ATTACHMENT 5.6

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Working document towards a preliminary draft new Report on sharing studies in the 2 500-2 690 MHz band between IMT-2000 and fixed Broadband Wireless Access (BWA) systems including nomadic applications in the same geographical area

[Editor's note: Studies below are based on provisional parameters, to be verified by the responsible WPs in ITU-R.]

[Editor´s note: Sharing studies addressing other systems, such as those contained in Doc. 8F/453 as well as other new sharing studies submitted to the next meeting of WP 8F (Finland), should be included in this Working Document.]

1 Introduction and scope

Editors note: We need to develop text for the scope of the report.

2 System A – IEEE 802.16-2004

Editors note: To editorially replace MS with SS where appropriate.

2.1 Interference scenarios to be analyzed

Deployment of IEEE 802.16-2004 systems in adjacent bands to IMT-2000 systems in the same geographical area in the 2 500-2 690 MHz band is likely to create similar adjacent channel interference problems as the ones addressed in M.2030 and IMT.MITIGATION due to inherent similarities of these two systems as far as the sharing studies are concerned. For instance, both systems will be deployed in multi-cell, wide-area deployments with base station transmitter heights and power levels in accordance with such deployments.

Adjacent-channel sharing of a frequency band by two systems deployed in the same geographical area creates the following four general cases for potential interference, which are not necessarily similar in terms of severity and likelihood of interference.

1) Base to base
2) Base to subscriber
3) Subscriber to base
4) Subscriber to subscriber

2.2 Methodologies

2.2.1 Deterministic analyses

In this section, we will analyze the impact of ACI between a CDMA-DS[1] system and a TDD system, namely, WiMAX TDD, which is based on IEEE 802.16-2004 OFDM/OFDMA[2] and its amendment 802.16e. The interference scenarios that can exist when these two technologies operate in adjacent spectrum are as follows.

1) Interference from a CDMA-DS base station (BS) and CDMA-DS mobile station (MS) to a WiMAX TDD BS.
2) Interference from a CDMA-DS BS and CDMA-DS MS to a WiMAX TDD MS.
3) Interference from a WiMAX TDD BS and WiMAX TDD MS to a CDMA-DS BS.
4) Interference from a WiMAX TDD BS and WiMAX TDD MS to a CDMA-DS MS.

In the interference analysis, the WiMAX TDD and CDMA-DS systems were modeled as operating in a macrocellular network. Additionally, the analysis was extended to include microcellular and indoor picocellular deployment scenarios for the CDMA-DS system.

WiMAX TDD characteristics are based on a 5 MHz nominal channel bandwidth; this sharing study does not apply to any WiMAX profiles with channel bandwidths other than 5 MHz[3].

Deterministic analyses are based on worst-case locations for the MSs.

2.2.2 Modeling of WiMAX TDD and IMT-2000 systems and their inter-system interference

The only form of interference modelled in this study is ACI that arises from the adjacent channel leakage (ACLR) from BS and MS transmissions in the WiMAX and CDMA-DS systems and the adjacent channel selectivity (ACS) of the BS and MS receivers in the WiMAX and CDMA-DS systems and the ability of these receivers to reject power legitimately transmitted in the adjacent channel. Given the transmitted powers, path losses in the selected scenarios and the ACLR and ACS performances of the BSs and MSs in each system, the effective interference may be calculated. Additionally, the effective interference is also calculated with and without the benefit of mitigation techniques. This interference is compared with the protection criteria (outlined in Section 2.2.4) to determine whether the systems are adequately protected. Our results are presented in Section 2.2.5.

[Editor's note: needs text to clarify the fact that if other channels bandwidth than 5 MHz are being used the ACIR values might be different.]

2.2.3 Input parameters and assumptions

For each of the deployment scenarios we considered three possible configurations for the relative locations of the CDMA-DS and WiMAX TDD BSs. In the first configuration the BSs were co-located. In the second configuration each CDMA-DS BS was situated 500 m away from the cell boundary of a WiMAX TDD BS. In the last configuration, each CDMA-DS BS was situated at the cell boundary of a WiMAX TDD BS, which was 1 km away from the WiMAX TDD BS. Furthermore, we also considered smaller separation distances of 10 m, 50 m and 100 m when analyzing interference between BSs. Results are included in Annex B.

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1 Code Division Multiple Access-Direct Sequence (CDMA-DS).

2 IEEE 802.16-2004 and IEEE 802.16e also include other duplex and access modes. In this document, "WiMAX TDD" refers to a subset as described above.

3 The IEEE 802.16 standard supports variable bandwidth sizes between 1.25 and 20 MHz.

In the analysis, propagation models defined by the European Telecommunications and Standards Institute (ETSI) were used to evaluate the path loss between two different BSs, between a BS and a MS, and between two different MSs. The details of these propagation models are described in Annex A. The channel bandwidth of the WiMAX TDD system was set to 5 MHz and the BS and MS parameters used in the interference analysis are shown in Table 1. These CDMA-DS values are identical to those in Report ITU-R M.2039 [18] and relevant standards whereas the antenna heights fall within typical values used in practical deployments.

TABLE 1

BS and MS parameters for various deployment scenarios

Parameter	**BS**				**WiMAX TDD MS**	**CDMA-DS FDD MS**
	WiMAX TDD Macro	**CDMA-DS FDD Macro**	**CDMA-DS FDD Micro**	**CDMA-DS FDD Pico**		
Antenna Height (m)	30	30	6	1.5	1.5	1.5
Antenna Gain (dBi)	18	17	5	0	6	0
Transmit Power (dBm)	36	43	38	24	20.0	21.0

ACS and ACLR characteristics generally assume the effects of transmissions in adjacent channels for devices of the same technology, assuming transmit and receive filters with noise bandwidths specific to that technology. In the cases of CDMA-DS and WiMAX TDD based on 5 MHz channels, the WiMAX TDD system has a noise bandwidth of 4.5 MHz, while the CDMA-DS system has a noise bandwidth of 3.84 MHz, corresponding to an 0.7 dB difference in noise level. However, WiMAX exhibits faster rolloff as it uses OFDM with 256 carriers. The CDMA-DS Nyquist filter response extends to a bandwidth of 4.6848 MHz. If the transmit spectral mask rolls off with increasing frequency offset in the first adjacent channel, the difference in ACS performance may be less than 0.7 dB. In the absence of measured data, we assume that the ACLR defined for the transmitting system and the ACS defined for the receiving systems represent the behaviour when the two systems interfere with one another. We note that this assumption will result in an error of less than 1 dB in the results.

The IEEE 802.16 standard supports variable bandwidth sizes between 1.25 and 20 MHz. Since this sharing study is based on a 5 MHz nominal channel bandwidth only, the ACLR and ACS values and the resulting ACIR and derived isolation values are only valid for a 5 MHz WiMAX TDD system. A WiMAX TDD system with less than 5 MHz bandwidth sharing the frequency band with CDMA-DS, would result in more interference (lower ACIR) to DS-CDMA, but less interference (higher ACIR) from CDMA-DS to WiMAX. A WiMAX TDD system with more than 5 MHz bandwidth sharing the frequency band with CDMA-DS, would result in less interference to DS-CDMA, but more interference from DS-CDMA to WiMAX. The exact numbers are for further study.

2.2.3.1 Adjacent channel leakage ratio and adjacent channel selectivity

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 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 ACS, which is 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 CDMA-DS BS and MS are defined by the specifications for the first and second adjacent channels, which correspond to carrier separations of 5 MHz and 10 MHz, respectively [3,4]. These values are set according to Table 2, which are also identical to those used in another co-existence study performed by the ITU [9].

TABLE 2

ACLR and ACS values (in decibels) for the CDMA-DS MS and BS based on'standard' equipment

	ACLR		ACS	
	First Adjacent Channel	Second Adjacent Channel	First Adjacent Channel	Other Adjacent Channels
BS	45	50	46	58
MS	33	43	33	43

The equivalent ACLR and ACS for the first and second adjacent channels of the WiMAX 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 [11], which can be used for sharing studies for the band 2 500 MHz-2 690 MHz. The proposed ACLR and ACS performance for the WiMAX TDD system is shown in Table 3.

TABLE 3

ACLR and ACS values (in decibels) for the WiMAX TDD MS and BS based on 'standard' equipment

	ACLR		ACS	
	First Adjacent Channel	Second Adjacent Channel	First Adjacent Channel	Other Adjacent Channels
BS	53.5	66	70	70
MS	33	51	40	59

2.2.3.2 Adjacent Channel Interference Ratio

In making our interference calculations we were interested in the composite effect of the transmitter and receiver imperfections, so the ACLR and ACS values defined above were combined to give a single adjacent channel interference ratio (ACIR) value using the following equation [5],

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

Using the above equation and the ACLR and ACS values listed in Table 2 and Table 3, we calculated the ACIR values for the various interference paths between the CDMA-DS equipment and the WiMAX equipment. These ACIR values are based on 'standard' equipment, which is defined as equipment that conforms to the UTRA specified requirements and the RF parameters specified by the WiMAX Forum.

TABLE 4

ACIR values (in decibels) for the interference paths of interest, when using 'standard' equipment

Interference Path	First Adjacent Channel	Second Adjacent Channel
TDD BS ⇒ FDD BS	45	57
FDD BS ⇒ TDD BS	45	50
TDD BS ⇒ FDD MS	33	43
FDD MS ⇒ TDD BS	33	43
FDD BS ⇒ TDD MS	39	49
TDD MS ⇒ FDD BS	33	50
TDD MS ⇒ FDD MS	30	42
FDD MS ⇒ TDD MS	32	43

2.2.4 Protection Criteria

In our analysis, the interference thresholds shown in Table 5 are used as the maximum interference limits that can be tolerated by the CDMA-DS and WiMAX TDD equipment. These thresholds are specified in Report ITU-R M.2039 [18] and the RF parameters specified by the WiMAX Forum [11] for the CDMA-DS and WiMAX equipment, respectively.

TABLE 5

Maximum interference limit (in decibels) for the WiMAX TDD and CDMA-DS FDD equipment

	Maximum Interference Limit	
	WiMAX TDD	CDMA-DS
BS	-110	-109
MS	-108	-105

By comparing the levels of interference received with the maximum interference limit, the additional isolation needed to ensure successful co-existence was obtained. This additional isolation was calculated for different frequency offsets between the carriers of the two systems to provide an indication of the size of the guard bands that would be required.

Having quantified the required isolation needed to ensure successful co-existence using ‘standard’ equipment, we introduced ACI mitigation techniques that provide additional isolation. Furthermore, we also extended the ACI analysis to consider the performance of ‘real’ equipment as opposed to ‘standard’ equipment that conforms exactly to the requirements provided by the specifications.

2.2.5 Results

In the following sections, the key results are summarised for the different interference and network deployment scenarios. Detailed descriptions of these results are given in Annexes B, C and D for interference between BSs, interference between a BS and a MS, and interference between MSs, respectively.

2.2.5.1 Interference between BSs

For the WiMAX TDD BS-to- CDMA-DS BS interference scenario, the additional isolation required to ensure successful co-existence is summarised in Table 6. Note that successful co-existence is achieved when additional isolation is not needed. The summary in Table 6 includes results for co-sited WiMAX TDD and CDMA-DS BSs, and for WiMAX TDD and CDMA-DS BSs separated by distances of 500 m and 1 km. Note that a negative value in this table signifies that the isolation provided by the ‘standard’ equipment is sufficient to limit the interference in that particular case to acceptable levels, and the absolute value indicates the size of the ‘margin’ available in the adjacent channel protection.

TABLE 6

A summary of the additional isolation needed (in decibels) when considering BS-to-BS interference for different BS separation distances. This was calculated based on ‘standard’ equipment performance

Deployment Scenario		TDD BS ⇒ FDD BS			FDD BS ⇒ TDD BS		
		Co-sited	**500 m**	**1 km**	**Co-sited**	**500 m**	**1 km**
TDD macro/ FDD macro	1st adj chan	70.0	40.3	34.3	78.0	48.3	42.3
	2nd adj chan	58.0	28.3	22.3	73.0	43.3	37.3
TDD macro/ FDD micro	1st adj chan	30.0	-3.0	-14.7	33.0	-0.0	-11.7
	2nd adj chan	18.0	-15.0	-26.7	28.0	-5.0	-16.7
TDD macro/ FDD pico	1st adj chan	20.0	-21.4	-33.4	9.0	-32.4	-44.4
	2nd adj chan	8.0	-33.4	-45.4	4.0	-37.4	-49.4

The results in Table 6 indicate that for a TDD macrocellular/FDD macrocellular deployment with different site separation distances, it is not feasible for the two technologies to co-exist without providing additional isolation. Similarly, for scenarios with co-sited TDD/FDD macrocellular sites for which an antenna coupling loss of 30 dB was assumed in the macro cell co-siting case, additional isolation is needed for all network deployments scenarios (ie, macrocellular, microcellular and picocellular). However, there are cases when the ‘standard’ equipment provides sufficient isolation for co-existence as indicated by the negative values in Table 6.

2.2.5.2 Interference between BS and MS

In the absence of a more thorough computer simulation analysis, we opted to study cases that presented a significant impact to the ACI performance of the two systems. Specifically, a situation could occur when a MS is at its cell boundary and close to a victim BS. This represents a worst-case interference scenario with the MS transmitting at full power whilst close to the victim BS. As a result of the close proximity between the BS and MS, the minimum coupling loss between the BS antenna and MS antenna was applied, which is described further in Annex C. The resulting additional isolation needed in this situation is shown in Table 7, which indicates that the performance of the BS is degraded due to interference from a nearby MS.

Similarly, the performance of the MS is severely affected by interference from the BS that could cause the call to be dropped. It is important to note that these scenarios are isolated cases and that they do not represent the average behaviour of the network. However, if these scenarios do occur in deployed networks, the localised performance degradation may be severe. One should note that similar behaviour occurs in uncoordinated CDMA-DS networks operating in adjacent channels, with the creation of dead zones in the vicinity of the other network's base stations.

In a recent UTRA TDD and CDMA-DS co-existence study by the ITU [9], Monte Carlo simulations were conducted to analyze the impact of BS-to-MS interference. The report concluded that the capacity loss due to this interference is small and negligible when averaged across the network. This indicated that based on an average network behaviour, successful co-existence can be achieved between a TDD and FDD system. This analysis can also be applied to the co-existence of WiMAX TDD and CDMA-DS technologies noting that the co-existence would be eased by the 2 dB greater tolerance to interference achieved by the WiMAX TDD system.

TABLE 7

A summary of the additional isolation needed (in decibels) when considering interference between BSs and MSs for selected scenarios using 'standard' equipment

Deployment Scenario		TDD MS => FDD BS	FDD BS => TDD MS	FDD MS => TDD BS	TDD BS => FDD MS
TDD macro/ FDD macro	1st adj chan	28.6	44.6	24.6	34.6
	2nd adj chan	11.6	34.6	14.6	24.6
TDD macro/ FDD micro	1st adj chan	48.5	59.5	16.4	26.4
	2nd adj chan	31.5	49.5	6.4	16.4
TDD macro/ FDD pico	1st adj chan	61.3	58.3	57.3	67.3
	2nd adj chan	44.3	48.3	47.3	57.3

2.2.5.3 Interference between MS and MS

Finally, for our analysis of the impact of ACI between a WiMAX TDD MS and a CDMA-DS MS, we identified a worst-case scenario when the MSs were close together and transmitting at maximum power. Although this scenario has a relatively low probability of occurring, it can exist when MSs are in a confined space [such as a bus or train], whilst being served by an external macrocellular or microcellular BS [9]. As an example, we quantified the ACI performance given that the separation distance between the MSs was 10 m, where a detailed description is given in Annex D. The results indicate that additional isolation of 40.3 dB and 28.3 dB would be needed for the first and second adjacent channels, respectively, to protect the CDMA-DS receiver, whilst additional isolation of 42.3 dB and 31.3 dB would be needed to protect the WiMAX TDD receiver, respectively. Note that this will also apply when a UTRA TDD MS is in close proximity to the CDMA-DS MS [9].

[It was shown by an ITU study [9] that the interference between MSs had a small and negligible impact on the average network capacity, which suggested that co-existence was feasible. This indicated that only the users in close proximity experienced severe ACI whilst the majority of other users were not affected. It is also important to note that inherent system procedures such as handover and power control can alleviate the impact of ACI between two MSs [17].*editors note to reflect summary of conclusions*]

2.2.5.4 Interference between BSs with Mitigation Techniques and Practical CDMA-DS Equipment Performance

In order to provide the additional isolation, the interference analysis between BSs was extended to incorporate mitigation techniques for the WiMAX TDD technology. There are various techniques that can be used to mitigate ACI, which are described in an ITU report on mitigation techniques [17]. This includes techniques such as adaptive antennas, handovers and power control. However in this study, we have identified the following key mitigation techniques that can offer additional ACI protection, which are described in Annex F. *[Editor M.2045 to be used [17]to provide basis of further discussion & material for this section.]*

1) The inclusion of a channel filter, which could provide approximately 60 dB of additional rejection in the RF front-end. This could potentially improve the ACLR and ACS performance in the first and second adjacent channels of the WiMAX TDD BS by 60 dB.
2) By following engineering guidelines and careful antenna siting, the antenna coupling loss could be increased to 39–54 dB when the antennas are mounted on the same mast. This could be further increased to 60–65 dB when the antennas are separated by a distance greater than three meters. Note that this benefit only applies when the BSs are co-sited in a macrocellular deployment.

A summary of the ACLR and ACS performance of the WiMAX TDD incorporating the mitigation techniques and practical CDMA-DS BSs is shown in Table 8.

TABLE 8

ACLR and ACS values (in decibels) for the WiMAX TDD BS that incorporates mitigation techniques and the practical performance of the CDMA-DS BS

	ACLR		ACS	
	First Adjacent Channel	Second Adjacent Channel	First Adjacent Channel	Other Adjacent Channels
CDMA-DS BS	57	74	65	75
WiMAX TDD BS	113.5	126	130	130

Using Equation (1) from Section 2.2.1.1, the resulting ACIR values for the BS-to-BS interference paths are shown in Table 9. It is observed that the lower ACLR and ACS performance of the CDMA-DS BS are the dominating factors in determining the final ACIR values.

TABLE 9

ACIR values (in decibels) that incorporate practical CDMA-DS BS performance and mitigation techniques

Interference Path	First Adjacent Channel	Second Adjacent Channel
TDD BS ⇒ FDD BS	65	75
FDD BS ⇒ TDD BS	57	74

By incorporating these ACIR values and an antenna coupling loss of 65 dB, the additional isolation needed by the BSs to ensure successful co-existence is shown in Table 10.

TABLE 10

A summary of the additional isolation needed (in decibels) when considering BS-to-BS interference for different BS separation distances. These results incorporate mitigation techniques for the WiMAX TDD BS and practical CDMA-DS BS performance

Deployment Scenario		TDD BS => FDD BS			FDD BS => TDD BS		
		Co-sited	500 m	1 km	Co-sited	500 m	1 km
TDD macro/ FDD macro	1st adj chan	15.0	20.3	14.3	31.0	36.3	30.3
	2nd adj chan	5.0	10.3	4.3	14.0	19.3	13.3
TDD macro/ FDD micro	1st adj chan	10.0	-23.0	-34.7	21.0	-12.0	-23.7
	2nd adj chan	0.0	-33.0	-44.7	4.0	-29.0	-40.7
TDD macro/ FDD pico	1st adj chan	0.0	-41.4	-53.4	-3.0	-44.4	-56.4
	2nd adj chan	-10.0	-51.4	-63.4	-20.0	-61.4	-73.4

By incorporating the mitigation techniques for WiMAX TDD, co-existence between the two technologies in a macrocellular deployment is still not feasible using a guard band of 5 MHz. When considering the FDD BS as the interference victim, the ACS of the CDMA-DS BS is not sufficient to guarantee successful co-existence. Similarly, the ACLR performance of the CDMA-DS BS allows too much ACI to fall into the WiMAX TDD receiver bandwidth. It should be noted that this situation would occur regardless of the technology type implemented in the central band of the IMT-2000 expansion spectrum. This is due to the more lenient receiver performance requirements of the CDMA-DS BS. However, in most cases, we would expect the CDMA-DS BSs to exceed these performance requirements, thus providing improved isolation between the two technologies.

Additional isolation for the first and second adjacent channels could be obtained by implementing a channel filter in the CDMA-DS BS RF front-end. This filter could offer an additional 60 dB rejection, which would be sufficient additional isolation to permit the successful co-existence of the two technologies [6]. It should also be noted that since the central band of the IMT-2000 expansion spectrum could also be used for CDMA-DS technology, it is an added incentive to ensure that the performance requirements of the CDMA-DS BS are improved, as a similar BS-to-BS interference problem will result when the a CDMA-DS downlink is adjacent to the CDMA-DS uplink.

In order to improve the performance of the CDMA-DS BS, a channel filter can be introduced, which provides a 60 dB improvement in the ACLR and ACS performance [6], as shown in Table 11. The resulting ACIR values derived from these ACLR and ACS values are shown in Table 12.

TABLE 11

ACLR and ACS values (in decibels) for the WiMAX TDD BS that incorporates mitigation techniques and the practical performance of the CDMA-DS BS with additional channel filter

	ACLR		ACS	
	First Adjacent Channel	Second Adjacent Channel	First Adjacent Channel	Other Adjacent Channels
CDMA-DS BS	117	134	125	135
WiMAX TDD BS	113.5	126	130	130

TABLE 12

ACIR values (in decibels) for the WiMAX TDD BS that incorporates mitigation techniques and the practical performance of the CDMA-DS BS with additional channel filter

Interference Path	First Adjacent Channel	Second Adjacent Channel
TDD BS ⇒ FDD BS	113	125
FDD BS ⇒ TDD BS	117	129

Using the ACIR values shown in Table 12, the resulting additional isolation needed for co-existence is summarized in Table 13, which also assumes an antenna coupling loss of 65 dB.

TABLE 13

A summary of the additional isolation needed (in decibels) when considering BS-to-BS interference for different BS separation distances. These results incorporate mitigation techniques for the WiMAX TDD BS and practical CDMA-DS BS performance with additional channel filter

Deployment Scenario		TDD BS => FDD BS			FDD BS => TDD BS		
		Co-sited	500 m	1 km	Co-sited	500 m	1 km
TDD macro/ FDD macro	1st adj chan	-33.0	-27.7	-33.7	-29.0	-23.7	-29.7
	2nd adj chan	-45.0	-39.7	-45.7	-41.0	-35.7	-41.7
TDD macro/ FDD micro	1st adj chan	-38.0	-71.0	-82.7	-39.0	-72.0	-83.7
	2nd adj chan	-50.0	-83.0	-94.7	-51.0	-84.0	-95.7
TDD macro/ FDD pico	1st adj chan	-48.0	-89.4	-101.4	-63.0	-104.4	-116.4
	2nd adj chan	-60.0	-101.4	-113.4	-75.0	-116.4	-128.4

With the addition of the channel filter at the CDMA-DS BS, the ACLR and ACS performance is improved sufficiently to ensure that the two BSs can co-exist successfully, as reported in Table 13. Improved specifications for the performance of CDMA-DS BSs are required to ensure successful co-existence with any technology that uses the central part of the IMT-2000 Expansion Band. We note that there are ongoing meetings to discuss the harmonisation of the IMT technologies that will be used in the IMT-2000 Expansion Band, with emphasis on co-existence [8].

2.2.5.5 Interference between BSs conforming to the FCC spectral mask

In the current implementation of WiMAX equipment in the USA, the Federal Communication Commission (FCC) spectral mask is used as a guide to ensure that the emissions level is restricted to a given limit [7]. This can be used to estimate the required ACLR performance of the WiMAX TDD BS (see Annex E for details). We also applied this mask to the CDMA-DS BS equipment and the resulting ACLR and ACS performance without mitigation techniques is summarised in Table 14. *[Editor M.2045 to be used [17]to provide basis of further discussion & material for this section. FCC spectrum mask needs to be cited as an example and references to other masks as part of this process.]*

TABLE 14

ACLR and ACS values (in decibels) for the WiMAX TDD BS and CDMA-DS BS without mitigation techniques. The ACLR was derived from the FCC spectral mask

	ACLR		**ACS**	
	First Adjacent Channel	**Second Adjacent Channel**	**First Adjacent Channel**	**Other Adjacent Channels**
WiMAX TDD Macro BS (Tx. Power = 36 dBm)	53.5	66.0	70.0	70.0
CDMA-DS Macro BS (Tx. Power = 43 dBm)	63.3	74.1	65.0	75.0
CDMA-DS Micro BS (Tx. Power = 38 dBm)	58.3	69.1	65.0	75.0
CDMA-DS Pico BS (Tx. Power = 24 dBm)	44.3	55.1	65.0	75.0

We also note that the WiMAX TDD ACLR values derived from the FCC spectral mask is identical to those specified by WiMAX Forum [11]. By using these ACLR and ACS values, the resulting ACIR is calculated and shown in Table 15. These ACIR values are then applied to quantify the additional isolation needed between the two BS, as shown in Table 16.

TABLE 15

ACIR values (in decibels) of interference paths of interest that are derived from ACLR and ACS values of Table 14, where the ACLR values are derived from the FCC spectral mask

Interference Path	First Adjacent Channel	Second Adjacent Channel
Macro TDD BS ⇒ Macro FDD BS	53	65
Macro FDD BS ⇒ Macro TDD BS	62	69
Macro TDD BS ⇒ Micro FDD BS	53	65
Micro FDD BS ⇒ Macro TDD BS	58	67
Macro TDD BS ⇒ Pico FDD BS	53	65
Pico FDD BS ⇒ Macro TDD BS	44	55

TABLE 16

A summary of the additional isolation needed (in decibels) when considering BS-to-BS interference for different BS separation distances. These results uses the ACIR values derived from the FCC spectral mask and mitigation techniques are not applied

Deployment Scenario		TDD BS => FDD BS			FDD BS => TDD BS		
		Co-sited	500 m	1 km	Co-sited	500 m	1 km
TDD macro/ FDD macro	1st adj chan	62.0	32.3	26.3	61.0	31.3	25.3
	2nd adj chan	50.0	20.3	14.3	54.0	24.3	18.3
TDD macro/ FDD micro	1st adj chan	22.0	-11.0	-22.7	20.0	-13.0	-24.7
	2nd adj chan	10.0	-23.0	-34.7	11.0	-22.0	-33.7
TDD macro/ FDD pico	1st adj chan	12.0	-29.4	-41.4	10.0	-31.4	-43.4
	2nd adj chan	0.0	-41.4	-53.4	-1.0	-42.4	-54.4

By using the ACIR values derived from the FCC mask and not applying mitigation techniques, additional isolation is needed in the macrocellular deployment as well as when the two BSs are co-sited. When mitigation techniques are applied, the ACS, ACLR and the resulting ACIR values improve as shown in Table 17 and Table 18, respectively. The mitigation techniques include the employment of additional channel filters for both BSs and PA linearization for the WiMAX TDD BS.

TABLE 17

ACLR and ACS values (in decibels) for the WiMAX TDD BS and CDMA-DS BS with mitigation techniques. The ACLR was derived from the FCC spectral mask

	ACLR		ACS	
	First Adjacent Channel	Second Adjacent Channel	First Adjacent Channel	Other Adjacent Channels
WiMAX TDD Macro BS (Tx. Power = 36 dBm)	113.5	126.0	130.0	130.0
CDMA-DS Macro BS (Tx. Power = 43 dBm)	123.3	134.1	125.0	135.0
CDMA-DS Micro BS (Tx. Power = 30 dBm)	118.3	129.1	125.0	135.0
CDMA-DS Pico BS (Tx. Power = 24 dBm)	104.3	115.1	125.0	135.0

TABLE 18

ACIR values (in decibels) of interference paths of interest that are derived from ACLR and ACS values of Table 17, where the ACLR values are derived from the FCC spectral mask and mitigation techniques are applied

Interference Path	First Adjacent Channel	Second Adjacent Channel
Macro TDD BS ⇒ Macro FDD BS	113	125
Macro FDD BS ⇒ Macro TDD BS	122	129
Macro TDD BS ⇒ Micro FDD BS	113	125
Micro FDD BS ⇒ Macro TDD BS	118	127
Macro TDD BS ⇒ Pico FDD BS	113	125
Pico FDD BS ⇒ Macro TDD BS	104	115

Using these ACIR values and assuming an antenna coupling loss of 65 dB, the ACI performance is shown in Table 19, which demonstrates that successful co-existence can be achieved with mitigation techniques.

TABLE 19

A summary of the additional isolation needed (in decibels) when considering BS-to-BS interference for different BS separation distances. These results incorporate mitigation techniques for the WiMAX TDD and CDMA-DS BSs. The ACLR used are derived from the FCC mask

Deployment Scenario		TDD BS => FDD BS			FDD BS => TDD BS		
		Co-sited	500 m	1 km	Co-sited	500 m	1 km
TDD macro/ FDD macro	1st adj chan	-33.0	-27.7	-33.7	-34.0	-28.7	-34.7
	2nd adj chan	-45.0	-39.7	-45.7	-41.0	-35.7	-41.7
TDD macro/ FDD micro	1st adj chan	-38.0	-71.0	-82.7	-40.0	-73.0	-84.7
	2nd adj chan	-50.0	-83.0	-94.7	-49.0	-82.0	-93.7
TDD macro/ FDD pico	1st adj chan	-48.0	-89.4	-101.4	-50.0	-91.4	-103.4
	2nd adj chan	-60.0	-101.4	-113.4	-61.0	-102.4	-114.4

2.2.6 Summary and conclusions of deterministic analyses

[Editors note: This section to be reviewed after the results have been completed.]

This deterministic analysis has quantified the impact of ACI between the WiMAX TDD and CDMA-DS technologies when deployed in adjacent frequency allocations within the IMT-2000 Expansion Band. Based on analysis of the BS-to-BS interference, the additional isolation needed to ensure successful co-existence is summarised in Table 6 for different BS-to-BS separation distances and “standard” BS equipment performance. The results in Table 6 show that when the BSs were co-located, the additional isolation needed to allow co-existence of the two systems was 73 dB for a guard band size of 5 MHz.

In the case of BS and MS interference, we identified specific scenarios for which the impact of the ACI could be severe. The additional isolation needed for successful co-existence when a MS using one technology (FDD or TDD) is close to a BS using the other technology is summarised in Table 7. Furthermore, this additional isolation would be needed regardless of the type of TDD technology employed, and similar interference also occurs between CDMA-DS networks operating on adjacent carriers. It was also noted that these scenarios were not representative of ‘typical’ network behaviour, and it has been shown that on average, the resulting capacity loss would be low [9].

The deterministic analysis of interference between MSs showed that the impact of ACI between MSs could be severe when the MSs were in close proximity. Specifically, for a separation distance of 10 m, the need for additional isolation of 34.3 dB was identified for the first adjacent channel of the CDMA-BS receiver. Again, it was noted that the probability of this scenario occurring is relatively low and the resulting ACI impact is severe regardless of the type of TDD technology deployed in the central band. Furthermore, this analysis represents a worst-case scenario for MS-to-MS interference. [Editors note: A better alignment is necessary with the M.2045 Report.]

The BS-to-BS interference analysis also considered the impact of employing mitigation techniques such as the use of additional channel filters in the WiMAX BSs, as well as allowing for the typical performance of real CDMA-DS BS equipment (as opposed to equipment that is only just compliant with the minimum requirements of the specifications). The resulting additional isolation needed for the two BSs to co-exist in a macrocellular deployment was summarised in Table 10, including the situation when the BS was co-sited.

The performance of the WiMAX TDD BS was improved significantly by using the mitigation techniques described, such that it was considerably better than the performance of practical CDMA-DS BS equipment. As a result, the ACIR performance was dominated primarily by the ACLR and ACS performance of the CDMA-DS BS. Even though the performance of the real CDMA-DS BS was assumed to be significantly better than that required by the specifications, it was insufficient to permit co-location of the BSs. Consequently, in order to allow co-location of two BSs of these two different systems, the ACLR and ACS performance of the CDMA-DS BS needs to be improved further. We note that this result applies to any technology that is implemented in the central band of the IMT-2000 Expansion Band (such as UTRA TDD, CDMA-DS downlink or WiMAX TDD) that would require BS transmissions close to the CDMA-DS uplink band. In order to improve the performance of the CDMA-DS BS, an additional channel filter was incorporated, which can offer an additional 60 dB rejection for the RF frontend [6]. Subsequently, it was demonstrated that by utilising a channel filter for the CDMA-DS BS, the two technologies can co-exist successfully without the need for guard bands, as shown in Table 13. Furthermore, there is an added incentive to improve the performance of the CDMA-DS BS, because such improvements will also be required if the central band is to be used for an external CDMA-DS technology.

The BS-to-BS interference analysis was then extended to consider the impact of the FCC spectral mask on the performance of the WiMAX TDD BS and CDMA-DS BS. We demonstrated that by utilising a channel filter for the CDMA-DS BS, in addition to the mitigation techniques for the WiMAX TDD BS, the two technologies can co-exist successfully without the need for guard bands, as shown in Table 19. However, without the mitigation techniques, the ACI performance was insufficient to guarantee co-existence, as shown in Table 16.]

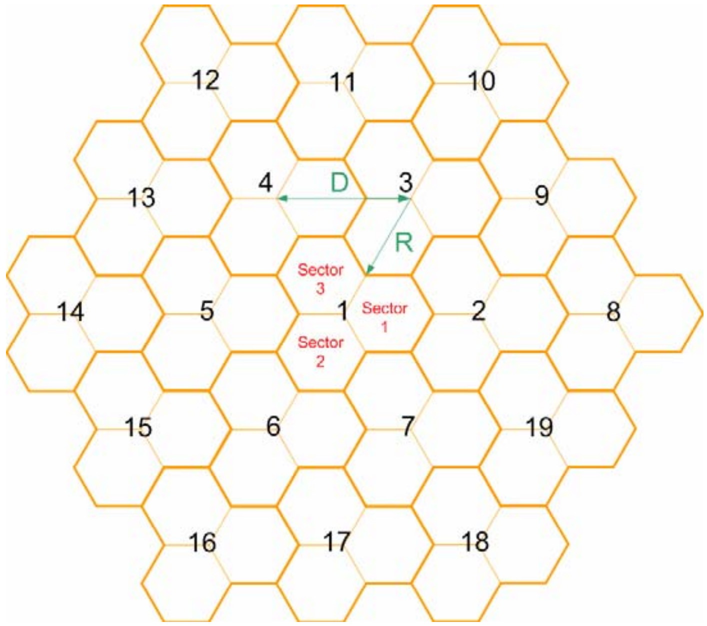
2.3 Statistical analyses

2.3.1 Modelling of IEEE 802.16 and IMT-2000 systems and their inter-system interference

[*Editors note: References to system A to be consistent throughout the doc*.] Three-sector clover-leaf cellular layout is used in this study as shown in Figure 2-1**.** *D* is the distance between two base stations within a system. In this study *D* is 1500 meters. *R* is the radius of a cell which is 1000 meters. [*Editors note: References to figures to be fixed by combining both cell representations.]*

FIGURE 2-1

Large area single system deployment using directional antenna

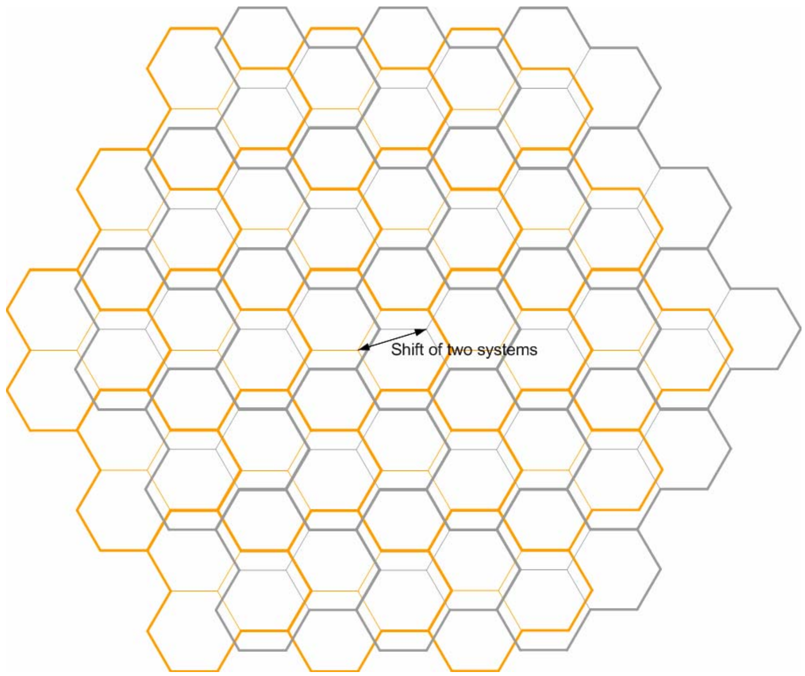


In Figure 2-2**,** two colors indicate overlay of two different systems, i.e. CDMA-DS and IEEE 802.16, in the same area. Wrap-around technique is used.

Both IEEE 802.16-2004, hereafter referred to as "16d", and IEEE P802.16e, hereafter referred to as "16e" are being considered. For brevity, when referring to these systems, term "802.16" is generically used to refer to either system.

FIGURE 2-2

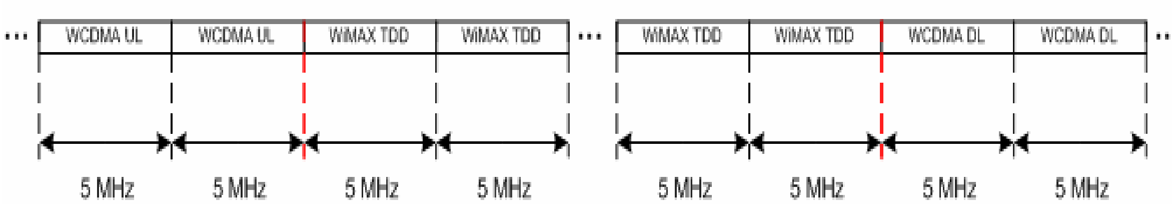
Large area multiple systems deployment using directional antenna



[*Editors note: Fig 2-1 & 2-2 to be combined.]* For the 802.16 systems simulated here, bandwidth being reused in each of the three sectors is defined as frequency reuse of 1x3x1. On the other hand, bandwidth being reused in each cell and shared by three sectors is defined as frequency reuse of 1x3x3.

FIGURE 2-3

Band-plan structure



2.3.2 SINR modelling

[Editors note: This section may be included in an Annex.]

SINR is given by [*editors note: Summation indices need to be added.*]

$$SINR = S - 10\log_{10}\left(\sum 10^{\frac{I_1}{10}} + \sum 10^{\frac{I_2}{10}} + 10^{\frac{N}{10}}\right),$$

$$N = -174 + 10\log_{10}\left(BW\ in\ Hz\right) + NF,$$

where, S is the desired signal strength in dBm at the receiver;

I_1 is the received co-channel interference in dBm;

I_2 is the received adjacent channel interference in dBm.

[*Editors note: It needs to mention that the ACS, ACLR, propagation models and other factors have been taken into account.*]

N is the thermal noise in dBm;

NF is the system noise figure in dB.

2.3.3 Propagation models

[Editors note: This section may be included in an Annex.]

2.3.3.1 BS-BS propagation model

The dual-slope LOS propagation model assumes free-space propagation until the breakpoint (d_{break}). After the breakpoint, the attenuation is increased due to diffraction/reflection effects.

$$L_{bs-bs} = \begin{cases} 40.7 + 20\log(d) & 1 \le d \le d_{break} \\ 40.7 - 20\log(d_{break}) + 40\log(d) & d > d_{break} \end{cases}$$

where, d is distance in meters.

The breakpoint is calculated as:

$$d_{break} = \frac{4 \cdot h_{tx} \cdot h_{rx}}{\lambda},$$

where h_{tx} and h_{rx} are the heights (over the reflecting surface) of the transmitter and the receiver. λ is the wavelength.

Standard deviation of 10 dB log-normal shadow fading is added to the path loss if the distance between two base stations is greater than the break point. *[Editors note: To reference M.2030 & check the frequency at which the model was calculated.]*

2.3.3.2 BS-MS propagation model

The path loss model used in this simulation is the model for vehicular test environment described in Appendix 1 to Annex 2 of Recommendation ITU-R M.1225. It is:

$$L_{bs-ms} = \left(40(1 - 4\times10^{-3}\Delta h_b)\right)\cdot\log_{10}(R) - 18\cdot\log_{10}(\Delta h_b) + 21\cdot\log_{10}(f) + 80,$$

where Δh_b is the height difference between BS antenna and the mean building rooftop height, its value here is 6 m; (BS height is 18 m, mean rooftop is 12 m):

R: transmitter-receiver separation in km, $R \geq 0.1\ km$;

f: carrier frequency in MHz.

Standard deviation of 10 dB log-normal shadow fading is added to the path loss if it is NLOS. In order to take into account the shadow fading correlation between the links in a cluster, when calculating path loss between two cells, the log-normal shadow fading for each link is composed of two components:

$$X_i = a Z_0 + b Z_i$$

Where $a^2 + b^2 = 1$, (assuming 50% correlation in this study i.e. $a = b = 1/\sqrt{2}$):

i: the link index;

Z_0: common to all links;

Z_i: independent for each link;

Z_0, Z_i: statistically independent and Gaussian distributed with zero mean and standard deviation of 10 dB. If the distance between BS and MS is less than 100m, LOS model is used. The minimum distance between BS and MS is assumed to be 1 m.

2.3.3.3 MS-MS propagation model

[*Editors note: Fix disparity from 2.2. Propagation needs to be checked against existing ITU-R Recommendations. If the model is not contained in an ITU-R Recommendation then it should be checked against ITU-R SG 3.*] Following is the MS-MS propagation model in NLOS condition 0:

$$L_{ms-ms} = -10\log\left(\frac{\lambda}{4\pi R}\right)^2 - 10\log\left[\frac{\lambda}{2\pi^2 r}\left(\frac{1}{\theta} - \frac{1}{2\pi + \theta}\right)^2\right] - 10\log\left[\left(\frac{d}{2\pi R}\right)^2 \frac{\lambda}{\sqrt{(\Delta h_m)^2 + d^2}}\left(\frac{1}{\phi} - \frac{1}{2\pi + \phi}\right)^2\right],$$

where

d: average separation between rows of buildings, its typical value is 80 m;

R: transmitter-receiver separation, $R > 1m$;

Δh_m: difference between the mean building height and the mobile antenna, its typical value is 10.5 m;

x: the horizontal distance between the mobile and the diffracting edges, typical value of 15 m;

$$r = \sqrt{(\Delta h_m)^2 + x^2}$$

$$\theta = \tan^{-1}\left(|\Delta h_m|/x\right)$$

Δh_b: the height difference between the base station antenna and the mean building height;

$$\phi = \tan^{-1}\left(|\Delta h_b|/d\right)$$

λ: wave length.

If two mobile stations are within 1 m of each other, the free space loss at 1 m is used. If they are between 1 m and 50 m, LOS or NLOS is chosen randomly. Standard deviation of 10 dB log-normal shadow fading is added to the path loss if it is NLOS. The way it is generated is the same as the one described in section 2.3.3.2.

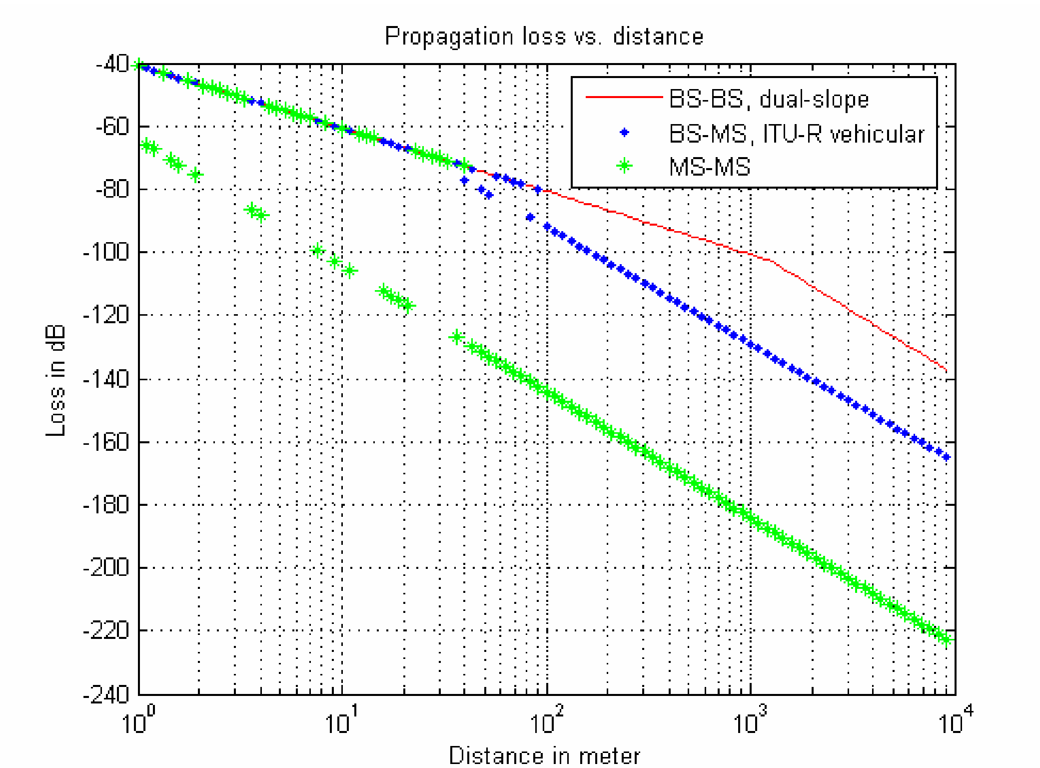
2.3.3.4 Propagation loss versus distance

[Editors note: This to be considered for Annex.]

The following figure shows the above three propagation models' loss versus distance before adding log-normal fading component in the 2.6 GHz band.

FIGURE 2-4

Propagation losses of different models



2.3.4 Directional antenna pattern

[Editors note: This needs to normatively reference ITU-R WP9D Liaison Statement & appropriate Rec.]

The antenna pattern used for each sector in a directional antenna which is specified as 0:

$$A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right],$$

where:

$-180 \le \theta \le +180$	is the angle from the antenna pointing direction;
θ_{3dB}	corresponds to 60 degrees;
$A_m = 30\ dB$	is the maximum attenuation.

2.3.5 CDMA-DS processing gain, SINR, and Eb/No

CDMA-DS processing gain is given by:

$$PG = 10 \cdot \log_{10}\left(\frac{chip\_rate}{user\_bit\_rate}\right).$$

CDMA-DS uplink *SINR* is given by:

$$SINR_{UL} = S - 10 \cdot \log_{10}(I_{own} + I_{other} + N),$$

where:

S	is the received desired signal;
I_{own}	is the interference caused by other users in the same sector;
I_{other}	is interference caused by other users in other sectors and other cells, as well as interference coming from 802.16;
N	is thermal noise including noise figure.

CDMA-DS downlink *SINR* is given by

$$SINR_{DL} = S - 10 \cdot \log_{10}(\alpha \cdot I_{own} + I_{other} + N),$$

where,

α	is the orthogonal factor.

CDMA-DS *Eb/No* is given by

$$Eb / No = PG + SINR.$$

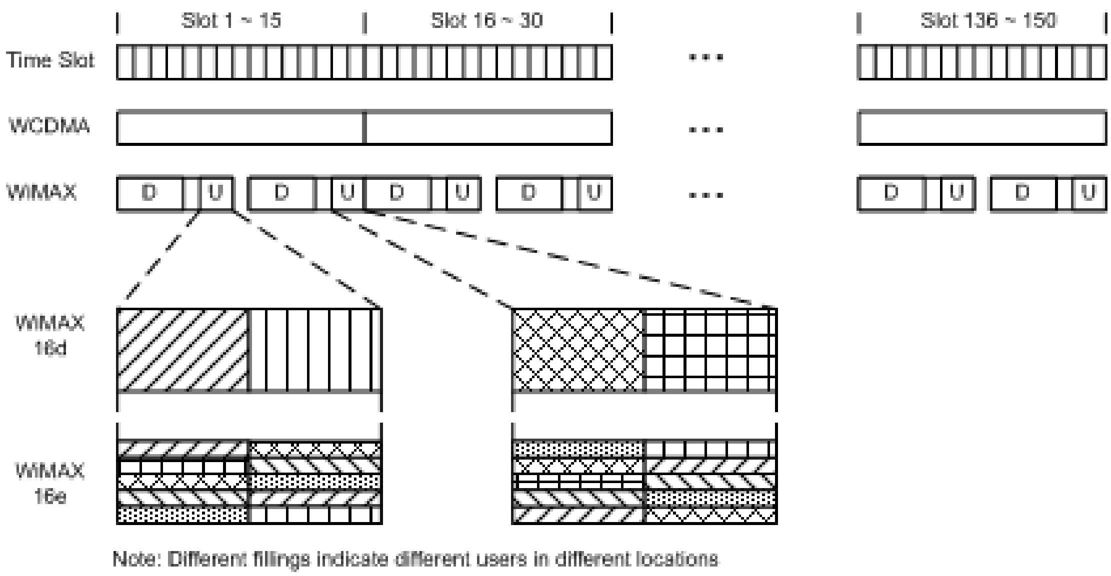
2.3.6 CDMA-DS power control

Power control algorithm considers intra-system as well as inter-system interference. Each CDMA-DS uplink does its own power control. At the end of power control, each CDMA-DS uplink transmits the least power to meet the *Eb/No* requirement at the base station. Base station transmits every code with the same power. Consequently the downlink power control algorithm considers the MS with the lowest receiving power level to ensure a working connection for each MS 0.

Each CDMA-DS frame contains 15 time slots, and each time slot lasts 0.667 ms. 802.16 TDD frame is assumed to be 5 ms. The duration of one CDMA-DS frame corresponds to two 802.16 TDD frames. During the 150-step power control period in CDMA-DS, interference from 802.16 TDD system is time variant depending on DL/UL ratio. In order to model the transition gaps between uplink and downlink in the TDD system, it is assumed that there is a gap of one slot between 802.16 downlink and uplink. This assumption is illustrated in Figure 2-5. When calculating *SINR* for CDMA-DS at the end of power control, interferences from 802.16 uplinks and 802.16 downlinks are considered separately.

FIGURE 2-5

CDMA-DS and 802.16 frames in time domain



2.3.7 Interference scenarios

2.3.7.1 CDMA-DS UL interference due to 802.16 TDD

Interference to CDMA-DS UL includes:

1. co-channel interference from the same sector;
2. co-channel interference from other sectors of the same cell and other cells of the same system;
3. adjacent channel interference from 802.16 uplinks/downlinks.

2.3.7.2 802.16 TDD interfered by CDMA-DS UL

Interference to 802.16 UL includes:

1. a. co-channel interference from the other cells' uplinks of the same system (for frequency reuse 1x3x3);

   b. co-channel interference from uplinks of other sectors of the same cell and uplinks of other cells of the same system (for frequency reuse 1x3x1);
2. adjacent channel interference from CDMA-DS UL.

Interference to 802.16 DL includes:

1. a. co-channel interference from the other cells' downlinks of the same system (for frequency reuse 1x3x3);

   b. co-channel interference from downlinks of other sectors of the same cell and downlinks of other cells of the same system (for frequency reuse of 1x3x1);
2. adjacent channel interference from CDMA-DS UL.

2.3.7.3 CDMA-DS DL interference due to 802.16 TDD

Interference to CDMA-DS DL includes:

1. co-channel interference from the same sector (need to considering orthogonal factor);
2. co-channel interference from other sectors of the same cell and other cells of the same system;
3. adjacent channel interference from 802.16 uplinks/downlinks.

2.3.7.4 802.16 TDD interfered by CDMA-DS DL

Interference to 802.16 UL includes:

1. a. co-channel interference from the other cells' uplinks of the same system (for frequency reuse 1x3x3);

   b. co-channel interference from uplinks of other sectors of the same cell and uplinks of other cells of the same system (for frequency reuse 1x3x1);
2. adjacent channel interference from CDMA-DS DL.

Interference to 802.16 DL includes:

1. a. co-channel interference from the other cells' downlinks of the same system (for frequency reuse 1x3x3);

   b. co-channel interference from downlinks of other sectors of the same cell and downlinks of other cells of the same system (for frequency reuse of 1x3x1);
2. adjacent channel interference from CDMA-DS DL.

2.3.8 Input parameters and assumptions

Tables below summarize the input parameters and assumptions.

TABLE 0-1

Common simulation assumptions and parameters

Cell layout	Macro 19 clover-leave cells, 3 sectors per cell
Cell size	Radius: R=1000 m
Shift of two systems	0, R/2, R
Spectrum band	2.500 ~ 2.690 GHz
Allocated bandwidth	5 MHz
802.16 system load	75%
16e active users	5 per sector
Antenna co-location Coupling Loss	50 dB
Power control	150 steps *SINR* based (CDMA-DS UL, CDMA-DS DL); No power control in 802.16
BS antenna type	Directional
Frequency reuse	CDMA-DS: 1 802.16: 1x3x1, 1x3x3

TABLE 0-2

802.16 TDD parameters

	BS	MS
Location	Center of the cell	Uniformly distributed
Max TX power	36 dBm	24 dBm for 16d; 20 dBm for 16e
Antenna gain	18 dBi	8 dBi for 16d; 3 dBi for 16e
Antenna height	18 m	1.5 m
ACLR @ 5 MHz	53.5 dB (93 dB for co-located)	37 dB for 16d; 33 dB for 16e
ACLR @ 10 MHz	66 dB (93 dB for co-located)	51 dB
ACS @ 5 MHz	70 dB	40 dB
ACS @ 10 MHz	70 dB	59 dB
Noise figure	3 dB	5 dB
DL/UL ratio	2:1	

TABLE 0-3

CDMA-DS FDD parameters

[Editors note: All values to be verified against M.2039.]

		BS	MS
Location		Center of the cell	Uniformly distributed
Max TX power		43 dBm	21 dBm
Antenna gain		18 dBi	0 dBi
Antenna height		18 m	1.5 m
Standard equipment	**ACLR @ 5 MHz**	45 dB	33 dB
	ACLR @ 10 MHz	50 dB	43 dB
	ACS @ 5 MHz	46 dB	33 dB
	ACS @ 10 MHz	58 dB	43 dB
Practical equipment	**ACLR @ 5 MHz**	57 dB (100 dB for co-located)	46 dB
	ACLR @ 10 MHz	74 dB (100 dB for co-located)	64 dB
	ACS @ 5 MHz	65 dB	58 dB
	ACS @ 10 MHz	75 dB	65 dB
Noise figure		3 dB	5 dB
Required *Eb/No*		6.1 dB for voice; 3.1 dB for data	7.9 dB for voice; 4.5 dB for data
Power control range		30 dB (1 dB per step)	80 dB (1 dB per step)

In co-locating antennas, Coupling Loss (CL) is usually used to capture the effects of energy interaction between the two systems. The typical minimum for CL is 30 dB and referred to as the Minimum Coupling Loss (MCL). ITU-R Report M.[MITIGATATION] reports that with proper antenna placement values of up to 70 dB are achievable with a few meters of antenna separation. The CL between two base stations is here assumed to be 50 dB to account for a more easily achievable deployment.

ACLR and ACS numbers for non-co-located case are from Documents 8F/TEMP/222 and 8F/TEMP/220. For co-located case, ACLR numbers are derived following the FCC rules, which states "*… when collocated, limit the undesired signal level at the affected licensee's base station receiver(s) at the collocation site to no more than -107 dBm*".

ACIR is calculated in linear scale by

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

2.3.9 Protection criteria

2.3.9.1 CDMA-DS performance evaluation criteria

CDMA-DS uplink loading in single system case is evaluated according to a 6 dB noise rise over the thermal noise. A simulation is run with a predefined number of users per sector. At the end of power control, the average noise rise is measured. If it is lower than or higher than 6 dB, the number of users per sector is increased or decreased respectively until the 6 dB noise rise is reached. The number of users per sector corresponding to the 6 dB noise rise is defined as *N_ul*. A link is outage if its *Eb/No* is less than (target *Eb/No* – 0.5 dB) at the end of power control. The uplink outage rate corresponding to the 6 dB noise rise is defined as *OR_ul_single.*

$$OR\_ul\_single = \frac{N\_total\_outage\_ul\_single}{N\_total\_ul}$$

where,

N_total_ul is the total uplinks in 19 cells;

$N\_total\_outage\_ul\_single$ is the total outage uplinks in single system case.

CDMA-DS uplink is loaded with *N_ul* per sector in multi-system case (with additional interference from 802.16). Outage rate is measured and defined as *OR_ul_multi*.

$$OR\_ul\_multi = \frac{N\_total\_outage\_ul\_multi}{N\_total\_ul}$$

where,

N_total_ul is the total uplinks simulated;

$N\_total\_outage\_ul\_multi$ is the total outage uplinks in multi-system case.

CDMA-DS uplink capacity loss due to additional interference from 802.16 is calculated by

$$C\_ul\_loss = 1 - \frac{(1 - OR\_ul\_multi)}{(1 - OR\_ul\_single)} = 1 - \frac{N\_ul\_multi}{N\_ul\_single},$$

where,

N_ul_single is the total uplinks which meet the required *Eb/No* in single system case;

N_ul_multi is the total uplinks which meet the required *Eb/No* in multi-system case.

CDMA-DS downlink loading in single system case is evaluated according to a 5% outage rate criterion. A simulation is run with a predefined number of users per sector. At the end of power control, *Eb/No* of each link is measured and compared with the target *Eb/No*. If it is lower than the target, this link is considered in outage. If the outage rate is higher than or lower than 5%, the number of users per sector is decreased or increased respectively until the 5% outage rate is reached. The number of users per sector corresponding to the 5% outage rate is defined as *N_dl*. The downlink outage rate is defined as *OR_dl_single*. CDMA-DS downlink is loaded with *N_dl* per sector in multi-system case (with additional interference from 802.16). Outage rate is measured and defined as *OR_dl_multi*. CDMA-DS downlink capacity loss due to additional interference from 802.16 is calculated by

$$C\_dl\_loss = 1 - \frac{(1 - OR\_dl\_multi)}{(1 - OR\_dl\_single)} = 1 - \frac{N\_dl\_multi}{N\_dl\_single},$$

where,

N_dl_single is the total downlinks of 19 cells which meet the required *Eb/No* in single system;

N_dl_multi is the total downlinks of 19 cells which meet the required *Eb/No* in multi-system.

2.3.9.2 802.16 performance evaluation criteria

802.16 system is 75% loaded; i.e., at any given time, 75% of sub-carriers are occupied. After each simulation the PDF of *SINR* of 802.16 links is plotted. The shift of *SINR* CDF curves to left indicates performance degradation due to additional interference from CDMA-DS.

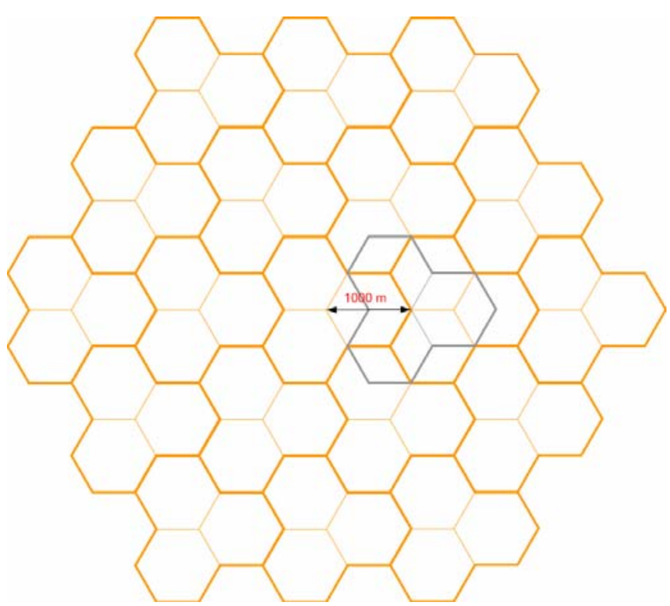
2.3.10 Results

In Table 0-3, two sets of ACLR and ACS numbers for CDMA-DS are shown, namely standard and practical. Practical numbers are generally higher than standard numbers. The ACLR and ACS values for 802.16 are shown in Table 0-3. Three shifts of two systems are simulated: 1000 m (shifted by one radius), 500 m (shifted by half radius), and co-located. Simulations are run both on the first adjacent channel and the second adjacent channel; namely, no guard-channel and one guard band (5 MHz) exist between the two systems. Voice only service is considered in CDMA-DS.

Both systems are assumed to have the same sector orientation; namely, antenna pointing directions of the two systems are parallel. Figure 2-1 illustrates deployment layout. Only one 802.16 cell is shown.

FIGURE 2-1

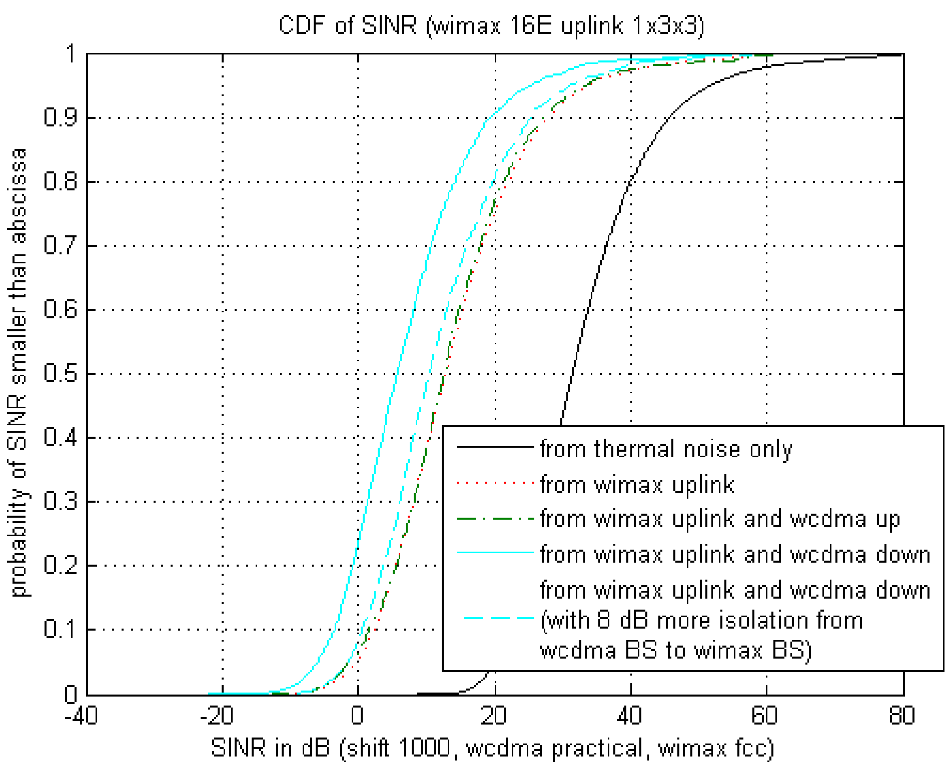
Two systems shifted by 1000 meters



This paragraph explains how to interpret the 802.16 performance curves. One such graph is depicted below as an example. Let's assume that *SINR* of 0 dB is the 802.16 system operating point. The black curve shows the CDF of *SNR* of single cell 802.16 system. Interference to the system in this case is thermal noise. Outage rate of single cell case is 0.0%. The red (dotted) curve is for the 19-cell single 802.16 system case. Both intra-system and thermal noise contribute to the interference in this case. Outage rate is at 5.0%. The dark green (dash-dotted) curve shows the 802.16 uplink performance when coexisting with a CDMA-DS system and operating on the adjacent channel of CDMA-DS uplink. This curve is almost the same as the red (dotted) curve. That means CDMA-DS uplink causes slight degradation to 802.16 uplink. 802.16 system outage is about 6.0%. The cyan (solid) curve illustrates the 802.16 uplink performance when coexisting with a CDMA-DS system and operating on the adjacent channel of CDMA-DS downlink. Interference is from intra-system, inter-system and thermal noise. This curve is about 8 dB off from the red curve to the left. The overall *SINR* is about 8 dB worse than the single 802.16 system case. Outage is about 22.0%. If 8 dB more isolation from CDMA-DS BS to 802.16 BS is achieved, the 802.16 uplink performance is shown in the dash cyan curve. This curve is about 3 dB off from the red (dotted) one to the left. It can be said that the interference from CDMA-DS downlink is almost the same as that from 802.16 system itself in average. Outage rate is about 8.0%. Hence the degradation caused by CDMA-DS downlink is small if there is 8 dB more isolation from CDMA-DS BS to 802.16 BS. Note that the interpretation methodology in this paragraph applies to section 2.3.10.1 to 2.3.10.2 sections in this document.

FIGURE 2-7

Example of a performance curve – 16e uplink performance in reuse 1x3x3



At any given instance there is only one active user per sector in 16d. It occupies the whole bandwidth and transmits at its maximum power. For 16e, there are five active users per sector at any given time. Each user occupies one fifth of the whole bandwidth and transmits at its maximum power. Users are uniformly distributed in the service area.

In this study, additional isolation values required in case of CDMA-DS victim are chosen to meet the 5% outage rate requirement in CDMA-DS performance. For 16d victim, additional isolation values are chosen to limit the total interference rise to be about 3 dB in average over the intra-system interference including thermal noise in 802.16 performance. Additional isolation can be achieved by improving transmit filter and receive filter. Additional isolation from CDMA-DS BS to 802.16 BS is needed for frequency reuse of 1x3x3.

2.3.10.1 Coexistence of CDMA-DS and 16d

At any given instance there is only one active user per sector in 16d. It occupies the whole bandwidth and transmits at its maximum power. Users are uniformly distributed in the service area.

In this study, additional isolation values required in case of CDMA-DS victim are chosen to meet the 5% outage rate requirement in CDMA-DS performance. For 16d victim, additional isolation values of are chosen to limit the total interference rise to be about 3 dB over the intra-system interference including thermal noise in 16d performance. These criteria apply to both 16d and 16e results.

Additional isolation can be achieved by improving transmit filter and receive filter. Additional isolation from CDMA-DS BS to 802.16 BS is needed for frequency reuse of 1x3x3.

2.3.10.2 Coexistence of CDMA-DS and 16e

At any given instance there are five active users per sector in 802.16e. Each user occupies one fifth of the whole bandwidth and transmits at its maximum power.

In this study 802.16e has 5 active users per sector, but 802.16d has only 1 active user per sector at any given time. No matter how much bandwidth a 16e user occupies, it is assumed that it always transmits at maximum power.

2.3.10.3 CDMA-DS system capacity loss due to coexistence with 802.16

The results with no guard band are summarized in table below.

TABLE 2.4

CDMA-DS system capacity loss when coexistence with 802.16 in the first adjacent channel

			CDMA-DS system capacity loss					
			Shift by 1000		Shift by 500		Co-located CL 50 dB FCC BS ACLR	
			CDMA-DS UL	CDMA-DS DL	CDMA-DS UL	CDMA-DS DL	CDMA-DS UL	CDMA-DS DL
CDMA-DS practical equipment	802. 16d	UL	3.25%	0.01%	4.17%	0.02%	6.48%	0.01%
		DL	1.39%	0.07%	1.23%	0.07%	27.17%	0.00%
	802. 16e	UL	7.73%	0.03%	7.52%	0.07%	10.64%	0.02%
		DL	1.41%	0.12%	1.49%	0.03%	27.83%	0.00%
CDMA-DS standard equipment	802. 16d	UL	3.89%	0.02%	4.43%	0.01%	N/A	
		DL	15.34%	1.33%	12.76%	1.05%		
	802. 16e	UL	7.57%	0.08%	7.62%	0.07%		
		DL	14.77%	1.17%	14.00%	0.82%		

The results with 5 MHz guard band are summarized in Table 2-5 with 5 MHz guard band.

TABLE 2-5

CDMA-DS system capacity loss when coexistence with 802.16 in the second adjacent channel (5 MHz guard band)

			CDMA-DS system capacity loss					
			Shift by 1000		Shift by 500		Co-located CL 50 dB FCC BS ACLR	
			CDMA-DS UL	CDMA-DS DL	CDMA-DS UL	CDMA-DS DL	CDMA-DS UL	CDMA-DS DL
CDMA-DS practical equipme	802. 16d	UL	2.45%	0.00%	2.74%	0.00%	1.15%	0.00%
		DL	0.00%	0.02%	0.00%	0.02%	2.45%	0.00%
	802. 16e	UL	5.41%	0.01%	3.97%	0.00%	0.36%	0.00%
		DL	0.00%	0.03%	0.00%	0.00%	2.20%	0.00%
CDMA-DS standard equipment	802. 16d	UL	2.04%	0.00%	1.80%	0.00%	N/A	
		DL	0.06%	0.51%	0.19%	0.19%		
	802. 16e	UL	2.59%	0.00%	2.30%	0.01%		
		DL	0.13%	0.39%	0.17%	0.24%		

TABLE 2-6

Additional isolation needed for coexistence

Shift	Coexistence		Additional isolation needed in dB							
			From 802.16 BS to CDMA-DS BS	From CDMA-DS BS to 802.16 BS	From 802.16 BS to CDMA-DS MS	From CDMA-DS MS to 802.16 BS	From 802.16 MS to CDMA-DS BS	From CDMA-DS BS to 802.16 MS	From 802.16 MS to CDMA-DS MS	From CDMA-DS MS to 802.16 MS
1000	CDMA-DS practical equipment	16d	0	0 (1x3x1) 9 (1x3x3)	0	0	0	0	0	0
		16e	0	0 (1x3x1) 8 (1x3x3)	0	0	4	0	0	0
	CDMA-DS standard equipment	16d	6	9 (1x3x1) 21 (1x3x3)	0	2 (1x3x1) 7 (1x3x3)	0	0	0	0
		16e	6	10 (1x3x1) 21 (1x3x3)	0	0 (1x3x1) 5 (1x3x3)	4	0	0	0
500	CDMA-DS practical equipment	16d	0	0 (1x3x1) 9 (1x3x3)	0	0	0	0	0	0
		16e	0	0 (1x3x1) 8 (1x3x3)	0	0	4	0	0	0
	CDMA-DS standard equipment	16d	6	9 (1x3x1) 21 (1x3x3)	0	0 (1x3x1) 5 (1x3x3)	0	0	0	0
		16e	6	10 (1x3x1) 21 (1x3x3)	0	0 (1x3x1) 4 (1x3x3)	4	0	0	0
0	CDMA-DS practical equipment	16d	8	9 (1x3x1) 21 (1x3x3)	0	0	0	0	0	0
		16e	8	9 (1x3x1) 21 (1x3x3)	0	0	4	0	0	0

2.3.11 Conclusions

Impacts between CDMA-DS and 802.16 are studied for different shift distances between two systems and for different ACIR values. Based on simulation results, required additional isolations between two systems are derived. Coexistence of CDMA-DS and 802.16 on the adjacent channel in the same geographical area in the 2 500-2 690 MHz band is feasible given the additional isolation is met.

1. The overall worst case scenarios are "uplink interfered by uplink" and "uplink interfered by downlink". The worst one is "uplink interfered by downlink". Interference to downlink is negligible.
2. Simulation results of for the two shift values of 1000 m and 500 m are almost the same. When shifted by 1000 meters, a victim BS is also 500 meters away from the strongest interfering BS.
3. CDMA-DS downlink system capacity loss due to interference from 802.16 is negligible.
4. When CDMA-DS equipped with practical ACLR and ACS values, coexistence of CDMA-DS and 802.16 (apart by 1000 meters or 500 meters) is feasible if additional isolations, as per Table 2-6, are met.
5. When CDMA-DS equipped with standard ACLR and ACS values, coexistence of CDMA-DS and 802.16 (apart by 1000 meters or 500 meters) is also possible if larger additional isolations, as per Table 2-6, are met.

6. CL between two co-located base stations is assumed to be 50 dB. ACLR of BS is strict based on the FCC rules for co-located case. 802.16 and CDMA-DS with practical equipment can be co-located if additional isolation, as per Table 2-6, between two base stations can be met.

7. When CL between two co-located base stations is increased to 70 dB, simulation results show that interference between CDMA-DS and 802.16 is negligible. In other words, two systems operating on adjacent channels can be co-located if their base station ACLR values meet the FCC rules and coupling loss of 70 dB.

Followings are conclusions for coexistence of two systems on the second adjacent channel.

8. When two systems are deployed with one guard channel (5 MHz), interference from 802.16 to CDMA-DS is negligible.

9. When CDMA-DS equipped with practical ACLR and ACS values, coexistence of CDMA-DS and 802.16 (apart by 1000 meters or 500 meters) is feasible.

10. When CDMA-DS equipped with standard ACLR and ACS values, coexistence of CDMA-DS and 802.16 (apart by 1000 meters or 500 meters) is also possible if larger additional isolations are met.

11. CL between two co-located base stations is assumed to be 50 dB. ACLR of BS is strict based on the FCC rules for co-located case. 802.16 and CDMA-DS with practical equipment can be co-located if additional isolation between two base stations can be met.

2.3.12 References

[1] "Guidelines for evaluation of radio transmission technologies for IMT-2000", Recommendation ITU-R M.1225, 1997.

[2] Miao Qingyu, Wang Wenbo, Yang Dacheng and Wang Daqing, "An investigation of interference between UTRA-TDD and FDD system", Beijing University of Posts and Telecommunications, and Nokia China R&D Center.

[3] 3GPP documentation, 3GPP TR 25.892 V2.0.0 (2004-06).

[4] 3GPP documentation, 3GPP TR 25.942 V6.4.0 (2005-03).

2.3.1 BS to BS scenario

[Editor's note: Depending on further studies submitted it may be necessary to establish separate sections to describe the Monte-Carlo simulation for various scenarios studied.[Editor's notes: here are questions on the three topics below:

1. How a location-based Monte-Carlo analysis can be tied to a time-based Monte-Carlo analysis?

2. What information can be potentially extracted from a location-based Monte-Carlo analysis in addition to information captured by a deterministic analysis?

3. More information are required about the assumptions and variables in the Monte-Carlo simulation.

Information are needed in this section to answer the above questions.]

In order to capture effects of multiple sources of interference, similar to what happens in network deployments, a network of 19 interfering cells in a clover-leaf pattern is considered. Statistical behavior of the interference is captured by collecting information from snapshots of the network's operation. In each snapshot, the victim station is placed at a random location in the center cell and the sum of all interference power is being calculated taking into account factors such as user

distribution, power control, path loss model, TDD activity factor, etc. By observing enough number of snapshots (e.g. ten thousand) meaningful statistics on interference power is obtained.
One outcome of the Monte-Carlo analysis, for any given scenario with a given set of input parameters, is the likelihood of interference in the form of CDF plots. Target criterion is put in place for maximum acceptable percentage of locations in proximity of an interfering station which would cause victim to be in outage. [An aggressive target value of 2% is considered.] Furthermore, similar to the presentation of results in M.2030, the amount of additional isolation required to remove the possibility of outage is extracted and reported.

Omni-directional as well as sectorized cells are analyzed in line with the methodologies approved by standard bodies. Also, two reuse factors schemes of 1:1 and 1:3 are analyzed as two primary frequency reuse schemes. System specification features affecting coexistence, such as the use of adaptive antennas, power control, and enhanced filtering are also included in the simulation.

The Monte Carlo analysis was done based on many snapshots of the interference situation throughout the network and statistics of the interference was extracted from CDF plots. In all scenarios, the sum of all powers from interfering stations into a single victim station, randomly located within the center cell, was calculated in each snapshot. Factors varying from one snapshot to the other could include the location of the victim, the antenna heights, the frequency assignments, etc. The CDF plots of this total interference then were used to come up with the likelihood of interference exceeding permissible levels as a function of the varying parameters.

Next, the amount of additional (or missing) isolation required to reach permissible interference levels was calculated and used as the main way of presenting the results. The results could be looked at in two different ways.

1) Percentage of victim locations at which no additional isolation, to any degree, is required. This number is desirable to be as close to 100% as possible.

2) The amount of missing (or additional) isolation for a given percentage of victim locations. This number needs to be as small as possible. [Values for additional isolation required to achieve full protection in 98% of the locations are being reported.]

2.3.2 BS to MS scenario

2.3.3 MS to BS scenario

2.3.4 MS to MS scenario

2.3.5 Modelling of System A and IMT-2000 systems and their inter-system interference

Propagation models used are the ones used in several ITU-R sharing studies including M.2030; dual-slope and Macrocell models *[Editor's note: add reference.]* were used to calculate path loss between two base stations and between a base station and a subscriber, respectively.

Antenna pattern used is based on a simplified pattern presented by the following formula.

$$A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$$

$$-180 \le \theta \le 180, \quad \theta_{3dB} = 60^\circ, \quad A_m = 30\ dB$$

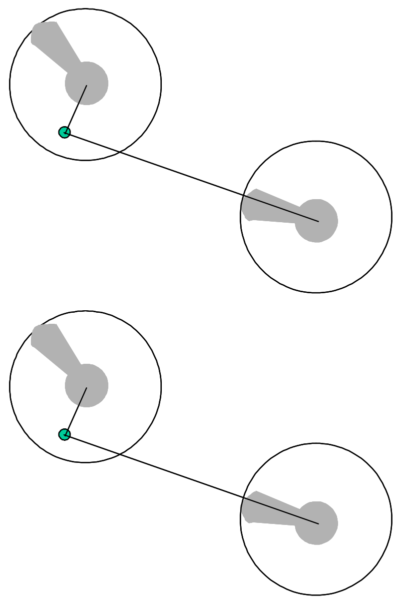
A_m is maximum attenuation with respect to the maximum gain in the antenna pattern.

Vertical pattern is assumed to have a beamwidth of 6 degrees, which is expected for an 18 dBi gain base station antenna.

OFDM/OFDMA-based TDD systems based on 802.16 are most likely to be deployed with Adaptive Antenna Systems (AAS) as an integrated feature of the radio interface. Statistical analysis is needed to examine the effects of utilization of AAS at the TDD base stations supporting portable/mobile users. In such analysis, users are uniformly distributed within cells and beams are formed to serve the users. Random direction of beams in time and space would result in a randomly varying level of worst-case interference in time and space. This randomness increases with the degree of mobility of users and its distribution tends to resemble that of a uniform random variable.

FIGURE 2

Geometry of beams in simple AAS implementation



Full analysis of AAS requires implementation of beam forming algorithm through distributing users and calculating the optimum branch weights to maximize SINR for each user. Since this is left to the individual implementations of AAS by the industry, a simpler, more generic approach is being taken to capture the effects of AAS on coexistence.

Figure 1 shows the geometry used in performing this analysis. The green dot represents the victim IMT-2000 FDD base station located in the cell area of an interfering TDD base station implementing AAS. The level of interference the victim BS receives in any instance of time depends on the orientation of the AAS beam in the cell as well as in all other 18 cells in the analysis, one of them being shown in Figure 1. Adaptive antenna pattern assumptions are consistent with Report ITU-R IMT.[MITIGATION]. It is also assumed that null-steering capabilities of the AAS technique are utilized to combat intra-network co-channel interference, not for solving inter-network adjacent-channel coexistence. Furthermore, the array is assumed to consist of $\boldsymbol{M} = 4$ antenna elements.

The mix of AAS and regular users is an important factor since regular DL traffic is more likely to contribute to interference than AAS DL traffic.

2.3.6 Input parameters and assumptions

[Editor's note: Depending on input contributions at subsequent meetings, including on system parameters, the structure of the document may be modified.]

Parameters of IMT-2000 systems under study are taken from ITU-R WP 8F Report M.2039. Following table lists parameters of 802.16-2004 OFDM/OFDMA TDD assumed in this analysis, which is a representative OFDM-based broadband system likely to be deployed in the 2 500-2 690 MHz band in several countries.

TABLE 1

Assumption parameters of 802.16-2004 OFDM/OFDMA TDD

	802.16-2004 OFDM/OFDMA TDD	
	Base Station (BS)	**Subscriber Station (SS)**
Deployment scenario	Macro cellular; fixed/nomadic	
Channel bandwidth	5 MHz	
TX power (rms)	36 dBm [1]	24 dBm
ACLR @ 5 MHz	53.5	37
ACLR @ 10 MHz	66	51
ACS @ 5 MHz	70	40
ACS @ 10 MHz	70	59
Antenna gain	18 dBi	8 dBi
Max. tolerable interference power (dBm)	–114 dBm[2]	–112 dBm[2]

1 FCC specifies a maximum 2 KW peak EIRP, which yields 36 dBm rms for an 18 dBi antenna gain and 9 dB back-off.

2 Assuming I/N of -10 dB, and Noise Figure of 3 dB for BS and 5 dB for SS.

[Editor's note: The ACLR values may vary depending on the adjacent system. The assumptions for ACLR values need to be clarified.]

ACLR numbers in the above table are consistent with FCC mask for this band in the United States. The results presented in section 4 of this contribution cover the case where only 802.16 system is complying with the FCC mask as well as the case where both systems are following the FCC mask.

2.3.7 Protection criteria

2.3.8 Results

Interference analyses are done in multiple stages to capture the effects of various parameters on the coexistence. In line with customary method in various standardization bodies, a network of 19 interfering cells surrounding a victim cell was designed to take the worst-case analysis one step closer to the real-world scenarios by including factors such as multi-cell deployment with varying antenna heights, frequency reuse, presence of users, sectorization, adaptive antennas, etc. The scenarios that were analyzed are reported below.

2.3.8.1 Interference from 802.16 TDD into CDMA-DS FDD

A. Network of Omnidirectional cells under worst case conditions

This case is analyzed only as a reference and is the closest situation to the deterministic worst case analysis. It assumes that TDD base stations are transmitting at maximum power and all stations use omnidirectional antennas of the same height above average rooftop level, with frequency reuse of 1:1. It should be noted that omnidirectional antennas typically have smaller gain values than the one in Table 1. Therefore, a gain of 12 dBi was used for the case of omnidirectional antennas.

B. Network of sectorized cells under practical conditions

Missing isolation and percentage of locations with no additional isolation was also calculated for a variety of situations that are more practical than the worst-case scenario. These include:

1) three-sector cells with sectorized antennas;

2) base station heights varying uniformly between 15 to 45 meters;

3) antenna installation heights varying uniformly between 2 to 10 meters above average rooftop level;

4) frequency reuse of 1:1 as well as 1:3;

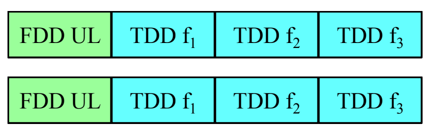
5) effect of beam-forming at the base station.

It is expected that urban environment, in which cells are smaller and user density and cell loading is larger, face more severe problems. Therefore, network of sectorized cells are only reported for the urban environment with cell radius of 1.5 km and ACI_{max} of -114 dBm for the FDD victim.

In case of reuse 1:3, three carriers are being considered, according to figure 3 below, adjacent to uplink carrier of the FDD victim.

FIGURE 3

Frequency arrangement for frequency reuse of 1:3



Results for interference from 802.16 TDD into CDMA-DS FDD

The following table summarizes the results for the case of interference from a network of 802.16 interferers into a single CDMA-DS victim.

TABLE 2

Results for the case of 802.16 TDD BS interference into CDMA-DS FDD BS

		% fully protected locations		Additional isolation required for 98% protection (dB)	
		0 spacing	1 carrier spacing	0 spacing	1 carrier spacing
Omnidirectional network	Reuse 1:1	0%	20.5%	21.5	12.5
	Reuse 1:1, AAS	83.5%	90.5%	14.5	6.5
Sectorized network	Reuse 1:1	3%	68%	24.5	10.5
	Reuse 1:3	64.5%		17.5	

From Table 2 above it can be observed that implementation of mitigation techniques are required to facilitate the coexistence. Referring to findings of previous work in WP 8F on mitigation techniques (Report ITU-R IMT.[MITIGATION]), one can note that addition of channel filters would provide for more than necessary additional isolation required for 98%, or higher, protection. It is, however, necessary that the implication and advantages of other possible mitigation techniques, including network deployment considerations such as cell orientation and antenna height and placement coordination, be included and studied.

2.3.8.2 Interference from CDMA-DS FDD into 802.16 TDD

A. Network of Omnidirectional cells under worst case conditions

Interference into an 802.16 TDD BS from a network of omni-directional FDD BS, all antennas of the same height, is analyzed.

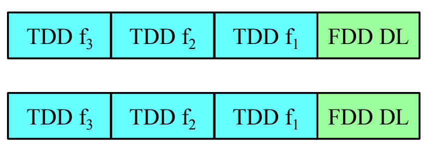
B. Network of sectorized cells under practical conditions

Total interference at a TDD victim BS in a network of 3-sector cells with varying antenna heights in reuse 1:1 condition was analyzed.

In case of reuse 1:3, three carriers are being considered, according to figure 4 below, adjacent to uplink carrier of the FDD victim.

FIGURE 4

Frequency arrangement for frequency reuse of 1:3



The case of an 802.16 TDD BS utilizing beam-forming surrounded by CDMA-DS FDD sectorized base stations of varying height was also analyzed. It is assumed that 90% of the UL traffic is AAS.

Results for interference from CDMA-DS FDD into 802.16 TDD

The following table summarizes the results for the case of interference from a network of CDMA-DS interferers into a single 802.16 victim.

TABLE 3

Results for the case of CDMA-DS BS interference into 802.16 TDD BS

		% fully protected locations		Additional isolation required for 98% protection (dB)	
		0 spacing	1 carrier spacing	0 spacing	1 carrier spacing
Omnidirectional network	standard mask	0%	0%	29.5	24.5
	FCC mask	4%	72.5%	21.5	9.5
	Reuse 1:1 with AAS	70%	82%	21	17.5
	Reuse 1:1, AAS, FCC mask	93.5%	97.5%	9	1.5
Sectorized network	Reuse 1:1	7.5%	34%	25	20
	Reuse 1:1, FCC mask	47.5%	91%	15.7	5.5
	Reuse 1:3	35%		21	
	Reuse 1:3, FCC mask	84%		11.5	

From Table 3 above it can be observed that implementation of mitigation techniques are required to facilitate the coexistence. Referring to findings of previous work in WP 8F on mitigation techniques (Report ITU-R IMT.[MITIGATION]), one can note that addition of channel filters would provide for more than necessary additional isolation required for 98%, or higher, protection. It is, however, necessary that the implication and advantages of other possible mitigation techniques, including network deployment considerations such as cell orientation and antenna height and placement coordination, be included and studied. It is also noted that implementation of FCC-like mask on both systems considerably improves the coexistence situation.

2.3.9 Conclusions

3 System B

Editors note: The structure of this section needs to be aligned with section 2 and the consistency within section 3 needs to be checked editorially.

Editors note: The material within section 3 needs to be further reviewed as the group did not have a chance to review this section in detail.

The 2 500-2 690 MHz band has been identified as an additional spectrum band for IMT-2000. This band has a high priority for CEPT.

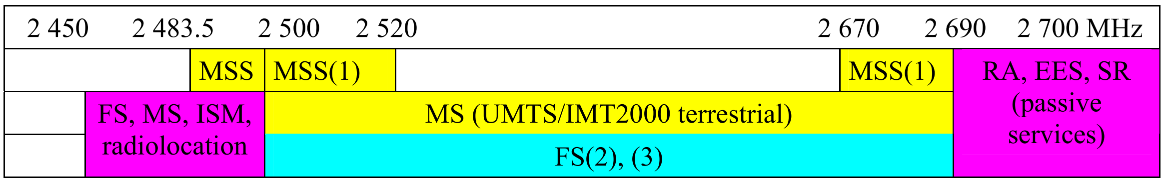
Therefore a first ECC Decision (02)06 on the designation of the band 2 500-2 690 MHz for UMTS/IMT-2000 concludes 1 January 2008 as the date when the band should be made available. The band 2 500-2 690 MHz is the only band available for IMT-2000 (in addition to the 2 GHz core band) in many European countries within a realistic timeframe.

Following this, a second ECC Decision (05)05 on the harmonised utilisation of spectrum for IMT-2000/UMTS operating within the band 2 500-2 690 MHz recently brought details on the arrangements, in line with the revision of Recommendation ITU-R M.1036. This whole band, which was allocated to the terrestrial component of IMT-2000/UMTS, is supposed to be available for IMT-2000/UMTS systems from 1 January 2008, subject to market demand and national licensing schemes.

In Region 1 the band 2 500-2 690 MHz is currently allocated on a primary basis to the fixed service and the mobile service and parts of the band are also allocated to several space services. Figure 1 sums up the allocated services in this band:

FIGURE 2

European frequency plan for the 2.5 GHz band



(1) In the RR the allocation of the frequency bands 2 500-2 520 MHz / 2 670-2 690 MHz to the mobile-satellite service (space-to-Earth) becomes effective on 1 January 2005 and is subject to coordination under No. 9.11A of the RR.

(2) With the introduction of UMTS/IMT-2000, the FS will become secondary in appropriate parts of the band in Europe. Therefore transitional arrangements for the FS may be considered.

(3) Within the band 2 500-2 670 MHz, MMDS is used in certain European countries namely Iceland, Ireland, Latvia and Lithuania. In some of these countries operation within 2 500-2 520 MHz and 2 670-2 690 MHz will be phased out.

This report concentrates on the compatibility studies between IMT2000/UMTS and MMDS (Multipoint Multimedia Distribution System). It uses all relevant parameters needed in interference studies for UMTS and MMDS. It should be noted that the parameters assumed in this report for the IMT-2000 terrestrial system are those of UMTS; other terrestrial IMT-2000 radio interfaces have not been considered. The interference scenarios have been investigated by deterministic and statistical approaches.

This report gives recommendations and guidance on the necessary guard bands between UMTS and MMDS for the development of detailed the spectrum arrangements for UMTS in the band 2 500-2 690 MHz. However, since these recommendations are based on parameters correct at the date of publication, it should be noted that any changes in parameters, for example, in the terrestrial UMTS emission masks, would require the recommendations of this report to be re-considered.

3 Sharing and adjacent band compatibility study methods

3.1 Interference mechanisms

The scenarios considered in these simulations are depicted in Figures 1 and 2 below. Figure 1 shows the interference paths from a terrestrial UMTS UE transmitter into an MMDS receiver (path E1) and from a UMTS base station transmitter into an MMDS receiver (path E2).

FIGURE 1

Interference path E

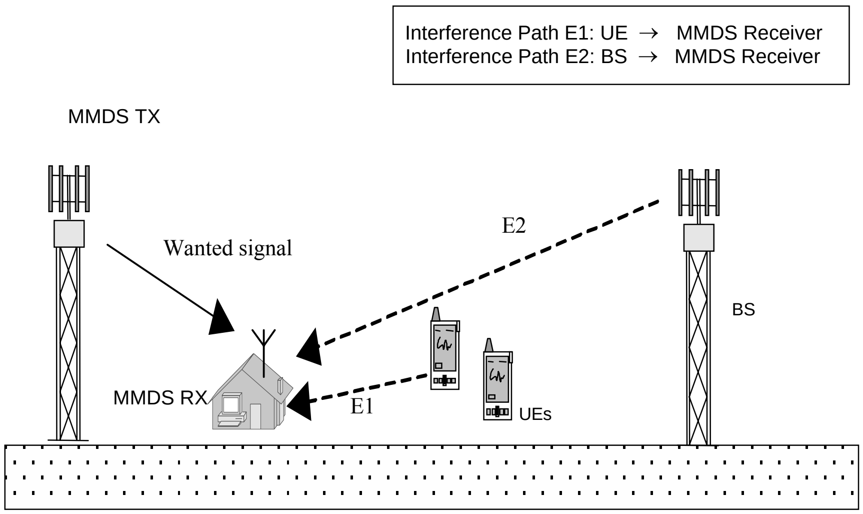
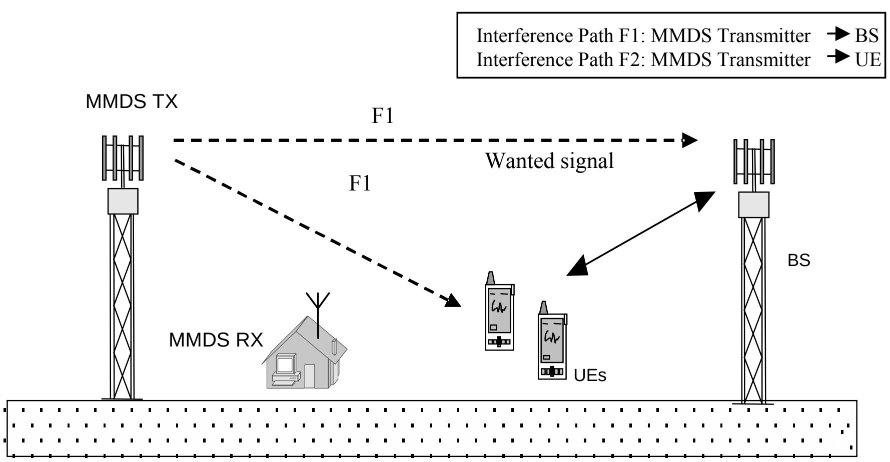


Figure 2 illustrates the interference paths from an MMDS transmitter into a UMTS base station receiver (path F1) and from an MMDS transmitter into a terrestrial UMTS UE. As the MMDS system is unidirectional there is no interference from the MMDS receiver into the UMTS system.

FIGURE 2

Interference path F



3.2 Minimum Coupling Loss (MCL) and Monte Carlo (MC) approaches

Within CEPT, two approaches have been used so far to assess interference between two systems.

The first one, the **Minimum Coupling Loss (MCL)**, allows computation, for a given system (a given set of transmitter and receiver parameters) of the minimum propagation loss (and hence derive the minimum separation distance) and/or the minimum adjacent band isolation (and hence derive the minimum guard band). For 3GPP compliant systems (terrestrial or satellite) operating with the same bandwidth, the adjacent band isolation is expressed by the ACIR, as explained below. It should be noted that the ACIR concept is useful when standard frequency carrier separations of 5, 10 or 15 MHz are envisaged. In the other cases, the use of Tx/Rx spectrum masks is necessary. The MCL between an interfering transmitter (Tx) and a victim receiver (Rx) is defined as:

$$MCL = T_x\,power(dBm/Ref.Bw) + T_x\,antenna\ gain(dBi) + R_x\,antenna\ gain(dBi)$$
$$- R_x\,\mathrm{int}erference\ threshold(dBm/Ref.Bw)$$

In case of minimum separation distance calculation (D_{min}):

$$MCL = Propagation\ model\ \ (D_{\min})$$

In case of minimum guard band calculation ($f_{separation}$):

$$MCL = Propagation\ model\,(D_{\min}) - ACIR(f_{separation})$$

The ACIR is defined as:

$$ACIR = \frac{1}{\dfrac{1}{ACLR} + \dfrac{1}{ACS}} \text{ (in linear terms)}$$

ACLR is the Adjacent Channel Leakage Ratio of the interfering Transmitter (i.e. the out-of-band power ratio falling into the adjacent channel), and ACS is the Adjacent Channel Selectivity (i.e. the power received in the adjacent channel after input filter) of the victim receiver.

However, in UMTS systems, the interference usually results in loss of capacity and/or of coverage. The assessment of the impact of interference therefore requires in some cases a simulation over a large number of transmitters and receivers and MCL may not be adequate to investigate this loss. In addition, MCL does not model power control or dynamic situations, which may be determining for some scenarios as for example those involving User Terminals as a victim.

The second approach is the **Monte Carlo (MC)** simulation, which gives a probability of interference for the given set of parameters and a deployment and power control model.

The acceptable interference probability used in Monte-Carlo studies will depend on the scenario under consideration.

Seamcat MC tool was used in most of the MC simulations presented in that report. The assumptions used in the Monte Carlo simulations are detailed in Annex B**,** and are based on work in ITU-R. Additional information is also included alongside the reported compatibility studies.

It is understood that only one of the approaches described above is not sufficient alone to describe in detail the interference problem, and to conclude on the problem of guard bands. The following points are relevant to the comparison of deterministic and statistical approaches:

- The MCL method is useful for an initial assessment of frequency sharing, and is suitable for fairly “static” interference situations (e.g. fixed links vs mobile base stations). It can however be pessimistic in some cases.

- The Monte-Carlo probabilistic method will generally give more realistic results. It is however complex to implement and will only give accurate results if the probability distributions of all the input parameters are well known.

3.3 Propagation models

The propagation models to be used for deriving the separation distances with MCL as well as with Monte-Carlo approaches are the following:

- For distances < 20 km, the modified Hata-Cost 231 median loss model is used for MCL. Typically this is used for co-located systems e.g. for frequency separation studies. This model is also implemented in SEAMCAT, adding a lognormal fading factor.
- For distances > 20 km, Rec. ITU-R P.452-10 for smooth earth. Typically this is used for non-co-located systems, e.g. for geographic separation.

4 Co-frequency sharing between MMDS and terrestrial UMTS

Interference path	Separation distance required (km)
UMTS UE→MMDS Rx	5
UMTS BS → MMDS Rx	5 pico cell, 25 micro cell, 70 macro cell
MMDS Tx → UMTS BS	5 pico cell, 25 micro cell, 70 macro cell
MMDS Tx → UMTS UE	5

The results show that co-frequency sharing between MMDS and UMTS/IMT-2000 services is feasible but only with relatively large separation distances (up to 70 km for macro cells) to minimise mutual interferences. The simulations indicate that co-frequency sharing may prove to be difficult due to the large separation distances required between the two services. Due to the high front-to-back ratio of MMDS receivers it may be possible to reduce the interference into MMDS receivers for co-channel sharing by ensuring that they are pointing away from UMTS service areas.

5 Adjacent band compatibility between MMDS and terrestrial UMTS

Interference path	Frequency separation required (MHz)
UMTS UE→MMDS Rx	0
UMTS BS → MMDS Rx	20
MMDS Tx → UMTS BS	15
MMDS Tx → UMTS UE	10

The results show that for adjacent channel operation between MMDS and terrestrial UMTS services operating in geographically separate locations a minimum frequency separation of 15 MHz will be necessary for macro and micro cell deployment of UMTS. For pico cell deployment no guard band is necessary. Due to the high front to back ratio of MMDS receivers it may be possible to reduce the interference into MMDS receivers for adjacent channel sharing by ensuring that they are pointing away from UMTS service areas.

6 Glossary and Abbreviations

Co-channel sharing

Co-channel sharing is the case where both system components are operating on the same frequency, but separated geographically.

Adjacent band compatibility

Adjacent band compatibility is the case where both system components are co-located and operate on adjacent frequencies.

ACI_{max}	maximum Adjacent Channel Interference
ACIR	Adjacent Channel Interference Ratio
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
BS	Base Station within terrestrial UMTS
DL	Downlink. In the case of IMT-2000: BS transmit, UE receive
FDD	Frequency Division Duplex
FS	Fixed service
MC	Monte Carlo
MCL	Minimum Coupling Loss
MCS	Minimum Carrier Separation
MMDS	Multipoint multimedia distribution system
MS	Mobile service
TDD	Time Division Duplex
UE	User Equipment within terrestrial UMTS
UL	Uplink. In the case of IMT-2000: UE transmit, BS receive
WP 8F	ITU-R Working Party 8F

System parameters

A.1 UMTS terrestrial system parameters

A.1.1 Base station

The reference document for the parameters of terrestrial system components is Report ITU-R M.2039 [1].

Base station as wanted system

TABLE A.1-1

IMT-2000 base station receive parameters

Cell type	Rural
Antenna type	120 degree sector
Max antenna gain (dBi) including feeder loss	17
Downtilt angle (deg)	2.5
Antenna height (m)	30
Polarisation	Linear
Receiver Noise Figure (dB)	5
Receiver Thermal Noise (dB/W/MHz)	–139
Interference criteria (Isat/Nth) (dB)	–10
Adjacent Channel Selectivity	FDD : TS 25.104 [2] TDD : TS 25.105 [3]

Base station as interfering system

TABLE A.1-2

IMT-2000 base station transmit parameters

Cell type	Rural (FDD)	Vehicular-Macro (FDD)	Pedestrian-Micro (FDD)	Pico-CBD (FDD)	Suburban and Urban (TDD)
Cell size (km)	10	1	0.315	0.04	0.2
Maximum Transmit Power for a 5 MHz channel (dBm) (standards)	43	43	38	27	27
Typical Transmit power for a 5 MHz channel (dBm)	40	40	35	27	27[4]
Operating bandwidth (MHz)	5	5	5	5	5
Antenna type	120 deg sector	120 deg sector	120 deg sector	Omni-directional	Omni-directional
Max antenna gain (dBi) including feeder loss	17	17	5	0	0
Downtilt angle (deg)	2.5	2.5	0	0	0
Antenna height (m)	30	30	5	1.5	1.5
Polarization	Linear	Linear	Linear	Linear	Linear
ACLR	TS 25.104 [2]				25.105 [3]

A.1.2 Mobile station

Mobile station parameters, for all deployments, are given in the tables below.

Mobile station as wanted station

TABLE A.1-3

IMT-2000 mobile station receive parameters

Antenna type	Isotropic
Max antenna gain (dBi)	0
Antenna feed loss (dB)	0
Antenna height (m)	1.5
Polarisation	Linear
Receiver Noise Figure (dB)	9
Receiver Thermal Noise (dB/W/MHz)	–135
Interference criteria (Isat/Nth) (dB)	–10
ACS	FDD : 25.101 [4] TDD : 25.102 [5]

4 Depending on the type of services and the related level of asymmetry, a duty cycle from 0% to 100% has to be added to the typical transmit power when dealing with W-CDMA TDD mode. In the analysis, a 50% duty cycle is assumed, giving reduction in the typical transmitter power of 3 dB.

Mobile station as interfering station:

TABLE A.1-4

IMT-2000 mobile station transmit parameters

Maximum Transmit power (dBm)	21 or 24			
Average Transmit Power (dBm) in FDD (from [6])	Rural	Vehicular-macro	Pedestrian -micro	Pico-CBD
	8.3 dBm	7.5 dBm	6.6 dBm	-2.5 dBm
Average Transmit Power (dBm) in TDD (from [7])	1.6 dBm (including 50% activity factor)			
Operating bandwidth (MHz)	5			
Antenna type	Isotropic			
Max antenna gain (dBi)	0			
Antenna feed loss (dB)	0			
Antenna height (m)	1.5			
Polarisation	Linear			
ACLR	FDD : 25.101 [4] TDD : 25.102 [5]			

A.1.3 Traffic characteristics

Table 4 of [1] gives IMT-2000 Traffic Model Characteristics for a Mature deployment scenario. Some of these characteristics are key parameters when modelling interference from UMTS-T uplinks (MS transmitting) into UMTS-S systems. They are summarised in Table A.1-5 and Table A.1-6.

TABLE A.1-5

Terrestrial parameters in FDD

Average number of UE/cell	Macro – rural	0.3 users/cell
	Macro- vehicular	7 users/cell
	Micro-pedestrian	65 users/cell
	Pico – In-building	2 users/cell
Cell range	Macro – rural	10 km
	Macro- vehicular	1 km
	Micro-pedestrian	315 m
	Pico – In-building	40 m
Percentage of terrestrial surface	Macro – rural	57%
	Macro- vehicular	2%
	Micro-pedestrian	2%
	Pico – In-building	0.02%
	No coverage	38.98%

TABLE A.1-6

Terrestrial parameters in TDD

Coverage	Urban and suburban indoor
Average number of UE/cell	53.42 users/cell
Cell range	200 m
Percentage of terrestrial surface	30% of urban and suburban, indoor deployment as described in Table A.1-5

A.2 MMDS system parameters

The system parameters for MMDS are listed in the table below

TABLE A.2-1

MMDS Parameters

Transmission parameters	
EIRP max	22 dBW = 52 dBm
Tx antenna gain (omnidirectional)*	0 dBi
Effective Tx antenna height	200 meters
Noise Floor	–102 dBm
Emission mask (compliant with ETSI EN 300 744)	Attenuation of at least 60 dB at 1 MHz outside the channel range
Reception parameters	
Effective Rx antenna Height	20 meters
Rx antenna max gain (directional) Front to back ratio	22 dBi 20 dB
C/I	25 dB
Receiver Sensitivity	–77 dBm
Receiver Blocking Response	25 dB
Other parameters	
Cell Radius	16 km – 40 km
Propagation Model	ITU-R 1546
Bandwidth	8 000 kHz

Editors note. * The Tx antenna gain Isotropic to provide the worst case scenario.

A.3 References in Annex A

[1] Report ITU-R M.2039: Characteristics of terrestrial IMT-2000 systems for frequency sharing / interference analyses, Geneva 2003.

[2] 3GPP 25.104 v530: Technical Specification Group Radio Access Networks; BS Radio Transmission and Reception (FDD).

[3] 3GPP 25.105 v510: Technical Specification Group Radio Access Networks; BS Radio Transmission and Reception (TDD).

[4] 3GPP 25.101 v530: Technical Specification Group Radio Access Networks; UE Radio Transmission and Reception (FDD).

[5] 3GPP 25.102 v510: Technical Specification Group Radio Access Networks; UE Radio Transmission and Reception (TDD).

[6] ECC Report 65: Adjacent band compatibility between UMTS and other services in the 2 GHz band.

[7] Document ECC PT1(03)024: First results of sharing and adjacent band compatibility studies between the terrestrial and satellite components of IMT-2000 in the 2.5 GHz band.

Detailed analysis of MMDS

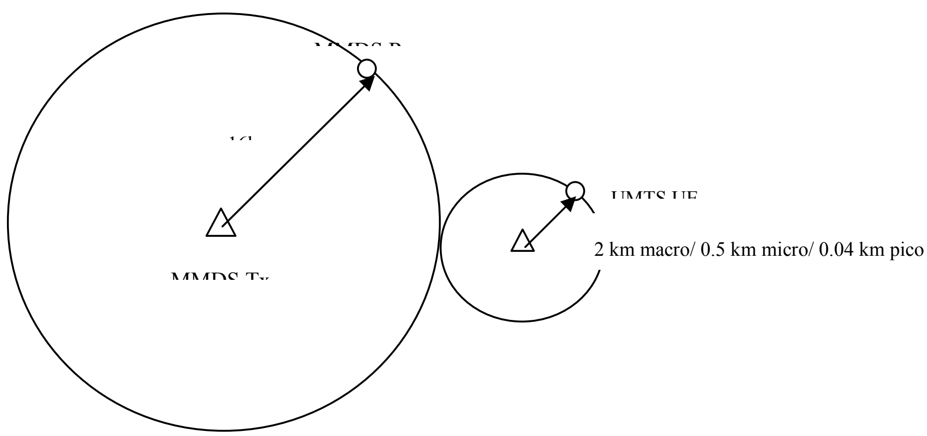
B.1 Adjacent channel results

The assumption has been made that the 2.5 GHz band will only be used in Ireland in urban areas for UMTS/IMT-2000 services while MMDS is predominantly used in rural areas. So in this study, adjacent channel sharing is considered in the cases where MMDS and UMTS/IMT-2000 FDD systems were operating in geographically separate locations.

Figure D.1 below is a representation of the two services operating in separate locations. An MMDS system can have cell sizes ranging from 16 km to 40 km radii, for these studies the 16 km radius was chosen as it represents a worst case scenario with the MMDS transmitter closest to the UMTS cell.

FIGURE D.1

Representation of an MMDS and UMTS systems service areas operating in geographically separate locations



B.1.1 Interference Path E1

There is no interference measured from the UMTS UE transmitting into the MMDS receiver. This is because the MMDS receiver blocking response plus C/I ratio is greater than the power emitted from the UMTS UE.

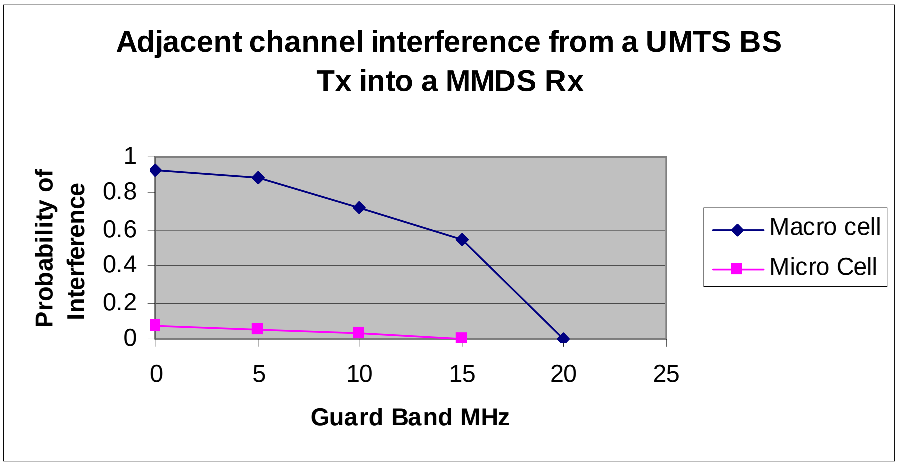
B.1.2 Interference Path E2

Figure D1.2 shows the results of interference simulations from a UMTS base station into a MMDS receiver for macro cell deployment. It can be seen that for MMDS and UMTS systems to operate in geographically separated locations a guard band of 20 MHz is required between the two systems for the macro cell deployment scenario and at least 15 MHz is required between the two systems for the micro cell deployment scenarios. For pico cell deployment of UMTS no guard band is necessary due to the low power levels from the pico cell transmitters compared to the MMDS receiver blocking and wanted received signal the MMDS receiver.

There is no interference from a UMTS base station into a MMDS receiver for pico cell deployment.

FIGURE D.1.2

Probability of adjacent channel interference from a UMTS base station Transmitter into a MMDS receiver

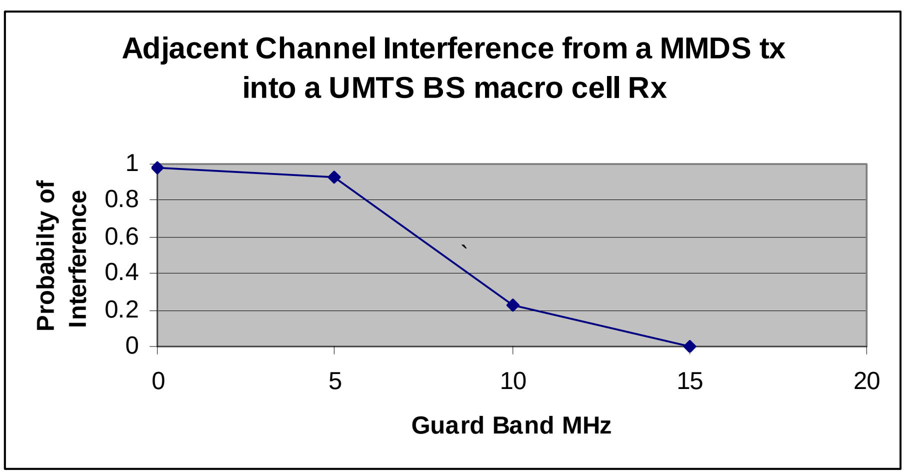


B.1.3 Interference path F1

Figure D.1.3 below shows the probability of interference from a MMDS transmitter into a UMTS base station receiver for macro cell deployment. It shows that a guard band of 15 MHz would be required to ensure no interference between the two systems. The SEAMCAT model did not show any interference into either a micro or pico cell from a MMDS transmitter. This is due to the lower antenna gain and height of the micro and pico cell receivers compared to the UMTS macro cell antenna.

FIGURE D.1.3

Probability of adjacent channel interference from a MMDS transmitter into a UMTS base station receiver

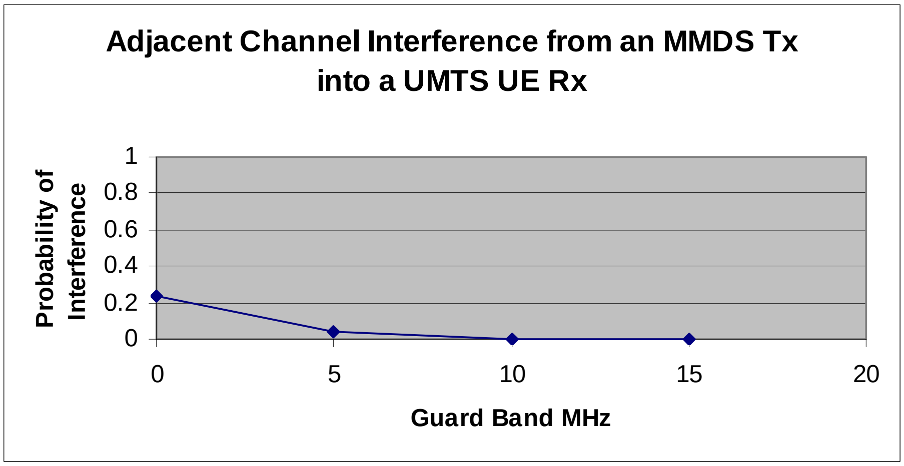


B.1.4 Interference path F2

Figure B.1.4 below shows the interference from a MMDS transmitter into a UMTS UE. It indicates that a guard band of 10 MHz would be required to prevent interference between the two systems.

FIGURE B.1.4

Probability of adjacent channel interference from a MMDS transmitter into a UMTS UE receiver



B.2 Co-frequency interference results

The co-frequency simulations investigated the possibility of both MMDS and UMTS/IMT-2000 services sharing the whole of the 2 520-2 670 MHz band and relying mainly on geographical separation to facilitate co-frequency usage.

B.2.1 Interference paths E1 and E2

FIGURE B.2.1-1

Probability of co- channel interference from a UMTS UE transmitter into a MMDS receiver

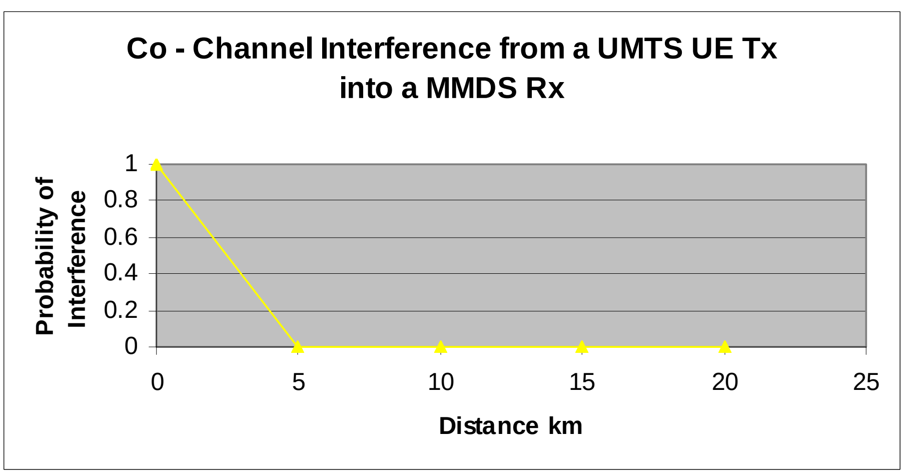
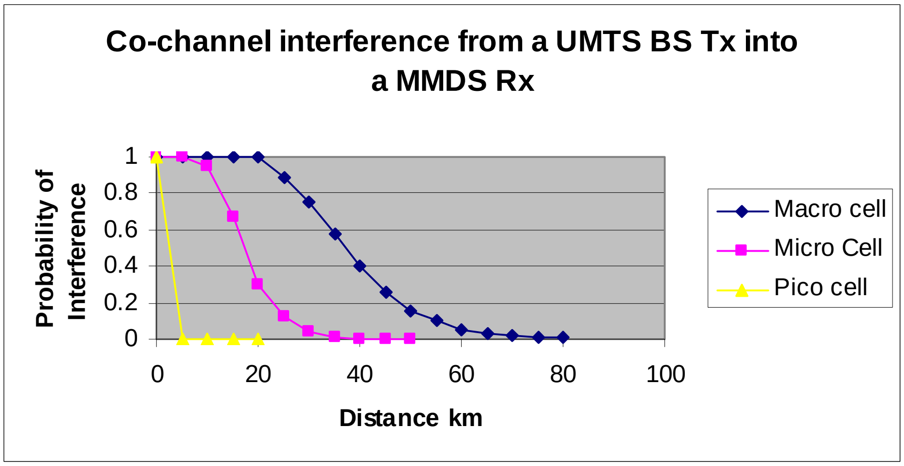


FIGURE B.2.1-2

Probability of co- channel interference from a UMTS base station transmitter into a MMDS receiver



B.2.2 Interference paths F1 and F2

FIGURE B.2.2-1

Probability of co- channel interference from a MMDS transmitter into a UMTS base station

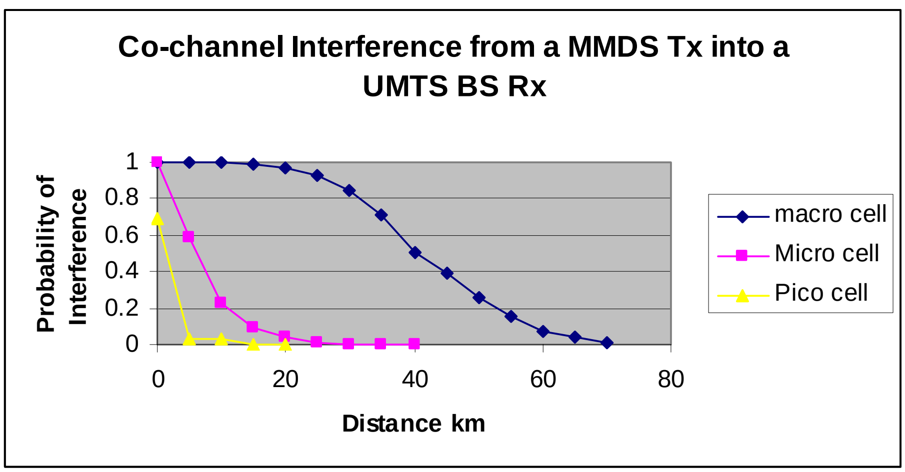
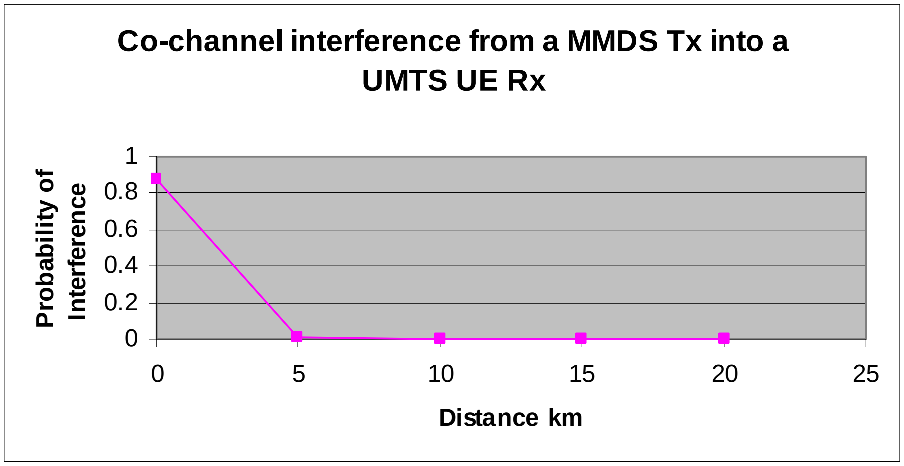


FIGURE B.2.2-2

Probability of co- channel interference from a MMDS Transmitter into a UMTS UE



The figures above show that in co-frequency scenarios the separation distances[5] required to prevent interference would be as follows:

- 5 km separation distance would be required to prevent interference from a UMTS UE transmitting into a MMDS receiver;
- 70 km separation distance between a UMTS base station transmitter and a MMDS receiver for macro cell deployment, 25 km for micro cell deployment and 5 km for pico cell deployment;
- 70 km separation distance would be required between a MMDS transmitter and a UMTS base station receiver, 25 km for micro cell deployment and 5 km for pico cell deployment;
- 5 km separation distance would be required between a MMDS transmitter and a UMTS UE receiver.

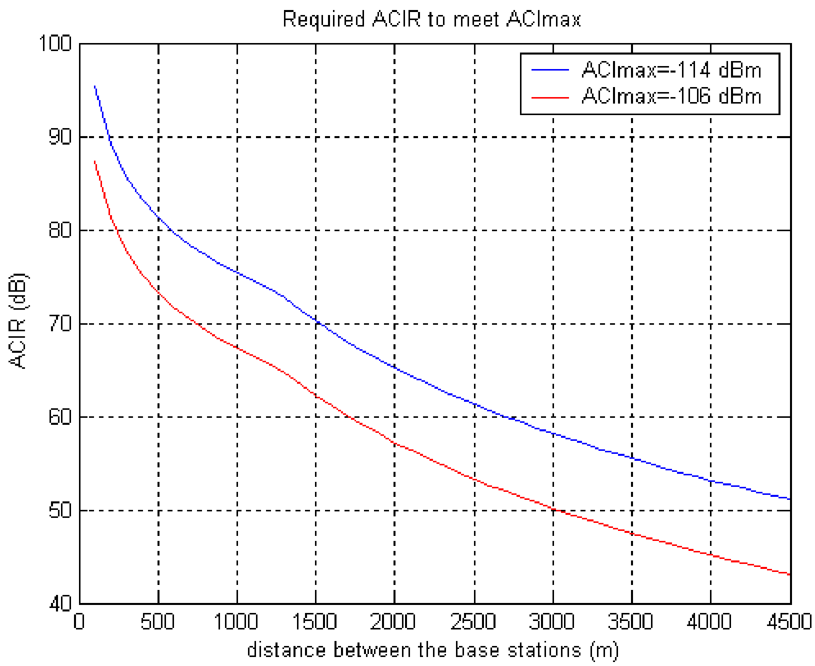
4 Mitigation techniques and their impacts

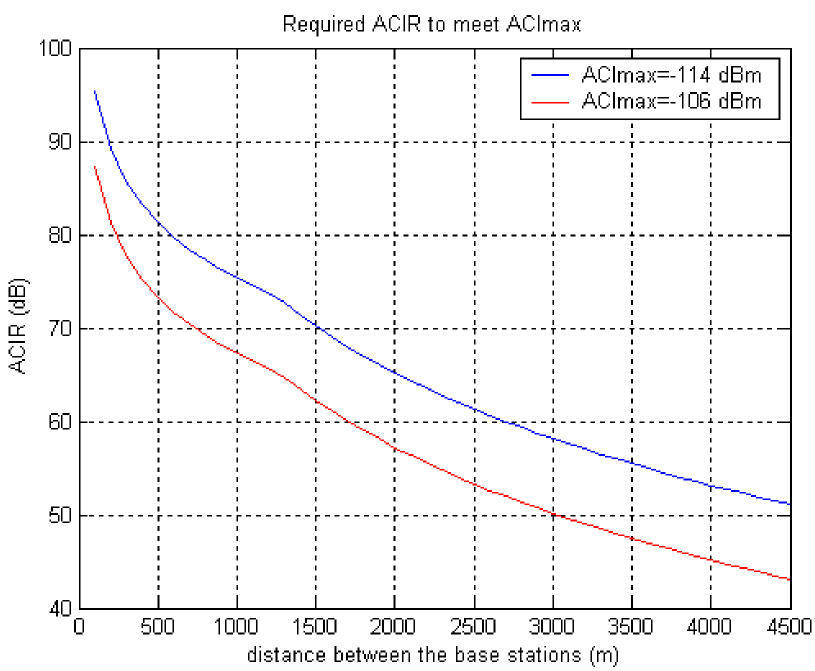
One of the interference mitigation techniques presented and discussed in Report ITU-R IMT.[MITIGATION] is the effect of better filters that would yield to better ACLR and ACS values. Specifically, it is evident from the BS-BS deterministic calculations that the worst-case separation distance is limited by the ACIR value. It is possible to alternatively calculate the required ACIR to achieve safe operation at a given separation distance as depicted below.

[5] Separation distances in this case are the required distances between cell centres.

FIGURE 5

ACIR vs separation distance





As seen in Figure 4, in order to achieve safe separation distance of less than 1.5 km, an ACIR of greater than 70 dB is required for target Maximum Adjacent Channel Interference (ACI_{max}) of –114 dBm. This is clearly not achievable with current IMT-2000 FDD specifications (ACS=46 dB). It is, however, expected that actual deployments of IMT-2000 systems use more selective transmitter masks with tighter out-of-band emission levels than what is currently specified.

If IMT-2000 FDD systems deploy more selective receiver filters, the coexistence situation would improve. To show the effect of ACS on coexistence, assuming an ACS of 70 dB would yield the following.

$$ACIR = 68.2 \text{ dB}$$

$$L_{req} = P + G_A - \text{Misc. Losses} - ACIR - ACI_{max} = 33 + 33 - 4 - 68.2 - (-114) = 107.8 \text{ dB}$$

The required path loss, L_{req}, is achieved at a separation distance of

$$D = 1\,678 \text{ m.}$$

This distance, in the order of the assumed cell radius for urban deployments of IMT-2000, presents a manageable coexistence situation, which could be handled through site-specific mitigation techniques for separation distances less than 1 678 meters, and requires no mitigation technique for larger separations.

Other mitigation techniques including the ones described in Report ITU-R IMT.[MITIGATION], need to be also considered and analyzed.

Conclusions and guidelines

[Editors note: New Header for Annexure. The material in the annexes in Doc. 8F/597 needs to be studied further & specifically we need to determine how much is included and how much can be normatively referenced consistent with the scope of this report.] [*Editors note this section to be reviewed after the results have been completed.]* [Editor's note: Material in annex A - F has not been reviewed yet.]

[Annex A

Propagation Models

A.1 BS-to-MS Propagation Model

When computing the worst-case condition, ie, that with minimum coupling loss (MCL), line-of - sight conditions are assumed. In this case, we find the point at which the combination of the BS antenna gain and free-space path loss have a minimum. Free-space path loss, L_{free}, is given by [12]

$$L_{free}(\text{dB}) = 20 \cdot \log f + 20 \cdot \log d + 32.44\,, \qquad \text{(A.1)}$$

where f is the operating frequency in megahertz and d is the distance in kilometers between the transmitting and receiving antennas.

For points other than the worst case locations in our interference analysis, we opted to use the propagation models defined by ETSI, as documented in Reference [10]. The vehicular and pedestrian propagation models are characterized by the following equations [10].

$$L_{Veh}(dB) = 40 \cdot (1 - 4 \times 10^{-3} \Delta h_{BS}) \cdot \log(d) - 18 \cdot \log(\Delta h_{BS}) + 21 \cdot \log f + 80\,, \qquad \text{(A.2)}$$

$$L_{Ped}(dB) = 40 \cdot \log(d) + 30 \cdot \log f + 49\,, \qquad \text{(A.3)}$$

where Δh_{BS} (specified in meters) is the difference between the BS antenna height and the average building height. In the analysis, the average building height is set to 24m and d (specified in kilometers) is the horizontal distance between the BS and the MS. f is the operating frequency in megahertz, which is set to 2 600 MHz. For the indoor propagation model, the following equation is used [10].

$$L_{Indoor}(dB) = 37 + 30 \cdot \log(d) + 18.3 \cdot n^{((n+2)/(n+1)-0.46)}, \tag{A.4}$$

where d is the distance between the MS and the BS in meters, and n is the number of floors in the transmission path.

A.2 BS-to-BS Propagation Models

For evaluating the path loss between a CDMA-DS macrocellular BS and a WiMAX TDD macrocellular BS that were not co-sited, we evaluated the worst-case scenario, in which a line-of-sight (LOS) path existed between the two BSs. This was considered to be the worst-case since it produced the highest level of ACI to each BS. In order to model this, we used the free space propagation model defined in equation A.1.

In the case of co-sited BSs, we used a coupling loss of 30 dB, which was approximately the minimum value measured by Allgon in its antenna isolation tests [13]. This value was also used in the ITU report on the co-existence of different networks [9].

For the path loss evaluation between the macrocellular WiMAX TDD BS and microcellular CDMA-DS BS when they were not co-sited, we used the vehicular model defined by Equation (A.2), which was also the assumption used in the ITU report on co-existence [9]. For the case in which the two BSs were co-sited but the antennas were located at different heights, a minimum coupling loss value was assumed, which will be explained in the subsequent relevant annexes.

Similarly, the outdoor-to-indoor model characterised by Equation (A.3) was used to calculate the path loss between a CDMA-DS picocellular BS and a WiMAX TDD macrocellular BS that were not co-sited [9]. For the co-sited case, the same coupling loss assumed for the macrocellular to microcellular situation was assumed, but a value of 10 dB was added to account for the building penetration loss [5].

A.3 MS-to-MS Propagation Models

In order to evaluate the interference between two MSs, a free space path loss model, given by equation A.1, was used for small separations. In the case of larger separations, the outdoor to indoor model was used when both MSs were located outdoors. Similarly, when both MSs were located indoors, the indoor propagation office model based on Equation (A.4) was used.

Annex B

Interference Analysis between BSs

This annex provides the interference analysis between a WiMAX TDD BS and a CDMA-DS BS. The ACLR and ACS values used for the CDMA-DS BS are identical to those used in a similar ITU report for co-existence study [9]. Similarly, the ACLR and ACS values for the WIMAX TDD BS are obtained from a set of RF parameters specified by the WiMAX Forum [11].

B.1 Interference Analysis between BSs in a CDMA-DS Macrocellular and WiMAX TDD Macrocellular Deployment

For co-sited BSs, we assumed a coupling loss value of 30 dB between co-sited antennas, which was also a value measured by Allgon [13] for horizontally separated antennas. Using the ACIR values listed in Table 4 and the maximum interference limits shown in Table 5, we calculated the additional isolation needed for the two BSs to co-exist. The additional isolation needed when the interference is generated from a TDD BS to a FDD BS is shown in Table 20. Similarly, the additional isolation needed when the interference is generated from a FDD BS to a TDD BS is shown in Table 21.

TABLE 20

Analysis for co-sited macrocellular BSs, where the FDD BS is the interference victim

	First Adjacent Channel at 5 MHz	**Second Adjacent Channel at 10 MHz**
Transmit Power (dBm)	36	36
Minimum Coupling Loss (dB)	30.0	30.0
ACIR (dB)	45	57
Interference Power at Receiver Input (dBm)	-39.0	-51.0
Allowed Interference Power (dBm)	-109.0	-109.0
Additional Isolation Needed (dB)	70.0	58.0

TABLE 21

Analysis for co-sited macrocellular BSs, where the TDD BS is the interference victim

	First Adjacent Channel at 5 MHz	**Second Adjacent Channel at 10 MHz**
Transmit Power (dBm)	43	43
Minimum Coupling Loss (dB)	30.0	30.0
ACIR (dB)	45	50
Interference Power at Receiver Input (dBm)	-32.0	-37.0
Allowed Interference Power (dBm)	-110.0	-110.0
Additional Isolation Needed (dB)	78.0	73.0

From this analysis, we can infer that in order for the BSs to be co-sited, an additional 73 dB of isolation is needed for the second adjacent channel (a guard band of 5 MHz). Therefore, with equipment that just conforms to the standards, it is not feasible to co-site a WiMAX BS and a CDMA-DS BS unless additional isolation is attained between the BSs.

When the BSs are not co-sited but separated by some distance, the path loss between the two BSs can be evaluated using the propagation models that were defined in Annex A. For example, with a BS-to-BS separation of 1,000 m, the path loss between two isotropic antennas is 100.7 dB, assuming free space path loss and an operating frequency of 2.6 GHz. This represents a worst-case scenario, in which a LOS path exists between the two BSs. By incorporating the effect of the transmitting and receiving antennas to produce an effective antenna gain of 35 dBi, the coupling loss between the two antennas decreases to 65.7 dB. By taking into account the ACIR and a transmit power of 36 dBm, the interference powers resulting from ACI at the FDD BS receiver are −74.7 dBm and −86.7 dBm for offsets of 5 MHz and 10 MHz, respectively. Consequently, based on an allowed interference level of −109 dBm for the CDMA-DS receiver, the additional isolations needed at frequency separations of 5 MHz and 10 MHz are 34.3 dB and 22.3 dB, respectively. The corresponding values for the additional isolation needed for different BS-to-BS separation distances are listed in Table 22, where the FDD BS is the interference victim. Similarly, Table 23 shows the additional isolation needed given that the TDD BS is the interference victim.

TABLE 22

Analysis when the macrocellular BSs are not co-sited, where the FDD BS is the interference victim

Distance (m)	Transmit Power (dBm)	Path Loss (dB)	Effective Antenna Gain (dBi)	ACIR (dB)		ACI at the Receiver (dBm)		Additional Isolation (dB)	
				5 MHz	10 MHz	5 MHz	10 MHz	5 MHz	10 MHz
10.0	36	60.7	35	45	57	-34.7	-46.7	74.3	62.3
50.0	36	74.7	35	45	57	-48.7	-60.7	60.3	48.3
100.0	36	80.7	35	45	57	-54.7	-66.7	54.3	42.3
500.0	36	94.7	35	45	57	-68.7	-80.7	40.3	28.3
1000.0	36	100.7	35	45	57	-74.7	-86.7	34.3	22.3

TABLE 23

Analysis when the macrocellular BSs are not co-sited, where the TDD BS is the interference victim

.Distance (m)	Transmit Power (dBm)	Path Loss (dB)	Effective Antenna Gain (dBi)	ACIR (dB)		ACI at the Receiver (dBm)		Additional Isolation (dB)	
				5 MHz	10 MHz	5 MHz	10 MHz	5 MHz	10 MHz
10.0	43	60.7	35	45	50	-27.7	-32.7	82.3	77.3
50.0	43	74.7	35	45	50	-41.7	-46.7	68.3	63.3
100.0	43	80.7	35	45	50	-47.7	-52.7	62.3	57.3
500.0	43	94.7	35	45	50	-61.7	-66.7	48.3	43.3
1000.0	43	100.7	35	45	50	-67.7	-72.7	42.3	37.3

From this analysis we conclude that, with equipment that just conforms to the standards, it is unlikely to be possible to use a macrocellular WiMAX TDD BS in the same area as a macrocellular CDMA-DS BS if LOS path exists between the two antennas and each site is in the main beam of the other site's antenna (ie, a worst case scenario). If the BSs are separated by 1 km and they operate on radio channels that are separated by 10 MHz (ie, the second adjacent channel), then the adjacent channel interference could be tolerated if the isolation between the two BSs could be increased by 22.3 dB. Furthermore, the additional isolation needed is increased to 37.3 dB if the interference victim is the TDD BS.

B.2 Interference Analysis between BSs in a CDMA-DS Microcellular and WiMAX TDD Macrocellular Deployment

In this section we analyze the interference between a TDD macrocell and a FDD microcell when the two BSs are co-sited. We assumed that the WiMAX TDD BS antenna was mounted at a height of 30 m and the CDMA-DS BS antenna was mounted above the ground at a height of 6 m, giving an antenna separation of 24 m. For this analysis, we needed to set a value for the minimum coupling loss between the two antennas. The coupling loss for this arrangement was measured by Allgon [13], suggesting that a vertical separation of 6 m between two co-sited antennas would provide a coupling loss of approximately 65-70 dB. The additional loss due to increasing the separation from 6 m to 24 m would be 12 dB assuming free space propagation. Hence, we opted to use a value of 77 dB to represent the coupling loss provided by a vertical separation distance of 24 m.

The results indicate that in order for a TDD macrocell and FDD microcell to be co-sited, additional isolation levels of 26 dB and 21 dB are needed for frequency separations of 5 MHz and 10 MHz, respectively.

TABLE 24

Analysis of the ACI from a TDD macrocellular BS to a co-sited FDD microcellular BS

	First Adjacent Channel at 5 MHz	**Second Adjacent Channel at 10 MHz**
Transmit Power (dBm)	36	36
Coupling Loss (dB)	77.0	77.0
ACIR (dB)	45	57
Interference Power at Receiver Input (dBm)	-86.0	-98.0
Allowed Interference Power (dBm)	-109.0	-109.0
Additional Isolation Needed (dB)	23.0	11.0

TABLE 25

Analysis of the ACI from a FDD microcellular BS to a co-sited TDD macrocellular BS

	First Adjacent Channel at 5 MHz	**Second Adjacent Channel at 10 MHz**
Transmit Power (dBm)	38	38
Coupling Loss (dB)	77.0	77.0
ACIR (dB)	45	50
Interference Power at Receiver Input (dBm)	-84.0	-89.0
Allowed Interference Power (dBm)	-110.0	-110.0
Additional Isolation Needed (dB)	26.0	21.0

For BSs that are not co-sited, the path loss between the BSs was evaluated using the UMTS vehicular model described in Annex A which was also used in the ITU study on co-existing networks [9]. We assumed that the two BS antennas were aligned to give the minimum coupling loss (worst-case scenario), which provides an effective antenna gain of 23 dBi (18 + 5). The results of our calculation for different BS-to-BS separations are listed in Table 26 and Table 27. Negative isolation values in these tables imply that the interference level is acceptable at the receiver and that no additional isolation is needed. The results of our analysis indicate that it is possible to operate at BS-to-BS separation distances of 500 m and 1,000 m without requiring additional BS-to-BS isolation.

TABLE 26

Analysis of the ACI from a TDD macrocellular BS to a FDD microcellular BS for different separation distances

Distance (m)	Transmit Power (dBm)	Path Loss (dB)	Effective Antenna Gain (dBi)	ACIR (dB)		ACI at the Receiver (dBm)		Additional Isolation (dB)	
				5 MHz	10 MHz	5 MHz	10 MHz	5 MHz	10 MHz
10.0	36	59.6	23	45	57	-45.6	-57.6	63.4	51.4
50.0	36	86.9	23	45	57	-72.9	-84.9	36.1	24.1
100.0	36	98.7	23	45	57	-84.7	-96.7	24.3	12.3
500.0	36	126.0	23	45	57	-112.0	-124.0	-3.0	-15.0
1000.0	36	137.7	23	45	57	-123.7	-135.7	-14.7	-26.7

TABLE 27

Analysis of the ACI from a FDD microcellular BS to a TDD macrocellular BS for different separation distances

Distance (m)	Transmit Power (dBm)	Path Loss (dB)	Effective Antenna Gain (dBi)	ACIR (dB)		ACI at the Receiver (dBm)		Additional Isolation (dB)	
				5 MHz	10 MHz	5 MHz	10 MHz	5 MHz	10 MHz
10.0	38	59.6	23	45	50	-43.6	-48.6	66.4	61.4
50.0	38	86.9	23	45	50	-70.9	-75.9	39.1	34.1
100.0	38	98.7	23	45	50	-82.7	-87.7	27.3	22.3
500.0	38	126.0	23	45	50	-110.0	-115.0	0.0	-5.0
1000.0	38	137.7	23	45	50	-121.7	-126.7	-11.7	-16.7

B.3 Interference Analysis between BSs in a CDMA-DS Picocellular and WiMAX TDD Macrocellular Deployment

In this deployment scenario, for the case in which BSs are co-sited, we must determine a minimum coupling loss between the two antennas for a vertical separation distance of 28.5 m (the macrocellular and picocellular antennas are 30 m and 1.5 m above the ground, respectively). Consequently, we would expect a coupling loss of 79 dB outdoors. In order to take into account the indoor location of the picocellular antenna, we added a building penetration loss of 10 dB to this value. This gave us a minimum coupling loss of 89 dB. The results of our analysis are listed in Table 28 and Table 29, which indicate the additional isolation needed for the two BSs to operate in a co-sited manner.

TABLE 28

Analysis of the ACI from a TDD macrocellular BS to a co-sited FDD picocellular BS

	First Adjacent Channel at 5 MHz	**Second Adjacent Channel at 10 MHz**
Transmit Power (dBm)	36	36
Coupling Loss (dB)	89	89.0
ACIR (dB)	45	57
Interference Power at Receiver Input (dBm)	-98.0	-110.0
Allowed Interference Power (dBm)	-109.0	-109.0
Additional Isolation Needed (dB)	11.0	-1.0

TABLE 29

Analysis of the ACI from a FDD picocellular BS to a co-sited TDD macrocellular BS

	First Adjacent Channel at 5 MHz	**Second Adjacent Channel at 10 MHz**
Transmit Power (dBm)	24	24
Coupling Loss (dB)	89.0	89.0
ACIR (dB)	45	50
Interference Power at Receiver Input (dBm)	-110.0	-115.0
Allowed Interference Power (dBm)	-110.0	-110.0
Additional Isolation Needed (dB)	0.0	-5.0

In this section, for the case in which the BSs are not co-sited, the path loss was calculated based on the UMTS outdoor-to-indoor model described in Annex A, which was also used in the ITU study on co-existing networks [9]. We also assumed an effective antenna gain value of 18 dBi, which was the summation of the maximum gains of the two antennas. The results of our analysis for the various separation distances are given in Table 30 and Table 31. Based on the results, it is possible to operate a TDD macrocell and a FDD picocell with separation distances of 500 m and 1,000 m without requiring additional BS-to-BS isolation.

TABLE 30

Analysis of the ACI from a TDD macrocellular BS to a FDD picocellular BS for different separation distances

Distance (m)	Transmit Power (dBm)	Path Loss (dB)	Effective Antenna Gain (dBi)	ACIR (dB)		ACI at the Receiver (dBm)		Additional Isolation (dB)	
				5 MHz	10 MHz	5 MHz	10 MHz	5 MHz	10 MHz
10.0	36	71.4	18	45	57	-62.4	-74.4	46.6	34.6
50.0	36	99.4	18	45	57	-90.4	-102.4	18.6	6.6
100.0	36	111.4	18	45	57	-102.4	-114.4	6.6	-5.4
500.0	36	139.4	18	45	57	-130.4	-142.4	-21.4	-33.4
1000.0	36	151.4	18	45	57	-142.4	-154.4	-33.4	-45.4

TABLE 31

Analysis of the ACI from a FDD picocellular BS to a TDD macrocellular BS for different separation distances

Distance (m)	Transmit Power (dBm)	Path Loss (dB)	Effective Antenna Gain (dBi)	ACIR (dB)		ACI at the Receiver (dBm)		Additional Isolation (dB)	
				5 MHz	10 MHz	5 MHz	10 MHz	5 MHz	10 MHz
10.0	24	71.4	18	45	50	-74.4	-79.4	35.6	30.6
50.0	24	99.4	18	45	50	-102.4	-107.4	7.6	2.6
100.0	24	111.4	18	45	50	-114.4	-119.4	-4.4	-9.4
500.0	24	139.4	18	45	50	-142.4	-147.4	-32.4	-37.4
1000.0	24	151.4	18	45	50	-154.4	-159.4	-44.4	-49.4

Annex C

Interference Analysis between BSs and MSs

In this section we examine the interference between BSs and MSs operating within macrocellular, microcellular and picocellular systems. A recent CDMA-DS and UTRA TDD co-existence study by the ITU [9] using a Monte Carlo simulation concluded that BS-to-MS interference had minimal impact on the capacity of the network. The results of the study reflected an ‘average’ network performance, which may not highlight certain scenarios in which the performance degradation due to ACI is severe. Hence, in our BS-MS analysis, we concentrate on a selection of scenarios that may have a severe impact on the ACI performance. We note that these are worst-case isolated scenarios, which are not representative of average network behaviour.

In FDD and TDD systems the MSs use power control to compensate for path loss variations. When CDMA-DS and WiMAX BSs are co-sited, the power levels received from MSs on adjacent channels are similar to those received on the desired channel, so the adjacent channel rejection is essentially sufficient. Furthermore, for adjacent FDD systems, co-siting is the optimum solution to mitigate against ACI, ie, BS-MS and MS-BS interference. Subsequently, in this BS-MS analysis we focus only on scenarios involving BSs that are not co-sited.

When BSs are not co-sited, an analytical approach becomes more difficult due to the variation of the power transmitted and received at the BS and MS, which is dependent on the relative positions of the BS and MS. This type of scenario is best analyzed using computer simulations. However, in the subsequent sections of this annex, we present a simple analytical model to highlight specific scenarios that may have an impact on the performance of two co-existing systems.

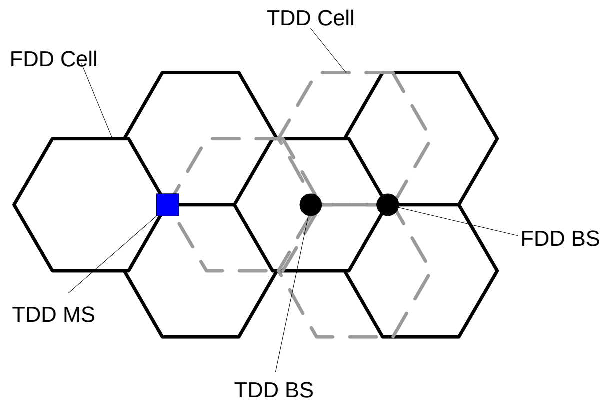
It should be noted that the interference suffered by FDD BS receivers from adjacent channel TDD MS transmissions, as well as the interference suffered by FDD MS receivers from adjacent channel TDD BS transmissions (at either end of the TDD band) is essentially the same interference that arises when uncoordinated CDMA-DS systems use adjacent FDD carriers, and ‘dead zones’ in the BS coverage are created.

C.1 Interference Analysis between BSs and MSs in a CDMA-DS Macrocellular and WiMAX TDD Macrocellular Deployment

In Figure 1, a potential scenario is presented, with a separation between the FDD and TDD BSs of 500 m. With this arrangement it is possible for the TDD MS to be operating at its cell boundary and to be located very close to the FDD BS (marked by the blue square in Figure 1). In this situation the FDD BS experiences worst-case uplink interference from the TDD MS, which is transmitting at maximum power because it is at the cell edge of its serving BS.

FIGURE 1

Macrocellular layout with 500 m offset between the FDD and TDD BSs



In order to analyze this scenario with the MS located very close to the BS, we needed to establish a minimum coupling loss between the BS antenna and the MS antenna. For the purposes of this investigation we based our analysis on the characteristics of the Andrew DB980G65N-R antenna, which is a 2,550 MHz antenna with a gain of 17.6 dBi, a horizontal 3 dB beamwidth of 65° and a vertical 3 dB beamwidth of 7.5°. We also assumed a macrocellular antenna height of 30 m and a MS height of 1.5 m. By taking the vertical gain characteristics of the antenna, we calculated the coupling loss for all vertical angles and the corresponding horizontal distance between the MS and BS. This provided us with a set of coupling loss values, the minimum value being our assumed minimum coupling loss. From this investigation, we derived a minimum coupling loss of 73.4 dB, for the FDD MS antenna with a gain of 0 dBi, and 67.4 dB for the TDD MS antenna with a gain of 6 dBi. The resulting calculation of the additional isolation needed for the different BS-to-MS interference scenarios is shown in Table 32. Note that the additional isolation is calculated based on a maximum interference limits shown in Table 5. The results indicate that for these worst-case scenarios, MSs and BSs can cause significant interference to each other and consequently require additional isolation.

TABLE 32

Analysis of the ACI between TDD macrocellular and FDD macrocellular systems, when the TDD and FDD BSs are separated by a distance of 500 m

Interference Scenario	Frequency Offset (MHz)	Transmit Power (dBm)	Coupling Loss (dB)	ACIR (dB)	ACI at the Receiver (dBm)	Additional Isolation (dB)
TDD MS ⇒ FDD BS	5	20	67.4	33	-80.4	28.6
	10	20	67.4	50	-97.4	11.6
FDD BS ⇒ TDD MS	5	43	67.4	39	-63.4	44.6
	10	43	67.4	49	-73.4	34.6
FDD MS ⇒ TDD BS	5	21	73.4	33	-85.4	24.6
	10	21	73.4	43	-95.4	14.6
TDD BS ⇒ FDD MS	5	36	73.4	33	-70.4	34.6
	10	36	73.4	43	-80.4	24.6

C.2 Interference Analysis between BSs and MSs in a CDMA-DS Microcellular and WiMAX TDD Macrocellular Deployment

A single microcellular FDD BS is considered. Such a base station is located at the cell boundary of a TDD BS, ie, 1 km away, a TDD MS that is also located at the same position as the FDD BS site will transmit at maximum power and therefore cause significant uplink interference to the FDD BS. As in the previous section, we established the minimum coupling loss value to use for this scenario. Using the methodology described in the previous section and assuming the microcellular antenna pattern shown in Figure 2, and the TDD MS antenna gain of 6 dBi, the minimum coupling loss value was set to 47.5 dB. The resulting interference analysis is shown in Table 33, which indicates that significant interference can exist in this scenario, hence requiring additional isolation.

FIGURE 2

Horizontal and vertical antenna patterns for the microcellular antenna

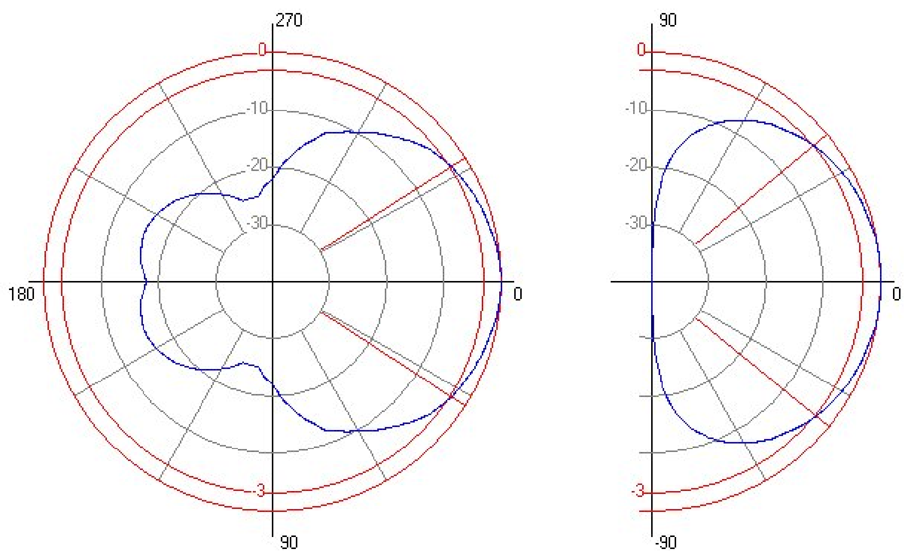


TABLE 33

Analysis of the ACI between TDD macrocellular and FDD microcellular systems, where the TDD and FDD BSs are separated by a distance of 1,000 m

Interference Scenario	Frequency Offset (MHz)	Transmit Power (dBm)	Coupling Loss (dB)	ACIR (dB)	ACI at the Receiver (dBm)	Additional Isolation (dB)
TDD MS ⇒ FDD BS	5	20	47.5	33	-60.5	48.5
	10	20	47.5	50	-77.5	31.5
FDD BS ⇒ TDD MS	5	38	47.5	39	-48.5	59.5
	10	38	47.5	49	-58.5	49.5

We can also examine a scenario in which a distance of 500 m separates the FDD and TDD BSs and the maximum range of the FDD microcell is 350 m[6]. In this scenario, when the FDD MS is at its cell boundary, ie, 150 m from the TDD cell site, the FDD MS is transmitting at maximum power and hence providing the worst-case uplink interference to the TDD BS. The UMTS vehicular model gives a path loss of 113.6 dB for a distance of 150 m. This translates to a coupling loss of 95.6 dB, if we assume antenna gains of 18 dBi at the BS and 0 dBi at the MS. Using these values we calculated the interference at the WiMAX TDD BS from a single CDMA-DS MS and vice versa, as shown in Table 34.

TABLE 34

Analysis of the ACI between TDD macrocellular and FDD microcellular systems, where the TDD and FDD BS are separated by a distance of 500 m

Interference Scenario	Frequency Offset (MHz)	Transmit Power (dBm)	Coupling Loss (dB)	ACIR (dB)	ACI at the Receiver (dBm)	Additional Isolation (dB)
FDD MS ⇒ TDD BS	5	21	95.6	33	-107.6	2.4
	10	21	95.6	43	-117.6	-7.6
TDD BS ⇒ FDD MS	5	36	95.6	33	-92.6	12.4
	10	36	95.6	43	-102.6	2.4

Although this is a simple analysis, it provides an indication of the problems that can occur. It is important to realise that we have only considered a single microcellular FDD BS positioned at different locations within the WiMAX TDD network. Although further investigation is required to understand the full impact of more complex deployment scenarios, our results suggest that interference problems could exist if a CDMA-DS microcellular network and a TDD macrocellular network using an adjacent channel are deployed in the same geographical area.

C.3 Interference Analysis between BSs and MSs in a CDMA-DS Picocellular and WiMAX TDD Macrocellular Deployment

This deployment scenario is similar to that discussed in the previous section in that the worst-case scenario occurs when the interfering MS is close to the victim BS. This can occur if the picocellular FDD BS is located at the boundary of the TDD macrocell and the TDD MS is transmitting at maximum power near the FDD BS because it is at the edge of its cell. Similarly, if the TDD macrocell is located near the boundary of the FDD picocell, a FDD MS can be transmitting at maximum power when it is close to the TDD BS.

In order to analyze this scenario, we assumed that since the heights of the picocellular BS and the MS are the same, a minimum separation of 1 m should be used. At this range, with 0 dBi antennas, the path loss (using free space) is 40.7 dB. With the 6 dBi TDD MS antenna, the path loss falls to 34.7 dB. The results of our interference analysis are shown in Table 35, which again indicates potential ACI problems.

[6] The cell size depends on propagation conditions and the value of 350 meters was chosen at it is considered reasonable for a microcell as mentioned in “Clark MV, Erceg V, Greenstein LJ, Reuse Efficiency in Urban Microcellular Networks, IEEE Trans VT, Vol 46, issue 2, May 1997 pp 279-288”.

TABLE 35

Analysis of the ACI between TDD macrocellular and FDD picocellular systems

Interference Scenario	Frequency Offset (MHz)	Transmit Power (dBm)	Coupling Loss (dB)	ACIR (dB)	ACI at the Receiver (dBm)	Additional Isolation (dB)
TDD MS ⇒ FDD BS	5	20	34.7	33	-47.7	61.3
	10	20	34.7	50	-64.7	44.3
FDD BS ⇒ TDD MS	5	24	34.7	39	-49.7	58.3
	10	24	34.7	49	-59.7	48.3
FDD MS ⇒ TDD BS	5	21	40.7	33	-52.7	57.3
	10	21	40.7	43	-62.7	47.3
TDD BS ⇒ FDD MS	5	36	40.7	33	-37.7	67.3
	10	36	40.7	43	-47.7	57.3

Annex D

Interference Analysis between MSs

Having analyzed the ACI between two BSs and between a MS and a BS, we concluded our analysis by examining the interference between two MSs. Once again we assumed that the FDD MS and TDD MS can tolerate a maximum ACI of −105 dBm and −108 dBm, respectively, before the system performance becomes seriously affected.

The worst-case scenario occurs when a TDD MS is located close to a FDD MS, and both are transmitting at the maximum transmitted power of 20 dBm and 21 dBm, respectively. In the previous sections the interference scenarios were analyzed by calculating the additional isolation needed to overcome the ACI. However, for the analysis of MS-to-MS interference detailed in this section we quantified the required separation distance between the two MSs in order to satisfy the maximum ACI level of −105 dBm, for the FDD MS and –108 dBm for the TDD MS. Calculation of the required separation distance to protect the TDD MS was based on the following path loss equation, assuming an effective antenna gain of 0 dBi for the FDD MS and 6 dBi for the TDD MS.

$$PathLoss(dB) = TxPower(dBm) + AntennaGains(dBi) - ACIR(dB) - (-108(dBm)) \qquad \text{(D.1)}$$

Based on a transmit power of 21 dBm and an ACIR of 32 dB, the path loss needed to satisfy the maximum ACI of −108 dBm was 103 dB for the first adjacent channel. Similarly, for the second adjacent channel with an ACIR of 43 dB, the path loss required was 92 dB. Assuming free space path loss between the MSs, the required separation distances were 1.3 km and 366 m for the first and second adjacent channels, respectively. Due to the unlikelihood that a LOS path would exist over these distances, particularly in an urban environment, it was more appropriate to use a path loss model that accounted for the effects of the buildings. However, we were unaware of any established simple models that could be used to calculate the path loss for this particular scenario. Using the UMTS pedestrian model (see Equation (A.2)) resulted in these distances decreasing to 62 m and 33 m, respectively. Alternatively, if we considered that the MSs were indoors and on the same floor, the indoor propagation model indicated separation distances of 159 m and 68 m, respectively.

The method described above can be reversed to calculate the additional isolation required to achieve a given separation distance between the interfering MSs. For example, in order to achieve a separation distance of 10 m and assuming that a LOS path exists between the two MSs, the additional isolation needed is shown Table 36.

From this simple analysis, it indicates that if MSs are in close proximity, significant ACI is generated that could cause a degradation in the performance of the victim MSs. Whether the performance of the MS is affected significantly depends on the signal strength provided by the serving cell.

TABLE 36

Analysis of interference from a CDMA DS (FDD) MS to a WiMAX TDD MS and *vice versa*

Source	**Victim**	**Distance (m)**	**Transmit Power (dBm)**	**Path Loss (dB)**	**Effective Antenna Gain (dB)**	**ACIR (dB)**		**ACI at the Receiver (dBm)**		**Additional Isolation (dB)**	
						5 MHz	**10 MHz**	**5 MHz**	**10 MHz**	**5 MHz**	**10 MHz**
FDD	TDD	10.0	21	60.7	6	32	43	-65.7	-76.7	42.3	31.3
TDD	FDD	10.0	20	60.7	6	30	42	-64.7	-76.7	40.3	28.3

Annex E

FCC Spectral Mask

The FCC emission limits state the following [7].

"*For BRS and EBS stations, the power of any emissions outside the licensee's frequency bands of operation shall be attenuated below the transmitter power (P) measured in watts … For fixed and temporary fixed digital stations, the attenuation shall be not less than 43 + 10 log (P) dB, unless a documented interference complaint is received from an adjacent channel licensee. Provided that the complaint cannot be mutually resolved between the parties, both licensees of existing and new systems shall reduce their out-of-band emissions by at least 67 + 10 log (P) dB measured at 3 MHz from their channel's edges for distances between stations exceeding 1.5 km. For stations separated by less than 1.5 km, the new licensee shall reduce attenuation at least 67 + 10 log (P) -20 log(D_{km}/1.5), or when colocated, limit the undesired signal level at the affected licensee's base station receiver(s) at the colocation site to no more than -107 dBm.*"

When the emission limits are applied to the WiMAX BS, the following conditions apply based on a transmit power of 36 dBm.

1) Away from the channel edge, the reduction in the emission level must be at least −49 dBc/MHz.

2) In addition to the above, at 3 MHz away, the reduction in the emission level must be at least −73 dBc/MHz.

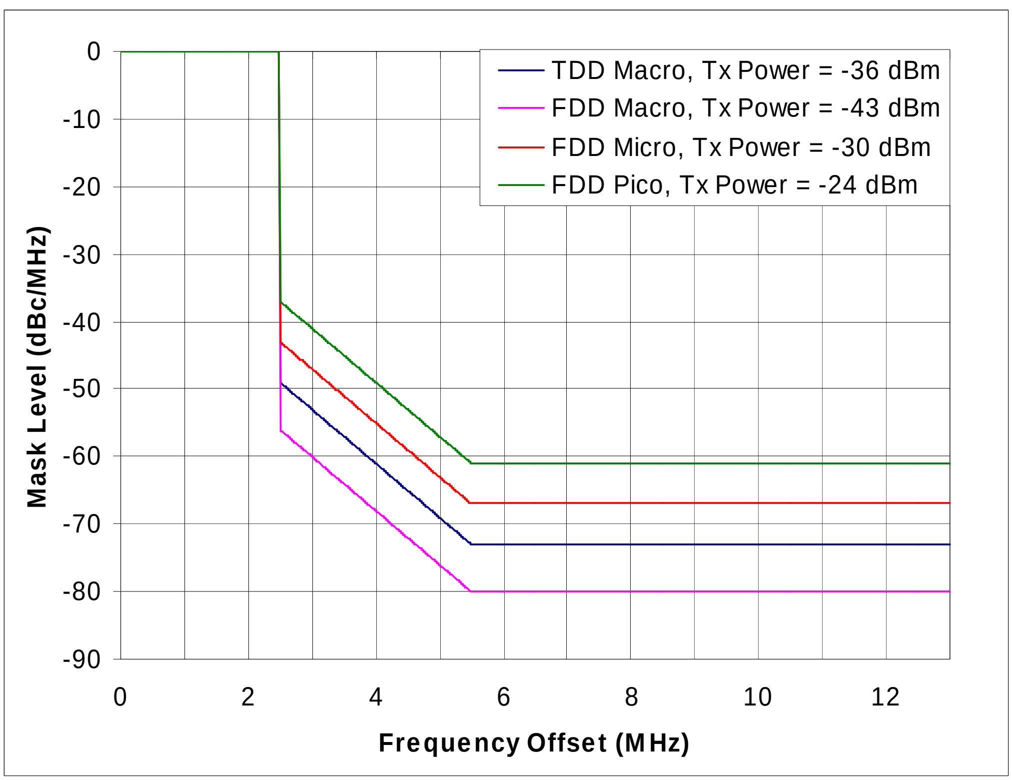
Using the above conditions the spectral mask shown in Figure 3 was derived. Subsequently, the ACLR for the first and second adjacent channel was extracted by integrating the spectral mask over the required adjacent channel bandwidths. In extracting the ACLR, we have assumed a nominal channel bandwidth of 4.5 MHz, which was obtained based on the scaling of a 10 MHz channel bandwidth WirelessHUMAN technology implementation [2a]. The value of 4.5 MHz is also considered reasonable when considering interference into CDMA-DS since the value lies about halfway between the 5 MHz channel spacing and the 3.84 MHz bandwidth implied by chip rate and accounts for non-flatness PSD leakage between 3.84 MHz and 5 MHz.

Similarly, when the emission limit are applied to the FDD technology, the spectral masks for the macro, micro and pico BSs are shown in Figure 3 for the different BS transmit powers. In calculating the ACLR values for the FDD BSs, we have used a nominal channel bandwidth equal to the chip rate of 3.84 MHz. This is inline with the ACLR and ACS measurement methodology specified by 3GPP in its co-existence study [5].

It was also noted that the FCC provides stricter limits when considering BSs that are in close proximity. We assumed that these limits would be met by implementing mitigation techniques. Hence in our interference analysis, the ACLR was calculated based on BSs that are separated by a distance greater than 1.5 km.

FIGURE 3

FCC spectral mask for WiMAX and FDD BSs



Annex F

Mitigation techniques

In this annex we provide some background information about the techniques that can be used to mitigate against ACI between CDMA-DS systems and WiMAX systems, including the derivations for the improvements in ACLR and ACS that were used in the main body of this report. We begin by examining the actual ACLR and ACS performance that might be expected of typical CDMA-DS equipment. While this is not a mitigation technique in itself, it does allow us to get a more realistic view of the ACI problem.

Following this we discuss briefly the improvements that can be gained by employing various mitigation techniques as described in the ITU report on mitigation techniques [17]. However, in this study, we only considered key mitigation techniques such as the employment of power amplifier linearization techniques, additional filtering at the BS and careful site design.

F.1 The ACLR and ACS of typical CDMA-DS equipment

Wilkinson and Howard [6] examined the co-existence of CDMA-DS and TDD systems in adjacent spectrum allocations. As part of this study, they assessed the typical adjacent channel performance that could be expected from real FDD and TDD equipment, which is found to be somewhat better than the minimum specifications. Using this information, we can take the typical performance of the CDMA-DS equipment and adjust our interference calculations to gain a more realistic view of the interaction between CDMA-DS and WiMAX systems. These ACLR and ACS values are set out in Table 37.

The ACLR of a UTRA TDD BS transmitter was reported to be 57 dB in the first adjacent channel. No value was reported for the second adjacent channel. Although we are more interested in the ACLR performance of CDMA-DS equipment, the RF circuits of a TDD BS are likely to have very similar performance to those of a FDD BS. For the ACLR of the second adjacent channel, we have made an assumption that the BS performance is 10 dB better than that of the MS, giving an ACLR of 74 dB.

The FDD BS receiver ACS was not explicitly reported, but can be computed from the results of some of the adjacent channel measurements. UTRA TDD signal levels of −37 dBm and −27 dBm were found to give a 1 dB noise rise in CDMA-DS BS receivers operating at channel offsets of 5 MHz and 10 MHz, respectively. Assuming a receiver noise figure of 5 dB, a 1 dB noise rise implies a total noise and interference power level of

$$-174 + 10\log(3.84e6) + 5 + 1 = -102 \text{ dBm},$$

giving ACS performance of $-37 - (-102) = 65$ dB and $-27 - (-102) = 75$ dB in the first and second adjacent channels, respectively.

For the MS, the transmitter ACLR was derived directly from measurements performed on a TDD MS and we again make the assumption that the CDMA-DS MS will have similar performance. For the MS ACS performance, a value of 55-60 dB was estimated for the first adjacent channel, but no value was given for the second adjacent channel. We again assume that this will be 10 dB worse than the equivalent BS ACS, giving a value of 65 dB.

TABLE 37

Typical 'real' equipment adjacent channel performance. (* indicates that the performance of the BS is 10 dB better than that of the MS)

Parameter	First Adjacent Channel at 5 MHz	Second Adjacent Channel at 10 MHz
BS transmitter ACLR (dB)	57 (TDD)	74*
BS receiver ACS (dB)	65	75
MS transmitter ACLR (dB)	46	64
MS receiver ACS (dB)	55-60	65*

Also, in a recent study into the ACI between uncoordinated CDMA-DS systems on behalf of the UK Telecommunications Regulator, Ofcom [15], ACLR and ACS values of typical FDD equipment were assessed. However, in this case there were no MS-to-MS or BS-to-BS interference cases to consider. Since the adjacent channel performance of the MS is, in general, worse than that of the BS, it was found that the MS performance dominated and therefore only the MS ACLR and ACS were considered. These values are set out in Table 38.

TABLE 38

Real CDMA-DS equipment performance [15]

Parameter	First Adjacent Channel at 5 MHz	Second Adjacent Channel at 10 MHz
MS ACLR (dB)	43	59
MS ACS (dB)	54.7	Not measured
MS 1 ACLR (dB)	44	58
MS 2 ACLR (dB)	47	61
MS ACS (dB)	33	Not measured

The values in the first two rows were from measurements performed on a FDD MS as part of the study, while those in the last three rows were taken from measurements reported by the mobile radio network operator Orange UK [16]. Comparing the values in Table 37 and Table 38 shows reasonable agreement for the MS, with the exception of the final MS ACS value shown in Table 38. However, it was noted that this value had been derived using a significantly different method [15].

F.3 Additional Filtering

A relatively straightforward way to reduce the interference between systems operating in adjacent frequency bands is to include additional filtering to improve the transmitter ACLR and/or the receiver ACS. Additional filtering can be incorporated into the BS relatively easily, while at the MS the size limitations preclude its use.

An example of a filter used for this purpose in a UTRA TDD BS is described by Howard and Wilkinson [6]. This is a single 5 MHz bandwidth channel filter centred at 1,907.5 MHz, giving a rejection of 60 dBc at offsets of ±5 MHz. This performance should be achievable by a similar 2.5 GHz filter. Using such a filter at a WiMAX BS would improve both the transmitter ACLR and receiver ACS by 60 dB (because of the TDD nature of WiMAX), thus reducing the interference between the WiMAX BS and any CDMA-DS BS or MS in its vicinity. Since the ACIR in each interference path is affected by both the transmitter ACLR and the receiver ACS (being effectively limited by the weaker of the two), the full benefit of the additional filtering will be obtainable when similar filtering is included within both system. Once again, it will only be practical for the filters to be incorporated into the FDD BS, so the full benefit can only be gained for BS-to-BS interference, although for the BS-to-MS and MS-to-BS interference paths the ACIR will be improved such that it is limited by the MS ACLR/ACS performance.

F.4 Site Design

In Annex B we established that the most significant factor affecting the co-existence of CDMA-DS and WiMAX will be the interference between the two types of BS when they are either co-sited, or are sited within each other's coverage area. Interference can be minimized by careful site design to keep the coupling loss between the different sites to a minimum.

Allgon [13] performed measurements of the isolation that can be achieved between different antennas in the GSM1800 band when mounted in a number of different configurations. Assuming that similar isolation can be achieved at the slightly higher frequencies of the 2.5 GHz expansion band, we can adjust the coupling loss values used in our calculations of interference between FDD and WiMAX BSs accordingly. When mounted on the same mast, antenna isolations of between 39 dB and 54 dB were achieved, with relative antenna orientations of between 90º and 180º. With a 1 m separation between antennas, the isolation could be increased to between 57 dB and 70 dB, for the same relative orientations. In practice, however, it may not be possible to maintain this level of isolation between all antennas if both co-sited cells are required to provide coverage through 360º of azimuth. In this case, it would be more appropriate to mount the antennas at different heights on the same mast, for which the measured isolation was between 45 dB and 70 dB for vertical separations of between 1.5 m and 6 m. With a vertical separation of around 3 m, 60-65 dB isolation was possible, which we can apply to the macrocell BS to macrocell BS interference case. However for the macrocell BS to microcell BS case and macrocell BS to picocell BS case, we have already assumed 70 dB and 80 dB coupling losses, respectively. The Allgon results confirm that these are reasonable values, and these are within the range of improvements reported in Report M.2045 [17], which states that improvements of 15-40 dB may be obtained over and above the 30 dB value often assumed. This corresponds to total coupling losses in the range of 45-70 dB. We have assumed 65 dB in our analysis.

For BSs that are not co-sited, we have assumed worst-case antenna orientations, ie, with the interfering BS antennas at the same heights and directly facing each other. With careful site planning this situation could be avoided but it would probably require cooperation and coordination between different operators.

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ATTACHMENT 5.7

Source: Doc. 8F/TEMP/289

Statement of principles and further guidelines for sharing studies

1. Introduction

This statement sets out general principles on sharing studies and further guidelines for conducting sharing analyses in time for WRC-07.

2. General principles on sharing studies within SWG Sharing

2.1 Sharing studies related to candidate bands will have the first priority for sharing and compatibility studies to be performed in the period 2006/07, noting that activities within SWG sharing will be contribution driven.

2.2 Sharing studies in SWG Sharing will be focused on candidate bands as identified by SWG Spectrum Bands.

2.3 SWG Sharing will take into account and make use of existing sharing studies wherever possible, assessing the appropriateness or otherwise of existing studies and where necessary adapting these studies to include the requirements of systems beyond IMT-2000. In this way advantage can be taken of studies in bands where there are existing primary mobile allocations and for which further large scale deployments may be proposed. Furthermore it should be noted that compatibility studies may still be useful to understand the impact of introducing IMT-2000 and systems beyond on existing usage and to highlight transitional issues. In particular, the potential impact of introducing high-density mobile systems in existing bands must be taken into account.

2.4 The first deliverable of sharing studies in candidate bands will be text liaised to SWG WRC for inclusion in the Draft CPM Report. The second deliverable for sharing studies in candidate bands will be studies for inclusion in a draft new Report/Recommendation to be completed prior to the WRC-07.

2.5 Sharing studies related to the band 2 500-2 690 MHz will be progressed as resources permit based on contributions received and documents carried forward as attachments to the Chairman's Report.

2.6 Parameters and their values used in sharing and compatibility studies should characterize both the transmission and the reception of radio signals for all the services and systems studied. Parameters used to characterize IMT-2000 systems must be consistent with those given in ITU-R Report M.2039. In the absence of agreed parameter values that characterize systems beyond IMT-2000, the data rate should be the starting point for developing parameters used in sharing studies. Values of all associated parameters, such as transmitter power, bandwidth, spectral efficiency and cell-size, should be adjusted accordingly to provide a specified quality of service.

2.7 Parameters that are used to characterize services, and systems of those services, that are other than IMT-2000 and systems beyond IMT-2000, must be consistent with appropriate ITU-R Recommendations and Reports. In the absence of Recommendations that can be used to characterize a particular system, WP 8F will liaison with the appropriate Study Group/Working Party to obtain the parameters and their associated values or obtain concurrence of the parameters and values that have been submitted to WP 8F for inclusion in sharing and compatibility studies.

2.8 The models used in sharing studies to simulate the propagation environment should be those given in ITU-R Recommendations or otherwise well-accepted by the technical community. Those propagation models that are not directly included in ITU-R Recommendations will be liaised to Study Group 3 and to the appropriate service study group for their concurrence that the propagation models proposed are acceptable for the application indicated.

2.9 The value of I/N_{th} (where I is the interference value into the victim receiver and N_{th} is the receiver thermal noise level) will be used as the interference criteria for co-channel interference into IMT-2000 systems and systems beyond IMT-2000. For assessing the interference from IMT-2000 systems into other systems, measures based on other parameters such as C/I or C/N, where C is the carrier amplitude and N is the thermal noise plus noise associated with the interference given in ITU-R Recommendations may be used where appropriate.

2.10 Sharing studies undertaken by WP 8F may result in the identification of interference mitigation strategies to improve compatibility between IMT-2000 and systems beyond IMT-2000 with incumbent systems. Because of the time pressures on WP 8F to complete sharing studies, detailed study of mitigation techniques may be left until after the deadline for the submission of text for the draft CPM Report dependent on input contributions and the availability of resources.

3. Further guidelines for sharing studies

3.1 Factors to be taken into account in determining a priority order for sharing studies should include whether or not the candidate bands identified:

- have existing mobile allocations, the status of the allocations and the applicability of the allocations across the three Regions;
- are identified in RR No. **5.317A**.

3.2 Parameters needed to undertake sharing and compatibility studies are likely to include parameters such as those listed below. For systems that have the capability to operate in variable bandwidth configurations, these parameters will need to be specified for all appropriate bandwidths.

Frequency band (GHz)
Maximum Tx output power (dBm)
e.i.r.p. (maximum) (dBm)
Link Bit/Data rate
Typical pico, micro, macro cell radius (km)
Channel width/spacing (MHz)
Antenna gain (range) (dBi)
Antenna type (Tx/Rx)
Antenna downtilt (degrees)
Antenna height (m)
Modulation
Feeder/multiplexer loss (minimum) (dB)
Receiver IF bandwidth (MHz)
Receiver noise figure (dB) and dynamic range
Receiver thermal noise (dBm/MHz)
Receiver interference threshold (dBm/MHz)
Receiver reference threshold (dBm/MHz)
Nominal Rx input level (dBm)
Rx input level for 1 x 10^{-3} BER (dBm)
Adjacent channel selectivity (dB)
Adjacent channel leakage ratio (dB)

3.3 For each case studied, interference analyses should be undertaken for both co-channel and adjacent channel operation between the IMT-2000 system (or the system beyond IMT-2000) and the other system.

3.4 For interference analyses that involve fixed stations and IMT-2000 base-stations, deterministic studies can be used to assess interference potential. For analyses where mobile stations are involved, including all instances of IMT-2000 (or Beyond IMT-2000) systems mobile station transmission and reception, Monte Carlo-type analyses are to be preferred.