations
- A restricted operation mask, liming the transmitter power, for use in channels between FDD and TDD deployments. This would effectively limit the use of the channel between and FDD and a TDD system to deployment of pico cells or indoor systems only.

Technical usage conditions are further considered in Section 8 of this report.

5.2 TDD/FDD Receiver Blocking

The previous section focussed on adjacent channel interference between FDD and TDD (and TDD and TDD) systems within the 2.6GHz band.

This section deals with the impact of receiver blocking that could occur between FDD and TDD systems within the band.

Figure 5.1 illustrates the regions of different types of incoming interference that can occur between neighbouring wireless systems.

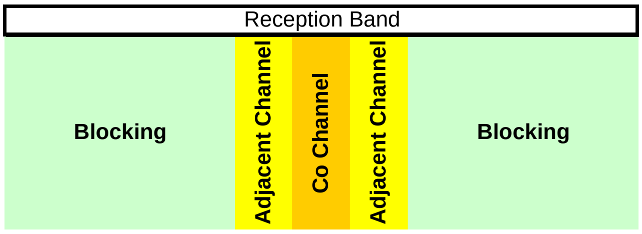


Figure 5.1: Types of Incoming Interference

Blocking can occur when an interferer transmits in a channel in the victim's reception band. The blocking performance for a receiver will typically be specified in terms of unwanted signals falling into the receiver pass band (In Band Blocking) and unwanted signals outside the pass band (Out of Band Blocking).

Within the 2.6GHz deployment scenarios considered in this report, interference due to blocking might occur if TDD systems are deployed within the receiver pass band of an FDD system.

The issue could be a particular concern if the 3GPP blocking specifications for FDD and TDD systems operating in the 2.6GHz are specified according to the CEPT band. In this case, there is a risk that the specifications may not fully reflect blocking requirements for different band plans introduced on a national basis.

ETSI TS 134 121[5] introduces the blocking characteristic thus:

> *The blocking characteristic is a measure of the receiver's ability to receive a wanted signal at its assigned channel frequency in the presence of an unwanted interferer on frequencies other than those of the spurious response or the adjacent channels, without this unwanted input signal causing a degradation of the performance of the receiver beyond a specified limit. The blocking performance shall apply at all frequencies except those at which a spurious response occur.*

Table 5.4 below summarises the blocking characteristics for UMTS equipment as proposed by 3GPP for FDD and TDD equipment respectively.

	Blocking Characteristic Band				
	Start (MHz)	End (MHz)	Interferer (dBm)	Wanted (dB)	Source
FDD Mobile (Band VII)	2605	2705	-44	-91	ETSI TS 134 121 (Table 6.5.1)
FDD Base Station	-	-	-40	-115	ETSI TS 125 104 (Table 7.5)
TDD Base Station	2500	2690	-40	-103	ETSI TS 125 105 (Table 7.4-1(d))

Table 5.4: Blocking Characteristics

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[5] ETSI TS 134 121-1 V7.0.0 (2006-03) Technical Specification Universal Mobile Telecommunications System (UMTS); User Equipment (UE) conformance specification; Radio transmission and reception (FDD); Part 1: Conformance specification (3GPP TS 34.121-1 version 7.0.0 Release 7)

In terms of the frequency bands of operation, ETSI TS 134 121 (User Equipment Conformance Specification) specifies the bands 2500-2570MHz and 2620-2690MHz for FDD operation, consistent with the CEPT plan. ETSI TS 125 105[6] specifies the band 2570 – 2620MHz for TDD operation. This impacts the in-band blocking specification – for instance, for an FDD mobile device, in-band blocking is defined for an unwanted interfering signal falling into the mobile receive pass band or the first 15MHz below or above the receive band. The mobile receive pass band is defined as 2620-2690MHz; with 15MHz on either side this extends the in-band blocking levels to 2605-2705MHz.

5.2.1 Deployment of TDD in the FDD Downlink Band

a) TDD Mobile to FDD Mobile where TDD operates in the FDD Downlink Band

An interferer of –44dBm (i.e. the blocking specification for an FDD mobile) is equivalent to an interferer of 30dBm (1 watt) at a distance of 43m (free space loss at 2.5GHz). Thus, in the worst case (TDD mobile at full power, FDD mobile at edge of reception, less than 43m of free space between mobiles), this suggests that blocking will occur.

Mitigation cannot easily be applied to mobiles other than by tailoring the FDD mobile receiver band, which may make the mobile 'non-standard'

This is a similar scenario to the adjacent channel interference scenarios discussed in Section 5.2.

b) TDD Base to FDD Mobile where TDD operates in the FDD Downlink Band

An interferer of –44dBm is equivalent to an interferer of 60dBm at a distance of 1350m (free space loss at 2.5GHz). Thus, in the worst case (TDD Base at full power, FDD mobile at edge of reception, less than 1350m of free space) blocking will again occur.

However, it is also noted that blocking of FDD mobiles could in also occur from FDD Base station transmissions, which are at a similar power level to the TDD transmissions.

A general method for reducing base to mobile blocking is to co-locate base stations. This avoids a large miss-match of received power levels at both the base station and at the mobile. However in the case of TDD operating in the FDD downlink, base station co-location is problematic due to FDD base transmit to TDD base receive blocking and adjacent channel issues.

[6] ETSI TS 125 105 V7.1.0 (2005-12) Technical Specification, Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (TDD) (3GPP TS 25.105 version 7.1.0 Release 7)

Filtering at the TDD base station does not resolve this problem, as the legitimate TDD transmissions cause the blocking.

c) TDD in the FDD Downlink Band Conclusion

The conclusion of this discussion of the 3GPP blocking specifications is that it is difficult to fully mitigate the effects of TDD systems causing blocking in the FDD downlink band without introducing 'non-standard' FDD mobile equipment with a reduced receive band.

5.2.2 Deployment of TDD in the FDD Uplink Band

a) TDD Base and Mobile to FDD Base where TDD operates in the FDD Uplink Band

An interferer of –40dBm (i.e. the blocking level for an FDD base station) is equivalent to an interferer of 60dBm at a distance of 850m (free space loss at 2.5GHz). Thus, in the worst case (TDD Base at full power, FDD base receiving from mobiles at the edge of reception, less than 850m free space between base stations), this suggests that blocking will occur between TDD base stations.

This is a similar scenario to the adjacent channel interference scenarios discussed in Section 5.2.

It is possible to apply filtering to the FDD Base Station to block TDD transmissions that fall within the FDD receive band.

b) TDD in the FDD Uplink Band Conclusion

It is possible to mitigate the effects of TDD in the FDD Uplink band without introducing 'non-standard' FDD equipment by adding filters to the FDD base station to block the TDD transmissions. This effectively reduces the FDD receive band to a region containing only FDD mobile transmissions.

5.2.3 TDD to FDD Where TDD Operates in the FDD Duplex Gap

Since the 3GPP specifications designate TDD operation to occur within the FDD duplex gap (i.e. the unpaired band in the CEPT band plan), and since the FDD duplex gap is not in the receiver band of either the FDD Mobile or the FDD Base Station (with the exception of a few MHz at the edges), blocking should not occur where TDD transmissions are restricted to the duplex gap.

However, it is not clear from the 3GPP specifications that the FDD mobile receiver blocking specification takes account of TDD transmissions in the unpaired band. For instance, the FDD user equipment (mobile) out of band blocking is defined for an unwanted interfering signal falling more than 15MHz below or above the mobile receiver band. This covers part of the band

2570-2620MHz designated for TDD in the 3GPP specification (the remainder falling within the in-band blocking specification). The TDD out-of-band emissions specification should reflect the corresponding FDD blocking specification.

5.2.4 Discussion on the Impact of FDD/TDD Receiver Blocking

The overall conclusion of this analysis of the potential for receiver blocking to occur is that the 3GPP blocking specifications for the 2GHz band have been developed in accordance with the CEPT band plan and hence blocking specifications for the base station and mobile standards are defined relative to the FDD pass bands designated in the CEPT plan. Alternative specifications are not considered to reflect alternative band plans implemented on a national basis.

Based on the information contained within the existing 3GPP specifications, our conclusion is that, from the limited perspective of blocking, there would be a preference for TDD to be deployed within the FDD duplex gap and the FDD uplink band, rather than the FDD downlink band (due to the impact of TDD blocking on the FDD mobile receiver). The FDD uplink band is a preferred location for TDD because it is possible to mitigate blocking effects of TDD transitions by fitting filters to standard FDD base stations, effectively reducing the base station receiver band to those channels used by FDD only.

The alternative mitigation for TDD in the downlink would be to modify mobiles, which would be more expensive and could affect roaming.

It is also not clear from the specifications reviewed as part of this study that the UTRA FDD and TDD specifications are compatible with each other when considering TDD systems deployed in the FDD duplex gap. For instance, in future iterations of the standards, it may be beneficial to seek to align FDD in-band and out-of-band blocking specifications with TDD (UTRA and WiMAX) out of band emission specifications.

5.3 External Interference Scenarios for 2.6GHz

This section summarises the results of our analysis of the potential for inbound and outbound interference between systems deployed within the 2.6GHz band (FDD and/or TDD) and existing services operating in spectrum that borders the 2.6GHz band.

As indicated in Table 4.3, interference scenarios considered were:

- Inbound and outbound interference effects between systems within the 2.6GHz band (FDD and TDD) and PMSE systems in the adjacent band
- Outbound interference from systems within the 2.6GHz band to Mobile Satellite Service (MSS) terminals receiving in the band 2483.5-2500MHz.

The other significant external mode of interference affecting the 2.6GHz band is believed to be that of incoming interference from MoD and/or CAA radar using the 2700-2900MHz band. Based on discussion with Ofcom, this matter is being considered by Ofcom's own engineers and hence is not covered further in this report.

A summary of results is provided below.

A full description of the PMSE interference modelling is provided in Appendix B.

A full description of the MSS interference modelling is provided in Appendix C.

5.3.1 Adjacent Channel Interference between UMTS/WiMAX FDD and TDD Systems and PMSE

This section summarises results of our analysis of compatibility between FDD/TDD systems in the 2.6GHz band and the following types of PMSE link that operate in adjacent bands[7]:

- Point to point temporary video links (coordinated, high power EIRP 20dBW
- Airborne (air-to-ground) video links (EIRP 7dBW)
- Portable/mobile video links (EIRP 6 dBW)
- Radio cameras (EIRP 0dBW).

In summary, the results of our analysis indicate that the worst-case interference between PMSE and FDD/TDD systems occurs between PMSE links and FDD/TDD base stations. Whether this interference scenario will occur or not depends on spectrum packaging decisions relating to the 2.6GHz band and on technical usage conditions (in some cases, if bands are used for FDD systems, co-incidence of base stations with PMSE links will be avoided since the PMSE bands are generally located adjacent to FDD uplink bands rather than downlinks).

A full description of modelling assumptions is provided in Appendix B. We have assumed that the PMSE systems comply with technical specification ETSI EN 302 064-1[8].

We assumed that the highest centre frequency of a PMSE link in the 2450-2500MHz band is 2495MHz, corresponding to a 7.5MHz offset to the nearest 5MHz channel in the 2500-2690MHz band. Since emissions at 7.5MHz offset are not specified in ETSI EN 302 064-1, which specifies out of band emissions

[7] We understand that usage restrictions apply to the use of the 2450-2500MHz PMSE band for airborne links, however, these links can be deployed in other PMSE bands adjacent to the other bands considered in this report (PMSE band 2025-2110MHz adjacent to 2010-2025MHz and PMSE band 2200-2290MHz, adjacent to 2290-2302MHz. Our PMSE analysis considers compatibility between FDD/TDD systems and each type of PMSE use to cover all potential adjacency issues.

[8] ETSI EN 302 064-1 – Electromagnetic Compatibility and Radio Spectrum Matters: Wireless Video Links Operating in the 1.3GHz to 50GHz Frequency Band

at 10MHz and 20MHz offsets, we have used the 10MHz emission level to approximate to a 7.5MHz channel separation.

The additional isolation (or margin) calculated to be required to avoid interference for a range of separation distances between different PMSE systems and FDD/TDD systems within the 2500-2690MHz band is summarised in Table 5.5, corresponding to 10MHz and 20MHz offsets respectively between the PMSE system and the nearest FDD/TDD system.

As in previous tables, where the result is negative, the value represents the margin that exists between interferer and victim. Red is used to highlight a requirement for additional isolation and green indicates a margin for safety.

Interference Path		Additional Isolation or Margin at 10MHz Offset (dB)				
Interferer	Victim	10	50	100	500	1000
Radio Camera 1W	TDD Base Station	45.3	17.4	5.3	-22.6	-34.7
Radio Camera 1W	TDD Fixed Sub	33.4	5.4	-6.6	-34.6	-46.6
Radio Camera 1W	TDD Mobile	29.4	1.4	-10.6	-38.6	-50.6
Radio Camera 1W	FDD Macro Base Station	43.4	15.5	3.4	-24.5	-36.6
Radio Camera 1W	FDD Micro Base Station	31.4	3.5	-8.6	-36.5	-48.6
Radio Camera 1W	FDD Pico Base Station	26.4	-1.5	-13.6	-41.5	-53.6
Portable/Mobile links	TDD Base Station	45.3	17.4	5.3	-22.6	-34.7
Portable/Mobile links	TDD Fixed Sub	33.6	5.6	-6.4	-34.4	-46.4
Portable/Mobile links	TDD Mobile	29.6	1.6	-10.4	-38.4	-50.4
Portable/Mobile links	FDD Macro Base Station	43.7	15.7	3.7	-24.3	-36.3
Portable/Mobile links	FDD Micro Base Station	31.7	3.7	-8.3	-36.3	-48.3
Portable/Mobile links	FDD Pico Base Station	26.7	-1.3	-13.3	-41.3	-53.3
Airborne links	TDD Base Station	56.1	42.1	36.1	22.1	16.1
Airborne links	TDD Fixed Sub	44.4	30.4	24.4	10.4	4.4
Airborne links	TDD Mobile	40.4	26.4	20.4	6.4	0.4
Airborne links	FDD Macro Base Station	54.5	40.5	34.5	20.5	14.5
Airborne links	FDD Micro Base Station	42.5	28.5	22.5	8.5	2.5
Airborne links	FDD Pico Base Station	37.5	23.5	17.5	3.5	-2.5
Temporary point to point	TDD Base Station	45.9	17.9	5.9	-22.1	-34.1
Temporary point to point	TDD Fixed Sub	37.6	9.6	-2.4	-30.4	-42.4
Temporary point to point	TDD Mobile	33.6	5.6	-6.4	-34.4	-46.4
Temporary point to point	FDD Macro Base Station	48.2	20.3	8.2	-19.7	-31.8
Temporary point to point	FDD Micro Base Station	36.2	8.3	-3.8	-31.7	-43.8
Temporary point to point	FDD Pico Base Station	31.2	3.3	-8.8	-36.7	-48.8
TDD Base Station	Radio Camera 1W	25.0	-3.0	-15.0	-43.0	-55.0
TDD Base Station	Portable/Mobile links	33.0	5.0	-7.0	-35.0	-47.0
TDD Base Station	Airborne links	43.7	29.7	23.7	9.7	3.7
TDD Base Station	Temporary point to point	45.0	17.0	5.0	-23.0	-35.0
TDD Fixed Sub	Radio Camera 1W	16.6	-11.4	-23.4	-51.4	-63.4
TDD Fixed Sub	Portable/Mobile links	24.6	-3.4	-15.4	-43.4	-55.4
TDD Fixed Sub	Airborne links	35.3	21.3	15.3	1.3	-4.7
TDD Fixed Sub	Temporary point to point	36.6	8.6	-3.4	-31.4	-43.4
TDD Mobile	Radio Camera 1W	7.6	-20.4	-32.4	-60.4	-72.4
TDD Mobile	Portable/Mobile links	15.6	-12.4	-24.4	-52.4	-64.4
TDD Mobile	Airborne links	26.3	12.3	6.3	-7.7	-13.7
TDD Mobile	Temporary point to point	27.6	-0.4	-12.4	-40.4	-52.4
FDD Mobile	Radio Camera 1W	13.6	-14.4	-26.4	-54.4	-66.4
FDD Mobile	Portable/Mobile links	21.6	-6.4	-18.4	-46.4	-58.4
FDD Mobile	Airborne links	32.3	18.3	12.3	-1.7	-7.7
FDD Mobile	Temporary point to point	33.6	5.6	-6.4	-34.4	-46.4

Interference Path		Additional Isolation or Margin at 20MHz Offset (dB)				
Interferer	Victim	10	50	100	500	1000
Radio Camera 1W	TDD Base Station	39.3	11.4	-0.7	-28.6	-40.7
Radio Camera 1W	TDD Fixed Sub	27.4	-0.6	-12.6	-40.6	-52.6
Radio Camera 1W	TDD Mobile	23.4	-4.6	-16.6	-44.6	-56.6
Radio Camera 1W	FDD Macro Base Station	37.4	9.4	-2.6	-30.6	-42.6
Radio Camera 1W	FDD Micro Base Station	25.4	-2.6	-14.6	-42.6	-54.6
Radio Camera 1W	FDD Pico Base Station	20.4	-7.6	-19.6	-47.6	-59.6
Portable/Mobile links	TDD Base Station	39.4	11.5	-0.6	-28.5	-40.6
Portable/Mobile links	TDD Fixed Sub	27.5	-0.4	-12.5	-40.4	-52.5
Portable/Mobile links	TDD Mobile	23.5	-4.4	-16.5	-44.4	-56.5
Portable/Mobile links	FDD Macro Base Station	37.5	9.6	-2.5	-30.4	-42.5
Portable/Mobile links	FDD Micro Base Station	25.5	-2.4	-14.5	-42.4	-54.5
Portable/Mobile links	FDD Pico Base Station	20.5	-7.4	-19.5	-47.4	-59.5
Airborne links	TDD Base Station	50.1	36.2	30.1	16.2	10.1
Airborne links	TDD Fixed Sub	38.3	24.3	18.3	4.3	-1.7
Airborne links	TDD Mobile	34.3	20.3	14.3	0.3	-5.7
Airborne links	FDD Macro Base Station	48.3	34.3	28.3	14.3	8.3
Airborne links	FDD Micro Base Station	36.3	22.3	16.3	2.3	-3.7
Airborne links	FDD Pico Base Station	31.3	17.3	11.3	-2.7	-8.7
Temporary point to point	TDD Base Station	41.2	13.2	1.2	-26.8	-38.8
Temporary point to point	TDD Fixed Sub	31.0	3.0	-9.0	-37.0	-49.0
Temporary point to point	TDD Mobile	27.0	-1.0	-13.0	-41.0	-53.0
Temporary point to point	FDD Macro Base Station	41.0	13.0	1.0	-27.0	-39.0
Temporary point to point	FDD Micro Base Station	29.0	1.0	-11.0	-39.0	-51.0
Temporary point to point	FDD Pico Base Station	24.0	-4.0	-16.0	-44.0	-56.0
TDD Base Station	Radio Camera 1W	22.6	-5.4	-17.4	-45.4	-57.4
TDD Base Station	Portable/Mobile links	30.6	2.6	-9.4	-37.4	-49.4
TDD Base Station	Airborne links	41.3	27.3	21.3	7.3	1.3
TDD Base Station	Temporary point to point	42.6	14.6	2.6	-25.4	-37.4
TDD Fixed Sub	Radio Camera 1W	13.6	-14.4	-26.4	-54.4	-66.4
TDD Fixed Sub	Portable/Mobile links	21.6	-6.4	-18.4	-46.4	-58.4
TDD Fixed Sub	Airborne links	32.3	18.3	12.3	-1.7	-7.7
TDD Fixed Sub	Temporary point to point	33.6	5.6	-6.4	-34.4	-46.4
TDD Mobile	Radio Camera 1W	4.6	-23.4	-35.4	-63.4	-75.4
TDD Mobile	Portable/Mobile links	12.6	-15.4	-27.4	-55.4	-67.4
TDD Mobile	Airborne links	23.3	9.3	3.3	-10.7	-16.7
TDD Mobile	Temporary point to point	24.6	-3.4	-15.4	-43.4	-55.4
FDD Mobile	Radio Camera 1W	-0.8	-28.8	-40.8	-68.8	-80.8
FDD Mobile	Portable/Mobile links	7.2	-20.8	-32.8	-60.8	-72.8
FDD Mobile	Airborne links	17.9	3.9	-2.1	-16.1	-22.1
FDD Mobile	Temporary point to point	-49.8	-77.8	-89.8	-117.8	-129.8

Table 5.5: Additional Isolation or Margin to Avoid Interference (without Mitigation): PMSE/FDD/TDD at 10 and 20MHz offsets

The results in Table 5.5 indicate that localised interference could occur between PMSE systems and FDD/TDD systems in all scenarios considered, if appropriate interference mitigation (e.g. band edge filtering) is not considered. Interference can occur in both directions, i.e. from PMSE to FDD/TDD systems and vice versa. The wideband characteristics of the PMSE spectrum mask means that increasing the frequency separation does not have a significant impact on the results unless a much larger frequency separation (in excess of 20MHz) is considered.

The next section of this report considers the impact of applying suitable mitigation in the form of filtering to the interference margin.

5.3.2 PMSE and FDD/TDD Interference with Mitigation

This section considers the feasibility of mitigating interference to PMSE systems and specifically the feasibility of filtering PMSE equipment to reduce the impact of inbound interference from FDD/TDD systems.

In order to understand the practicality and performance of filters that could be applied to PMSE systems to reject unwanted interference from FDD/TDD systems in neighbouring spectrum, we approached a filter supplier specialising in PMSE equipment. This supplier offers a range of filters, which can be added to video links to mitigate interference. The relevant filters fall in to two categories – filters for use with frequency converters, and 10MHz channel specific filters.

Down converter filters can be fitted to the PMSE link receiver to provide rejection of unwanted signals. We understand that a range of band limiting filters is available for use in high RF environments. Our assessment is that filters similar to these would be useful for blocking interference to PMSE links from FDD/TDD base stations. Our assessment is that a suitable filter could be developed to provide 30dB isolation at the PMSE link.

We understand that off-the-shelf channel filters are available for PMSE today that provide adequate protection for most of the current PMSE channels (with the possible exception of the top channel).

It is noted that, in future, new PMSE equipment may be manufactured with a reduced receiver band to align with the new PMSE assignments in the UK (once the 2.6GHz band is no longer available for assignments). However, in the meantime, it may be necessary to consider the addition of filters to attenuate not only adjacent channels but also the whole of the 2.6GHz band. This would also be beneficial to reduce possible effects of blocking of PMSE receivers from UMTS/WiMAX systems.

To indicate the effect of mitigation on PMSE links, we have estimated that filtering that provides additional 30dB isolation should be feasible in future. To illustrate the impact of this, we have incorporated additional 30dB isolation in to our ACI calculation.

The results are summarised in Table 5.6.

Interference Path		Additional Isolation or Margin at 10MHz Offset (dB)				
Interferer	Victim	10	50	100	500	1000
Radio Camera 1W	TDD Base Station	15.3	-12.6	-24.7	-52.6	-64.7
Radio Camera 1W	TDD Fixed Sub	3.4	-24.6	-36.6	-64.6	-76.6
Radio Camera 1W	TDD Mobile	-0.6	-28.6	-40.6	-68.6	-80.6
Radio Camera 1W	FDD Macro Base Station	13.4	-14.5	-26.6	-54.5	-66.6
Radio Camera 1W	FDD Micro Base Station	1.4	-26.5	-38.6	-66.5	-78.6
Radio Camera 1W	FDD Pico Base Station	-3.6	-31.5	-43.6	-71.5	-83.6
Portable/Mobile links	TDD Base Station	15.3	-12.6	-24.7	-52.6	-64.7
Portable/Mobile links	TDD Fixed Sub	3.6	-24.4	-36.4	-64.4	-76.4
Portable/Mobile links	TDD Mobile	-0.4	-28.4	-40.4	-68.4	-80.4
Portable/Mobile links	FDD Macro Base Station	13.7	-14.3	-26.3	-54.3	-66.3
Portable/Mobile links	FDD Micro Base Station	1.7	-26.3	-38.3	-66.3	-78.3
Portable/Mobile links	FDD Pico Base Station	-3.3	-31.3	-43.3	-71.3	-83.3
Airborne links	TDD Base Station	26.1	12.1	6.1	-7.9	-13.9
Airborne links	TDD Fixed Sub	14.4	0.4	-5.6	-19.6	-25.6
Airborne links	TDD Mobile	10.4	-3.6	-9.6	-23.6	-29.6
Airborne links	FDD Macro Base Station	24.5	10.5	4.5	-9.5	-15.5
Airborne links	FDD Micro Base Station	12.5	-1.5	-7.5	-21.5	-27.5
Airborne links	FDD Pico Base Station	7.5	-6.5	-12.5	-26.5	-32.5
Temporary point to point	TDD Base Station	15.9	-12.1	-24.1	-52.1	-64.1
Temporary point to point	TDD Fixed Sub	7.6	-20.4	-32.4	-60.4	-72.4
Temporary point to point	TDD Mobile	3.6	-24.4	-36.4	-64.4	-76.4
Temporary point to point	FDD Macro Base Station	18.2	-9.7	-21.8	-49.7	-61.8
Temporary point to point	FDD Micro Base Station	6.2	-21.7	-33.8	-61.7	-73.8
Temporary point to point	FDD Pico Base Station	1.2	-26.7	-38.8	-66.7	-78.8
TDD Base Station	Radio Camera 1W	-5.0	-33.0	-45.0	-73.0	-85.0
TDD Base Station	Portable/Mobile links	3.0	-25.0	-37.0	-65.0	-77.0
TDD Base Station	Airborne links	13.7	-0.3	-6.3	-20.3	-26.3
TDD Base Station	Temporary point to point	15.0	-13.0	-25.0	-53.0	-65.0
TDD Fixed Sub	Radio Camera 1W	-13.4	-41.4	-53.4	-81.4	-93.4
TDD Fixed Sub	Portable/Mobile links	-5.4	-33.4	-45.4	-73.4	-85.4
TDD Fixed Sub	Airborne links	5.3	-8.7	-14.7	-28.7	-34.7
TDD Fixed Sub	Temporary point to point	6.6	-21.4	-33.4	-61.4	-73.4
TDD Mobile	Radio Camera 1W	-22.4	-50.4	-62.4	-90.4	-102.4
TDD Mobile	Portable/Mobile links	-14.4	-42.4	-54.4	-82.4	-94.4
TDD Mobile	Airborne links	-3.7	-17.7	-23.7	-37.7	-43.7
TDD Mobile	Temporary point to point	-2.4	-30.4	-42.4	-70.4	-82.4
FDD Mobile	Radio Camera 1W	-16.4	-44.4	-56.4	-84.4	-96.4
FDD Mobile	Portable/Mobile links	-8.4	-36.4	-48.4	-76.4	-88.4
FDD Mobile	Airborne links	2.3	-11.7	-17.7	-31.7	-37.7
FDD Mobile	Temporary point to point	3.6	-24.4	-36.4	-64.4	-76.4

Interference Path		Additional Isolation or Margin at 20MHz Offset (dB)				
Interferer	Victim	10	50	100	500	1000
Radio Camera 1W	TDD Base Station	9.3	-18.6	-30.7	-58.6	-70.7
Radio Camera 1W	TDD Fixed Sub	-2.6	-30.6	-42.6	-70.6	-82.6
Radio Camera 1W	TDD Mobile	-6.6	-34.6	-46.6	-74.6	-86.6
Radio Camera 1W	FDD Macro Base Station	7.4	-20.6	-32.6	-60.6	-72.6
Radio Camera 1W	FDD Micro Base Station	-4.6	-32.6	-44.6	-72.6	-84.6
Radio Camera 1W	FDD Pico Base Station	-9.6	-37.6	-49.6	-77.6	-89.6
Portable/Mobile links	TDD Base Station	9.4	-18.5	-30.6	-58.5	-70.6
Portable/Mobile links	TDD Fixed Sub	-2.5	-30.4	-42.5	-70.4	-82.5
Portable/Mobile links	TDD Mobile	-6.5	-34.4	-46.5	-74.4	-86.5
Portable/Mobile links	FDD Macro Base Station	7.5	-20.4	-32.5	-60.4	-72.5
Portable/Mobile links	FDD Micro Base Station	-4.5	-32.4	-44.5	-72.4	-84.5
Portable/Mobile links	FDD Pico Base Station	-9.5	-37.4	-49.5	-77.4	-89.5
Airborne links	TDD Base Station	20.1	6.2	0.1	-13.8	-19.9
Airborne links	TDD Fixed Sub	8.3	-5.7	-11.7	-25.7	-31.7
Airborne links	TDD Mobile	4.3	-9.7	-15.7	-29.7	-35.7
Airborne links	FDD Macro Base Station	18.3	4.3	-1.7	-15.7	-21.7
Airborne links	FDD Micro Base Station	6.3	-7.7	-13.7	-27.7	-33.7
Airborne links	FDD Pico Base Station	1.3	-12.7	-18.7	-32.7	-38.7
Temporary point to point	TDD Base Station	11.2	-16.8	-28.8	-56.8	-68.8
Temporary point to point	TDD Fixed Sub	1.0	-27.0	-39.0	-67.0	-79.0
Temporary point to point	TDD Mobile	-3.0	-31.0	-43.0	-71.0	-83.0
Temporary point to point	FDD Macro Base Station	11.0	-17.0	-29.0	-57.0	-69.0
Temporary point to point	FDD Micro Base Station	-1.0	-29.0	-41.0	-69.0	-81.0
Temporary point to point	FDD Pico Base Station	-6.0	-34.0	-46.0	-74.0	-86.0
TDD Base Station	Radio Camera 1W	-7.4	-35.4	-47.4	-75.4	-87.4
TDD Base Station	Portable/Mobile links	0.6	-27.4	-39.4	-67.4	-79.4
TDD Base Station	Airborne links	11.3	-2.7	-8.7	-22.7	-28.7
TDD Base Station	Temporary point to point	12.6	-15.4	-27.4	-55.4	-67.4
TDD Fixed Sub	Radio Camera 1W	-16.4	-44.4	-56.4	-84.4	-96.4
TDD Fixed Sub	Portable/Mobile links	-8.4	-36.4	-48.4	-76.4	-88.4
TDD Fixed Sub	Airborne links	2.3	-11.7	-17.7	-31.7	-37.7
TDD Fixed Sub	Temporary point to point	3.6	-24.4	-36.4	-64.4	-76.4
TDD Mobile	Radio Camera 1W	-25.4	-53.4	-65.4	-93.4	-105.4
TDD Mobile	Portable/Mobile links	-17.4	-45.4	-57.4	-85.4	-97.4
TDD Mobile	Airborne links	-6.7	-20.7	-26.7	-40.7	-46.7
TDD Mobile	Temporary point to point	-5.4	-33.4	-45.4	-73.4	-85.4
FDD Mobile	Radio Camera 1W	-30.8	-58.8	-70.8	-98.8	-110.8
FDD Mobile	Portable/Mobile links	-22.8	-50.8	-62.8	-90.8	-102.8
FDD Mobile	Airborne links	-12.1	-26.1	-32.1	-46.1	-52.1
FDD Mobile	Temporary point to point	6.9	-21.1	-33.1	-61.1	-73.1

Table 5.6: Additional Isolation or Margin to Avoid Interference (with Mitigation): PMSE/FDD/TDD at 10 and 20MHz offsets

The results of our analysis, assuming mitigation is applied to the PMSE link (30dB filtering), suggest that the majority of interference instances can be overcome assuming additional isolation from the filter is available. The exceptions to this are:

- Interference from airborne links
- Localised interference if systems are deployed very close to each other (e.g. 10 metres separation).

In relation to interference from airborne links, it is noted that these links will normally operate at high altitude from a helicopter. In view of the likely flying altitude of the helicopter and taking account of typical pattern losses for a UMTS/WiMAX antenna, it is likely that the likelihood of the airborne interference scenario occurring in practice is limited. This is addressed in Appendix B of this report.

Considering the probability of localised interference occurring between PMSE and UMTS/WiMAX links it is noted that this depends on the proximity of PMSE links to UMTS/WiMAX base stations as well as the number and distribution of PMSE links across the UK.

Considering the probability of a PMSE link being deployed close to a UMTS or WiMAX base station, it is noted that the latter may be deployed at locations across the UK. However, PMSE links tend to be clustered around particular news events, often for defined periods only, and are not generally distributed across the UK.

Table 5.6 summarises the number of PMSE assignments that were issued during 2005 in bands relevant to this study (source: Ofcom/JFMG).

Frequency Band	PMSE Licences/Assignments
2025-2110MHz	32 licences, 733 assignments
2200-2290MHz	39 licences, 156 assignments
2390-2600MHz	77 licences, 1261 assignments

Table 5.6: Number of PMSE Assignments Nationally

It has not been possible to comment on the likelihood of co-incidence of these assignments with areas where UMTS/WiMAX base stations might typically be deployed since precise information on the location of PMSE assignments and the duration of their use was not available.

However, the number of assignments in operation suggests that the probability of localised interference occurring will be limited. This could form the basis of further analysis, if required.

5.3.3 Adjacent Channel Interference from FDD/TDD Systems to Mobile Satellite Terminals in the 2483.5-2500MHz Band

The band 2483.5-2500MHz is allocated to the Mobile Satellite Service (MSS) on a global basis and used by the Globalstar system. The 2483.5-2500MHz band provides the Space-Earth link for this system.

The Earth Station providing Globalstar coverage to the UK is located within central Europe and does not transmit in the 2GHz band, and hence is not considered further in this report. We have, therefore, focussed on the potential for FDD/TDD systems operating in the 2.6GHz band to cause adjacent channel interference to Globalstar terminals in the UK.

The parameters assumed in our calculation are provided in Appendix D.

Results of our analysis are summarised in Table 5.7. This illustrates the required additional isolation or margin at 5 and 10MHz offsets (between the carrier frequency of the FDD/TDD channel and the MSS mobile channel), for a range of geographic separations.

Interference Path		Additional Isolation or Margin at 5MHz Offset (dB)				
Interferer	Victim	10	50	100	500	1000
TDD Base Station	Globalstar Mobile	75.1	47.8	36.0	8.7	-3.0
TDD Fixed Sub	Globalstar Mobile	64.7	37.4	25.6	-1.7	-13.4
TDD Mobile	Globalstar Mobile	58.4	-10.8	-23.8	-55.8	-63.8
FDD Mobile	Globalstar Mobile	56.4	-12.8	-25.8	-57.8	-65.8

Interference Path		Additional Isolation or Margin at 10MHz Offset (dB)				
Interferer	Victim	10	50	100	500	1000
TDD Base Station	Globalstar Mobile	59.0	31.7	19.9	-7.4	-19.1
TDD Fixed Sub	Globalstar Mobile	50.6	23.3	11.5	-15.8	-27.5
TDD Mobile	Globalstar Mobile	40.4	-28.8	-41.8	-73.8	-81.8
FDD Mobile	Globalstar Mobile	46.4	-22.9	-35.9	-67.9	-75.9

Table 5.7: Additional Isolation or Margin to Avoid Interference: FDD/TDD and MSS (Globalstar)

The results summarised in Table 5.7 illustrate that the 'worst case' interference to Globalstar terminals is from FDD/TDD base stations causing interference to mobile reception. This worst-case interference will occur if the lower channels of the 2.6GHz band are used for TDD systems, in which case both TDD base stations and fixed subscriber stations (e.g. of an IEEE802.16d system deployment) will interfere with Globalstar mobile terminal reception.

If the lower channels of the 2.6GHz band are used for FDD, this worst-case scenario is avoided since the FDD base stations will transmit in the upper duplex pair. However, localised interference could occur between FDD and Globalstar mobiles.

As discussed in Section 5.2, the probability of mobile-mobile interference occurring in practice is dependent on a number of factors including the likelihood of devices being co-incident within the interfering range (less than 10 metres – effectively in the same room), the FDD MS transmission power (depending on its location within the cell) and other factors.

Taking these into account, and taking into account that the total global subscriber base for Globalstar is around 200,000 (as of February 2006), this suggests that the likelihood of co-incidence between FDD/TDD terminals in the UK and Globalstar terminals is very low.

6. ADJACENT CHANNEL INTERFERENCE (ACI) ANALYSIS 2010-2025MHZ

This section summarises the results of our modelling applicable to external ACI effects for the 2010-2025MHz band. Internal effects (e.g. FDD/TDD co-existence) will be similar to those presented in Section 5 for the 2.6GHz band.

This section is in two parts:

- Adjacent channel interference to/from UMTS FDD, UMTS TDD and WiMAX TDD and PMSE systems operating in the 2025-2110MHz band
- Adjacent channel interference to/from UMTS FDD, UMTS TDD and WiMAX TDD to mobile satellite services (MSS) in the 1980-2010MHz band.

6.1 Scenarios

Our Phase 1 results confirmed the following external interference modes for further investigation in relation to the 2010-2025MHz band. This assumes, based on our Phase 1 results, that the 2010-2025MHz band might be used for:

- TDD systems such as 3GPP TDD or IEEE802.16d/e WiMAX[9]
- FDD uplink (e.g. of a 3GPP FDD system), with the downlink in another band (e.g. existing UMTS spectrum or 2500-2690MHz).

Mode	Effect
Inbound ACI	MSS to FDD (BS), TDD (BS) and/or TDD (MS) PMSE to FDD (BS), TDD (BS) and/or TDD (MS) MoD to FDD (BS), TDD (BS) and/or TDD (MS)
Outbound ACI	FDD (MS), TDD (BS) and/or TDD (MS) to MSS satellites in 1980-2010MHz FDD (MS), TDD (BS) and/or TDD (MS) to PMSE in 2025-2110MHz

Table 6.1: Interference Modes: 2010-2025MHz

Issues of possible inbound interference from MoD use of the band 2025-2110MHz are not addressed further in this report.

6.2 Inbound Interference: PMSE and MSS

This section presents results of our analysis applying to the potential for inbound interference to cellular and/or mobile broadband systems in the 2010-2025MHz band from existing services in adjacent bands (MSS and PMSE).

[9] The preference for 10MHz channels for WiMAX makes this band a poor substitute to the 2500-2690MHz band and our view is that 2010-2025MHz band might be more suited to UMTS TDD in a 5MHz raster

6.2.1 Inbound Interference from MSS (1980-2010MHz) to 2010-2025MHz

The 1980-2010MHz and 2170-2200MHz bands are allocated to the Mobile Satellite Service (MSS), forming part of the Satellite Personal Communications Services (SPCS) Decision (ERC Decision (97) 03).

Whilst the band is unused at present, there are believed to be various trials underway to investigate use of the 2GHz MSS allocations for hybrid satellite/terrestrial broadcast networks (e.g. see http://www.home.alcatel.com/vpr/vpr.nsf/DateKey/18072006uk). Such systems employ geostationary satellites with a network of terrestrial repeaters, to provide urban and indoor coverage. The terrestrial repeaters can share spectrum in the satellite band due their low power.

The 1980-2010MHz band is used for the Earth to Space link to satellites, with the 2170-2200MHz forming the Space to Earth link to terminals.

The potential for MSS Earth Stations to interfere with UMTS FDD and TDD systems in the 2010-2025MHz band was studied by CEPT in ERC Report 65.

This investigated interference from and to satellite Mobile Earth Stations (MES). The results of this analysis (MES interference to UMTS at 2010 MHz) are provided in Figure 6.1. Given the very low probability of a MES being located within the UMTS cell area, the ERC study concluded the predicted interference probability to be acceptable (and also concluded the dominant mode of interference would be inbound interference from UMTS to satellites, covered in Section 6.3 of this report).

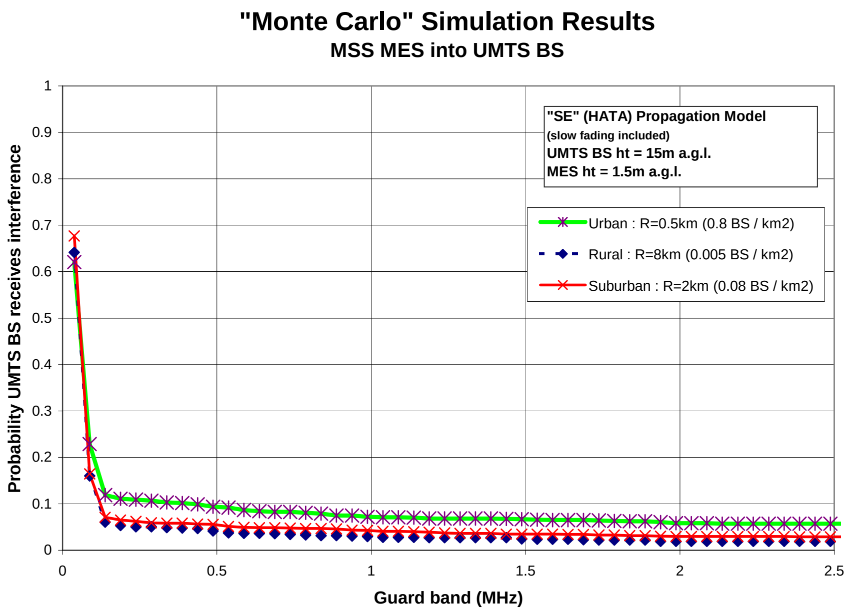


Figure 6.1: Probability of MSS MES Interference to UMTS (Source: ERC Report 65)

6.2.2 Inbound interference from PMSE to 2010-2025MHz

Results of modelling to identify the potential for PMSE systems (wireless cameras, temporary point to point links, airborne video links and portable video links) to create inbound interference to cellular and mobile broadband systems is discussed in Sections 5.3.1 and 5.3.2 of this report. The full analysis is contained in Appendix B.

Of particular relevance to the 2010-2025MHz band is the fact that the PMSE band 2025-2110MHz is the preferred band for airborne PMSE links (e.g. air to ground video links from helicopters), since other PMSE bands (e.g. the 2.4-2.5GHz band and 3.5GHz) impose restrictions on airborne use due to coordination requirements with other services). The results of our analysis suggest that PMSE airborne links are particularly prone to causing adjacent channel interference, due to the low propagation losses. However, the interference becomes less of a problem when there is a separation greater than 1km between the PMSE link and an UMTS/WiMAX base station (see Table 5.6). In practice, it is noted that there is likely to be a significant altitude difference between the airborne link and ground-based UMTS or WiMAX systems, significantly reducing the likelihood of this interference scenario occurring.

Advice from JFMG suggests that the typical operational height of a 'flying eye' or relay helicopter is above 1500m. With this, it can be concluded that the probability of the worst-case interference scenarios we have predicted (PMSE airborne link to TDD base station receiver with less than 1km separation) occurring is low.

Appendix B of this report considers the effect of helicopter altitude and of typical pattern losses for UMTS/WiMAX antennas on the likelihood of interference occurring from PMSE airborne links.

With this, our results suggest that:

- Localised interference could occur from all types of PMSE links to TDD base station receivers if no mitigation is applied. The interfering distances for different types of base station are: within 200 metres of a macro base station, within 100 metres of a micro base station and within 75 metres of a pico base station. Due to the wideband nature of the PMSE system, interference will affect both channels in the 2290-2302MHz band (assuming 2 x 5MHz channels)
- The addition of filtering (e.g. band stop filtering) would avoid interference in the majority of cases
- Some coordination of deployment of PMSE links near TDD base stations, where practical, may be beneficial to avoid PMSE links being set up within the interfering distances described above.

6.3 Outbound Interference MSS and PMSE

This section presents results of our analysis applying to the potential for outbound interference from cellular and/or mobile broadband systems in the 2010-2025MHz band to existing services in adjacent bands (MSS and PMSE).

6.3.1 Interference to MSS satellites 1980-2010MHz

As indicated in Section 6.2.1, the potential for interference between MSS systems in the 1980-2010MHz band and UMTS FDD and TDD systems in the 2010-2025MHz band was previously studied extensively by the CEPT in ERC Report 65.

This investigated interference to MSS satellites from UMTS systems (outdoor and indoor TDD systems) concluded that the worst-case scenario was that of aggregated interference from outdoor macro TDD base stations to satellites.

For this, the report concluded that a small guard band (500kHz) would be required - noting that filtering may reduce the interference effects, however, the practical considerations of filter roll-off may still require guard-bands to adequately reduce interference into the adjacent satellite band.

The report does not consider whether the 500kHz guard band is created within the 2010-2025MHz band or the 1980-2010MHz band (or between both). For the purposes of our analysis of spectrum packaging options (see Section 8), we have considered the guard band being accommodated within the 2010-2025MHz band.

It is noted that the 500kHz guard band relates to interference from TDD base stations. If the 2010-2025MHz band was to be used as an FDD uplink, the interference caused by FDD mobiles is less than that from base stations, resulting in a smaller guard band requirement.

6.3.2 Outbound Interference to PMSE (2025-2110MHz)

Results of our modelling to identify the potential for PMSE systems (wireless cameras, temporary point to point links, airborne video links and portable video links) to receive interference from cellular and mobile broadband systems is discussed in Sections 5.3.1 and 5.3.2 of this report. The full analysis is contained in Appendix B.

In particular, the results show that PMSE systems could receive interference from TDD base stations deployed in the top two channels in the 2010-2025MHz band, within a 200 metre radius (between the base station and the PMSE receiver).

Discussion with a PMSE vendor confirmed that PMSE users are already familiar with the effects of incoming interference from existing UMTS base stations at the 2110MHz band edge.

Various mitigation techniques are already employed (channel filters, retuning equipment to receive in an alternative available channel, receiver antenna improvements etc.).

Discussion with one filter supplier specialising in PMSE equipment suggests that a range of filters can be added to video links to mitigate interference. Based on this, we re-calculated our results assuming 30dB additional isolation in the form of a filter (either band edge or channel filter). This confirms that the majority of interference scenarios are avoided, with the remaining cases being limited to co-sited systems or those located very close to each other (10 metre separation).

6.3.3 Outbound Interference to Space Science Services (Space Research) in 2025-2110MHz

In addition to the outbound interference scenarios identified above, it is noted that ECC Decision (06) 01 recommends a 300kHz guard band at the 2025MHz boundary with the band 2025-2110MHz to protect space science services.

Referring to ERC Report 65, this guard band is to protect space science services (space research and space operations), Earth-Space link, for compliance with ITU-R Recommendation SA.1154 (which describes provisions to protect space research, space operations and earth exploration satellite).

A decision is required as to whether this guard band is to be incorporated in to the UK plan for the band 2010-2025MHz. Our spectrum packaging analysis in Section 8 assumes this guard band is included within one of the spectrum packages.

7. ADJACENT CHANNEL INTERFERENCE (ACI) ANALYSIS 2290-2302MHZ

This section summarises the results of our modelling applicable to external ACI effects for the 2290-2302MHz band. Internal effects (e.g. FDD/TDD co-existence) will similar to those presented in Section 5 for the 2.6GHz band.

This section considers adjacent channel interference to/from UMTS FDD, UMTS TDD and WiMAX systems operating in the 2290-2302MHz band to PMSE systems operating in the 2200-2290MHz band.

It is noted that Space Research (Space to Earth and Space to Space) and Earth Exploration Satellite (Space to Earth and Space to Space) are allocated spectrum adjacent to the 2290MHz band edge. Since usage of this band is to be confirmed, this adjacency is not considered further in this report.

7.1 Scenarios

Our Phase 1 results confirmed the following external interference modes for further investigation in relation to the 2290-2302MHz band.

Within the band 2290-2302MHz, we assume that either TDD systems (UMTS and/or WiMAX) or an FDD uplink could be deployed. However, it should be noted that there was minimal interest from cellular and mobile broadband industry in obtaining spectrum in the band 2290-2302MHz since its use is not harmonised with other European countries.

If the band 2290-2302MHz is used for PMSE (e.g. as an adjunct to the existing band 2200-2290MHz), this could provide an additional PMSE channel. In this case, adjacent channel interference will be limited to localised effects between neighbouring PMSE systems (noting that JFMG currently coordinates channel assignments for PMSE).

Mode	Effect
Inbound ACI	PMSE to FDD (BS), TDD (BS) and/or TDD (MS) MoD to FDD (BS), TDD (BS) and/or TDD (MS)
Outbound ACI	FDD (MS), TDD (BS) and/or TDD (MS) to PMSE in 2200-2290MHz

Table 7.1: Interference Modes: 2290-2302MHz

Issues of inbound interference from MoD use of the band 2310-2350MHz are not addressed further in this report.

7.2 Inbound and Outbound Interference Between FDD/TDD Systems and PMSE

7.2.1 Inbound interference from PMSE to 2290-2302MHz

Results of modelling to identify the potential for PMSE systems (wireless cameras, temporary point to point links, airborne video links and portable video links) to create inbound interference to cellular and mobile broadband systems is discussed in Sections 5.3.1 and 5.3.2 of this report. The full analysis is contained in Appendix B.

If the 2290-2302MHz band is used for TDD or FDD uplink deployment, this suggests that, in line with recommendations on the 2010-2025MHz band:

- Localised interference could occur from all types of PMSE links to TDD base station receivers. The interfering distances for different types of base station are: within 200 metres of a macro base station, within 100 metres of a micro base station and within 75 metres of a pico base station. Due to the wideband nature of the PMSE system, interference will affect both channels in the 2290-2302MHz band (assuming 2 x 5MHz channels)
- The addition of filtering at the PMSE transmitter (e.g. band stop filtering) would avoid interference
- Some coordination of deployment of PMSE links near TDD base stations, where practical, may be beneficial to avoid PMSE links being set up within the interfering distances described above.

7.2.2 Outbound Interference to PMSE (2200-2290MHz)

Results of our modelling to identify the potential for PMSE systems (wireless cameras, temporary point to point links, airborne video links and portable video links) to receive interference from cellular and mobile broadband systems is discussed in Sections 5.3.1 and 5.3.2 of this report. The full analysis is contained in Appendix B.

In particular, the results show that PMSE systems could receive interference from TDD base stations using either channel in the band 2290-2302MHz (assuming 2 x 5MHz channels within the band), within a 200-metre radius (i.e. between the base station and the PMSE receiver).

Discussion with a PMSE vendor confirmed that PMSE users are already familiar with the effects of incoming interference from existing UMTS base stations at the 2110MHz band edge. Various mitigation techniques are already employed (channel filters, retuning equipment to receive in an alternative available channel, receiver antenna improvements etc.). In addition, the use of filtering on the TDD base station could reduce the potential for interference.

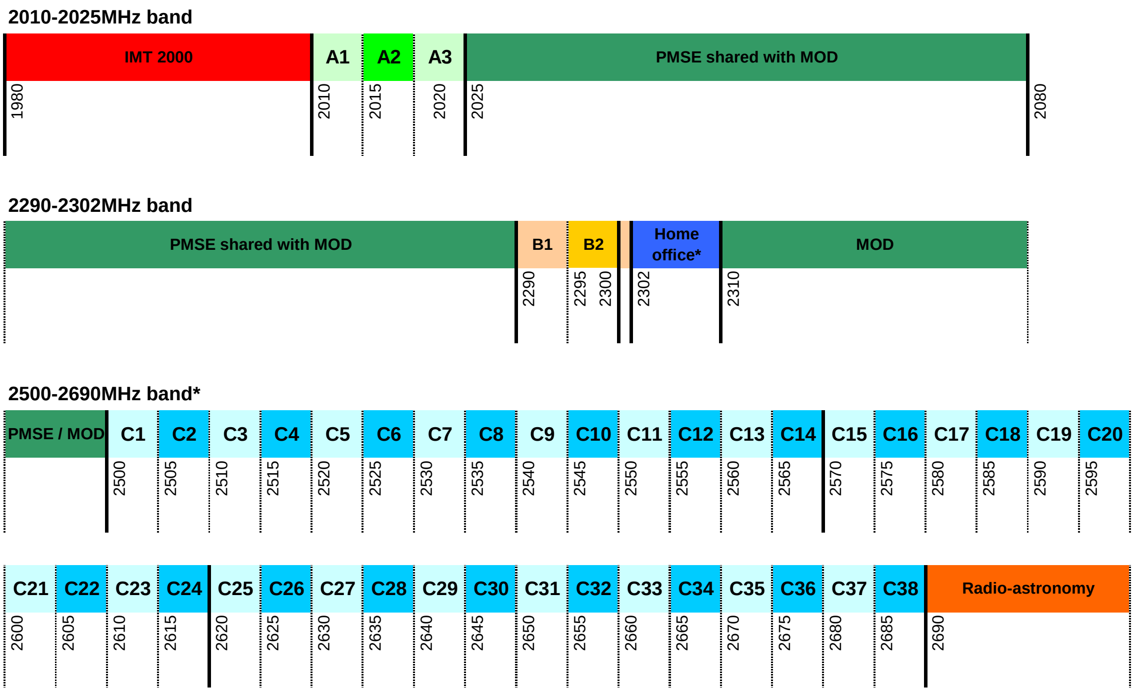
8. SPECTRUM PACKAGING AND TECHNICAL USAGE CONDITIONS

This section discusses the impact of our interference analysis on the packing of spectrum for award of the 2500-2690MHz, 2010-2025MHz and 2290-2302MHz bands, and on technical usage conditions for the three bands.

8.1 Theoretical Band Plans

Theoretical channel plans for the three bands under study, based on a nominal 5MHz channel raster, were developed by DotEcon during Phase 1 of the Economic Study on the award options for the three bands.

These channel plans are provided in Figure 8.1 below. The remainder of this section refers to channel numbering consistent with these plans, to discuss the implications of our adjacent channel interference assessment on the packaging of spectrum for award.



*Under the CEPT plan, blocks C1-C14 paired with C25-C40 are specified for UMTS FDD, uplink and downlink respectively; blocks C15-C24 are specified for UMTS TDD. However, Ofcom is no obliged to conform to this plan.

Figure 8.1: Reference Band Plans (Source: DotEcon)

8.2 Spectrum Packaging Implications

Results of our adjacent channel interference analysis and their relevance to packaging of spectrum in the three available bands is discussed below, per band.

8.2.1 2010-2025MHz

Results of our ACI analysis for the 2010-2025MHz band suggests the following impact on packaging of spectrum in this band:

- At band edge with A1 (2010MHz): 500kHz guard band is required to reduce outbound interference from TDD base stations to MSS satellites (in accordance with ECC Decision (06) 01
- At the band edge with A3 (2025MHz): Mitigation required to protect PMSE from outbound interference (e.g. use of filtering and/or power restrictions). In addition, A2 and A3 suffer inbound interference from PMSE
- At the band edge with A3 (2025MHz): 300kHz guard band is recommended in ECC Decision (06) 01 to provide protection to Space Science Services in 2025-2110 MHz[10].

This suggests the following options for packaging of the band:

- Assign the 2010-2025MHz band as one block 2010.5-2024.7MHz
- Assign two channels of 4.7MHz width and one channel of 4.8MHz width
- Assign two channels of 4.8MHz widths and one channel of 4.6MHz width.

This is illustrated in Figure 8.2 below.

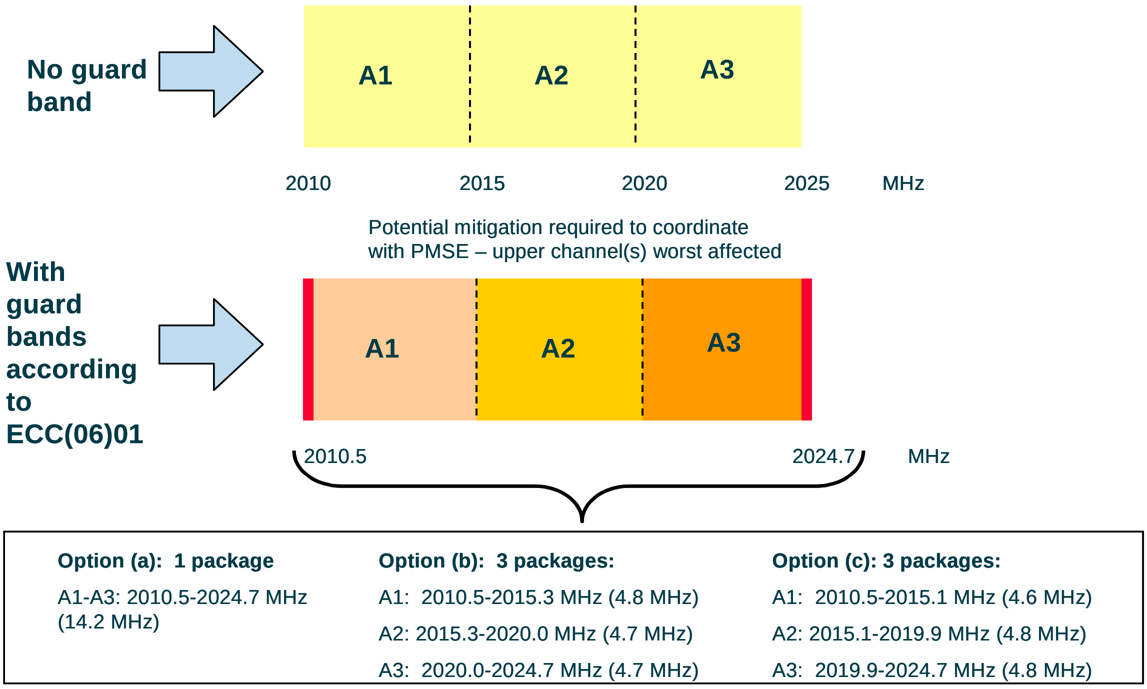


Figure 8.2: Impact of ACI on Band Plan 2010-2025MHz

[10] It needs to be confirmed whether this guard band is required in the UK plan

8.2.2 2290-2302MHz

Results of our ACI analysis for the 2290-2302MHz band suggests the following impact on packaging of spectrum in this band:

- At boundary with B1 (2290MHz) – no guard band with PMSE recommended but mitigation required to reduce the impact of localised interference. However, if B1 and B2 are used for PMSE, mitigation may not be required, since the channels can be incorporated in to the existing PMSE band plan
- At boundary with B2 (2302MHz) – possible restricted usage due to inbound interference from MoD (TBC).

This suggests the following options for packaging of the band:

- One package of 10 (or 12) MHz
- Two packages of 5MHz (e.g. 2290-2295MHz and 2290-2300MHz, with 2MHz unallocated
- Two packages of 6MHz (2290-2296MHz and 2296-2302MHz.

This is illustrated in Figure 8.3 below.

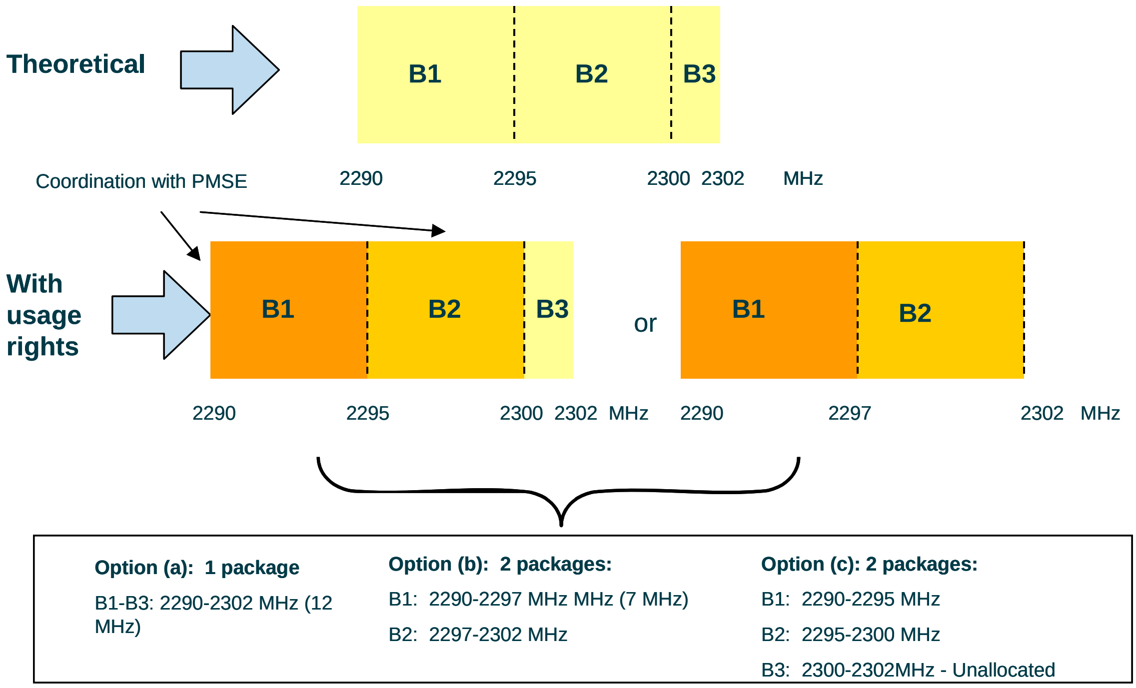


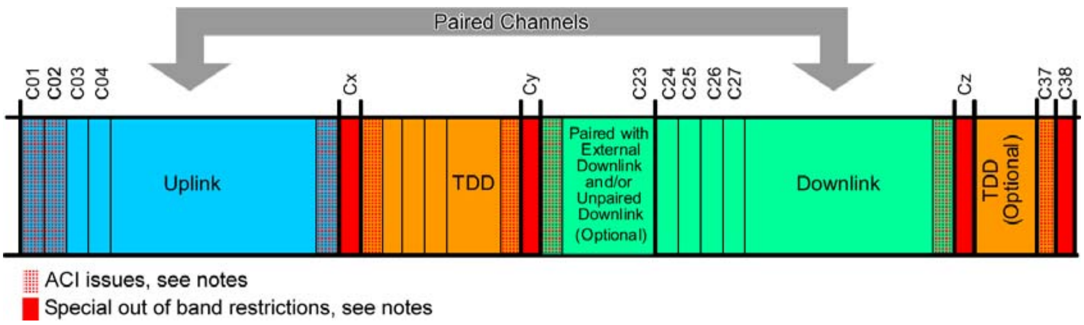
Figure 8.3: Impact of ACI on Band Plan 2290-2302MHz

8.2.3 2500-2690MHz

Results of our analysis of internal and external adjacent channel interference affecting the 2500-2690MHz band suggests the following:

- At 2500MHz (affecting channels C1 and C2) – affected by incoming and outgoing interference to/from PMSE. Affects both FDD and TDD systems but outgoing interference is worse if TDD systems are deployed in C1
- At 2500MHz (affecting channel C1 if used for TDD) – restricted technical usage conditions on TDD base station transmission to limit interference to MSS terminals. Restriction not applicable if C1 used for FDD as mobile/mobile interference is localised only
- At FDD/TDD boundaries (adjacent channel) – FDD/TDD co-existence not achievable at 5MHz offset (i.e. adjacent channel) without restricted technical usage conditions, limiting base station power to pico cell type only
- At FDD/TDD boundaries (second adjacent channel) – site coordination if systems are co-located plus use of band stop filtering at base station sites
- At TDD/TDD boundaries – synchronisation of systems will avoid ACI occurring but also requires coordination of usage (e.g. equivalent up/down timeslot allocation).

The impact on the 2.6GHz band plan is illustrated in Figure 8.4 below.



In the diagram above:
–Cx is between 2500MHz and 2570MHz depending on the split between TDD and FDD
–Cy is between Cx and 2620MHz, depending on the amount of externally paired spectrum (if any)
–Cz is between point 2620MHz and 2690MHz, depending on the split between TDD and FDD
–Cx and Cz are always separated by 120MHz being the FDD duplex spacing.

Figure 8.4: Impact of ACI on Band Plan 2500-2690MHz

8.3 Technical Usage Conditions

This section considers appropriate technical usage conditions that are suggested by the results of our ACI analysis. We have considered technical usage conditions in terms of radiated power (EIRP) masks, which define the maximum EIRP of the signal at increasing offsets from its channel centre frequency. Masks have been defined assuming 5MHz channel spacing, however can also be applied to other channel widths.

Figure 8.5 defines the spectrum mask for FDD and TDD mobile devices. This is based on the 3GPP specification for mobile stations. We recommend this mask is used as the starting point to define technical usage conditions for the award of the three bands in relation to mobile transmit conditions.

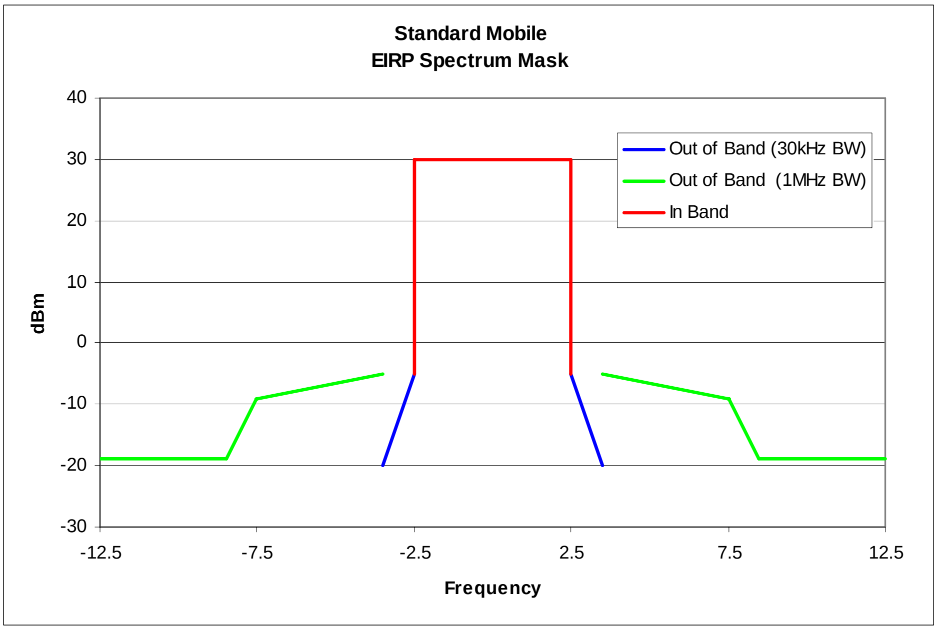


Figure 8.5: EIRP Mask (Mobile Stations)

In relation to technical usage conditions for base stations deployed in the three bands, we have defined four spectrum masks as follows:

- Standard base station mask – for channels in which no ACI restrictions apply. This is based on 3GPP FDD and TDD 'macro' base station out of band emission specifications
- Type A1 mask – to protect the second lower adjacent channel at FDD/TDD boundaries. This mask is a modification of the standard mask, to incorporate additional isolation required at the lower band edge
- Type A2 mask – to protect the second upper adjacent channel at FDD/TDD boundaries. This mask is a modification of the standard mask, to incorporate additional isolation at the upper band edge
- Type B mask – to protect both lower and upper first adjacent channels at FDD/TDD boundaries. This is based on the 3GPP 'pico' base station mask.

The four masks are illustrated in Figure 8.6.

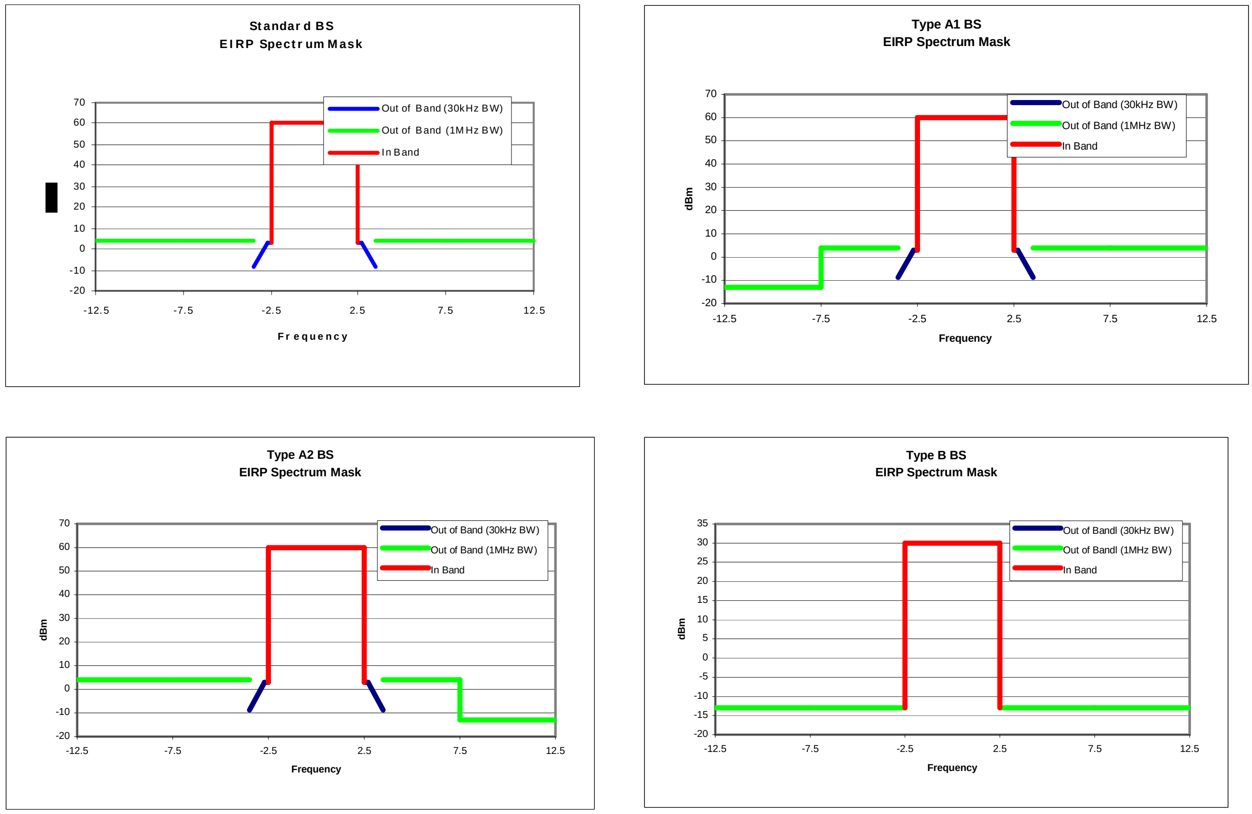


Figure 8.6: Base Station Spectrum Masks

8.4 Typical Deployment Densities

It is noted that Ofcom has consulted on defining out-of-band Spectrum Usage Rights (SUR) in terms of an aggregated power flux density, or power spectral density, such as:

"The OOB PFD at any point up to a height H m above ground level should not exceed XdBW/m2/MHz for more than Y% of the time and more than Z% of locations in any area A km2".

Definition of usage rights in this form requires analysis of the network deployment, to model the number of transmitters in a given area.

For this to be evaluated, Mason has assessed typical cell densities for various WiMAX, UMTS and MBMS networks that might be deployed in the 2.6GHz band in the UK. These could be used as input to determining SUR for use of the 2.6GHz band.

8.4.1 Great Britain Geography Breakdown

Table 8.1 shows the breakdown of Great Britain (GB) geography into five classifications. This is based on Ordinance Survey data, which is typically used in radio planning tools. This particular data was supplied by ATDI Limited and analysed within the ICS Telecom tool.

Land Usage	Total Area km^2	% Area
Hydro	3450	1.5%
Rural	184739	80.3%
Suburban	7015	3.1%
Urban 8m	12578	5.5%
Wood	22197	9.7%
TOTALS	229979	100.0%

Table 8.1: GB Geography Breakdown

8.4.2 Population Analysis

There is a wide range of population densities within each of the geography classifications in Table 8.1 above.

In the case of mobile and wireless broadband services for use in the home, the highest cell densities within networks will be required in areas with the highest population density.

In the case of both mobile phone and data technologies, coverage of homes is becoming increasingly important as mobile operators aim to replace fixed line phone calls with calls on mobile phones. There is a good collation between business, retail and work place locations with residential population when viewed on a large scale, and so population density is a useful approximation of the areas requiring good mobile coverage.

The key difference between full mobile coverage and coverage of population is the additional coverage put in place to cover roads running between urban centres, and to a lesser extent, the railway network. Many new high data rate networks may not be concerned with road coverage, where the prime requirement is for voice and low data rate services as this requirement as is met by existing GSM networks. Should a new entrant wish to build a national network covering roads and rural areas they may consider complementing any 2.6GHz spectrum secured with lower frequency spectrum, which is in many ways better suited to providing open road and rural coverage.

Table 8.2 provides results of Mason's analysis of how many cells of a given size are required to cover the populated areas of Great Britain. The results are aggregated from a detailed analysis of 30,833 km^2 tiles covering all GB postcodes. Tiles have been ranked in descending order of population and it is assumed that an operator would commence roll-out in the most populated areas.

Accumulative Area (km^2)	Area %	Accumative Population	Population Density (P/km^2) for each % bin	Population % of Total	0.7	1	2	3	4	5	7	10
536	0.43%	2924250	5456	5%	**349**	171	43	19	11	7	4	2
1236	0.57%	5848500	4178	10%	**803**	394	99	44	25	16	9	4
2124	0.72%	8772750	3293	15%	**1380**	677	170	76	43	28	14	7
3236	0.90%	11697000	2630	20%	**2103**	1031	258	115	65	42	22	11
4572	1.08%	14621250	2189	25%	**2971**	1456	364	162	91	59	30	15
6124	1.26%	17545500	1884	30%	**3979**	1950	488	217	122	78	40	20
7872	1.42%	20469750	1673	35%	5114	2506	627	**279**	157	101	52	26
9812	1.57%	23394000	1507	40%	6374	3124	781	**348**	196	125	64	32
11988	1.76%	26318250	1344	45%	7788	3816	954	424	239	153	**78**	39
14408	1.96%	29242500	1208	50%	9360	4587	1147	510	287	184	**94**	46
17140	2.21%	32166750	1070	55%	11135	5456	1364	607	341	219	**112**	55
20216	2.49%	35091000	951	60%	13133	6435	1609	715	403	258	**132**	65
23692	2.82%	38015250	841	65%	15391	7542	1886	838	472	302	**154**	76
27684	3.24%	40939500	733	70%	17984	8813	2204	980	551	353	**180**	89
32340	3.77%	43863750	628	75%	21009	10295	2574	1144	644	412	**211**	103
37956	4.55%	46788000	521	80%	24657	12082	3021	1343	756	484	**247**	121
45220	5.89%	49712250	403	85%	29376	14394	3599	1600	900	576	**294**	144
55304	8.18%	52636500	290	90%	35927	17604	4401	1956	1101	705	**360**	177
71464	13.10%	55560750	181	95%	46424	22748	5687	2528	1422	910	**465**	228
123344	42.06%	58485000	56	100%	80126	39262	9816	4363	2454	1571	**802**	393
	100.00%											

Table 8.2: Number of Cells Required for GB Population Coverage

From this analysis, it is estimated that a network constructed of 1km radius cells would require 80,126 cells to cover 100% of the population. It is noted that 10% of this figure (around 8,000) is required to cover 50% of the population.

8.4.3 WiMAX Cell Sizes

In practice the cell size in less populated areas is considerably bigger than that in dense urban areas. In relation to WiMAX network deployment, we have assumed that the WiMAX network is aiming to provide wireless broadband coverage to homes in populated areas.

Analysis of a 2.6GHz WiMAX (802.11e) link budget (10MHz TDD) performed by Mason has produced the following cell radii:

Classification	Cell Radius(km)
Urban	0.7
Suburban	3
Rural	7

Table 8.3: 2.6GHz WiMAX Cell Sizes

Our market analysis from Phase 1 of this study suggests that 802.11e technology would be deployed for both fixed and mobile requirements as the technology offers performance improvements over the previous 802.11d standard.

Cell sizes are driven primarily by differences in the radio propagation environment. Where there is a very high demand for service, an additional layer of cells may be required with much smaller radii. These may be complemented by in-building solutions and distributed antenna systems. These second layer enhancements are likely to be installed some time after the initial roll-out and launch of the network, and only in areas where the network utilisation is high and expected to outgrow the capacity of the first layer network.

Figure 8.7 plots the number of cells required for increasing population coverage, for a range of cell radii.

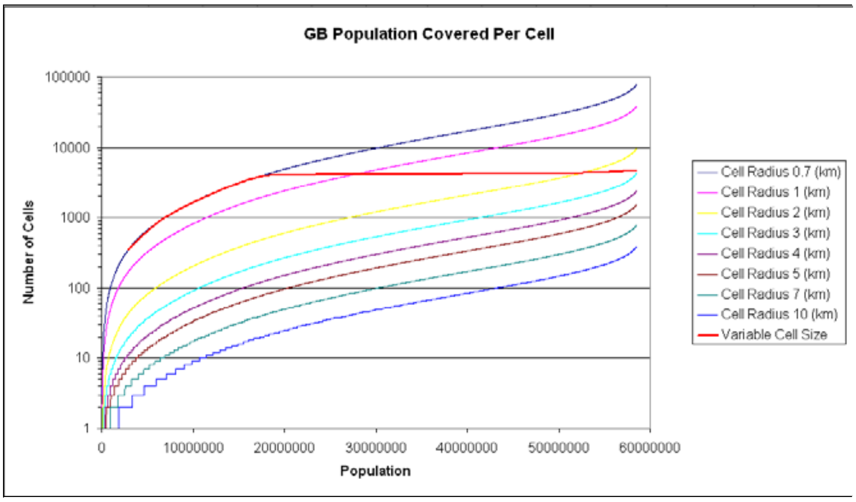


Figure 8.7: GB Population Against Cell Size

The red line in Figure 8.7 shows the estimated number of WiMAX cells based on cell sizes stated in Table 8.3.

The break down is as follows:

Classification	Cell Radius(km)	Count
Urban	0.7	3979
Suburban	3	131
Rural	7	738
	Total	4848

Table 8.6: Breakdown of WiMAX Cells

8.4.4 UMTS Cell Sizes

Table 8.4 illustrates Mason's analyis of a typical UK 3G roll-out, for a 2GHz UMTS network.

Classification	Count
Urban	5227
Suburban	120
Rural	1948
Total	7295

Table 8.4: Breakdown of 2 GHz UMTS Cells

The difference in cell numbers between Tables 8.3 and 8.4 may be accounted for in part by discrepancies between the precise grid reference of a site placement as well as differing coverage objectives. The other main difference is road and rail coverage, which will account for a proportion of UMTS sites classified as rural in our breakdown.

Taking these factors into account, our view is that the average difference between 2.6GHz WiMAX and/or a new UMTS build compared to a 2GHz UMTS HSDPA roll-out providing similar services will be small.

8.4.5 Summary

Our view is that cell sizes for 2.6GHz WiMAX networks will be similar to those for 2GHz UMTS HSDPA systems being deployed today.

Cell sizes are driven by a combination of factors:

- Radio propagation environment
- Cell capacity requirements
- Service mix.

Table 8.5 summarises our view of typical cell density for networks that might be deployed in the 2.6GHz band (e.g. UMTS HSDPA, MBMS, WiMAX).

GB Land Usage	GB Total Area km2	% Area	Cells	Cell Density (per km^2)
Hydro	3450	1.5%	0	0
Rural	184739	80.3%	738	0.0040
Suburban	7015	3.1%	131	0.0187
Urban 8m	12578	5.5%	3979	0.3163
Wood	22197	9.7%	0	0
TOTALS	229979	100.0%	4848	

Table 8.5: Typical 2.6GHz Cell Sizes

9. COST OF INTERFERENCE MITIGATION

This section considers the cost of filtering discussed in this report to provide mitigation from many of the ACI scenarios considered.

To investigate the cost and feasibility of filtering, we have contacted a respected filter supplier in Germany. The remainder of this section is based on preliminary information provided by the filter supplier (since required filters would need to be developed specifically as they do not exist on the market today), and our own analysis.

9.1 Scenarios

Our results recommend filtering being required in a number of cases:

- Blocking ACI emissions from base stations at FDD/TDD boundaries within the 2500-2690MHz
- Blocking ACI emissions from PMSE transmitters at band edges with UMTS and or WiMAX systems.

9.2 Cost of Filtering

Filtering requirements for each scenario are discussed below.

9.2.1 FDD/TDD Boundaries

Again, in the case of blocking ACI emissions at TDD/FDD boundaries, a Band Stop filter of 10MHz designed to protect second and third adjacent channels (the first channel being a guard band/restricted use channel) would be the most appropriate solution. Such filters could be fitted to TDD base stations to prevent ACI to the FDD uplink, and at FDD base stations to prevent ACI to the TDD base station receive.

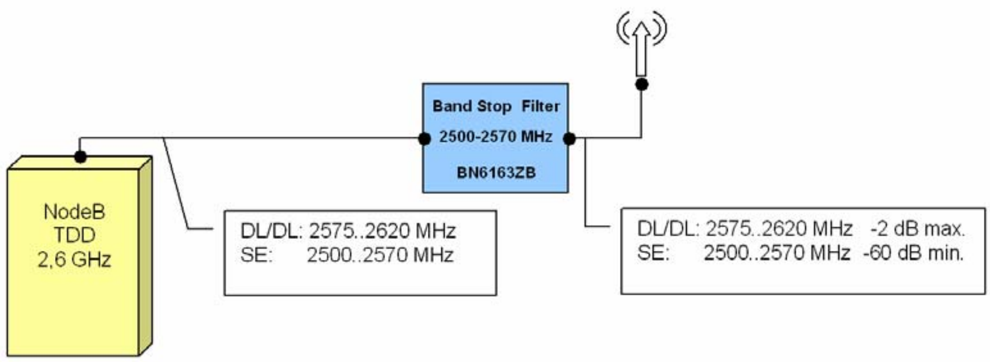


Figure 8.2: Band Stop Filter to protect FDD (frequencies illustrate one example scenario only)

The estimated price per filter is EUR1000.00. This is based on a typical 10 cavity Band Stop Filter. (Source: Spinner). In general, the complexity and price of a filter depends strongly on the number of cavities needed to meet the isolation requirements.

9.2.2 PMSE

Discussion with a PMSE vendor confirmed that channel filters are available today that are used by the PMSE industry to remove interference from adjacent PMSE use. These filters are manufactured to pass a specific channel, although adjustments to filters can be made with the correct equipment and technical knowledge (i.e. could not be done by a user, for instance).

Typical filters have a low insertion loss (less than 2dB), but with a relatively wide pass band (30MHz), thus are useful for blocking second or third adjacent channels, but not the first adjacent channel. The cost of these filters is around £200 each.

It is noted that use of these filters creates a significant logistical issue to PMSE users to ensure that the correct channel filter is available at the outside broadcast site, particularly if channels are changed at short notice.

It is noted that the development of band edge filters (to reduce ACI emissions at band edges of PMSE bands with adjacent UMTS bands) could prevent inbound interference from PMSE to UMTS systems in future.

The feasibility of these requires further consideration. We have spoken to one filter supplier who specialises in PMSE equipment, who offers a range of filters that can be added to PMSE video links to mitigate interference. The filters fall in to two categories – filters for use with frequency converters and 10MHz channel specific filters.

In down conversion filters, the front-end filter section includes a low noise amplifier providing rejection of unwanted signals. The filter manufacturer that we contacted for this study suggested that a range of additional band limiting filters is available for PMSE for use in high RF environments. Additional filters are priced at around £800. This compares with a 10MHz channel filter, which typically cost around £200. These filters offer closer protection of a specific channel but have the disadvantage that it must be carefully calibrated to pass that channel.

APPENDIX A

INTERFERENCE ANALYSIS: CO EXISTENCE OF DIFFERENT 2.6GHZ SYSTEMS (UMTS FDD, UMTS TDD, WIMAX TDD)

Introduction

This Section focuses on Adjacent Channel Interference (ACI) within the 2.6GHz Band, between different systems that might be deployed in neighbouring spectrum blocks.

Both FDD/TDD and TDD/TDD coexistence is investigated:

- Input parameters are based on FDD WCDMA and TDD IEEE802.16d/e (WiMAX). The approach, levels of interference and mitigation techniques are equally applicable to TDD CDMA. This is because the first order effects are due to the duplexer method employed (TDD or FDD) whilst differences in air interface technology (WCDMA or OFDM) have only a second order effect
- A 5MHz channel width has been modelled for both FDD and TDD. An 802.16 TDD system with more than 5MHz bandwidth sharing the frequency band with WCDMA, would typically result in less interference to WCDMA, but more interference from WCDMA to 802.16.

The analysis draws on the following sources of information:

- ITU-R Working Party 8F (Doc. Ref. 8F/TEMP/391-E)
- ITU-R Reconditions M.2030 and M.2045
- An article by Tim Wilkinson and Paul Howard published by the IEEE
- Work completed by Mason Communications.

Adjacent Channel Interference Definitions

For this analysis, we have used definitions of adjacent channel interference (ACI) used in various CEPT ECC PT1 and ITU-R Working Party 8F studies on IMT-2000.

The level of interference received depends on the spectral 'leakage' of the interferer's transmitter and the adjacent channel blocking performance of the receiver. For the transmitter, the spectral leakage is characterized by the *Adjacent Channel Leakage Ratio* (ACLR), which is defined as:

- The ratio of the transmitted power to the power measured in the adjacent radio frequency (RF) channel at the output of a receiver filter.

Similarly, the adjacent channel performance of the receiver is characterized by the Adjacent Channel Selectivity (ACS), which is defined as:

- The ratio of the power level of unwanted ACI to the power level of co-channel interference that produces the same bit error ratio (BER) performance in the receiver.

The ACLR and ACS values for the WCDMA base station and mobile station are defined by the specifications for the first and second adjacent channels, which correspond to carrier separations of 5MHz and 10MHz, respectively.

The equivalent ACLR and ACS for the first and second adjacent channels of an 802.16 TDD system are left to the industry and local regulations in the IEEE 802.16 specifications. However a set of RF parameters has been specified by the WiMAX Forum, which have been used for sharing studies for the band 2500MHz - 2690MHz within ITU-R Working Party 8F. Therefore, we have used these parameters in our analysis.

Basic Radio Parameters

The radio parameters on which our analysis is based are summarised in Table A1.

Data highlighted in yellow is taken from ITU-R Recommendation.M2030.

Mason has estimated the data highlighted in blue for this study.

All other data is taken from ITU-R Working Party 8F document 391-E, Tables 2.1-1, 2.1-2 and 2.2-2.

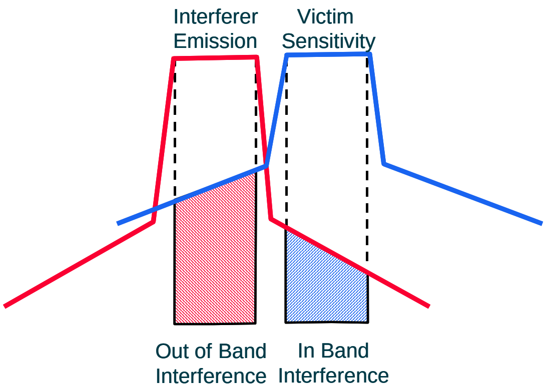
Victim and Interferer Parameters	Tx Power	Antenna Gain	Antenna Height	Inteference	ACLR (dB) 5MHz	ACLR (dB) 10 MHz	ACLR (dB) 15MHz	ACS (dB) 5MHz	ACS (dB) 10MHz	ACS (dB) 15MHz
TDD Base Station	36.0	18.0	30.0	-110.0	53.5	66.0	70.0	70.0	70.0	70.0
TDD Fixed Sub	24.0	8.0	1.5	-108.0	37.0	51.0	54.1	40.0	59.0	66.0
TDD Mobile	20.0	3.0	1.5	-109.0	33.0	51.0	54.1	40.0	59.0	66.0
FDD Macro Base Station	43.0	17.0	30.0	-109.0	45.0	50.0	67.0	46.0	58.0	66.0
FDD Micro Base Station	38.0	5.0	6.0	-109.0	45.0	50.0	67.0	46.0	58.0	66.0
FDD Pico Base Station	24.0	0.0	1.5	-109.0	45.0	50.0	67.0	46.0	58.0	66.0
FDD Mobile	21.0	0.0	1.5	-105.0	33.0	43.0	57.6	33.0	43.0	48.9

Table A1: Parameters Assumed in our Analysis

Interference Mechanisms

Figure A1 below illustrates the interference mechanisms relevant to our FDD/TDD co-existence analysis. The out-of-band power from the interferer that falls within the pass band of the victim is controlled by the ACLR. The main transmit signal power from the interferer is out-of-band and is attenuated by the ACS.

ACLR of the interferer and ASC of the victim can be combined to give ACIR using the given formula.



$$ACIR = \frac{1}{\dfrac{1}{ACLR} + \dfrac{1}{ACS}}.$$

Figure A1: Definition of Adjacent Channel Interference

Adjacent Channel Interference Ratio for 5 and 10MHz Offsets from the Carrier Centre Frequency

The relevant adjacent channel interference ratios, for 5MHz and 10MHz offsets between carriers, for each interference scenario considered is provided in Table A2.

Interference Path			ACIR (dB)		
Class	Interferer	Victim	5MHz	10MHz	15MHz
Base to Base	FDD Macro Base Station	TDD Base Station	45.0	50.0	65.2
	TDD Base Station	FDD Macro Base Station	45.3	57.4	64.5
	FDD Micro Base Station	TDD Base Station	45.0	50.0	65.2
	TDD Base Station	FDD Micro Base Station	45.3	57.4	64.5
	FDD Pico Base Station	TDD Base Station	45.0	50.0	65.2
	TDD Base Station	FDD Pico Base Station	45.3	57.4	64.5
	TDD Base Station	TDD Base Station	53.4	64.5	67.0
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	38.8	49.5	63.5
	FDD Micro Base Station	TDD Fixed Sub	38.8	49.5	63.5
	FDD Pico Base Station	TDD Fixed Sub	38.8	49.5	63.5
	TDD Base Station	TDD Fixed Sub	39.8	58.2	64.5
Base to Mobile	TDD Base Station	FDD Mobile	33.0	43.0	48.9
	FDD Macro Base Station	TDD Mobile	38.8	49.5	63.5
	FDD Micro Base Station	TDD Mobile	38.8	49.5	63.5
	FDD Pico Base Station	TDD Mobile	38.8	49.5	63.5
	TDD Base Station	TDD Mobile	39.8	58.2	64.5
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	36.5	50.2	53.8
	TDD Fixed Sub	FDD Micro Base Station	36.5	50.2	53.8
	TDD Fixed Sub	FDD Pico Base Station	36.5	50.2	53.8
	TDD Fixed Sub	TDD Base Station	37.0	50.9	54.0
Mobile to Base	TDD Mobile	FDD Macro Base Station	32.8	50.2	53.8
	TDD Mobile	FDD Micro Base Station	32.8	50.2	53.8
	TDD Mobile	FDD Pico Base Station	32.8	50.2	53.8
	FDD Mobile	TDD Base Station	33.0	43.0	57.4
	TDD Mobile	TDD Base Station	33.0	50.9	54.0
Mobile to Mobile	TDD Mobile	FDD Mobile	30.0	42.4	47.8
	FDD Mobile	TDD Mobile	32.2	42.9	57.0
	TDD Mobile	TDD Mobile	32.2	50.4	53.8
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	31.5	42.4	47.8
	TDD Fixed Sub	FDD Mobile	31.5	42.4	47.8
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	32.2	42.9	57.0
	TDD Mobile	TDD Mobile	32.2	50.4	53.8
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	35.2	50.4	53.8

Figure A2: Adjacent Channel Interference Ratios for Scenarios Considered

Co-location Coupling Losses

Table A3 lists the total propagation loss associated with co-located equipment and also mobile devices within close proximity of fixed devices and mobile devices.

In the case of base station to base station antennas, vertical separation and antenna pattern losses are taken into account.

In the case of mobile devices a small amount of horizontal separation (1m) is assumed.

Class	Co-location Antenna Coupling Loss		(dB)	ITU 8F Table
Base - Base	FDD Macro Base Station	TDD Base Station	30.0	B2
	FDD Micro Base Station	TDD Base Station	77.0	B5
	FDD Pico Base Station	TDD Base Station	89.0	B9
Base - Mobile/Fixed	FDD Mobile	TDD Base Station	73.4	C1
	FDD Macro Base Station	TDD Fixed Sub	65.4	C1
	FDD Macro Base Ststion	TDD Mobile	70.4	C1
	FDD Micro Base Station	TDD Fixed Sub	45.5	C2
	FDD Micro Base Ststion	TDD Mobile	50.5	C2
	FDD Pico Base Station	TDD Fixed Sub	32.7	C3
	FDD Pico Base Ststion	TDD Mobile	37.7	C3
Mobile - Mobile	Mobile	Mobile	40.7	1m free space

Table A3: Propagation Loss Associated with Co-Located Equipment

Propagation Models

Different propagation models are assumed for different modes of interference.

Modes of interference considered are:

- FDD base station to adjacent TDD base station (macro, micro, pico)
- TDD base station to adjacent FDD or TDD base station (macro, micro, pico)
- FDD mobile to TDD mobile
- TDD mobile to FDD or TDD mobile
- TDD ‘fixed subscriber’ station to FDD base station or FDD/TDD mobile
- FDD or TDD mobile to TDD fixed subscriber station
- FDD or TDD base station to TDD or FDD mobile.

Variation is small over short distances but more significant at 100m or more. Assumed propagation models are given in Table A4.

Propagation Loss			losses(dB) for distance(m)				
Class	Description	Reference	10	50	100	500	1000
Macro - Macro	Free Space Lose	ITU-R PN.525	60.7	74.7	80.7	94.7	100.7
Macro - Micro	ITU Vehicular	ITU-R M.1225	59.6	86.9	98.7	126.0	137.7
Macro - Pico	ITU Pedestrian	ITU-R M.1225	71.4	99.4	111.4	139.4	151.4
Mobile - Mobile	ITU Hybrid	ITU-R PN.525 / ITU-R M.1225	60.7	130.0	143.0	175.0	183.0

Table A4: Propagation Models

Results

The additional isolation required to prevent ACI is calculated by the formulae below.

- Co-location Additional Isolation (dB) = Tx Power - Antenna Coupling Loss - ACIR - Interference Limit
- Non Co-located Additional Isolation (dB) = Tx Power + Tx Gain + Rx Gain - Propagation Loss - ACIR - Interference Limit.

Where the result is negative, the value represents the margin that exists between interferer and victim.

In the case of directional antennas, both antennas of interferer and victim are modelled as pointing directly at each other with no down tilt (worst case)

In the case of devices with power control, the interferer is assumed to be transmitting at full power (worst case).

Results are summarised as follows.

Additional Isolation or Margin at Different Frequency Offsets Offset

The additional isolation required to prevent ACI for the various FDD/TDD interference modes is summarised in Tables A5, A6 and A7 for 5MHz, 10MHz and 15MHz frequency offset respectively. Results are also presented for a range of separation distances (between interfering and interfered system).

In the following tables red is used to highlight a requirement for additional isolation and green indicates a margin of safety.

Interference Path			Additional Isolation or Margin at 5MHz Offset (dB)					
Class	Interferer	Victim	Co-lo [1]	10	50	100	500	1000
Base to Base	FDD Macro Base Station	TDD Base Station	78.0		68.3	62.3	48.3	42.3
	TDD Base Station	FDD Macro Base Station	69.7		60.0	54.0	40.0	34.0
	FDD Micro Base Station	TDD Base Station	26.0		39.1	27.3	0.0	-11.7
	TDD Base Station	FDD Micro Base Station	22.7		35.8	24.0	-3.3	-15.0
	FDD Pico Base Station	TDD Base Station	0.0		7.6	-4.4	-32.4	-44.4
	TDD Base Station	FDD Pico Base Station	10.7		18.3	6.3	-21.7	-33.7
	TDD Base Station	TDD Base Station	62.6		53.9	47.9	33.9	27.9
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	46.8	76.5	62.5	56.5	42.5	36.5
	FDD Micro Base Station	TDD Fixed Sub	61.7	60.6	33.3	21.5	-5.8	-17.5
	FDD Pico Base Station	TDD Fixed Sub	16.2	29.7	1.8	-10.3	-38.2	-50.3
	TDD Base Station	TDD Fixed Sub	66.5	70.6	43.3	31.5	4.2	-7.5
Base to Mobile	TDD Base Station	FDD Mobile	34.6	66.4	39.1	27.3	0.0	-11.7
	FDD Macro Base Station	TDD Mobile	42.8	73.6	46.3	34.5	7.2	-4.5
	FDD Micro Base Station	TDD Mobile	34.8	56.6	29.3	17.5	-9.8	-21.5
	FDD Pico Base Station	TDD Mobile	56.5	37.6	10.3	-1.5	-28.8	-40.5
	TDD Base Station	TDD Mobile	31.8	66.6	39.3	27.5	0.2	-11.5
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	31.1	61.9	34.6	22.8	-4.5	-16.2
	TDD Fixed Sub	FDD Micro Base Station	51.0	49.9	22.6	10.8	-16.5	-28.2
	TDD Fixed Sub	FDD Pico Base Station	63.8	44.9	17.6	5.8	-21.5	-33.2
	TDD Fixed Sub	TDD Base Station	31.6	63.4	36.1	24.3	-3.0	-14.7
Mobile to Base	TDD Mobile	FDD Macro Base Station	25.8	56.6	29.3	17.5	-9.8	-21.5
	TDD Mobile	FDD Micro Base Station	45.7	44.6	17.3	5.5	-21.8	-33.5
	TDD Mobile	FDD Pico Base Station	58.5	39.6	12.3	0.5	-26.8	-38.5
	FDD Mobile	TDD Base Station	24.6	56.4	29.1	17.3	-10.0	-21.7
	TDD Mobile	TDD Base Station	23.6	58.4	31.1	19.3	-8.0	-19.7
Mobile to Mobile	TDD Mobile	FDD Mobile	54.3	37.3	-32.0	-45.0	-77.0	-85.0
	FDD Mobile	TDD Mobile	57.1	40.1	-29.2	-42.2	-74.2	-82.2
	TDD Mobile	TDD Mobile	56.1	42.1	-27.2	-40.2	-72.2	-80.2
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	56.8	45.9	18.6	6.8	-20.5	-32.2
	TDD Fixed Sub	TDD Mobile	60.8	52.9	25.6	13.8	-13.5	-25.2
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	56.1	45.2	17.9	6.1	-21.2	-32.9
	TDD Mobile	TDD Fixed Sub	55.1	47.2	19.9	8.1	-19.2	-30.9
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	56.1	52.0	38.0	32.0	18.0	12.0

Table A5: Additional Isolation or Margin at 5MHz Offset

Mason

Interference Path			Additional Isolation or Margin at 10MHz Offset (dB)					
Class	Interferer	Victim	Co-lo [1]	10	50	100	500	1000
Base to Base	FDD Macro Base Station	TDD Base Station	73.0		63.3	57.3	43.3	37.3
	TDD Base Station	FDD Macro Base Station	57.6		47.9	41.9	27.9	21.9
	FDD Micro Base Station	TDD Base Station	21.0		34.1	22.3	-5.0	-16.7
	TDD Base Station	FDD Micro Base Station	10.6		23.7	11.9	-15.4	-27.1
	FDD Pico Base Station	TDD Base Station	-5.0		2.6	-9.4	-37.4	-49.4
	TDD Base Station	FDD Pico Base Station	-1.4		6.2	-5.8	-33.8	-45.8
	TDD Base Station	TDD Base Station	51.5		42.7	36.7	22.7	16.7
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	36.1	65.8	51.8	45.8	31.8	25.8
	FDD Micro Base Station	TDD Fixed Sub	51.0	49.9	22.6	10.8	-16.5	-28.2
	FDD Pico Base Station	TDD Fixed Sub	5.5	19.1	-8.9	-20.9	-48.9	-60.9
	TDD Base Station	TDD Fixed Sub	48.1	52.2	24.9	13.1	-14.2	-25.9
Base to Mobile	TDD Base Station	FDD Mobile	24.6	56.4	29.1	17.3	-10.0	-21.7
	FDD Macro Base Station	TDD Mobile	32.1	62.9	35.6	23.8	-3.5	-15.2
	FDD Micro Base Station	TDD Mobile	24.1	45.9	18.6	6.8	-20.5	-32.2
	FDD Pico Base Station	TDD Mobile	45.8	26.9	-0.4	-12.2	-39.5	-51.2
	TDD Base Station	TDD Mobile	13.4	48.2	20.9	9.1	-18.2	-29.9
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	17.4	48.2	20.9	9.1	-18.2	-29.9
	TDD Fixed Sub	FDD Micro Base Station	37.3	36.2	8.9	-2.9	-30.2	-41.9
	TDD Fixed Sub	FDD Pico Base Station	50.1	31.2	3.9	-7.9	-35.2	-46.9
	TDD Fixed Sub	TDD Base Station	17.7	49.5	22.2	10.4	-16.9	-28.6
Mobile to Base	TDD Mobile	FDD Macro Base Station	8.4	39.2	11.9	0.1	-27.2	-38.9
	TDD Mobile	FDD Micro Base Station	28.3	27.2	-0.1	-11.9	-39.2	-50.9
	TDD Mobile	FDD Pico Base Station	41.1	22.2	-5.1	-16.9	-44.2	-55.9
	FDD Mobile	TDD Base Station	14.6	46.4	19.1	7.3	-20.0	-31.7
	TDD Mobile	TDD Base Station	5.7	40.5	13.2	1.4	-25.9	-37.6
Mobile to Mobile	TDD Mobile	FDD Mobile	41.9	24.9	-44.4	-57.4	-89.4	-97.4
	FDD Mobile	TDD Mobile	46.4	29.4	-39.9	-52.9	-84.9	-92.9
	TDD Mobile	TDD Mobile	37.9	23.9	-45.4	-58.4	-90.4	-98.4
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	45.9	35.0	7.7	-4.1	-31.4	-43.1
	TDD Fixed Sub	TDD Mobile	49.9	42.0	14.7	2.9	-24.4	-36.1
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	45.4	34.5	7.2	-4.6	-31.9	-43.6
	TDD Mobile	TDD Fixed Sub	36.9	29.0	1.7	-10.1	-37.4	-49.1
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	40.9	36.9	22.9	16.9	2.9	-3.1

Table A6: Additional Isolation or Margin at 10MHz Offset

Interference Path			Additional Isolation or Margin at 15MHz Offset (dB)					
Class	Interferer	Victim	Co-lo [1]	10	50	100	500	1000
Base to Base	FDD Macro Base Station	TDD Base Station	57.8		48.0	42.0	28.0	22.0
	TDD Base Station	FDD Macro Base Station	50.5		40.7	34.7	20.7	14.7
	FDD Micro Base Station	TDD Base Station	5.8		18.9	7.1	-20.2	-31.9
	TDD Base Station	FDD Micro Base Station	3.5		16.6	4.8	-22.5	-34.2
	FDD Pico Base Station	TDD Base Station	-20.2		-12.6	-24.7	-52.6	-64.7
	TDD Base Station	FDD Pico Base Station	-8.5		-1.0	-13.0	-41.0	-53.0
	TDD Base Station	TDD Base Station	49.0		40.3	34.3	20.3	14.3
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	22.1	51.8	37.8	31.8	17.8	11.8
	FDD Micro Base Station	TDD Fixed Sub	37.0	35.9	8.6	-3.2	-30.5	-42.2
	FDD Pico Base Station	TDD Fixed Sub	-8.5	5.1	-22.9	-34.9	-62.9	-74.9
	TDD Base Station	TDD Fixed Sub	41.8	45.9	18.6	6.8	-20.5	-32.2
Base to Mobile	TDD Base Station	FDD Mobile	18.7	50.5	23.2	11.4	-15.9	-27.6
	FDD Macro Base Station	TDD Mobile	18.1	48.9	21.6	9.8	-17.5	-29.2
	FDD Micro Base Station	TDD Mobile	10.1	31.9	4.6	-7.2	-34.5	-46.2
	FDD Pico Base Station	TDD Mobile	31.8	12.9	-14.4	-26.2	-53.5	-65.2
	TDD Base Station	TDD Mobile	7.1	41.9	14.6	2.8	-24.5	-36.2
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	13.8	44.6	17.3	5.5	-21.8	-33.5
	TDD Fixed Sub	FDD Micro Base Station	33.7	32.6	5.3	-6.5	-33.8	-45.5
	TDD Fixed Sub	FDD Pico Base Station	46.5	27.6	0.3	-11.5	-38.8	-50.5
	TDD Fixed Sub	TDD Base Station	14.6	46.4	19.1	7.3	-20.0	-31.7
Mobile to Base	TDD Mobile	FDD Macro Base Station	4.8	35.6	8.3	-3.5	-30.8	-42.5
	TDD Mobile	FDD Micro Base Station	24.7	23.6	-3.7	-15.5	-42.8	-54.5
	TDD Mobile	FDD Pico Base Station	37.5	18.6	-8.7	-20.5	-47.8	-59.5
	FDD Mobile	TDD Base Station	0.2	32.0	4.7	-7.1	-34.4	-46.1
	TDD Mobile	TDD Base Station	2.6	37.4	10.1	-1.7	-29.0	-40.7
Mobile to Mobile	TDD Mobile	FDD Mobile	36.5	19.5	-49.8	-62.8	-94.8	-102.8
	FDD Mobile	TDD Mobile	32.3	15.2	-54.0	-67.0	-99.0	-107.0
	TDD Mobile	TDD Mobile	34.5	20.4	-48.8	-61.8	-93.8	-101.8
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	40.5	29.6	2.3	-9.5	-36.8	-48.5
	TDD Fixed Sub	TDD Mobile	44.5	36.6	9.3	-2.5	-29.8	-41.5
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	31.3	20.4	-6.9	-18.7	-46.0	-57.7
	TDD Mobile	TDD Fixed Sub	33.5	25.6	-1.7	-13.5	-40.8	-52.5
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	37.5	33.4	19.5	13.4	-0.5	-6.6

Table A7: Additional Isolation or Margin at 15MHz Offset

The results of this analysis demonstrate that FDD/TDD and/or TDD/TDD co-existence is not feasible at a 5MHz offset (5MHz separation between centre frequencies i.e. systems operating in adjacent 5MHz channels), without appropriate interference mitigation. The worst case interference mode is base station to base station, for which separation distances of significantly greater than 1km would be required between base stations to avoid interference.

Interference between an UMTS FDD base station and a WiMAX ‘fixed subscriber’ station is also problematic, with separation distances again in excess of 1km being required.

Localised interference also occurs between mobiles at short range (less than 10 metres).

The results of this analysis also suggest that FDD/TDD and TDD/TDD co-existence at 10MHz and 15MHz offsets are also not feasible without appropriate interference mitigation.

To consider appropriate mitigation techniques, we used analysis presented within ITU-R Recommendation M.2045, along with a number of additional mitigation techniques based on Mason’s experience in radio site planning.

Possible mitigation techniques are summarised below, including their estimated impact (in providing additional isolation between interferer and interfered system)1. Site placement – Typically 17dB Additional Isolation for Macro to Micro

Site placement as a mitigation technique is mainly applicable to the micro to macro scenarios that assumes rooftop and street level deployment respectively with a significant antenna height differential. As a result, the coupling between micro BSs that are close to a macro BS will be reduced. The benefits are provided by the vertical antenna patterns of the macro and micro BS antennas. However, in non-LoS conditions the improvements may be reduced.

2. Antenna separation – Typically 10-15dB above the standard 30dB for Macro-to-Macro co-location

Coupling between two antennas located in the same site can be reduced by separating the antennas vertically, horizontally or back-to-back by a few metres.

For network planning purposes the widely accepted figure of the coupling loss for co located antennas that are not coordinated is 30dB. Higher values of coupling loss are achievable where the three types of separations described above are available. The improvement is achievable using the antenna patterns only, without the use of any additional screening or absorption material.

3. Antenna polarization – (Only a few dB, limited scope for application)

It is possible to get additional isolation between two linearly polarized BS antennas by having them orthogonally polarized to each other. As an example, using vertical polarization on one antenna and horizontal polarization on the other can reduce the degree of coupling between the two. The coupling effect is quantified in terms of an antenna characteristic known as cross-polar discrimination (XPD).

4. Adaptive antennas (little impact on ‘peak’ interference but does significantly reduce the probability of interference)

Adaptive antennas may be defined as “an array of antennas that is able to change its antenna pattern dynamically to adjust to noise, interference and multipath”. Adaptive antennas are used to enhance received signals and may also be used to form beams for transmission. The direct benefit from the use of adaptive antennas on the coexistence, however, is due to the fact that the RF energy radiated by antenna arrays is both lower than that from conventional antennas for the same e.i.r.p. and focused in limited, specific regions of a cell rather than wide sectors.

5. Transmitter/receiver improvements (Base Stations only)

Filtering can add 9-15dB improvements at 5MHz offset, 68dB at 10MHz offset (Based on ITU-RM2045, to be cross checked with filter manufacturers)

Power amplifier linearization techniques 18dB at 5MHz offset, 13dB at 10MHz offset

For BS-to-BS interference, filtering or linearization or both can be used to reduce the unwanted emissions from one BS to another thus reducing the interference at the victim BS. In a similar manner, receiver filtering may reduce the in band interference to the victim BS.

For a given degree of complexity and filter insertion loss, a greater mitigation will be achieved for a single carrier than for a multi-carrier network.

Additional filtering can be incorporated into the base station relatively easily, while at the mobile station the size limitations preclude its use. (ITU Working Party 8F document 391-E).

60dB attenuation with minimal insertion loss is achievable with readily available low cost technology. The size permits integration into the base station. (e.g. Tim Wilkinson, Paul Howard of IP Wireless, IEEE 2004.).

6. TDD power control (Mobile to Mobile, typically a range of 70dB in 1dB steps)

TDD DL (downlink) power control is an integral part of the TDD standard and is used to increase system capacity. In addition to increasing system capacity, power control also provides added immunity to DL interference as the BS can adapt the power it transmits to a victim MS. In particular, using the power control, the signal to the TDD MS can be raised to counter the interference of an FDD MS uplink (UL) on an adjacent frequency. Power control is applicable to all cell types (pico, micro and macro).

7. Mobile handover (Mobile to Mobile)

Handover has been incorporated into cellular type mobile systems mainly to facilitate mobility; however as a by-product it maintains system performance in the presence of RF channel impairments. By handing off the mobile station, a change is introduced (different RF channel, time slot, frequency band, etc.) consistent with the capabilities, design, and deployment rules for the system, and in the process the system has the ability to choose a better channel.

Handover, while not designed to mitigate interference, may function in some cases as a work around to interference. This unintended benefit of handover might be useful in some cases but should not be considered as the predominant means or method of interference control, particularly for externally imposed interference. In any event, the efficacy of handover in interference situations and how it might be utilized is a balance between the benefit achieved and the adverse system impacts that accrue.

8. Antenna azimuth (Macro to Macro – up to 20dB)

Where TDD /FDD macro base stations employ sectored antennas, azimuths could be coordinated to reduce antenna gain in the direction of the interferer.

Azimuth isolation of 20dB can be achieved between two cells utilising three sectored antennas with typical beam widths of 65 degrees. Azimuths of interferer and victim are offset by 60 degrees from the line of sight as per Figure A3 below.

Whilst this could increase isolation by as much as 20dB there are often many other considerations to be taken into account when selecting antenna azimuths.

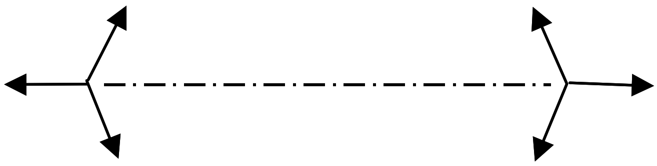


Figure A3: Mitigation Using Antenna Azimuth

9. TDD synchronisation

This technique can completely remove TDD-to-TDD ACI issues.

When applied, both base stations are synchronised such that reception and transition do not occur simultaneously in adjacent channels. Thus mobiles are also synchronised by the standard operation of TDD.

Synchronisation may only be appropriate when adjacent channels are based on the same or similar technology. Differing technologies may have different time frames, which preclude synchronisation.

Synchronisation may not be completely effective where the length of uplink and downlink time slots are adjusted dynamically or are adjusted to suit an asymmetric service such as mobile TV. However, synchronisation could still make a significant reduction in interference under these conditions.

Streaming TDD applications such as mobile TV behave more like FDD downlinks from an interference perspective. Therefore it is preferable to site these applications close to FDD downlink rather than FDD uplink spectrum.

TDD channels will require two quite different spectrum masks: A strict mask for use where minimal coordination between neighbours is employed and a second more relaxed mask, which can be used where more involved coordination with the neighbouring channel operators is in place and mitigation techniques are applied (such as TDD synchronisation). The precise details of this relaxed mask can be agreed between neighbouring channel operators with the restriction that adjacent channels outside of the coordinated channel block are not adversely affected.

10. Reduce transmission power (all modes, 0 to 15dB)

To achieve the same coverage with less power, more base stations may be required. Alternatively the base stations may be moved closer to the system users, reducing propagation losses

Low power systems are often used in-building or within complexes such as airports, train stations, tunnels and stadiums where the high concentration of users may justify a distributed antenna solution that increases base station capacity with minimal EIRP from any single antenna

Low power systems may be able to utilise channels that are unsuitable for full power use

Results with Mitigation with 10MHz or 15MHz Offset

The addition of appropriate mitigation in the interference path could provide the additional isolation indicated in Table A8. Different mitigation techniques will be applicable depending on the interference scenario and whether systems are co-located.

It is noted that results are presented for 10MHz and 15MHz offsets. The 5MHz offset case has not been illustrated since it is assumed that the main mitigation technique (TX/RX filtering) is not feasible at this frequency offset, requiring greater separation between the interfering and interfered system spectrum masks.

Interference Path			Mitigation at 10MHz or 15MHz Offset (dB)					
Class	Interferer	Victim	Site Placement	Site Eng.	Tx /Rx Filter	Antenna Azimuth	Co Lo Total	Separate Total
Base to Base	FDD Macro Base Station	TDD Base Station		15	60	5	75	65
	TDD Base Station	FDD Macro Base Station		15	60	5	80	65
	FDD Micro Base Station	TDD Base Station	12		50		62	62
	TDD Base Station	FDD Micro Base Station	12		50		62	62
	FDD Pico Base Station	TDD Base Station	17		30		47	47
	TDD Base Station	FDD Pico Base Station	17		30		47	47
	TDD Base Station	TDD Base Station		15	50		65	50
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub			60	5	65	65
	FDD Micro Base Station	TDD Fixed Sub			55	5	60	60
	FDD Pico Base Station	TDD Fixed Sub			40	5	45	45
	TDD Base Station	TDD Fixed Sub			60	5	65	65
Base to Mobile	TDD Base Station	FDD Mobile			60		60	60
	FDD Macro Base Station	TDD Mobile			60		60	60
	FDD Micro Base Station	TDD Mobile			55		55	55
	FDD Pico Base Station	TDD Mobile			40		40	40
	TDD Base Station	TDD Mobile			60		60	60
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station			60	5	65	65
	TDD Fixed Sub	FDD Micro Base Station			55	5	60	60
	TDD Fixed Sub	FDD Pico Base Station			40	5	45	45
	TDD Fixed Sub	TDD Base Station			60	5	65	65
Mobile to Base	TDD Mobile	FDD Macro Base Station			60		60	60
	TDD Mobile	FDD Micro Base Station			55		55	55
	TDD Mobile	FDD Pico Base Station			40		40	40
	FDD Mobile	TDD Base Station			60		60	60
	TDD Mobile	TDD Base Station			60		60	60
Mobile to Mobile	TDD Mobile	FDD Mobile					0	0
	FDD Mobile	TDD Mobile					0	0
	TDD Mobile	TDD Mobile					0	0
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile					0	0
	TDD Fixed Sub	FDD Mobile					0	0
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub					0	0
	TDD Mobile	TDD Mobile					0	0
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub				10	10	10

Table A8: Effect of Mitigation at 10MHz or 15MHz Offset

The impact of including appropriate interference mitigation within the calculation is summarised in Tables A9 and A10 below, which show the additional isolation at

10MHz and 15MHz offsets. As indicated by these tables, all results are now positive, with the exception of the co-located BS-BS case for 10MHz offset, and the mobile interference scenarios (for which there is no appropriate mitigation).

Interference Path			Additional Isolation or Margin at 10MHz Offset (dB)					
Class	Interferer	Victim	Co-lo [1]	10	50	100	500	1000
Base to Base	FDD Macro Base Station	TDD Base Station	-2.0	12.3	-1.7	-7.7	-21.7	-27.7
	TDD Base Station	FDD Macro Base Station	-22.4	-3.1	-17.1	-23.1	-37.1	-43.1
	FDD Micro Base Station	TDD Base Station	-41.0	-0.6	-27.9	-39.7	-67.0	-78.7
	TDD Base Station	FDD Micro Base Station	-51.4	-11.0	-38.3	-50.1	-77.4	-89.1
	FDD Pico Base Station	TDD Base Station	-52.0	-16.4	-44.4	-56.4	-84.4	-96.4
	TDD Base Station	FDD Pico Base Station	-48.4	-12.8	-40.8	-52.8	-80.8	-92.8
	TDD Base Station	TDD Base Station	-13.5	6.7	-7.3	-13.3	-27.3	-33.3
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	-28.9	0.8	-13.2	-19.2	-33.2	-39.2
	FDD Micro Base Station	TDD Fixed Sub	-9.0	-10.1	-37.4	-49.2	-76.5	-88.2
	FDD Pico Base Station	TDD Fixed Sub	-39.5	-25.9	-53.9	-65.9	-93.9	-105.9
	TDD Base Station	TDD Fixed Sub	-16.9	-12.8	-40.1	-51.9	-79.2	-90.9
Base to Mobile	TDD Base Station	FDD Mobile	-35.4	-3.6	-30.9	-42.7	-70.0	-81.7
	FDD Macro Base Station	TDD Mobile	-27.9	2.9	-24.4	-36.2	-63.5	-75.2
	FDD Micro Base Station	TDD Mobile	-30.9	-9.1	-36.4	-48.2	-75.5	-87.2
	FDD Pico Base Station	TDD Mobile	5.8	-13.1	-40.4	-52.2	-79.5	-91.2
	TDD Base Station	TDD Mobile	-46.6	-11.8	-39.1	-50.9	-78.2	-89.9
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	-47.6	-16.8	-44.1	-55.9	-83.2	-94.9
	TDD Fixed Sub	FDD Micro Base Station	-22.7	-23.8	-51.1	-62.9	-90.2	-101.9
	TDD Fixed Sub	FDD Pico Base Station	5.1	-13.8	-41.1	-52.9	-80.2	-91.9
	TDD Fixed Sub	TDD Base Station	-47.3	-15.5	-42.8	-54.6	-81.9	-93.6
Mobile to Base	TDD Mobile	FDD Macro Base Station	-51.6	-20.8	-48.1	-59.9	-87.2	-98.9
	TDD Mobile	FDD Micro Base Station	-26.7	-27.8	-55.1	-66.9	-94.2	-105.9
	TDD Mobile	FDD Pico Base Station	1.1	-17.8	-45.1	-56.9	-84.2	-95.9
	FDD Mobile	TDD Base Station	-45.4	-13.6	-40.9	-52.7	-80.0	-91.7
	TDD Mobile	TDD Base Station	-54.3	-19.5	-46.8	-58.6	-85.9	-97.6
Mobile to Mobile	TDD Mobile	FDD Mobile	41.9	24.9	-44.4	-57.4	-89.4	-97.4
	FDD Mobile	TDD Mobile	46.4	29.4	-39.9	-52.9	-84.9	-92.9
	TDD Mobile	TDD Mobile	37.9	23.9	-45.4	-58.4	-90.4	-98.4
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	45.9	35.0	7.7	-4.1	-31.4	-43.1
	TDD Fixed Sub	TDD Mobile	49.9	42.0	14.7	2.9	-24.4	-36.1
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	45.4	34.5	7.2	-4.6	-31.9	-43.6
	TDD Mobile	TDD Fixed Sub	36.9	29.0	1.7	-10.1	-37.4	-49.1
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	30.9	26.9	12.9	6.9	-7.1	-13.1

Table A9: Additional Isolation at 10MHz Offset with Mitigation

Interference Path			Additional Isolation or Margin at 15MHz Offset (dB)					
Class	Interferer	Victim	Co-lo [1]	10	50	100	500	1000
Base to Base	FDD Macro Base Station	TDD Base Station	-17.2	-13.0	-27.0	-33.0	-47.0	-53.0
	TDD Base Station	FDD Macro Base Station	-29.5	-25.3	-39.3	-45.3	-59.3	-65.3
	FDD Micro Base Station	TDD Base Station	-56.2	-15.8	-43.1	-54.9	-82.2	-93.9
	TDD Base Station	FDD Micro Base Station	-58.5	-18.1	-45.4	-57.2	-84.5	-96.2
	FDD Pico Base Station	TDD Base Station	-67.2	-31.7	-59.6	-71.7	-99.6	-111.7
	TDD Base Station	FDD Pico Base Station	-55.5	-20.0	-48.0	-60.0	-88.0	-100.0
	TDD Base Station	TDD Base Station	-16.0	-10.7	-24.7	-30.7	-44.7	-50.7
Base to Fixed Sub	FDD Macro Base Station	TDD Fixed Sub	-42.9	-13.2	-27.2	-33.2	-47.2	-53.2
	FDD Micro Base Station	TDD Fixed Sub	-23.0	-24.1	-51.4	-63.2	-90.5	-102.2
	FDD Pico Base Station	TDD Fixed Sub	-53.5	-39.9	-67.9	-79.9	-107.9	-119.9
	TDD Base Station	TDD Fixed Sub	-23.2	-19.1	-46.4	-58.2	-85.5	-97.2
Base to Mobile	TDD Base Station	FDD Mobile	-41.3	-9.5	-36.8	-48.6	-75.9	-87.6
	FDD Macro Base Station	TDD Mobile	-41.9	-11.1	-38.4	-50.2	-77.5	-89.2
	FDD Micro Base Station	TDD Mobile	-44.9	-23.1	-50.4	-62.2	-89.5	-101.2
	FDD Pico Base Station	TDD Mobile	-8.2	-27.1	-54.4	-66.2	-93.5	-105.2
	TDD Base Station	TDD Mobile	-52.9	-18.1	-45.4	-57.2	-84.5	-96.2
Fixed Sub to Base	TDD Fixed Sub	FDD Macro Base Station	-51.2	-20.4	-47.7	-59.5	-86.8	-98.5
	TDD Fixed Sub	FDD Micro Base Station	-26.3	-27.4	-54.7	-66.5	-93.8	-105.5
	TDD Fixed Sub	FDD Pico Base Station	1.5	-17.4	-44.7	-56.5	-83.8	-95.5
	TDD Fixed Sub	TDD Base Station	-50.4	-18.6	-45.9	-57.7	-85.0	-96.7
Mobile to Base	TDD Mobile	FDD Macro Base Station	-55.2	-24.4	-51.7	-63.5	-90.8	-102.5
	TDD Mobile	FDD Micro Base Station	-30.3	-31.4	-58.7	-70.5	-97.8	-109.5
	TDD Mobile	FDD Pico Base Station	-2.5	-21.4	-48.7	-60.5	-87.8	-99.5
	FDD Mobile	TDD Base Station	-59.8	-28.0	-55.3	-67.1	-94.4	-106.1
	TDD Mobile	TDD Base Station	-57.4	-22.6	-49.9	-61.7	-89.0	-100.7
Mobile to Mobile	TDD Mobile	FDD Mobile	36.5	19.5	-49.8	-62.8	-94.8	-102.8
	FDD Mobile	TDD Mobile	32.3	15.2	-54.0	-67.0	-99.0	-107.0
	TDD Mobile	TDD Mobile	34.5	20.4	-48.8	-61.8	-93.8	-101.8
Fixed Sub to Mobile	TDD Fixed Sub	FDD Mobile	40.5	29.6	2.3	-9.5	-36.8	-48.5
	TDD Fixed Sub	TDD Mobile	44.5	36.6	9.3	-2.5	-29.8	-41.5
Mobile to Fixed Sub	FDD Mobile	TDD Fixed Sub	31.3	20.4	-6.9	-18.7	-46.0	-57.7
	TDD Mobile	TDD Fixed Sub	33.5	25.6	-1.7	-13.5	-40.8	-52.5
Fixed Sub to Fixed Sub	TDD Fixed Sub	TDD Fixed Sub	27.5	23.4	9.5	3.4	-10.5	-16.6

Table A10: Additional Isolation at 10MHz Offset with Mitigation

Mobile-Mobile ACI

There are few mitigation techniques that can be applied to reduce mobile-mobile interference other than frequency separation. However it is generally recognised that mobile-mobile interference affects different devices at different times due to the mobility of the system. This means that at any instant in time only a proportion of vulnerable devices are affected.

There are five key factors that affect the probability of interference occurring between mobile devices:

- The strength of wanted signal the victim is attempting to receive
- The dynamic transmit power of the interferer
- The radio propagation environment
- Proximity of victim and interferer
- ACIR of that particular combination of victim and interferer.

In the analysis so far, we have defined the outcome for a range of proximities assuming that the interferer is operating at full power and the receiver is at the limit of reception. To assess the likelihood of interference occurring, we need to explore how probable each of these assumptions is.

Receiver Signal Strength: Consider a 1km macro cell. According to the prediction models described in ITU-R M.1225, the difference in signal strength between 0.5km and 1km from the base station is approximately 10dB. 75% of the cell area is between 0.5km and 1km from the base station. Assuming evenly distributed users, 75% of users in the cell will have a mean predicted signal strength within 10dB of that found at the cell edge.

However, when planning the coverage network designers will include a slow fade margin (10dB) to account for approximations in the terrain model. Thus, for 50% of these users, the received signal strength will more than 10dB (the slow fade margin) above the predicted level.

Thus 37.5% of users in a cell receive a signal less than 10dB above the minimum receive signal strength.

Transmission Power: Assuming a balanced link budget, a similar argument can be made for the uplink, thus 37.5% of users in a cell transmit at less than 10dB below full power.

Taking this into account, a brief consideration of the probability of mobile-mobile interference occurring is as follows.

The % of 2.6GHz ACI interferer devices in the UK is assumed to be 5% of all mobile devices. (i.e. 5% of all mobile devices will use the 2.6GHz band)

The % of these operating at within 10dB of full power: 37%

The % of 2.6GHz ACI Victim devices in the UK: 5% of all mobile devices.

The % of these operating within 10dB of minimum receiver signal strength: 37%

The area around an Interferer in which interference to a Victim device may occur: 25m radius = 2000m^2.

Based on our assumptions, this area could contain up to 200 mobile devices in high user density areas (large offices, airports etc.) thus on average 1.9% (4) of these will be potential victims and 1.9% (4) will be potential interferers.

The probability that devices will be in use: (3% of time).

The probability that at least one Interferer and Victim within 25m will be in use simultaneously: 12% of 12% = 1.4% of time.

Thus 1.9% of mobile devices in high user density areas will suffer from the effects of 2.6GHz mobile to mobile ACI for 1.4% of the time.

It is also noted that mobile cell hand over may resolve some of these instances of mobile-mobile ACI.

Summary of FDD/TDD and TDD/TDD Analysis

Generally the effects of interference are not symmetrical for adjacent channel operators using different technologies. Whilst a FDD base station may both suffer from and cause interference to TDD base stations, the TDD interferers (low frequency) and TDD victims (higher frequency) will probably belong to different operators.

In general the interference level caused by an FDD (macro) base station to a TDD base station is higher than from a TDD base station to an FDD base station; this also applies for FDD mobile to TDD mobile.

There are several mitigation techniques that can be applied to FDD and TDD base stations. However, even when many of these mitigation techniques are applied together they may be insufficient for macro base station to macro base station compatibility with a 10MHz offset, unless a physical separation of over 100m is also achieved.

Close proximity of TDD/FDD base stations in adjacent channels exacerbates mobile-mobile ACI at the cell edge, as adjacent mobiles transmit at full power and receive the weaker cell edge signal. At the FDD uplink boundary, TDD mobiles will suffer interference: at the FDD downlink boundary, FDD mobiles will suffer interference.

Our analysis suggests that detailed coordination between FDD and TDD operators will be required when using adjacent channels. Good physical separation between FDD and TDD base stations is highly desirable; even so, further mitigation is also required.

Our view is that TDD/FDD base station co-location can potentially be achieved for frequency separations of 15MHz or more with suitable mitigation. With frequency separations less than this, co-location can be achieved with the coordination of services between operators (i.e. by synchronising TDD systems to remove up/down link clashes). However, whilst it is feasible to synchronise TDD systems using the same technology (e.g. two UMTS TDD systems), our view is that it is not feasible to synchronise different TDD systems (e.g. UMTS TDD with WiMAX). Detailed site coordination between adjacent TDD systems will therefore be required at less than 15 MHz offset therefore.

It is noted that TDD mobile to TDD mobile ACI may also be avoided, or mitigated by use of synchronisation.

FDD mobile to TDD mobile is a special case that is difficult to mitigate by handset design. However, this is a localised effect for which probability of co-incidence is low.

Mobile to mobile interference can be avoided by handover to an adjacent cell – a cell that is adjacent in space and/or frequency. Handover due to interference has an impact on cell capacity and possibly knock on effects for the loading of and interference created by adjacent cells. Therefore this is not an ideal mechanism for resolving interference.

TDD mobile to FDD pico base station is also a concern exacerbated by the low height and broad elevation lobe of the pico cell antenna.

In summary:

- A frequency separation of at least 10MHz between the centre frequencies of standard mask TDD and FDD uplink channels is highly desirable. Some temporal risks of ACI remain from FDD mobile Tx to TDD mobile Rx, and TDD/FDD mobiles to TDD fixed subscribers. This residual ACI is difficult to mitigate against but should only affect a small subset of users
- A frequency separation of 10MHz between the centre frequencies of standard mask TDD and FDD downlink channels is also highly desirable. Even with this in place base station mitigation and coordination will be necessary. Some temporal risks of ACI remain from TDD mobile Tx to FDD mobile Rx. This residual ACI is difficult to mitigate against but should only affect a small subset of users
- Co-located TDD base stations will require channel filtering and site engineering to facilitate TDD/TDD coexistence wherever synchronisation is not practical

APPENDIX B

INTERFERENCE ANALYSIS: INBOUND AND OUTBOUND INTERFERENCE BETWEEN PMSE AND UMTS/WIMAX

Introduction

This analysis covers compatibility between FDD/TDD in the 2.6 GHz and related bands, and the following types of PMSE link that operate in adjacent bands:

- Point-to-point temporary video links (coordinated, high power EIRP 20dBW)
- Airborne video links (EIRP 7dBW)
- Potable / mobile video links (EIRP 6dBW)
- Radio Cameras (EIRP 0dBW).

We have assumed all of the PMSE devices complies with parameters defined in ETSI EN 302 064-1 [1]. Deployment assumptions for each type of link are described below.

Point-to-Point Temporary Video Links

Figure B1 illustrates the typical deployment of a temporary video link.

Parameters assumed by Mason for the analysis of inbound/outbound interference between temporary video links and UMTS/WiMAX systems are as follows:

- Transmitter EIRP 20dBW, directional antenna
- Receiver sensitivity –92dBm
- Bandwidth 8MHz in a 10MHz channel
- Modulation COFDM/DVB-T
- May be vehicle mounted with a hydraulic mast
- Mason has assumed a Tx and Rx antenna gain of 20dBi..

Figure B1: PMSE Temporary Video Link

Airborne Video Links

Airborne video links refer to ‘flying eye’ or relay helicopters used for PMSE news gathering, as illustrated in Figure B2.

Parameters assumed by Mason for the analysis of inbound/outbound interference between airborne links and UMTS/WiMAX systems are as follows:

- Transmitter EIRP 7dBW
- Receiver sensitivity –92dBm
- Bandwidth 8MHz in a 10MHz channel
- Modulation COFDM/DVB-T
- Particularly prone to interference due to low propagation losses (free space loss).
- Mason has assumed a transmit/receive antenna gain of 8dBi.

Figure B2: ‘Flying Eye’ or Relay Helicopter

Potable/Mobile Video Links

Figure B3 illustrates a typical portable video link.

Parameters assumed by Mason for the analysis of inbound/outbound interference between these video links and UMTS/WiMAX systems are as follows:

- Transmitter EIRP 6dBW, directional antenna
- Receiver sensitivity –92dBm
- Bandwidth 8MHz in a 10MHz channel
- Modulation COFDM/DVB-T
- Directional antennas can limit interference
- Mason has assumed a Tx and Rx antenna gain of 8dBi.

Figure B3: Portable Video Link

Low Power Radio Cameras

The final category of PMSE use considered in our analysis was low power radio cameras, as illustrated in Figure B4.

Parameters assumed by Mason for the analysis of inbound/outbound interference between radio cameras and UMTS/WiMAX systems are as follows:

- Transmitter 0dBW EIRP or less (100mW typical)
- Receiver sensitivity –92dBm
- Bandwidth 8MHz in a 10MHz channel
- Modulation COFDM/DVB-T.

Figure B4: Radio Camera

Out of Band Emissions for PMSE

For the analysis of outbound interference from PMSE to WCDMA/WiMAX systems operating in an adjacent band, we have assumed the out of band emissions mask specified in ETSI EN 302 064-1 applies for all PMSE video equipment. This is illustrated in Figure B5.

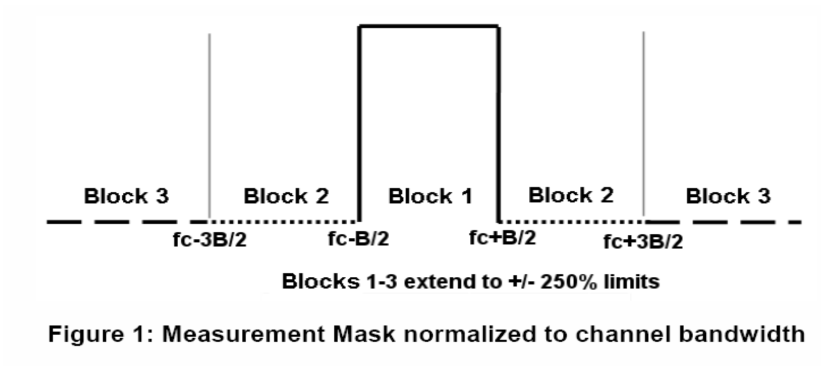


Figure B5: PMSE Out of Band Emissions

7.3.4.1 Integrated power limits relative to P_{MAX}

$P_0 < 0,3$ W eirp

Table 3

	Each half of the region	Both halves of the region
Block 2	-36 dB	-33 dB
Block 3	-42 dB	-39 dB

$P_0 > 0,3$ W eirp

Table 4

	Each half of the region	Both halves of the region
Block 2	-36 dB - 10 log (P_0/0,3)	-33 dB - 10 log (P_0/0,3)
Block 3	-42 dB - 10 log (P_0/0,3)	-39 dB - 10 log (P_0/0,3)

Figure B6: PMSE Out of Band Emissions

Interference Scenarios

The various potential adjacencies between PMSE and UMTS/WiMAX systems in the bands under study are:

- ACI PMSE 2485MHz to/from FDD/TDD 2502.5MHz (17.5MHz offset, analysis uses 20MHz ACIR from out of band emissions mask)
- ACI PMSE 2030MHz to/from FDD/TDD 2022.2MHz (7.8MHz offset, analysis uses 10MHz ACIR)[11]
- ACI PMSE 2285MHz to/from FDD/TDD 2292MHz (7MHz offset, analysis uses 10MHz ACIR)[12].

Based on possible band plans discussed in the main body of this report, interference modes affecting FDD (WCDMA) systems are:

- Outgoing Interference from FDD uplink i.e. Mobile Transmit
- Incoming Interference to FDD uplink i.e. Base station receive.

Interference modes affecting TDD (WCDMA / WiMAX) systems are:

- Outgoing Interference from TDD (Base & Mobile)
- Incoming Interference from TDD (Base & Mobile).

Interference modes considered in our analysis were therefore:

- UMTS TDD and/or WiMAX macro/micro/pico base stations interfering with PMSE systems[13]

[11] 7.8MHz is the lowest offset resulting from three proposed future band plans for the PMSE Band 2025 – 2110MHz

[12] Low power cameras and low power video links only in the PMSE band 2200 – 2290MHz

- PMSE systems interfering with UMTS FDD, UMTS TDD and/or WiMAX macro/micro/pico base stations
- PMSE systems interfering with UMTS TDD and/or WiMAX TDD mobiles
- WiMAX TDD fixed subscriber stations or TDD mobiles interfering with PMSE systems.

Basic Radio Terminal Parameters

Inbound and outbound interference effects between PMSE systems in the bands 2025-2110MHz, 2290-2290MHz and 2450-2500MHz bands and UMTS/WiMAX systems in the 2010-2025MHz, 2290-2302MHz and 2500-2690MHz bands respectively were considered.

A summary of victim and interferer parameters used in our assessment are summarised in Table B1.

This draws on data from ITU 8F 391-E (for UMTS and WiMAX FDD/TDD systems) and ETSI EN 302 064-1 (for PMSE).

Mason has derived the data highlighted in yellow for this study.

Victim and Interferer Parameters	Tx Power (dBm)	Antenna Gain (dBi)	Antenna Height (m)	Inteference Limit (dB)	ACLR (dB)				ACS (dB)			
					5MHz	10 MHz	15MHz	20MHz	5MHz	10MHz	15MHz	20MHz
TDD Base Station	36.0	18.0	30.0	-110.0	53.5	66.0	70.0	70.0	70.0	70.0	70.0	70.0
TDD Fixed Sub	24.0	8.0	1.5	-108.0	37.0	51.0	54.1	54.1	40.0	59.0	66.0	66.0
TDD Mobile	20.0	3.0	1.5	-109.0	33.0	51.0	54.1	54.1	40.0	59.0	66.0	66.0
FDD Macro Base Station	43.0	17.0	30.0	-109.0	45.0	50.0	67.0	67.0	46.0	58.0	66.0	66.0
FDD Micro Base Station	38.0	5.0	6.0	-109.0	45.0	50.0	67.0	67.0	46.0	58.0	66.0	66.0
FDD Pico Base Station	24.0	0.0	1.5	-109.0	45.0	50.0	67.0	67.0	46.0	58.0	66.0	66.0
FDD Mobile	21.0	0.0	1.5	-105.0	33.0	43.0	57.6	57.6	33.0	43.0	48.9	48.9
Radio Camera 1W	30.0	0.0	1.5	-107	-	41.2	-	47.2	-	70.0	-	70.0
Portable/Mobile links	28.0	8.0	1.5	-107	-	47.2	-	53.2	-	70.0	-	70.0
Airborne links	29.0	8.0	1000.0	-107	-	48.2	-	54.2	-	70.0	-	70.0
Temporary point to point	30.0	20.0	10.0	-107	-	61.2	-	67.2	-	70.0	-	70.0

Table B1: Interferer and Interfered System Parameters for UMTS/WiMAX and PMSE Assessment

Propagation Models

The ITU-R outdoor pedestrian propagation model (ITU-R M.1225) has been assumed in our analysis, since this was considered to best reflect the environment where PMSE is used.

Results

Adjacent Channel Interference Ratios for 10 and 20MHz Offsets from the relevant carrier centre frequency, for each mode of interference considered, are summarised in Table B2.

[13] FDD base stations were not modelled since an FDD downlink band is not planned adjacent to the existing PMSE bands – planned bands are either FDD uplink or TDD.

Interference Path		ACIR (dB)	
Interferer	Victim	10MHz	20MHz
Radio Camera 1W	TDD Base Station	41.2	47.2
Radio Camera 1W	TDD Fixed Sub	41.2	47.2
Radio Camera 1W	TDD Mobile	41.2	47.2
Radio Camera 1W	FDD Macro Base Station	41.1	47.2
Radio Camera 1W	FDD Micro Base Station	41.1	47.2
Radio Camera 1W	FDD Pico Base Station	41.1	47.2
Portable/Mobile links	TDD Base Station	47.2	53.1
Portable/Mobile links	TDD Fixed Sub	46.9	53.0
Portable/Mobile links	TDD Mobile	46.9	53.0
Portable/Mobile links	FDD Macro Base Station	46.9	53.0
Portable/Mobile links	FDD Micro Base Station	46.9	53.0
Portable/Mobile links	FDD Pico Base Station	46.9	53.0
Airborne links	TDD Base Station	48.2	54.1
Airborne links	TDD Fixed Sub	47.9	53.9
Airborne links	TDD Mobile	47.9	53.9
Airborne links	FDD Macro Base Station	47.8	53.9
Airborne links	FDD Micro Base Station	47.8	53.9
Airborne links	FDD Pico Base Station	47.8	53.9
Temporary point to point	TDD Base Station	60.7	65.4
Temporary point to point	TDD Fixed Sub	57.0	63.6
Temporary point to point	TDD Mobile	57.0	63.6
Temporary point to point	FDD Macro Base Station	56.3	63.6
Temporary point to point	FDD Micro Base Station	56.3	63.6
Temporary point to point	FDD Pico Base Station	56.3	63.6
TDD Base Station	Radio Camera 1W	64.5	67.0
TDD Base Station	Portable/Mobile links	64.5	67.0
TDD Base Station	Airborne links	64.5	67.0
TDD Base Station	Temporary point to point	64.5	67.0
TDD Fixed Sub	Radio Camera 1W	50.9	54.0
TDD Fixed Sub	Portable/Mobile links	50.9	54.0
TDD Fixed Sub	Airborne links	50.9	54.0
TDD Fixed Sub	Temporary point to point	50.9	54.0
TDD Mobile	Radio Camera 1W	50.9	54.0
TDD Mobile	Portable/Mobile links	50.9	54.0
TDD Mobile	Airborne links	50.9	54.0
TDD Mobile	Temporary point to point	50.9	54.0
FDD Mobile	Radio Camera 1W	43.0	57.4
FDD Mobile	Portable/Mobile links	43.0	57.4
FDD Mobile	Airborne links	43.0	57.4
FDD Mobile	Temporary point to point	43.0	57.4

Table B2: Adjacent Channel Interference Ratios for 10 and 20MHz Offsets for each Mode of Interference

Additional Isolation or Margin at 10MHz Offset for a Range of Separation Distances

Results of our analysis of the potential for interference to/from PMSE and UMTS/WiMAX for each potential mode of interference is summarised in Table B3, for the ‘worst case’ frequency offset (worst case offset defined as 7.5MHz offset between centre frequencies assuming 5MHz cellular/broadband channel adjacent to a 10MHz PMSE channel).

The analysis illustrates the additional isolation (or interference margin) calculated for each scenario, for a range of separation distances between the interfering and interfered system.

The results are colour coded to highlight the most severe interference cases. Red represents scenarios where significant additional isolation is required to avoid interference (which might be achieved either through filtering, separation of systems and/or other mitigation techniques). Green represents an interference scenario where no additional isolation is required (the positive number giving the interference margin that exists). The final column of the table shows the exact separation distance (in metres) at which ACI ceases to be a problem.

Interference Path		Additional Isolation or Margin at 10MHz Offset (dB)					Required Separation
Interferer	Victim	10	50	100	500	1000	Distance (m)
Radio Camera 1W	TDD Base Station	45.3	17.4	5.3	-22.6	-34.7	136
Radio Camera 1W	TDD Fixed Sub	33.4	5.4	-6.6	-34.6	-46.6	68
Radio Camera 1W	TDD Mobile	29.4	1.4	-10.6	-38.6	-50.6	54
Radio Camera 1W	FDD Macro Base Station	43.4	15.5	3.4	-24.5	-36.6	122
Radio Camera 1W	FDD Micro Base Station	31.4	3.5	-8.6	-36.5	-48.6	61
Radio Camera 1W	FDD Pico Base Station	26.4	-1.5	-13.6	-41.5	-53.6	46
Portable/Mobile links	TDD Base Station	45.3	17.4	5.3	-22.6	-34.7	136
Portable/Mobile links	TDD Fixed Sub	33.6	5.6	-6.4	-34.4	-46.4	69
Portable/Mobile links	TDD Mobile	29.6	1.6	-10.4	-38.4	-50.4	55
Portable/Mobile links	FDD Macro Base Station	43.7	15.7	3.7	-24.3	-36.3	124
Portable/Mobile links	FDD Micro Base Station	31.7	3.7	-8.3	-36.3	-48.3	62
Portable/Mobile links	FDD Pico Base Station	26.7	-1.3	-13.3	-41.3	-53.3	46
Airborne links	TDD Base Station	56.1	42.1	36.1	22.1	16.1	Note 1
Airborne links	TDD Fixed Sub	44.4	30.4	24.4	10.4	4.4	Note 1
Airborne links	TDD Mobile	40.4	26.4	20.4	6.4	0.4	Note 1
Airborne links	FDD Macro Base Station	54.5	40.5	34.5	20.5	14.5	Note 1
Airborne links	FDD Micro Base Station	42.5	28.5	22.5	8.5	2.5	Note 1
Airborne links	FDD Pico Base Station	37.5	23.5	17.5	3.5	-2.5	Note 1
Temporary point to point	TDD Base Station	45.9	17.9	5.9	-22.1	-34.1	140
Temporary point to point	TDD Fixed Sub	37.6	9.6	-2.4	-30.4	-42.4	87
Temporary point to point	TDD Mobile	33.6	5.6	-6.4	-34.4	-46.4	69
Temporary point to point	FDD Macro Base Station	48.2	20.3	8.2	-19.7	-31.8	161
Temporary point to point	FDD Micro Base Station	36.2	8.3	-3.8	-31.7	-43.8	81
Temporary point to point	FDD Pico Base Station	31.2	3.3	-8.8	-36.7	-48.8	60
TDD Base Station	Radio Camera 1W	25.0	-3.0	-15.0	-43.0	-55.0	42
TDD Base Station	Portable/Mobile links	33.0	5.0	-7.0	-35.0	-47.0	67
TDD Base Station	Airborne links	43.7	29.7	23.7	9.7	3.7	Note 1
TDD Base Station	Temporary point to point	45.0	17.0	5.0	-23.0	-35.0	133
TDD Fixed Sub	Radio Camera 1W	16.6	-11.4	-23.4	-51.4	-63.4	26
TDD Fixed Sub	Portable/Mobile links	24.6	-3.4	-15.4	-43.4	-55.4	41
TDD Fixed Sub	Airborne links	35.3	21.3	15.3	1.3	-4.7	Note 1
TDD Fixed Sub	Temporary point to point	36.6	8.6	-3.4	-31.4	-43.4	82
TDD Mobile	Radio Camera 1W	7.6	-20.4	-32.4	-60.4	-72.4	15
TDD Mobile	Portable/Mobile links	15.6	-12.4	-24.4	-52.4	-64.4	25
TDD Mobile	Airborne links	26.3	12.3	6.3	-7.7	-13.7	Note 1
TDD Mobile	Temporary point to point	27.6	-0.4	-12.4	-40.4	-52.4	49
FDD Mobile	Radio Camera 1W	13.6	-14.4	-26.4	-54.4	-66.4	22
FDD Mobile	Portable/Mobile links	21.6	-6.4	-18.4	-46.4	-58.4	35
FDD Mobile	Airborne links	32.3	18.3	12.3	-1.7	-7.7	Note 1
FDD Mobile	Temporary point to point	33.6	5.6	-6.4	-34.4	-46.4	69

Table B3: Additional Isolation or Margin to avoid Interference: 10MHz Offset

Note 1: The effect of the altitude of airborne links, taking account of typical pattern losses for UMTS/WiMAX antennas is considered later in this section.

Additional Isolation or Margin at 20MHz Offset

Results of our analysis of the potential for interference between PMSE and UMTS/WiMAX for each potential mode of interference for the 20MHz frequency offset case (i.e. second adjacent channel, or 17.5MHz between centre frequencies) is summarised in Table B4.

Interference Path		Additional Isolation or Margin at 20MHz Offset (dB)					Required Separation Distance (m)
Interferer	Victim	10	50	100	500	1000	
Radio Camera 1W	TDD Base Station	39.3	11.4	-0.7	-28.6	-40.7	96
Radio Camera 1W	TDD Fixed Sub	27.4	-0.6	-12.6	-40.6	-52.6	48
Radio Camera 1W	TDD Mobile	23.4	-4.6	-16.6	-44.6	-56.6	38
Radio Camera 1W	FDD Macro Base Station	37.4	9.4	-2.6	-30.6	-42.6	86
Radio Camera 1W	FDD Micro Base Station	25.4	-2.6	-14.6	-42.6	-54.6	43
Radio Camera 1W	FDD Pico Base Station	20.4	-7.6	-19.6	-47.6	-59.6	32
Portable/Mobile links	TDD Base Station	39.4	11.5	-0.6	-28.5	-40.6	97
Portable/Mobile links	TDD Fixed Sub	27.5	-0.4	-12.5	-40.4	-52.5	49
Portable/Mobile links	TDD Mobile	23.5	-4.4	-16.5	-44.4	-56.5	39
Portable/Mobile links	FDD Macro Base Station	37.5	9.6	-2.5	-30.4	-42.5	87
Portable/Mobile links	FDD Micro Base Station	25.5	-2.4	-14.5	-42.4	-54.5	44
Portable/Mobile links	FDD Pico Base Station	20.5	-7.4	-19.5	-47.4	-59.5	33
Airborne links	TDD Base Station	50.1	36.2	30.1	16.2	10.1	Note 1
Airborne links	TDD Fixed Sub	38.3	24.3	18.3	4.3	-1.7	Note 1
Airborne links	TDD Mobile	34.3	20.3	14.3	0.3	-5.7	Note 1
Airborne links	FDD Macro Base Station	48.3	34.3	28.3	14.3	8.3	Note 1
Airborne links	FDD Micro Base Station	36.3	22.3	16.3	2.3	-3.7	Note 1
Airborne links	FDD Pico Base Station	31.3	17.3	11.3	-2.7	-8.7	33
Temporary point to point	TDD Base Station	41.2	13.2	1.2	-26.8	-38.8	107
Temporary point to point	TDD Fixed Sub	31.0	3.0	-9.0	-37.0	-49.0	60
Temporary point to point	TDD Mobile	27.0	-1.0	-13.0	-41.0	-53.0	47
Temporary point to point	FDD Macro Base Station	41.0	13.0	1.0	-27.0	-39.0	106
Temporary point to point	FDD Micro Base Station	29.0	1.0	-11.0	-39.0	-51.0	53
Temporary point to point	FDD Pico Base Station	24.0	-4.0	-16.0	-44.0	-56.0	40
TDD Base Station	Radio Camera 1W	22.6	-5.4	-17.4	-45.4	-57.4	37
TDD Base Station	Portable/Mobile links	30.6	2.6	-9.4	-37.4	-49.4	58
TDD Base Station	Airborne links	41.3	27.3	21.3	7.3	1.3	Note 1
TDD Base Station	Temporary point to point	42.6	14.6	2.6	-25.4	-37.4	116
TDD Fixed Sub	Radio Camera 1W	13.6	-14.4	-26.4	-54.4	-66.4	22
TDD Fixed Sub	Portable/Mobile links	21.6	-6.4	-18.4	-46.4	-58.4	35
TDD Fixed Sub	Airborne links	32.3	18.3	12.3	-1.7	-7.7	Note 1
TDD Fixed Sub	Temporary point to point	33.6	5.6	-6.4	-34.4	-46.4	69
TDD Mobile	Radio Camera 1W	4.6	-23.4	-35.4	-63.4	-75.4	13
TDD Mobile	Portable/Mobile links	12.6	-15.4	-27.4	-55.4	-67.4	21
TDD Mobile	Airborne links	23.3	9.3	3.3	-10.7	-16.7	Note 1
TDD Mobile	Temporary point to point	24.6	-3.4	-15.4	-43.4	-55.4	41
FDD Mobile	Radio Camera 1W	-0.8	-28.8	-40.8	-68.8	-80.8	10
FDD Mobile	Portable/Mobile links	7.2	-20.8	-32.8	-60.8	-72.8	15
FDD Mobile	Airborne links	17.9	3.9	-2.1	-16.1	-22.1	Note 1
FDD Mobile	Temporary point to point	-49.8	-77.8	-89.8	-117.8	-129.8	30

Table B4: Additional Isolation or Margin to avoid Interference: 20MHz offset

Results indicated in Tables B3 and B4 illustrates that localised interference is predicted to occur in all scenarios considered. The worst scenarios are those involving PMSE airborne links (this is further discussed in the next section) and temporary point-to-point links, which have a higher transmitted EIRP.

This suggests that operation of PMSE systems in adjacent frequency blocks to an FDD/TDD system will result in localised interference unless appropriate interference mitigation is applied.

Effect of Interference Mitigation

Results above were re-calculated assuming 30dB additional isolation is achieved through installation of an appropriate filter on the PMSE link receiver.

Tables B5 and B6 summarise results for 10MHz and 20MHz offset cases, respectively.

Interference Path		Additional Isolation or Margin at 10MHz Offset (dB)				
Interferer	Victim	10	50	100	500	1000
Radio Camera 1W	TDD Base Station	15.3	-12.6	-24.7	-52.6	-64.7
Radio Camera 1W	TDD Fixed Sub	3.4	-24.6	-36.6	-64.6	-76.6
Radio Camera 1W	TDD Mobile	-0.6	-28.6	-40.6	-68.6	-80.6
Radio Camera 1W	FDD Macro Base Station	13.4	-14.5	-26.6	-54.5	-66.6
Radio Camera 1W	FDD Micro Base Station	1.4	-26.5	-38.6	-66.5	-78.6
Radio Camera 1W	FDD Pico Base Station	-3.6	-31.5	-43.6	-71.5	-83.6
Portable/Mobile links	TDD Base Station	15.3	-12.6	-24.7	-52.6	-64.7
Portable/Mobile links	TDD Fixed Sub	3.6	-24.4	-36.4	-64.4	-76.4
Portable/Mobile links	TDD Mobile	-0.4	-28.4	-40.4	-68.4	-80.4
Portable/Mobile links	FDD Macro Base Station	13.7	-14.3	-26.3	-54.3	-66.3
Portable/Mobile links	FDD Micro Base Station	1.7	-26.3	-38.3	-66.3	-78.3
Portable/Mobile links	FDD Pico Base Station	-3.3	-31.3	-43.3	-71.3	-83.3
Airborne links	TDD Base Station	26.1	12.1	6.1	-7.9	-13.9
Airborne links	TDD Fixed Sub	14.4	0.4	-5.6	-19.6	-25.6
Airborne links	TDD Mobile	10.4	-3.6	-9.6	-23.6	-29.6
Airborne links	FDD Macro Base Station	24.5	10.5	4.5	-9.5	-15.5
Airborne links	FDD Micro Base Station	12.5	-1.5	-7.5	-21.5	-27.5
Airborne links	FDD Pico Base Station	7.5	-6.5	-12.5	-26.5	-32.5
Temporary point to point	TDD Base Station	15.9	-12.1	-24.1	-52.1	-64.1
Temporary point to point	TDD Fixed Sub	7.6	-20.4	-32.4	-60.4	-72.4
Temporary point to point	TDD Mobile	3.6	-24.4	-36.4	-64.4	-76.4
Temporary point to point	FDD Macro Base Station	18.2	-9.7	-21.8	-49.7	-61.8
Temporary point to point	FDD Micro Base Station	6.2	-21.7	-33.8	-61.7	-73.8
Temporary point to point	FDD Pico Base Station	1.2	-26.7	-38.8	-66.7	-78.8
TDD Base Station	Radio Camera 1W	-5.0	-33.0	-45.0	-73.0	-85.0
TDD Base Station	Portable/Mobile links	3.0	-25.0	-37.0	-65.0	-77.0
TDD Base Station	Airborne links	13.7	-0.3	-6.3	-20.3	-26.3
TDD Base Station	Temporary point to point	15.0	-13.0	-25.0	-53.0	-65.0
TDD Fixed Sub	Radio Camera 1W	-13.4	-41.4	-53.4	-81.4	-93.4
TDD Fixed Sub	Portable/Mobile links	-5.4	-33.4	-45.4	-73.4	-85.4
TDD Fixed Sub	Airborne links	5.3	-8.7	-14.7	-28.7	-34.7
TDD Fixed Sub	Temporary point to point	6.6	-21.4	-33.4	-61.4	-73.4
TDD Mobile	Radio Camera 1W	-22.4	-50.4	-62.4	-90.4	-102.4
TDD Mobile	Portable/Mobile links	-14.4	-42.4	-54.4	-82.4	-94.4
TDD Mobile	Airborne links	-3.7	-17.7	-23.7	-37.7	-43.7
TDD Mobile	Temporary point to point	-2.4	-30.4	-42.4	-70.4	-82.4
FDD Mobile	Radio Camera 1W	-16.4	-44.4	-56.4	-84.4	-96.4
FDD Mobile	Portable/Mobile links	-8.4	-36.4	-48.4	-76.4	-88.4
FDD Mobile	Airborne links	2.3	-11.7	-17.7	-31.7	-37.7
FDD Mobile	Temporary point to point	3.6	-24.4	-36.4	-64.4	-76.4

Table B5: Additional Margin/Isolation, with 30 dB Mitigation: 10MHz Offset

Interference Path		Additional Isolation or Margin at 20MHz Offset (dB)				
Interferer	Victim	10	50	100	500	1000
Radio Camera 1W	TDD Base Station	9.3	-18.6	-30.7	-58.6	-70.7
Radio Camera 1W	TDD Fixed Sub	-2.6	-30.6	-42.6	-70.6	-82.6
Radio Camera 1W	TDD Mobile	-6.6	-34.6	-46.6	-74.6	-86.6
Radio Camera 1W	FDD Macro Base Station	7.4	-20.6	-32.6	-60.6	-72.6
Radio Camera 1W	FDD Micro Base Station	-4.6	-32.6	-44.6	-72.6	-84.6
Radio Camera 1W	FDD Pico Base Station	-9.6	-37.6	-49.6	-77.6	-89.6
Portable/Mobile links	TDD Base Station	9.4	-18.5	-30.6	-58.5	-70.6
Portable/Mobile links	TDD Fixed Sub	-2.5	-30.4	-42.5	-70.4	-82.5
Portable/Mobile links	TDD Mobile	-6.5	-34.4	-46.5	-74.4	-86.5
Portable/Mobile links	FDD Macro Base Station	7.5	-20.4	-32.5	-60.4	-72.5
Portable/Mobile links	FDD Micro Base Station	-4.5	-32.4	-44.5	-72.4	-84.5
Portable/Mobile links	FDD Pico Base Station	-9.5	-37.4	-49.5	-77.4	-89.5
Airborne links	TDD Base Station	20.1	6.2	0.1	-13.8	-19.9
Airborne links	TDD Fixed Sub	8.3	-5.7	-11.7	-25.7	-31.7
Airborne links	TDD Mobile	4.3	-9.7	-15.7	-29.7	-35.7
Airborne links	FDD Macro Base Station	18.3	4.3	-1.7	-15.7	-21.7
Airborne links	FDD Micro Base Station	6.3	-7.7	-13.7	-27.7	-33.7
Airborne links	FDD Pico Base Station	1.3	-12.7	-18.7	-32.7	-38.7
Temporary point to point	TDD Base Station	11.2	-16.8	-28.8	-56.8	-68.8
Temporary point to point	TDD Fixed Sub	1.0	-27.0	-39.0	-67.0	-79.0
Temporary point to point	TDD Mobile	-3.0	-31.0	-43.0	-71.0	-83.0
Temporary point to point	FDD Macro Base Station	11.0	-17.0	-29.0	-57.0	-69.0
Temporary point to point	FDD Micro Base Station	-1.0	-29.0	-41.0	-69.0	-81.0
Temporary point to point	FDD Pico Base Station	-6.0	-34.0	-46.0	-74.0	-86.0
TDD Base Station	Radio Camera 1W	-7.4	-35.4	-47.4	-75.4	-87.4
TDD Base Station	Portable/Mobile links	0.6	-27.4	-39.4	-67.4	-79.4
TDD Base Station	Airborne links	11.3	-2.7	-8.7	-22.7	-28.7
TDD Base Station	Temporary point to point	12.6	-15.4	-27.4	-55.4	-67.4
TDD Fixed Sub	Radio Camera 1W	-16.4	-44.4	-56.4	-84.4	-96.4
TDD Fixed Sub	Portable/Mobile links	-8.4	-36.4	-48.4	-76.4	-88.4
TDD Fixed Sub	Airborne links	2.3	-11.7	-17.7	-31.7	-37.7
TDD Fixed Sub	Temporary point to point	3.6	-24.4	-36.4	-64.4	-76.4
TDD Mobile	Radio Camera 1W	-25.4	-53.4	-65.4	-93.4	-105.4
TDD Mobile	Portable/Mobile links	-17.4	-45.4	-57.4	-85.4	-97.4
TDD Mobile	Airborne links	-6.7	-20.7	-26.7	-40.7	-46.7
TDD Mobile	Temporary point to point	-5.4	-33.4	-45.4	-73.4	-85.4
FDD Mobile	Radio Camera 1W	-30.8	-58.8	-70.8	-98.8	-110.8
FDD Mobile	Portable/Mobile links	-22.8	-50.8	-62.8	-90.8	-102.8
FDD Mobile	Airborne links	-12.1	-26.1	-32.1	-46.1	-52.1
FDD Mobile	Temporary point to point	6.9	-21.1	-33.1	-61.1	-73.1

Table B6: Additional Margin/Isolation, with 30 dB Mitigation: 20MHz Offset

Impact of Altitude of Airborne Links on the Potential for Interference

The above analysis indicates that airborne links should be considered more closely to investigate the effects of significant altitude difference between the airborne link and ground-based systems, in view of likely flying altitudes of the helicopter and taking account of typical pattern losses for an UMTS/WiMAX antenna.

The basic link parameters used to derive the interference margin assumed in our analysis are summarised in Table B7.

Transmit Power	29.0	dBm
Antenna Gain Tx (dBi)	8.0	dBi
Antenna Gain Rx (dBi)	18.0	dBi
ACIR 10MHz	48.2	dB
Interference Limit	-110.0	dBm
Margin [4]	116.8	dB

Table B7: Parameters for Airborne to Ground Interference Analysis

The figure below illustrates a typical air-to-ground interference scenario, to illustrate the effect of altitude between the helicopter and the ground based UMTS/WiMAX network. Note the altitude of the helicopter above the victim antenna (750m) is assumed to be a worst case, since flight altitudes are usually higher than this.

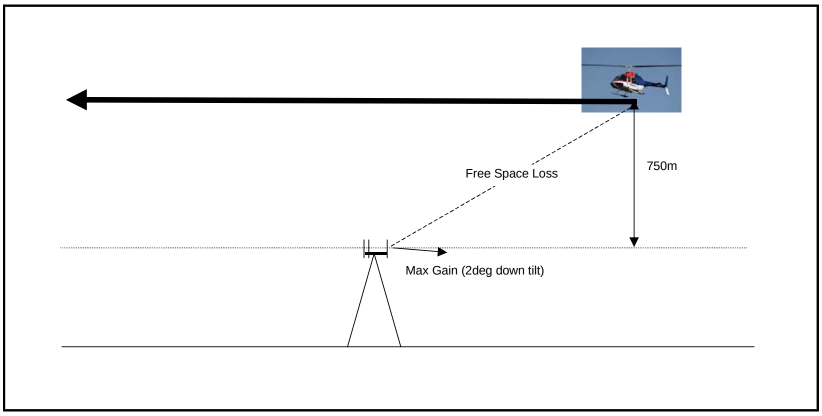


Figure B7: A Typical Air-to-Ground Interference Scenario

As illustrated in Figure B7, the maximum gain of the UMTS/WiMAX antenna will be directed downwards rather than upwards.

[14] The Margin in Table B5 does not including propagation and antenna pattern losses

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Taking account of a typical antenna pattern and how this impacts the interference path with a PMSE helicopter link, results of analysis are presented in Figure B8, which shows:

- Pattern losses for a typical UMTS Node B antenna; a Thales 2122 with a 65° horizontal beam width, 6.5° vertical beam width and 2° down tilt (in blue)
- Free space loss (in pink)
- The combination of these two items with the interference margin shown in Table B4 (in purple).

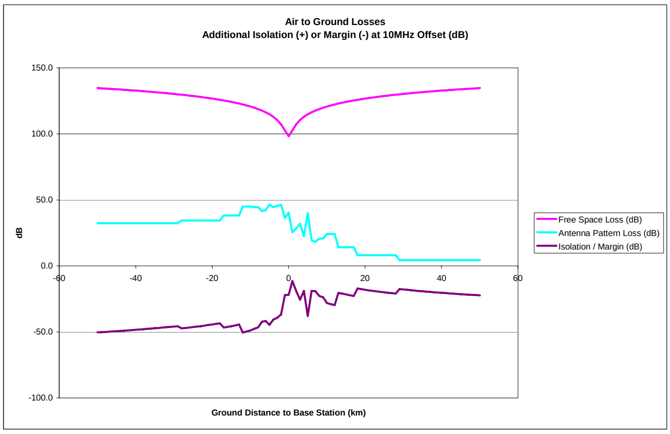

Figure B8: Analysis of antenna losses, propagation losses and margin

From Figure B8 we see that there is a clear margin of several dB between an airborne interferer and a ground-based base station victim. This is because as the aircraft approaches the interference victim the high angle of elevation ensures that the drop in free space loss is more than compensated by increases in antenna pattern losses. Similar modelling has demonstrated that there is also a margin of safety for the reverse scenario (ground interferer, airborne victim).

Based on this analysis, it can be concluded that the modes of interference between airborne PMSE and 2.6GHz ground based FDD and TDD equipment will not pose a significant problem in practice, taking account of realistic propagation paths between the UMTS/WiMAX network on the ground and a helicopter flying overhead.

Mitigation Techniques

Various mitigation techniques might be appropriate for the ground based interference scenarios considered.

In the event that PMSE is the interfered system, there are a number of techniques that PMSE users can apply:

- Position receiver closer to camera and away from sources of interference (note: the PMSE technicians will probably have limited access to the venue, and so the receiver is rarely positioned in an optimal position)
- Receive antenna improvements (directional antenna, antenna diversity)
- Addition of band edge or channel specific filters. Whilst band edge filters are not widely used today, a range of channel specific filters is available for PMSE links today. These are manufactured to pass a specific channel. These filters offer protection of the channel but have the disadvantage that they must be carefully calibrated to pass a specific channel. Typical filters have a low insertion loss (less than 2dB), but with a relatively wide pass band (30MHz), thus they are useful for blocking 2nd or 3rd adjacent channels, but not the 1st adjacent channel. Filter types and cost are addressed in the main body of this report. If channel filters are used, it is noted there is a significant logistical issue in ensuring that the correct filter is available, particularly if channels are changed at short notice
- Ad-hoc channel re-assignments. Operators obtain an event licence in advance for a specific channel. Inevitably, operators sometimes resort to 'scanning' channels and selecting one that appears to be free from interference (it is noted that whilst this may resolve incoming interference, it could exacerbate outgoing interference).

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Summary

A summary of our analysis of potential for interference between PMSE systems in the 2025-2110MHz, 2200-2290MHz and 2450-2500MHz bands with UMTS/WiMAX systems deployed in the 2010-2025MHz, 2290-2302MHz and 2500-2690MHz bands is as follows:

- It may be appropriate to exclude use of airborne PMSE in channels adjacent to FDD/TDD base stations, if this is feasible
- Localised terrestrial PMSE inbound/outbound ACI is an issue in the immediate vicinity of Base stations
- FDD Macro Base Stations are susceptible to PMSE ACI within a 200m radius
- TDD Macro Base Stations may cause and be susceptible to PMSE ACI within a 200m radius.
- Particularly in the band 2010-2025MHz, TDD Base Stations may cause, and be susceptible to, PMSE interference from airborne links at low altitudes, since the adjacent PMSE band is the preferred band for deployment of airborne links due to restrictions in other bands. Interference will occur particularly if the 2025-2110 PMSE band is re-planned such that the lowest PMSE channel is centred on 2030MHz. However, our analysis of the impact of the likely altitude difference between a PMSE airborne link and an UMTS/WiMAX network, taking account of the antenna pattern loss of the UMTS/WiMAX system in the direction of the airborne link, suggests that interference will be isolated in practice.

It is noted that PMSE users are already familiar with incoming interference from existing UMTS base stations, as the current PMSE band is adjacent to the UMTS 2GHz downlink. However, outgoing interference from PMSE to the FDD uplink (or to TDD base stations) will be a new phenomenon, and could be exacerbated by PMSE users switching channels on an ad-hoc basis (as is the current practice to avoid incoming interference).

Residual PMSE equipment, designed to operate in the 2390 to 2690MHz band, may remain in circulation for years to come. As users will not receive signal from FDD base stations when scanning the FDD uplink channels, users may assume the channels are not in use.

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APPENDIX C

INTERFERENCE ANALYSIS: OUTBOUND INTERFERENCE TO MSS (GLOBALSTAR) TERMINALS IN 2483.5-2500MHZ

Introduction

This section presents results of analysis considering the potential for interference from UMTS/WiMAX systems deployed in channels at the lower band edges of the 2500-2690MHz band to terminals of the Globalstar satellite system operating in the 2483.5-2500MHz band.

The 2483.5-2500MHz band is allocated to the Mobile Satellite Service (MSS) Space-Earth on a global basis and used by the Globalstar system.

Our analysis considers the potential for FDD/TDD systems operating in the 2.6 GHz band to cause adjacent channel interference to Globalstar terminals, which receive signals in the 2483.5-2500MHz band.

Radio Parameters Used in the Analysis

Parameters used in our analysis are summarised in Tables C1, C2 and C3.

Globalstar Sensitivity to Interfrence	
Interference Density, Io	-210 dBW
10% of Io	-220 dBW
1/(10*LOG(spreading bandwidth))	-60.9 dBW
Maximum level of Interfrerence	-159.1 dBW
Maximum level of Interfrerence	-129.1 dBm

Table C1: Globalstar Terminal Interference Levels

Victim and Interferer Parameters	Tx Power (dBm)	Antenna Gain (dBi)	Antenna Height (m)	Inteference Limit (dB)	ACLR (dB) 5MHz	ACLR (dB) 10 MHz	ACS (dB) 5MHz	ACS (dB) 10MHz
TDD Base Station	36.0	18.0	30.0	-110.0	53.5	66.0	70.0	70.0
TDD Fixed Sub	24.0	8.0	1.5	-108.0	37.0	51.0	40.0	59.0
TDD Mobile	20.0	3.0	1.5	-109.0	33.0	51.0	40.0	59.0
FDD Macro Base Station	43.0	17.0	30.0	-109.0	45.0	50.0	46.0	58.0
FDD Micro Base Station	38.0	5.0	6.0	-109.0	45.0	50.0	46.0	58.0
FDD Pico Base Station	24.0	0.0	1.5	-109.0	45.0	50.0	46.0	58.0
FDD Mobile	21.0	0.0	1.5	-105.0	33.0	43.0	33.0	43.0
Globalstar Mobile	-	0.0	1.5	-129.1	-	-	50.0	70.0

Table C2: ACLR Values for Globalstar Analysis

Interference Path: Interferer	Interference Path: Victim	ACIR (dB) 5MHz	ACIR (dB) 10MHz	Propagation Model
TDD Base Station	Globalstar Mobile	48.4	64.5	ITU Vehicular
TDD Fixed Sub	Globalstar Mobile	36.8	50.9	ITU Vehicular
TDD Mobile	Globalstar Mobile	32.9	50.9	ITU Hybrid
FDD Mobile	Globalstar Mobile	32.9	43.0	ITU Hybrid

Table C3: Propagation Models for Globalstar Analysis

Results

Results of our analysis, indicating the additional isolation (or margin) at 5 and 10MHz offsets between FDD/TDD interferer and Globalstar terminal, are summarised in

Tables C4 and C5. Results are presented for a range of separation distances between the interferer and the victim terminal.

Interference Path		Additional Isolation or Margin at 5MHz Offset (dB)				
Interferer	Victim	10	50	100	500	1000
TDD Base Station	Globalstar Mobile	75.1	47.8	36.0	8.7	-3.0
TDD Fixed Sub	Globalstar Mobile	64.7	37.4	25.6	-1.7	-13.4
TDD Mobile	Globalstar Mobile	58.4	-10.8	-23.8	-55.8	-63.8
FDD Mobile	Globalstar Mobile	56.4	-12.8	-25.8	-57.8	-65.8

Table C4: FDD/TDD Interference to Globalstar terminals: 5MHz Offset

Results for 10 MHz offset:

Interference Path		Additional Isolation or Margin at 10MHz Offset (dB)				
Interferer	Victim	10	50	100	500	1000
TDD Base Station	Globalstar Mobile	59.0	31.7	19.9	-7.4	-19.1
TDD Fixed Sub	Globalstar Mobile	50.6	23.3	11.5	-15.8	-27.5
TDD Mobile	Globalstar Mobile	40.4	-28.8	-41.8	-73.8	-81.8
FDD Mobile	Globalstar Mobile	46.4	-22.9	-35.9	-67.9	-75.9

Table C5: FDD/TDD Interference to Globalstar terminals: 5MHz Offset

The analysis demonstrates that the worst-case interference is created if the lower channels in the band 2500-2690MHz are used for TDD:

- TDD Base stations and TDD Fixed subscribers could cause ACI to Globalstar users within a radius of 500m and 200m respectively
- If used for FDD, the lower part of the 2.6GHz band will be the uplink (mobile transmit), which will cause less interference to Globalstar terminals
- Mobile-mobile interference will occur either from FDD or TDD mobiles (depending on which of the band plans considered in the main body of this report is assumed), but will be localised to areas where the distance between terminals is very small.

It is noted that the probability of interference in practice will depend on other factors (e.g. likelihood of terminals being co-incident, FDD MS transmission power, which will depend on its position in the cell). This has not been considered in detail in our analysis.