REPORT ITU-R M.2113

Report on sharing studies in the 2 500-2 690 MHz band between IMT-2000 and fixed broadband wireless access systems including nomadic applications in the same geographical area

(2007)

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1 Introduction and scope

The 2 500-2 690 MHz band was identified at WRC-2000 as an additional spectrum band that Administrations may choose to make available for IMT-2000 terrestrial.

Consequently, ITU-R has undertaken sharing studies in the 2 500 MHz to 2 690 MHz band between IMT-2000 terrestrial systems and other services as required by Resolution 223 (WRC-2000). This Report focuses on sharing with broadband wireless access systems particularly on fixed systems, including nomadic applications.

1.1 Scope

There is a risk of co-channel and adjacent channel interference between IMT-2000 terrestrial systems and other systems in the band, for example, Broadband wireless access systems such as MMDS or IEEE 802.16. This Report addresses coexistence between the following:

– 802.16 TDD, which is based on the IEEE 802.16 series of standards, and IMT-2000 CDMA-DS;

– MMDS and CDMA-DS;

– MMDS and CDMA-TDD.

It is suggested that further revisions of this Report should include other combinations of technologies, for example co-existence between IEEE 802.16 and TD-SCDMA.

Mobile application of IEEE 802.16 is out of the scope of the study.

1.2 Frequency arrangement

The spectrum band ranging from 2 500 MHz to 2 690 MHz as shown in Table 1 described in draft revision of Recommendation ITU-R M.1036-2 – Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications-2000 (IMT-2000) in the bands 806-960 MHz, 1 710-2 025 MHz, 2 110-2 200 MHz and 2 500-2 600 MHz, has three possible frequency arrangements; C1, C2, and C3. In frequency arrangements C1 and C2, the paired frequency bands at either end of the spectrum will host an IMT-2000 frequency division duplex (FDD) technology such as CDMA-DS[1]. The FDD allocation will consist of 2 × 70 MHz paired spectrum with a 120 MHz duplex spacing, leaving 50 MHz in the centre. The central band can be used by either a time division duplex (TDD) technology (C1) or an "external" FDD downlink band in conjunction with a FDD uplink band allocated elsewhere (C2). Option C3 provides for flexible use of either TDD or FDD throughout the band with no specific blocks.

TABLE 1

Possible allocations of the 2.5 GHz IMT-2000 band

Frequency arrangement	Mobile station transmitter (MHz)	Centre gap (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	Centre gap usage
C1	2 500–2 570	50	2 620–2 690	120	TDD
C2	2 500–2 570	50	2 620–2 690	120	FDD DL (external)
C3	Flexible FDD/TDD				

[1] Code division multiple access-direct sequence (CDMA-DS).

2 System A – Systems based on standards developed in IEEE 802.16

2.1 Interference scenarios to be analyzed

Deployment of systems based on standards developed by IEEE 802.16[2], hereafter simply referred to as 802.16 for the sake of brevity, 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 Reports ITU-R M.2030 – Coexistence between IMT-2000 time division duplex and frequency division duplex terrestrial radio interface technologies around 2 600 MHz operating in adjacent bands and in the same geographical area and ITU-R M.2045 – Mitigating techniques to address coexistence between IMT-2000 time division duplex and frequency division duplex radio interface technologies within the frequency range 2 500-2 690 MHz operating in adjacent bands and in the same geographical area, 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.

a) Base to base

b) Base to subscriber

c) Subscriber to base

d) Subscriber to subscriber.

This section addresses the impact of adjacent channel interference (ACI) between a CDMA-DS system and a TDD system, namely, 802.16 TDD[3]. The interference scenarios that can exist when these two technologies operate in adjacent spectrum are as follows:

– Interference from a CDMA-DS base station and CDMA-DS mobile station to a 802.16 TDD base station.

– Interference from a CDMA-DS base station and CDMA-DS mobile station to a 802.16 TDD SS.

– Interference from a 802.16 TDD base station and 802.16 TDD SS to a CDMA-DS base station.

– Interference from a 802.16 TDD base station and 802.16 TDD SS to a CDMA-DS mobile station.

In the interference analysis, the 802.16 TDD and CDMA-DS systems were modelled as operating in a macrocellular network. Additionally, the analysis was extended to include microcellular and indoor picocellular deployment scenarios for the CDMA-DS system.

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[2] Working Group IEEE 802.16 has developed and published standards IEEE Std 802.16-2004 titled – IEEE Standard for Local and Metropolitan Area Networks, Part 16: Air Interface for fixed broadband wireless access systems, and its amendment to include mobility IEEE Std 802.16e-2005 titled – Amendment to IEEE standard for local and metropolitan area networks, Part 16: Air Interface for fixed broadband wireless access systems – Physical and medium access control layers for combined fixed and mobile operation in licensed bands.

[3] IEEE 802.16-2004 and IEEE 802.16e-2005 also include other duplex and access modes. In this document, “802.16 TDD” refers to a subset as described above.

2.2 Modelling of inter-system interference: ACLR, ACS and ACIR

The only form of interference modelled in this study is ACI that arises from the adjacent channel leakage (ACLR) from base station, SS and mobile station transmissions in the 802.16 TDD and CDMA-DS systems and the adjacent channel selectivity (ACS) of the base station, SS and mobile station receivers in the 802.16 TDD 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 base stations, SSs and mobile stations 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 § 2.4.3 and 2.5.9) to determine whether the systems are adequately protected. Our results are presented in § 2.4.4, 2.5 and 2.6.

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.

In order to determine the composite effect of the transmitter and receiver imperfections, the ACLR and ACS values are combined to give a single adjacent channel interference ratio (ACIR) value using the equation (1)[4]:

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

2.3 Basic system characteristics

Sections 2.4, 2.5 and 2.6 contain analyses of the impact of ACI between a CDMA-DS system and a TDD system, namely, 802.16 TDD, which is based on IEEE 802.16-2004 OFDM/OFDMA and its amendment IEEE 802.16e-2005[5, 6]. First the basic parameters and characteristics of these systems are described. Unless otherwise stated in the text, these are the definitions that are used in the analysis below for System A.

2.3.1 802.16 TDD

Regarding IEEE 802.16 systems, both IEEE 802.16-2004 and IEEE 802.16e-2005 are considered in the report. The standard IEEE 802.16-2004 addresses fixed broadband wireless access.

The standard IEEE 802.16e-2005 adds support for mobile stations. In this document two scenarios are considered, namely, IEEE 802.16-2004 operating in a fixed scenario (termed "Fixed") and IEEE 802.16e-2005 only when operating in a nomadic scenario (termed "Nomadic").

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4 3GPP [March 2005] Radio frequency (RF) system scenarios. 3GPP TS 25.942 Version 6.4.0.

5 [IEEE 2004] IEEE 802.16. IEEE standard for local and Metropolitan area networks Part 16: Air interface for fixed broadband wireless access systems.

6 IEEE 802.16. IEEE standard for local and Metropolitan area networks Part 16: Amendments for physical and medium access control layers for combined and mobile operations in licensed bands. IEEE 802.16e-2005. Approved in December 2005 and published in February 2006.

The IEEE 802.16 TDD standard supports various channel bandwidths between 1.25 and 20 MHz. This sharing study is based on a 5 MHz nominal channel bandwidth only, and so the ACLR and ACS values and the resulting ACIR and derived isolation values are only valid for a 5 MHz 802.16 TDD system. An 802.16 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 802.16 TDD. An 802.16 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 802.16 TDD. The exact numbers are for further study and are not addressed in this Report.

When performing sharing studies related to BWA systems, appropriate parameters are given in Report ITU-R M.2116 – Characteristics of broadband wireless access systems operating in the mobile service for use in sharing studies. Parameters for "Fixed" 802.16 TDD were provided by the WiMAX Forum[*] and considered appropriate for preliminary studies. Parameters for the "fixed" and "nomadic" scenarios are given in Table 2[7].

TABLE 2

802.16 TDD parameters
(Report ITU-R M.2116)

	Base station	SS	
		Fixed	Nomadic
Max TX power	36 dBm	24 dBm	20 dBm
Antenna gain	18 dBi	8 dBi	3 dBi
Antenna height	30 m	4 m	1.5 m
ACLR @ 5 MHz[(1)]	53.5 dB	37 dB	33 dB
ACLR @ 10 MHz[(1)]	66 dB	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		

(1) Defined as the ratio of the on-channel transmitted power to the power transmitted in adjacent channels as measured at the output of the receiver filter, ACLR represents the interference power into a receiver operating in the adjacent channel(s). ACLR_*n* in the table are ACLR values at *n* 5-MHz channels away calculated with a receiver filter bandwidth of 4.5 MHz. The IEEE 802.16e standard does not specify ACLR information. These are values provided by the WiMAX Forum specifically with regard to 2 500-2 690 MHz frequency band and are still subject to further study that can lead to a revision of the Report.

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* WiMax Forum http://www.wimaxforum.org/technology/documents/WiMAXForum_RFChar_8A.pdf

7 The ACLR and ACS values used for the IEEE 802.16 TDD system in this report are intended only for coexistence studies and apply to channels close to an FDD/TDD boundary. These values are not minimum performance requirements, which have not yet been specified

2.3.2 CDMA-DS

When performing sharing studies between IMT-2000 and other technologies, appropriate parameters for the IMT-2000 technologies are given in Report ITU-R M.2039 – Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses. The parameters of CDMA-DS used in the analyses are given in Table 3.

TABLE 3

CDMA-DS parameters
(Report ITU-R M.2039)

	Macrocell base station	Microcell base station	Picocell base station	Mobile station
Max TX power	43 dBm	38 dBm	24 dBm	21 dBm
Antenna gain	17 dBi	5 dBi	0 dBi	0 dBi
Antenna height	30 m	6 m	1.5 m	1.5 m
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
Noise figure	5 dB			9 dB
Required E_b/N_0	6.1 dB			7.9 dB
Power control range	30 dB (1 dB per step)			80 dB (1 dB per step)

The ACLR and ACS values for the CDMA-DS base station and mobile station are defined by the 3GPP specifications for the first and second adjacent channels, which correspond to carrier separations of 5 MHz and 10 MHz, respectively[8, 9]. These values are also identical to those used in another co-existence study performed by the ITU (see Report ITU-R M.2030).

2.3.3 ACIR values for co-existence analysis between 802.16 TDD and CDMA-DS

Using equation (1) and the ACLR and ACS values listed in Table 2 and Table 3, ACIR values are calculated for the various interference paths between the CDMA-DS equipment and the 802.16 TDD equipment. These ACIR values, shown in Table 4, 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. The difference in ACIR values between fixed and nomadic subscriber stations is explicitly stated in Table 4 as indicated below.

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 802.16 TDD based on 5 MHz channels, the 802.16 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 a 0.7 dB difference in noise level. However, 802.16 TDD exhibits faster roll off as it uses OFDM with 256 carriers. The CDMA-DS Nyquist

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[8] 3GPP [June 2004] Base station (BS) radio transmission and reception (FDD). 3GPP TS 25.104, Version 6.6.0.

[9] 3GPP [March 2004] User equipment (UE) radio transmission and reception (FDD). 3GPP TS 25.101, Version 6.4.0.

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, it is assumed 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. This assumption will result in an error of less than 1 dB in the results.

TABLE 4

ACIR values (dB) for the interference paths of interest, when using standard equipment

Interference path	First adjacent channel	Second adjacent channel
TDD base station ⇒ FDD base station	45	57
FDD base station ⇒ TDD base station	45	50
TDD base station ⇒ FDD mobile station	33	43
FDD mobile station ⇒ TDD base station	33	43
FDD base station ⇒ TDD SS	39	49
TDD SS ⇒ FDD base station	33 (nomadic) 36 (fixed)	50
TDD SS ⇒ FDD mobile station	30 (nomadic) 32 (fixed)	42
FDD mobile station ⇒ TDD SS	32	43

2.4 Deterministic analyses of interference using standard values

2.4.1 Evaluation methodology

For base station to base station interference, deterministic analyses were performed for specific separations and deployment scenarios, whereas when mobiles and SSs, which have locations that are not fixed by the network operators, worst-case locations for the mobile stations and SSs were considered, with mobiles stations and SSs transmitting at maximum power. In all cases, the protection criteria used are as defined in § 2.4.3

2.4.2 Input parameters and assumptions

For each of the deployment scenarios (macro-macro; macro-micro; and macro-pico) five possible configurations are considered for the relative locations of the CDMA-DS and 802.16 TDD base stations. In the first configuration the base stations were co-located with coupling losses of 30 dB, 77 dB and 87 dB assumed for the macro-macro, macro-micro and macro-pico cases, respectively, as explained in Annex B. In the other configurations each CDMA-DS base station was situated 100, 300, 500 and 1 000 m away from the cell boundary of an 802.16 TDD base station respectively. Furthermore, smaller separation distances of 10 m, 50 m and 100 m are also considered when analyzing interference between base stations. Results are included in Annex B.

In the analysis, propagation models as described in Annex A were used to evaluate the path loss between two different base stations, between a base station and a mobile station or a SS, and between a mobile station and a SS. The channel bandwidth of the 802.16 TDD system was set to 5 MHz and the base station and SS parameters used in the interference analysis are shown in Table 2. The CDMA-DS values are presented in Table 3.

2.4.3 Protection criteria

In the deterministic analysis, the interference thresholds shown in Table 5 are used as the maximum interference limits that can be tolerated by the CDMA-DS and 802.16 TDD equipment. These thresholds are specified in Report ITU-R M.2039 and the RF parameters specified by the WiMAX Forum for the CDMA-DS and 802.16 TDD equipment, respectively.

TABLE 5

Maximum interference limit for the 802.16 TDD and CDMA-DS FDD equipment

	Maximum interference limit (dBm)	
	802.16 TDD	**CDMA-DS**
Base station	–110	–109
Mobile station/SS	–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.

2.4.4 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 base stations, interference between a base station and a mobile station or a SS, and interference between a mobile station and a SS, respectively.

2.4.4.1 Interference between base stations

For the 802.16 TDD base station-to- CDMA-DS base station 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 4 includes results for co-sited 802.16 TDD and CDMA-DS base stations, and for 802.16 TDD and CDMA-DS base stations separated by distances of 100 m, 300 m, 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 (dB) when considering base station-to-base station interference for different base station separation distances

Deployment scenario		TDD base station ⇒ FDD base station				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/ FDD macro	1st adj chan	70.0	54.3	44.7	40.3	34.3
	2nd adj chan	58.0	42.3	32.7	28.3	22.3
TDD macro/ FDD micro	1st adj chan	23.0	13.8	–4.3	–12.8	–24.2
	2nd adj chan	11.0	1.8	–16.3	–24.8	–36.2
TDD macro/ FDD pico	1st adj chan	11.0	–3.1	–21.3	–29.7	–41.1
	2nd adj chan	–1.0	–15.1	–33.3	–41.7	–53.1
Deployment scenario		**FDD base station ⇒ TDD base station**				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/ FDD macro	1st adj chan	78.0	62.3	52.7	48.3	42.3
	2nd adj chan	73.0	57.3	47.7	43.3	37.3
TDD macro/ FDD micro	1st adj chan	26.0	16.8	–1.3	–9.8	–21.2
	2nd adj chan	21.0	11.8	–6.3	–14.8	–26.2
TDD macro/ FDD pico	1st adj chan	0.0	–14.1	–32.3	–40.7	–52.1
	2nd adj chan	–5.0	–19.1	–37.3	–45.7	–57.1

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 additional isolation is needed for all network deployments scenarios (ie, macrocellular, microcellular and picocellular) with the exception of the TDD macrocell and the FDD picocell operating in the second adjacent channel. However, there are cases when the standard equipment provides sufficient isolation for co-existence as indicated by the negative values in Table 6.

2.4.4.2 Interference between base station and mobile station; and between a base station and a SS

Section 2.5 describes a thorough computer simulation analysis for this interference scenario; however in the deterministic study, only cases that presented a significant impact to the ACI performance of the two systems were studied. Specifically, a situation could occur when a mobile station is at its cell boundary and close to a victim base station. This represents a worst-case interference scenario with the mobile station transmitting at full power whilst close to the victim base station. As a result of the close proximity between the base station and mobile station, the minimum coupling loss between the base station antenna and mobile station 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 base station is degraded due to interference from a nearby mobile station.

TABLE 7

A summary of the additional isolation needed (dB) when considering interference between base stations and mobile stations

Deployment scenario		Fixed SS => FDD base station	FDD base station => Fixed SS	Nomadic SS => FDD base station	FDD base station => Nomadic SS	FDD mobile station => TDD base station	TDD base station => FDD mobile station
TDD macro/ FDD macro	1st adj chan	30.1	45.1	23.3	39.3	22.3	32.3
	2nd adj chan	16.1	35.1	6.3	29.3	12.3	22.3
TDD macro/ FDD micro	1st adj chan	56.2	66.2	43.2	54.2	22.3	32.3
	2nd adj chan	42.2	56.2	26.2	44.2	12.3	22.3
TDD macro/ FDD pico	1st adj chan	54.3	46.3	58.3	55.3	22.3	32.3
	2nd adj chan	40.3	36.3	41.3	45.3	12.3	22.3

It should be noted that the interference levels are quite high, indicating that also in more favourable conditions co-existence might prove difficult.

Similarly, the performance of the mobile station is severely affected by interference from the base station that could cause the call to be dropped. It is important to note that these scenarios are particular 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. Following the same methodology, the additional isolation needed for CDMA-DS base station to CDMA-DS mobile station to enable coexistence according to the protection criteria are shown in Table 8. In general, the additional isolation levels are similar, with the differences caused by the greater EIRP of the fixed SS compared with the CDMA mobile stations, and the differences in ACLR performance of the TDD SSs compared with the CDMA-DS mobile stations.

TABLE 8

A summary of the additional isolation needed (dB) when considering interference between base stations and mobile stations in adjacent CDMA-DS networks without collocation for comparison purposes

Deployment scenario		FDD mobile station => FDD base station	FDD base station => FDD mobile station
FDD macro	1st adj chan	21.3	39.3
	2nd adj chan	11.3	29.3
FDD micro	1st adj chan	41.2	54.2
	2nd adj chan	31.2	44.2
FDD pico	1st adj chan	56.3	55.3
	2nd adj chan	46.3	45.3

2.4.4.3 Interference between mobile station and SS

Finally, analysis of the impact of ACI between a 802.16 TDD SS and a CDMA-DS mobile station, was based on a worst-case scenario when the mobile station and SS were close together and transmitting at maximum power. Such a scenario can exist when mobile stations are in a confined space, such as the same room, a bus or train, whilst being served by an external macrocellular or microcellular base station (see Report ITU-R M.2030). For example, the ACI performance was quantified given that the separation distance between the mobile station and fixed SS was 3.5 m, where a detailed description is given in Annex D. The results indicate that additional isolation of 53.3 dB and 43.3 dB would be needed for the first and second adjacent channels, respectively, to protect the CDMA-DS receiver, from a fixed SS, whilst additional isolation of 53.3 dB and 42.3 dB would be needed to protect the fixed SS receiver, respectively, as shown in Table 9.

TABLE 9

A summary of the additional isolation needed (dB) to protect mobile stations and SSs using standard values

	Fixed SS => FDD mobile station	FDD mobile station => Fixed SS	Nomadic SS => FDD mobile station	FDD mobile station => Nomadic SS
1st adj chan	53.3	53.3	57.3	59.3
2nd adj chan	42.3	43.3	45.3	48.3

Similarly, additional isolation of 57.3 dB and 45.3 dB would be needed for the first and second adjacent channels, respectively, to protect the CDMA-DS receiver from a Nomadic SS with a separation of 1 m, whilst additional isolation of 59.3 dB and 48.3 dB would be needed to protect the Nomadic SS receiver from the CDMA-DS mobile station, respectively. Note that similar isolations would be required if a UTRA TDD mobile station were in close proximity to the CDMA-DS mobile station (see Report ITU-R M.2030).

Note that these additional isolation values are similar to those required between CDMA-DS picocell base stations and 802.16 TDD SSs or CDMA-DS mobile stations as outlined in § 2.4.4.2 in Tables 7 and 8 respectively. The differences arise because the powers are a little different and the ACIR performance, though dominated by the mobile stations is worse.

These represent worst case situations as in general mobile stations do not transmit at maximum power and need to receive at the extremes of the link budget, ie when noise-limited. However, it is interesting to also consider less extreme situations that are more likely to occur. In most situations either the output power of the interferer is lower or the tolerated level of external interference subjected to the victim receiver is higher than in the examples above.

Considering the example evaluated above of protecting a CDMA DS mobile station (victim) from a fixed SS (interferer) for the first adjacent channel an approximate 50 dB additional isolation is required.

If the interferer output power is decreased by 10 dB (compared to this example), and also the tolerated level of interference is increased by 5 dB (compared to the example), there would still be a requirement for an extra 35 (50-10 – 5) dB isolation.

Alternatively, if the output power is decreased by 30 dB (compared to the example) and the victim SS is located such that an extra 25 dB external interference (compared to the example) can be tolerable, there is no need for additional isolation; in fact there is a 5 dB margin (50-30 – 25 = –5).

The output power of the interferer is influenced by factors such as the distance to its serving base station and the system load. The tolerable external interference at the victim receiver depends on factors such as its distance to its serving base station and the available link budget margin.

2.4.5 Summary of deterministic analysis

This deterministic analysis has quantified the impact of ACI between the 802.16 TDD and CDMA-DS technologies when deployed in adjacent bands, without guard bands, within the 2 500-2 690 MHz band. Based on analysis of the base station-to-base station interference, the additional isolation needed to ensure successful co-existence is summarised in Table 6 for different base station-to-base station separation distances and "standard" base station equipment performance. Further results for smaller base station-to-base station separations are given in Annex B. The results in Table 6 show that when the base stations 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, whilst 43 dB is needed with a separation distance of 500 m.

In the case of 802.16 TDD base station and CDMA-DS mobile station interference and CDMA-DS base station and 802.16 TDD SS interference, specific scenarios are identified for which the impact of the ACI could be severe. The additional isolation needed for successful co-existence when a CDMA-DS mobile station is close to a 802.16 TDD base station and when a 802.16 TDD SS is close to a CDMA-DS base station is summarised in Table 5. Furthermore, additional isolation would be needed for similar interference scenarios that also occur between CDMA-DS networks operating on adjacent carriers when base stations are not collocated.

The deterministic analysis of interference between a mobile station and a SS showed that the impact of ACI between a mobile station and a SS could be severe when the mobile station and the SS were in close proximity. Specifically, for a separation distance of 3.5 m, additional isolation of 57.3 dB for Fixed was identified for the first adjacent channel of the CDMA-DS receiver, while in the Nomadic case, additional isolation of 49.3 dB was needed with 1 m separation, a level of isolation similar to that needed to protect SSs from CDMA-DS picocells. Furthermore, this analysis represents a worst-case scenario for mobile station-to-SS interference at these separations.

2.5 Statistical analysis

In order to capture dynamic features such as power control and more realistic user behaviour in terms of location and the services used, a statistical analysis is necessary, in addition to the more straightforward deterministic analysis of the previous section.

2.5.1 Evaluation methodology

The two systems, 802.16 TDD and CDMA-DS are modelled using a Monte Carlo approach, with a hexagonal grid of cells used for each network. Intrasystem and intersystem interference is modelled, with mobiles being placed randomly in cells. The results of a number of snapshots are combined to produce cumulative density functions (CDFs) of the interference. The capacity loss that results from the introduction of intersystem interference is computed.

2.5.1.1 Simulation procedure

The simulation procedure is as follows:

Step 1: Configure system deployment layout and simulation parameters.

Step 2: Place subscriber stations in the service area with the selected base station deployment (using 802.16 TDD nomadic case as an example here).

Step 2.1: Place a large number of subscribers stations in each sector. For example, drop 40 subscriber stations in each sector in 802.16 TDD. The more subscriber stations dropped, the less the chance that a sector has less than 5 associated subscriber stations (nomadic case). However, the more subscriber stations dropped, the longer the simulation time on the selection process.

Step 2.2: Calculate each link's path-loss, including antenna gain and shadow fading. Each subscriber station chooses its base station based on the strongest signal it receives (or the least loss). After this step, most likely each sector may have different number of associated subscriber stations.

Step 2.3: If any sector has less than 5 associated subscriber stations (nomadic case), go back to Step 2.1. Otherwise, go to Step 2.4.

Step 2.4: For each sector, randomly choose 5 subscriber stations (nomadic case) from all of its associated users as the active users for this time slot.

Step 3: Perform iterative power control and SINR calculation (see Fig. 3)

Step 4: Collect statistics (see Fig. 3).

Step 5: Repeat Steps 2 to 5 until the number of snap shots is reached.

Step 6: Generate CDF of SINR and process results.

2.5.2 Input parameters and assumptions

Table 10 summarize the input parameters and assumptions, made in addition to the parameters for 802.16 TDD and CDMA-DS given in Tables 2 and 3, respectively.

TABLE 10

Common simulation assumptions and parameters

Cell layout	Macro 19 clover-leaf cells, 3 sectors per cell
Cell size	Radius: R = 1 000 m
Shift of two systems	Six different offset locations
Spectrum band	2.500 ~ 2.690 GHz
Allocated bandwidth	5 MHz
802.16 TDD system load	75%
Nomadic active users	5 per sector
Power control	150 steps SINR based (CDMA-DS UL, CDMA-DS DL) with 1 dB step size; No power control in 802.16 TDD
Base station antenna type	Directional
Frequency reuse	CDMA-DS: 1 802.16 TDD: 1 × 3 × 1, 1 × 3 × 3
Base station locations	Center of the cell
Mobile station/SS locations	Uniformly distributed
Mobile station/SS antenna type	Omnidirectional
Minimum coupling loss between collocated base stations	50 dB – Note that this coupling loss is larger than that given in Reports ITU-R M.2030 and (ITU-R M.2116); however it lies within the range of improved coupling losses given in Report ITU-R M.2045.

Table 11 gives the ACIR values between 802.16 TDD and CDMA-DS for standard CDMA-DS equipment, ie, equipment that just meets its specifications.

TABLE 11

ACIR values when using standard CDMA-DS equipment

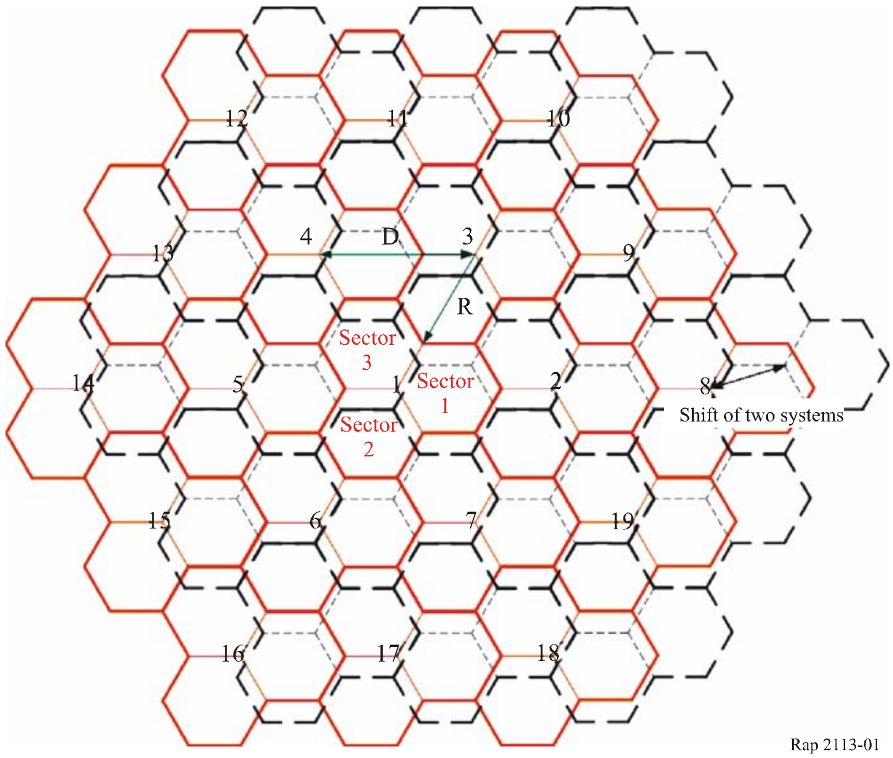
a) Interference path	b) First adjacent channel	c) Second adjacent channel
d) 802.16 TDD base station to CDMA-DS base station	e) 45.3 dB	f) 57.4 dB
g) CDMA-DS base station To 802.16 TDD base station	h) 45.0 dB	i) 50.0 dB
j) 802.16 TDD base station to CDMA-DS mobile station	k) 33.0 dB	l) 43.0 dB
m) CDMA-DS mobile station to 802.16 TDD base station	n) 33.0 dB	o) 43.0 dB
802.16 TDD mobile station To CDMA-DS base station	36.5 dB (fixed) 32.8 dB (nomadic)	50.2 dB
CDMA-DS base station To 802.16TDD mobile station	38.8 dB	49.5 dB
802.16 TDD mobile station To CDMA-DS mobile station	31.5 dB (fixed) 30.0 dB (nomadic)	42.4 dB
CDMA-DS mobile station To 802.16 TDD mobile station	32.2 dB	42.9 dB

2.5.2.1 Network deployment

Three-sector clover-leaf cellular layout is used in this study as shown in Fig. 1. *D* is the distance between two base stations within a system. In this study *D* is 1 500 m. *R* is the radius of a cell which is 1 000 m.

FIGURE 1

Large area multiple systems deployment using directional antennas



In Fig. 1, the two colors indicate overlay of two different systems, i.e. CDMA-DS and 802.16 TDD, in the same area. The simulation area is wrapped around to remove edge effects.

2.5.2.2 User characteristics

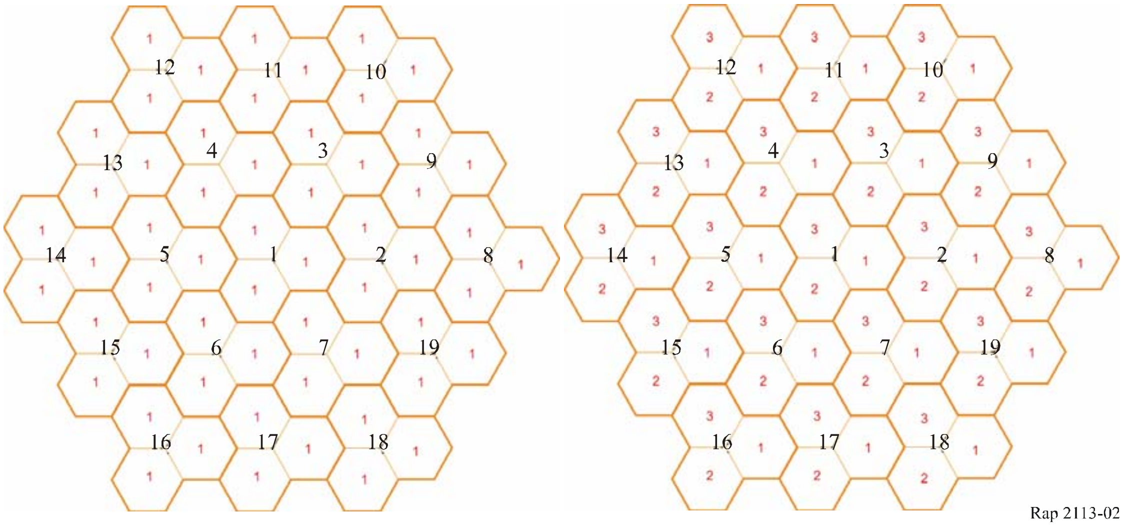
At any given instance there is only one active user per sector in the 802.16 (fixed). It occupies 75% of the whole bandwidth and transmits at its maximum power. For 802.16 (nomadic), there are five active users per sector at any given time. Each user occupies one fifth of the 75% of the whole bandwidth and transmits at its maximum power. Users are uniformly distributed in the service area.

2.5.2.3 Frequency reuse

Frequency reuse schemes of 1 × 3 × 1 and 1 × 3 × 3 in the 802.16 TDD systems are shown in Fig. 2.

FIGURE 2

802.16 TDD frequency reuse schemes 1 × 3 × 1 (left) and 1 × 3 × 3 (right)



Following is how frequency reuse schemes (1 × 3 × 1 and 1 × 3 × 3) and loading factor (75%) are defined. For frequency reuse 1 × 3 × 1, each sector in the whole service area uses the same 5 MHz bandwidth. Each sector independently and randomly chooses 75% sub-carriers within the whole 5 MHz bandwidth as this sector's active sub-carriers. In the nomadic case, each sector has five simultaneously active users. Each sector evenly and randomly divides its active sub-carriers between users.

For frequency reuse 1 × 3 × 3, each cell uses the same 5 MHz bandwidth, but each sector only occupies 5/3 MHz bandwidth. To simplify the simulation, it is assumed that this "5/3 MHz" is uniformly distributed in the 5 MHz bandwidth. In other words, base stations evenly and randomly divides all of its sub-carriers to the three sectors. It is also assumed that all base stations have the same assignment. For example, the sub-carriers in Sector A of Cell 1 are the same as those in Sector A of Cell 2; the sub-carriers in Sector B of Cell 1 are the same as those in Sector B of Cell 2; the sub-carriers in Sector C of Cell 1 are the same as those in Sector C of Cell 2. As to the 75% loading, Each sector independently and randomly chooses 75% sub-carriers within the whole 5/3 MHz bandwidth as this sector's active sub-carriers. In the nomadic case, each sector has five simultaneously active users. Each sector evenly and randomly divides its active sub-carriers between the users.

In the simulation model, no matter how much bandwidth a base station or a subscriber station of 802.16 TDD occupies, it always transmits at its maximum power. In other words, the power is transmitted on those carriers that are used. For example, in the1 × 3 × 1 nomadic case, 100% of the base station power is distributed over 75% of the carriers, and 100% of the subscriber station power is distributed over 15% of the carriers.

2.5.2.4 Propagation models

The models are described in Annex A.

2.5.2.5 Directional antenna pattern

The base station antenna is directional. Both the horizontal and the vertical antenna patterns are considered in the study. The horizontal antenna pattern is specified as [36PP, 2004]:

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

where:

$-180 \leq \theta \leq +180$: horizontal angle from the antenna pointing direction

θ_{3dB}: corresponds to 65°

$A_m = 30$ dB: maximum attenuation (see Recommendation ITU-R M.1646)[10].

Given the cell size used in this study, base station down inclination angle of 4° is chosen. The vertical antenna pattern is specified as (see Recommendations ITU-R M.1646 and ITU-R F.1336[11]):

$$G(\theta) = \max(G_1(\theta), G_2(\theta))$$

$$G_1(\theta) = G_0 - 12\left(\frac{\theta}{\theta_3}\right)^2$$

$$G_2(\theta) = G_0 - 12 + 10\ \log\left(\left(\max\left\{\frac{|\theta|}{\theta_3}, 1\right\}\right)^{-1.5} + k\right)$$

$$\theta_3 = \frac{31000 \times 10^{-0.1G_0}}{\varphi_s}$$

where:

$G(\theta)$: gain relative to an isotropic antenna (dBi)

G_0: maximum gain in or near the horizontal plane (dBi)

θ: absolute value of the elevation angle relative to the angle of maximum gain (degrees), ranging from 0° to 90°

θ_3: 3 dB beamwidth in the vertical plane (degrees)

φ_s: 3 dB beamwidth in the horizontal plane (degrees), φ_s = 65 is chosen in this study

k: parameter which accounts for the side-lobe levels of the antenna, k = 0 is chosen in this study (reference in *recommends* 2.1.2 of Recommendation ITU-R F.1336).

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[10] Parameters to be used in co-frequency sharing and pfd threshold studies between terrestrial IMT-2000 and broadcasting-satellite service (sound) in the 2 630-2 655 MHz band.

[11] Reference radiation patterns of omnidirectional, sectoral and other antennas in point-to-multipoint systems for use in sharing studies in the frequency range from 1 GHz to about 70 GHz.

2.5.2.6 SINR modelling

SINR is given by:

$$SINR = S - 10\ \log_{10}\left(\sum_{i=1}^{n_C} 10^{\frac{I_{C,i}}{10}} + \sum_{j=1}^{n_A} 10^{\frac{I_{A,j}}{10}} + 10^{\frac{N}{10}} \right)$$

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

where S is the desired signal strength (dBm) at the receiver:

- n_C: number of co-channel interfering transmissions
- $I_{C,i}$: co-channel interference received from the i^{th} transmitter (dBm)
- n_A: number of adjacent channel interfering transmissions
- $I_{A,j}$: adjacent channel interference received from the j^{th} transmitter (dBm) as reduced by the ACS and ACLR
- N: thermal noise (dBm)
- NF: system noise figure (dB).

2.5.2.7 CDMA-DS processing gain, SINR, and E_b/N_0

CDMA-DS processing gain is given by:

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

CDMA-DS uplink SINR is given by:

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

where:

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

CDMA-DS downlink SINR is given by:

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

where:

α: orthogonality factor, which is 0.4 in this study[12].

CDMA-DS E_b/N_0 is given by:

$$E_b/N_0 = PG + SINR$$

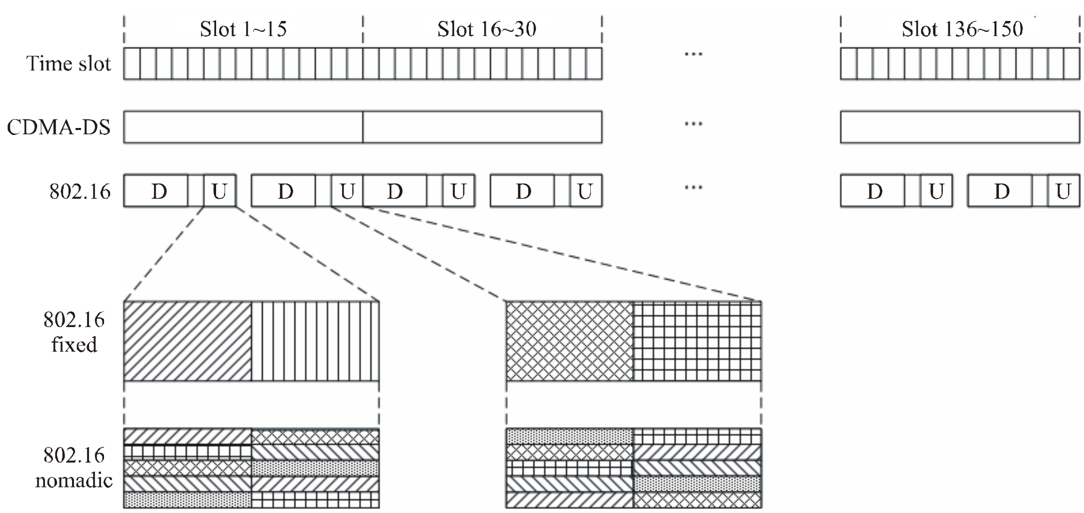
2.5.2.8 CDMA-DS power control and collection of interference information

The 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 E_b/N_0 requirement at the base station. The base station transmits every code with the same power. Consequently the downlink power control algorithm considers the mobile station with the lowest receiving power level to ensure a working connection for each mobile station[12]. The power control step size is 1 dB.

Each CDMA-DS frame contains 15 time slots, and each time slot lasts 0.667 ms. An 802.16 TDD frame is assumed to be 5 ms. The duration of one CDMA-DS frame thus corresponds to two 802.16 TDD frames. During the 150-step power control period in CDMA-DS, described below, 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 TDD downlink and uplink. This assumption is illustrated in Fig. 3. When calculating SINR for CDMA-DS at the end of the power control period, interference from 802.16 TDD uplinks and 802.16 TDD downlinks are considered separately.

FIGURE 3

CDMA-DS and 802.16 TDD frames in time domain



Note 1 – Different fillings indicate different users in different locations.

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As shown in Fig. 3, CDMA-DS FDD power control is affected by TDD DL and TDD UL. Following is the details in the 150-step power control:

Step 1 to 4: FDD is interfered by TDD DL

Step 5: FDD is not interfered by TDD (DL/UL transition gap, silent)

[12] See Note [4], page 5.

Step 6 to 7: FDD is interfered by TDD UL

Step 8: FDD is not interfered by TDD (UL/DL transition gap, silent)

Step 9 to 12: FDD is interfered by TDD DL

Step 13: FDD is not interfered by TDD (DL/UL transition gap, silent)

Step 14 to 15: FDD is interfered by TDD UL

Step 16: repeats Step 1, and so on.

At the end of power control, interference from TDD DL/UL to FDD is calculated separately. Specifically, at the end of Step 147, interference from TDD DL to FDD and interference from FDD to TDD DL are calculated; at the end of Step 150, interference from TDD UL to FDD and interference from FDD to TDD UL are calculated.

2.5.2.9 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 E_b/N_0 is less than (target E_b/N_0 – 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:

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

where:

N_total_ul: total uplinks in 19 cells

N_total_outage_ul_single: 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 TDD). Outage rate is measured and defined as OR_ul_multi:

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

where:

N_total_ul: total uplinks simulated

N_total_outage_ul_multi: total outage uplinks in multi-system case.

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

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

where:

N_ul_single: number of uplinks which meet the required E_b/N_0 in single system case

N_ul_multi: number of uplinks which meet the required E_b/N_0 in multi-system case.

The interference is unacceptable when C_ul_loss exceeds 5%.

One method for calculating the additional loss required is to reduce the interference sufficiently that the outage rate does not exceed 5%.

The second method for determining the additional isolation required to mitigate the 802.16 interference on the CDMA-DS uplink is described below.

Assume that the single CDMA-DS system uplink capacity is N_ul_single, and UL_Add_iso is the additional isolation when 802.16 TDD base station interferes CDMA-DS system base station, then:

N_ul_multi is obtained through simulation according to the 6 dB uplink noise rise criterion when co-existing with 802.16 TDD system. Where the CDMA-DS uplink noise rise is:

$$\text{Ul\_NR\_multi\_dB} = 10 \times \log_{10}\left(\frac{\text{UL\_R} \times \text{P\_intra} + \dfrac{\text{UL\_RxP\_inter}}{\text{UL\_Add\_iso}} + N_0}{N_0}\right)$$

Thus the CDMA-DS system uplink capacity loss is:

$$\text{C\_ul\_loss} = 1 - \frac{\text{N\_ul\_multi}}{\text{N\_ul\_single}}$$

When C_ul_loss equals to 5%, the corresponding UL_Add_iso.is the additional isolation needed for CDMA-DS system with 802.16 TDD in the adjacent band.

Note that this interference constraint is more stringent than in Table 5. The 5% capacity loss with a noise rise of 6 dB corresponds to an I/N constraint of −8.24 dB, and an interference limit of −111.4 dBm.

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, E_b/N_0 of each link is measured and compared with the target E_b/N_0. 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 TDD). Outage rate is measured and defined as OR_dl_multi. CDMA-DS downlink capacity loss due to additional interference from 802.16 TDD is calculated by

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

where:

N_dl_single: total downlinks of 19 cells which meet the required E_b/N_0 in single

N_dl_multi: total downlinks of 19 cells which meet the required E_b/N_0 in multi-system.

2.5.2.10 802.16 TDD performance evaluation criteria

In the simulations, the 802.16 TDD system is 75% loaded; i.e., at any given time, 75% of sub-carriers are occupied. After each simulation instantaneous SINR at each 802.16 TDD receiver is collected.

In order to get 802.16 TDD system level performance, 802.16 TDD link level performance results have to be obtained. The following table shows the 802.16 TDD link level performance simulation results in AWGN. 802.16 TDD physical layer is modeled. Neither ARQ nor scheduler gain (multi-user diversity) is included. The following table gives the required SNR to achieve the corresponding coding and modulation schemes for 1% packet error rate (PER) of 100 bytes convolutional turbo-coded (CTC) packets. Each result is averaged over 10,000 packets.

Outage is subsequently evaluated for 802.16 TDD: Outage occurs when the link SINR drops below –5.88 dB.

TABLE 12

Signal to noise ratio and modulation efficiency of 802.16 TDD physical layer for 1% PER

	SNR	Modulation efficiency relative to 1/2 rate-coded QPSK
QPSK CTC ½,6	–5.88	1/6
QPSK CTC ½,4	–4.12	1/4
QPSK CTC ½,2	–1.1	0.5
QPSK CTC ½	1.9	1
QPSK CTC ¾	5.2	1.5
16-QAM CTC ½	7.2	2
16-QAM CTC ¾	11.6	3
64-QAM CTC 2/3	15.6	4
64-QAM CTC ¾	17.3	4.5

The 802.16 TDD average modulation efficiency is calculated based on each link's instantaneous SINR and the SNR values in the above table, assuming that the interference is noise-like. It is given by:

$$\overline{ME} = \frac{\sum_{i=1}^{N} MEi}{N}$$

where:

MEi: modulation efficiency of the ith link

N: number of total links.

The loss in the modulation efficiency is calculated by:

$$\text{ME\_loss} = 1 - \frac{\overline{\text{ME}}\text{multi}}{\overline{\text{ME}}\text{single}}$$

where:

$\overline{\text{ME}}\text{single}$: average modulation efficiency of the 802.16 TDD system without CDMA-DS interference

$\overline{\text{ME}}\text{multi}$: average modulation efficiency of the 802.16 TDD system when coexisting with a CDMA-DS system.

2.5.3 Interference scenarios

2.5.3.1 CDMA-DS UL interference due to 802.16 TDD

Interference to CDMA-DS UL includes:

1 intra-system interference from the same sector;

2 intra-system interference from other sectors of the same cell and other cells of the same system;

3 adjacent channel interference from 802.16 TDD uplinks/downlinks.

2.5.3.2 802.16 TDD interfered by CDMA-DS UL

Interference to 802.16 TDD UL includes:

1 a) co-channel interference from the other cells' uplinks of the same system (for frequency reuse 1 × 3 × 3);

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 1 × 3 × 1);

2 adjacent channel interference from CDMA-DS UL.

Interference to 802.16 TDD DL includes:

1 a) co-channel interference from the other cells' downlinks of the same system (for frequency reuse 1 × 3 × 3);

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 1 × 3 × 1);

2 adjacent channel interference from CDMA-DS UL.

2.5.3.3 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 TDD uplinks/downlinks.

2.5.3.4 802.16 TDD interfered by CDMA-DS DL

Interference to 802.16 TDD UL includes:

1 a) co-channel interference from the other cells' uplinks of the same system (for frequency reuse 1 × 3 × 3);

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 1 × 3 × 1);

2 adjacent channel interference from CDMA-DS DL.

Interference to 802.16 TDD DL includes:

1 a) co-channel interference from the other cells' downlinks of the same system (for frequency reuse 1 × 3 × 3);

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 1 × 3 × 1);

2 adjacent channel interference from CDMA-DS DL.

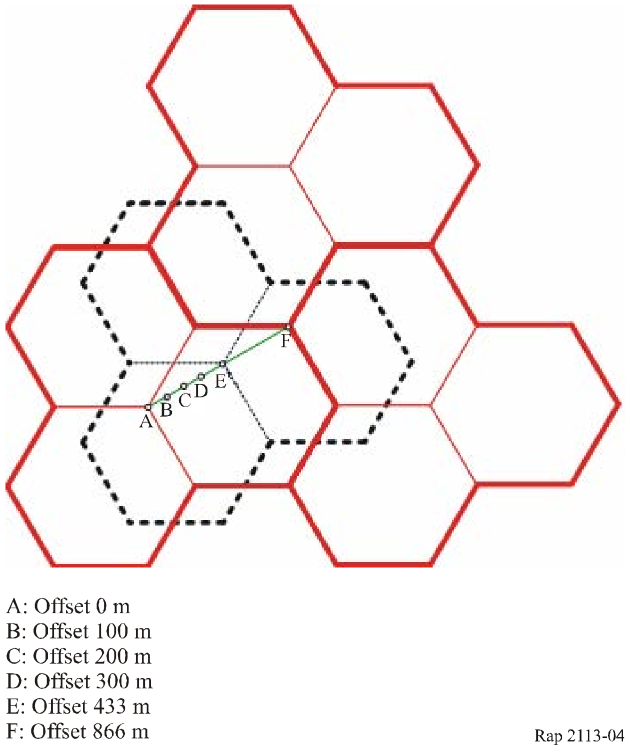
2.5.4 Results of statistical analysis

The standard ACLR and ACS numbers for CDMA-DS are used (see Table 3). The ACLR and ACS values for 802.16 TDD are taken from Table 2. Six offsets between two systems are simulated: 0 m (co-located), 100 m, 200 m, 300 m, 433 m, and 866 m. Simulations are run both on the first adjacent channel and the second adjacent channel; namely, no guard-channel and one guard-channel (5 MHz) exist between the two systems. Two frequency reuse schemes are considered in 802.16 TDD. Voice-only services are considered in CDMA-DS. Simulation is performed for more than 300 snapshots. Since the wrap-around technique is used to eliminate edge cell effects, information can be collected in all 19 cells (57 sectors) for each snapshot.

Both systems are assumed to have the same sector orientation; namely, that the antennas of the two systems point in the same three parallel directions. Figure 4 illustrates deployment layout. Only three cells of CDMA-DS and one cell of 802.16 TDD are shown.

FIGURE 4

Six offset positions of the two systems



In this study, additional isolation values required in case of CDMA-DS victim are chosen to meet the 5% capacity loss requirement in CDMA-DS performance. For the 802.16 TDD victim, additional isolation values are chosen to meet the 5% average modulation efficiency loss. Additional isolation can be achieved through the use of mitigating techniques (see Report ITU-R M.2045).

2.5.4.1 Standard CDMA-DS coexistence with 802.16 TDD with no guard band

The standard CDMA-DS system capacity loss due to interference from 802.16 TDD is shown in Table 13, and the 802.16 TDD average modulation efficiency loss and outage rate due to interference from standard CDMA-DS is shown in Table 14, and Table 15, respectively. The additional isolation required to ensure successful coexistence is given in Table 16. The shaded areas in all result tables of the statistical analysis show that additional isolation is needed for co-existence for those areas.

TABLE 13

Standard CDMA-DS system capacity loss with 802.16 TDD in the first adjacent channel

		Standard CDMA-DS system capacity loss (%)											
		Offset by 0 m		**Offset by 100 m**		**Offset by 200 m**		**Offset by 300 m**		**Offset by 433 m**		**Offset by 866 m**	
		UL	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**
802.16 TDD fixed	UL	52	0	21	0	15	0	12	0	10	0	10	0
	DL	98	0	56	0	45	0	43	0	37	0	37	1
802.16 TDD nomadic	UL	52	1	19	1	16	2	12	2	12	1	11	1
	DL	98	0	53	0	46	1	42	1	42	0	39	0

TABLE 14

802.16 TDD average modulation efficiency loss (including the users in outage) with standard CDMA-DS in the first adjacent channel

			Offset by 0 m		**Offset by 100 m**		**Offset by 200 m**		**Offset by 300 m**		**Offset by 433 m**		**Offset by 866 m**	
			CDMA-DS		**CDMA-DS**		**CDMA-DS**		**CDMA-DS**		**CDMA-DS**		**CDMA-DS**	
			UL	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**
802.16 efficiency loss (%)	802.16 TDD fixed (1 × 3 × 1)	UL	6	99	5	79	6	76	7	75	7	75	8	77
		DL	16	4	13	4	11	3	12	3	11	2	10	2
	802.16 TDD fixed (1 × 3 × 3)	UL	12	99	12	87	13	85	14	85	13	85	16	86
		DL	21	6	17	6	16	5	16	5	15	5	15	5
	802.16 TDD nomadic (1 × 3 × 1)	UL	8	99	8	84	11	79	7	79	10	78	11	79
		DL	17	3	13	3	13	4	12	4	13	3	12	2
	802.16 TDD nomadic (1 × 3 × 3)	UL	15	99	15	91	19	88	14	88	18	88	19	89
		DL	22	5	18	5	18	6	16	6	17	5	16	5

TABLE 15

802.16 TDD outage rate with standard CDMA-DS in the first adjacent channel

			Offset by 0 m		**Offset by 100 m**		**Offset by 200 m**		**Offset by 300 m**		**Offset by 433 m**		**Offset by 866 m**		**802.16 TDD single system**
			CDMA-DS		**CDMA-DS**		**CDMA-DS**		**CDMA-DS**		**CDMA-DS**		**CDMA-DS**		
			UL	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	
802.16 TDD outage rate (%)	802.16 TDD fixed (1 × 3 × 1)	UL	10	99	10	68	10	63	10	61	10	60	11	62	7.8
		DL	9	0	7	1	7	1	7	1	6	1	6	1	0.0
	802.16 TDD fixed (1 × 3 × 3)	UL	2	99	3	66	3	60	3	58	3	57	3	60	0.5
		DL	8	0	7	1	7	1	7	1	5	1	5	1	0.0
	802.16 TDD nomadic (1 × 3 × 1)	UL	16	99	16	78	18	72	16	72	17	70	17	71	12.5
		DL	11	1	9	1	8	1	7	1	7	1	7	1	0.3
	802.16 TDD nomadic (1 × 3 × 3)	UL	4	99	5	76	6	70	4	70	5	68	6	69	0.5
		DL	10	1	8	1	7	1	7	1	6	1	6	1	0.0

TABLE 16

Additional isolation needed for coexistence of 802.16 TDD and standard CDMA-DS in the first adjacent channel

Offset (m)	Coexistence		Additional isolation needed (dB)							
			From 802.16 TDD base station to CDMA-DS base station	From CDMA-DS base station to 802.16 TDD base station	From 802.16 TDD base station to CDMA-DS mobile station	From CDMA-DS mobile station to 802.16 TDD base station	From 802.16 TDD subscriber station to CDMA-DS base station	From CDMA-DS base station to 802.16 TDD subscriber station	From 802.16 TDD subscriber station to CDMA-DS mobile station	From CDMA-DS mobile station to 802.16 TDD subscriber station
0	CDMA-DS standard	Fixed	44	55 (1× 3 × 1) 60 (1 × 3 × 3)	0	0	0	0	0	3 (1 × 3 × 1) 5 (1 × 3 × 3)
		Nomadic	44	57 (1 × 3 × 1) 62 (1 × 3 × 3)	0	0	4	0	0	3 (1 × 3 × 1) 6 (1 × 3 × 3)
100	CDMA-DS standard	Fixed	26	35 (1 × 3 × 1) 43 (1 × 3 × 3)	0	0	0	0	0	3 (1 × 3 × 1) 5 (1 × 3 × 3)
		Nomadic	26	37 (1 × 3 × 1) 44 (1 × 3 × 3)	0	0	4	0	0	3 (1 × 3 × 1) 6 (1 × 3 × 3)
200	CDMA-DS standard	Fixed	21	31 (1 × 3 × 1) 38 (1 × 3 × 3)	0	0	0	0	0	3 (1 × 3 × 1) 5 (1 × 3 × 3)
		Nomadic	21	30 (1 × 3 × 1) 38 (1 × 3 × 3)	0	0	4	0	0	3 (1 × 3 × 1) 6 (1 × 3 × 3)
300	CDMA-DS standard	Fixed	17	28 (1 × 3 × 1) 34 (1 × 3 × 3)	0	0	0	0	0	3 (1 × 3 × 1) 5 (1 × 3 × 3)
		Nomadic	17	27 (1 × 3 × 1) 34 (1 × 3 × 3)	0	0	4	0	0	3 (1 × 3 × 1) 6 (1 × 3 × 3)
433	CDMA-DS standard	Fixed	15	26 (1 × 3 × 1) 33 (1 × 3 × 3)	0	0 (1 × 3 × 1) 1 (1 × 3 × 3)	0	0	0	3 (1 × 3 × 1) 5 (1 × 3 × 3)
		Nomadic	16	26 (1 × 3 × 1) 33 (1 × 3 × 3)	0	0 (1 × 3 × 1) 1 (1 × 3 × 3)	4	0	0	3 (1 × 3 × 1) 6 (1 × 3 × 3)
866	CDMA-DS standard	Fixed	15	26 (1 × 3 × 1) 33 (1 × 3 × 3)	0	0 (1 × 3 × 1) 2 (1 × 3 × 3)	0	0	0	3 (1 × 3 × 1) 5 (1 × 3 × 3)
		Nomadic	15	26 (1 × 3 × 1) 33 (1 × 3 × 3)	0	0 (1 × 3 × 1) 2 (1 × 3 × 3)	4	0	0	3 (1 × 3 × 1) 6 (1 × 3 × 3)

Followings are some observations and explanations on the results. These observations and explanations apply to the corresponding results in the remainder of the statistical analyses unless explicitly stated otherwise.

Some CDMA-DS system capacity loss values are higher than 5%, but they are not marked as problematic scenarios which need additional isolation for successful coexistence. Actually, no additional isolation is needed for those scenarios. Standard CDMA-DS coexistence with 802.16 fixed TDD with an offset of 100 m is chosen as an example. The CDMA-DS uplink capacity loss due to interference from 802.16 TDD fixed uplink (including thermal noise and CDMA-DS uplink co-channel interference) is 21%, but the additional isolation from 802.16 TDD fixed subscriber station to CDMA-DS base station is 0 dB to ensure successful coexistence. CDMA-DS uplink power control is affected by both 802.16 TDD downlink and 802.16 TDD uplink. Since the interference from 802.16 TDD base station to CDMA-DS base station is severe, during the power control period CDMA-DS mobile stations have to increase their transmit power to try to get higher SINR at the base station. At the end of the power control period, the calculated CDMA-DS uplink SINR due to 802.16 TDD uplink (including thermal noise and CDMA-DS uplink co-channel interference) is bad since the CDMA-DS uplink co-channel interference is severe. This causes the CDMA-DS uplink capacity loss due to interference from 802.16 TDD fixed uplink to 21%. As the interference from 802.16 TDD base station to CDMA-DS base station decreases by adding more additional isolation from 802.16 TDD base station to CDMA-DS base station, the CDMA-DS uplink capacity loss due to interference from 802.16 TDD fixed uplink (including thermal noise and CDMA-DS uplink co-channel interference) drops to 5% without adding any additional isolation from 802.16 TDD subscriber station to CDMA-DS base station.

Similar phenomena appear in the 802.16 TDD efficiency loss table. Some 802.16 TDD efficiency loss values are higher than 5%, but they are not marked as problematic scenarios and no additional isolation is needed. Standard CDMA-DS coexistence with 802.16 TDD nomadic 1 × 3 × 3 TDD with an offset of 100 m is chosen as an example. The 802.16 TDD uplink efficiency loss due to CDMA-DS uplink is 15%, but the additional isolation from CDMA-DS mobile station to 802.16 TDD base station is 0 dB to ensure successful coexistence. CDMA-DS uplink power control is affected by both 802.16 TDD downlink and 802.16 TDD uplink. Since the interference from 802.16 TDD base station to CDMA-DS base station is severe, during the power control period CDMA-DS mobile stations have to increase their transmit power to try to get higher SINR at the base station. At the end of the power control period, the calculated 802.16 TDD uplink SINR due to CDMA-DS uplink is bad since the CDMA-DS uplinks transmit at higher power. This causes the 802.16 TDD efficiency loss due to interference from CDMA-DS uplink to 15%. As the interference from 802.16 TDD base station to CDMA-DS base station decreases by adding more additional isolation from 802.16 TDD base station to CDMA-DS base station, the 802.16 TDD uplink efficiency loss due to interference from CDMA-DS uplink drops to 5% without adding any additional isolation from CDMA-DS mobile station to 802.16 TDD base station.

A similar approach can be used to explain the cases of interference from CDMA-DS to 802.16 TDD downlink.

The outage rate of 802.16 TDD with frequency reuse of 1 × 3 × 3 is smaller than that of 802.16 TDD with frequency reuse of 1 × 3 × 1 both for single system and for multiple systems, but the modulation efficiency loss of 802.16 TDD with frequency reuse of 1 × 3 × 3 is higher than that of 802.16 TDD with frequency reuse of 1 × 3 × 1 since the case of 1 × 3 × 3 is more sensitive to the adjacent channel interference. Consequently, the additional isolation required from CDMA-DS to 802.16 TDD with frequency reuse of 1 × 3 × 3 is higher than that of 1 × 3 × 1.

The required additional isolation from CDMA-DS mobile station to 802.16 TDD base station is 0 dB for offset distances of 0, 100, 200, 300 m, while the requirement is 1 to 2 dB for offset distances of 433, and 866 m with frequency reuse of 1 × 3 × 3. Normally the transmit power of the

CDMA-DS mobile at the cell edge is higher than that of the CDMA-DS mobile which is closer to its base station. As the 802.16 TDD base station moves further from the CDMA-DS base station, the 802.16 TDD base station experiences more adjacent channel interference from the CDMA-DS mobile. This phenomenon does not happen in requirement of additional isolation from 802.16 TDD subscriber station to CDMA-DS base station, because 802.16 TDD subscriber station always transmits at the same power level.An alternative approach to evaluating the interference between the two systems included in another study is to measure the noise rise in the CDMA-DS uplink. The CDMA-DS uplink noise rise is measured in the multi-system simulation. In the simulation, CDMA-DS system load is assumed to be the same as that of the single system.

The parameters of 802.16 TDD remain the same as that of the single system scenario.

The CDMA-DS uplink noise rise is calculated using the following expression:

$$UL\_NR\_multi\_dB = 10\ \log_{10}\left(\frac{UL\_RxP\_intra + UL\_RxP\_inter + N_0}{N_0}\right)$$

where:

UL_RxP_intra: total uplink received intra-system interference, ie, the total power received from other CDMA-DS mobile stations

UL_RxP_inter: total uplink received inter-system interference, ie, the power received from the 802.16 TDD system base stations or subscriber stations, depending on the part of the TDD frame.

The noise rise that occurs when the 802.16 system is introduced, i.e., UL_NR_multi_dB, is shown in Table 17. The uplink values (UL) show the noise rise caused by CDMA-DS and 802.16 uplink interference measured in Step 150, ie at the end of an uplink transmission, and the downlink values (DL) show the noise rise caused by CDMA-DS uplink and 802.16 downlink interference, measured in Step 147, i.e., at the end of a downlink transmission. The noise rises observed are considerably greater than 6 dB. When the noise rise is high, the outage shown in Table 13 was high. For example, when collocated with 50 dB coupling loss, the noise rise is 46.6 dB and the outage is 98%. Since most CDMA-DS mobile stations have been dropped and those remaining are transmitting a high power, when the uplink starts the interference is dominated by interference from other CDMA-DS users, as the power control responds slowly to the reduction in external interference. The downlink interference is dominant.

TABLE 17

CDMA-DS system uplink noise rise with 802.16 TDD in the first adjacent channel (dB)

			CDMA-DS system uplink noise rise (dB)					
			Offset by 0 m	**Offset by 100 m**	**Offset by 200 m**	**Offset by 300 m**	**Offset by 433 m**	**Offset by 866 m**
Standard CDMA-DS	802.16 TDD fixed	**UL**	22.3	21.3	21.1	20.7	20.7	19.7
		DL	46.6	36.0	30.8	28.3	26.9	25.9
	802.16 TDD nomadic	**UL**	23.5	22.3	21.7	21.5	22.1	20.4
		DL	46.6	36.1	31.0	28.6	27.4	26.2

In Table 18 the CDMA-DS downlink system capacity loss that occurs when the 802.16 system is introduced. The capacity losses shown in Table 13 are of similar magnitude, when taking rounding into account. Losses caused by 802.16 downlink are a little greater with the 433 m and 866 m separations.

TABLE 18

CDMA-DS system downlink capacity loss with 802.16 TDD in the first adjacent channel

			CDMA-DS system downlink capacity loss (%)					
			Offset by 0 m	**Offset by 100 m**	**Offset by 200 m**	**Offset by 300 m**	**Offset by 433 m**	**Offset by 866 m**
Standard CDMA-DS	802.16 fixed	**UL**	1.0	0.9	0.8	1.0	1.3	1.7
		DL	0.8	0.7	0.9	0.9	2.4	3.6
	802.16 nomadic	**UL**	1.2	1.0	1.0	1.0	1.1	1.4
		DL	0.8	0.7	0.9	1.2	2.3	3.0

In Table 19 the average modulation efficiency loss in the 802.16 system when the CDMA-DS system is introduced in the adjacent channel. The losses shown in Table 14 are considerably greater than those shown in Table 19.

TABLE 19

802.16 TDD average modulation efficiency loss with CDMA-DS in the first adjacent channel

				CDMA-DS											
				Offset by 0 m		**Offset by 100 m**		**Offset by 200 m**		**Offset by 300 m**		**Offset by 433 m**		**Offset by 866 m**	
				UL	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**
802.16 TDD efficiency loss (%)	Standard CDMA-DS	802.16 fixed (1 × 3 × 1)	UL	0.3	91.1	0.5	55.7	0.7	46.7	1.2	45.8	2.6	44.8	3.2	43.6
			DL	2.0	0.8	1.7	1	1.5	1.3	1.4	1.6	1.4	1.6	1.1	1
		802.16 fixed (1 × 3 × 3)	UL	0.2	92.1	0.2	65.7	0.4	57.9	0.7	54.5	1.7	54.2	2.6	52.8
			DL	0.5	0.3	0.5	0.4	0.4	0.6	0.4	1	0.3	1	0.3	0.5
		802.16 nomadic (1 × 3 × 1)	UL	0.4	92.3	0.4	59.9	0.7	50.7	1.3	46.9	2.6	46.1	3.3	43.7
			DL	2.4	0.7	2	0.8	1.7	1.2	1.6	1.5	1.6	1.6	1.3	1
		802.16 nomadic (1 × 3 × 3)	UL	0.2	93	0.2	67.1	0.4	58.6	0.7	55.8	1.7	56	2.6	55.7
			DL	0.6	0.3	0.5	0.4	0.4	0.7	0.4	0.9	0.4	1.1	0.4	0.7

In Table 20 the additional isolation needed to reduce the noise rise in the CDMA-DS system to 6 dB with a capacity loss of 5% is given. Additional isolation is only required in the base station to base station interference path: No additional isolation is required for any other path. The additional isolations needed between base stations shown in Table 20 are considerably greater than those shown in Table 16 as these are sufficient to reduce the noise rise to 6 dB with a capacity loss of 5%, ie, to reduce the 802.16 interference to −111.4 dBm.

The earlier simulations included a substantial unknown link margin. In cases of large link margins each additional dB in the link margin results in 1dB less isolation and vice versa.

TABLE 20

Additional isolation needed (dB) to reduce interference from IEEE802.16 to CDMA-DS

	Offset (m)	802.16 TDD	From 802.16 TDD base station to CDMA-DS base station	From 802.16 TDD base station to CDMA-DS mobile station	From 802.16 TDD SS to CDMA-DS base station	From 802.16 TDD SS to CDMA-DS mobile station
Standard CDMA-DS	0	Fixed	53	0	0	0
		Nomadic	53	0	0	0
	100	Fixed	43	0	0	0
		Nomadic	43	0	0	0
	200	Fixed	36	0	0	0
		Nomadic	36	0	0	0
	300	Fixed	32	0	0	0
		Nomadic	32	0	0	0
	433	Fixed	30	0	0	0
		Nomadic	30	0	0	0
	866	Fixed	29	0	0	0
		Nomadic	29	0	0	0

In Table 21 the additional isolation values needed to reduce the modulation efficiency loss of the 802.16 system to 5% are given. Additional isolation is only required in the base station to base station interference path: No additional isolation is required for any other path.

TABLE 21

Additional isolation needed (dB) to reduce CDMA-DS interference to IEEE802.16

	Offset (m)	802.16 TDD	From CDMA-DS base station to 802.16 TDD base station	From CDMA-DS base station to 802.16 TDD SS	From CDMA-DS mobile station to 802.16 TDD base station	From CDMA-DS mobile station to 802.16 TDD SS
Standard CDMA-DS	0	Fixed	40 (1 × 3 × 1) 43 (1 × 3 × 3)	0	0	0
		Nomadic	40 (1 × 3 × 1) 43 (1 × 3 × 3)	0	0	0
	100	Fixed	30 (1 × 3 × 1) 33 (1 × 3 × 3)	0	0	0
		Nomadic	30 (1 × 3 × 1) 33 (1x3x3)	0	0	0
	200	Fixed	25 (1 × 3 × 1) 27 (1 × 3 × 3)	0	0	0
		Nomadic	26 (1 × 3 × 1) 27 (1 × 3 × 3)	0	0	0

TABLE 21 (*end*)

	Offset (m)	802.16 TDD	From CDMA-DS base station to 802.16 TDD base station	From CDMA-DS base station to 802.16 TDD SS	From CDMA-DS mobile station to 802.16 TDD base station	From CDMA-DS mobile station to 802.16 TDD SS
Standard CDMA-DS	300	Fixed	21 (1 × 3 × 1) 25 (1 × 3 × 3)	0	0	0
		Nomadic	22 (1 × 3 × 1) 25 (1 × 3 × 3)	0	0	0
	433	Fixed	17 (1 × 3 × 1) 21 (1 × 3 × 3)	0	0	0
		Nomadic	17 (1 × 3 × 1) 22 (1 × 3 × 3)	0	0	0
	866	fixed	15 (1 × 3 × 1) 18 (1 × 3 × 3)	0	0	0
		Nomadic	15 (1 × 3 × 1) 19 (1 × 3 × 3)	0	0	0

2.5.4.2 Standard CDMA-DS coexistence with 802.16 TDD with one guard channel (5 MHz)

The standard CDMA-DS system capacity loss due to interference from 802.16 TDD is shown in Table 22, and the 802.16 TDD average modulation efficiency loss and outage rate due to interference from standard CDMA-DS is shown in Table 23, and Table 24, respectively. The additional isolation required to ensure successful coexistence is given in Table 25.

TABLE 22

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

		Standard CDMA-DS system capacity loss (%)											
		Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m	
		UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL
802.16 TDD fixed	UL	33	1	7	0	4	0	2	0	2	0	1	0
	DL	85	1	27	0	17	0	13	0	10	0	8	0
802.16 TDD nomadic	UL	35	0	7	0	5	0	2	0	1	0	1	0
	DL	87	0	27	0	20	0	12	0	9	0	9	0

TABLE 23

802.16 TDD average modulation efficiency loss (including the users in outage) with standard CDMA-DS in the second adjacent channel (5 MHz guard band)

			Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m	
			CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS	
			UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL
802.16 TDD efficiency loss (%)	802.16 fixed (1 × 3 × 1)	UL	0	99	2	67	0	61	0	61	1	62	0	61
		DL	6	1	4	0	2	1	2	0	3	2	4	0
	802.16 fixed (1 × 3 × 3)	UL	2	99	3	78	1	74	0	74	2	75	2	75
		DL	10	2	6	1	5	1	4	1	5	3	5	2
	802.16 nomadic (1 × 3 × 1)	UL	2	99	1	69	2	65	3	65	1	64	2	65
		DL	7	0	4	0	4	1	2	2	4	1	2	1
	802.16 nomadic (1 × 3 × 3)	UL	4	99	3	81	4	78	4	79	2	78	4	80
		DL	11	1	8	1	7	1	4	2	6	2	4	2

TABLE 24

802.16 TDD outage rate with standard CDMA-DS in the second adjacent channel (5 MHz guard band)

			Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m		802.16 TDD Single System
			CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		
			UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	
802.16 TDD outage rate (%)	802.16 TDD fixed (1 × 3 × 1)	UL	8	98	8	56	8	48	8	47	8	46	8	45	7.8
		DL	3	0	1	0	1	0	1	0	1	0	1	0	0.0
	802.16 TDD fixed (1 × 3 × 3)	UL	1	98	1	52	1	44	1	43	1	42	1	41	0.5
		DL	2	0	1	0	1	0	1	0	1	0	1	0	0.0
	802.16 TDD nomadic (1 × 3 × 1)	UL	13	99	13	62	13	57	13	57	13	55	13	55	12.5
		DL	3	0	2	0	2	0	1	0	1	1	1	1	0.3
	802.16 TDD nomadic (1 × 3 × 3)	UL	1	99	1	58	1	53	1	53	1	51	1	51	0.5
		DL	3	0	2	0	1	0	1	0	1	0	1	0	0.0

TABLE 25

Additional isolation needed for coexistence of 802.16 TDD and standard CDMA-DS in the second adjacent channel (5 MHz guard band)

Offset (m)	Coexistence		Additional isolation needed (dB)							
			From 802.16 TDD base station to CDMA-DS base station	From CDMA-DS base station to 802.16 TDD base station	From 802.16 TDD base station to CDMA-DS mobile station	From CDMA-DS mobile station to 802.16 TDD base station	From 802.16 TDD subscriber station to CDMA-DS base station	From CDMA-DS base station to 802.16 TDD subscriber station	From 802.16 TDD subscriber station to CDMA-DS mobile station	From CDMA-DS mobile station to 802.16 TDD subscriber station
0	CDMA-DS standard	Fixed	32	50 (1 × 3 × 1) 55 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	32	52 (1 × 3 × 1) 57 (1 × 3 × 3)	0	0	0	0	0	0
100	CDMA-DS standard	Fixed	14	31 (1 × 3 × 1) 38 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	14	32 (1 × 3 × 1) 39 (1 × 3 × 3)	0	0	0	0	0	0
200	CDMA-DS standard	Fixed	9	26 (1 × 3 × 1) 33 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	9	25 (1 × 3 × 1) 33 (1 × 3 × 3)	0	0	0	0	0	0
300	CDMA-DS standard	Fixed	6	23 (1 × 3 × 1) 29 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	6	22 (1 × 3 × 1) 29 (1 × 3 × 3)	0	0	0	0	0	0
433	CDMA-DS standard	Fixed	4	21 (1 × 3 × 1) 28 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	4	21 (1 × 3 × 1) 28 (1 × 3 × 3)	0	0	0	0	0	0
866	CDMA-DS standard	Fixed	3	21 (1 × 3 × 1) 28 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	3	21 (1 × 3 × 1) 28 (1 × 3 × 3)	0	0	0	0	0	0

2.5.5 Summary of statistical analysis of standard CDMA-DS coexistence with 802.16 TDD

The statistical analysis quantifies the impact of the first and the second adjacent channel interference between standard CDMA-DS and 802.16 TDD on system capacity loss or modulation efficiency loss for different offset distances. Based on the Monte Carlo simulation results, the amounts of additional isolation between these two systems are provided to ensure successful coexistence. Since the 5 MHz guard band provides more frequency isolation, the results of the second adjacent channel is better than those of the first adjacent channel.

Due to the existence of LoS between base stations, the worst adjacent channel interference is experienced between the base stations of these two systems.

One study shows that for the worst case of two co-located base stations operating on the first adjacent channel, as high as 44 dB additional isolation is needed from 802.16 base station to standard CDMA-DS base station, and 62 dB additional isolation is needed from standard CDMA-DS base station to 802.16 base station for nomadic case with frequency reuse of 1 × 3 × 3, with a coupling loss of 50 dB. As the offset of these two systems is increased from co-located to 866 m, the additional isolation requirement becomes smaller.

A second study shows that for the worst case of two co-located base stations operating on the first adjacent channel, as high as 53 dB additional isolation is needed from 802.16 base station to standard CDMA-DS base station, and 43 dB additional isolation is needed from standard CDMA-DS base station to 802.16 base station for nomadic case with frequency reuse of 1 × 3 × 3, with a coupling loss of 50 dB. As the offset of these two systems is increased from co-located to 866 m, the additional isolation requirement becomes smaller.

The adjacent channel interference from standard CDMA-DS uplink to 802.16 TDD uplink is negligible for most scenarios. A small amount of additional isolation from CDMA-DS mobile station to 802.16 TDD base station is required for offsets of 433 m and 866 m.

There is some interference from 802.16 TDD nomadic uplink to standard CDMA-DS uplink. Additional isolation of 4 dB is required from 802.16 TDD nomadic subscriber station to CDMA-DS base station. On the other hand, the adjacent channel interference from 802.16 TDD fixed uplink to CDMA-DS uplink is negligible and no additional isolation is needed from 802.16 TDD fixed subscriber station to CDMA-DS base station.

There is some interference from standard CDMA-DS uplink to 802.16 TDD downlink. Additional isolation of 3 to 6 dB is required from CDMA-DS mobile station to 802.16 TDD subscriber station.

The adjacent channel interference from 802.16 TDD to standard CDMA-DS downlink is negligible for all scenarios. No additional isolation from 802.16 TDD base station to CDMA-DS mobile station and from 802.16 TDD subscriber station to CDMA-DS mobile station is required.

The adjacent channel interference from standard CDMA-DS downlink to 802.16 TDD downlink is negligible. No additional isolation from CDMA-DS base station to 802.16 TDD subscriber station is required.

The second study shows that no additional isolation is required in any interference path other than base station to base station.

Each additional isolation requirement of the second adjacent channel case is better than the correspondent part of the first adjacent channel case.

2.6 Mitigation techniques and their impacts

In this section we analyze the impact of mitigation techniques. Some general techniques are described in Annex F. For example, one of the interference mitigation techniques presented in

Annex F and discussed in Report ITU-R M.2045 is the effect of better filters that would yield better ACLR and ACS values.

A second mitigation technique described in Report ITU-R M.2045 and Annex F is the use of special site design to increase the isolation between antennas. The benefit of increased coupling loss between antennas is also considered and analyzed.

Enhanced isolation values for CDMA-DS equipment, i.e., improved ACLR and ACS values are also derived in Annex F, and these will be considered first.

2.6.1 Deterministic analysis of interference using enhanced isolation values for CDMA-DS

Enhanced isolation values are given in Table 26, replicated from Table 87. Note that these values are not specified in any existing document, and that there is currently no plan to update the standard with such enhanced values. These enhanced isolation values, with the exception of the base station ACS are all better than the equivalent 802.16 TDD parameters, and consequently the performance is now limited by the 802.16 equipment. The combined ACIR is given in Table 27. The methodology for calculating the additional isolation is the same as that used in § 2.4.

TABLE 26

Enhanced isolation values used for CDMA-DS (taken from Annex F)

Parameter	First adjacent channel at 5 MHz	Second adjacent channel at 10 MHz
Base station ACLR (dB)	57	74
Base station ACS (dB)	65	75
Mobile station ACLR (dB)	46	64
Mobile station ACS (dB)	58	65

TABLE 27

ACIR values (dB) for the interference paths of interest, with enhanced isolation values for CDMA-DS

Interference path	First adjacent channel	Second adjacent channel
TDD base station ⇒ FDD base station	53	65
FDD base station ⇒ TDD base station	57	69
TDD base station ⇒ FDD mobile station	52	62
FDD mobile station ⇒ TDD base station	46	63
FDD base station ⇒ TDD SS	40	59
TDD SS ⇒ FDD base station	33 (nomadic) 37 (fixed)	51

TABLE 27 (*end*)

Interference path	First adjacent channel	Second adjacent channel
TDD SS ⇒ FDD mobile station	33 (nomadic) 37 (fixed)	51
FDD mobile station ⇒ TDD SS	39	58

2.6.1.1 Interference between base stations

The summary in Table 28 includes results for co-sited 802.16 TDD and CDMA-DS base stations, and for 802.16 TDD and CDMA-DS base stations separated by distances of 100 m, 200 m, 500 m and 1 km. Note that a negative value in this table signifies that the enhanced isolation values are 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 28

A summary of the additional isolation needed (dB) when considering base station-to-base station interference for different base station separation distances. This was calculated using enhanced isolation values for CDMA-DS

Deployment scenario		TDD base station ⇒ FDD base station				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/FDD macro	1st adj chan	62.0	46.3	36.7	32.3	26.3
	2nd adj chan	50.0	34.3	24.7	20.3	14.3
TDD macro/FDD micro	1st adj chan	15.0	5.8	–12.3	–20.8	–32.2
	2nd adj chan	3.0	–6.2	–24.3	–32.8	–44.2
TDD macro/FDD pico	1st adj chan	3.0	–11.1	–29.3	–37.7	–49.1
	2nd adj chan	–9.0	–23.1	–41.3	–49.7	–61.1
Deployment scenario		**FDD base station ⇒ TDD base station**				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/FDD macro	1st adj chan	66.0	50.3	40.7	36.3	30.3
	2nd adj chan	54.0	38.3	28.7	24.3	18.3
TDD macro/FDD micro	1st adj chan	14.0	4.8	–13.3	–21.8	–33.2
	2nd adj chan	2.0	–7.2	–25.3	–33.8	–45.2
TDD macro/FDD pico	1st adj chan	–12.0	–26.1	–44.3	–52.7	–64.1
	2nd adj chan	–24.0	–38.1	–56.3	–64.7	–76.1

Although the additional isolation values are lower in Table 28, than in Table 6 (which uses standard values), we still find 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 further 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) with the exception of the TDD macrocell and the FDD picocell operating in the second adjacent channel.

2.6.1.2 Interference between base station and mobile station; and between a base station and a SS

Using the enhanced isolation values in the worst case situation with the mobile station transmitting at full power whilst close to the victim base station and using the minimum coupling loss between the base station antenna and mobile station antenna was applied, which is described further in Annex C. The resulting additional isolation needed in this situation is shown in Table 29, which indicates that the performance of the base station is degraded due to interference from a nearby mobile station, although the enhanced isolation values for CDMA-DS do not degrade the performance of the 802.16 TDD base station when operating in the second adjacent channel. Similar interference occurs in FDD networks operating in adjacent spectrum.

TABLE 29

A summary of the additional isolation needed (dB) when considering interference between base stations and mobile stations for selected scenarios using enhanced isolation values for CDMA-DS

Deployment scenario		Fixed SS => FDD base station	FDD base station => Fixed SS	Nomadic SS => FDD base station	FDD base station => Nomadic SS	FDD mobile station => TDD base station	TDD base station => FDD mobile station
TDD macro/ FDD macro	1st adj chan	29.1	44.1	23.3	38.3	9.3	13.3
	2nd adj chan	15.1	25.1	5.3	19.3	–7.7	3.3
TDD macro/ FDD micro	1st adj chan	55.2	65.2	43.2	53.2	9.3	13.3
	2nd adj chan	41.2	46.2	25.2	34.2	–7.7	3.3
TDD macro/ FDD pico	1st adj chan	53.3	45.3	58.3	54.3	9.3	13.3
	2nd adj chan	39.3	26.3	40.3	35.3	–7.7	3.3

2.6.1.3 Interference between mobile station and SS

Finally, analysis of the impact of ACI between a 802.16 TDD SS and a CDMA-DS mobile station with enhanced isolation values, was based on a worst-case scenario when the mobile station and SS were close together and transmitting at maximum power. The results indicate that additional isolation of 44.3 dB and 30.3 dB would be needed for the first and second adjacent channels, respectively, to protect the CDMA-DS receiver, from a fixed SS, whilst additional isolation of 46.3 dB and 27.3 dB would be needed to protect the fixed SS receiver, respectively.

Similarly, additional isolation of 54.3 dB and 36.3 dB would be needed for the first and second adjacent channels, respectively, to protect the CDMA-DS receiver from a Nomadic SS with a separation of 1 m, whilst additional isolation of 52.3 dB and 33.3 dB would be needed to protect the Nomadic SS receiver from the CDMA-DS mobile station, respectively.

In line-of-sight (LoS) conditions, using the breakpoint model described in Annex A, the separation distances needed to protect the receivers from each other were computed, and these values are presented in Table 30.

TABLE 30

A summary of the line-of-sight separations in meters needed to protect mobile stations and SSs using enhanced isolation values for CDMA-DS

	Fixed SS => FDD mobile station	FDD mobile station => Fixed SS	Nomadic SS => FDD mobile station	FDD mobile station => Nomadic SS
1st adj chan	438	390	201	179
2nd adj chan	183	82	65	46

2.6.2 Deterministic analysis of interference between base stations with mitigation techniques and enhanced isolation values for CDMA-DS

In order to provide the additional isolation, the interference analysis between base stations was extended to incorporate mitigation techniques for the 802.16 TDD technology. There are various techniques that can be used to mitigate ACI, which are described in Report ITU-R M.2045. This includes techniques such as adaptive antennas, handovers and power control. However this study identifies the following key mitigation techniques that can offer additional ACI protection, which are described in Annex F:

a) The inclusion of a channel filter, which could provide approximately 60 dB of additional rejection in the RF front-end of the base station. This could potentially improve the ACLR and ACS performance in the first and second adjacent channels of the 802.16 TDD base station by 60 dB. Note that such a filter requirement is extremely challenging in 1st adjacent channel with today's technologies.

b) 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 base stations are co-sited in a macrocellular deployment.

A summary of the ACLR and ACS performance of the 802.16 TDD incorporating the RF front-end filter and enhanced isolation values for the CDMA-DS base station is shown in Table 31.

TABLE 31

ACLR and ACS values (dB) for the 802.16 TDD base station that incorporates mitigation techniques and enhanced isolation values for the CDMA-DS base station

	ACLR		ACS	
	First adjacent channel	Second adjacent channel	First adjacent channel	Other adjacent channels
CDMA-DS base station	57	74	65	75
802.16 TDD base station	113.5	126	130	130

Using equation (1) from § 2.2, the resulting ACIR values for the base station-to-base station interference paths are shown in Table 32. It is observed that the lower ACLR and ACS performance of the CDMA-DS base station are the dominating factors in determining the final ACIR values.

TABLE 32

ACIR values (dB) that incorporate enhanced isolation values for the CDMA-DS base station and the RF front-end filter for the TDD base station

Interference path	First adjacent channel	Second adjacent channel
TDD base station ⇒ FDD base station	65	75
FDD base station ⇒ TDD base station	57	74

By incorporating these ACIR values and an antenna coupling loss of 65 dB, the additional isolation needed by the base stations to ensure successful co-existence is shown in Table 33.

TABLE 33

A summary of the additional isolation needed (dB) when considering base station-to-base station interference for different base station separation distances. These results incorporate the RF front-end filter for the 802.16 TDD base station and enhanced isolation values for the CDMA-DS base station

Deployment scenario		TDD base station ⇒ FDD base station				
		Co-sited	100 m	300 m	500 m	1 km
TDD macro/ FDD macro	1st adj chan	15.0	34.3	24.7	20.3	14.3
	2nd adj chan	5.0	24.3	14.7	10.3	4.3
TDD macro/ FDD micro	1st adj chan	3.0	–6.2	–24.3	–32.8	–44.2
	2nd adj chan	–7.0	–16.2	–34.3	–42.8	–54.2
TDD macro/ FDD pico	1st adj chan	–9.0	–23.1	–41.3	–49.7	–61.1
	2nd adj chan	–19.0	–33.1	–51.3	–59.7	–71.1
Deployment scenario		**FDD base station ⇒ TDD base station**				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/ FDD macro	1st adj chan	31.0	50.3	40.7	36.3	30.3
	2nd adj chan	14.0	33.3	23.7	19.3	13.3
TDD macro/ FDD micro	1st adj chan	14.0	4.8	–13.3	–21.8	–33.2
	2nd adj chan	–3.0	–12.2	–30.3	–38.8	–50.2
TDD macro/ FDD pico	1st adj chan	–12.0	–26.1	–44.3	–52.7	–64.1
	2nd adj chan	–29.0	–43.1	–61.3	–69.7	–81.1

By incorporating the mitigation techniques for 802.16 TDD, co-existence between the two technologies in a macrocellular deployment it is still not feasible using a guard band of 5 MHz. When considering the FDD base station as the interference victim, the ACS of the CDMA-DS base station is not sufficient to guarantee successful co-existence. Similarly, the ACLR performance of the CDMA-DS base station allows too much ACI to fall into the 802.16 TDD receiver bandwidth.

However, the CDMA-DS base stations utilising enhanced isolation values would provide improved isolation between the two technologies.

In order to improve the performance of the CDMA-DS base station[13], similar RF channel filters can be introduced, which provide a 60 dB improvement in the ACLR and ACS performance [Wilkinson and Howard, 2004], as shown in Table 34. The introduction of such filters in a CDMA-DS base station precludes the use of multicarrier power amplifier implementations. The resulting ACIR values derived from these ACLR and ACS values are shown in Table 35.

TABLE 34

ACLR and ACS values (dB) for the CDMA-DS and 802.16 TDD base stations that incorporate RF front-end filters and the enhanced isolation values of the CDMA-DS base station

	ACLR		**ACS**	
	First adjacent channel	**Second adjacent channel**	**First adjacent channel**	**Other adjacent channels**
CDMA-DS base station	117	134	125	135
802.16 TDD base station	113.5	126	130	130

TABLE 35

ACIR values (dB) that incorporate CDMA-DS and 802.16 TDD base station RF front-end filters and the enhanced isolation values of the CDMA-DS base station

Interference path	**First adjacent channel**	**Second adjacent channel**
TDD base station ⇒ FDD base station	113	125
FDD base station ⇒ TDD base station	117	129

Using the ACIR values shown in Table 35, the resulting additional isolation needed for co-existence is summarized in Table 36, which also assumes an antenna coupling loss of 65 dB.

[13] It should also be noted that since the central band of the 2 500-2 690 MHz spectrum could also be used for CDMA-DS technology, it is an added incentive to ensure that the performance of the CDMA-DS base station are improved.

TABLE 36

A summary of the additional isolation needed (dB) when considering base station-to-base station interference for different base station separation distances. These results incorporate special site solutions for co-located base stations, RF front-end filters for CDMA-DS and 802.16 TDD base stations and enhanced isolation values for the CDMA-DS base station

Deployment scenario		**TDD base station ⇒ FDD base station**				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/ FDD macro	1st adj chan	–33.0	–13.7	–23.3	–27.7	–33.7
	2nd adj chan	–45.0	–25.7	–35.3	–39.7	–45.7
TDD macro/ FDD micro	1st adj chan	–45.0	–54.2	–72.3	–80.8	–92.2
	2nd adj chan	–57.0	–66.2	–84.3	–92.8	–104.2
TDD macro/ FDD pico	1st adj chan	–57.0	–71.1	–89.3	–97.7	–109.1
	2nd adj chan	–69.0	–83.1	–101.3	–109.7	–121.1
Deployment scenario		**FDD base station ⇒ TDD base station**				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/ FDD macro	1st adj chan	–29.0	–9.7	–19.3	–23.7	–29.7
	2nd adj chan	–41.0	–21.7	–31.3	–35.7	–41.7
TDD macro/ FDD micro	1st adj chan	–46.0	–55.2	–73.3	–81.8	–93.2
	2nd adj chan	–58.0	–67.2	–85.3	–93.8	–105.2
TDD macro/ FDD pico	1st adj chan	–72.0	–86.1	–104.3	–112.7	–124.1
	2nd adj chan	–84.0	–98.1	–116.3	–124.7	–136.1

When using the more conservative filter characteristics suggested in Report ITU-R M.2045, and reproduced in Annex F, taking the minimum values for ACS improvement, the ACIR values shown in Table 37 are obtained when both systems incorporate channel filters. Note that with guard bands of 1 MHz and 2 MHz the conservative assumption is made that the ACLR and ACS is that of the first adjacent channel.

TABLE 37

ACIR values (dB) for the 802.16 TDD base station that incorporates the ITU-R M.2045 channel filter and the enhanced isolation values of the CDMA-DS base station improved by the ITU-R M.2045 channel filter

Interference path	**First adjacent channel 5 MHz offset**	**First adjacent channel 6 MHz offset**	**First adjacent channel 7 MHz offset**	**Second adjacent channel ≥10 MHz offset**
TDD base station ⇒ FDD base station	62	88	124	133
FDD base station ⇒ TDD base station	66	92	128	137

These values are used to compute the additional isolation required for different frequency offsets and the results are presented in Table 38.

TABLE 38

A summary of the additional isolation needed (dB) when considering base station-to-base station interference for different base station separation distances. These results incorporate special site solutions for co-located base stations, ITU-R M.2045 channel filters for CDMA-DS and 802.16 TDD base stations and enhanced isolation values for the CDMA-DS base station

Deployment scenario		**TDD base station ⇒ FDD base station**				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/ FDD macro	5 MHZ	18.0	37.3	27.7	23.3	17.3
	6 MHz	–8.0	11.3	1.7	–2.7	–8.7
	7 MHz	–44.0	–24.7	–34.3	–38.7	–44.7
	10 MHz	–53.0	–33.7	–43.3	–47.7	–53.7
TDD macro/ FDD micro	5 MHz	6.0	–3.2	–21.3	–29.8	–41.2
	6 MHz	–20.0	–29.2	–47.3	–55.8	–67.2
	7 MHz	–56.0	–65.2	–83.3	–91.8	–103.2
	10 MHz	–65.0	–74.2	–92.3	–100.8	–112.2
TDD macro/ FDD pico	5 MHz	–6.0	–20.1	–38.3	–46.7	–58.1
	6 MHz	–32.0	–46.1	–64.3	–72.7	–84.1
	7 MHz	–68.0	–82.1	–100.3	–108.7	–120.1
	10 MHz	–77.0	–91.1	–109.3	–117.7	–129.1
Deployment scenario		**FDD base station ⇒ TDD base station**				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/ FDD macro	5 MHZ	22.0	41.3	31.7	27.3	21.3
	6 MHz	–4.0	15.3	5.7	1.3	–4.7
	7 MHz	–40.0	–20.7	–30.3	–34.7	–40.7
	10 MHz	–49.0	–29.7	–39.3	–43.7	–49.7
TDD macro/ FDD micro	5 MHz	5.0	–4.2	–22.3	–30.8	–42.2
	6 MHz	–21.0	–30.2	–48.3	–56.8	–68.2
	7 MHz	–57.0	–66.2	–84.3	–92.8	–104.2
	10 MHz	–66.0	–75.2	–93.3	–101.8	–113.2
TDD macro/ FDD pico	5 MHz	–21.0	–35.1	–53.3	–61.7	–73.1
	6 MHz	–47.0	–61.1	–79.3	–87.7	–99.1
	7 MHz	–83.0	–97.1	–115.3	–123.7	–135.1
	10 MHz	–92.0	–106.1	–124.3	–132.7	–144.1

Summary of deterministic analysis with mitigation techniques

With the addition of the 60 dB channel filter at the CDMA-DS base station, the ACLR and ACS performance is improved sufficiently to ensure that the two base stations can co-exist successfully, as reported in Tables 33-38. With the ITU-R M.2045 conservative filter, coexistence is possible provided that the channel centre separation is increased to 7 MHz or more, ie, 1 MHz guard band.

The base station-to-base station interference analysis also considered the impact of employing mitigation techniques such as the use of additional channel filters in the 802.16 TDD base stations, as well as allowing for enhanced isolation values for CDMA-DS base station equipment. The resulting additional isolation needed for the two base stations to co-exist in a macrocellular deployment was summarised in Table 35, including the situation when the base station was co-sited.

The performance of the 802.16 TDD base station was improved significantly by using the mitigation techniques described, such that it was considerably better than the performance of CDMA-DS base station equipment assuming enhanced isolation values for ACLR and ACS. As a result, the ACIR performance was dominated primarily by the ACLR and ACS performance of the CDMA-DS base station. Even though the enhanced isolation values were used, ie, the performance of the CDMA-DS base station was assumed to be significantly better than that required by the specifications, these values were insufficient to permit co-location of the base stations.

By utilising a channel filter providing an additional rejection of 60 dB [Wilkinson and Howard, 2004] for the CDMA-DS base station, the two technologies could co-exist successfully without the need for guard bands, as shown in Table 38.

By utilising a channel filter for the CDMA-DS base station, in addition to the mitigation techniques for the 802.16 TDD base station, the two technologies could co-exist successfully without the need for guard bands, as shown in Table 37. Using the unoptimised filter described in Report ITU-R M.2045, it was found that coexistence requires the use of 1 MHz guard bands for the macrocell-to-macrocell interference case.

2.6.3 Statistical analysis of interference using enhanced values for CDMA-DS

Enhanced ACLR and ACS values for CDMA-DS are used in this section. These values are in Table 39.

TABLE 39

Enhanced ACLR and ACS values used for CDMA-DS
(taken from Annex F)

Parameter	First adjacent channel at 5 MHz	Second adjacent channel at 10 MHz
Base station ACLR (dB)	57	74
Base station ACS (dB)	65	75
Mobile station ACLR (dB)	46	64
Mobile station ACS (dB)	58	65

Table 40 contains the ACIR values between 802.16 TDD and CDMA-DS when using the enhanced values for CDMA-DS.

TABLE 40

ACIR values calculated from enhanced CDMA-DS equipment

Interference path	First adjacent channel	Second adjacent channel
802.16 TDD base station to CDMA-DS base station	53.2 dB	65.5 dB
CDMA-DS base station to 802.16 TDD base station	56.8 dB	68.5 dB
802.16 TDD base station to CDMA-DS mobile station	52.2 dB	62.5 dB
CDMA-DS mobile station to 802.16 TDD base station	46.0 dB	63.0 dB
802.16 TDD mobile station to CDMA-DS base station	37.0 dB (Fixed) 33.0 dB (Nomadic)	51.0 dB
CDMA-DS base station to 802.16 TDD mobile station	39.9 dB	58.9 dB
802.16 TDD mobile station to CDMA-DS mobile station	37.0 dB (Fixed) 33.0 dB (Nomadic)	50.8 dB
CDMA-DS mobile station to 802.16 TDD mobile station	39.0 dB	57.8 dB

2.6.3.1 Enhanced CDMA-DS coexistence with 802.16 TDD with no guard band

The enhanced CDMA-DS system capacity loss due to interference from 802.16 TDD is shown in Table 41, and the 802.16 average modulation efficiency loss and outage rate due to interference from enhanced CDMA-DS is shown in Table 42, and Table 43, respectively. The additional isolation required to ensure successful coexistence is given in Table 44.

TABLE 41

Enhanced CDMA-DS system capacity loss with 802.16 TDD in the first adjacent channel

		Enhanced CDMA-DS system capacity loss (%)											
		Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m	
		UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL
802.16 fixed	UL	41	0	13	0	8	0	5	0	4	0	4	0
	DL	92	0	39	0	27	0	20	0	18	0	15	0
802.16 nomadic	UL	42	1	12	1	10	1	6	1	6	1	7	0
	DL	93	0	36	0	28	0	20	0	17	0	18	0

TABLE 42

802.16 TDD average modulation efficiency loss (including the users in outage) with enhanced CDMA-DS in the first adjacent channel

			Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m	
			CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS	
			UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL
802.16 efficiency loss (%)	802.16 fixed (1 × 3 × 1)	UL	1	98	1	49	0	43	0	41	2	39	2	38
		DL	9	3	5	4	6	4	5	3	5	2	4	3
	802.16 fixed (1 × 3 × 3)	UL	2	99	1	62	1	57	1	55	2	55	2	55
		DL	14	5	10	6	9	6	8	5	8	5	7	5
	802.16 nomadic (1 × 3 × 1)	UL	2	98	1	54	1	49	0	42	0	43	0	45
		DL	11	2	5	3	5	4	5	3	6	3	5	2
	802.16 nomadic (1 × 3 × 3)	UL	3	99	2	69	3	64	1	60	2	61	2	62
		DL	16	4	10	5	9	6	8	4	9	5	9	5

TABLE 43

802.16 TDD outage rate with enhanced CDMA-DS in the first adjacent channel

			Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m		802.16 Single System
			CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		
			UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	
802.16 outage rate (%)	802.16 fixed (1 × 3 × 1)	UL	8	96	8	40	8	33	8	29	8	26	8	24	7.8
		DL	5	0	3	1	2	1	2	1	2	1	2	1	0.0
	802.16 fixed (1 × 3 × 3)	UL	1	96	1	35	1	27	1	23	1	20	1	18	0.5
		DL	4	0	2	1	2	1	2	0	2	1	2	1	0.0
	802.16 nomadic (1 × 3 × 1)	UL	13	97	13	49	13	43	13	38	13	36	13	38	12.5
		DL	6	1	3	1	3	1	3	1	3	1	3	1	0.3
	802.16 nomadic (1 × 3 × 3)	UL	1	97	1	43	1	36	1	30	1	28	1	29	0.5
		DL	5	0	3	1	2	1	2	1	2	1	2	1	0.0

TABLE 44

Additional isolation needed for coexistence of 802.16 TDD and enhanced CDMA-DS in the first adjacent channel

Offset (m)	Coexistence		Additional isolation needed (dB)							
			From 802.16 base station to CDMA-DS base station	From CDMA-DS base station to 802.16 base station	From 802.16 base station to CDMA-DS mobile station	From CDMA-DS mobile station to 802.16 base station	From 802.16 subscriber station to CDMA-DS base station	From CDMA-DS base station to 802.16 subscriber station	From 802.16 subscriber station to CDMA-DS mobile station	From CDMA-DS mobile station to 802.16 subscriber station
0	CDMA-DS enhanced	Fixed	36	43 (1 × 3 × 1) 48 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	36	45 (1 × 3 × 1) 50 (1 × 3 × 3)	0	0	3	0	0	0
100	CDMA-DS enhanced	Fixed	19	24 (1 × 3 × 1) 31 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	18	25 (1 × 3 × 1) 32 (1 × 3 × 3)	0	0	3	0	0	0
200	CDMA-DS enhanced	Fixed	13	19 (1 × 3 × 1) 26 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	13	19 (1 × 3 × 1) 27 (1 × 3 × 3)	0	0	3	0	0	0
300	CDMA-DS enhanced	Fixed	9	16 (1 × 3 × 1) 22 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	9	15 (1 × 3 × 1) 22 (1 × 3 × 3)	0	0	3	0	0	0
433	CDMA-DS enhanced	Fixed	8	15 (1 × 3 × 1) 21 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	8	14 (1 × 3 × 1) 21 (1 × 3 × 3)	0	0	3	0	0	0
866	CDMA-DS enhanced	Fixed	7	14 (1 × 3 × 1) 21 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	8	14 (1 × 3 × 1) 21 (1 × 3 × 3)	0	0	3	0	0	0

Again, the interference between the two systems has been evaluated by measuring the noise rise in the CDMA-DS uplink using enhanced isolation values. In Table 45 the noise rise that occurs when the 802.16 system is introduced. The uplink values (UL) show the noise rise caused by CDMA-DS and 802.16 uplink interference, but excluding 802.16 downlink interference and the downlink values (DL) show the noise rise caused by CDMA-DS uplink and 802.16 downlink interference. The noise rises observed are considerably greater than 6 dB. The outage shown in Table 41 was low because there was sufficient link margin to accommodate this noise rise. The downlink interference is generally larger than the downlink interference.

TABLE 45

CDMA-DS system uplink noise rise with 802.16 TDD in the first adjacent channel assuming enhanced isolation values (dB)

			CDMA-DS system uplink noise rise (dB)					
			Offset by 0 m	**Offset by 100 m**	**Offset by 200 m**	**Offset by 300 m**	**Offset by 433 m**	**Offset by 866 m**
Enhanced CDMA-DS	802.16 TDD fixed	UL	22.0	19.0	18.8	18.3	16.9	15.8
		DL	28.8	28.6	24.3	22.5	20.8	20.0
	nomadic 802.16 TDD	UL	23.1	20.0	19.7	18.9	16.9	15.8
		DL	29.3	28.8	24.7	22.8	20.8	20.0

In Table 46 the CDMA-DS downlink system capacity loss that occurs when the 802.16 system is introduced. The capacity losses shown in Table 41 are of similar magnitude, when taking rounding into account.

TABLE 46

CDMA-DS system downlink capacity loss with 802.16 TDD in the first adjacent channel assuming enhanced isolation values

			CDMA-DS system downlink capacity loss (%)					
			Offset by 0 m	**Offset by 100 m**	**Offset by 200 m**	**Offset by 300 m**	**Offset by 433 m**	**Offset by 866 m**
Enhanced CDMA-DS	802.16 fixed	UL	0.4	0.4	0.6	0.4	0.6	0.7
		DL	0.3	0.3	0.2	0.2	0.2	0.3
	802.16 nomadic	UL	0.6	0.5	0.4	0.4	0.4	0.7
		DL	0.4	0.3	0.2	0.2	0.3	0.4

In Table 47 the average modulation efficiency loss in the 802.16 system when the CDMA-DS system is introduced in the adjacent channel. The losses shown in Table 42 are greater than those shown in Table 47.

TABLE 47

802.16 TDD average modulation efficiency loss with CDMA-DS in the first adjacent channel assuming enhanced isolation values

				CDMA-DS											
				Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m	
				UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL
802.16 modulation efficiency loss (%)	Enhanced CDMA-DS	802.16 fixed (1 × 3 × 1)	UL	0.0	23.3	0	29.1	0	20.9	0.1	16.1	0.1	12.1	0.1	10.6
			DL	0.7	0.8	0.4	0.8	0.3	1.2	0.3	1.5	0.2	1.7	0.2	1.1
		802.16 fixed (1 × 3 × 3)	UL	0.0	34.2	0	41.5	0	32.6	0	27.7	0	23.6	0.1	19.8
			DL	0.2	0.2	0.1	0.3	0.1	0.6	0.1	0.9	0.1	1.1	0	0.4
		802.16 nomadic (1 × 3 × 1)	UL	0.0	28.5	0	31.1	0	22.7	0.1	18.2	0.1	15.0	0.1	13.1
			DL	0.8	0.6	0.5	0.8	0.4	1.2	0.4	1.5	0.3	1.6	0.2	1.0
		802.16 nomadic (1 × 3 × 3)	UL	0.0	33.5	0	41.7	0	32.5	0	27.8	0	23.9	0.1	19.3
			DL	0.2	0.2	0.1	0.3	0.1	0.6	0.1	0.8	0.1	1	0	0.5

In Table 48 the additional isolation needed to reduce the noise rise in the CDMA-DS system to 6 dB is given. Additional isolation is only required in the base station to base station interference path: No additional isolation is required for any other path. The additional isolations needed between base stations and shown in Table 48 are considerably greater than those shown in Table 44 as these are sufficient to reduce the noise rise to 6 dB, with a capacity loss of 5%, ie, an allowance for external interference of −111.4 dBm.

TABLE 48

Additional isolation needed (dB) to reduce interference from IEEE802.16 to CDMA-DS assuming enhanced isolation values

Offset (m)	802.16 TDD	From 802.16 TDD base station to CDMA-DS base station	From 802.16 TDD base station to CDMA-DS mobile station	From 802.16 TDD SS to CDMA-DS base station	From 802.16 TDD SS to CDMA-DS mobile station
0	Fixed	33	0	0	0
	Nomadic	33	0	0	0
100	Fixed	35	0	0	0
	Nomadic	35	0	0	0
200	Fixed	28	0	0	0
	Nomadic	28	0	0	0
300	Fixed	24	0	0	0
	Nomadic	24	0	0	0

TABLE 48 (*end*)

Offset (m)	802.16 TDD	From 802.16 TDD base station to CDMA-DS base station	From 802.16 TDD base station to CDMA-DS mobile station	From 802.16 TDD SS to CDMA-DS base station	From 802.16 TDD SS to CDMA-DS mobile station
433	Fixed	22	0	0	0
	Nomadic	22	0	0	0
866	Fixed	21	0	0	0
	Nomadic	21	0	0	0

In Table 49 the additional isolation values needed to modulation efficiency loss of the 802.16 system to 5% are given. Additional isolation is only required in the base station to base station interference path: No additional isolation is required for any other path.

TABLE 49

Additional isolation needed (dB) to reduce CDMA-DS interference to IEEE802.16 assuming enhanced isolation values

Offset (m)	802.16 TDD	From CDMA-DS base station to 802.16 TDD base station	From CDMA-DS base station to 802.16 TDD SS	From CDMA-DS mobile station to 802.16 TDD base station	From CDMA-DS mobile station to 802.16 TDD SS
0	Fixed	15 (1 × 3 × 1) 18 (1 × 3 × 3)	0	0	0
	Nomadic	15 (1 × 3 × 1) 18 (1 × 3 × 3)	0	0	0
100	Fixed	18 (1 × 3 × 1) 21 (1 × 3 × 3)	0	0	0
	Nomadic	18 (1 × 3 × 1) 21 (1 × 3 × 3)	0	0	0
200	Fixed	13 (1 × 3 × 1) 15 (1 × 3 × 3)	0	0	0
	Nomadic	14 (1 × 3 × 1) 15 (1 × 3 × 3)	0	0	0
300	Fixed	9 (1 × 3 × 1) 13 (1 × 3 × 3)	0	0	0
	Nomadic	22(1 × 3 × 1) 25 (1 × 3 × 3)	0	0	0
433	Fixed	5 (1 × 3 × 1) 9 (1 × 3 × 3)	0	0	0
	Nomadic	5 (1 × 3 × 1) 10 (1 × 3 × 3)	0	0	0
866	Fixed	3 (1 × 3 × 1) 6 (1 × 3 × 3)	0	0	0
	Nomadic	3 (1 × 3 × 1) 7 (1 × 3 × 3)	0	0	0

2.6.3.2 Enhanced CDMA-DS coexistence with 802.16 TDD with one guard band (5 MHz)

The enhanced CDMA-DS system capacity loss due to interference from 802.16 TDD is shown in Table 50, and the 802.16 average modulation efficiency loss and outage rate due to interference from enhanced CDMA-DS is shown in Table 51, and Table 52, respectively. The additional isolation required to ensure successful coexistence is given in Table 53.

TABLE 50

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

		Enhanced CDMA-DS system capacity loss (%)											
		Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m	
		UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL
802.16 fixed	UL	20	1	3	0	1	0	0	0	0	0	1	0
	DL	64	1	13	0	5	0	2	0	2	0	2	0
802.16 nomadic	UL	22	0	3	0	1	0	1	0	0	0	0	0
	DL	68	0	13	0	5	0	5	0	2	0	1	0

TABLE 51

802.16 TDD average modulation efficiency loss (including the users in outage) with enhanced CDMA-DS in the second adjacent channel (5 MHz guard band)

			Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m	
			CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS	
			UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL
802.16 efficiency loss (%)	802.16 fixed (1 × 3 × 1)	UL	0	88	1	21	0	15	1	12	0	9	0	6
		DL	0	0	1	0	0	0	0	1	0	1	0	0
	802.16 fixed (1 × 3 × 3)	UL	0	94	1	32	0	25	1	22	0	19	0	16
		DL	2	0	1	0	1	0	0	1	0	1	0	0
	802.16 nomadic (1 × 3 × 1)	UL	0	89	0	25	1	18	0	14	0	15	0	6
		DL	0	0	0	0	0	0	0	0	1	1	1	0
	802.16 nomadic (1 × 3 × 3)	UL	0	94	0	36	1	30	1	26	1	26	1	18
		DL	2	0	1	0	1	1	0	0	1	1	1	0

TABLE 52

802.16 TDD outage rate with enhanced CDMA-DS in the second adjacent channel (5 MHz guard band)

			Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m		802.16 Single System
			CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		
			UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	
802.16 outage rate (%)	802.16 fixed (1 × 3 × 1)	UL	8	78	8	19	8	14	8	12	8	11	8	10	7.8
		DL	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	802.16 fixed (1 × 3 × 3)	UL	1	78	1	13	1	6	1	5	1	3	1	2	0.5
		DL	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	802.16 nomadic (1 × 3 × 1)	UL	12	84	13	27	13	22	13	20	13	19	12	14	12.5
		DL	0	0	0	0	0	0	0	0	0	0	0	0	0.3
	802.16 nomadic (1 × 3 × 3)	UL	0	83	1	17	1	11	1	8	1	7	1	3	0.5
		DL	0	0	0	0	0	0	0	0	0	0	0	0	0.0

TABLE 53

Additional isolation needed for coexistence of 802.16 TDD and enhanced CDMA-DS in the second adjacent channel (5 MHz guard band)

Offset (m)	Coexistence		Additional isolation needed (dB)							
			From 802.16 base station to CDMA-DS base station	From CDMA-DS base station to 802.16 base station	From 802.16 base station to CDMA-DS mobile station	From CDMA-DS mobile station to 802.16 base station	From 802.16 subscriber station to CDMA-DS base station	From CDMA-DS base station to 802.16 subscriber station	From 802.16 subscriber station to CDMA-DS mobile station	From CDMA-DS mobile station to 802.16 subscriber station
0	CDMA-DS enhanced	Fixed	24	31 (1 × 3 × 1) 36 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	24	33 (1 × 3 × 1) 38 (1 × 3 × 3)	0	0	0	0	0	0
100	CDMA-DS enhanced	Fixed	7	13 (1 × 3 × 1) 19 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	6	13 (1 × 3 × 1) 20 (1 × 3 × 3)	0	0	0	0	0	0
200	CDMA-DS enhanced	Fixed	0	7 (1 × 3 × 1) 15 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	0	7 (1 × 3 × 1) 15 (1 × 3 × 3)	0	0	0	0	0	0
300	CDMA-DS enhanced	Fixed	0	5 (1 × 3 × 1) 11 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	0	4 (1 × 3 × 1) 11 (1 × 3 × 3)	0	0	0	0	0	0
433	CDMA-DS enhanced	Fixed	0	3 (1 × 3 × 1) 10 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	0	3 (1 × 3 × 1) 10 (1 × 3 × 3)	0	0	0	0	0	0
866	CDMA-DS enhanced	fixed	0	2 (1 × 3 × 1) 9 (1 × 3 × 3)	0	0	0	0	0	0
		Nomadic	0	2 (1 × 3 × 1) 9 (1 × 3 × 3)	0	0	0	0	0	0

2.6.3.3 Summary of statistical analysis of enhanced CDMA-DS coexistence with 802.16 TDD

The statistical analysis quantifies the impact of the first and the second adjacent channel interference between enhanced CDMA-DS and 802.16 TDD on system capacity loss or modulation efficiency loss for different offset distances. Based on the Monte Carlo simulation results, the amounts of additional isolation between these two systems are provided to ensure successful coexistence. Since the 5 MHz guard band provides more frequency isolation, the results of the second adjacent channel is better than those of the first adjacent channel.

Due to the existence of LOS between base stations, the worst adjacent channel interference is experienced between the base stations of these two systems.

One study shows that for the worst case of two co-located base stations operating on the first adjacent channel, as high as 36 dB additional isolation is needed from 802.16 base station to standard CDMA-DS base station, and 50 dB additional isolation is needed from standard CDMA-DS base station to 802.16 base station for nomadic case with frequency reuse of 1 × 3 × 3, with a coupling loss of 50 dB. As the offset of these two systems is increased from co-located to 866 meters, the additional isolation requirement becomes smaller.

A second study shows that for the worst case of two co-located base stations operating on the first adjacent channel, as high as 33 dB additional isolation is needed from 802.16 base station to standard CDMA-DS base station, and 18 dB additional isolation is needed from standard CDMA-DS base station to 802.16 base station for nomadic case with frequency reuse of 1 × 3 × 3, with a coupling loss of 50 dB. As the offset of these two systems is increased from co-located to 866 m, the additional isolation requirement becomes smaller.

There is some interference from 802.16 nomadic uplink to enhanced CDMA-DS uplink. Additional isolation of 3 dB is required from 802.16 nomadic subscriber station to CDMA-DS base station. On the other hand, the adjacent channel interference from 802.16 fixed uplink to enhanced CDMA-DS uplink is negligible and no additional isolation is needed from 802.16 fixed subscriber station to enhanced CDMA-DS base station.

The adjacent channel interference from 802.16 TDD to enhanced CDMA-DS downlink is negligible for all scenarios. No additional isolation from 802.16 base station to CDMA-DS mobile station and from 802.16 subscriber station to CDMA-DS mobile station is required.

The adjacent channel interference from enhanced CDMA-DS to 802.16 TDD downlink is negligible for all scenarios. No additional isolation from enhanced CDMA-DS base station to 802.16 subscriber station and from enhanced CDMA-DS mobile station to 802.16 subscriber station is required.

The adjacent channel interference from enhanced CDMA-DS uplink to 802.16 uplink is negligible. No additional isolation from enhanced CDMA-DS mobile station to 802.16 base station is required.

The second study shows that no additional isolation is required in any interference path other than base station to base station.

Each additional isolation requirement of the second adjacent channel case is better than the correspondent part of the first adjacent channel case.

2.7 Conclusions to analyses of System A

2.7.1 Scope and limitations

This section addresses coexistence between 802.16 TDD, which is based on the IEEE 802.16 series of standards, and the CDMA-DS component of IMT-2000 in the band 2 500-2 690 MHz.

The feasibility of certain scenarios is subject to a trade off between technical, regulatory and economical factors. In this Section different points of view have been reflected which correspond to different trade off choices. The above views are by no means excluding other points of views. The conclusions below reflect only the studies made in this Section.

Note that throughout this report the IEEE 802.16 ACLR and ACS defined in Report ITU-R M.2116 are used, the values have not been specified in any IEEE standard at the time of drafting this Report.

First, results are presented for a basic coexistence analysis using approaches similar to those in Report ITU-R M.2030, and the results of this study are consistent with that Report.

Second results are presented with improved performances and other mitigation techniques.

2.7.2 Basic results of coexistence study

These are the basic results in this Report:

2.7.2.1 Base station to base station: General observations

a) Several scenarios and parameter settings examined are associated with severe interference problems, especially those associated with macro-macro and macro-micro deployments.

   – This holds for both co-located and in-proximity scenarios.

b) For several scenarios large values of separation distances are needed to obtain sufficiently low interference conditions.

2.7.2.2 Interference between CDMA DS and IEEE 802.16 base stations in proximity

The shaded cells in tables below show situations with negative excess interference level figures when coexistence is possible, and white cells show situations with positive figures when coexistence is *not possibl*e according to the assumptions made in this Report.

TABLE 54

Excess interference when the base stations are not co-sited, where the CDMA DS base station is the interference victim

Distance (m)	Excess interference (dB)					
	Macrocell to macrocell		Macrocell to microcell		Macrocell to picocell	
	5 MHz	10 MHz	5 MHz	10 MHz	5 MHz	10 MHz
10.0	74.3	62.3	51.8	39.8	34.9	22.9
50.0	60.3	48.3	25.2	13.2	8.3	–3.7
100.0	54.3	42.3	13.8	1.8	–3.1	–15.1
500.0	40.3	28.3	–12.8	–24.8	–29.7	–41.7
1 000.0	34.3	22.3	–24.2	–36.2	–41.1	–53.1

TABLE 55

Excess interference when the macro cellular base stations are not co-sited, where the IEEE 802.16 base station is the interference victim

Distance (m)	Excess interference (dB)					
	Macrocell to macrocell		Microcell to macrocell		Picocell to macrocell	
	5 MHz	10 MHz	5 MHz	10 MHz	5 MHz	10 MHz
10.0	82.3	77.3	54.8	49.8	23.9	18.9
50.0	68.3	63.3	28.2	23.2	–2.7	–7.7
100.0	62.3	57.3	16.8	11.8	–14.1	–19.1
500.0	48.3	43.3	–9.8	–14.8	–40.7	–45.7
1 000.0	42.3	37.3	–21.2	–26.2	–52.1	–57.1

For macro cellular base stations the following conclusions can be drawn:

a) Interference problems may occur with distances up to 1 000 m considered in this study for adjacent channels with up to 10 MHz carrier separation.

b) The interference problem cannot be resolved simply by reducing the power without severely compromising the range.

c) Guard bands of larger sizes could be considered for future studies.

For macro versus micro cellular base stations the following conclusions can be made:

a) Interference problems will occur for distances up to between 200 m and 300 m for systems in channels with up to 10 MHz carrier separation without LoS.

b) Guard bands of larger sizes could be considered for future studies.

For macro versus pico cellular base stations the following conclusions can be made:

a) A distance of less than 50 m is sufficient between the macro and the pico base station without line-of-sight.

b) In many deployment cases, at least such distances can be expected, and hence this case poses a less likely coexistence problem.

c) However, picocell base stations in tall buildings might come close to outdoor macrocell base stations and care must be taken when deploying in such scenarios.

2.7.2.3 Base station-base station co-location:

a) Using a minimum coupling loss of 30 dB for macro base stations, for the first adjacent channel an excess interference of 70 dB and 78 dB is obtained, when CDMA-DS and 802.16 TDD are victims respectively. The corresponding numbers for the second adjacent channel are 58 dB and 73 dB.

b) Coverage and capacity will be severely affected when there is such excessive interference.

c) Based on the existing specifications and assumptions, and using very high coupling loss, even a guard band of 5 MHz will not remove the problem.

d) Increasing the vertical distance between the antennas will increase the coupling loss and reduce the interference.

e) Even in the macrocell/microcell case with a coupling loss of 77 dB corresponding to a vertical antenna distance of 24 m, the interference is more than 20 dB above the protection criterion.

2.7.2.4 CDMA DS base station to IEEE 802.16 SS and CDMA DS mobile station to IEEE 802.16 base station interference results

Table 56 shows the excess interference caused by base stations and mobile stations.

TABLE 56

A summary of the additional isolation needed (dB) when considering interference between base stations and mobile stations

Deployment scenario		Fixed SS => FDD base station	FDD base station => Fixed SS	Nomadic SS => FDD base station	FDD base station => Nomadic SS	FDD mobile station => TDD base station	TDD base station => FDD mobile station
TDD macro/ FDD macro	1st adj chan	30.1	45.1	23.3	39.3	22.3	32.3
	2nd adj chan	16.1	35.1	6.3	29.3	12.3	22.3
TDD macro/ FDD micro	1st adj chan	56.2	66.2	43.2	54.2	22.3	32.3
	2nd adj chan	42.2	56.2	26.2	44.2	12.3	22.3
TDD macro/ FDD pico	1st adj chan	54.3	46.3	58.3	55.3	22.3	32.3
	2nd adj chan	40.3	36.3	41.3	45.3	12.3	22.3

a) Mobile station-base station and base station-mobile station interference between IEEE 802.16 TDD and CDMA-DS can be severe.

– Similar mobile station-base station and base station-mobile station interference exists between FDD systems operating in adjacent channels.

b) Mobile station-base station and base station-mobile station interference can be mitigated by co-location (with the consequence on base station-base station interference as concluded above).

c) Monte-Carlo simulations have been made using a distance between base stations *within* a system of 1 500 m, and various distances *between* base station in different systems.For the studied scenarios with uniformly-distributed outdoor-only users, Monte-Carlo simulations suggest that mobile station-base station, base station-mobile station interference will have a small or negligible impact on the system capacity when averaged over the system.

2.7.2.5 CDMA DS mobile station – IEEE 802.16 SS interference results

The following general observations can be made:

a) The Monte Carlo simulations suggest that mobile station-SS interference will have a small or negligible impact on the system capacity when averaged over the system and using uniform outdoor-only user densities.

b) Deterministic mobile station-SS calculations suggest that a mobile station might create severe interference to another geographically and spectrally close SS, and vice versa in scenarios such as in an office building, a bus or a city hot spot.

c) Non-uniform user distributions are not studied in this Report and need further investigation.

2.7.3 Methods for decreasing base station-base station interference

In the above section, it has been established that sharing poses severe interference problems in many scenarios. In this section, some possible mitigation techniques, site engineering techniques or other measures are listed that could reduce the problem.

There are a number of actions that can be taken alone or in combination in order to combat the base station-base station interference problems. Note that many of the measures need to be taken at both operators' networks in order to be meaningful. All actions are associated with some kind of cost or other difficulties that must be taken into account as well, as there is always a trade off to consider:

a) Higher performance filters at both transmitter and receiver side.

b) Multi system co-planning in order to locate base stations far from all victim system base stations. This would require, in the case of multiple operators, cooperation between competitors.

   – The studies show that even then dense urban deployment are very difficult

c) Appropriate guard bands larger than 10 MHz must be considered for several scenarios to allow for flexibility of deployment in the absence of additional channel filters.

d) Low power operation of interfering systems reduces the problem but also reduces coverage and flexibility of deployment.

e) Appropriate values of guard bands, realistic filter requirements, etc., will depend on a number of factors and a definitive answer is not given in this Report, nevertheless some example conclusions may be drawn.

   – Base station to base station interference may be resolved in the collocated case using a channel filter with the characteristics described in Report ITU-R M.2045 in conjunction with increased isolation through site design and a guard band of 1-2 MHz depending on the co-location scenario. Note that this channel filter has an associated insertion loss of 2 dB which will affect coverage and/or capacity[14].

   – Base station to base station interference in the non-collocated case may require similar additional filtering and coordination to ensure either that macrocell base stations are separated by at least 100 m, or main beam coupling does not occur, or obstacles to the radio path are present.

   – The use of such filters may be required throughout the network.

f) Adaptive antenna solutions are not studied in this Report and need further investigation.

3 System B – Systems based on standards developed for MMDS

In this section compatibility studies between IMT-2000/UMTS and MMDS (multipoint multimedia distribution system) are presented. It should be noted that the parameters assumed in this Report for the IMT-2000 terrestrial system are those of UMTS, namely CDMA-DS and CDMA-TDD[15]; 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

[14] Note that channel filters precludes the use of multicarrier power amplifier base station architectures.

[15] CDMA-TDD is IMT2000 CDMA TDD (time code), otherwise known as UTRA TDD.

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.

3.1 Interference scenarios to be analyzed

The scenarios considered in these simulations are depicted in Figs. 5 and 6. Figure 5 shows the interference paths from a terrestrial UMTS mobile station transmitter into an MMDS receiver (path E1) and from a UMTS base station transmitter into an MMDS receiver (path E2).

FIGURE 5

Interference path E

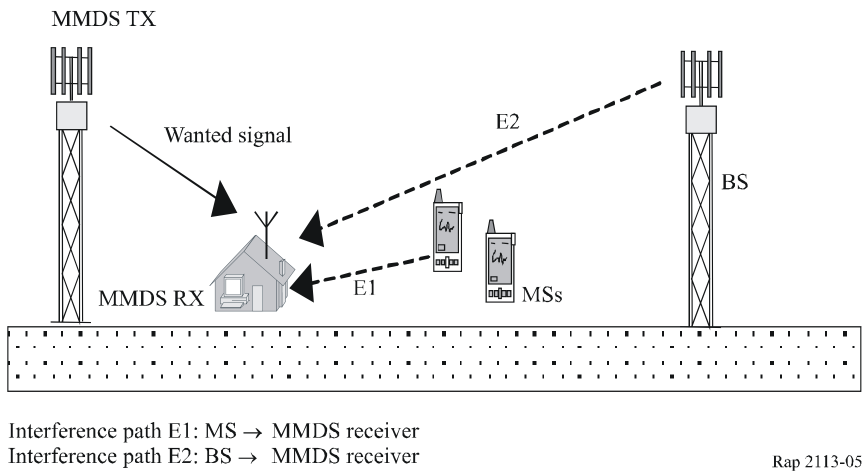
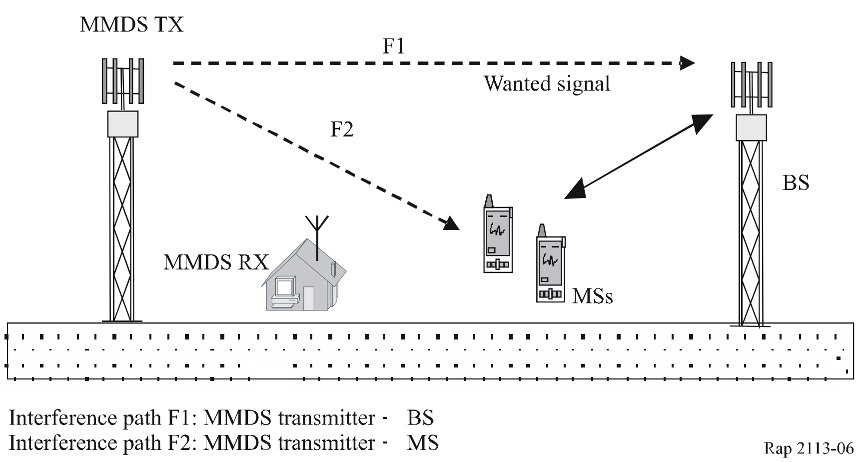


Figure 6 illustrates the interference paths from an MMDS transmitter into a UMTS base station receiver (path F1) and from an MMDS transmitter into a terrestrial UMTS UEmobile station. As the MMDS system is unidirectional there is no interference from the MMDS receiver into the UMTS system.

FIGURE 6

Interference path F



Within CEPT, two approaches have been used so far to assess interference between two systems. One is the deterministic analysis based on the minimum coupling loss (MCL), and the second is statistical, using Monte-Carlo simulation. The approaches are described below.

3.2 Deterministic analysis

A deterministic analysis, based on the 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:

$$\text{MCL} = T_x \text{ power(dBm/Ref} \cdot Bw) + T_x \text{ antenna gain (dBi)} + R_x \text{ antenna gain (dBi)} - R_x \text{ interference threshold (dBm)/Ref} \cdot Bw)$$

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

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

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

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

However, in CDMA 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.

Therefore a deterministic analysis is not appropriate and has not been performed.

3.3 Statistical analysis

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.

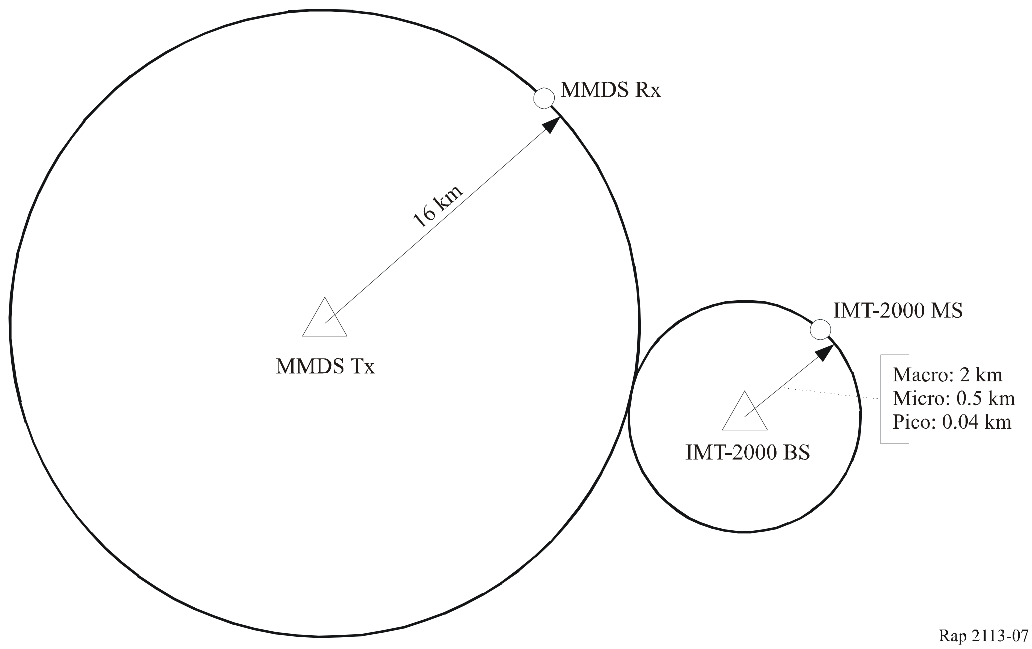
3.3.1 Input parameters and assumptions

In this study, adjacent channel sharing is considered in the cases where MMDS and CDMA-DS systems were operating in geographically separate locations. For example, in Ireland, the 2.5 GHz band will only be used in urban areas for IMT-2000 services while MMDS is predominantly used in rural areas.

Figure 7 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 7

Representation of an MMDS and IMT-2000 systems service areas operating in geographically separate locations



3.3.1.1 IMT-2000 terrestrial system parameters

3.3.1.1.1 Base station

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

Base station as wanted system

TABLE 57

IMT-2000 base station receive parameters

Cell type	Rural
Antenna type	120° sector
Max antenna gain (dBi) including feeder loss	17
Downtilt angle (degrees)	2.5

TABLE 57 (*end*)

Antenna height (m)	30
Polarisation	Linear
Receiver noise figure (dB)	5
Receiver thermal noise (including noise figure (dB(W/MHz))	–139
Interference criteria (I_{sat}/N_{th}) (dB)	–10
Adjacent channel selectivity	FDDCDMA-DS: TS 25.104[(1)] CDMA-TDD: TS 25.105[(2)]

(1) 3GPP [June 2004] Base station (BS) radio transmission and reception (FDD) 3GPP TS 25.104, Version 6.6.0.

(2) 3GPP. Base station (BS) radio transmission and reception (TDD). 3GPP TS 25.105, Version 5.1.0.

Base station as interfering system

TABLE 58

IMT-2000 base station transmit parameters

Cell type	**Rural (CDMA-DS)**	**Vehicular-macro (CDMA-DS)**	**Pedestrian-micro (CDMA-DS)**	**Pico-CBD (CDMA-DS)**	**Suburban and urban (CDMA-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[(1)]
Operating bandwidth (MHz)	5	5	5	5	5
Antenna type	120° sector	120° sector	120° sector	Omni-directional	Omni-directional
Max antenna gain (dBi) including feeder loss	17	17	5	0	0
Downtilt angle (degrees)	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)]

(1) 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.

(2) 3GPP [June 2004] Base station (BS) radio transmission and reception (FDD) 3GPP TS 25.104, Version 6.6.0.

(3) 3GPP. Base station (BS) radio transmission and reception (TDD). 3GPP TS 25.105, Version 5.1.0.

3.3.1.1.2 Mobile station

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

Mobile station as wanted station

TABLE 59

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 (including noise figure) (dB(W/MHz))	–135
Interference criteria (*I*/*N*) (dB)	–10
ACS	CDMA-DS: 25.101[(1)] CDMA-TDD: 25.102[(2)]

(1) 3GPP [March 2004] User equipment (UE) radio transmission and reception (FDD). 3GPP TS 25.101 Version 6.4.0.

(2) 3GPP. User equipment (UE) radio transmission and reception (TDD). 3GPP TS 25.102, Version 5.1.0.

Mobile station as interfering station:

TABLE 60

IMT-2000 mobile station transmit parameters

Maximum transmit power (dBm)	**21 or 24**			
Average transmit power (dBm) in FDD (from[(1)])	**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[(2)])	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			

TABLE 60 (*end*)

Maximum transmit power (dBm)	**21 or 24**			
Average transmit power (dBm) in FDD (from[1])	**Rural**	**Vehicular-macro**	**Pedestrian-micro**	**Pico-CBD**
	8.3 dBm	**7.5 dBm**	**6.6 dBm**	**–2.5 dBm**
Polarisation	Linear			
ACLR	CDMA-DS: 25.101[3] CDMA-TDD: 25.102[4]			

(1) ECC Report 65. Adjacent band compatibility between UMTS and other services in the 2 GHz band.

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

(3) 3GPP [March 2004] User equipment (UE) radio transmission and reception (FDD). 3GPP TS 25.101, Version 6.4.0.

(4) 3GPP. User equipment (UE) radio transmission and reception (TDD). 3GPP TS 25.102, Version 5.1.0.

3.3.1.1.3 Traffic characteristics

Table 4 of Report ITU-R M.2039 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 (mobile station transmitting) into UMTS-S systems. They are summarised in Tables 61 and 62.

TABLE 61

Terrestrial parameters in CDMA-DS

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 62

Terrestrial parameters in CDMA-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 61

3.3.1.2 MMDS system parameters

The system parameters for MMDS are listed in the Table 63.

TABLE 63

MMDS parameters

Transmission parameters	
EIRP max	22 dBW = 52 dBm
Tx antenna gain (omnidirectional)(1)	0 dBi
Effective Tx antenna height	200 m
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 m
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

(1) The Tx antenna gain is assumed to be isotropic to provide the worst case scenario.

3.3.1.3 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[16] 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, Recommendation ITU-R P.452-10 for smooth earth. Typically this is used for non-co-located systems, e.g. for geographic separation.

3.3.2 Protection criteria

The MMDS, CDMA-DS and CDMA-TDD systems are each being protected by *I*/*N* of –10 dB.

3.3.3 Results

The results cover the two scenarios, namely, adjacent channel results in geographically separate areas, and co-channel results in geographically separate areas.

3.3.3.1 Adjacent channel results

3.3.3.1.1 Interference path E1

There is no interference measured from the CDMA-DS mobile station transmitting into the MMDS receiver. This is because the MMDS receiver blocking response plus *C*/*I* ratio is greater than the power received from the CDMA-DS mobile station.

3.3.3.1.2 Interference path E2

Figure 8 shows the results of interference simulations from a CDMA-DS 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.

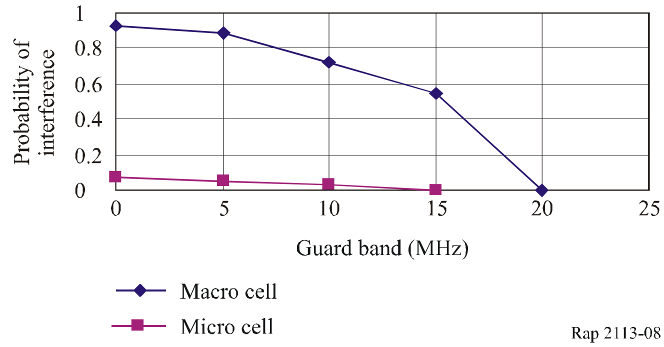
There is no interference from a CDMA-DS base station into a MMDS receiver for pico cell deployment.

---

[16] Report ITU-R SM.2028-1 (Appendix 1 to Annex 2) named “modified hata model”.

FIGURE 8

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

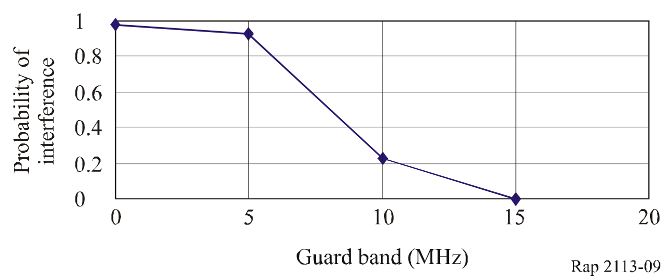


3.3.3.1.3 Interference path F1

Figure 9 shows the probability of interference from a MMDS transmitter into a CDMA-DS mobile station 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 CDMA-DS mobile station macro cell antenna.

FIGURE 9

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

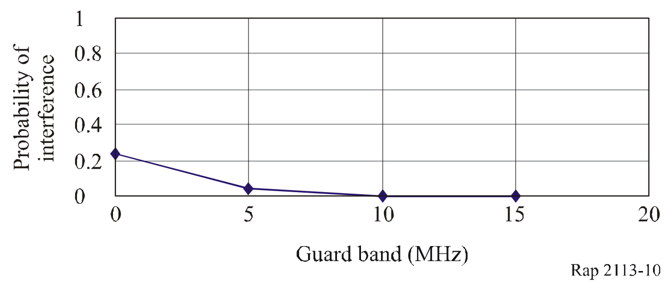


3.3.3.1.4 Interference path F2

Figure 10 shows the interference from a MMDS transmitter into a CDMA-DS mobile station. It indicates that a guard band of 10 MHz would be required to prevent interference between the two systems.

FIGURE 10

Probability of adjacent channel interference from a MMDS transmitter into a CDMA-DS mobile station receiver



3.3.3.2 Co-frequency interference results

The co-frequency simulations investigated the possibility of both MMDS and 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.

3.3.3.2.1 Interference paths E1 and E2

FIGURE 11

Probability of co-channel interference from a CDMA-DS mobile station transmitter into a MMDS receiver

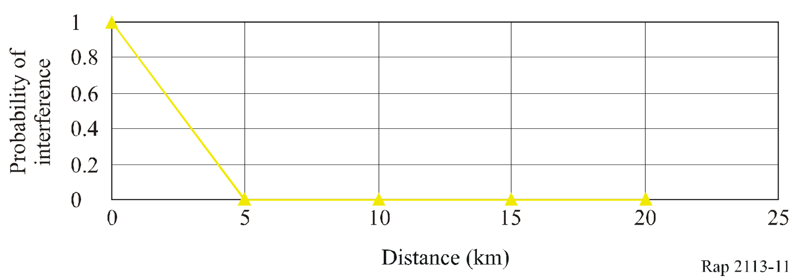
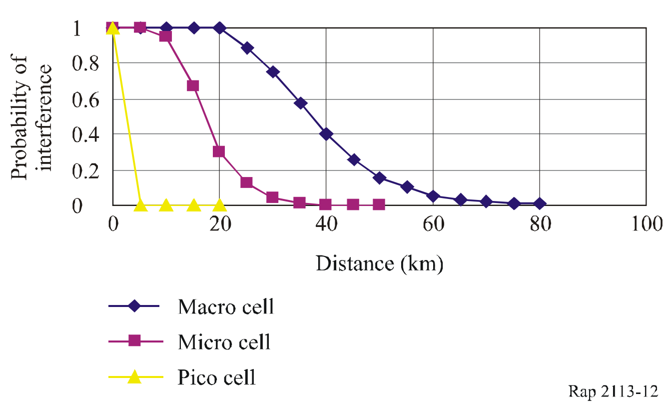


FIGURE 12

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



3.3.3.2.2 Interference paths F1 and F2

FIGURE 13

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

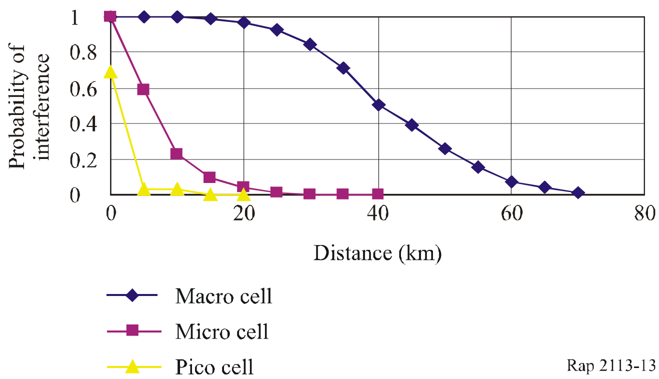
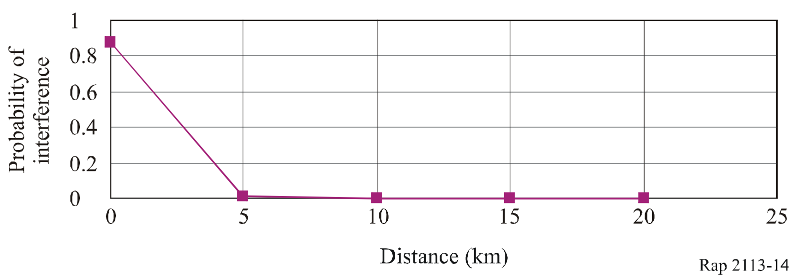


FIGURE 14

Probability of co-channel interference from a MMDS transmitter into a CDMA-DS mobile station



3.4 Mitigation techniques and their impact

General mitigation techniques are described in Annex F but their impact has not been studied in this Report for System B.

3.5 Summary and conclusions

3.5.1 Co-frequency sharing between MMDS and terrestrial IMT-2000

The figures, in § 3.3.3.2, above show that in co-frequency scenarios the separation distances[17] required to prevent interference would be as follows:

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

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

– 70 km separation distance would be required between a MMDS transmitter and a CDMA-DS 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 CDMA-DS mobile station receiver;

and these are tabulated in Table 64.

TABLE 64

Co-channel sharing results interference path	**Separation distance required (km)**
CDMA-DS mobile station →MMDS Rx	5
CDMA-DS base station → MMDS Rx	5 pico cell, 25 micro cell, 70 macro cell
MMDS Tx → CDMA-DS base station	5 pico cell, 25 micro cell, 70 macro cell
MMDS Tx → CDMA-DS mobile station	5

The results in Table 64 show that co-frequency sharing between MMDS and 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 IMT-2000 service areas.

3.5.2 Adjacent band compatibility between MMDS and terrestrial IMT-2000

The results in Table 65 show that for adjacent channel operation between MMDS and CDMA-DS services operating in geographically separate locations a minimum frequency separation of 15 MHz will be necessary for macro and micro cell deployment of CDMA-DS. 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 CDMA-DS service areas.

TABLE 65

Adjacent band sharing results

Interference path	**Frequency separation required (MHz)**
CDMA-DS mobile station → MMDS Rx	0
CDMA-DS base station → MMDS Rx	20
MMDS Tx → CDMA-DS base station	15
MMDS Tx → CDMA-DS mobile station	10

This study does not address coexistence between MMDS and CDMA-DS or CDMA-TDD in the same geographic area such that the service areas overlap.

4 Conclusions

In this report sharing between IMT-2000 and two specific examples of fixed and nomadic BWA systems has been studied. The conclusions for IMT-2000 CDMA DS sharing with System A (IEEE 802.16 TDD) in adjacent channels can be found in § 2.7, and the conclusions for IMT-2000 CDMA DS and CDMA TDD sharing with System B (MMDS) can be found in § 3.5.

5 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
AM	Amplitude modulation
BER	Bit error rate
BS	Base station
CDMA-DS	Code division multiple access-direct sequence
CDMA-TDD	Code division multiple access-time division duplex
CTC	Convolutional turbo code
DL	Downlink. In the case of IMT-2000: base station transmit, mobile station receive
FCC	Federal communications commission
FDD	Frequency division duplex
FS	Fixed service
IEEE	Institute of Electrical and Electronics Engineers
LoS	Line of sight
MC	Monte-Carlo
MCL	Minimum coupling loss
MCS	Minimum carrier separation
MMDS	Multipoint multimedia distribution system
MS	Mobile station
NLoS	Non-line of sight
OFDM	Orthogonal frequency division multiplexing
OFDMA	Orthogonal frequency division multiple access

PER	Packet error rate
QoS	Quality of service
QPSK	Quadrature phase shift keying
RF	Radio frequency
SINR	Signal to noise and interference ratio
SS	Subscriber station (applies only to 802.16 TDD)
TDD	Time division duplex
TX	Transmitter
UL	Uplink. In the case of IMT-2000: mobile station transmit, base station receive
UTRA	UMTS Terrestrial radio access
WP 8F	Radiocommunication Working Party 8F

Annex A

Propagation models

1 Base station-to-mobile station/SS propagation model

1.1 Deterministic analysis

For the deterministic analysis, when computing the worst-case condition, ie, for a base station and mobile station/SS in close proximity, line-of -sight (LoS) conditions are assumed when evaluating the minimum coupling loss (MCL) for this scenario. The MCL is the point at which the combination of the base station antenna gain and free-space path loss has a minimum. For a frequency of 2.6 GHz, the free space path loss, L_{free}, is given by

$$L_{freespace} = 40.7 + 20\ \log_{10}(d) \qquad \text{dB} \tag{2}$$

where d is the distance (m) between the transmitting and receiving antennas.

Equation (2) will give the highest level of interference between a base station and a mobile station/SS assuming that no reflected path is constructively added to the direct path. equation (9) of Recommendation ITU-R P.452-12 – Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above about 0.7 GHz, is a more complete version of the free-space path loss model that includes time variability and gaseous absorption terms. As stated in § 2 of Recommendation ITU-R P.452-12, for short paths the median time percentage applies and at 2.6 GHz gaseous absorption is negligible. Therefore, at 2.6 GHz the free space path loss model described in Recommendation ITU-R P.452-12 is identical to equation (2) for the deterministic scenarios considered in this Report.

Furthermore, for short base station to mobile station/SS separation distances, the free space path loss calculated by equation (2) lies within the lower and upper bounds defined by the LoS model described in Recommendation ITU-R P.1411-3 – Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz. The free space path loss is 6 dB higher than the lower bound. This lower bound path loss is based on the assumption that the direct and ground reflected paths perfectly combine. This additive effect would not occur all the time, and it is unrealistic to assume perfect additive ground reflections would be obtained for an urban street environment containing street furniture, vehicles and pedestrians.

The method used for evaluating the MCL between base stations and mobile stations/SSs is described in Annex C.

1.2 Statistical analysis

In the statistical simulation, the NLoS1 model described in Recommendation ITU-R P.1411-3 is used for the base station to mobile station/SS propagation model. It is assumed that the street width is 25 m in a medium sized city, the distance between two building rows is 100 m[18], the street orientation with respect to the direction of the path is uniformly distributed between 0º and 90º, and the length of the path covered by buildings, *l,* is 75% of *d*. Note that Recommendation ITU-R P.1411-4 – Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz, provides a clarification and extension to the number of conditions covered above 2 GHz for equation (19) of Recommendation ITU-R P.1411-3. A method for selecting between the LoS model and the NLoS1 model is used following the method described in [3GPP, 2005]. If the distance between a mobile station/SS and a base station is less than 30 m, the LoS model is used. If the distance is between 30 m and 100 m [3GPP, 2005], the LoS path loss (see § 1.1) or NLoS1 path loss is chosen randomly. The probability for LoS, *P(LoS)*, increases with decreasing separation, *R*, as follows:

$$P(LoS) = \begin{cases} 1 & R \le R_1 \\ \frac{R_2 - R}{R_2 - R_1} & R_1 < R < R_2 \\ 0 & R \ge R_2 \end{cases} \tag{3}$$

where R_1 is 30 m and R_2 is 100 m [3GPP, 2005].

In the statistical simulation, lognormal shadow fading with a standard deviation of 10 dB is added to the path loss if the NLoS1 model is used. If the resulting path loss is less than the free space path loss, the free space loss value is used. In order to take into account the shadow fading correlation between links, it is assumed that the shadow fading correlation is 1 within a cell and it is 0.5 between two cells. In other words, the lognormal shadow fading for each link is composed of two components:

$$X_i = a Z_0 + b Z_i \tag{4}$$

where:

$$a^2 + b^2 = 1, \ (a = b = 1/\sqrt{2})$$

i: cell index

Z_0: fading component that is common to all links

Z_i: fading component that is common to the links in a cell and that is independent for different cells.

Note that Z_0, Z_i are statistically independent and Gaussian random variables with zero mean and a standard deviation of 10 dB.

[18] Refer to § 2 for comments about the insensitivity of the NLoS1 model to variations of the street width and the distance between building rows (or diffracting edges).

2 Base station-to-base station propagation models

2.1 Deterministic analysis

For evaluating the path loss between a CDMA-DS macrocellular base station and a 802.16 TDD macrocellular base station that are not co-sited, the worst-case scenario is examined, in which a LoS path exists between the two base stations. This is considered to be the worst-case since it produces the highest level of ACI to each base station. The free space propagation model defined in equation (2) is used. The same considerations outlined at the beginning of § 1.1 apply, but the argument for using the free space propagation model is further strengthened in this case, because it is even less likely that the roof tops can be thought of as a smooth reflecting surface.

In the case of co-sited macrocellular base stations, a MCL value is applied as described in Annex B to evaluate the base station to base station interference.

For the path loss evaluation in the deterministic analysis between the macrocellular 802.16 TDD base station and microcellular CDMA-DS base station when they are not co-sited, the NLoS1 path loss model given in Recommendation ITU-R P.1411-3 is used. This model consists of three terms, as follows:

$$L(d) = L_{freespace} + L_{rts} + L_{msd} \tag{5}$$

Using the assumption that $\Delta h_b > 0$ m, that the street orientation is 45º with respect to the direction of the propagation path, and that the settled field distance is not obtained, the model becomes:

$$L = L_{free} - 8.2 - 10\log_{10}(w) + 10\log_{10}(f) + 20\log_{10}(\Delta h_m) + 3.25 - 10\log_{10}\left((2.35)^2\left(\frac{\Delta h_b}{R}\sqrt{\frac{b}{\lambda}}\right)^{1.8}\right) \tag{6}$$

where:

w: street width (set to 25 m)

Δh_m: difference between the average building height and the mobile station antenna height (which in this case is the microcellular base station height)

b: the distance between successive diffracting screens (buildings), assumed to be 100 m.

These values are consistent with the values adopted for the statistical analysis. However, the choice of values for w and b is not critical because the path loss calculated by equation (6) is relatively insensitive to the variation of these parameters.

The path loss is more sensitive to the street orientation parameter that is present in the NLoS1 path loss model that equation (6) is derived from. An orientation halfway between the minimum and maximum orientations (0º and 90º) has been chosen, ie, 45º. An alternative would be to assume a rectilinear street grid, and choose an orientation corresponding to the median path loss, ie, an orientation of about 31º would produce the median path loss for this scenario that is just over 2 dB less than the path loss for an orientation of 45º.

Δh_m is the difference between the base station antenna height and the average building height, for which the value of 6 m is used. The average building height is set to 24 m to be consistent with the rooftop height specified in § 2.3.2 of Report ITU-R M.2030 and R (specified in kilometers) is the horizontal distance between the base station and the mobile station; f is the operating frequency in megahertz, which is set to 2 600 MHz.

For a microcellular base station height of 6 m[19] (and with Δh_m set to 18 m) the model simplifies to

$$L_{bs} - b_s = 38 \log_{10}(R) + 147.2 \tag{7}$$

For the case in which the two base stations are co-sited but the antennas are located at different heights, a minimum coupling loss value is assumed, which is explained in Annex B.

Similarly, the non-LoS model characterised by equation (6) is used to calculate the path loss between a CDMA-DS picocellular base station (of height 1.5 m and with Δh_m set to 22.5 m) and with a 802.16 TDD macrocellular base station that are not co-sited in the deterministic analysis, with the assumption of an additional 10 dB building penetration loss [3GPP, 2005]. The resulting equation is

$$L_{bs} - b_s = 38 \log_{10}(R) + 159.1 \tag{8}$$

For the co-sited case, a minimum coupling loss is evaluated in a similar fashion as above for the macrocellular to microcellular situation (and described in Annex B), but a value of 10 dB is added to account for the building penetration loss [3GPP, 2005].

2.2 Statistical analysis

For the statistical simulation described in § 2.5 and § 2.6.3, the dual-slope LoS propagation model is adopted. This assumes free-space propagation until a breakpoint distance, d_{break}. After the breakpoint, the attenuation is increased due to diffraction/reflection effects. Since the propagation between two base stations is LoS, no shadow fading is added.

$$L_{bs-bs} = \begin{cases} 0.7 + 20 \log_{10}(d) & 1 \le d \le d_{break} \\ 40.7 - 20 \log_{10}(d_{break}) + 40 \log_{10}(d) & d > d_{break} \end{cases} \tag{9}$$

where, d is distance (m).

The breakpoint is calculated as:

$$d_{break} = \frac{4 \cdot h_{tx} \cdot h_{rx}}{\lambda} \tag{10}$$

where h_{tx} and h_{rx} are the heights (over the reflecting surface) of the transmitter and the receiver. (both are set to 6 m for evaluating macrocell base station to base station path loss); and λ is the wavelength.

This model lies between the upper and lower bound models declared in Recommendation ITU-R P.1411-3, and represents path losses 6 dB greater than the lower bound therein. As stated in § 2.1, the use of this model is justified by the fact that a series of adjacent rooftops cannot be viewed as a perfectly conducting surface needed to support the constructive addition of direct and reflected paths to produce path loss values at the lower bound.

2.3 Mobile station-to-SS propagation models

2.3.1 Deterministic analysis

In order to evaluate the interference between a mobile station and a SS, a free space path loss model, given by equation (2), is used for small separations. Justification for the use of this model

[19] Note this height is outside the declared range of mobile heights (1 to 3 m) in Recommendation ITU-R P.1411-3. However, this height is only slightly beyond the declared range and the propagation model does not exhibit any discontinuities as a function of mobile height. For an increase of mobile height from 1 to 6 m, each 1m increase corresponds to an approximate 0.4 to 0.5 dB decrease in path loss.

and how it relates to Recommendations ITU-R P.1411-3 and ITU-R P.452-12 is given in § 1.1. In the case of larger separations, when both mobile station and SS are located outdoors the LoS model based on equation (9) is used.

2.3.2 Statistical analysis

In the statistical analysis, a more complex model is required. In § 3.1 of Recommendation ITU-R P.1411-3, it is suggested that a street canyon model may be used in a microcellular or picocellular environment when the base station is below roof top height. In order to evaluate the path loss between a mobile and a SS, this model would appear to apply. However, § 4.2.2 of Recommendation ITU-R P.1411-3 describes a UHF model for calculating propagation loss within street canyons (NLoS2). A more suitable SHF street canyon model is under development in Radiocommunication Study Group 3. The street canyon model requires detailed information about the 2D layout of the buildings and streets for a particular city. Using this information for a particular city would make it difficult for the results to be generally applicable to other cities. Furthermore, it is difficult to implement the model in a meaningful way in any generic scenario.

Since the studies in this Report were performed, a version of the street canyon model that could be applied to a generic study was incorporated in the proposed revision to Recommendation ITU-R P.1411-3.

Early work on the revision of Recommendation ITU-R P.1411-3 extended the range of the NLoS1 model with low base station heights to frequencies greater than 2 GHz. This enhanced NLoS1 model has been adopted to evaluate the mobile-to-SS path loss for the statistical analysis. Also as outlined in § 1.2, a method is used that considers the probability of the mobile station and SS being in LoS for small separation distances, which has been used in a previous 3GPP study [3GPP, 2005]. In general, this would mean an underestimation of path loss for small separation distances compared to the street canyon model. When the distance between a mobile station and a SS is larger than 20 m, the NLoS1 path loss model described in Recommendation ITU-R P.1411-3[20] is applied with the assumptions described in § 1.2 of this Annex. If a mobile station and SS are within 1 m of each other, the free space loss at 1 m is used. If they are between 1 m and 20 m, LoS is used. If they are between 20 m and 50 m [3GPP, 2005], LoS or NLoS is chosen randomly. The probability for LoS, *P(LoS)*, increases with decreasing separation, *R*, as follows:

$$P(LoS) = \begin{cases} 1 & R \le R_1 \\ \frac{R_2 - R}{R_2 - R_1} & R_1 < R < R_2 \\ 0 & R \ge R_2 \end{cases} \tag{11}$$

where:

R_1: 20 m

R_2: 50 m [3GPP, 2005].

Lognormal shadow fading is added to the path loss if a mobile station and SS are not in LoS, as described in § 1.2 to this Annex.

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[20] Note that for interference between a mobile station and a nomadic SS, the antenna height of one of these terminals (1.5 m) would be outside the declared range of "base station" heights (4 to 50 m) in the NLoS1 model described in Recommendation ITU-R P.1411-3. This does not occur when the interference between a fixed SS (4 m height) and a mobile station is considered.

Annex B

Interference analysis between base stations

This Annex provides the interference analysis between a 802.16 TDD base station and a CDMA-DS base station. The ACLR and ACS values used for the CDMA-DS base station are identical to those used in Report ITU-R M.2030. (Similarly, the ACLR and ACS values for the 802.16 TDD base station are obtained from a set of RF parameters specified by the WiMAX Forum.)

1 Interference analysis between base stations in a CDMA-DS macrocellular and 802.16 TDD macrocellular deployment

For co-sited base stations, a coupling loss value of 30 dB is assumed between co-sited antennas, which was also a value measured by Allgon [1999] for horizontally separated antennas. Using the ACIR values listed in Table 4 and the maximum interference limits shown in Table 5, the additional isolation needed for the two base stations to co-exist is calculated. The additional isolation needed when the interference is generated from a TDD base station to a FDD base station is shown in Table 66. Similarly, the additional isolation needed when the interference is generated from a FDD base station to a TDD base station is shown in Table 67.

TABLE 66

Analysis for co-sited macrocellular base stations, where the FDD base station 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 67

Analysis for co-sited macrocellular base stations, where the TDD base station 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, in order for the base stations 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 802.16 TDD base station and a CDMA-DS base station unless additional isolation is attained between the base stations.

When the base stations are not co-sited but separated by some distance, the path loss between the two base stations can be evaluated using the propagation models that were defined in Annex A. For example, with a base station-to-base station 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 base stations. 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 base station 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 base station-to-base station separation distances are listed in Table 68, where the FDD base station is the interference victim. Similarly, Table 69 shows the additional isolation needed given that the TDD base station is the interference victim.

TABLE 68

Analysis when the macrocellular base stations are not co-sited, where the FDD base station 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
200	36	86.8	35	45	57	–60.8	–72.8	48.2	36.2
300	36	90.3	35	45	57	–64.3	–76.3	44.7	32.7
433	36	93.5	35	45	57	–67.5	–79.5	41.5	29.5
500.0	36	94.7	35	45	57	–68.7	–80.7	40.3	28.3
866.0	36	99.5	35	45	57	–73.5	–85.5	35.5	23.5
1 000.0	36	100.7	35	45	57	–74.7	–86.7	34.3	22.3

TABLE 69

Analysis when the macrocellular base stations are not co-sited, where the TDD base station 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
200.0	43	86.8	35	45	50	–53.8	–58.8	56.2	51.2
300.0	43	90.3	35	45	50	–57.3	–62.3	52.7	47.7
433.0	43	93.5	35	45	50	–60.5	–65.5	49.5	44.5
500.0	43	94.7	35	45	50	–61.7	–66.7	48.3	43.3
866.0	43	99.5	35	45	50	–66.5	–71.5	43.5	38.5
1 000.0	43	100.7	35	45	50	–67.7	–72.7	42.3	37.3

The conclusion of this analysis is that, with equipment that just conforms to the standards, it is unlikely to be possible to use a macrocellular 802.16 TDD base station in the same area as a macrocellular CDMA-DS base station if LoS path exists between the two antennas and each site is in the main beam of the other site's antenna (i.e., a worst case scenario), without mitigation techniques. If the base stations are separated by 1 km and they operate on radio channels that are separated by 10 MHz (i.e., the second adjacent channel), an additional isolation between the two base stations of by 22.3 dB is needed. Furthermore, the additional isolation needed is increased to 37.3 dB if the interference victim is the TDD base station.

2 Interference analysis between base stations in a CDMA-DS microcellular and 802.16 TDD macrocellular deployment

This section contains an analysis of the interference between a TDD macrocell and a FDD microcell when the two base stations are co-sited. The 802.16 TDD base station antenna was mounted at a height of 30 m and the CDMA-DS base station antenna was mounted above the ground at a height of 6 m, giving an antenna separation of 24 m. This analysis needed a value for the minimum coupling loss between the two antennas. The coupling loss for this arrangement was measured by Allgon [1999], 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, a value of 77 dB was used 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 70

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

	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 71

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

	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 base stations that are not co-sited, the path loss between the base stations was evaluated using the non-line-of-sight model described in Annex A which is defined in Recommendation ITU-R P.1411-3. The two base station 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 base station-to-base station separations are listed in Tables 26 and 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 base station-to-base station separation distances of 300 m to 1 000 m without requiring additional base station-to-base station isolation, but additional isolation would be needed for shorter distances.

TABLE 72

Analysis of the ACI from a TDD macrocellular base station to a FDD microcellular base station 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	71.2	23	45	57	–57.2	-69.2	51.8	39.8
50.0	36	97.8	23	45	57	–83.8	-95.8	25.2	13.2
100.0	36	109.2	23	45	57	–95.2	-107.2	13.8	1.8
200.0	36	120.6	23	45	57	–106.6	-118.6	2.4	-9.6
300.0	36	127.3	23	45	57	–113.3	-125.3	-4.3	-16.3
433.0	36	133.4	23	45	57	–119.4	-131.4	-10.4	-22.4
500.0	36	135.8	23	45	57	–121.8	-133.8	-12.8	-24.8
866.0	36	144.8	23	45	57	–130.8	-142.8	-21.8	-33.8
1000.0	36	147.2	23	45	57	–133.2	145.2	-24.2	-36.2

TABLE 73

Analysis of the ACI from a FDD microcellular base station to a TDD macrocellular base station 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	71.2	23	45	50	–55.2	–60.2	54.8	49.8
50.0	38	97.8	23	45	50	–81.8	–86.8	28.2	23.2
100.0	38	109.2	23	45	50	–93.2	–98.2	16.8	11.8
200.0	38	120.6	23	45	50	–104.6	–109.6	5.4	0.4
300.0	38	127.3	23	45	50	–111.3	–116.3	–1.3	–6.3
433.0	38	133.4	23	45	50	–117.4	–122.4	–7.4	–12.4
500.0	38	135.8	23	45	50	–119.8	–124.8	–9.8	–14.8
866.0	38	144.8	23	45	50	–128.8	–133.8	–18.8	–23.8
1000.0	38	147.2	23	45	50	–131.2	–136.2	–21.2	–26.2

3 Interference analysis between base stations in a CDMA-DS picocellular and 802.16 TDD macrocellular deployment

In this deployment scenario, for the case in which base stations are co-sited, the a minimum coupling loss has been determined between the two antennas with a vertical separation distance of 28.5 m in the following way (the macrocellular and picocellular antennas are 30 m and 1.5 m above the ground, respectively). Consequently, a coupling loss of 79 dB outdoors is expected. In order to take into account the indoor location of the picocellular antenna, a building penetration loss of 10 dB is added to this value yielding a minimum coupling loss of 89 dB. The results of this analysis are listed in Tables 74 and 75, which indicate the additional isolation needed for the two base stations to operate in a co-sited manner.

TABLE 74

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

	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 75

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

	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 base stations are not co-sited, the path loss was calculated based on the non-line-of-sight model described in Annex A. 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 76 and Table 77. Based on the results, it is possible to operate a TDD macrocell and a FDD picocell with separation distances of 100 m to 1 000 m without requiring additional base station-to-base station isolation.

TABLE 76

Analysis of the ACI from a TDD macrocellular base station to a FDD picocellular base station 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	83.1	18	45	57	–74.1	–86.1	34.9	22.9
50.0	36	109.7	18	45	57	–100.7	–112.7	8.3	–3.7
100.0	36	121.1	18	45	57	–112.1	–124.1	–3.1	–15.1
200.0	36	132.6	18	45	57	–123.6	–135.6	–14.6	–26.6
300.0	36	139.3	18	45	57	–130.3	–142.3	–21.3	–33.3
433.0	36	145.3	18	45	57	–136.3	–148.3	–27.3	–39.3
500.0	36	147.7	18	45	57	–138.7	–150.7	–29.7	–41.7
866.0	36	156.8	18	45	57	–147.8	–159.8	–38.8	–50.8
1 000.0	36	159.1	18	45	57	–150.1	–162.1	–41.1	–53.1

TABLE 77

Analysis of the ACI from a FDD picocellular base station to a TDD macrocellular base station 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	83.1	18	45	50	–86.1	–91.1	23.9	18.9
50.0	24	109.7	18	45	50	–112.7	–117.7	–2.7	–7.7
100.0	24	121.1	18	45	50	–124.1	–129.1	–14.1	–19.1
200.0	24	132.6	18	45	50	–135.6	–140.6	–25.6	–30.6
300.0	24	139.3	18	45	50	–142.3	–147.3	–32.3	–37.3
433.0	24	145.3	18	45	50	–148.3	–153.3	–38.3	–43.3
500.0	24	147.7	18	45	50	–150.7	–155.7	–40.7	–45.7
866.0	24	156.8	18	45	50	–159.8	–164.8	–49.8	–54.8
1 000.0	24	159.1	18	45	50	–162.1	–167.1	–52.1	–57.1

Annex C

Interference analysis between base stations and mobile station/SSs

In this section we examine the interference between base stations and mobile stations operating within macrocellular, microcellular and picocellular systems. A recent CDMA-DS and UTRA TDD co-existence study by the ITU (see Report ITU-R M.2030) using a Monte-Carlo simulation concluded that base station-to-mobile station 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 base station-mobile station 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 mobile stations use power control to compensate for path loss variations. When CDMA-DS and 802.16 TDD base stations are co-sited, the power levels received from mobile stations 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, base station-mobile station and mobile station-base station interference. Subsequently, in this base station-mobile station analysis we focus only on scenarios involving base stations that are not co-sited.

When base stations are not co-sited, an analytical approach becomes more difficult due to the variation of the power transmitted and received at the base station and mobile station, which is dependent on the relative positions of the base station and mobile station. 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 base station receivers from adjacent channel SS transmissions, as well as the interference suffered by FDD mobile station receivers from adjacent channel TDD base station 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 base station coverage are created.

1 Interference analysis between base stations and mobile station/SSs in a CDMA-DS macrocellular and 802.16 TDD macrocellular deployment

The worst case interference from a TDD SS to a FDD base station would occur when the SS operates at its cell boundary and is located very close to the FDD base station. In this situation the FDD base station experiences worst-case uplink interference from the SS, which is transmitting at maximum power because it is at the cell edge of its serving base station. Similarly, the worst case interference from a FDD mobile station to a TDD base station would occur when the mobile station operates at its cell boundary and is located very close to the TDD base station.

In order to analyze this scenario with the mobile station or SS located very close to the base station, we need to establish a minimum coupling loss between the base station antenna and the mobile station or SS 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 mobile station or SS height of 1.5 m unless indicated otherwise. 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 mobile station or SS and base station. 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 75.7 dB, for the FDD mobile station antenna with a gain of 0 dBi, and 66.9 dB for the “Fixed” SS antenna with a gain of 8 dBi as it is mounted at a height of 4 m, and 72.7 dB for the “Nomadic” SS antenna with a gain of 3 dBi.

The resulting calculation of the additional isolation needed for the different base station-to-mobile station/SS interference scenarios is shown in Table 78. Note that the additional isolation is calculated based on the maximum interference limits shown in Table 6. The results indicate that for these worst-case scenarios, mobile station/SSs and base stations can cause significant interference to each other and consequently require additional isolation to ensure co-existence between systems.

TABLE 78

Analysis of the ACI between TDD macrocellular and FDD macrocellular base stations and mobile stations/SSs

Interference scenario	Frequency offset (MHz)	Transmit power (dBm)	Coupling loss (dB)	ACIR (dB)	ACI at the receiver (dBm)	Additional isolation (dB)
Fixed SS ⇒ FDD base station	5	24	66.9	36	–78.9	30.1
	10	24	66.9	50	–92.9	16.1
FDD base station ⇒ Fixed SS	5	43	66.9	39	–62.9	45.1
	10	43	66.9	49	–72.9	35.1
Nomadic SS ⇒ FDD base station	5	20	72.7	33	–85.7	23.3
	10	20	72.7	50	–102.7	6.3
FDD base station ⇒ Nomadic SS	5	43	72.7	39	–68.7	39.3
	10	43	72.7	49	–78.7	29.3
FDD mobile station ⇒ TDD base station	5	21	75.7	33	–87.7	22.3
	10	21	75.7	43	–97.7	12.3
TDD base station ⇒ FDD mobile station	5	36	75.7	33	–72.7	32.3
	10	36	75.7	43	–82.7	22.3

2 Interference analysis between base stations and mobile stations in a CDMA-DS microcellular and 802.16 TDD macrocellular deployment

The worst case interference between a TDD SS and a microcellular FDD base station would occur when the SS is at its cell edge and located close to the FDD base station site. This is similar to the worst case interference considered in the last section between a TDD SS and a macrocellular FDD base station. The SS would transmit at maximum power and therefore cause significant uplink interference to the FDD base station. The minimum coupling loss between the TDD SS and microcellular CDMA-DS base station can be calculated using the methodology described in the previous section.

Assuming the microcellular antenna pattern shown in Fig. 15*, and the TDD SS antenna gain of 8 dBi or 3 dBi, with heights of 4 m or 1.5 m, the minimum coupling loss value was set to 40.8 dB or 52.8 dB. Note that the SS antenna was assumed to be pointed at the FDD base station.

The resulting interference analysis is shown in Table 79, which indicates that significant interference can exist in this scenario, hence requiring additional isolation to ensure co-existence between systems.

FIGURE 15

Horizontal and vertical antenna patterns for the microcellular antenna

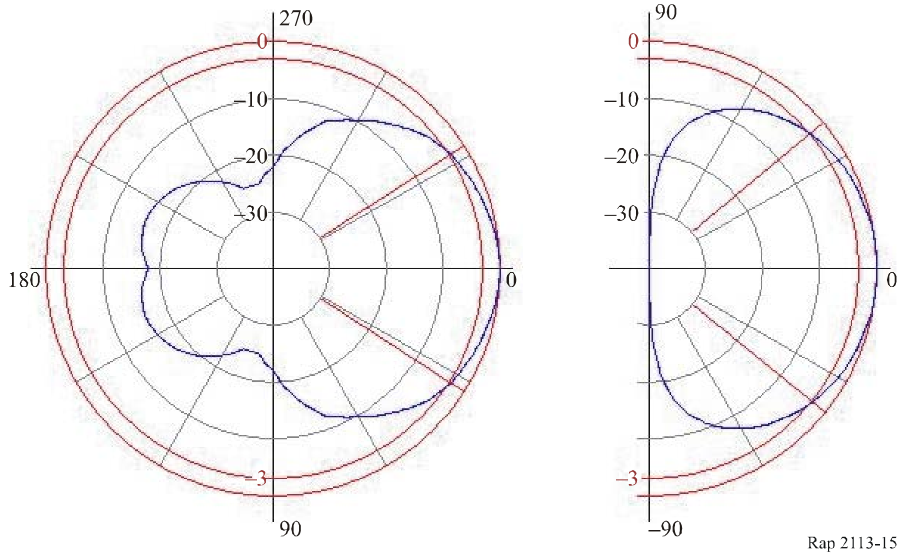


TABLE 79

Analysis of the ACI between TDD SSs and FDD microcellular base stations

Interference scenario	Frequency offset (MHz)	Transmit power (dBm)	Coupling loss (dB)	ACIR (dB)	ACI at the receiver (dBm)	Additional isolation (dB)
Fixed SS ⇒ FDD base station	5	24	40.8	36	–52.8	56.2
	10	24	40.8	50	–66.8	42.2
Nomadic SS ⇒ FDD base station	5	20	52.8	33	–65.8	43.2
	10	20	52.8	50	–82.8	26.2
FDD base station ⇒ Fixed SS	5	38	40.8	39	–41.8	66.2
	10	38	40.8	49	–51.8	56.2
FDD base station ⇒ Nomadic SS	5	38	52.8	39	–53.8	54.2
	10	38	52.8	49	–63.8	44.2

* Jaybeam microcell antenna pattern Type 5027, http://www.jaybeam.co.uk/sec_products/usa/frame_techcontent.php?q_fami=001002001002&q_item=5027000.

The worst case interference scenario between a FDD mobile station (served by a FDD microcell) and a TDD base station is basically the same as that described in § 1, ie, a FDD mobile station located at its cell edge and also located close to a TDD base station. Therefore, the results shown in the lower four rows of Table 78 also apply here.

Although this is a simple analysis, it provides an indication of the problems that can occur. It is important to realise that only the worst case interference scenarios possible have been considered. Although further investigation is required to understand the full impact of more complex deployment scenarios, the 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.

3 Interference analysis between base stations and mobile stations in a CDMA-DS picocellular and 802.16 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 mobile station is close to the victim base station. This can occur if the picocellular FDD base station is located at the boundary of the TDD macrocell and the TDD mobile station is transmitting at maximum power near the FDD base station 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 mobile station can be transmitting at maximum power when it is close to the TDD base station.

When analyzing the first of the two interference conditions outlined above, a minimum separation of 1 m should be used since the heights of the picocellular CDMA-DS base station and the mobile station are the same. At this range, with 0 dBi antennas, the path loss (using free space) is 40.7 dB. With the 3 dBi 'Nomadic' SS antenna the path loss falls to 37.7 dB.

In the fixed case, with a SS antenna height of 4 m, and a pico cellular base station height of 1.5 m, we assume that the maximum coupling loss occurs at an elevation of 45° and the maximum gains are developed. Therefore, with a separation of 3.5 m and total gains of 8 dBi, the coupling loss would be 43.7 dB.

The results of our interference analysis are shown in Table 80, which again indicates potential ACI problems.

TABLE 80

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)
Fixed SS ⇒ FDD base station	5	24	43.7	36	–55.7	54.3
	10	24	43.7	50	–69.7	40.3
FDD base station ⇒ Fixed SS	5	24	43.7	39	–58.7	46.3
	10	24	43.7	49	–68.7	36.3
Nomadic SS ⇒ FDD base station	5	20	37.7	33	–50.7	58.3
	10	20	37.7	50	–67.7	41.3
FDD base station ⇒ Nomadic SS	5	24	37.7	39	–52.7	55.3
	10	24	37.7	49	–62.7	45.3

Considering the latter of the two interference conditions that were introduced at the beginning of this section, the worst case interference scenario between a FDD mobile station (located at the cell edge of its serving picocell base station) and a TDD base station is the same as that described in § 1 and § 2. In other words, the interference between a FDD mobile station and a TDD *macrocellular* base station needs to be considered. Therefore, the results shown in the lower four rows of Table 78 also apply here.

Annex D

Interference analysis between mobile stations and SSs

Having analyzed the ACI between two base stations and between a mobile station and a base station, we concluded our analysis by examining the interference between a mobile station and a SS. Once again we assumed that the FDD mobile station and TDD SS 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 SS is located close to a FDD mobile station, 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 mobile station-to-SS interference detailed in this section we quantified the required separation distance between the two mobile stations in order to satisfy the maximum ACI level of −105 dBm, for the FDD mobile station and –108 dBm for the TDD mobile station. Calculation of the required separation distance to protect a "Fixed" SS was based on the following path loss equation, assuming an effective antenna gain of 0 dBi for the FDD mobile station and 8 dBi for the SS.

$$\text{PathLoss(dB)} = \text{TxPower(dBm)} + \text{AntennaGains(dBi)} - \text{ACIR(dB)} - (-108\text{(dBm)}) \qquad (12)$$

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 105 dB for the first adjacent channel. Similarly, for the second adjacent channel with an ACIR of 43 dB, the path loss required was 94 dB. Assuming free space path loss between the SS and the mobile station, the required separation distances were 1.6 km and 460 m for the first and second adjacent channels, respectively. Using the break point model (equation (5)), the distances reduced to 584 m and 310 m in line of sight.

A similar computation for the nomadic SSs results in separations of 918 m and 259 m if free space path loss is assumed, and 268 m and 142 m if the breakpoint model is used.

The separations required to protect a FDD mobile station from the TDD SS transmissions are similar.

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.

The method described above can be reversed to calculate the additional isolation required to achieve a given separation distance between the interfering mobile stations. For example, in order to achieve a separation distance of 3.5 m for the "Fixed" SS and assuming that a LoS path exists between the SS and the mobile stations, the additional isolation needed is shown Table 81. Similarly the isolation needed with a separation of 1 m is given in Table 82 for the "Nomadic" SSs.

From this simple analysis, it indicates that if mobile stations are in close proximity, significant ACI is generated that could cause a degradation in the performance of the victim mobile stations.

Whether the performance of the mobile station is affected significantly depends on the signal strength provided by the serving cell, and the transmit power of the interfering mobile.

TABLE 81

Analysis of interference from a CDMA DS (FDD) mobile station to a 802.16 "Fixed" TDD mobile station and *vice versa*

Source	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
FDD	TDD	3.5	21	51.7	8	32	43	–54.7	–65.7	53.3	42.3
TDD	FDD	3.5	24	51.7	8	32	42	–51.7	–61.7	53.3	43.3

TABLE 82

Analysis of interference from a CDMA DS (FDD) mobile station to a 802.16 "Nomadic" TDD mobile station and *vice versa*

Source	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
FDD	TDD	1.0	21	40.7	3	32	43	–48.7	–59.7	59.3	48.3
TDD	FDD	1.0	20	40.7	3	30	42	–47.7	–59.7	57.3	45.3

Annex E

FCC spectral mask

The FCC emission limits state the following [FCC, 2004]:

> "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 802.16 TDD base station, the following conditions apply based on a transmit power of 36 dBm:

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

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

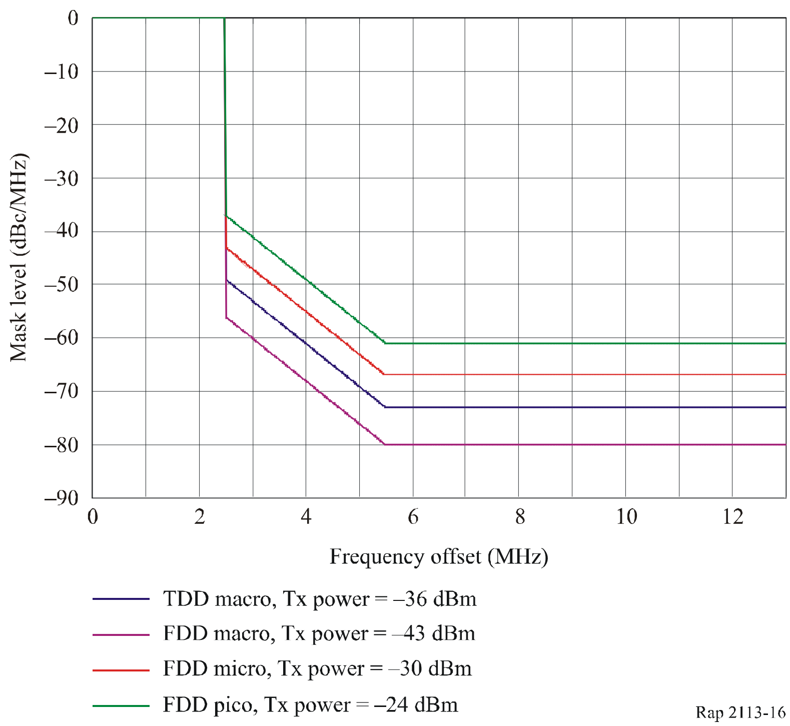
Using the above conditions the spectral mask shown in Fig. 16 was derived. Subsequently, the ACLR for the first and second adjacent channel was extracted by integrating the spectral mask over the required adjacent channel bandwidths. In extracting the ACLR, we have assumed a nominal channel bandwidth of 4.5 MHz, which was obtained based on the scaling of a 10 MHz channel bandwidth WirelessHUMAN technology implementation [IEEE, 2004]. 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 base stations are shown in Fig. 16 for the different base station transmit powers. In calculating the ACLR values for the FDD base stations, 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 [EGPP, 2005].

It was also noted that the FCC provides stricter limits when considering base stations 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 base stations that are separated by a distance greater than 1.5 km.

FIGURE 16

FCC spectral mask for 802.16 and FDD base stations



1 Interference between base stations conforming to the FCC spectral mask for *existing* licensees

In the current implementation of 802.16 equipment in the United States of America, the Federal Communication Commission (FCC) spectral mask is used as a guide to ensure that the emissions level is restricted to a given limit [FCC, 2004]. This analysis used only the mask values that apply for separations exceeding 1.5 km, to compute the additional isolation levels required, corresponding to the *existing licensee*. The more stringent masks that are specified for smaller distances or for the collocated condition were *not* used. The FCC mask can be used to estimate the required ACLR performance of the 802.16 TDD base station. This mask was also applied to the CDMA-DS base station equipment and the resulting ACLR performance is summarised in Table 83. This table also contains enhanced isolation values for ACS as described in Annex F. In the collocated condition a coupling loss of 65 dB was assumed, also described in Annex F.

TABLE 83

ACLR and ACS values (dB) for the 802.16 TDD base station and CDMA-DS base station without mitigation techniques. The ACLR was derived from the FCC spectral mask assuming a 4.5 MHz receiver bandwidth for 802.16

	ACLR		ACS	
	First adjacent channel	**Second adjacent channel**	**First adjacent channel**	**Other adjacent channels**
802.16 TDD Macro base station (Tx. Power = 36 dBm)	53.5	66.0	70.0	70.0
CDMA-DS Macro base station (Tx. Power = 43 dBm)	60.6	73.0	65.0	75.0
CDMA-DS Micro base station (Tx. Power = 38 dBm)	55.6	68.0	65.0	75.0
CDMA-DS Pico base station (Tx. Power = 24 dBm)	41.6	54.0	65.0	75.0

It was noted that the 802.16 TDD ACLR values derived from the FCC spectral mask is identical to those specified by WiMAX Forum. By using these ACLR and ACS values, the resulting ACIR is calculated and shown in Table 84. These ACIR values are then applied to quantify the additional isolation needed between the two base stations, as shown in Table 85.

TABLE 84

ACIR values (dB) of interference paths of interest that are derived from ACLR and ACS values of Table 83, where the ACLR values are derived from the FCC spectral mask

Interference path	First adjacent channel	Second adjacent channel
Macro TDD base station ⇒ Macro FDD base station	53	65
Macro FDD base station ⇒ Macro TDD base station	60	68
Macro TDD base station ⇒ Micro FDD base station	53	65
Micro FDD base station ⇒ Macro TDD base station	55	66
Macro TDD base station ⇒ Pico FDD base station	53	65
Pico FDD base station ⇒ Macro TDD base station	42	54

TABLE 85

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

Deployment scenario		TDD base station ⇒ FDD base station				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/ FDD macro	1st adj chan	27.0	46.3	36.7	32.3	26.3
	2nd adj chan	15.0	34.3	24.7	20.3	14.3
TDD macro/ FDD micro	1st adj chan	15.0	5.8	–12.3	–20.8	–32.2
	2nd adj chan	3.0	–6.2	–24.3	–32.8	–44.2
TDD macro/ FDD pico	1st adj chan	3.0	–11.1	–29.3	–37.7	–49.1
	2nd adj chan	–9.0	–23.1	–41.3	–49.7	–61.1
Deployment scenario		**FDD base station ⇒ TDD base station**				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
TDD macro/ FDD macro	1st adj chan	28.0	47.3	37.7	33.3	27.3
	2nd adj chan	20.0	39.3	29.7	25.3	19.3
TDD macro/ FDD micro	1st adj chan	21.0	6.8	–11.3	–19.8	–31.2
	2nd adj chan	10.0	–4.2	–22.3	–30.8	–42.2
TDD macro/ FDD pico	1st adj chan	3.0	–11.1	–29.3	–37.7	–49.1
	2nd adj chan	–9.0	–23.1	–41.3	–49.7	–61.1

By using the ACIR values derived from the FCC mask and without applying mitigation techniques, additional isolation is needed in the macrocellular deployment (and microcellular deployment for separation distances of 100 m or less) as well as when the two base stations are co-sited. It is noted that the FCC mask specifies that additional isolation is needed to reduce the ACLR when base stations are closer than 1.5 km, and especially when collocated. Corresponding improvements in ACS would be needed, and these improvements in ACIR would be achieved through the use of appropriate mitigation techniques.

2 Interference between base stations conforming to the FCC spectral mask for *new* licensees

Since the distances involved are less than 1.5 km, a more stringent requirement applies to new licencees, measured at offsets of at least 3 MHz. As the ACLR of the first adjacent channel is dominated by the interference close to the channel edge, the more stringent requirement has a negligible effect. The benefit is observed in the second adjacent channel (which is more than 3 MHz from the band edge).

Firstly, the collocated condition must be addressed. In this case, the FCC specifies that:

> "the new licensee shall ... 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."

It should be noted that this level exceeds the protection criteria of –110 dBm for 802.16 TDD base stations and –109 dBm for CDMA-DS base stations. Thus this requirement is insufficient.

When the receivers are not collocated, the new licensee must provide additional distance dependent attenuation of "–20 log(D_{km}/1.5)", which corresponds to an increase of 3.5 dB at 1 km, and 9.5 dB at 500 m. Assuming that the ACS of the base station receivers is similarly improved, then the ACIR may be improved by this value. Since for the macrocell base station heights specified, the propagation model is used within the breakpoint, this additional distance dependent attenuation exactly cancels the reduction in path loss. The additional isolation needed between the two base stations, as shown in Table 86. The rules are insufficient to ensure coexistence with the specified assumptions for noise figure, antenna gain and interference margin.

TABLE 86

A summary of the additional isolation needed (dB) when considering base station-to-base station interference for different base station separation distances. These results use the ACIR values derived from the FCC spectral mask assuming that the ACSs are improved by the distance dependent formulation also

Deployment scenario TDD macrocell and:		**TDD base station ⇒ FDD base station**				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
FDD macro	2nd adj chan	2.0	10.7	10.7	10.7	10.7
FDD micro	2nd adj chan	2.0	–29.7	–38.3	–42.3	–47.7
FDD pico	2nd adj chan	2.0	–46.7	–55.2	–59.2	–64.7
Deployment scenario TDD macrocell and:		**FDD base station ⇒ TDD base station**				
		Co-sited	**100 m**	**300 m**	**500 m**	**1 km**
FDD macro	2nd adj chan	3.0	15.7	15.7	15.7	15.7
FDD micro	2nd adj chan	3.0	–27.7	–36.3	–40.3	–45.7
FDD pico	2nd adj chan	3.0	–46.7	–55.2	–59.2	–64.7

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 802.16 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 potential for enhanced ACLR and ACS performance of CDMA-DS equipment, based on limited measurements that have been published.

Following this we discuss briefly the improvements that can be gained by employing various mitigation techniques as described in Report ITU-R M.2045. However, in this study, we only considered key mitigation techniques such as the employment of power amplifier linearization techniques, additional filtering at the base station and careful site design.

1 Enhanced ACLR and ACS isolation for CDMA-DS equipment

In this section an enhanced set of ACLR and ACS values for terminals and base stations is defined to be used as a complement to the standard ACLR and ACS values. The technical feasibility of these enhanced values under certain conditions is shown in external publications [Wilkinson and Howard, 2004; Multiple Access Communication Ltd., 2004]. In practice, there are basically two ways to ensure these enhanced values in real coexistence scenarios: either by enhancing the relevant ACLR and ACS standards specifications for the 2.6 GHz band, or for the local administrator to impose regulations requiring enhanced ACLR and ACS values.

Wilkinson and Howard [2004] examined the co-existence of CDMA-DS and TDD systems in adjacent spectrum allocations. As part of this study, they assessed the adjacent channel performance of FDD and TDD equipment. Using this information, we can take the assumed ACLR/ACS performance of the CDMA-DS equipment and adjust our interference calculations to gain a complementary view of the interaction between CDMA-DS and 802.16 systems. These ACLR and ACS values are set out in Table 87. Although the reported values in Table 87 cannot be used to form a general expectation of the performance for future equipment operating in the 2.6 GHz band, they do show that it is technically possible to obtain such values. Hence, they can be used to form a set of enhanced ACLR/ACS values for the sake of calculation to complement those using the standard values

The ACLR of a UTRA TDD base station transmitter was reported to be 57 dB in the first adjacent channel[21]. No value was reported for the second adjacent channel. Although ACLR performance of CDMA-DS equipment is more important for the purpose of this study, the RF circuits of a TDD base station are likely to have very similar performance to those of a FDD base station that uses a single carrier power amplifier implementation. For the ACLR of the second adjacent channel, we have made an assumption that the base station performance is 10 dB better than that of the mobile station, giving an ACLR of 74 dB.

The FDD base station 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 base station 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 mobile station, the transmitter ACLR was derived directly from measurements performed on a TDD mobile station and we again make the assumption that the CDMA-DS mobile station will have similar performance. For the mobile station 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 base station ACS, giving a value of 65 dB.

[21] The base station used a 20 W power amplifier operating at the reduced level of 5 W. It is assumed that a power amplifier generally would have similar enhanced ACLR performance when limited to operate at only 25% of its nominal power.

TABLE 87

Reported or assumed equipment adjacent channel performance

Parameter	First adjacent channel at 5 MHz	Second adjacent channel at 10 MHz
Base station ACLR (dB)	57 (TDD)	74*
Base station ACS (dB)	65	75
Mobile station ACLR (dB)	46	64
Mobile station ACS (dB)	55-60	65*

* Indicates that the performance of the base station is assumed to be 10 dB better than that of the mobile station

Also, in a recent study into the ACI between uncoordinated CDMA-DS systems on behalf of the UK Telecommunications Regulator, Ofcom [Multiple Access Communication Ltd., 2004], ACLR and ACS values of some FDD equipment were assessed. However, in this case there were no mobile station-to-mobile station or base station-to-base station interference cases to consider. Since the adjacent channel performance of the mobile station is, in general, worse than that of the base station, it was found that the mobile station performance dominated and therefore only the mobile station ACLR and ACS were considered. These values are set out in Table 88.

TABLE 88

Reported CDMA-DS equipment performance
Multiple Access Communication Ltd., 2004

Parameter	First adjacent channel at 5 MHz	Second adjacent channel at 10 MHz
Mobile station ACLR (dB)	43	59
Mobile station ACS (dB)	54.7	Not measured
Mobile station 1 ACLR (dB)	44	58
Mobile station 2 ACLR (dB)	47	61
Mobile station ACS (dB)	33	Not measured

The values in the first two rows were from measurements performed on a FDD mobile station 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 [Joyce *et al.*, 2003]. Comparing the values in Table 87 and Table 88 shows reasonable agreement for the mobile station, with the exception of the final mobile station ACS value shown in Table 88. However, it was noted that this value had been derived using a significantly different method [Multiple Access Communication Ltd., 2004].

Although all terminals must fulfil the minimum specified ACLR and ACS values, it is not surprising to find differences, even large ones, as Table 88 suggests. This spread is due to many factors including the vendor specific trade off between performance and production cost.

In this section a set of enhanced ACLR and ACS isolation values have been derived. These enhanced isolation values, given in Table 87, could potentially be used in the 2.6 GHz band.

2 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 base station relatively easily, while at the mobile station the size limitations preclude its use.

An example of a filter used for this purpose in a UTRA TDD base station is described by Wilkinson and Howard [2004]. 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 802.16 base station would improve both the transmitter ACLR and receiver ACS by 60 dB (because of the TDD nature of 802.16), thus reducing the interference between the 802.16 base station and any CDMA-DS base station or mobile station 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 base station, so the full benefit can only be gained for base station-to-base station interference, although for the base station-to-mobile station and mobile station-to-base station interference paths the ACIR will be improved such that it is limited by the mobile station ACLR/ACS performance.

In Report ITU-R M.2045, a conservative approach was taken, in that rather than redesign the filter for the 2.6 GHz band, requiring a smaller fractional bandwidth and therefore higher Q resonators, the filter was frequency scaled, so that the passband was increased from 4.2 MHz to 5.7 MHz, and the –60 dB bandwidth increases from 6 MHz to 8.2 MHz. Consequently, the rejection quoted in Report ITU-R M.2045 is considerably poorer, and we have reproduced this in Table 89.

TABLE 89

Improvements in adjacent channel performance obtainable from the use of a channel filter according to Report ITU-R M.2045

Guard band	ACLR improvement	ACS improvement
0 MHz	9 dB	9-15 dB
1 MHz	35 dB	>35 dB
2 MHz	71 dB	>71 dB
5 MHz (2nd adjacent channel)	68 dB	>68 dB

3 Site design

In Annex B we established that the most significant factor affecting the co-existence of CDMA-DS and 802.16 will be the interference between the two types of base station 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 [1999] 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 band, we can adjust the coupling loss values used in our calculations of interference between FDD and 802.16 base stations accordingly. When mounted on the same mast, antenna isolations of between 39 dB and 54 dB were achieved [Allgon, 1999], 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 base station to macrocell base station interference case. However for the macrocell base station to microcell base station case and macrocell base station to picocell base station 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 ITU-R M.2045, 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 base stations that are not co-sited, we have assumed worst-case antenna orientations, ie, with the interfering base station 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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