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Coexistence between IMT-2000 CDMA-DS and IMT-2000 OFDMA-TDD-WMAN in the 2 500-2 690 MHz band operating in adjacent bands in the same area

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REPORT ITU-R M.2146

Coexistence between IMT-2000 CDMA-DS and IMT-2000 OFDMA-TDD-WMAN in the 2 500-2 690 MHz band operating in adjacent bands in the same area

(2009)

1 Introduction and scope

The 2 500-2 690 MHz band has been identified as a frequency band that administrations may choose to make available for IMT-2000. Consequently, ITU-R has undertaken sharing studies in the 2 500 MHz to 2 690 MHz band between IMT-2000 systems and other services as required by Resolution 223 (WRC-07). Report 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, focused on coexistence analysis for sharing between TDD-based and FDD-based IMT-2000 systems, specifically CDMA-DS and CDMA-TDD, operating in adjacent bands. Report 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, addressed mitigation techniques to enable harmonious coexistence of these technologies. Report ITU-R M.2113 –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, addressed both coexistence analysis and mitigation of sharing between IMT-2000, specifically CDMA-DS and CDMA-TDD and broadband wireless access systems that support fixed and/or nomadic applications.

With the incorporation of OFDMA-TDD-WMAN as the 6th IMT-2000 radio interface, a study of coexistence between OFDMA-TDD-WMAN and other components of IMT-2000 is appropriate to extend the analysis provided in Report ITU-R M.2030. This Report addresses coexistence between the OFDMA-TDD-WMAN and CDMA-DS components of IMT-2000.

2 Interference scenarios to be analysed

Deployment of IMT-2000 OFDMA-TDD-WMAN, a mobile broadband wireless acess (MBWA) system based on standards developed by IEEE 802.16[1], adjacent to other IMT-2000 systems in the same area in the 2 500-2 690 MHz band is likely to create similar adjacent channel interference situations as those addressed in Reports ITU-R M.2030 and ITU-R M.2045 due to inherent similarities of these systems as far as the sharing characteristics 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.

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[1] 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 entitled “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”.

Adjacent-channel sharing of a frequency band by two systems deployed in the same 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 Report contains two analyses of the impact of adjacent channel interference (ACI) between a CDMA-DS system and an OFDMA-TDD-WMAN system. In one analysis OFDMA-TDD-WMAN is deployed with 5 MHz channels, and in the other with 10 MHz channels. The analysis of the systems operating in 5 MHz channels is extended to consider the benefits of mitigation techniques.

The interference paths that can exist when these two technologies operate in adjacent spectrum are as follows:

Interference from a CDMA-DS base station to an OFDMA-TDD-WMAN base station.

Interference from a CDMA-DS base station to an OFDMA-TDD-WMAN mobile station.

Interference from a CDMA-DS mobile station to an OFDMA-TDD-WMAN base station.

Interference from a CDMA-DS mobile station to an OFDMA-TDD-WMAN mobile station.

Interference from an OFDMA-TDD-WMAN base station to a CDMA-DS base station.

Interference from an OFDMA-TDD-WMAN base station to a CDMA-DS mobile station.

Interference from an OFDMA-TDD-WMAN mobile station to a CDMA-DS base station.

Interference from an OFDMA-TDD-WMAN mobile station to a CDMA-DS mobile station.

Note that not all of these interference paths result in significant interference in any given configuration. For example, if the OFDMA-TDD-WMAN channel is adjacent to the CDMA-DS FDD downlink channel, then only interference Paths 1, 2, 6 and 8 are relevant. Alternatively, when the OFDMA-TDD-WMAN channel is adjacent to the CDMA-DS FDD uplink channel, then only interference Paths 3, 4, 5 and 7 are relevant.

In the interference analysis, the OFDMA-TDD-WMAN and CDMA-DS systems are modelled as operating in a macrocellular network. Additionally, the deterministic analysis includes microcellular and indoor picocellular deployment scenarios for the CDMA-DS system only.

3 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 and mobile station transmissions in the OFDMA-TDD-WMAN and CDMA-DS systems and the adjacent channel selectivity (ACS) of the base station and mobile station receivers in the OFDMA-TDD-WMAN 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 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 § 5.3, § 6.2.8 and § 6.2.9) to determine whether the systems are adequately protected. Our results are presented in § 5, 6 and 7. The level of interference received depends on the spectral “leakage” of the interferer’s transmitter and the adjacent channel 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)[2]:

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

4 Basic system characteristics

Sections 5, 6 and 7 contain analyses of the impact of ACI between a CDMA-DS system and a TDD system, namely, OFDMA-TDD-WMAN, which is based on IEEE 802.16-2004 OFDM/OFDMA and its amendment IEEE 802.16e-2005[3, 4]. 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 B.

4.1 OFDMA-TDD-WMAN

Parameters of MBWA systems, including 5 MHz OFDMA-TDD-WMAN, for use in sharing studies are given in Report ITU-R M.2039 – Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses. These OFDMA-TDD-WMAN parameters are given in Table 1.

For OFDMA-TDD-WMAN using a 10 MHz channel bandwidth the characteristics are as shown in Table 2. Note that the ACLR and ACS values apply for a bandwidth of 5 MHz rather than 10 MHz, and that all other parameters are identical to the 5 MHz scenario. Figure 1 shows the spectral layout of the channels when the OFDMA-TDD-WMAN transmission occurs adjacent to the CDMA-DS base station transmission without a guardband, whilst Fig. 2 shows the layout when there is a 5 MHz guardband. Note that the ACLRs given in Table 2 represent the value measured in a 5 MHz CDMA-DS channel relative to the full 10 MHz wanted signal power, and the ACSs given in the table refer to the selectivity of the 10 MHz OFDMA-TDD-WMAN receiver filter in discriminating against a 5 MHz transmission. In this Report, the term "first adjacent channel" implies no guardband, while the term "second adjacent channel" implies a 5 MHz guardband, irrespective of the OFDMA-TDD-WMAN channel bandwidth.

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[2] 3GPP [March 2005] Radio frequency (RF) system scenarios. 3GPP TR 25.942 Version 6.4.0.

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

[4] IEEE [February 2005] 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.

TABLE 1

5 MHz OFDMA-TDD-WMAN parameters*
(extracted from Report ITU-R M.2039)

	Base station	Mobile station
Max transmit power	36 dBm	20 dBm
Antenna gain	18 dBi	0 dBi
Antenna height	30 m	1.5 m
ACLR @ 5 MHz	53.5 dB	33 dB
ACLR @ 10 MHz	66 dB	43 dB
ACS @ 5 MHz	46 dB	33 dB
ACS @ 10 MHz	56 dB	47 dB
Noise figure	3 dB	5 dB
Downlink/uplink ratio	2:1	

* These ACLR values can also be found in Recommendations ITU-R M.1580 – Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-2000, and ITU-R M.1581 – Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-2000, and these ACS numbers as well as the other parameter values are also found in Report ITU-R M.2039.

TABLE 2

10 MHz OFDMA-TDD-WMAN parameters

	Base station	Mobile station
Max transmit power	36 dBm	20 dBm
Antenna gain	18 dBi	0 dBi
Antenna height	30 m	1.5 m
ACLR(5 MHz) @ 7.5 MHz	53.7 dB	33.4 dB
ACLR(5 MHz) @ 12.5 MHz	66.2 dB	43.4 dB
ACS(5 MHz) @ 7.5 MHz	46 dB	33 dB
ACS(5 MHz) @ 12.5 MHz	56 dB	47 dB
Noise figure	3 dB	5 dB
Downlink/uplink ratio	2:1	

FIGURE 1

10 MHz OFDMA-TDD-WMAN adjacent to 5 MHz CDMA-DS without a guardband (termed the "first adjacent channel" in this study)

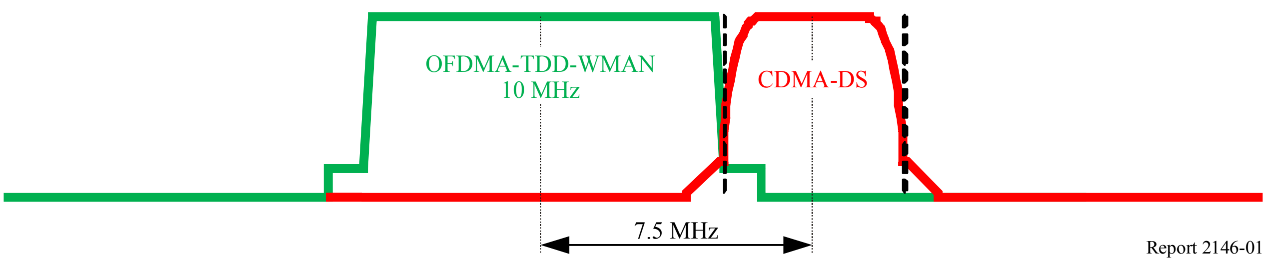
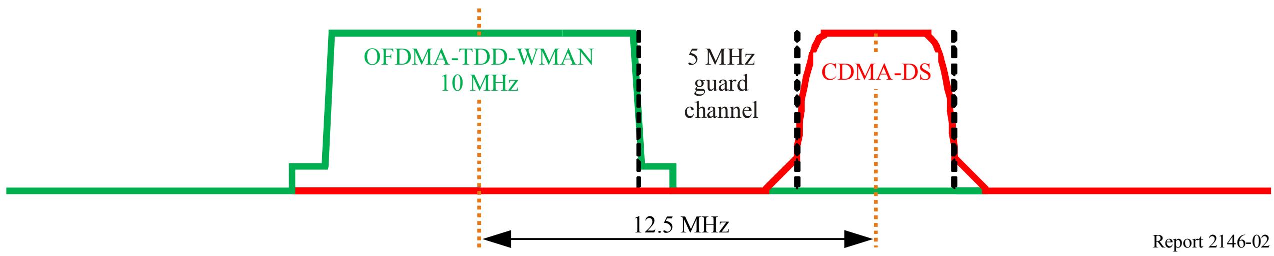


FIGURE 2

10 MHz OFDMA-TDD-WMAN adjacent to 5 MHz CDMA-DS with a 5 MHz guardband (termed the "second adjacent channel" in this study)



4.2 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. The parameters of CDMA-DS used in the analyses are given in Table 3. As for the OFDMA-TDD-WMAN ACLR and ACS parameter values, refer to § 3.3.1 for further information about the CDMA-DS ACLR and ACS values presented in Table 3.

TABLE 3

CDMA-DS parameters for use in the 5 MHz study
(extracted from Report ITU-R M.2039)

	Macrocell base station	Microcell base station	Picocell base station	Mobile station
Max transmit 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 @ 5 MHz	58 dB			43 dB
Noise figure	5 dB			9 dB
Required E_b/N_0	6.1 dB for voice			7.9 dB for voice
Power control range	30 dB (1 dB per step)			71 dB (1 dB per step)

Although the CDMA-DS system is identical in both the 5 MHz and 10 MHz studies, the ACLR and ACS parameters are different to those given in Report ITU-R M.2039 as different bandwidths and frequency offsets need to be taken into account. Based on the spectrum mask for CDMA-DS[5, 6], shown in Fig. 3, ACLR values for a 10 MHz adjacent channel have been derived by using the equation defined in Recommendation ITU-R SM.1541-1 – Unwanted emissions in the out-of-band domain. Note that this method produces a lower bound for the ACLR. For the first adjacent channel, the ACLR value is calculated by integrating interference power in the 9 MHz receiver

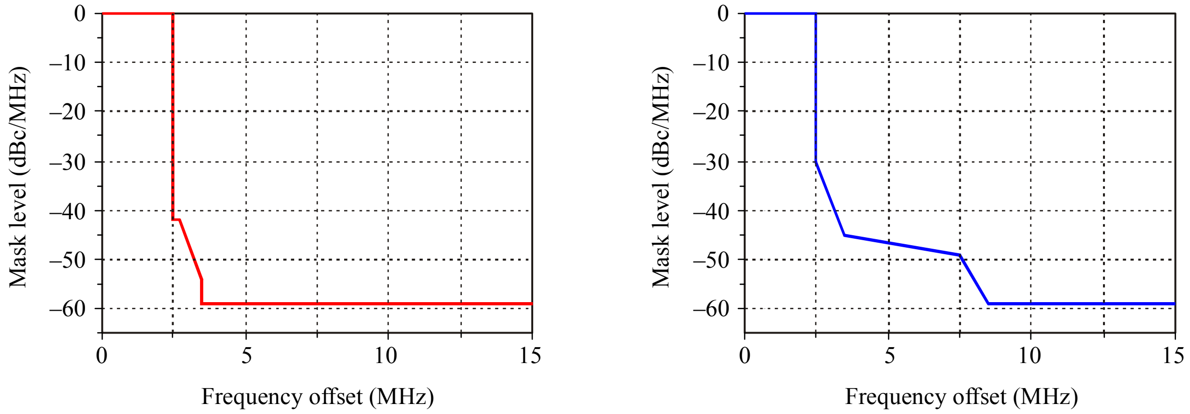
[5] Recommendation ITU-R M.1580-2.

[6] Recommendation ITU-R M.1581-2.

bandwidth, thus ACLR value at 7.5 MHz frequency offset is defined. For the second adjacent channel, the ACLR value is calculated by integrating the interference power in the 9 MHz receiver bandwidth of the signal centred in the 10 MHz channel separated by 5 MHz, thus the ACLR value at 12.5 MHz frequency offset is defined.

FIGURE 3

Spectrum masks of CDMA-DS base station and mobile station



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Parameters for IMT-2000 CDMA-DS technologies used in the sharing study with 10 MHz OFDMA-TDD-WMAN are given in the Table 4. To calculate the ACS values of CDMA-DS receivers, the formulation of Jensen *et al*. [2000] is used.

TABLE 4

CDMA-DS parameters for use in the 10 MHz OFDMA-TDD-WMAN analysis

	Macrocell base station	**Microcell base station**	**Picocell base station**	**Mobile station**
Max transmit 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 @ 7.5 MHz	43 dB			31 dB
ACLR @ 12.5 MHz (Note 1)	46 dB			45 dB
ACS @ 7.5 MHz	49 dB			36 dB
ACS @ 12.5 MHz (Note 1)	61 dB			46 dB
Noise figure	5 dB			9 dB
Required E_b/N_0	6.1 dB for voice			7.9 dB for voice
Power control range	30 dB (1 dB per step)			80 dB (1 dB per step)

NOTE 1 – In this case, a 5 MHz guard channel is assumed.

4.3 ACIR values for coexistence analysis between OFDMA-TDD-WMAN and CDMA-DS

Using equation (1) and the ACLR and ACS values listed in Tables 1 and 3, the ACIR values can be calculated for the various interference paths between the CDMA-DS equipment and the 5 MHz OFDMA-TDD-WMAN equipment. These ACIR values, shown in Table 5, are based on equipment that conforms to the CDMA-DS specified requirements[7, 8] and the RF parameters specified in Report ITU-R M.2039.

TABLE 5

ACIR values (dB) for the interference paths of interest, for 5 MHz OFDMA-TDD-WMAN

Interference path	Interference source	Victim receiver	First adjacent channel	Second adjacent channel
5	OFDMA-TDD-WMAN base station	CDMA-DS base station	45.3	57.4
1	CDMA-DS base station	OFDMA-TDD-WMAN base station	42.5	49.0
6	OFDMA-TDD-WMAN base station	CDMA-DS mobile station	33.0	43.0
3	CDMA-DS mobile station	OFDMA-TDD-WMAN base station	32.8	42.8
2	CDMA-DS base station	OFDMA-TDD-WMAN mobile station	32.7	45.2
7	OFDMA-TDD-WMAN mobile station	CDMA-DS base station	32.8	42.9
8	OFDMA-TDD-WMAN mobile station	CDMA-DS mobile station	30.0	40.0
4	CDMA-DS mobile station	OFDMA-TDD-WMAN mobile station	30.0	41.5

Similarly, by using 10 MHz OFDMA-TDD-WMAN parameters and CDMA-DS parameters in Tables 2 and 4 respectively, the ACIR values can be calculated for each interference path and the result is shown in Table 6.

[7] 3GPP [June 2004] Base station (BS) radio transmission and reception (FDD). 3GPP TS 25.104, Version 6.6.0.

[8] 3GPP [March 2004] User equipment (UE) radio transmission and reception (FDD). 3GPP TS 25.101, Version 6.4.0.

TABLE 6

ACIR values (dB) for the interference paths of interest, for 10 MHz OFDMA-TDD-WMAN

Interference path	Interference source	Victim receiver	First adjacent channel	Second adjacent channel
5	10 MHz OFDMA-TDD-WMAN base station	CDMA-DS base station	47.7	59.9
1	CDMA-DS base station	10 MHz OFDMA-TDD-WMAN base station	41.2	45.6
6	10 MHz OFDMA-TDD-WMAN base station	CDMA-DS mobile station	35.9	46.0
3	CDMA-DS mobile station	10 MHz OFDMA-TDD-WMAN base station	30.9	44.7
2	CDMA-DS base station	10 MHz OFDMA-TDD-WMAN mobile station	32.6	43.5
7	10 MHz OFDMA-TDD-WMAN mobile station	CDMA-DS base station	33.3	43.3
8	10 MHz OFDMA-TDD-WMAN mobile station	CDMA-DS mobile station	31.5	41.5
4	CDMA-DS mobile station	10 MHz OFDMA-TDD-WMAN mobile station	28.9	42.9

5 Deterministic analyses of interference

5.1 Evaluation methodology

For base station to base station interference, deterministic analyses were performed for specific separations and deployment scenarios, whereas for mobile stations, which have locations that are not fixed by the network operators, worst-case locations for the mobile stations were considered, with the mobile stations transmitting at maximum power. In all cases, the protection criteria used are as defined in § 5.3.

5.2 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 OFDMA-TDD-WMAN 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 2. 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 OFDMA-TDD-WMAN base station respectively. Furthermore, smaller separation distances of 10 m, 50 m and 100 m, and other larger separation distances of 200 m, 433 m and 866 m are also considered when analysing interference between base stations. Results are included in Annex 2.

In the analysis, propagation models as described in Annex 1 were used to evaluate the path loss between two different base stations, between a base station and a mobile station, and between mobile stations. The channel bandwidth of the OFDMA-TDD-WMAN system was set to 5 MHz or 10 MHz and the base station and mobile station parameters used in the interference analysis are shown in Tables 2 and 3. The CDMA-DS values are presented in Table 4.

5.3 Protection criteria

In this analysis, the interference thresholds shown in Table 7 are used as the maximum interference limits that can be tolerated by the CDMA-DS and OFDMA-TDD-WMAN equipment. These thresholds are specified in Report ITU-R M.2039 for the CDMA-DS and 5 MHz OFDMA-TDD-WMAN equipment.

TABLE 7

Maximum interference limit (dB) for the OFDMA-TDD-WMAN and CDMA-DS equipment

Station type	Maximum interference limit (dBm)		
	5 MHz OFDMA-TDD-WMAN	10 MHz OFDMA-TDD-WMAN	CDMA-DS
Base station	–110	–107	–109
Mobile station	–108	–105	–105

The difference between the levels of interference received and the maximum interference limit yields the additional isolation needed to ensure successful coexistence. This additional isolation is calculated for different frequency offsets between the carriers of the two systems to provide an indication of the size of the guardbands that would be required.

5.4 Results

In the following subsections, the key results are summarized for different interference and network deployment scenarios. Detailed descriptions of these results are given in Annexes 2, 3 and 4 for interference between base stations, interference between a base station and a mobile station (and vice-versa), and interference between mobile stations, respectively.

5.4.1 Interference between base stations

For the 5 MHz OFDMA-TDD-WMAN base station-to-CDMA-DS base station interference scenario, the additional isolation required to ensure successful coexistence when the OFDMA-TDD-WMAN base station transmits in a channel adjacent to the CDMA-DS uplink channel is summarized in Table 8a. Similarly, Table 8b contains the additional isolation required to ensure coexistence, when the OFDMA-TDD-WMAN base station receives in a channel close to the CDMA-DS downlink channel. Note that successful coexistence is achieved when additional isolation is not needed. The summary in Tables 8a and 8b includes results for co-sited OFDMA-TDD-WMAN and CDMA-DS base stations, and for OFDMA-TDD-WMAN 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 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 8a

A summary of the additional isolation needed (dB) to protect CDMA-DS base station receivers from interference from 5 MHz OFDMA-TDD-WMAN base station transmissions (interference Path 5) for different base station separation distances

Deployment scenario		Co-sited	100 m	300 m	500 m	1 km
OFDMA-TDD-WMAN macro/CDMA-DS macro	1st adjacent channel	69.7	54.0	44.4	40.0	34.0
	2nd adjacent channel	57.6	41.9	32.3	27.9	21.9
OFDMA-TDD-WMAN macro/CDMA-DS micro	1st adjacent channel	22.7	13.5	–4.6	–13.1	–24.5
	2nd adjacent channel	10.6	1.4	–16.7	–25.2	–36.6
OFDMA-TDD-WMAN macro/CDMA-DS pico	1st adjacent channel	10.7	–3.4	–21.6	–30.0	–41.4
	2nd adjacent channel	–1.4	–15.5	–33.7	–42.1	–53.5

TABLE 8b

A summary of the additional isolation needed (dB) to protect 5 MHz OFDMA-TDD-WMAN base station receivers from interference from CDMA-DS base station transmissions (interference Path 1) for different base station separation distances

Deployment scenario		Co-sited	100 m	300 m	500 m	1 km
OFDMA-TDD-WMAN macro/CDMA-DS macro	1st adjacent channel	80.5	64.8	55.2	50.8	44.8
	2nd adjacent channel	74.0	58.3	48.7	44.3	38.3
OFDMA-TDD-WMAN macro/CDMA-DS micro	1st adjacent channel	28.5	19.3	1.2	–7.3	–18.7
	2nd adjacent channel	22.0	12.8	–5.3	–13.8	–25.2
OFDMA-TDD-WMAN macro/CDMA-DS pico	1st adjacent channel	2.5	–11.6	–29.8	–38.2	–49.6
	2nd adjacent channel	–4.0	–18.1	–36.3	–44.7	–56.1

Similarly, a summary of the additional isolation required for 10 MHz OFDMA-TDD-WMAN is given in Tables 9a and 9b.

TABLE 9a

A summary of the additional isolation needed (dB) to protect CDMA-DS base station receivers from interference from 10 MHz OFDMA-TDD-WMAN base station transmissions (interference Path 5) for different base station separation distances

Deployment scenario		Co-sited	100 m	300 m	500 m	1 km
OFDMA-TDD-WMAN macro/CDMA-DS macro	1st adjacent channel	67.3	51.6	42.0	37.6	31.6
	2nd adjacent channel	55.1	39.4	29.8	25.4	19.4
OFDMA-TDD-WMAN macro/CDMA-DS micro	1st adjacent channel	20.3	11.1	–7.0	–15.5	–26.9
	2nd adjacent channel	8.1	–1.1	–19.2	–27.7	–39.1
OFDMA-TDD-WMAN macro/CDMA-DS pico	1st adjacent channel	8.3	–5.8	–24.0	–32.4	–43.8
	2nd adjacent channel	–3.9	–18.0	–36.2	–44.6	–56.0

TABLE 9b

A summary of the additional isolation needed (dB) to protect 10 MHz OFDMA-TDD-WMAN base station receivers from interference from CDMA-DS base station transmissions (interference Path 1) for different base station separation distances

Deployment scenario		Co-sited	100 m	300 m	500 m	1 km
OFDMA-TDD-WMAN macro/ CDMA-DS macro	1st adjacent channel	78.8	63.1	53.5	49.1	43.1
	2nd adjacent channel	74.4	58.7	49.1	44.7	38.7
OFDMA-TDD-WMAN macro/CDMA-DS micro	1st adjacent channel	26.8	17.6	–0.5	–9.0	–20.4
	2nd adjacent channel	22.4	13.2	–4.9	–13.4	–24.8
OFDMA-TDD-WMAN macro/CDMA-DS pico	1st adjacent channel	0.8	–13.3	–31.5	–39.9	–51.3
	2nd adjacent channel	–3.6	–17.7	–35.9	–44.3	–55.7

The results in Tables 8a, 8b, 9a and 9b indicate that for an OFDMA-TDD-WMAN macrocellular/ CDMA-DS macrocellular deployment with different site separation distances, additional isolation is required to ensure satisfactory coexistence. Similarly, for scenarios with co-sited OFDMA-TDD-WMAN/CDMA-DS macrocellular sites for which an antenna coupling loss of 30 dB is assumed, additional isolation is needed for all network deployments scenarios (i.e. CDMA-DS macrocellular, microcellular and picocellular networks). However, there are cases when the equipment provides sufficient isolation for coexistence as indicated by the negative values in Tables 8a, 8b, 9a and 9b; for example with the CDMA-DS picocell in the second adjacent channel, or with the CDMA-DS picocell in the first adjacent channel and the OFDMA-TDD-WMAN channel adjacent to the CDMA-DS FDD downlink channel (when only interference Path 1 is relevant).

5.4.2 Interference between base stations and mobile stations

Section 6 describes a thorough computer simulation analysis; however in the deterministic study, only cases that presented a significant impact to the ACI performance of the two systems are studied. Specifically, a situation could occur where 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 in the first or second adjacent channels 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 is applied, which is described further in Annex 3. The additional isolation needed in this situation is shown in Table 10, which indicates that the performance of the base station will be degraded due to interference from a nearby mobile station. The additional isolation required when considering interference between base station and mobiles when OFDMA-TDD-WMAN uses a 10 MHz channel bandwidth is summarized in Table 11.

TABLE 10

A summary of the additional isolation needed (dB) when considering interference between base stations and mobile stations for selected scenarios using CDMA-DS and OFDMA-TDD-WMAN operating in 5 MHz channels

Deployment scenarios		OFDMA-TDD-WMAN mobile station => CDMA-DS base station (interference Path 7)	CDMA-DS base station => OFDMA-TDD-WMAN mobile station (interference Path 2)	CDMA-DS mobile station => OFDMA-TDD-WMAN base station (interference Path 3)	OFDMA-TDD-WMAN base station => CDMA-DS mobile station (interference Path 6)
5 MHz OFDMA-TDD-WMAN macro/CDMA-DS macro	1st adjacent channel	20.5	42.6	22.5	32.3
	2nd adjacent channel	10.4	30.1	12.5	22.3
5 MHz OFDMA-TDD-WMAN macro/CDMA-DS micro	1st adjacent channel	40.4	57.5	As above	
	2nd adjacent channel	30.3	45.0		
5 MHz OFDMA-TDD-WMAN macro/CDMA-DS pico	1st adjacent channel	55.5	58.6	As above	
	2nd adjacent channel	45.4	46.1		

TABLE 11

A summary of the additional isolation needed (dB) when considering interference between base stations and mobile stations for scenarios using CDMA-DS equipment and 10 MHz OFDMA-TDD-WMAN equipment

Deployment scenarios		10 MHz OFDMA-TDD-WMAN mobile station => CDMA-DS base station (interference Path 7)	CDMA-DS base station => 10 MHz OFDMA-TDD-WMAN mobile station (interference Path 2)	CDMA-DS mobile station => 10 MHz OFDMA-TDD-WMAN base station (interference Path 3)	10 MHz OFDMA-TDD-WMAN base station => CDMA-DS mobile station (interference Path 6)
10 MHz OFDMA-TDD-WMAN macro/CDMA-DS macro	1st adjacent channel	20.0	39.7	21.4	29.4
	2nd adjacent channel	10.0	28.8	7.6	19.3
10 MHz OFDMA-TDD-WMAN macro/CDMA-DS micro	1st adjacent channel	39.9	54.6	As above	
	2nd adjacent channel	29.9	43.7		
10 MHz OFDMA-TDD-WMAN macro/CDMA-DS pico	1st adjacent channel	55.0	55.7	As above	
	2nd adjacent channel	45.0	44.8		

It should be noted that the interference levels are quite high, indicating that also in more favourable conditions coexistence 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 localized 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 12. In general, the additional isolation levels are similar, with the differences arising from the differences in ACLR performance of the OFDMA-TDD-WMAN mobile stations compared with the CDMA-DS mobile stations.

TABLE 12

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 adjacent channel	21.3	39.3
	2nd adjacent channel	11.3	29.3
FDD micro	1st adjacent channel	41.2	54.2
	2nd adjacent channel	31.2	44.2
FDD pico	1st adjacent channel	56.3	55.3
	2nd adjacent channel	46.3	45.3

5.4.3 Interference between mobile stations

Finally, analysis of the impact of ACI between an OFDMA-TDD-WMAN mobile station and a CDMA-DS mobile station is based on a worst-case scenario where the mobile stations are close together and transmitting at maximum power, and where the TDD channel is adjacent to the CDMA-DS FDD downlink channel. Although this scenario has a relatively low probability of occurring, it could 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), or if the same person wished to use the OFDMA-TDD-WMAN transceiver and the CDMA-DS transceiver simultaneously. For example, the ACI performance can be quantified if the separation distance between the mobile stations is only 1 m, where a detailed description is given in Annex 4. The results for the 5 MHz OFDMA-TDD-WMAN system indicate that additional isolation of 54.3 dB and 44.3 dB would be needed for the first and second adjacent channels, respectively, to fully protect the CDMA-DS receiver from the OFDMA-TDD-WMAN transmission, i.e. Interference Path 8, whilst additional isolations of 58.3 dB and 46.8 dB would be needed to fully protect the OFDMA-TDD-WMAN receiver, i.e. interference Path 4, as shown in Table 13.

TABLE 13

A summary of the additional isolation needed (dB) to protect mobile stations from each other (1 m away)

	5 MHz OFDMA-TDD-WMAN mobile station => CDMA-DS mobile station	**CDMA-DS mobile station => 5 MHz OFDMA-TDD-WMAN mobile station**	**10 MHz OFDMA-TDD-WMAN mobile station => CDMA-DS mobile station**	**CDMA-DS mobile station => 10 MHz OFDMA-TDD-WMAN mobile station**
1st adjacent channel	54.3	58.3	52.8	56.4
2nd adjacent channel	44.3	46.8	42.8	42.4

Similarly, calculations for the 10 MHz OFDMA-TDD-WMAN system indicate that additional isolations of 52.8 dB and 42.8 dB would be needed for the first and second adjacent channels, respectively, to fully protect the CDMA-DS receiver from the OFDMA-TDD-WMAN transmission, *i.e.* Interference Path 8, whilst additional isolations of 56.4 dB and 42.4 dB would be needed to fully protect the OFDMA-TDD-WMAN receiver, i.e. Interference Path 4, in the first and second adjacent channels, respectively. Note that similar isolations would be required if a CDMA-TDD mobile station were in such close proximity to the CDMA-DS mobile station (see Report ITU-R M.2030). Hence, this interference scenario is not particular to the deployment of OFDMA-TDD-WMAN in the band.

Note that these additional isolation values are similar to those required between CDMA-DS picocell base stations and OFDMA-TDD-WMAN mobile stations or CDMA-DS mobile stations as outlined in § 5.4.2 in Tables 10 and 11 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, i.e. 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 an OFDMA-TDD-WMAN mobile station (interferer) for the first adjacent channel an approximate 55 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 40 (55 – 10 – 5) dB isolation.

Alternatively, if the output power is decreased by 30 dB (compared to the example) and the victim mobile station is located such that an extra 30 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 (55 – 30 – 30 = –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.

A deterministic study shows the worst-case interference. A statistical study as in § 6 gives results of the average conditions.

5.5 Summary of deterministic analysis

This deterministic analysis has quantified the impact of ACI between the OFDMA-TDD-WMAN and CDMA-DS technologies when deployed in adjacent bands, without guardbands, 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 coexistence is summarized in Tables 8a and 9b for different base station-to-base station separation distances. Further results for smaller base station-to-base station separations are given in Annex 2. The results in Tables 8a and 9b show that when the base stations were co-located, the additional isolation needed to allow coexistence of the two systems was 74-74.4 dB for a guardband size of 5 MHz, whilst 44.3-44.7 dB is needed with a separation distance of 500 m.

In the case of OFDMA-TDD-WMAN base station and CDMA-DS mobile station interference and CDMA-DS base station and OFDMA-TDD-WMAN mobile station interference, specific scenarios are identified for which the impact of the ACI could be severe. The additional isolation needed for successful coexistence when a CDMA-DS mobile station is close to an OFDMA-TDD-WMAN base station and when an OFDMA-TDD-WMAN mobile station is close to a CDMA-DS base station is summarized in Tables 10 and 11. 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 mobile stations showed that the impact of ACI could be severe when the mobile stations were in close proximity. Specifically, for a separation distance of 1 m, additional isolation of 54.3 dB for the 5 MHz OFDMA-TDD-WMAN system was identified for the first adjacent channel of the CDMA-DS receiver, while in the 10 MHz case, additional isolation of 52.8 dB was needed. These are a level of isolation similar to that needed to protect mobile stations from CDMA-DS picocells. Furthermore, this analysis represents a worst-case scenario for mobile station-to-mobile station interference at these separations.

6 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.

6.1 Evaluation methodology and simulation procedure

The two systems, OFDMA-TDD-WMAN 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 loss that results from the introduction of intersystem interference is computed.

The simulation procedure is as follows:

Step 1: Configure system deployment layout and simulation parameters.

Step 2: Place mobile stations in the service area and let mobile station select its base station (using OFDMA-TDD-WMAN as an example here).

Step 2.1: Place a large number of mobile stations in each sector. For example, drop 40 mobile stations in each sector in OFDMA-TDD-WMAN. The more mobile stations dropped, the less the chance that a sector has less than 5 associated mobile stations. However, the more mobile stations dropped, the longer the simulation time on the base station selection process.

Step 2.2: Calculate each link's path-loss, including antenna gain and shadow fading. Each mobile 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 mobile stations.

Step 2.3: If any sector has less than 5 associated mobile stations, go back to Step 2.1. Otherwise, go to Step 2.4.

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

Step 3: Perform iterative power control and SINR calculation.

Step 4: Collect statistics.

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

Step 6: Process results.

6.2 Input parameters and assumptions

Table 14 summarizes the input parameters and assumptions.

TABLE 14

Common simulation assumptions and parameters

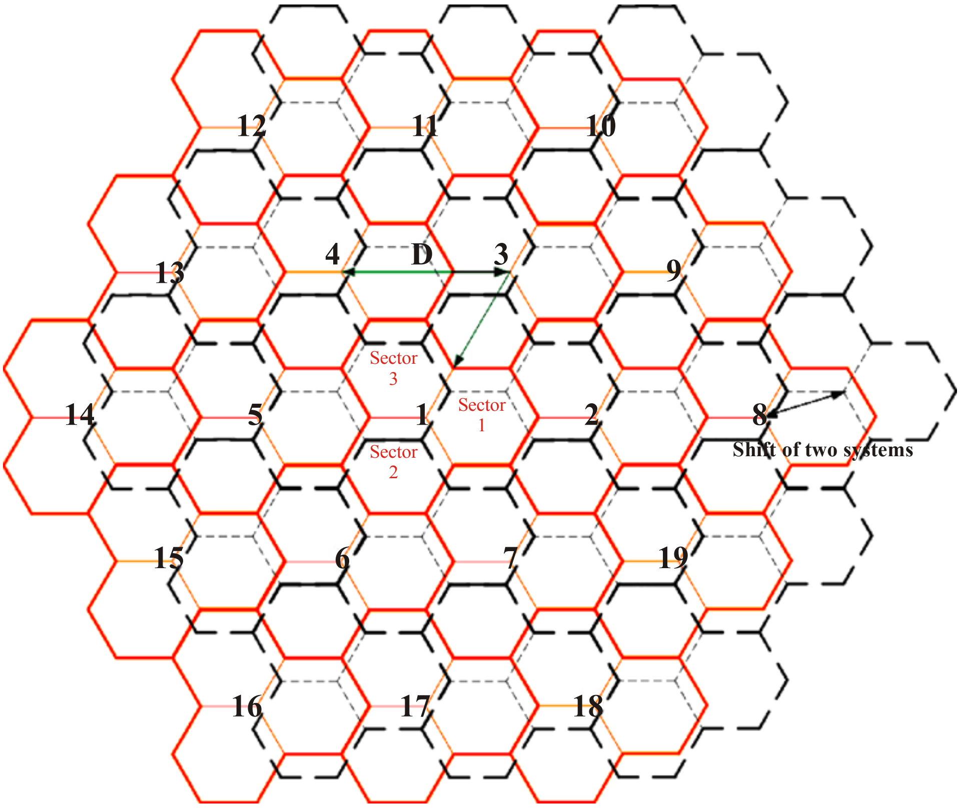
Cell layout	Macro 19 clover-leaf cells, 3 sectors per cell
Cell size	Radius: R = 1 000 m
Shift of two systems	Six different offset locations
Spectrum band	2.500 ~ 2.690 GHz
Allocated bandwidth	5 MHz
OFDMA-TDD-WMAN system load	75%
OFDMA-TDD-WMAN active users	5 per sector
Power control	150 steps SINR based (CDMA-DS UL, CDMA-DS DL); no power control in OFDMA-TDD-WMAN
Base station antenna type	Directional
Frequency reuse	CDMA-DS: 1 OFDMA-TDD-WMAN: 1 × 3 × 1, 1 × 3 × 3
Base station locations	Center of the cell
Mobile station locations	Uniformly distributed
Mobile station 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.

6.2.1 Network deployment

Three-sector clover-leaf cellular layout is used in this study as shown in Fig. 4. 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 4

Large area multiple systems deployment using directional antennas



In Fig. 4**,** the two colours indicate overlay of two different systems, i.e. CDMA-DS and OFDMA-TDD-WMAN, in the same area. The simulation area is wrapped around to remove edge effects.

6.2.2 Frequency reuse

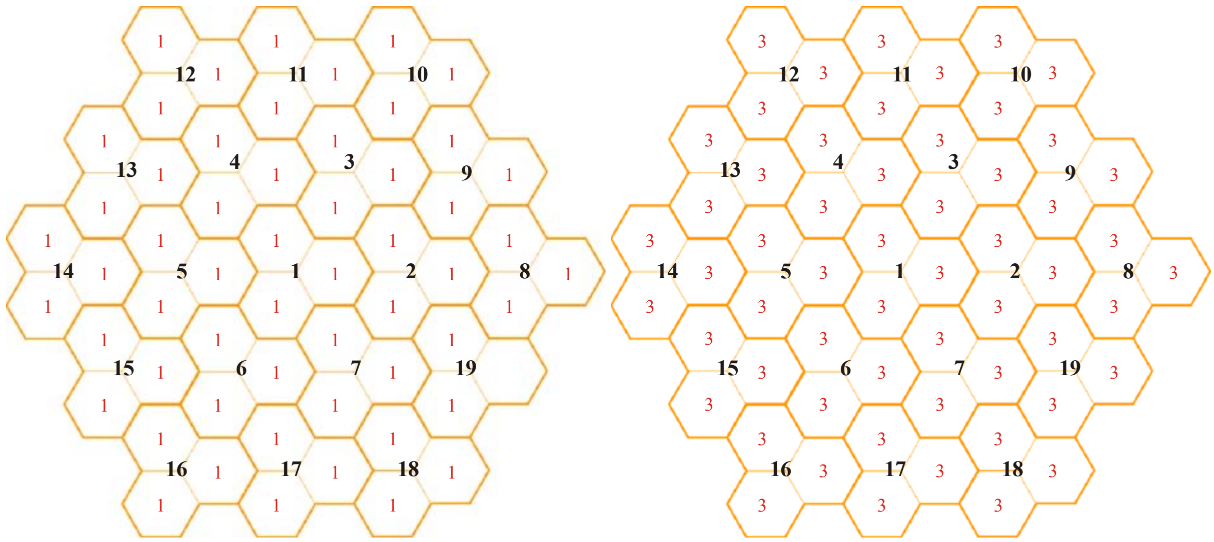
Frequency reuse schemes of 1 × 3 × 1 and 1 × 3 × 3 in the OFDMA-TDD-WMAN systems are shown in Fig. 5.

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. 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 simulation, it is assumed that this "5/3 MHz" is uniformly distributed in the 5 MHz bandwidth. In other words, base station 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. Each sector has five simultaneously active users. Each sector evenly and randomly divides its active sub-carriers between users.

FIGURE 5

OFDMA-TDD-WMAN frequency reuse schemes 1 × 3 × 1 (left) and 1 × 3 × 3 (right)



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

6.2.3 Propagation models

The models are described in Annex 1.

6.2.4 Directional antenna pattern

The base station antenna is directional. Both horizontal and vertical antenna patterns are considered in the study. The horizontal antenna pattern is specified as[9]:

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

where:

$-180 \le \theta \le +180$:	horizontal angle from the antenna pointing direction
θ_{3dB}:	corresponds to 65°
$A_m = 30$ dB:	maximum attenuation (see Recommendation ITU-R M.1646 – 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).

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[9] 3GPP [June 2004] Feasibility study for orthogonal frequency division multiplexing (OFDM) for UTRAN enhancement (Release 6), 3GPP TR 25.892 Version 6.0.0.

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 – 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):

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

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

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

$$\theta_3 = \frac{31\,000 \times 10^{-0.1G_0}}{\varphi_s}$$

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), $\varphi_s = 65$ 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).

6.2.5 SINR modelling

SINR is given by:

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

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

where:

- S: 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).

6.2.6 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:

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

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 OFDMA-TDD-WMAN

N: the thermal noise including the noise figure.

CDMA-DS downlink SINR is given by:

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

where, α is the orthogonality factor, which is 0.4 in this study.

CDMA-DS E_b/N_0 is given by:

$$E_b/N_0 = PG + SINR$$

6.2.7 CDMA-DS power control

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[10]. The power control step size is 1 dB.

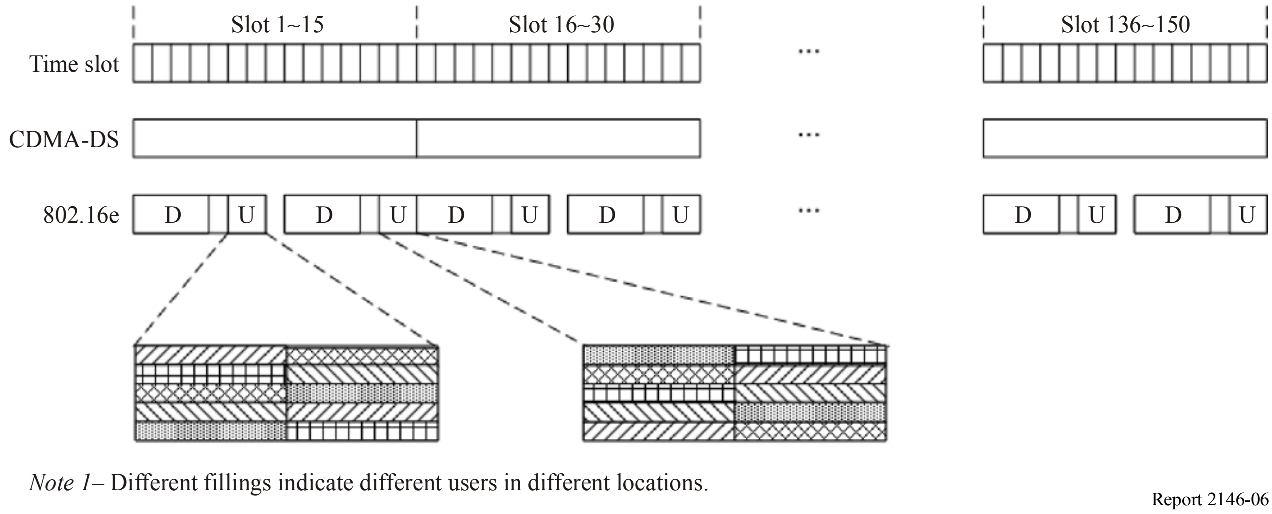
Each CDMA-DS frame contains 15 time slots, and each time slot lasts 0.667 ms. An OFDMA-TDD-WMAN frame is assumed to be 5 ms. The duration of one CDMA-DS frame thus corresponds to two OFDMA-TDD-WMAN frames. During the 150-step power control period in CDMA-DS, described below, interference from OFDMA-TDD-WMAN system is time variant depending on DL/UL ratio. In order to model the transition gaps between uplink and downlink in the TDD

[10] 3GPP [March 2005] RF system scenarios, 3GPP TR 25.942 Version 6.4.0.

system, it is assumed that there is a gap of one slot between OFDMA-TDD-WMAN downlink and uplink. This assumption is illustrated in Fig. 6. When calculating *SINR* for CDMA-DS at the end of the power control period, interferences from OFDMA-TDD-WMAN uplinks and OFDMA-TDD-WMAN downlinks are considered separately.

FIGURE 6

CDMA-DS and OFDMA-TDD-WMAN frames in time domain



As shown in Fig. 6, 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)

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.

6.2.8 CDMA-DS performance evaluation criteria

CDMA-DS capacity loss of 5% or less due to additional interference from OFDMA-TDD-WMAN is deemed acceptable. In the simulation, additional isolation from OFDMA-TDD-WMAN to CDMA-DS is added to reduce the interference and to decrease the capacity loss. When the capacity loss reaches 5%, the corresponding additional isolation is the additional isolation needed for successful coexistence of the two systems.

Two methods are used to calculate CDMA-DS uplink capacity loss:

Method 1

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. 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 is increased or decreased respectively until the 6 dB noise rise is reached. The number of users corresponding to the 6 dB noise rise is defined as $N_{\_UL\_single}$. A link is in 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 number of users which are not in outage is defined as $N_{\_UL\_single\_xx}$.

In the multi-system case, CDMA-DS uplink is loaded with $N_{\_UL\_single}$ users and with additional interference from OFDMA-TDD-WMAN. After power control, the number of users which are not in outage is defined $N_{\_UL\_multi\_xx}$.

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

$$CL_{\_UL\_loss\_1} = 1 - (N_{\_UL\_multi\_xx} / N_{\_UL\_single\_xx})$$

Method 2

Method 2 is identical to that proposed by 3GPP[10] and is explained as follows.

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. 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 is increased or decreased respectively until the 6 dB noise rise is reached. The number of users corresponding to the 6 dB noise rise is defined as $N_{\_UL\_single}$.

In the multi-system case with additional interference from OFDMA-TDD-WMAN, CDMA-DS uplink loading is determined according to the 6 dB noise rise and it is defined as $N_{\_UL\_multi}$.

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

$$CL_{\_UL\_loss\_2} = 1 - (N_{\_UL\_multi} / N_{\_UL\_single})$$

Two methods are described to calculate CDMA-DS downlink capacity loss:

Method 1

Single system simulation is run to find the number of users $N_{\_DL\_single}$, which fulfils the relation:

$$P(E_b/N_0 < \text{threshold}, N_{\_DL\_single}) \leq 5\%$$

The number of users which can meet the required E_b/N_0 is defined as $N_{\_DL\_single\_xx}$.

In the multi-system case, CDMA-DS downlink is loaded with $N_{\_DL\_single}$ users and with additional interference from OFDMA-TDD-WMAN. At the end of power control, the number of users which can meet the required E_b/N_0 is defined as $N_{\_DL\_multi\_xx}$.

CDMA-DS downlink capacity loss due to additional interference from OFDMA-TDD-WMAN is calculated by:

$$CL_{\_DL\_loss\_1} = 1 - (N_{\_DL\_multi\_xx} / N_{\_DL\_single\_xx})$$

Method 2

Method 2 is identical to that proposed by 3GPP[10] and is explained.

Single system simulation is run to find the number of users $N_{\_DL\_single}$, which fulfils the relation:

$$P(E_b/N_0 < \text{threshold}, N_{\_DL\_single}) \leq 5\%$$

Multi-system simulation with interference from OFDMA-TDD-WMAN is run to find the number of users $N_{\_DL\_multi}$, which fulfils the relation:

$$P(E_b/N_0 < \text{threshold}, N_{\_DL\_multi}) \leq 5\%$$

The capacity loss in DL is calculated as:

$$CL_{\_DL\_loss\_2} = 1 - (N_{\_DL\_multi} / N_{\_DL\_single})$$

The difference between "Method 1" and "Method 2" is that noise rise criterion or outage ratio criterion of CDMA system capacity is applied in "Method 2", and the two criteria are not used in "Method 1". When the intersystem interference is not serious, the differences between the results of "Method 1" and "Method 2" are not very different. With the increase of intersystem interference, the differences will enlarge. Further study on the differences between those methods is not made in this version of the Report.

In this version of the Report, both "Method 1" and "Method 2" are used for the uplink, and only "Method 1" is used for the downlink analysis.

6.2.9 OFDMA-TDD-WMAN performance evaluation criteria

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

In order to get OFDMA-TDD-WMAN system level performance, OFDMA-TDD-WMAN link level performance results have to be obtained. The following table shows the OFDMA-TDD-WMAN link level performance simulation results in AWGN. OFDMA-TDD-WMAN physical layer is modelled. 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 OFDMA-TDD-WMAN: Outage occurs when the link SINR drops below –5.88 dB.

TABLE 15

Signal to noise ratio and modulation efficiency of OFDMA-TDD-WMAN 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 ⅔	15.6	4
64-QAM CTC ¾	17.3	4.5

The OFDMA-TDD-WMAN 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:

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

where ME_i is modulation efficiency of the i^{th} link and N is the number of total links.

The loss in the modulation efficiency is calculated by:

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

where:

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

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

In the case of OFDM-TDD-WMAN, a loss in modulation efficiency of 5% due to additional interference from CDMA-DS is deemed acceptable unless otherwise indicated.

6.3 Interference scenarios

6.3.1 CDMA-DS UL interfered by OFDMA-TDD-WMAN

Interference to CDMA-DS UL includes:

1 co-channel interference from the same sector;

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

3 adjacent channel interference from OFDMA-TDD-WMAN uplinks/downlinks.

6.3.2 OFDMA-TDD-WMAN interfered by CDMA-DS UL

Interference to OFDMA-TDD-WMAN UL includes:

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

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 $1 \times 3 \times 1$);

2 adjacent channel interference from CDMA-DS UL.

Interference to OFDMA-TDD-WMAN DL includes:

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

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 $1 \times 3 \times 1$);

2 adjacent channel interference from CDMA-DS UL.

6.3.3 CDMA-DS DL interfered by OFDMA-TDD-WMAN

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 OFDMA-TDD-WMAN uplinks/downlinks.

6.3.4 OFDMA-TDD-WMAN interfered by CDMA-DS DL

Interference to OFDMA-TDD-WMAN UL includes:

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

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 $1 \times 3 \times 1$);

2 adjacent channel interference from CDMA-DS DL.

Interference to OFDMA-TDD-WMAN DL includes:

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

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 $1 \times 3 \times 1$);

2 adjacent channel interference from CDMA-DS DL.

6.4 Results of statistical analysis

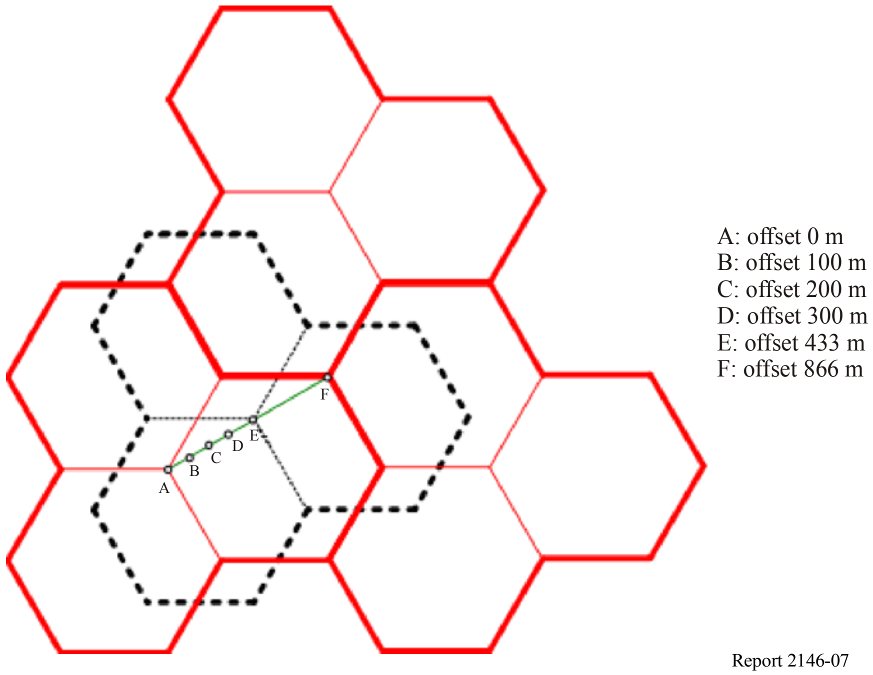
The ACLR and ACS numbers for CDMA-DS are used. Six offsets between two systems are simulated: 0 m (co-located), 100 m, 200 m, 300 m, 433 m and 866 m. Simulations are run both on the first adjacent channel and the second adjacent channel; namely, no guard-channel and one guard-channel (5 MHz) exist between the two systems. Two frequency reuse schemes are considered in OFDMA-TDD-WMAN. 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 border effects due to a limited simulation area, 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 7 illustrates deployment layout. Only three cells of CDMA-DS and one cell of OFDMA-TDD-WMAN are shown.

FIGURE 7

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 OFDMA-TDD-WMAN 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.

6.4.1 CDMA-DS coexistence with OFDMA-TDD-WMAN with no guardband

In this section, the results of a static simulation of CDMA-DS coexisting with 5 MHz OFDMA-TDD-WMAN in the same area with no guardband are given.

The CDMA-DS system capacity loss due to interference from OFDMA-TDD-WMAN is shown in Table 16, and the CDMA-DS base station noise rise due to interference from OFDMA-TDD-WMAN downlink is shown in Table 17. The OFDMA-TDD-WMAN average modulation efficiency loss and outage rate due to interference from CDMA-DS is shown in Tables 18 and 19, respectively. The additional isolation required to ensure successful coexistence is given in Table 20. In the tables of results, the cells that are shaded in pink are those that need additional isolation.

TABLE 16

CDMA-DS system capacity loss with OFDMA-TDD-WMAN 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	
		UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL
OFDMA-TDD-WMAN	UL	40	7	17	7	14	7	12	7	10	7	9	7
	DL	98	0	56	1	49	0	45	0	41	0	40	1

TABLE 17

CDMA-DS base station noise rise with OFDMA-TDD-WMAN in the first adjacent channel (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
OFDMA-TDD-WMAN DL	47.6	32.4	27.3	24.6	22.6	21.4

TABLE 18

OFDMA-TDD-WMAN average modulation efficiency loss (including the users in outage) with 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
OFDMA-TDD-WMAN (1 × 3 × 1)	UL	7	99	7	93	7	92	7	91	6	92	6	92
	DL	64	5	57	5	57	5	56	5	52	5	53	5
OFDMA-TDD-WMAN (1 × 3 × 3)	UL	12	99	12	96	12	96	12	95	12	96	12	96
	DL	76	9	70	9	70	9	69	9	65	9	66	9

TABLE 19

OFDMA-TDD-WMAN outage rate with 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		OFDMA-TDD-WMAN 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	
OFDMA-TDD-WMAN (1 × 3 × 1)	UL	14	99	13	88	14	86	14	85	13	86	14	87	10.8
	DL	46	2	40	2	40	2	39	3	34	3	34	3	0.8
OFDMA-TDD-WMAN (1 × 3 × 3)	UL	4	99	4	87	5	85	5	85	4	85	5	87	1.1
	DL	44	1	38	1	38	1	37	2	32	2	32	2	0.1

In Table 17, the noise rise values are significantly greater than the 6 dB noise rise that is commonly used to dimension CDMA-DS networks, implying that there is considerable link margin.

The additional isolation was also evaluated using Method 2 (labelled the "6 dB noise rise rule" in Table 20. In this case, the additional attenuation was increased such that the interference from OFDMA-TDD-WMAN caused 5% capacity loss with a noise rise limited to 6 dB.

TABLE 20

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

Offset (m)	Additional isolation needed (dB)										
	From OFDMA-TDD-WMAN base station to CDMA-DS base station		From CDMA-DS base station to OFDMA-TDD-WMAN base station		From OFDMA-TDD-WMAN base station to CDMA-DS mobile station	From CDMA-DS mobile station to OFDMA-TDD-WMAN base station	From OFDMA-TDD-WMAN mobile station to CDMA-DS base station	From CDMA-DS base station to OFDMA-TDD-WMAN mobile station	From OFDMA-TDD-WMAN mobile station to CDMA-DS mobile station	From CDMA-DS mobile station to OFDMA-TDD-WMAN mobile station	
	5% capacity loss rule	6 dB noise rise rule	5% loss criterion for 1 × 3 × 3	10% loss criterion for 1 × 3 × 3						5% loss criterion for 1 × 3 × 3	10% loss criterion for 1 × 3 × 3
0	44	51	61 (1 × 3 × 1) 66 (1 × 3 × 3)	61 (1 × 3 × 1) 62 (1 × 3 × 3)	0	0	0	0 (1 × 3 × 1) 5 (1 × 3 × 3)	3	12 (1 × 3 × 1) 17 (1 × 3 × 3)	12 (1 × 3 × 1) 12 (1 × 3 × 3)
100	27	35	44 (1 × 3 × 1) 48 (1 × 3 × 3)	44 (1 × 3 × 1) 44 (1 × 3 × 3)	0	0	0	0 (1 × 3 × 1) 5 (1 × 3 × 3)	3	12 (1 × 3 × 1) 17 (1 × 3 × 3)	12 (1 × 3 × 1) 12 (1 × 3 × 3)
200	21	29	38 (1 × 3 × 1) 43 (1 × 3 × 3)	38 (1 × 3 × 1) 38 (1 × 3 × 3)	0	0	0	0 (1 × 3 × 1) 5 (1 × 3 × 3)	3	12 (1 × 3 × 1) 17 (1 × 3 × 3)	12 (1 × 3 × 1) 12 (1 × 3 × 3)
300	18	26	36 (1 × 3 × 1) 41 (1 × 3 × 3)	36 (1 × 3 × 1) 36 (1 × 3 × 3)	0	0	0	0 (1 × 3 × 1) 5 (1 × 3 × 3)	3	12 (1 × 3 × 1) 17 (1 × 3 × 3)	12 (1 × 3 × 1) 12 (1 × 3 × 3)
433	16	24	33 (1 × 3 × 1) 38 (1 × 3 × 3)	33 (1 × 3 × 1) 34 (1 × 3 × 3)	0	0	0	0 (1 × 3 × 1) 5 (1 × 3 × 3)	3	12 (1 × 3 × 1) 17 (1 × 3 × 3)	12 (1 × 3 × 1) 12 (1 × 3 × 3)
866	15	22	32 (1 × 3 × 1) 37 (1 × 3 × 3)	32 (1 × 3 × 1) 33 (1 × 3 × 3)	0	0	0	0 (1 × 3 × 1) 5 (1 × 3 × 3)	3	12 (1 × 3 × 1) 17 (1 × 3 × 3)	12 (1 × 3 × 1) 12 (1 × 3 × 3)

In the OFDMA-TDD-WMAN single system case, i.e. in the absence of adjacent channel interference, simulations show that the downlink average modulation efficiency of 1 × 3 × 3 is 3.01 and the downlink average modulation efficiency of 1 × 3 × 1 is 1.50. Due to the fact that the 1 × 3 × 3 case has much less intra-system interference, it is much more sensitive to the inter-system interference. With 10% efficiency loss of 1 × 3 × 3 case, its downlink average modulation efficiency becomes 2.71, which is still much greater than that of 1 × 3 × 1 case (1.50). Similarly, in the OFDMA-TDD-WMAN single system case, simulations show that the uplink average modulation efficiency of 1 × 3 × 3 is 2.49 and the uplink average modulation efficiency of 1 × 3 × 1 is 1.22. Again, because there is much less intra-system interference, the 1 × 3 × 3 case is considerably more sensitive to the inter-system interference. A 10% loss in modulation efficiency in the 1 × 3 × 3 case results in its uplink average modulation efficiency becoming 2.24, which is still much larger than that of 1 × 3 × 1 case in the absence of adjacent channel interference (1.22). Given that, the additional isolations for 1 × 3 × 3 case are provided for both efficiency losses of 5% and 10%.

The following paragraphs include observations and explanations of 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 shaded pink, i.e. marked as problematic scenarios which need additional isolation for successful coexistence. Actually, no additional isolation is needed for those scenarios. CDMA-DS coexistence with OFDMA-TDD-WMAN with an offset of 100 m is chosen as an example. The CDMA-DS uplink capacity loss due to interference from OFDMA-TDD-WMAN uplink (including thermal noise and CDMA-DS uplink co-channel interference) is 17%, but the additional isolation from OFDMA-TDD-WMAN mobile station to CDMA-DS base station is 0 dB to ensure successful coexistence. CDMA-DS uplink power control is affected by both OFDMA-TDD-WMAN downlink and OFDMA-TDD-WMAN uplink. Since the interference from OFDMA-TDD-WMAN 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 interference due to OFDMA-TDD-WMAN uplink (including thermal noise and CDMA-DS uplink co-channel interference) is bad since the CDMA-DS uplink co-channel interference is so severe, consequently distant CDMA-DS mobile stations have insufficient power to achieve an acceptable SINR, despite the disappearance of interference from the OFDMA-TDD-WMAN downlink transmission. This causes the CDMA-DS uplink capacity loss due to interference from OFDMA-TDD-WMAN uplink to be measured as 17%. Note that most of the interference actually comes from other CDMA-DS mobile stations, whose power has been elevated to overcome the interference from the OFDMA-TDD-WMAN downlink. As the interference from OFDMA-TDD-WMAN base station to CDMA-DS base station decreases by adding more additional isolation from OFDMA-TDD-WMAN base station to CDMA-DS base station, the CDMA-DS mobile stations are able to operate with lower transmit powers, and so the CDMA-DS uplink capacity loss due to interference from OFDMA-TDD-WMAN uplink (including thermal noise and CDMA-DS uplink co-channel interference) drops to 5% without adding any additional isolation from OFDMA-TDD-WMAN mobile station to CDMA-DS base station.

Similar phenomena appear in the OFDMA-TDD-WMAN efficiency loss table. Some OFDMA-TDD-WMAN efficiency loss values are higher than 5%, but they are not marked as problematic scenarios and no additional isolation is needed. CDMA-DS coexistence with OFDMA-TDD-WMAN $1 \times 3 \times 3$ TDD with an offset of 100 m is chosen as an example. The OFDMA-TDD-WMAN uplink efficiency loss due to CDMA-DS uplink is 12%, but the additional isolation from CDMA-DS mobile station to OFDMA-TDD-WMAN base station is 0 dB to ensure successful coexistence. CDMA-DS uplink power control is affected by both OFDMA-TDD-WMAN downlink and OFDMA-TDD-WMAN uplink. Since the interference from OFDMA-TDD-WMAN 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 OFDMA-TDD-WMAN uplink SINR due to CDMA-DS uplink is bad since the CDMA-DS uplinks transmit at higher power. This causes the OFDMA-TDD-WMAN efficiency loss due to interference from CDMA-DS uplink to 12%. As the interference from OFDMA-TDD-WMAN base station to CDMA-DS base station decreases by adding more additional isolation from OFDMA-TDD-WMAN base station to CDMA-DS base station, the OFDMA-TDD-WMAN uplink efficiency loss due to interference from CDMA-DS uplink drops to 5% without adding any additional isolation from CDMA-DS mobile station to OFDMA-TDD-WMAN base station.

The outage rate of OFDMA-TDD-WMAN with frequency reuse of $1 \times 3 \times 3$ is smaller than that of 802.16 TDD with frequency reuse of $1 \times 3 \times 1$ both for single system and for multiple systems, but the modulation efficiency loss of OFDMA-TDD-WMAN with frequency reuse of $1 \times 3 \times 3$ is higher than that of OFDMA-TDD-WMAN 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 OFDMA-TDD-WMAN with frequency reuse of 1 × 3 × 3 is higher than that of 1 × 3 × 1.

6.4.2 CDMA-DS coexistence with OFDMA-TDD-WMAN with a 5 MHz guardband

In this section, results are provided from a static simulation of CDMA-DS coexisting with 5 MHz OFDMA-TDD-WMAN in the same geographic areas with guardband of 5 MHz are provided.

The CDMA-DS system capacity loss due to interference from OFDMA-TDD-WMAN is shown in Table 21, and the CDMA-DS base station noise rise due to interference from OFDMA-TDD-WMAN downlink is shown in Table 22. The OFDMA-TDD-WMAN average modulation efficiency loss and outage rate due to interference from CDMA-DS is shown in Tables 23 and 24, respectively. The additional isolation required to ensure successful coexistence is given in Table 25. The shaded areas in all result tables of the statistical analysis indicate that additional isolation is needed for coexistence for those conditions.

TABLE 21

CDMA-DS system capacity loss with OFDMA-TDD-WMAN with a 5 MHz guardband (%)

		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
OFDMA-TDD-WMAN	UL	32	1	7	1	4	1	2	1	1	1	0	1
	DL	89	0	29	0	20	0	14	0	11	0	8	0

TABLE 22

CDMA-DS base station noise rise with OFDMA-TDD-WMAN with a 5 MHz guardband (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
OFDMA-TDD-WMAN DL	35.9	22.0	17.3	14.9	13.1	11.8

TABLE 23

OFDMA-TDD-WMAN average modulation efficiency loss (including the users in outage) with CDMA-DS with a 5 MHz guardband (%)

		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
		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS		CDMA-DS	
OFDMA-TDD-WMAN (1 × 3 × 1)	UL	1	99	1	84	1	80	1	79	1	80	1	82
	DL	26	1	17	1	15	1	13	1	12	1	11	1
OFDMA-TDD-WMAN (1 × 3 × 3)	UL	2	99	2	91	2	88	2	88	2	88	2	90
	DL	41	2	29	2	26	2	23	2	21	2	20	2

TABLE 24

OFDMA-TDD-WMAN outage rate with CDMA-DS with a 5 MHz guardband (%)

		Offset by 0 m		Offset by 100 m		Offset by 200 m		Offset by 300 m		Offset by 433 m		Offset by 866 m		OFDMA-TDD-WMAN 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	
OFDMA-TDD-WMAN (1 × 3 × 1)	UL	11	99	11	76	11	72	11	70	11	70	11	72	10.8
	DL	13	1	9	1	7	1	6	1	6	1	5	1	0.8
OFDMA-TDD-WMAN (1 × 3 × 3)	UL	2	99	1	75	1	70	1	68	1	68	2	70	1.1
	DL	11	0	7	0	6	0	5	0	4	0	4	0	0.1

TABLE 25

Additional isolation needed for coexistence of OFDMA-TDD-WMAN and CDMA-DS with a 5 MHz guardband (dB)

Offset (m)	Additional isolation needed (dB)										
	From OFDMA-TDD-WMAN base station to CDMA-DS base station		From CDMA-DS base station to OFDMA-TDD-WMAN base station		From OFDMA-TDD-WMAN base station to CDMA-DS mobile station	From CDMA-DS mobile station to OFDMA-TDD-WMAN base station	From OFDMA-TDD-WMAN mobile station to CDMA-DS base station	From CDMA-DS base station to OFDMA-TDD-WMAN mobile station	From OFDMA-TDD-WMAN mobile station to CDMA-DS mobile station	From CDMA-DS mobile station to OFDMA-TDD-WMAN mobile station	
	5% capacity loss rule method 1	6 dB noise rise rule method 2	5% loss criterion for 1 × 3 × 3	10% loss criterion for 1 × 3 × 3						5% loss criterion for 1 × 3 × 3	10% loss criterion for 1 × 3 × 3
0	32	39	**55 (1 × 3 × 1) 60 (1 × 3 × 3)**	**55 (1 × 3 × 1) 56 (1 × 3 × 3)**	0	0	0	0	0	**0 (1 × 3 × 1) 5 (1 × 3 × 3)**	**0 (1 × 3 × 1) 0 (1 × 3 × 3)**
100	15	23	**38 (1 × 3 × 1) 42 (1 × 3 × 3)**	**38 (1 × 3 × 1) 38 (1 × 3 × 3)**	0	0	0	0	0	**0 (1 × 3 × 1) 5 (1 × 3 × 3)**	**0 (1 × 3 × 1) 0 (1 × 3 × 3)**
200	9	17	**32 (1 × 3 × 1) 37 (1 × 3 × 3)**	**32 (1 × 3 × 1) 32 (1 × 3 × 3)**	0	0	0	0	0	**0 (1 × 3 × 1) 5 (1 × 3 × 3)**	**0 (1 × 3 × 1) 0 (1 × 3 × 3)**
300	6	14	**30 (1 × 3 × 1) 35 (1 × 3 × 3)**	**30 (1 × 3 × 1) 30 (1 × 3 × 3)**	0	0	0	0	0	**0 (1 × 3 × 1) 5 (1 × 3 × 3)**	**0 (1 × 3 × 1) 0 (1 × 3 × 3)**
433	4	12	**27 (1 × 3 × 1) 32 (1 × 3 × 3)**	**27 (1 × 3 × 1) 28 (1 × 3 × 3)**	0	0	0	0	0	**0 (1 × 3 × 1) 5 (1 × 3 × 3)**	**0 (1 × 3 × 1) 0 (1 × 3 × 3)**
866	3	10	**26 (1 × 3 × 1) 31 (1 × 3 × 3)**	**26 (1 × 3 × 1) 27 (1 × 3 × 3)**	0	0	0	0	0	**0 (1 × 3 × 1) 5 (1 × 3 × 3)**	**0 (1 × 3 × 1) 0 (1 × 3 × 3)**

Examining Table 25, it is apparent that additional isolation is required to protect each of the base station receivers from the other system's base station transmitter. The isolation required is less than without a guardband.

6.5 Summary of static simulations of CDMA-DS coexistence with OFDMA-TDD-WMAN

The statistical analysis quantifies the impact of the first and the second adjacent channel interference between CDMA-DS and OFDMA-TDD-WMAN operating in 5 MHz channels 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 guardband 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 line-of-sight (LoS) between base stations, the worst adjacent channel interference is experienced between the base stations of these two systems.

The 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 OFDMA-TDD-WMAN base station to CDMA-DS base station using the 5% capacity loss rule (as much as 51 dB additional isolation is needed from OFDMA-TDD-WMAN base station to CDMA-DS base station using the 6 dB noise rise rule), and 66 dB additional isolation is needed from CDMA-DS base station to OFDMA-TDD-WMAN base station for case with frequency reuse of 1 × 3 × 3. (61 dB additional isolation is needed from CDMA-DS base station to OFDMA-TDD-WMAN base station for case with frequency reuse of 1 × 3 × 3 using the 10% loss criterion.) 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 between uplink and downlink of two different systems is negligible, and no additional isolation is needed between mobile station and base station of two different systems.

There is some interference from OFDMA-TDD-WMAN uplink to CDMA-DS downlink. Additional isolation of 3 dB is required from OFDMA-TDD-WMAN mobile station to CDMA-DS mobile station when operating on the first adjacent channel.

There is some interference from CDMA-DS uplink to OFDMA-TDD-WMAN downlink. Additional isolation of 12 or 17 dB is required from CDMA-DS mobile station to OFDMA-TDD-WMAN mobile station when operating on the first adjacent channel, for 1 × 3 × 1 or 1 × 3 × 3 case respectively. If the 10% modulation efficiency loss criterion is used in the 1 × 3 × 3 case the additional isolation required is 12 dB.

Each additional isolation requirement in the second adjacent channel case is better than the corresponding requirement in the first adjacent channel case. Significantly, no additional isolation is required between mobile stations and base stations, and no additional isolation is required between mobile stations of the two systems, except that in the 1 × 3 × 3 case, 5 dB isolation would be needed to meet the 5% modulation efficiency loss criterion in OFDMA-TDD-WMAN. No additional isolation is needed for the 1 × 3 × 3 case using the 10% modulation efficiency loss criterion.

7 Mitigation techniques and their impact

7.1 Deterministic analysis of interference between base stations with mitigation techniques

In order to provide the additional isolation needed to enable coexistence, the interference analysis between base stations has been extended to incorporate mitigation techniques for the OFDMA-TDD-WMAN and CDMA-DS technologies operating in 5 MHz channels. There are various techniques that can be used to mitigate ACI, which are described in Report ITU-R M.2045. These techniques include adaptive antennas, handovers and power control, among others. However, this study identifies the following key mitigation techniques that can offer additional ACI protection, which are also described in Annex 5.

a) The inclusion of a channel filter, as described in Report ITU-R M.2045 is considered which could provide approximately 68 dB of additional rejection in the RF front-end in the second adjacent channel. A smaller improvement is obtainable in the 1st adjacent channel. In order to facilitate coexistence in the first adjacent channel, then even tighter filter performance is required. For example, in Annex 6 the effect of such a filter with the characteristics described in Annex 5 is presented. Note that such a filter characteristic is extremely challenging in the 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 metres. Note that this benefit only applies when the base stations are co-sited in a macrocellular deployment, as the coupling losses for the macrocell-to-microcell and macrocell-to-picocell cases are already 77 dB and 89 dB, respectively.

Using the values suggested in Report ITU-R M.2045 for the performance of the channel filter, (and reproduced in Annex 5), and taking the minimum values for ACS improvement (from the range of values specified in Table 66 of Annex 5), the ACIR values shown in Table 26 are obtained when both systems incorporate channel filters. Note that with guardbands of 1 MHz and 2 MHz the conservative assumption is made that the ACLR and ACS in the absence of the channel filter is that of the first adjacent channel, in reality it should improve with increasing spacing. The ACIR values in Table 26 are used to compute the additional isolation required for different frequency offsets and the results are presented in Table 27a and Table 27b.

TABLE 26

ACIR values (dB) for the interference paths of interest with additional channel filters used by both OFDMA-TDD-WMAN and CDMA-DS base stations that conform to the performance specified in Report ITU-R M.2045

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
OFDMA-TDD-WMAN base station ⇒ CDMA-DS base station	54.3	80.3	116.3	125.4
CDMA-DS base station ⇒ OFDMA-TDD-WMAN base station	51.5	77.5	113.5	117

TABLE 27a

A summary of the additional isolation needed (dB) to protect CDMA-DS base station receivers from interference from 5 MHz OFDMA-TDD-WMAN base station transmissions (interference Path 5) for different base station separation distances. These results assume that additional channel filters are used by OFDMA-TDD-WMAN and CDMA-DS base stations that conform to the performance specified in Report ITU-R M.2045. An antenna coupling loss of 65 dB is assumed for the co-sited macrocell deployment scenario

Deployment scenario		Co-sited	100 m	300 m	500 m	1 km
OFDMA-TDD-WMAN macro/ CDMA-DS macro	5 MHz	25.7	45.0	35.4	31.0	25.0
	6 MHz	–0.3	19.0	9.4	5.0	–1.0
	7 MHz	–36.3	–17.0	–26.6	–31.0	–37.0
	10 MHz	–45.4	–26.1	–35.7	–40.1	–46.1
OFDMA-TDD-WMAN macro/ CDMA-DS micro	5 MHz	13.7	4.5	–13.6	–22.1	–33.5
	6 MHz	–12.3	–21.5	–39.6	–48.1	–59.5
	7 MHz	–48.3	–57.5	–75.6	–84.1	–95.5
	10 MHz	–57.4	–66.6	–84.7	–93.2	–104.6
OFDMA-TDD-WMAN macro/ CDMA-DS pico	5 MHz	1.7	–12.4	–30.6	–39.0	–50.4
	6 MHz	–24.3	–38.4	–56.6	–65.0	–76.4
	7 MHz	–60.3	–74.4	–92.6	–101.0	–112.4
	10 MHz	–69.4	–83.5	–101.7	–110.1	–121.5

TABLE 27b

A summary of the additional isolation needed (dB) to protect 5 MHz OFDMA-TDD-WMAN base station receivers from interference from CDMA-DS base station transmissions (interference Path 1) for different base station separation distances. These results assume that additional channel filters are used by OFDMA-TDD-WMAN and CDMA-DS base stations that conform to the performance specified in Report ITU-R M.2045. An antenna coupling loss of 65 dB is assumed for the co-sited macrocell deployment scenario

Deployment scenario		Co-sited	100 m	300 m	500 m	1 km
OFDMA-TDD-WMAN macro/ CDMA-DS macro	5 MHz	36.5	55.8	46.2	41.8	35.8
	6 MHz	10.5	29.8	20.2	15.8	9.8
	7 MHz	–25.5	–6.2	–15.8	–20.2	–26.2
	10 MHz	–29.0	–9.7	–19.3	–23.7	–29.7
OFDMA-TDD-WMAN macro/ CDMA-DS micro	5 MHz	19.5	10.3	–7.8	–16.3	–27.7
	6 MHz	–6.5	–15.7	–33.8	–42.3	–53.7
	7 MHz	–42.5	–51.7	–69.8	–78.3	–89.7
	10 MHz	–46.0	–55.2	–73.3	–81.8	–93.2
OFDMA-TDD-WMAN macro/ CDMA-DS pico	5 MHz	–6.5	–20.6	–38.8	–47.2	–58.6
	6 MHz	–32.5	–46.6	–64.8	–73.2	–84.6
	7 MHz	–68.5	–82.6	–100.8	–109.2	–120.6
	10 MHz	–72.0	–86.1	–104.3	–112.7	–124.1

Summary of deterministic analysis with mitigation techniques

With the ITU-R M.2045 filter, the ACLR and ACS performance is improved sufficiently to ensure that the two base stations can coexist successfully provided that the channel centre separation is increased to 7 MHz or more, i.e. 2 MHz guardband, as reported in Tables 27a and 27b, respectively.

It was found that coexistence requires the use of 2 MHz guardbands for the macrocell-to-macrocell interference case; 1 MHz for the microcell-macrocell case; and no guardband for the picocell-macrocell case.

7.2 Statistical studies using channel filters for CDMA-DS and OFDMA-TDD-WMAN

7.2.1 CDMA-DS coexistence with OFDMA-TDD-WMAN with 2 MHz guardband

The CDMA-DS UL system capacity loss due to interference from OFDMA-TDD-WMAN DL is shown in Table 28, and the CDMA-DS base station noise rise due to interference from OFDMA-TDD-WMAN DL is shown in Table 29. The OFDMA-TDD-WMAN UL average modulation efficiency loss and outage rate due to interference from CDMA-DS DL is shown in Tables 30 and 31, respectively. The additional isolation required to ensure successful coexistence is given in Table 32.

The results show that the interference between base stations of these two systems is negligible and no additional isolation is needed between them for successful coexistence with a 2 MHz guardband.

TABLE 28

CDMA-DS UL system capacity loss with OFDMA-TDD-WMAN with 2 MHz guardband (%)

	Offset by 0 m	Offset by 100 m	Offset by 200 m	Offset by 300 m	Offset by 433 m	Offset by 866 m
OFDMA-TDD-WMAN DL	0	0	0	0	0	0

TABLE 29

CDMA-DS base station noise rise with OFDMA-TDD-WMAN with 2 MHz guardband (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
OFDMA-TDD-WMAN DL	6	6	6	6	6	6

TABLE 30

OFDMA-TDD-WMAN UL average modulation efficiency loss (including the users in outage) with CDMA-DS with 2 MHz guardband (%)

Frequency reuse	Offset by 0 m	Offset by 100 m	Offset by 200 m	Offset by 300 m	Offset by 433 m	Offset by 866 m
1 × 3 × 1	1	1	0	0	0	0
1 × 3 × 3	1	1	0	0	0	0

TABLE 31

OFDMA-TDD-WMAN UL outage rate with CDMA-DS with a 2 MHz guardband (%)

Frequency reuse	Offset by 0 m	Offset by 100 m	Offset by 200 m	Offset by 300 m	Offset by 433 m	Offset by 866 m	OFDMA-TDD-WMAN single system
1 × 3 × 1	11	11	11	11	11	11	10.8
1 × 3 × 3	1	1	1	1	1	1	1.1

TABLE 32

Additional isolation needed for coexistence of OFDMA-TDD-WMAN and CDMA-DS with 2 MHz guardband (dB)

Offset (m)	From OFDMA-TDD-WMAN base station to CDMA-DS base station		From CDMA-DS base station to OFDMA-TDD-WMAN base station			
	5% capacity loss rule method 1	6 dB noise rise rule method 2	5% loss criterion		10% loss criterion	
			1 × 3 × 1	1 × 3 × 3	1 × 3 × 1	1 × 3 × 3
0	0	0	0	0	0	0
100	0	0	0	0	0	0
200	0	0	0	0	0	0
300	0	0	0	0	0	0
433	0	0	0	0	0	0
866	0	0	0	0	0	0

7.2.2 CDMA-DS coexistence with OFDMA-TDD-WMAN with a 5 MHz guardband

The CDMA-DS UL system capacity loss due to interference from OFDMA-TDD-WMAN DL is shown in Table 33, and the CDMA-DS base station noise rise due to interference from OFDMA-TDD-WMAN DL is shown in Table 34. The OFDMA-TDD-WMAN UL average modulation efficiency loss and outage rate due to interference from CDMA-DS DL is shown in Tables 35 and 36, respectively. The additional isolation required to ensure successful coexistence is given in Table 37.

The results show that the interference between base stations of these two systems is negligible and no additional isolation is needed between them for successful coexistence with a 5 MHz guardband.

TABLE 33

CDMA-DS UL system capacity loss with OFDMA-TDD-WMAN with a 5 MHz guardband (%)

	Offset by 0 m	Offset by 100 m	Offset by 200 m	Offset by 300 m	Offset by 433 m	Offset by 866 m
OFDMA-TDD-WMAN DL	0	0	0	0	0	0

TABLE 34

CDMA-DS base station noise rise with OFDMA-TDD-WMAN with a 5 MHz guardband (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
OFDMA-TDD-WMAN DL	6	6	6	6	6	6

TABLE 35

OFDMA-TDD-WMAN UL average modulation efficiency loss (including the users in outage) with CDMA-DS with a 5 MHz guardband (%)

Frequency reuse	Offset by 0 m	Offset by 100 m	Offset by 200 m	Offset by 300 m	Offset by 433 m	Offset by 866 m
1 × 3 × 1	0	0	0	0	0	0
1 × 3 × 3	0	0	0	0	0	0

TABLE 36

OFDMA-TDD-WMAN UL outage rate with CDMA-DS with a 5 MHz guardband (%)

Frequency reuse	Offset by 0 m	Offset by 100 m	Offset by 200 m	Offset by 300 m	Offset by 433 m	Offset by 866 m	OFDMA-TDD-WMAN single system
1 × 3 × 1	11	11	11	11	11	11	10.8
1 × 3 × 3	1	1	1	1	1	1	1.1

TABLE 37

Additional isolation needed for coexistence of OFDMA-TDD-WMAN and CDMA-DS with a 5 MHz guardband (dB)

<table>
<tr><th rowspan="3">Offset (m)</th><th colspan="2">From OFDMA-TDD-WMAN base station to CDMA-DS base station</th><th colspan="4">From CDMA-DS base station to OFDMA-TDD-WMAN base station</th></tr>
<tr><th rowspan="2">5% capacity loss rule method 1</th><th rowspan="2">6 dB noise rise rule method 2</th><th colspan="2">5% loss criterion</th><th colspan="2">10% loss criterion</th></tr>
<tr><th>1 × 3 × 1</th><th>1 × 3 × 3</th><th>1 × 3 × 1</th><th>1 × 3 × 3</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>100</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>200</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>300</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>433</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>866</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Summary of statistical analysis with mitigation techniques

With the Report ITU-R M.2045 filter, the ACLR and ACS performance is improved sufficiently to ensure that the two base stations can coexist successfully provided that the channel centre separation is increased to 7 MHz or more, i.e., 2 MHz guardband.

8 Conclusions

8.1 Scope and limitations

This Report addresses coexistence between the OFDMA TDD WMAN component of IMT-2000, 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.

First, results are presented for a basic coexistence analysis using approaches similar to those in Reports ITU-R M.2030 and ITU-R M.2113, and the results of this study are consistent with those reports.

Second results are presented with improved performances and other mitigation techniques, in a similar manner to Report ITU-R M.2113.

8.2 Basic results of coexistence study

These are the basic results in this Report.

8.2.1 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.

8.2.2 Interference between CDMA DS and OFDMA TDD WMAN 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. Note that the situation is very similar for 5 and 10 MHz OFDMA TDD WMAN systems; only 5 MHz results have been presented here.

TABLE 38

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	74.0	61.9	51.5	39.4	34.6	22.5
50.0	60.0	47.9	24.9	12.8	8.0	–4.1
100.0	54.0	41.9	13.5	1.4	–3.4	–15.5
300.0	44.4	32.3	–4.6	–16.7	–21.6	–33.7
500.0	40.0	27.9	–13.1	–25.2	–30.0	–42.1
1 000.0	34.0	21.9	–24.5	–36.6	–41.4	–53.5

TABLE 39

Excess interference when the macrocellular base stations are not co-sited, where the OFDMA TDD WMAN 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	84.8	78.3	57.3	57.3	26.4	19.9
50.0	70.8	64.3	30.7	24.2	–0.2	–6.7
100.0	64.8	58.3	19.3	12.8	–11.6	–18.1
300.0	55.2	48.7	1.2	–5.3	–29.8	–36.3
500.0	50.8	44.3	–7.3	–13.8	–38.2	–44.7
1 000.0	44.8	38.3	–18.7	–25.2	–49.6	–56.1

For macrocellular 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) Guardbands of larger sizes could be considered for future studies.

For macro versus microcellular 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) Guardbands 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 LoS.

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.

8.2.3 Base station-base station co-location

a) Using a minimum coupling loss (MCL) of 30 dB for macro base stations, for the first adjacent channel an excess interference of 69.7 and 80.5 dB is obtained, when CDMA-DS and OFDMA TDD WMAN are victims respectively. The corresponding numbers for the second adjacent channel are 57.6 and 74.0 dB.

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

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

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

d) 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.

8.2.4 CDMA DS base station to OFDMA TDD WMAN mobile station and CDMA DS mobile station to OFDMA TDD WMAN base station interference results

Table 40 shows the excess interference caused by base stations and mobile stations in the 5 MHz case. 10 MHz results are similar.

TABLE 40

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

Deployment scenarios		OFDMA-TDD-WMAN mobile station => CDMA-DS base station	CDMA-DS base station => OFDMA-TDD-WMAN mobile station	CDMA-DS mobile station => OFDMA-TDD-WMAN base station	OFDMA-TDD-WMAN base station => CDMA-DS mobile station
5 MHz OFDMA-TDD-WMAN macro/CDMA-DS macro	1st adjacent channel	20.5	42.6	22.5	32.3
	2nd adjacent channel	10.4	30.1	12.5	22.3
5 MHz OFDMA-TDD-WMAN macro/CDMA-DS micro	1st adjacent channel	40.4	57.5	As above	
	2nd adjacent channel	30.3	45.0		
5 MHz OFDMA-TDD-WMAN macro/CDMA-DS pico	1st adjacent channel	55.5	58.6	As above	
	2nd adjacent channel	45.4	46.1		

a) Mobile station-base station and base station-mobile station interference between OFDMA TDD WMAN 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.

8.2.5 CDMA DS mobile station – OFDMA TDD WMAN mobile station interference results

The following general observations can be made:

a) The Monte-Carlo simulations suggest that mobile station-mobile station 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 mobile station, 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.

8.3 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 deployments are very difficult.

c) Appropriate guardbands 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 guardbands, 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 guardband 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[11].

– 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.

9 References

3GPP [March 2001] Physical layer aspects of UTRA high speed downlink packet access (Release 4), 3GPP TR 25.848 Version 4.0.0.

3GPP [June 2004] Feasibility study for orthogonal frequency division multiplexing (OFDM) for UTRAN enhancement (Release 6), 3GPP TR 25.892 Version 6.0.0.

3GPP [March 2005] RF system scenarios, 3GPP TR 25.942 Version 6.4.0.

IEEE [2004] IEEE 802.16-2004 – IEEE 802.16, IEEE standard for local and metropolitan area networks. Part 16: Air interface for fixed broadband wireless access systems.

IEEE [2005] IEEE 802.16e-2005 – 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.

JENSEN, O. K. *et al*. [February 2000] RF Receiver requirements for 3G W-CDMA mobile equipment, *Microwave J.*, Vol. 43, p. 22-46.

10 Glossary and abbreviations

3GPP	Third Generation Partnership Project
AAS	Adaptive antenna system
ACI	Adjacent channel interference
ACIR	Adjacent channel interference ratio
ACLR	Adjacent channel leakage ratio
ACS	Adjacent channel selectivity
ARQ	Automatic repeat request
BER	Bit error rate
BS	Base station
BW	Bandwidth
C/I	Carrier power to Interference power ratio
CDF	Cumulative probability density function
CDMA-DS	Code division multiple access-direct sequence

[11] Note that channel filters preclude the use of multi-carrier power amplifier base station architectures.

CDMA-TDD	Code division multiple access-time division duplex
CTC	Convolutional turbo code
DL	Downlink (base station transmits, mobile station receives)
E_b/N_0	Energy per bit over noise power spectral density
FDD	Frequency division duplex
IEEE	Institute of Electrical and Electronics Engineers
IMT-2000	International Mobile Telecommunications - 2000
LoS	Line of sight
MBWA	Mobile broadband wireless access
MCL	Minimum coupling loss
MS	Mobile station
NLoS	Non-line of sight
OFDM	Orthogonal frequency division multiplexing
OFDMA	Orthogonal frequency division multiple access
PC	Power control
PER	Packet error rate
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
RF	Radio frequency
SINR	Signal to interference and noise ratio
SNR	Signal to noise ratio
TDD	Time division duplex
UL	Uplink (Mobile station transmits, base station receives)
WCDMA	Wideband code division multiple access
WMAN	Wireless Metropolitan Area Network

11 List of annexes

Annex 1 – Propagation models

Annex 2 – Interference analysis between base stations

Annex 3 – Interference analysis between base stations and mobile stations

Annex 4 – Interference analysis between mobile stations

Annex 5 – Mitigation techniques

Annex 6 – Mitigation with a filter achieving 60 dB rejection in the adjacent channel

Annex 1

Propagation models

1 Base station-to-mobile station propagation model

1.1 Deterministic analysis

For the deterministic analysis, when computing the worst-case condition, i.e. for a base station and mobile station in close proximity, LoS conditions are assumed when evaluating the 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 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 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.1411-4 – 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. 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.

1.2 Statistical analysis

In the statistical simulation, the model entitled "Propagation over roof-tops for urban area" described in § 4.2.1 of Recommendation ITU-R P.1411-4 is used for modelling the path loss between a base station and a mobile station. This model is also known as the NLoS1 model. It is assumed that the street width is 20 m, the distance between two building rows is 100 m[12], the street orientation with respect to the direction of the path is uniformly distributed between 0° and 90°, and the length of the path covered by buildings, l, is 75% of d. If the distance between a mobile station and a base station is less than 20 m, the LoS model is used.

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[12] 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).

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:

$$X_i = a Z_0 + b Z_i \tag{3}$$

where:

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

i: cell index

Z_0: fading component that is common to all links, and

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.

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 to evaluate the base station to base station interference.

For the path loss evaluation in the deterministic analysis between the macrocellular OFDMA-TDD-WMAN 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.1411-4 is used. This model consists of three terms, as follows:

$$L(d) = L_{freespace} + L_{rts} + L_{msd} \tag{4}$$

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

$$L = L_{free} - 8.2 - 10\log_{10}(w) + 10\log_{10}(f) + 20\log_{10}(\Delta h_m) + 3.25 - 10\log_{10}\left((2.35)^2\left(\frac{\Delta h_b}{R}\sqrt{\frac{b}{\lambda}}\right)^{1.8}\right) \tag{5}$$

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: 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 (5) 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 (5) is derived from. An orientation halfway between the minimum and maximum orientations (0° and 90°) has been chosen, i.e. 45°. An alternative would be to assume a rectilinear street grid, and choose an orientation corresponding to the median path loss, i.e. an orientation of about 31° would produce the median path loss for this scenario that is just over 2 dB less than the path loss for an orientation of 45°.

Δh_b 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 km) is the horizontal distance between the base station and the mobile station; f is the operating frequency in MHz, which is set to 2 600 MHz.

For a microcellular base station height of 6 m[13] (and with Δh_m set to 18 m) the model simplifies to:

$$L_{bs-bs} = 38\log_{10}(R) + 147.2 \tag{6}$$

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.

Similarly, the non-LoS model characterized by equation (5) 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 an OFDMA-TDD-WMAN macrocellular base station that are not co-sited in the deterministic analysis, with the assumption of an additional 10 dB building penetration loss[10]. The resulting equation is:

$$L_{bs-bs} = 38\log_{10}(R) + 159.1 \tag{7}$$

For the co-sited case, a minimum coupling loss is evaluated in a similar fashion as above for the macrocellular to microcellular situation, but a value of 10 dB is added to account for the building penetration loss[10].

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

[13] Note this height is outside the declared range of mobile heights (1 to 3 m) in Recommendation ITU-R P.1411-4. 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 1 m increase corresponds to an approximate 0.4 to 0.5 dB decrease in path loss.

breakpoint, the attenuation is increased due to diffraction/reflection effects. Since the propagation between two base stations is LoS, no shadow fading is added:

$$L_{bs-bs} = \begin{cases} 40.7 + 20\log_{10}(d) & 1 \le d \le d_{break} \\ \\ 40.7 - 20\log_{10}(d_{break}) + 40\log_{10}(d) & d > d_{break} \end{cases} \tag{8}$$

where, d is distance (m).

The breakpoint is calculated as:

$$d_{break} = \frac{4 \cdot h_{tx} \cdot h_{rx}}{\lambda} \tag{9}$$

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.1411-4, 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.

3 Mobile station-to-mobile station propagation models

3.1 Deterministic analysis

In order to evaluate the interference between a mobile station and a mobile station, a free-space path loss model, given by equation (2), is used for small separations. Justification for the use of this model and how it relates to Recommendations ITU-R P.1411-4 and ITU-R P.452-12 is given in § 1.1. In the case of larger separations, when both mobile stations are located outdoors the LoS model based on equation (8) is used.

3.2 Statistical analysis

In the statistical analysis, a more complex model is required. In § 3.1 of Recommendation ITU-R P.1411-4, it is suggested that a street canyon model may be used in a microcellular or picocellular environment when the base station is below rooftop height. In order to evaluate the path loss between two mobile stations, this model would apply. In § 4.3 of Recommendation ITU-R P.1411-4 a UHF model for calculating propagation loss within street canyons is described that is suitable for statistical modelling without detailed information about the 2D layout of the buildings and streets for a particular city. In this study, it is assumed that the parameter L_{urban} is 6.8 dB and the street width is 20 m. The description of the model is reproduced here for convenience.

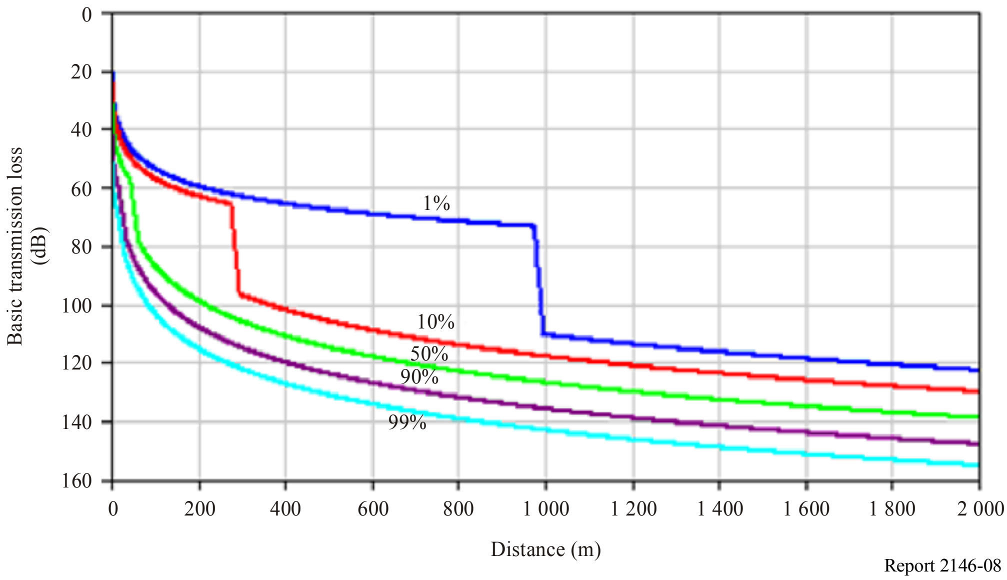
3.3 Propagation between terminals located below rooftop height at UHF

The model described below is intended for calculating the basic transmission loss between two terminals of low height in urban environments. It includes both the LoS and non-line-of-sight (NLoS) regions, and models the rapid decrease in signal level noted at the corner between the LoS and NLoS regions. The model includes the statistics of location variability in the LoS and NLoS regions, and provides a statistical model for the corner distance between the LoS and NLoS regions.

Figure 8 illustrates the LoS, NLoS and corner regions, and the statistical variability predicted by the model.

FIGURE 8

Curves of basic transmission loss not exceeded for 1, 10, 50, 90 and 99% of locations (frequency = 400 MHz, suburban)



This model is recommended for propagation between low-height terminals where both terminal antenna heights are near street level, well below rooftop height, but are otherwise unspecified. It is reciprocal with respect to transmitter and receiver and is valid for frequencies in the range 300-3 000 MHz. The model is based on measurements made in the UHF band with antenna heights between 1.9 and 3.0 m above ground, and transmitter-receiver distances up to 3 000 m.

The parameters required are the frequency f (MHz) and the distance between the terminals d (m).

– Calculate the median value of the LoS loss:

$$L_{LoS}^{median}(d) = 32.45 + 20\log_{10} f + 20\log_{10}(d/1\,000) \tag{10}$$

– For the required location percentage, p (%), calculate the LoS location correction:

$$\Delta L_{LoS}(p) = 1.5624\sigma\left(\sqrt{-2\ln(1-p/100)} - 1.1774\right), \text{ with } \sigma = 7 \quad \text{dB} \tag{11}$$

Alternatively values of the LoS correction for p = 1, 10, 50, 90 and 99% are given in Table 6.

– Add the LoS location correction to the median value of LoS loss:

$$L_{LoS}(d,p) = L_{LoS}^{median}(d) + \Delta L_{LoS}(p) \tag{12}$$

– Calculate the median value of the NLoS loss:

$$L_{NLoS}^{median}(d) = 9.5 + 45\log_{10} f + 40\log_{10}(d/1\,000) + L_{urban} \tag{13}$$

L_{urban} depends on the urban category and is 0 dB for suburban, 6.8 dB for urban and 2.3 dB for dense urban/high-rise.

– For the required location percentage, p (%), add the NLoS location correction:

$$\Delta L_{NLoS}(p) = \sigma N^{-1}(p/100), \text{ with } \sigma = 7 \quad \text{dB} \tag{14}$$

N−1( ) is the inverse normal cumulative distribution function. An approximation to this function, good for p between 1 and 99% is given by the location variability function *Qi(x)* of Recommendation ITU-R P.1546 – Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz. Alternatively values of the NLoS location correction for p = 1, 10, 50, 90 and 99% are given in Table 6 of Recommendation ITU-R P.1411-4.

– Add the NLoS location correction to the median value of NLoS loss:

$$L_{NLoS}(d,p) = L_{NLoS}^{median}(d) + \Delta L_{NLoS}(p) \tag{15}$$

– For the required location percentage, p (%), calculate the distance d_{LoS} for which the LoS fraction F_{LoS} equals p:

$$\begin{aligned} d_{LoS}(p) &= 212\left(\log_{10}(p/100)\right)^2 - 64\log_{10}(p/100) && \text{if } p < 45 \\ d_{LoS}(p) &= 79.2 - 70(p/100) && \text{otherwise} \end{aligned} \tag{16}$$

Values of d_{LoS} for p = 1, 10, 50, 90 and 99% are given in Table 6 of Recommendation ITU-R P.1411-4. This model has not been tested for $p < 0.1\%$. The statistics were obtained from two cities in the UK and may be different in other countries. Alternatively, if the corner distance is known in a particular case, set $d_{LoS}(p)$ to this distance.

– The path loss at the distance d is then given as:

– If $d < d_{LoS}$, then $L(d, p) = L_{LoS}(d, p)$

– If $d > d_{LoS} + w$, then $L(d, p) = L_{NLoS}(d, p)$

– Otherwise linearly interpolate between the values $L_{LoS}(d_{LoS}, p)$ and $L_{NLoS}(d_{LoS} + w, p)$:

$$\begin{aligned} L_{LoS} &= L_{LoS}(d_{LoS}, p) \\ L_{NLoS} &= L_{NLoS}(d_{LoS} + w, p) \\ L(d,p) &= L_{LoS} + (L_{NLoS} - L_{LoS})(d - d_{LoS})/w. \end{aligned}$$

The width w is introduced to provide a transition region between the LoS and NLoS regions. This transition region is seen in the data and typically has a width of w = 20 m.

TABLE 41

Table of LoS and NLoS location variability corrections

p (%)	**ΔL_{LoS} (dB)**	**ΔL_{NLoS} (dB)**	**d_{LoS} (m)**
1	–11.3	–16.3	976
10	–7.9	–9.0	276
50	0.0	0.0	44
90	10.6	9.0	16
99	20.3	16.3	10

4 References

RF system scenarios 3GPP TR 25.942, Version 6.4.0.

Annex 2

Interference analysis between base stations

This annex provides the interference analysis between an OFDMA-TDD-WMAN 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 Reports ITU-R M.2030 and ITU-R M.2039. Similarly, the ACLR and ACS values for the OFDMA-TDD-WMAN base station are obtained from a set of RF parameters specified in Report ITU-R M.2116 – Characteristics of broadband wireless access systems operating in the land mobile service for use in sharing studies.

1 Interference analysis between base stations in a CDMA-DS macrocellular and OFDMA-TDD-WMAN 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 3 and the maximum interference limits shown in Table 7, the additional isolation needed for the two base stations to coexist is calculated. The additional isolation needed when the interference is generated from an OFDMA-TDD-WMAN base station to a CDMA-DS base station is shown in Table 42. Similarly, the additional isolation needed when the interference is generated from a CDMA-DS base station to an OFDMA-TDD-WMAN base station is shown in Table 43.

TABLE 42

Analysis for co-sited macrocellular base stations, where the CDMA-DS 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)	45.3	57.4
Interference power at receiver input (dBm)	–39.3	–51.4
Allowed interference power (dBm)	–109.0	–109.0
Additional isolation needed (dB)	69.7	57.6

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 guardband of 5 MHz). Therefore, with equipment that just conforms to the standards, it is not feasible to co-site an OFDMA-TDD-WMAN base station and a CDMA-DS base station unless additional isolation is attained between the base stations.

TABLE 43

Analysis for co-sited macrocellular base stations, where the OFDMA-TDD-WMAN 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)	42.5	49
Interference power at receiver input (dBm)	–29.5	–36.0
Allowed interference power (dBm)	–110.0	–110.0
Additional isolation needed (dB)	80.5	74.0

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 1. 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 CDMA-DS base station receiver are −75.0 dBm and −87.1 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 (refer to Table 4), the additional isolations needed at frequency separations of 5 MHz and 10 MHz are 34.0 dB and 21.9 dB, respectively. The corresponding values for the additional isolation needed for different base station-to-base station separation distances are listed in Table 44, where the CDMA-DS base station is the interference victim. Similarly, Table 45 shows the additional isolation needed when the OFDMA-TDD-WMAN base station is the interference victim.

TABLE 44

Analysis when the macrocellular base stations are not co-sited, where the CDMA-DS 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	45.3	57.4	–35.0	–47.1	74.0	61.9
50.0	36	74.7	35	45.3	57.4	–49.0	–61.1	60.0	47.9
100.0	36	80.7	35	45.3	57.4	–55.0	–67.1	54.0	41.9
200.0	36	86.8	35	45.3	57.4	–61.1	–73.2	47.9	35.8
300.0	36	90.3	35	45.3	57.4	–64.6	–76.7	44.4	32.3
433.0	36	93.5	35	45.3	57.4	–67.8	–79.9	41.2	29.1
500.0	36	94.7	35	45.3	57.4	–69.0	–81.1	40.0	27.9
866.0	36	99.5	35	45.3	57.4	–73.8	–85.9	35.2	23.1
1 000.0	36	100.7	35	45.3	57.4	–75.0	–87.1	34.0	21.9

TABLE 45

Analysis when the macrocellular base stations are not co-sited, where the OFDMA-TDD-WMAN 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	42.5	49.0	–25.2	–31.7	84.8	78.3
50.0	43	74.7	35	42.5	49.0	–39.2	–45.7	70.8	64.3
100.0	43	80.7	35	42.5	49.0	–45.2	–51.7	64.8	58.3
200.0	43	86.8	35	42.5	49.0	–51.3	–57.8	58.7	52.2
300.0	43	90.3	35	42.5	49.0	–54.8	–61.3	55.2	48.7
433.0	43	93.5	35	42.5	49.0	–58.0	–64.5	52.0	45.5
500.0	43	94.7	35	42.5	49.0	–59.2	–65.7	50.8	44.3
866.0	43	99.5	35	42.5	49.0	–64.0	–70.5	46.0	39.5
1 000.0	43	100.7	35	42.5	49.0	–65.2	–71.7	44.8	38.3

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 OFDMA-TDD-WMAN base station in the same area as a macrocellular CDMA-DS base station if a 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). 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), then the adjacent channel interference could be tolerated by the CDMA-DS base station if the isolation between the two base stations could be increased by 21.9 dB. Furthermore, the additional isolation needed increases to 37.3 dB if the interference victim is the OFDMA-TDD-WMAN base station.

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

Now consider the interference between an OFDMA-TDD-WMAN macrocell and a CDMA-DS microcell when the two base stations are co-sited. The OFDMA-TDD-WMAN base station antenna is assumed to be mounted at a height of 30 m and the CDMA-DS base station antenna is assumed to be mounted above the ground at a height of 6 m, giving an antenna separation of 24 m. 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 is used to represent the coupling loss provided by a vertical separation distance of 24 m.

The results in Tables 46 and 47 indicate that in order for an OFDMA-TDD-WMAN macrocell and CDMA-DS microcell base station to be co-sited, additional isolation levels of 28.5 dB and 22 dB are needed for frequency separations of 5 MHz and 10 MHz, respectively.

TABLE 46

Analysis of the ACI from an OFDMA-TDD-WMAN macrocellular base station to a co-sited CDMA-DS 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)	45.3	57.4
Interference power at receiver input (dBm)	–86.3	–98.4
Allowed interference power (dBm)	–109.0	–109.0
Additional isolation needed (dB)	22.7	10.6

TABLE 47

Analysis of the ACI from a CDMA-DS microcellular base station to a co-sited OFDMA-TDD-WMAN 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)	42.5	49
Interference power at receiver input (dBm)	–81.5	–88.0
Allowed interference power (dBm)	–110.0	–110.0
Additional isolation needed (dB)	28.5	22.0

For base stations that are not co-sited, the path loss between the base stations can be evaluated using the vehicular propagation model described in Annex 1 equation (6), which is derived from Recommendation ITU-R P.1411-4. Aligning the two base station antennas to give the worst-case minimum coupling loss provides an effective antenna gain of 23 dBi (18 + 5). The results of the calculation for different base station-to-base station separations are listed in Tables 48 and 49. 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 the analysis indicate that it is possible to operate at base station-to-base station separation distances of 300 m and greater without requiring additional base station-to-base station isolation.

TABLE 48

Analysis of the ACI from an OFDMA-TDD-WMAN macrocellular base station to a CDMA-DS 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	45.3	57.4	–57.5	–69.6	51.5	39.4
50.0	36	97.8	23	45.3	57.4	–84.1	–96.2	24.9	12.8
100.0	36	109.2	23	45.3	57.4	–95.5	–107.6	13.5	1.4
200.0	36	120.6	23	45.3	57.4	–106.9	–119.0	2.1	–10.0
300.0	36	127.3	23	45.3	57.4	–113.6	–125.7	–4.6	–16.7
433.0	36	133.4	23	45.3	57.4	–119.7	–131.8	–10.7	–22.8
500.0	36	135.8	23	45.3	57.4	–122.1	–134.2	–13.1	–25.2
866.0	36	144.8	23	45.3	57.4	–131.1	–143.2	–22.1	–34.2
1 000.0	36	147.2	23	45.3	57.4	–133.5	–145.6	–24.5	–36.6

TABLE 49

Analysis of the ACI from a CDMA-DS microcellular base station to an OFDMA-TDD-WMAN 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	42.5	49	–52.7	–59.2	57.3	50.8
50.0	38	97.8	23	42.5	49	–79.3	–85.8	30.7	24.2
100.0	38	109.2	23	42.5	49	–90.7	–97.2	19.3	12.8
200.0	38	120.6	23	42.5	49	–102.1	–108.6	7.9	1.4
300.0	38	127.3	23	42.5	49	–108.8	–115.3	1.2	–5.3
433.0	38	133.4	23	42.5	49	–114.9	–121.4	–4.9	–11.4
500.0	38	135.8	23	42.5	49	–117.3	–123.8	–7.3	–13.8
866.0	38	144.8	23	42.5	49	–126.3	–132.8	–16.3	–22.8
1 000.0	38	147.2	23	42.5	49	–128.7	–135.2	–18.7	–25.2

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

Consider the deployment scenario of co-sited CDMA-DS picocellular and OFDMA-TDD-WMAN macrocellular base stations. As the macrocellular and picocellular antennas are 30 m and 1.5 m above the ground, respectively, the loss in excess of 65 dB (following the methodology adopted in the previous section) would be 14 dB assuming free-space propagation. 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 50 and 51, which indicate the additional isolation needed for the two base stations to operate in a co-sited manner.

TABLE 50

Analysis of the ACI from an OFDMA-TDD-WMAN macrocellular base station to a co-sited CDMA-DS 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)	45.3	57.4
Interference power at receiver input (dBm)	–98.3	–110.4
Allowed interference power (dBm)	–109.0	–109.0
Additional isolation needed (dB)	10.7	–1.4

TABLE 51

Analysis of the ACI from a CDMA-DS picocellular base station to a co-sited OFDMA-TDD-WMAN 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)	42.5	49
Interference power at receiver input (dBm)	–107.5	–114.0
Allowed interference power (dBm)	–110.0	–110.0
Additional isolation needed (dB)	2.5	–4.0

For the case in which the base stations are not co-sited, the path loss is calculated based on the vehicular model with additional building penetration loss described in Annex 1 equation (7), which is derived from Recommendation ITU-R P.1411-4. The effective antenna gain used was 18 dBi, which is the summation of the maximum gains of the two antennas. The results of the analysis for the various separation distances are given in Tables 52 and 53. Based on the results, it is possible to operate an OFDMA-TDD-WMAN macrocell and a CDMA-DS picocell with separation distances of at least 100 m without requiring additional base station-to-base station isolation.

TABLE 52

Analysis of the ACI from an OFDMA-TDD-WMAN macrocellular base station to a CDMA-DS 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	45.3	57.4	–74.4	–86.5	34.6	22.5
50.0	36	109.7	18	45.3	57.4	–101.0	–113.1	8.0	–4.1
100.0	36	121.1	18	45.3	57.4	–112.4	–124.5	–3.4	–15.5
200.0	36	132.6	18	45.3	57.4	–123.9	–136.0	–14.9	–27.0
300.0	36	139.3	18	45.3	57.4	–130.6	–142.7	–21.6	–33.7
433.0	36	145.3	18	45.3	57.4	–136.6	–148.7	–27.6	–39.7
500.0	36	147.7	18	45.3	57.4	–139.0	–151.1	–30.0	–42.1
866.0	36	156.8	18	45.3	57.4	–148.1	–160.2	–39.1	–51.2
1 000.0	36	159.1	18	45.3	57.4	–150.4	–162.5	–41.4	–53.5

TABLE 53

Analysis of the ACI from a CDMA-DS picocellular base station to an OFDMA-TDD-WMAN 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	42.5	49	–83.6	–90.1	26.4	19.9
50.0	24	109.7	18	42.5	49	–110.2	–116.7	–0.2	–6.7
100.0	24	121.1	18	42.5	49	–121.6	–128.1	–11.6	–18.1
200.0	24	132.6	18	42.5	49	–133.1	–139.6	–23.1	–29.6
300.0	24	139.3	18	42.5	49	–139.8	–146.3	–29.8	–36.3
433.0	24	145.3	18	42.5	49	–145.8	–152.3	–35.8	–42.3
500.0	24	147.7	18	42.5	49	–148.2	–154.7	–38.2	–44.7
866.0	24	156.8	18	42.5	49	–157.3	–163.8	–47.3	–53.8
1 000.0	24	159.1	18	42.5	49	–159.6	–166.1	–49.6	–56.1

4 Interference analysis between base stations in a CDMA-DS macrocellular and 10 MHz OFDMA-TDD-WMAN macrocellular deployment

An analysis similar to that described in § 1 was followed for the 10 MHz case. For co-sited base stations, a coupling loss value of 30 dB is assumed between co-sited antennas. The additional isolation needed for different base station-to-base station separation distances are listed in Table 54, where the CDMA-DS base station is the interference victim. Similarly, Table 55 shows the additional isolation needed when the OFDMA-TDD-WMAN base station is the interference victim.

TABLE 54

Additional isolation between the 10 MHz OFDMA-TDD-WMAN base station and the CDMA-DS base station, where the CDMA-DS 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
Co-sited	36	30	0	47.7	59.9	–41,7	–53.9	67.3	55.1
50.0	36	74.7	35	47.7	59.9	–51.4	–63.6	57.6	45.4
100.0	36	80.7	35	47.7	59.9	–57.4	–69.6	51.6	39.4
200.0	36	86.8	35	47.7	59.9	–63.5	–75.7	45.5	33.3
300.0	36	90.3	35	47.7	59.9	–67.0	–79.2	42.0	29.8
433.0	36	93.5	35	47.7	59.9	–70.2	–82.4	38.8	26.6
500.0	36	94.7	35	47.7	59.9	–71.4	–83.6	37.6	25.4
866.0	36	99.5	35	47.7	59.9	–76.2	–88.4	32.8	20.6
1 000.0	36	100.7	35	47.7	59.9	–77.4	–89.6	31.6	19.4

TABLE 55

Additional isolation between the 10 MHz OFDMA-TDD-WMAN base station and the CDMA-DS base station, where the OFDMA-TDD-WMAN 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
Co-sited	43	30	0	41.2	45.6	–23.9	–28.3	83.1	78.7
50.0	43	74.7	35	41.2	45.6	–37.9	–42.3	69.1	64.7
100.0	43	80.7	35	41.2	45.6	–43.9	–48.3	63.1	58.7
200.0	43	86.8	35	41.2	45.6	–50.0	–54.4	57.0	52.6
300.0	43	90.3	35	41.2	45.6	–53.5	–57.9	53.5	49.1
433.0	43	93.5	35	41.2	45.6	–56.7	–61.1	50.3	45.9
500.0	43	94.7	35	41.2	45.6	–57.9	–62.3	49.1	44.7
866.0	43	99.5	35	41.2	45.6	–62.7	–67.1	44.3	39.9
1 000.0	43	100.7	35	41.2	45.6	–63.9	–68.3	43.1	38.7

The conclusion of this analysis is similar to the conclusion for the 5 MHz system in that, with equipment that just conforms to the standards, it is unlikely to be possible to use a macrocellular 10 MHz OFDMA-TDD-WMAN base station in the same area as a macrocellular CDMA-DS base station if a 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).

5 Interference analysis between base stations in a CDMA-DS microcellular and 10 MHz OFDMA-TDD-WMAN macrocellular deployment

Now consider the interference between an OFDMA-TDD-WMAN macrocell and a CDMA-DS microcell when the two base stations are co-sited. The OFDMA-TDD-WMAN base station antenna is assumed to be mounted at a height of 30 m and the CDMA-DS base station antenna is assumed to be mounted above the ground at a height of 6 m, giving an antenna separation of 24 m. 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 is used to represent the coupling loss provided by a vertical separation distance of 24 m. For base stations that are not co-sited, the path loss between the base stations can be evaluated using the propagation model given by equation (6) in Annex 1, which is derived from Recommendation ITU-R P.1411-4. Aligning the two base station antennas to give the worst-case minimum coupling loss provides an effective antenna gain of 23 dBi (18 + 5). The results of the calculation for different base station-to-base station separations are listed in Tables 56 and 57. 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 the analysis indicate that it is typically possible to operate at base station-to-base station separation distances of at least 300 m provided there is no LoS without requiring additional base station-to-base station isolation.

TABLE 56

Analysis of the ACI from an 10 MHz OFDMA-TDD-WMAN macrocellular base station to a CDMA-DS 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
Co-sited	36	77	0	47.7	59.9	–59.9	–72.1	49.1	36.9
50.0	36	97.8	23	47.7	59.9	–86.5	–98.7	22.5	10.3
100.0	36	109.2	23	47.7	59.9	–97.9	–110.1	11.1	–1.1
200.0	36	120.6	23	47.7	59.9	–109.3	–121.5	–0.3	–12.5
300.0	36	127.3	23	47.7	59.9	–116.0	–128.2	–7.0	–19.2
433.0	36	133.4	23	47.7	59.9	–122.1	–134.3	–13.1	–25.3
500.0	36	135.8	23	47.7	59.9	–124.5	–136.7	–15.5	–27.7
866.0	36	144.8	23	47.7	59.9	–133.5	–145.7	–24.5	–36.7
1 000.0	36	147.2	23	47.7	59.9	–135.9	–148.1	–26.9	–39.1

TABLE 57

Analysis of the ACI from a CDMA-DS microcellular base station to an 10 MHz OFDMA-TDD-WMAN 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
Co-sited	38	77	0	41.2	45.6	–51.4	–55.8	55.6	51.2
50.0	38	97.8	23	41.2	45.6	–78.0	–82.4	29.0	24.6
100.0	38	109.2	23	41.2	45.6	–89.4	–93.8	17.6	13.2
200.0	38	120.6	23	41.2	45.6	–100.8	–105.2	6.2	1.8
300.0	38	127.3	23	41.2	45.6	–107.5	–111.9	–0.5	–4.9
433.0	38	133.4	23	41.2	45.6	–113.6	–118.0	–6.6	–11.0
500.0	38	135.8	23	41.2	45.6	–116.0	–120.4	–9.0	–13.4
866.0	38	144.8	23	41.2	45.6	–125.0	–129.4	–18.0	–22.4
1 000.0	38	147.2	23	41.2	45.6	–127.4	–131.8	–20.4	–24.8

6 Interference analysis between base stations in a CDMA-DS picocellular and a 10 MHz OFDMA-TDD-WMAN macrocellular deployment

Consider the deployment scenario of co-sited CDMA-DS picocellular and OFDMA-TDD-WMAN macrocellular base stations. As the macrocellular and picocellular antennas are 30 m and 1.5 m above the ground, respectively, the loss in excess of 65 dB (following the methodology adopted in the previous section) would be 14 dB assuming free-space propagation. 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. For the case in which the base stations are not co-sited, the path loss is calculated using the model described by equation (7) in Annex 1, which is derived from Recommendation ITU-R P.1411-4. The effective antenna gain used was 18 dBi, which is the summation of the maximum gains of the two antennas. The results of the analysis for the various separation distances are given in Tables 52 and 53. Based on the results, it is possible to operate an OFDMA-TDD-WMAN macrocell and a CDMA-DS picocell with separation distances of 500 m and 1 000 m without requiring additional base station-to-base station isolation.

TABLE 58

Analysis of the ACI from an OFDMA-TDD-WMAN macrocellular base station to a CDMA-DS 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
Co-sited	36	89	0	47.7	59.9	–100.7	–112.9	8.3	–3.9
50.0	36	109.7	18	47.7	59.9	–103.4	–115.6	5.6	–6.6
100.0	36	121.1	18	47.7	59.9	–14.8	–127.0	–5.8	–18.0
200.0	36	132.6	18	47.7	59.9	–126.3	–138.5	–17.3	–29.5
300.0	36	139.3	18	47.7	59.9	–133.0	–145.2	–24.0	–36.2
433.0	36	145.3	18	47.7	59.9	–139.0	–151.2	–30.0	–42.2
500.0	36	147.7	18	47.7	59.9	–141.4	–153.6	–32.4	–44.6
866.0	36	156.8	18	47.7	59.9	–150.5	–162.7	–41.5	–53.7
1 000.0	36	159.1	18	47.7	59.9	–152.8	–165.0	–43.8	–56.0

TABLE 59

Analysis of the ACI from a CDMA-DS picocellular base station to an OFDMA-TDD-WMAN 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
Co-sited	24	89	0	41.2	45.6	–82.3	–86.7	24.7	20.3
50.0	24	109.7	18	41.2	45.6	–108.9	–113.3	–1.9	–6.3
100.0	24	121.1	18	41.2	45.6	–120.3	–124.7	–13.3	–17.7
200.0	24	132.6	18	41.2	45.6	–131.8	–136.2	–24.8	–29.2
300.0	24	139.3	18	41.2	45.6	–138.5	–142.9	–31.5	–35.9
433.0	24	145.3	18	41.2	45.6	–144.5	–148.9	–37.5	–41.9
500.0	24	147.7	18	41.2	45.6	–146.9	–151.3	–39.9	–44.3
866.0	24	156.8	18	41.2	45.6	–156.0	–160.4	–49.0	–53.4
1 000.0	24	159.1	18	41.2	45.6	–158.3	–162.7	–51.3	–55.7

7 References

ALLGON [October 1999] Antenna-to-antenna isolation measurements, 3GPP TSG RAN WG4 Meeting No. 8, TDOC 631/99.

Annex 3

Interference analysis between base stations and mobile stations

In this annex the interference between base stations and mobile stations operating within macrocellular, microcellular and picocellular systems is examined. A recent CDMA-DS and CDMA-DS TDD coexistence 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 the base station-to-mobile station analysis, a selection of scenarios that may have a severe impact on the ACI performance are studied. 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. Therefore, when CDMA-DS (FDD) and OFDMA-TDD-WMAN 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, i.e. base station-mobile station and mobile station-base station interference. Subsequently, this base station-mobile station analysis includes only 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 analysed using computer simulations. However, in the subsequent sections of this annex, a simple analytical model is presented to highlight specific scenarios that may have an impact on the performance of two coexisting systems.

It should be noted that the interference suffered by CDMA-DS base station receivers from adjacent channel mobile station transmissions, as well as the interference suffered by CDMA-DS mobile station receivers from adjacent channel OFDMA-TDD-WMAN 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 stations in a CDMA-DS macrocellular and OFDMA-TDD-WMAN macrocellular deployment

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

In order to analyse this scenario, the minimum coupling loss between the base station antenna and the mobile station antenna has to be evaluated. This investigation used 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°. A macrocellular antenna height of 30 m and a mobile station height of 1.5 m are assumed. By taking the vertical gain characteristics of the antenna, the coupling loss can be calculated for all vertical angles and the corresponding horizontal distance between the mobile station and base station. This provides us with a set of coupling loss values, the minimum value being the assumed minimum coupling loss. From this investigation, the minimum coupling loss is 75.7 dB for a mobile station antenna with a gain of 0 dBi. The resulting calculation of the additional isolation needed for the different base station-to-mobile station interference scenarios is shown in Table 60. Note that the additional isolation is calculated based on the maximum interference limits shown in Table 4. The results indicate that for these worst-case scenarios, mobile stations and base stations can cause significant interference to each other and consequently require additional isolation.

TABLE 60

Analysis of the ACI between OFDMA-TDD-WMAN macrocellular and CDMA-DS macrocellular base stations and mobile stations

Interference scenario	Frequency offset (MHz)	Transmit power (dBm)	Coupling loss (dB)	ACIR (dB)	ACI at the receiver (dBm)	Additional isolation (dB)
OFDMA-TDD-WMAN mobile station ⇒ CDMA-DS base station	5	20	75.7	32.8	–88.5	20.5
	10	20	75.7	42.9	–98.6	10.4
CDMA-DS base station ⇒ OFDMA-TDD-WMAN mobile station	5	43	75.7	32.7	–65.4	42.6
	10	43	75.7	45.2	–77.9	30.1
CDMA-DS mobile station ⇒ OFDMA-TDD-WMAN base station	5	21	75.7	32.8	–87.5	22.5
	10	21	75.7	42.8	–97.5	12.5
OFDMA-TDD-WMAN base station ⇒ CDMA-DS 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 5 MHz OFDMA-TDD-WMAN macrocellular deployment

The worst-case interference between an OFDMA-TDD-WMAN mobile station and a microcellular CDMA-DS base station would occur when the mobile station is at its cell edge and located close to the CDMA-DS base station site. This is similar to the worst-case interference considered in the last section between an OFDMA-TDD-WMAN mobile station and a macrocellular CDMA-DS base station. The mobile station would transmit at maximum power and therefore cause significant uplink interference to the CDMA-DS base station. The minimum coupling loss between the OFDMA-TDD-WMAN mobile station 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. 60, and the OFDMA-TDD-WMAN mobile station antenna gain of 0 dBi, the minimum coupling loss value is 55.8 dB. The resulting interference analysis is shown in Table 61, which indicates that significant interference can exist in this scenario, hence requiring additional isolation to ensure coexistence between systems.

FIGURE 9

Horizontal and vertical antenna patterns for the microcellular antenna

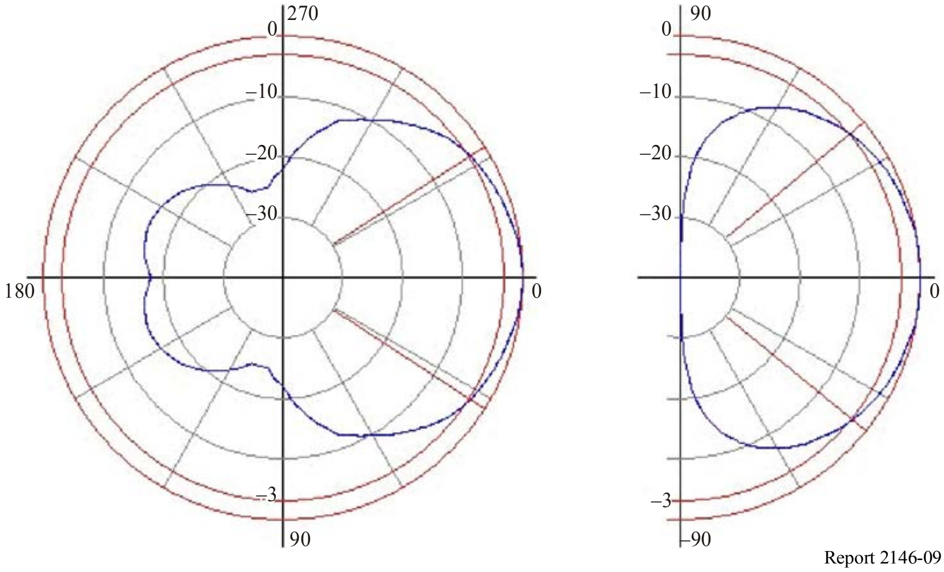


TABLE 61

Analysis of the ACI between OFDMA-TDD-WMAN mobile stations and CDMA-DS microcellular base stations

Interference scenario	Frequency offset (MHz)	Transmit power (dBm)	Coupling loss (dB)	ACIR (dB)	ACI at the receiver (dBm)	Additional isolation (dB)
OFDMA-TDD-WMAN mobile station ⇒ CDMA-DS base station	5	20	55.8	32.8	–68.6	40.4
	10	20	55.8	42.9	–78.7	30.3
CDMA-DS base station ⇒ OFDMA-TDD-WMAN mobile station	5	38	55.8	32.7	–50.5	57.5
	10	38	55.8	45.2	–63	45.0

The worst-case interference scenario between a CDMA-DS mobile station (served by a CDMA-DS microcell) and an OFDMA-TDD-WMAN base station is basically the same as that described in § 1, i.e. a CDMA-DS mobile station located at its cell edge and also located close to an OFDMA-TDD-WMAN base station. Therefore, the results shown in the lower four rows of Table 60 also apply here. Although this is a simple analysis, it provides an indication of the problems that can occur. It is important to realize 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 an OFDMA-TDD-WMAN macrocellular network using an adjacent channel are deployed in the same area.

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

This deployment scenario is similar to that discussed in the previous two sections 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 CDMA-DS base station is located at the boundary of the OFDMA-TDD-WMAN macrocell and the OFDMA-TDD-WMAN mobile station is transmitting at maximum power near the CDMA-DS base station because it is at the edge of its cell. Similarly, if the OFDMA-TDD-WMAN macrocell base station is located near the boundary of the CDMA-DS picocell, a CDMA-DS mobile station can be transmitting at maximum power when it is close to the OFDMA-TDD-WMAN macrocellular base station.

When analysing the first of 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 OFDMA-TDD-WMAN mobile station are the same. At this range, with 0 dBi antennas, the path loss (using the free-space propagation model) is 40.7 dB. The results of the interference analysis are shown in Table 62, which again indicates potential ACI problems.

TABLE 62

Analysis of the ACI between OFDMA-TDD-WMAN mobile stations and CDMA-DS picocellular base stations

Interference scenario	Frequency offset (MHz)	Transmit power (dBm)	Coupling loss (dB)	ACIR (dB)	ACI at the receiver (dBm)	Additional isolation (dB)
OFDMA-TDD-WMAN mobile station ⇒ CDMA-DS base station	5	20	40.7	32.8	–53.5	55.5
	10	20	40.7	42.9	–63.6	45.4
CDMA-DS base station ⇒ OFDMA-TDD-WMAN mobile station	5	24	40.7	32.7	–49.4	58.6
	10	24	40.7	45.2	–61.9	46.1

Considering the latter of the two interference conditions that were introduced at the beginning of this section, the worst-case interference scenario between a CDMA-DS mobile station (located at the cell edge of its serving picocell base station) and an OFDMA-TDD-WMAN base station is the same as that described in § 1 and 2. In other words, the interference between a CDMA-DS mobile station and a *macrocellular* base station needs to be considered. Therefore, the results shown in the lower four rows of Table 60 also apply here.

4 Interference analysis between base stations and mobile stations in a CDMA-DS and a 10 MHz OFDMA-TDD-WMAN deployment

The results of interference analysis between a 10 MHz OFDMA-TDD-WMAN mobile station and CDMA-DS base station are presented in Table 63. The interference from a base station to a mobile station is more severe than the interference from the mobile station to the base station and the interference between the base station and the mobile station becomes more severe in the pico-cell deployment scenario for the CDMA-DS base station compared with the microcell and macrocell deployment scenarios.

TABLE 63

Analysis of the ACI between the 10 MHz OFDMA-TDD-WMAN mobile station and CDMA-DS base station

Interference scenario	Transmit power (dBm)	Coupling loss (dB)	ACIR (dB)		ACI at the receiver (dBm)		Additional isolation (dB)	
			1st adjacent channel	2nd adjacent channel	1st adjacent channel	2nd adjacent channel	1st adjacent channel	2nd adjacent channel
10 MHz OFDMA-TDD-WMAN mobile station ⇒ CDMA-DS macrocell base station	20	75.7	33.3	43.3	–89.0	–99.0	20.0	10.0
CDMA-DS macrocell base station ⇒ 10 MHz OFDMA-TDD-WMAN mobile station	43	75.7	32.6	43.5	–65.3	–76.2	39.7	28.8
10 MHz OFDMA-TDD-WMAN mobile station ⇒ CDMA-DS microcell base station	20	55.8	33.3	43.3	–69.1	–79.1	39.9	29.9
CDMA-DS microcell base station ⇒ 10 MHz OFDMA-TDD-WMAN mobile station	38	55.8	32.6	43.5	–50.4	–61.3	54.6	43.7
10 MHz OFDMA-TDD-WMAN mobile station ⇒ CDMA-DS picocell base station	20	40.7	33.3	43.3	–54.0	–64.0	55.0	45.0
CDMA-DS pico-cell base station ⇒ 10 MHz OFDMA-TDD-WMAN mobile station	24	40.7	32.6	43.5	–49.3	–60.2	55.7	44.8

Table 64 shows that the interference between a 10 MHz OFDMA-TDD-WMAN base station and a CDMA-DS mobile station is of a similar level to the case of interference between a 10 MHz OFDMA-TDD-WMAN mobile station and a CDMA-DS macrocell base station. Note that the interference that 10 MHz OFDMA-TDD-WMAN causes to CDMA-DS systems is less than the interference that CDMA-DS systems cause to 10 MHz OFDMA-TDD-WMAN systems.

TABLE 64

Analysis of the ACI between the 10 MHz OFDMA-TDD-WMAN base station and CDMA-DS mobile station

Interference scenario	Transmit power (dBm)	Coupling loss (dB)	ACIR (dB)		ACI at the receiver (dBm)		Additional isolation (dB)	
			1st adjacent channel	2nd adjacent channel	1st adjacent channel	2nd adjacent channel	1st adjacent channel	2nd adjacent channel
CDMA-DS mobile station ⇒ 10 MHz OFDMA-TDD-WMAN base station	21	75.7	30.9	44.7	–85.6	–99.4	21.4	7.6
10 MHz OFDMA-TDD-WMAN base station ⇒ CDMA-DS mobile station	43	75.7	32.6	43.5	–65.3	–76.2	39.7	28.8

Annex 4

Interference analysis between mobile stations

Having analysed the ACI between two base stations and between a mobile station and a base station (and vice versa), the final interference mechanism to consider is the interference between two mobile stations. Note that the CDMA-DS mobile station can tolerate a maximum ACI of –105 dBm, while the 5 MHz and 10 MHz OFDMA-TDD-WMAN mobile stations can tolerate a maximum ACI of –108 dBm and –105 dBm, respectively, before the system performance becomes seriously affected (refer to Table 7).

The worst-case scenario occurs when an OFDMA-TDD-WMAN mobile station is located close to a CDMA-DS mobile station, and both are transmitting at the maximum transmitted power of 20 dBm and 21 dBm, respectively. For example, in order to achieve a separation distance of 1 m and assuming that a LoS path exists between the two mobile stations, the additional isolation needed is shown in Table 65.

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 station. Whether the performance of the mobile station is affected significantly depends on the signal strength provided by the serving cell.

TABLE 65

Analysis of interference from a CDMA DS (FDD) mobile station to an OFDMA-TDD-WMAN mobile station and *vice versa*

Interference case	Distance (m)	Transmit power (dBm)	Path loss (dB)	Effective antenna gain (dBi)	ACIR (dB)		ACI at the receiver (dBm)		Additional isolation (dB)	
					1st adjacent channel	2nd adjacent channel	1st adjacent channel	2nd adjacent channel	1st adjacent channel	2nd adjacent channel
CDMA-DS ⇒ 5 MHz OFDMA-TDD-WMAN	1.0	21	40.7	0	30	41.5	–49.7	–61.2	58.3	46.8
5 MHz OFDMA-TDD-WMAN ⇒ CDMA-DS	1.0	20	40.7	0	30.0	40.0	–50.7	–60.7	54.3	44.3
CDMA-DS ⇒ 10 MHz OFDMA-TDD-WMAN	1.0	21	40.7	0	28.9	42.9	–48.6	–62.6	56.4	42.4
10 MHz OFDMA-TDD-WMAN ⇒ CDMA-DS	1.0	20	40.7	0	31.5	41.5	–52.2	–62.2	52.8	42.8

Annex 5

Mitigation techniques

In this annex background information is provided about the techniques that can be used to mitigate against ACI between CDMA-DS systems and OFDMA-TDD-WMAN systems, including the derivations for the improvements in ACLR and ACS that were used in the main body of this Report.

A brief discussion of the improvements that can be gained by employing various mitigation techniques as described in Report ITU-R M.2045 follows. However, only key mitigation techniques such as the employment of additional filtering at the base station and careful site design are considered in this study.

1 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. It should be noted that such filters will add insertion loss, thus reducing the link budget, and also affect signal quality.

An example of a filter used for this purpose in a CDMA-DS TDD base station is described by Wilkinson [2004]. This is a single 5 MHz bandwidth channel filter centred at 1 907.5 MHz, giving a rejection of 60 dBc for a 3.84 MHz bandwidth centred at offsets of ±5 MHz. This filter performance is challenging, and beyond the capabilities of conventional cavity filters, but may be achievable with dielectric resonator technology. To achieve similar rejection with a 2.5 GHz filter would require even higher Q resonators. Using such a filter at an OFDMA-TDD-WMAN base station would improve both the transmitter ACLR and receiver ACS by 60 dB (because of the TDD nature of OFDMA-TDD-WMAN), thus reducing the interference between the OFDMA-TDD-WMAN base station and any CDMA-DS base station or mobile station in its vicinity. Since the ACIR for each interference path is affected by 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 systems. Once again, it will only be practical for the filters to be incorporated into the CDMA-DS base station (and not the CDMA-DS mobile 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 to converting the design of the filter centred at 1 907 MHz 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 this has been reproduced in Table 66. It should be noted that this filter has an insertion loss of 2 dB.

TABLE 66

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

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

2 Site design

Annex 2 established that the most significant factor affecting the coexistence of CDMA-DS and OFDMA-TDD-WMAN 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 2 500-2 690 MHz band the coupling loss values used in the calculations of interference between CDMA-DS and OFDMA-TDD-WMAN base stations can be adjusted accordingly. According to [Allgon, 1999], when mounted on the same mast, antenna isolations of between 39 dB and 54 dB were achieved, with relative antenna orientations of between 90° and 180°. 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 360° 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, and this is applied to the macrocell base station-to-macrocell base station interference case. 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. In the analysis 30 dB and 65 dB are used, to represent worst- and best-case scenarios, respectively.

Note that for the macrocell base station-to-microcell base station case and macrocell base station-to-picocell base station case, coupling losses of 77 dB and 89 dB are assumed, respectively. Refer to Annex 2 for details regarding the calculation of these values.

For base stations that are not co-sited, worst-case antenna orientations are assumed, i.e. 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.

Nevertheless, downtilt is frequently used to control interference in cellular networks, and Report ITU-R M.2039, indicates that downtilt of 2.5° should be used in sharing studies. Assuming that the base station antennas are the same height, then using the formulation given in Recommendation ITU-R F.1336-2 – 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, for the elevation pattern, the increase in path loss resulting from downtilts of 2.5° and 5° can be computed as shown in Table 67.

TABLE 67

Increases in isolation for worst-case orientation of macrocell base station antennas using downtilt

Vertical beamwidth	Downtilt 2.5°		Downtilt 5°	
	Gain reduction (dB)	Coupling loss increase (dB)	Gain reduction (dB)	Coupling loss increase (dB)
5°	3.00	6.00	12.00	24.00
7°	1.53	3.06	6.12	12.24
9°	0.92	1.85	3.70	7.41

Having considered the case for base stations of identical height (i.e. at an elevation angle of 0°), the case with different antenna heights should be considered. The main beam given by equation (8b) in Recommendation ITU-R F.1336-2[14], is of the form:

$$G = G_0 - 12\left(\frac{\theta}{\theta_3}\right)^2 \qquad \text{dBi} \qquad (17)$$

[14] IEEE 802.16e-2005-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 operation in licensed bands.

where:

G: gain

G_0: maximum gain

θ: elevation angle, relative to the main beam

θ_3: beamwidth.

If α represents downtilt, and β represents the angle of elevation of one antenna relative to the other, then the combined antenna gain becomes:

$$G_{combined} = 2G_0 - 12\left(\frac{\alpha+\beta}{\theta_3}\right)^2 - 12\left(\frac{\alpha-\beta}{\theta_3}\right)^2 = 2\left[G_0 - 12\left(\frac{\alpha}{\theta_3}\right)^2\right] - 2\left[12\left(\frac{\beta}{\theta_3}\right)^2\right] \quad \text{dBi} \qquad (18)$$

and the result is that differences in height merely increase the coupling loss compared with the case when both antennas are at the same height because the term containing β is always negative. Note that equation (8b) only applies to gains of up to 12 dB less than the maximum antenna gain.

3 References

ALLGON [October 1999] Antenna-to-antenna isolation measurements. 3GPP TSG RAN WG4 Meeting No. 8, TDOC 631/99.

Annex 6

Mitigation with a filter achieving 60 dB rejection in the adjacent channel

In this annex the interference analysis between base stations has been extended to incorporate the following mitigation techniques for the OFDMA-TDD-WMAN and CDMA-DS technologies operating in 5 MHz channels, which are described in Annex 5.

1 The inclusion of a channel filter, which could provide approximately 60 dB of additional rejection in the RF front-end. This could potentially improve the ACLR and ACS performance in the first and second adjacent channels of the OFDMA-TDD-WMAN and CDMA-DS base stations by 60 dB[15]. Note that such a filter requirement is extremely challenging in the 1st adjacent channel with today's technologies.

2 By following engineering guidelines and careful antenna siting, the antenna coupling loss could be increased to 39-54 dB when the antennas are mounted on the same mast. This could be further increased to 60-65 dB when the antennas are separated by a distance greater than three metres. Note that this benefit only applies when the base stations are co-sited in a macrocellular deployment, as the coupling losses for the macrocell-to-microcell and macrocell-to-picocell cases are already 77 dB and 89 dB, respectively.

[15] 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 is improved.

A summary of the ACLR and ACS performances of OFDMA-TDD-WMAN and CDMA-DS base stations incorporating the RF front end channel filters, is shown in Table 68. The resulting ACIR values derived from these ACLR and ACS values are shown in Table 69.

TABLE 68

ACLR and ACS values (dB) for the 5 MHz OFDMA-TDD-WMAN and CDMA-DS base stations with additional channel filters in both base stations

Base station type	ACLR		ACS	
	First adjacent channel	Second adjacent channel	First adjacent channel	Other adjacent channels
CDMA-DS	105	110	106	118
OFDMA-TDD-WMAN	113.5	126	106	116

TABLE 69

ACIR values (dB) for the interference paths of interest with additional channel filters used by both 5 MHz OFDMA-TDD-WMAN and CDMA-DS base stations

Interference path	First adjacent channel	Second adjacent channel
OFDMA-TDD-WMAN base station ⇒ CDMA-DS base station	105.3	117.4
CDMA-DS base station ⇒ OFDMA-TDD-WMAN base station	102.5	109.0

1 Deterministic analysis incorporating the 60 dB channel filter

Using the ACIR values shown in Table 69, the resulting additional isolation needed for coexistence is summarized in Tables 70 and 71, which also assumes an antenna coupling loss of 65 dB for the co-sited macrocell deployment scenario (i.e. the second mitigation technique in the list above is adopted). These results suggest that the two systems can coexist provided that the base stations antennas are carefully located if co-sited (to obtain an antenna coupling loss of 65 dB) and that channel filters are employed in both base stations.

Summary of deterministic analysis with mitigation techniques

With the addition of the 60 dB channel filter at the CDMA-DS and OFDMA-TDD-WMAN base stations, the ACLR and ACS performance is improved sufficiently to ensure that the two base stations can coexist successfully, as reported in Tables 70 and 71.

TABLE 70

A summary of the additional isolation needed (dB) to protect CDMA-DS base station receivers from interference from 5 MHz OFDMA-TDD-WMAN base station transmissions (interference Path 5) for different base station separation distances. These results assume that additional channel filters are used by OFDMA-TDD-WMAN and CDMA-DS base stations. An antenna coupling loss of 65 dB is assumed for the co-sited macrocell deployment scenario

Deployment scenario		Co-sited	100 m	300 m	500 m	1 km
OFDMA-TDD-WMAN macro/ CDMA-DS macro	1st adjacent channel	–25.3	–6.0	–15.6	–20.0	–26.0
	2nd adjacent channel	–37.4	–18.1	–27.7	–32.1	–38.1
OFDMA-TDD-WMAN macro/CDMA-DS micro	1st adjacent channel	–37.3	–46.5	–64.6	–73.1	–84.5
	2nd adjacent channel	–49.4	–58.6	–76.7	–85.2	–96.6
OFDMA-TDD-WMAN macro/CDMA-DS pico	1st adjacent channel	–49.3	–63.4	–81.6	–90.0	–101.4
	2nd adjacent channel	–61.4	–75.5	–93.7	–102.1	–113.5

TABLE 71

A summary of the additional isolation needed (dB) to protect 5 MHz OFDMA-TD-WMAN base station receivers from interference from CDMA-DS base station transmissions (interference Path 1) for different base station separation distances. These results assume that additional channel filters are used by OFDMA-TDD-WMAN and CDMA-DS base stations. An antenna coupling loss of 65 dB is assumed for the co-sited macrocell deployment scenario

Deployment scenario		Co-sited	100 m	300 m	500 m	1 km
OFDMA-TDD-WMAN macro/ CDMA-DS macro	1st adjacent channel	–14.5	4.8	–4.8	–9.2	–15.2
	2nd adjacent channel	–21.0	–1.7	–11.3	–15.7	–21.7
OFDMA-TDD-WMAN macro/CDMA-DS micro	1st adjacent channel	–31.5	–40.7	–58.8	–67.3	–78.7
	2nd adjacent channel	–38.0	–47.2	–65.3	–73.8	–85.2
OFDMA-TDD-WMAN macro/CDMA-DS pico	1st adjacent channel	–57.5	–71.6	–89.8	–98.2	–109.6
	2nd adjacent channel	–64.0	–78.1	–96.3	–104.7	–116.1

2 Statistical studies using 60 dB channel filters for CDMA-DS and OFDMA-TDD-WMAN

2.1 CDMA-DS coexistence with OFDMA-TDD-WMAN with no guardband

The CDMA-DS UL system capacity loss due to interference from OFDMA-TDD-WMAN DL is shown in Table 72, and the CDMA-DS base station noise rise due to interference from OFDMA-TDD-WMAN DL is shown in Table 73. The OFDMA-TDD-WMAN UL average modulation efficiency loss and outage rate due to interference from CDMA-DS DL is shown in Tables 74 and 75, respectively. The additional isolation required to ensure successful coexistence is given in Table 76.

The results show that with the addition of the 60 dB channel filter at the base station transmitters and receivers the interference between base stations of these two systems is negligible and no additional isolation is needed between them for successful coexistence with no guardband.

TABLE 72

CDMA-DS UL system capacity loss with OFDMA-TDD-WMAN 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**
OFDMA-TDD-WMAN DL	0	0	0	0	0	0

TABLE 73

CDMA-DS base station noise rise with OFDMA-TDD-WMAN in the first adjacent channel (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**
OFDMA-TDD-WMAN DL	6	6	6	6	6	6

TABLE 74

OFDMA-TDD-WMAN UL average modulation efficiency loss (including the users in outage) with CDMA-DS in the first adjacent channel (%)

OFDMA-TDD-WMAN frequency reuse	**Offset by 0 m**	**Offset by 100 m**	**Offset by 200 m**	**Offset by 300 m**	**Offset by 433 m**	**Offset by 866 m**
1 ×3 × 1	1	1	0	0	0	0
1 ×3 × 3	1	1	0	0	0	0

TABLE 75

OFDMA-TDD-WMAN UL outage rate with CDMA-DS in the first adjacent channel (%)

OFDMA-TDD-WMAN frequency reuse	**Offset by 0 m**	**Offset by 100 m**	**Offset by 200 m**	**Offset by 300 m**	**Offset by 433 m**	**Offset by 866 m**	**OFDMA-TDD-WMAN single system**
1 × 3 × 1	11	11	11	11	11	11	10.8
1 × 3 × 3	1	1	1	1	1	1	1.1

TABLE 76

Additional isolation needed for coexistence of OFDMA-TDD-WMAN and CDMA-DS in the first adjacent channel (dB)

Offset (m)	From OFDMA-TDD-WMAN base station to CDMA-DS base station		From CDMA-DS base station to OFDMA-TDD-WMAN base station			
	5% capacity loss rule (Method 1)	6 dB noise rise rule (Method 2)	5% loss criterion		10% loss criterion	
			1 × 3 × 1	1 × 3 × 3	1 × 3 × 1	1 × 3 × 3
0	0	0	0	0	0	0
100	0	0	0	0	0	0
200	0	0	0	0	0	0
300	0	0	0	0	0	0
433	0	0	0	0	0	0
866	0	0	0	0	0	0

2.2 CDMA-DS coexistence with OFDMA-TDD-WMAN with one guardband (5 MHz)

The CDMA-DS UL system capacity loss due to interference from OFDMA-TDD-WMAN DL is shown in Table 77, and the CDMA-DS base station noise rise due to interference from OFDMA-TDD-WMAN DL is shown in Table 78. The OFDMA-TDD-WMAN UL average modulation efficiency loss and outage rate due to interference from CDMA-DS DL is shown in Tables 79 and 80, respectively. The additional isolation required to ensure successful coexistence is given in Table 81.

The results show that the interference between base stations of these two systems is negligible and no additional isolation is needed between them for successful coexistence with one guardband.

TABLE 77

CDMA-DS UL system capacity loss (%) with OFDMA-TDD-WMAN in the second adjacent channel (5 MHz guardband)

	Offset by 0 m	Offset by 100 m	Offset by 200 m	Offset by 300 m	Offset by 433 m	Offset by 866 m
OFDMA-TDD-WMAN DL	0	0	0	0	0	0

TABLE 78

CDMA-DS base station noise rise (dB) with OFDMA-TDD-WMAN in the second adjacent channel (5 MHz guardband)

	Offset by 0 m	Offset by 100 m	Offset by 200 m	Offset by 300 m	Offset by 433 m	Offset by 866 m
OFDMA-TDD-WMAN DL	6	6	6	6	6	6

TABLE 79

OFDMA-TDD-WMAN UL average modulation efficiency loss (%) including the users in outage with CDMA-DS in the second adjacent channel (5 MHz guardband)

OFDMA-TDD-WMAN frequency reuse	Offset by 0 m	Offset by 100 m	Offset by 200 m	Offset by 300 m	Offset by 433 m	Offset by 866 m
1 ×3 × 1	0	0	0	0	0	0
1 ×3 × 3	0	0	0	0	0	0

TABLE 80

OFDMA-TDD-WMAN UL outage rate (%) with CDMA-DS in the second adjacent channel (5 MHz guardband)

OFDMA-TDD-WMAN frequency reuse	Offset by 0 m	Offset by 100 m	Offset by 200 m	Offset by 300 m	Offset by 433 m	Offset by 866 m	OFDMA-TDD-WMAN single system
1 × 3 × 1	11	11	11	11	11	11	10.8
1 × 3 × 3	1	1	1	1	1	1	1.1

TABLE 81

Additional isolation (dB) needed for coexistence of OFDMA-TDD-WMAN and CDMA-DS in the second adjacent channel (5 MHz guardband)

Offset (m)	From OFDMA-TDD-WMAN base station to CDMA-DS base station		From CDMA-DS base station to OFDMA-TDD-WMAN base station			
	5% capacity loss rule (Method 1)	6 dB noise rise rule (Method 2)	5% loss criterion		10% loss criterion	
			1 × 3 × 1	1 × 3 × 3	1 × 3 × 1	1 × 3 × 3
0	0	0	0	0	0	0
100	0	0	0	0	0	0
200	0	0	0	0	0	0
300	0	0	0	0	0	0
433	0	0	0	0	0	0
866	0	0	0	0	0	0