Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

COEXISTENCE BETWEEN MOBILE SYSTEMS IN THE 2.6 GHz FREQUENCY BAND AT THE FDD/TDD BOUNDARY

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0 EXECUTIVE SUMMARY

This report has investigated coexistence between FDD and TDD networks in the 2500 – 2690 MHz band. The scenarios studied were interference between base stations, between base stations and terminals, and between terminals.

The feasibility of certain scenarios is subject to a trade-off between technical, regulatory and economical factors. In this document different points of view have been reflected which correspond to different trade-off choices. Elements to determine these choices are outside the scope of this report, which is exclusively technical. Those views are by no means excluding other points of view. The conclusions below reflect only the results presented in this document.

Some of the material contained in this report has been extracted from ITU-R documents and information from other sources such as ETSI standards approved or in preparation.

In addition to solutions mentioned below, interference situations and mitigation can be handled through agreements directly between operators.

This ECC Report should not be considered in isolation. CEPT Report 19 provides separate guidance on coexistence between FDD and TDD in the 2.6 GHz band through the use of block edge masks. The scenarios developed in this ECC Report do not include the use of block edge masks and this ECC Report may therefore not be applicable to cases where administrations authorise use of this spectrum on the basis of the least restrictive technical conditions contained in CEPT Report 19.

Interference between base stations
Without additional mitigation measures, several scenarios are associated with severe interference problems, especially those associated with macro-macro deployments. Interference is high for both co-located and in-proximity scenarios, when using the parameters of the standards without any interference mitigating techniques.

There are a number of actions that can be taken alone or in combination in order limit the interference between base stations. All actions necessary to avoid implementing a guard band are associated with an increased level of complexity, as there is always a trade off to consider.

The interference limiting techniques considered here are guard bands, additional front-end filters, restricted channels, deployment restrictions and special site engineering (for co-siting case).

The use of guard bands, where appropriate, should not be considered in isolation but in conjunction with other solutions such as additional front-end filters and restricted channels. For the 2nd adjacent channel, additional front-end filters can be expected to give sufficient protection. For the 1st adjacent channel, one may decrease the output power down to 25 dBm EIRP (a "restricted channel") and add additional front-end filtering. To avoid the need of additional filtering, one could place the base station indoors or without line of sight to the interfered base station, to decrease the interference sufficiently.

For co-siting one may use vertical antenna separation to decrease the interference. Together with additional front-end filters (applied to both macro base stations involved) this gives sufficiently low interference for the 2nd adjacent channel, but not for the 1st.

Interference between base stations and terminals
For the uplink, deterministic analysis show that interference from TDD mobile stations into FDD base stations and from FDD mobile stations into TDD base stations may be severe, in particular cases but they do not represent the average behaviour of the network. It can be mitigated by co-location of base stations or by any of the above mentioned interference mitigating techniques, with the consequence on base station-base station interference as discussed above.
However, a statistical analysis shows that the coexistence problems can be alleviated.

For the downlink, Monte Carlo simulations show that for uniformly-distributed outdoor-only users, base station-mobile station interference will have a small or negligible impact on the system capacity when averaged over the system.

Interference between terminals

A deterministic (worst-case) analysis of interference between terminal stations shows that the impact can be severe when the mobile stations are close to each other. Monte Carlo simulations suggest that interference between terminal stations will have a small or negligible impact on the system capacity when averaged over a system of uniformly-distributed outdoor-only users. Non-uniform user distributions are not studied in this report.

1 INTRODUCTION

During the year 2008, the 2500 – 2690 MHz band will be licensed in many CEPT countries. Indeed, in some of these, the licensing procedure has already begun. It is thus important that licensing conditions together with system characteristics defined in standardization documents ensure that the interference is limited to acceptable levels. This document contains information about the crucial system parameters pertaining to coexistence characteristics of FDD and TDD systems, a summary of relevant coexistence studies performed in various fora to date, as well as some further analysis.

The 2500 – 2690 MHz band was identified for IMT-2000 at WRC-2000 and for IMT at WRC-07. Furthermore, ETSI BRAN is currently working on a harmonized standard for Broadband Data Transmission Systems [4] (referenced as BDTS in this report) which may also be used in this band. Similarly, ETSI has published the harmonised standard for UMTS [2] [3] (referenced as UTRA in this report). As a result, it is important to analyze the coexistence of such different systems in this band.

CEPT has established the least restrictive technical conditions, based on the concept of block edge masks, which are sufficient to avoid harmful interference, in this band. These conditions are contained in CEPT Report 019 [5].

Table 1 below presents the different alternatives for the 2500 – 2690 MHz band described in ECC Decision (05)05. In the case of solution C1, there will be a border between FDD UL and TDD at 2 570 MHz, and one between TDD and FDD DL at 2 620 MHz. Other solutions than those presented in Table 1 have been suggested by some administrations, but the same principal co-existence scenarios will be present between FDD and TDD, although possibly at other frequencies. There will also be interference scenarios between unsynchronized and adjacent TDD networks within a TDD band, which will have similar characteristics as those between FDD and TDD networks. ECC Decision (05)05 further states, that any necessary guard bands between FDD and TDD systems should be taken from TDD spectrum.

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

Table 1: Possible allocations of the 2.5 GHz IMT-2000 band (ECC/DEC/(05)05)

Table 2 provides the EC decision framework, based on which alternative band plans (to the ones of table 1) can be derived.

Assigned block size	5 MHz multiples
FDD duplex spacing	120 MHz
FDD uplink	Starting at 2 500 MHz Extending to a maximum limit of 2 570 MHz
FDD downlink	Starting at 2 620 MHz Extending to a maximum limit of 2 690 MHz
TDD and other usage modes complying with block edge mask	2 570-2 620 MHz Outside 2 570-2 620 MHz, usage decided on a national level in equal parts in both the upper part starting at 2 690 MHz (extending downwards) and the lower part starting at 2 570 MHz (extending downwards)

Table 2

This report only addresses compatibility aspects between FDD and TDD systems and provides elements to ensure that no harmful interference will occur from one system to another, irrespectively of the frequency plan.

2 SCOPE OF THE DOCUMENT

The co-existence issue considered here is adjacent channel interference between FDD and TDD systems. The coexistence between two TDD unsynchronized systems is not strictly assessed in the report; however, since most parameters are similar, most of the results of the FDD/TDD scenario can be extended to two unsynchronized TDD systems scenario. Co-channel interference between geographically adjacent areas (cross-border coordination) has not been studied. However, this issue is considered as an important matter to be further studied and would be covered in another ECC document.

The results are to a large extent based on analysis performed in ITU-R [1] [7], but also includes ideas from the work in CEPT Report 019 [5] and the standardization in ETSI [2] [3] [4]. The systems considered are primarily UTRA FDD [2] and UTRA TDD [3] systems compliant with the ETSI EN 301 908, as well as BDTS TDD systems compliant with draft ETSI EN 302 544 (parts 1 and 2) standard [4]. The analysis also incorporates a more general perspective, based on technology neutrality as described in [5].

For the purposes of this document, it is assumed that operators are deploying their networks, using equipment compliant with the above standards, without detailed coordination, although in reality coordination including site engineering may be necessary in certain cases. Additionally, in EC countries, networks will be deployed in accordance with the technical conditions of the EC decision.

To avoid scenarios that are too pessimistic, assumptions are made about realistic deployment scenarios, such as minimum distances between interfering base stations and about antenna down tilt.

The deployment scenarios within CEPT vary considerably from one area to another, but the analysis primarily takes into account urban scenarios with dense network deployments, as those are expected to present the highest levels of interference.

This report does not cover interference to or from services below 2 500 MHz or above 2 690 MHz, or other services than mobile/nomadic/fixed that may be deployed in the 2 500-2 690 MHz range.

3 COEXISTENCE STUDIES FOR THE 2.6 GHZ BAND

3.1 Considered coexistence studies and standards

Results from two coexistence studies carried out by ITU-R involving FDD and TDD systems and relevant for the 2.6 GHz band are included in this document. Furthermore, some results from input documents to ECC PT1 are included as well.

The following coexistence studies and standards are considered in this document:

1. Report ITU-R M.2030 [1], covering coexistence between UTRA TDD versus UTRA FDD, referred to as ITU-R **M.2030**.
2. Report ITU-R **M.2113** [7], concerning sharing between UTRA FDD and TDD versus fixed and nomadic broadband wireless access.
3. Harmonized EN for IMT-2000, CDMA FDD [2] and TDD [3], referred to as **UTRA FDD** and UTRA **TDD**.
4. Draft Harmonized EN for Broadband Data Transmission Systems in 2500 – 2690 MHz [4], referred to as **Draft ETSI BRAN HEN**, defining BDTS TDD systems.
5. ECC PT1 input contributions.
6. CEPT Report 019 [5]**.**
7. Report ITU-R M.2116, Characteristics of broadband wireless access systems operating in the land mobile service for use in sharing studies [6].
8. Report ITU-R M.2045 on the Mitigating techniques to address coexistence between IMT-2000 TDD and FDD within the frequency range 2 500-2 690 MHz operating in adjacent bands and in the same geographical area [8].

3.2 System Parameters including protection criteria

The relevant system parameters for TDD, such as ACLR and ACS, BS and MS output power etc have been listed below in Table 2. The table contains several sets of parameters, since the values assumed have not been the same in all documents [1] [3] [4] [7]. In this context it should be noted that ITU-R has produced a document on Broadband Wireless Access characteristics [6]. Those parameters are equivalent to the ones used in the report ITU-R M.2113 [7].

The abbreviations URC, RC, TRP and EIRP in Table 3 are used for Unrestricted Channel, Restricted Channel, Total Radiated Power and Equivalent/Effective Isotropically Radiated Power, and indicates for which assumptions the values have been derived, see further [5].

Table 4 contains parameters for the FDD systems.

Although in CEPT Report 019 no ACLR values are developed, the tables contain values derived from the Block Edge Masks and maximum in-band E.I.R.P. Appendix A contains a description of how the parameters in the CEPT Report 019 column have been derived.

The last column of Tables 3 and 4 contains parameters that will be referred to as “reference parameters” throughout this Report. The intention is to use these reference parameters to the greatest extent possible in the analysis, and whenever that is not possible (e.g. when the analysis has been carried out in another context and is only referenced here) explain the differences from reference parameters, and the influence on the results. The objective is to avoid the confusion that otherwise would result from differences in input parameters. The reference parameters have been selected as those most likely to be applied to systems involved in co-existence scenarios for this frequency band. The values that have been chosen are from the ETSI standards [2], [3] and [4], and agreed assumptions about system deployment from CEPT Report 019.

Clarifications to Tables 3 & 4:

1. The parameters below apply to TDD/FDD with a 5 MHz bandwidth.
2. Channel, as used in this report, refers to a 5 MHz bandwidth.
3. There are two different ACLR values for BDTS TDD: a "general requirement", referred to as Class 1, and a requirement for coexistence scenarios with UTRA FDD (additional requirement), referred as Class 2. For BDTS TDD systems the ACLR values are also given
   - for "Class 1" for intra-system operation (not used in these studies)
   - for "Class 2" for inter-operator situation, applicable to coexistence scenarios at an FDD/TDD boundary and between unsynchronized TDD blocks. For Class 2, two values are given, corresponding to receivers of two different bandwidths, 4.75 and 3.84 MHz respectively, and with different receiver filters, see [4] for details.
4. ACLR for the first adjacent channel for UTRA TDD has been computed from the absolute value -36 dBm, taken from the ETSI TFES standard, and also assuming a base station output power of 43 dBm. For the second adjacent channel, the ETSI TFES standard provides the value - 32 dBm. However, there is also a test tolerance of 4 dB for this value, so the same ACLR, - 79 dB, is assumed for the second adjacent channel. These values are valid for co-existence scenarios.
5. ACS for UTRA is defined by having requirements on Bit Error Ratio measured on the wanted signal in the presence of an interfering signal.
6. Maximum Base station output power is not specified in harmonised standards.
7. The two different values for MS ACLR 1st adjacent and output power in ITU-R M.2113 correspond to fixed and nomadic terminals.
8. The TDD parameters used in report ITU-R M.2030 represent UTRA TDD, 3.84 Mchip/s. However, the results of the coexistence analysis are general enough to be of interest for other TDD systems as well with a bit of caution. The major differences are that the ACLR values for the base station are higher and the ACS for both base station and terminal is lower.

	ITU-R M.2113 (802.16 TDD)	ETSI BRAN (BDTS TDD)	ITU-R M.2030 TDD	ETSI TFES (UTRA TDD)	CEPT Report 019	Reference Parameters[1]
BS 1st adj ACLR (dB)	53.5	Class2: 49.7 / 52.7	70	Class2: 79	NRC : 45.5 RC[2]: 31.5	52.7
BS 2nd adj ACLR (dB)	66	Class2: 62.2 / 65.2	70	Class2: 79	NRC : 99 RC: 40[1]	65.2
MS 1st adj ACLR (dB)	37/33	32.2	33	32.2	Mobile: 29,5 Fixed: 33.5	32.2
MS 2nd adj ACLR (dB)	51	42.2	43	42.2	Mobile: 41 Fixed: 45	42.2
BS 1st adj ACS (dB)	70	Not defined	46		Not defined	70/46
BS 2nd adj ACS (dB)	70	Not defined	58		Not defined	70/58
MS 1st adj ACS (dB)	40	Not defined	33		Not defined	-
MS 2nd adj ACS (dB)	59	Not defined	43		Not defined	-
BS Max Power (dBm/5 MHz)	36	Not defined	43	Not specified	NRC: 44 RC: 25	43
MS Max Power (dBm/5 MHz)	Fixed: 24 Mobile:20	26	21	24	Fixed: 35 Mobile: 31	24
Macro BS max antenna gain (dBi), including feeder loss	18 (no feeder loss)	Not defined	15	Not defined	17	17
Micro BS max antenna gain (dBi), including feeder loss	Not defined	Not defined	6	Not defined	Not defined	-
Pico BS max antenna gain (dBi) (including feeder loss)	Not defined	Not defined	High chip rate :0 Low chip rate, TD-SDCMA :3	Not defined	3	3
Macro BS antenna downtilt coupling loss	Not defined	Not defined	Not defined	Not defined	3 dB/antenna	3 dB/ antenna
MS max gain (dBi)	Fixed:8 Nomadic:3	Not defined	Not defined	Not defined	0 for TS	0
Block sizes	5 MHz	5 MHz	5 MHz	5 MHz	multiples of 5MHz	5

Table 3: TDD parameters used in various contexts

[1] The Reference Parameters have been commonly agreed for the additional studies compared to those contained in the ITU-R Reports.
[2] Relaxed TDD restricted blocks have been considered to derive the values relating to the RC (restricted channels). For these relaxed values, it is assumed that the base stations are placed indoors.

	ITU-R M.2039 (UTRA FDD)	ETSI TFES (UTRAFDD)	CEPT Report 019	Reference Parameters
BS 1st adj ACLR (dB)	45	44.2	NRC: 45.5	44.2
BS 2nd adj ACLR (dB)	50	49.2	NRC: 99	49.2
MS 1st adj ACLR (dB)	33	32.2	Mobile: 29,5 Fixed: 33,5	32.2
MS 2nd adj ACLR (dB)	43	42.2	Mobile: 41 Fixed: 45	42.2
BS 1st adj ACS (dB)	46	-	Not defined	46
BS 2nd adj ACS (dB)	58	-	Not defined	58
MS 1st adj ACS (dB)	33	-	Not defined	33
MS 2nd adj ACS (dB)	43	-	Not defined	43
Macro/Micro/Pico BS Max Power (dBm/5 MHz)	43/38/24	Not defined	44 (Macro)	43/38/24
MS Max Power (dBm/5 MHz)	21	24	Fixed: 35 Mobile: 31	24
BS antenna max gain (dBi), Macro/Micro/Pico	17/5/0	Not defined	17/-/3	17/5/0
Macro BS Antenna downtilt coupling loss	Not defined	Not defined	3 dB/antenna	3 dB/antenna
MS max gain (dBi)	0	Not defined	0	0
Block sizes	5 MHz	5 MHz	multiples of 5MHz	5 MHz

Table 4: FDD parameters

Interference protection ratios based on I/N=-6 dB for UTRA-FDD, UTRA-TDD and BRAN-TDD are summarized in table 5. The noise figures of the table are extracted from the Report ITU-R M.2030 (UTRA-FDD and UTRA-TDD) and from Report ITU-R M.2016 for BRAN-TDD.

	UTRA-FDD		UTRA-TDD		BDTS-TDD (5 MHz)	
	BS	UE	BS	UE	BS	UE
Channel bandwidth (MHz)	3.84	3.84	3.84	3.84	4.75	4.75
Noise Figure (dB)	5	9	5	9	3	5
Noise Level (dBm)	-103	-99	-103	-99	-104	-102
I/N (dB)	-6	-6	-6	-6	-6	-6
Interference protection level (dBm)	-109	-105	-109	-105	-110	-108

Table 5: Interference protection ratios

3.3 Propagation Models

A number of different propagation models have been used in the various studies referenced in this document. However, the Line of Sight scenario with Free Space Propagation is the most important in case of line of sight interference paths exist, but otherwise will yield unduly pessimistic results when used within an interference analysis. Macro Base Stations in close proximity are likely to have LoS or near-LoS conditions, which is true also for terminals that are close to each other (if body losses and other obstructions are ignored). The use of other propagation models is more appropriate in other cases (e.g. ITU-R P.1411) and these are identified below for each particular case.

Just as for the system characteristics above, there is a reference assumption for the propagation, which is also connected to the assumption about uncoordinated deployment of different operators. It is assumed that BS-BS interference should be low enough at the distance of 100 meters. (See also [5].) Results for other distances are sometimes incorporated as well to provide a sensitivity analysis. Co-siting information is also included, as this is an additional important scenario, with a conservative assumption of a 30 dB[3] coupling loss, unless mitigation techniques are included.

3.4 Interference Scenarios

In ITU-R M.2030 and ITU-R M.2113 adjacent channel interference (1st and 2nd adjacent channel) has been studied for BS-BS, BS-MS and MS-MS scenarios, both with deterministic analysis (interference budgets) and with probabilistic analysis (system simulations). The exception is that BS-BS interference has only been studied with deterministic methods in ITU-R M.2030. The results provided are for the border between FDD and TDD systems, although one may expect similar interference scenarios between adjacent TDD operators as well, unless they are synchronized.

3.5 BS-BS Interference

The base station to base station interference scenario assumes high output power and the LoS propagation characteristics between two nearby base stations. Furthermore, this is a static interference scenario, except from the variations in output power, unlike the situation with a terminal that will switch off or move to another location after a while. The analysis below covers interference between base stations that are deployed at different sites as well as for those that are co-sited, and includes basic scenarios as well as those with interference limiting techniques.

[3] See note 6 in ITU-R Report M.2116 [6].

3.5.1 Results without interference mitigating techniques

Co-channel interference
Co-channel interference is not considered in this report. However it should be pointed out that the interference mitigating techniques suggested below (e.g filtering) for the adjacent channel scenario are not all applicable to the co-channel case, which may lead to increased separation distances for co-channel situations (e.g. cross-border coordination).

Adjacent channel interference (1st and 2nd adjacent channels)
Tables 6 through 9 contain the deterministic results from ITU-R M.2030 (macro - macro) and ITU-R M.2113 (also including micro and pico cells). Negative values indicate that the interference is low enough to allow coexistence between the two systems without additional measures. Note that the results from ITU-R M.2030 are based on the parameters contained in the table 3 of this report (column “ITU-R M.2030 TDD”). These parameters are different from those used to determine the Block Edge Masks in CEPT Report 019. Therefore, the results are different from those obtained with the BEM.

According to Report ITU-R M.2030, Tables 6 and 7 represent the rural (coverage limited) case, and not the urban scenarios with dense network deployments.

Description of scenario (+propagation model)	Carrier separation (MHz)	Tx power (including activity factor) (dBm)	Effective antenna gain (dBi)	ACIR (dB)	Accepted level of I_{ext} low/high (dBm)	Required path loss (dB)	Required separation distance (m)
TDD macro to FDD macro (LoS)	5	40	30	46	–114/–106	138/130	9 541/6 020
	10	40	30	58	–114/–106	126/118	4 782/3 017
FDD macro to TDD macro (LoS)	5	43	30	42	–114/–106	145/137	14 275/9 007
	10	43	30	49	–114/–106	138/130	9 541/6 020

Table 6 : Required geographical separation to avoid TDD BS - FDD BS interference. Deterministic analysis fROM M.2030 (Tables 25 and 26)

Description of scenario (+propagation model)	Tx power (including activity factor) (dBm)	Effective antenna gain (dBi)	Reference separation distance (m)	Path loss (dB)	Accepted level of I_{ext} at Rx (dBm)	Required ACIR (dB)	Missing isolation 5 MHz carrier separation (dB)
TDD macro to FDD macro (LoS)	40	30	100	80.7	–114/–106	103.3/95.3	57.3/49.3
FDD macro to TDD macro (LoS)	43	30	100	80.7	–114/–106	106.3/98.3	64.3/56.3

Table 7: Required additional isolation, TDD BS – FDD BS interference, 1st adjacent channel. Deterministic analysis from M.2030 (Tables 27 and 28)

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

Table 8: Excess interference when the base stations are not co-sited, where the CDMA DS base station is the interference victim. Deterministic analysis from ITU-R M.2113 (Table 2.7-1)

Note: according to table 7, the reference separation distance between two base stations is 100 m.

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	82.3	77.3	54.8	49.8	23.9	18.9
50.0	68.3	63.3	28.2	23.2	-2.7	-7.7
100.0	**62.3**	**57.3**	**16.8**	**11.8**	**-14.1**	**-19.1**
500.0	48.3	43.3	-9.8	-14.8	-40.7	-45.7
1 000.0	42.3	37.3	-21.2	-26.2	-52.1	-57.1

Table 9: Excess interference when the base stations are not co-sited, where the IEEE 802.16 base station is the interference victim. Deterministic analysis from ITU-R M.2113 (Table 2.7-2)

Note: according to table 7, the reference separation distance between two base stations is 100 m.

Table 10 below contains results for BS – BS interference that have been obtained from system simulation analysis. In this analysis antenna down-tilting was only used for the TDD system. Furthermore, the evaluation methodology was based on the capacity or modulation efficiency loss due to adjacent channel interference. For FDD, a capacity loss of 5% was accepted compared to the corresponding simulations without external interference, whereas for TDD a modulation efficiency loss of 5% was accepted.

	First Adjacent Channel				**5 MHz Guard Band (Second adj channel)**			
Offset in meters	**Coexistence**		**From 802.16 TDD base station to UTRA FDD base station**	**From UTRA FDD base station to 802.16 TDD base station**	**Coexistence**		**From 802.16 TDD base station to UTRA FDD base station**	**From UTRA FDD base station to 802.16 TDD base station**
0	UTRA FDD	**802.16 TDD** fixed	44	55 (1x3x1) 60 (1x3x3)	UTRA FDD standard	**802.16 TDD** Fixed	32	50 (1x3x1) 55 (1x3x3)
		802.16 TDD nomadic	44	57 (1x3x1) 62 (1x3x3)		**802.16 TDD** nomadic	32	52 (1x3x1) 57 (1x3x3)
100	UTRA FDD	**802.16 TDD fixed**	**26**	**35 (1x3x1) 43 (1x3x3)**	**UTRA FDD standard**	**802.16 TDD Fixed**	**14**	**31 (1x3x1) 38 (1x3x3)**
		802.16 TDD nomadic	**26**	**37 (1x3x1) 44 (1x3x3)**		**802.16 TDD nomadic**	**14**	**32 (1x3x1) 39 (1x3x3)**
433	UTRA FDD standard	**802.16 TDD** fixed	15	26 (1x3x1) 33 (1x3x3)	UTRA FDD standard	**802.16 TDD** Fixed	4	21 (1x3x1) 28 (1x3x3)
		802.16 TDD nomadic	16	26 (1x3x1) 33 (1x3x3)		**802.16 TDD** nomadic	4	21 (1x3x1) 28 (1x3x3)
866	UTRA FDD standard	**802.16 TDD** fixed	15	26 (1x3x1) 33 (1x3x3)	UTRA FDD standard	**802.16 TDD** Fixed	3	21 (1x3x1) 28 (1x3x3)
		802.16 TDD nomadic	15	26 (1x3x1) 33 (1x3x3)		**802.16 TDD** nomadic	3	21 (1x3x1) 28 (1x3x3)

Table 10: Additional isolation needed (dB) for coexistence of 802.16 TDD and standard UTRA FDD in the first and second adjacent channel. Probabilistic analysis from ITU-R M.2113 (Tables 2.5.4.1-4 and 2.5.4.2-4)

Note 1: according to table 7, the reference separation distance between two base stations is 100 m.

Information about co-siting scenarios is also available. Table 11 contains such information from ITU-R M.2030, and Table 12 contains results from ITU-R M.2113. Negative values indicate that coexistence is possible without additional measures. Both reports use a conservative co-siting coupling loss of 30 dB for macro – macro interference. In ITU-R M.2113 interference between macro and micro/pico cells was studied as well. In those cases the interference is lower due to the vertical separation of the base station antennas. It is worthwhile to note that in the specification for UTRA TDD base stations there is a requirement corresponding to an ACLR of 123 dB for the 1st and 2nd adjacent channels for a base station using 43 dBm output power.

Interfered system	C_Tx_ (dBm)	ACS of Rx	ACLR of Tx	ACIR	Int@_Rcvr (dBm)	Threshold exceeded (–109 dBm)
UTRA TDD	43	46 @ 5 MHz	45 @ 5 MHz	42.46	–29.46	Yes
UTRA TDD	43	58 @ 10 MHz	50 @ 10 MHz	49.36	–36.36	Yes
UTRA FDD	40.2	46 @ 5 MHz	70 @ 5 MHz	45.98	–35.78	Yes
UTRA FDD	40.2	58 @ 10 MHz	70 @ 10 MHz	57.73	–47.53	Yes

NOTE – TDD BS Tx output power = 43 dBm
TDD BS activity factor = –2.8 dB
C_Tx_ = 43 +(–2.8) = 40.2 for TDD Tx power.

Table 11 : Calculated values of interference between TDD and FDD systems, co-siting scenario, macro base stations.Deterministic results from M.2030 (Table 31)

Note: table 12 provides the additional isolation needed to limit the interference to the acceptable threshold of -109 dBm. Those results are not strictly aligned with the ones obtained from data contained in Table 11. It can be explained by the difference of input parameters used in the Reports ITU-R M.2030 and M.2113.

Deployment scenario		TDD / FDD	FDD / TDD
TDD macro/ FDD macro	1st adj chan	70.0	78.0
	2nd adj chan	58.0	73.0
TDD macro/ FDD micro	1st adj chan	23.0	26.0
	2nd adj chan	11.0	21.0
TDD macro/ FDD pico	1st adj chan	11.0	0.0
	2nd adj chan	-1.0	-5.0

Table 12: Co-siting scenarios, additional isolation needed. Deterministic results from Report ITU-R M.2113 (Table 2.4-2)

For the case UTRA FDD and TDD, the following analysis from M.2030 shows the effect of blocking for the co-siting case.

A receiver is typically defined as overloaded when the total received input power exceeds the receivers 1 dB compression point minus a safety margin (typically 10 dB).

MAI_Over = 1 dB Compression Point – Safety Margin

MAI = Maximum Allowed Interference.
A blocking value of – 40 dBm is used as specified in 3GPP. The total received carrier power is defined by:

C_Rx_ = C_Tx_ – *ACIR* – *MCL*

where:

C_Rx_ : total carrier power received at input port of the interfered station (dBm)

C_Tx_ : total carrier power transmitted at the output port of the interfering station (dBm)

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

MCL : minimum coupling loss = 30 dB.

Table 13 contains results based on these assumptions, and shows that in some cases the interference exceeds the limit for what is acceptable.

Interfered system	C_Tx_ (dBm)	ACS of Rx	ACLR of Tx	ACIR	C_Rx (dBm)	MAI_Over threshold exceeded? (– 40 dBm)
UTRA TDD	43	46 @ 5 MHz	45 @ 5 MHz	42.46	–29.46	Yes
UTRA TDD	43	58 @ 10 MHz	50 @ 10 MHz	49.36	–36.36	Yes
UTRA FDD	40.2	46 @ 5 MHz	70 @ 5 MHz	45.98	–35.78	Yes
UTRA FDD	40.2	58 @ 10 MHz	70 @ 10 MHz	57.73	–47.53	No

Table 13: Computed values showing interference at the Rx of the interfered system Deterministic analysis from ITU-R M.2030 (Table 32) (co-sited scenario)

It is clear that considering only the parameters from the equipment standards taken in isolation, the interference between a TDD system and a FDD system is significant, whether base stations are co-sited or not, even with a guard band of 5 MHz. Report ITU-R M.2030 has stricter TDD ACLR, but interference is still high. For scenarios within CEPT with dense deployment in cities it is obviously not realistic to obtain sufficient isolation by geographical separation only, even with a guard band of 5 MHz, unless additional measures are taken.

3.5.2 Results with interference mitigating techniques

The deterministic analysis results in ITU-R Report M.2113 Section 2.6.2 (Table 36 and 38) contain relevant results for FDD/TDD BS-BS interference. These apply the interference mitigation techniques discussed within ITU-R Report M.2045 to the results obtained in ITU-R Report M.2113 Section 2.5. The conclusions of these studies are generally in line with the following additional analysis.

In the analysis below, the interference is divided into two parts. The first represents the interference experienced by the receiver due to its limited selectivity, i.e. the “ACS” part, and the second represents the interference due to the transmitter leakage of the interfering system into adjacent spectrum, i.e. the “ACLR” part. It is convenient to separate these two in this context to clarify which measures need to be taken at the receiver and the transmitter respectively. Furthermore, ACS, ACLR and ACIR are not used in the development of the WAPECS concept for the 2 500 – 2 690 MHz band. Instead, block edge masks specify maximum EIRP outside operators’ blocks.

3.5.2.1 Adjacent Channel Interference Due to Receiver Imperfections

First consider interference due to the limited selectivity of the receiver. It is clear from the above that at least the two channels nearest to the interfered carrier must be given special treatment. Assuming that we do not want to use two channels as guard bands, and that we do not want to impose geographical restrictions on deployment, other than the baseline assumption of 100 meter separation, we can either decrease the power of the transmitter, or improve the selectivity of the receiver.

Let us first consider improving the selectivity of the receiver by introducing an additional front-end filter. It is assumed here that such a filter may improve the selectivity for the second adjacent and beyond channels by about 50 dB. Adding filters to the base stations will of course increase the network complexity, partly due to the additional hardware and partly due to installation and maintenance. However, since the 2.6 GHz band is being made available as a new band, the implementation of such filters would be easier than if they had to be implemented in an existing network. Report ITU-R M.2045 indicates that the insertion loss associated with such a filter would be 2 dB approximately. This will of course affect quality and coverage of the system where the filters are applied.

However, some filter manufacturers have indicated values as low as 0.6 dB that would reduce the effect of desensitization.. It is thus important to keep in mind the balance between the applied measures in the interfered network and the gain from using these channels.

Table 12 contains results from a deterministic base station – base station analysis, with interference from TDD to FDD. The reference parameters of Tables 2 and 3 are used. Downtilt coupling loss has been applied to a macro base station also when the other base station is a micro or pico station, as it is considered unlikely that they will be in the direction of the highest antenna gain in the vertical direction. Free Space propagation has been used in these calculations. This may be considered somewhat pessimistic, as the restricted channel may be used by pico/micro cells on ground level. On the other hand, pico base stations may also be used in buildings on the same level as macro base stations.

For the second adjacent channel, a 50 dB additional filter improves the situation sufficiently for a base station-base station distance of 100 meters.

For the first adjacent channel, it is useful to consider another technique, known as *restricted channels*. For these channels the maximum allowed power is restricted, so as to achieve the desired coexistence properties, possibly in combination with other measures. For instance, a TDD channel adjacent to an FDD uplink channel may have its BS power restricted to that of a terminal (25 dBm/5 MHz EIRP, according to CEPT Report 019) to mimic the interference caused by FDD terminals to the FDD base stations (see also CEPT Report 019). Table 14 shows the additional receiver isolation needed for sufficiently low interference, for the 1^{st} and 2^{nd} adjacent channel. For the first adjacent channel a further decrease in interference is necessary. Tables 15 and 16 contain similar results for TDD interfered by FDD. Two sets of ACS values have been used. The first corresponds to those used in ITU-R M.2113, column 2 in Table 2, and the second corresponds to values from ITU-R M.2030, column 4 in Table 2.

Excess interference (dB)	**Downtilt coupling loss (dB)**	**Rx Filter (dB)**	**Indoor prop. Loss (dB)**	**1^{st} adj (dB)**	**2^{nd} adj (dB)**
Unrestricted Channel 61 dBm (EIRP)	6	-	-	NA	42
	6	50	-	NA	-8
Restricted Channel 25 dBm (EIRP)	3	-	-	21	9
	3	50	-	-	-41
	3	-	15	6	-6

Table 14: Additional isolation needed due to limited receiver selectivity (ACS), when the base stations are separated by 100 meters, where the FDD macro base station is the victim. Selectivity improvements by additional front-end filters are included, 50 dB for the second adjacent channel (Deterministic analysis

Note: the scenario of a TDD macro base station transmitting in the adjacent channel of a receiving FDD macro base station should be avoided

Excess interference (dB)	**Downtilt coupling loss (dB)**	**Rx Filter (dB)**	**Indoor prop. Loss (dB)**	**1^{st} adj (dB)**	**2^{nd} adj (dB)**
Unrestricted Channel 61 dBm (EIRP)	6	-	-	NA	31
	6	50	-	NA	-19

Table 15: Additional isolation needed due to limited receiver selectivity (ACS) when the base stations are separated by 100 meters, where the TDD macro base station is the victim. ACS values from column ITU-R M.2113 in Table 2 have been used, 70 dB for both the first and the second adjacent channel. Selectivity improvements by additional front-end filters are included, 50 dB for the second adjacent channel. Deterministic analysis

Note: the scenario of a TDD macro base station receiving in the adjacent channel of a transmitting FDD macro base station should be avoided.

Excess interference (dB)	Downtilt coupling loss (dB)	Rx Filter (dB)	Indoor prop. Loss (dB)	1st adj (dB)	2nd adj (dB)
Unrestricted Channel 61 dBm (EIRP)	6	-	-	NA	43
	6	50	-	NA	-7

Table 16 : Additional isolation needed due to limited receiver selectivity (ACS) when the base stations are separated by 100 meters, where the TDD macro base station is the victim. ACS values from M.2030 in Table 2 have been used, 46 dB for the first and 58 dB for the second adjacent channel. Selectivity improvements by additional front-end filters are included, 50 dB for the second adjacent channel. Deterministic analysis

Note: the scenario of a TDD macro base station receiving in the adjacent channel of a transmitting FDD macro base station should be avoided.

3.5.2.2 Adjacent Channel Interference due to Transmitter imperfections

Leakage of transmitted power into adjacent channels is the second reason for adjacent channel interference. The methods for decreasing interference are decreased power and more efficient suppression of the leaking signal from the transmitter. Guard bands and geographical separation are of course also an option, see 3.5.2.1.

Table 17 contains the results for TDD interference to an FDD system, with downtilt coupling loss, additional front-end filters and indoor propagation loss. The same assumptions as in the previous section have been used.

An unrestricted channel as a 1st adjacent channel will cause too high interference. For the 2nd adjacent channel however, a front-end filter is sufficient to guarantee sufficiently low interference. For the restricted channel, protection is sufficiently high for the 1st adjacent channel when the interfering base station is placed indoors, or where there is not line-of-sight to the base station receiver.

Table 18 contains the corresponding results for FDD interference to TDD, and the results are very similar, albeit with somewhat higher interference levels.

Excess interference (dB)	Downtilt coupling loss (dB)	Tx Filter (dB)	Indoor prop. Loss (dB)	1st adj (dB)	2nd adj (dB)
Unrestricted Channel 61 dBm (EIRP)	6	0	-	NA	35
	6	50	-	NA	-15
Restricted Channel 25 dBm (EIRP)	3	0	-	14	2
	3	50	-	-	-48
	3	0	15	-1	-13

Table 17 : Additional isolation needed due to transmitter imperfections, when the base stations are separated by 100 meters, and where the FDD macro base station is the victim. Adjacent channel emission improvements by additional front-end filters are included, 50 dB for the second adjacent channel. Deterministic analysis

Note: the scenario of a TDD macro base station transmitting in the adjacent channel of a receiving FDD macro base station should be avoided

Excess interference (dB)	**Downtilt coupling loss (dB)**	**Rx Filter (dB)**	**Indoor prop. Loss (dB)**	**1st adj (dB)**	**2nd adj (dB)**
Unrestricted Channel 61 dBm (EIRP)	6	0	-	57	52
	6	50	-	-	2

Table 18 : Excess interference due to transmitter imperfections, when the base stations are separated by 100 meters, and where the TDD macro base station is the victim. Adjacent channel emission improvements by additional front-end filters are included, 50 dB for the second adjacent channel. Deterministic analysis

Note: the scenario of a TDD macro base station receiving in the adjacent channel of a transmitting FDD macro base station should be avoided

In CEPT Report 019, a limit of -45 dBm/MHz EIRP on base station output power in the TDD and FDD uplink channels is suggested (with some exceptions). This limit is not described by providing an ACLR value, but is stipulated directly as a fixed number. This corresponds to
-39 dBm/3.84 MHz, which with the same assumptions as above results in -109 dBm (6 dB antenna tilting loss) interference to another base station. In other words, interference will be sufficiently low.

The analysis in the preceding paragraph also shows that it will be necessary to apply additional front-end filters to FDD and TDD systems with co-existence characteristics according to Tables 2 and 3 to suppress adjacent channel interference to such levels. For an unrestricted channel, this is only relevant for the 2nd adjacent channel, where an additional 34/50 dB of suppression is needed on top of the (reference) values of 65/49 dB for TDD and FDD from Tables 3 and 4. For the restricted channel, only applicable to TDD, the ACLR for the first adjacent channel must be increased by an additional 10 dB for TDD compared to the reference value, whereas the ACLR for the second channel is sufficiently high.

Another methodology, similar to a restricted channel but applied to the interfered system, is to accept higher than normal interference in channels near the block edge. For instance, assuming that an interfering base station transmits 61 dBm EIRP on its own channel, and has an ACLR of 44.2 dB, the interference to a macro base station on the adjacent channel, 100 meters away, will be roughly -53 dBm, assuming an antenna coupling loss of 3 dB per antenna but no additional front-end filter. This is too high for normal operation of the interfered base station, but the channel may nevertheless be useful for other purposes, such as micro or pico cells which may benefit from additional protection from houses etc. For instance, in CEPT Report 019, it is suggested that the FDD DL should limit its interference into the closest adjacent TDD channel to 4 dBm/MHz EIRP, which with similar assumptions as above (macro – macro interference) will lead to -59 dBm interference into a 5 MHz channel. Again this is too high for normal macro BS operation, but for micro/pico cells with additional protection through propagation loss and lower antenna gain it may still be of use.

If this methodology is employed, any users of such a channel should be aware that the adjacent unrestricted channel will use output power that has not been limited so as to protect adjacent channels from interference.

Based on a different deterministic methodology described in Appendix B to assess the interference from TDD base stations to FDD base stations, the following tables (19 and 20) provide the probability of interference in terms of FDD BS Rx desensitization (3dB), without (table 19) and with (table 20) mitigation techniques (additional 10 dB Tx filtering).

TDD Block	Urban	Suburban	Rural	Road/Rail
Restricted (indoor)	26,2%	3%	0.3%	5.2%

Table 19: The probability of FDD BS Rx desensitization (3dB) due to Restricted Block TDD interference

TDD Block	Urban	Suburban	Rural	Road/Rail
Restricted (indoor)	8.3%	0.9%	0.1%	2.9%

Table 20: The probability of FDD BS Rx desensitization (3dB) due to Restricted Block TDD interference (ACI mitigation, 10 dB Tx filtering)

The results show that the probability of desensitization for an FDD BS may be up to 26.2% (without mitigation) or 8.3% (with mitigation), when the TDD restricted channel is used indoors in accordance with the restricted channel BEM (according to CEPT Report 019).

As noted in 3.5.2.1, in these restricted channels, BS power is restricted to that of a terminal (25 dBm/5 MHz EIRP) to mimic the interference caused by FDD terminals to the FDD base stations. Therefore similar desensitization effects could result from an FDD mobile station for a given location, transmitting at the same power.

3.5.2.3 In-Band Non-Adjacent Interference

CEPT Report 019 has defined a block edge mask (baseline requirement) of -45 dBm/MHz to ensure the protection of the TDD mobile and base stations as well as the FDD base stations.

The table 21 shows a comparison of the transmission levels beyond 10 MHz from the channel edge derived from the BEM and the spurious emissions defined in ETSI standards [2], [3] and [4].

The table 21 shows that the BS additional spurious emissions defined in the three IMT-2000 systems (UTRA-FDD, UTRA-TDD, OFDM-TDD-WMAN) standards can not reach the WAPECS/BEM requirements for frequency range beyond 10 MHz from the block edge. In order to offer the in-band protection as required by WAPECS/BEM, external filter at BS transmitter is needed not only for the frequency range at the first and second adjacent channels, as described in the section 3.5.2.2, but also for the frequency range beyond 10 MHz from the block edge, the required additional attenuation is between 10 dB and 17 dB for macro cells, depending the equipment used and the antenna gain, as shown in the table 16. The need of external filter covering a wide frequency range from the first adjacent channel to the band edge (2500 MHz) will reduce interference to nearby networks but also increase the network deployment complexity.

	WAPECS/BEM for Unrestricted block	**WAPECS/BEM for restricted and relaxed block**	**UTRA-FDD**	**UTRA-TDD**	**BDTS-TDD**
Beyond 10 MHz from the channel edge	-45 dBm/MHz eirp =-62 dBm/MHz at BS antenna connector	-22 dBm/MHz eirp =-22 to -27 dBm/MHz at BS antenna connector (depending on antenna gain)	-52 dBm/MHz over 2 570-2 610 MHz	-48.8 dBm/MHz over 2 500-2 570 MHz for Wide Area BS -45.8 dBm/MHz over 2 500-2 570 MHz for Local area BS	-45 dBm/MHz over 2 500-2 570 MHz

Table 21

3.5.2.4 Co-siting solutions

To improve the situation in a co-sited scenario one may employ special site engineering methods. One can expect an increased coupling loss compared to the standard assumption of 30 dB which was used in the calculations above.

By following engineering guidelines and separating antennas in the vertical direction, the antenna coupling loss can be increased substantially. For instance, for a vertical separation of three meters it may be possible to increase the coupling loss with 30-35 dB, which gives a total coupling loss of 60–65 dB (see further Annex F of ITU-R M.2113). Note that this benefit only applies to macro base stations, as an additional distance between antennas already has been taken into account above in the case of macro-micro or macro-pico base station interference.

Tables 10 and 11 indicate that roughly speaking the additional protection needed for co-sited macro base stations is 70-80 dB for the 1st adjacent channel and 60-70 dB for the second.
For the 1st adjacent channel the 30-35 dB from special site engineering will thus not be sufficient. However, site engineering together with power restrictions, a “restricted channel” with a maximum EIRP of 25 dBm should be enough. It is however not anticipated that a restricted channel will be used for a macro base station. For the 2nd adjacent channel, site engineering together with either a restricted channel or an additional front-end filter is sufficient. As mentioned above, front-end filters are associated with additional complexity, a decrease in signal quality and insertion losses which lead to decreased quality and coverage. This report has not quantified these effects. However, since the 2.6 GHz band is being made available as a new band, the implementation of such filters would be easier than if they had to be implemented in an existing network. Report ITU-R M.2045 indicates that the insertion loss associated with such a filter would be 2 dB approximately. This will of course affect quality and coverage of the system where the filters are applied.
However, some filter manufacturers have indicated values as low as 0.6 dB that would reduce the effect of desensitization.

3.5.3 Summary of BS-BS Interference

Without additional mitigation measures, several scenarios are associated with severe interference problems, especially those associated with macro-macro deployments. This holds for both co-located and in-proximity scenarios. For a distance of 100m between macro base stations, the excess interference is in the range of 50-60 dB and therefore requires additional measures to be taken. According to the Report ITU-R M.2030, interference problems may occur with distances up to 1000m for adjacent channels with up to 10MHz carrier separation without mitigation techniques.

Using a conservative minimum coupling loss of 30 dB for co-sited macro base stations, for the first adjacent channel an excess interference of more than 70 dB is obtained. For the second adjacent channel, the excess interference will be about 60 dB or higher.

There are a number of actions that can be taken alone or in combination in order to limit the interference between base stations. Note that many of the measures need to be taken in both operators' networks in order to be meaningful. All actions are associated with a level of complexity that must be taken into account as well, as there is always a trade off to consider.

The interference limiting techniques considered here are guard bands, additional front-end filters, restricted channels (applicable to both transmission and reception), deployment restrictions and site engineering (for co-siting). The undesirable consequence of guard bands is that spectrum is not used. Although additional front-end filters are associated with an increased hardware complexity, as well as decreased signal quality and decreased coverage depending upon the insertion loss of the filters, they can minimise guard band requirements. This increased spectrum utility has to be weighed against the impact of deployment restrictions, e.g. a requirement on indoor deployment, which might limit the use of the spectrum for the operator while permitting an operator to make use of a channel that would have otherwise been a guard band.

The figures presented in this report that are extracted from ITU-R Report M.2113 represent worst case antenna configurations; i.e. victim and interferer antennas at the same height and pointing directly at one another. ITU-R Report M.2045 includes the site placement mitigation techniques to improve upon the results obtained within M.2030, and it is essential that these are considered when conducting any interference analysis between two IMT systems within this band. However, the deployment restrictions resulting from such site placement mitigation techniques have to be weighed against the achievable coexistence improvement.
Given that report ITU-R M.2030 showed even a 10 MHz guard band to be insufficient without mitigation techniques or very large separation distances, the use of guard bands, where appropriate, should not be considered in isolation but in conjunction with other solutions such as front-end filters, restricted channels and other techniques addressed in ITU-R Report M.2045. Front-end filters can be expected to suppress the transmission/reception of interference about 50 dB on the second adjacent channel. For the 2nd adjacent channel this gives sufficiently low interference.

To decrease interference on the 1st adjacent channel sufficiently, one may decrease the output power down to 25 dBm/5 MHz EIRP (a "restricted channel") and add additional front-end filtering. To avoid the need of additional filtering, one could place the base station indoors or without line of sight between interfering base stations. If the second channel is restricted to 25 dBm and used indoors, no additional front-end filter is needed.

For co-siting one may use vertical antenna separation to decrease the interference. 3 meters of separation may give 60-65 dB coupling loss, instead of 30 dB which is conservatively assumed. Together with front-end filters (applied to both macro base stations involved) this gives sufficiently low interference for the 2nd adjacent channel, but not for the 1st.

3.6 BS-MS Interference

Interference between BS and MS is similar to that between BS and pico/micro BS in the sense that the propagation is of the same kind. However, it is also important to note the differences. Terminals are mobile and often employ power control with a large dynamic range, which means that interference from them will come and go, whereas interference from a base station will have a more static character.

3.6.1 Results without interference mitigating techniques

Table 22 contains information about interference between terminals and base stations, obtained from a deterministic analysis in Report ITU-R M.2113. For interference between adjacent FDD networks one would obtain similar interference levels, if one assumes that the FDD terminals are transmitting at maximum power, and furthermore have no interference margin. However, this is often not the case in a city environment, with a dense deployment of base stations and terminals that are not noise limited outdoors, resulting in lower terminal power as well as an interference margin.

Deployment scenario		802.16 TDD Fixed SS => UTRA FDD base station	UTRA FDD base station => 802.16 TDD Fixed SS	802.16 TDD Nomadic SS => UTRA FDD base station	UTRA FDD base station => 802.16 TDD Nomadic SS	UTRA FDD mobile station => 802.16 TDD base station	802.16 TDD base station => UTRA FDD mobile station
TDD macro/ FDD macro	1st adj chan	30.1	45.1	23.3	39.3	22.3	32.3
	2nd adj chan	16.1	35.1	6.3	29.3	12.3	2.3
TDD macro/ FDD micro	1st adj chan	56.2	66.2	43.2	54.2	22.3	32.3
	2nd adj chan	42.2	56.2	26.2	44.2	12.3	22.3
TDD macro/ FDD pico	1st adj chan	54.3	46.3	58.3	55.3	22.3	32.3
	2nd adj chan	40.3	36.3	41.3	45.3	12.3	22.3

Table 22 : A summary of the additional isolation needed (in decibels) when considering interference between base stations and mobile stations. Deterministic analysis from ITU-R M.2113 (Table 2.4-4)

It is important to note that these scenarios are particular cases (deterministic analysis) and that they do not represent the average behaviour of the network. However, if these scenarios do occur in deployed networks, the localised performance degradation may be severe. One should note that similar behaviour occurs in uncoordinated UTRA FDD networks operating in adjacent channels, with the creation of dead zones in the vicinity of the other network's base stations.

Since terminals commonly employ power control and since the activity of a terminal will vary considerably over time, it is appropriate to also perform a probabilistic analysis when terminals are involved. Results from both ITU-R M.2030 and ITU-R M.2113 indicate that with a homogeneously distributed terminal population, the system impact is low, as table 23 indicates. Although this is not a very realistic scenario, it is non-trivial to perform a probabilistic study with a heterogeneous terminal distribution due to the lack of available and agreed models for such distributions.

Offset (m)	Coexistence		Additional isolation needed (dB)					
			From 802.16 TDD base station to UTRA FDD mobile station		From UTRA FDD mobile station to 802.16 TDD base station		From 802.16 TDD subscriber station to UTRA FDD base station	From UTRA FDD base station to 802.16 TDD subscriber station
			First adjacent channel	Second adjacent channel	First adjacent channel	Second adjacent channel	Second adjacent channel	Second adjacent channel
0	UTRA FDD standard	802.16 TDD Fixed	0	0	0	0	0	0
		802.16 TDD Nomadic	0	0	0	0	0	0
100	UTRA FDD standard	802.16 TDD Fixed	0	0	0	0	0	0
		802.16 TDD Nomadic	0	0	0	0	0	0
200	UTRA FDD standard	802.16 TDD Fixed	0	0	0	0	0	0
		802.16 TDD Nomadic	0	0	0	0	0	0
300	UTRA FDD standard	802.16 TDD Fixed	0	0	0	0	0	0
		802.16 TDD Nomadic	0	0	0	0	0	0
433	UTRA FDD standard	802.16 TDD Fixed	0	0	0 (1×3×1) 1 (1×3×3)	0	0	0
		802.16 TDD Nomadic	0	0	0 (1×3×1) 1 (1×3×3)	0	0	0
866	UTRA FDD standard	802.16 TDD Fixed	0	0	0 (1×3×1) 2 (1×3×3)	0	0	0
		802.16 TDD Nomadic	0	0	0 (1×3×1) 2 (1×3×3)	0	0	0

Table 23: Additional isolation needed (dB) for coexistence of 802.16 TDD and standard CDMA-DS in the first and second adjacent channel. Probabilistic analysis from ITU-R M.2113 (Table 16 and Table 25)

3.6.2 Results with interference mitigating techniques

Due to the size of terminals, it is not possible to include additional filters to improve selectivity or transmission leakage. Even if filters are implemented in the base station this will not improve the situation substantially, since the ACS of the terminals dominates in the interference analysis. Co-siting of base stations will decrease the likelihood of near-far problems, but this is a solution that may cause difficulties for FDD-TDD scenarios, where there will be BS – BS interference as well. Power control is commonly employed in terminal stations and will decrease interference to base stations considerably.

3.6.3 Summary of BS-MS interference

For the uplink, deterministic analysis show that interference from TDD mobile stations into FDD base stations and from FDD mobile stations into TDD base stations may be severe in particular cases but they do not represent the average behaviour of the network.

It can be mitigated by co-location of base stations or by any of the above mentioned interference mitigating techniques, with the consequence on base station-base station interference as discussed above.
However, a statistical analysis, as mentioned in table 23, shows that the coexistence problems can be alleviated.

For the downlink, Monte Carlo simulations show that for uniformly-distributed outdoor-only users, base station-mobile station interference will have a small or negligible impact on the system capacity when averaged over the system.

3.7 MS-MS Interference

The impact of MS-MS interference can be difficult to ascertain, due to the strong influence of the terminal distribution. It is clear that two terminals in close proximity may interfere with each other strongly, especially when the terminal transmits at full power, i.e when located at the border of the coverage area of their base station. However, it is difficult to determine how often this happens. Consequently, the deterministic analysis found below has been complemented with a qualitative discussion of the relevance of such results. It is essential that when considering MS-MS interference, Monte Carlo analyses must be conducted to capture a more realistic system behavior, and correspondingly to determine levels of interference that will be experienced within a real system. Such analysis would need to include realistic assumptions such as appropriate user distribution (i.e. non uniform), user activity factor, type of services, etc.

3.7.1 Results

The results in Table 24 have been obtained by deterministic analysis in ITU-R M.2113 for a scenario where the terminals are separated by 3.5 meters (for fixed TDD subscriber station to FDD mobile terminal) or 1m (for nomadic TDD subscriber station to FDD mobile terminal), and under the assumptions that both are transmitting at maximum power and that they are noise limited. In such a scenario it is clear that interference between terminals may be strong. In many situations the interference may be less serious, for instance if the terminals are capable of power control, in which case they may transmit with considerably lower power. The results obtained in Report ITU-R M.2030 are very similar, i.e. there may be severe consequences for those subjected to this type of interference, but power control may relieve the situation considerably.

System simulations carried out in both ITU-R studies indicate that system level capacity loss due to MS-MS interference is quite low in scenarios with homogeneously deployed terminals just as for the MS-BS case. However, the assumption of a homogeneously distributed population of terminals means that these results are not entirely realistic in areas where it is common with congregations of active terminals, for instance on buses and trains, in city squares, meeting rooms and shopping malls etc. Statistical results in ITU-R Report M.2113 (Tables 16, 20, 21 and 25) indicate that MS-SS interference is not a concern.

	802.16 TDD Fixed SS => UTRA FDD mobile station	UTRA FDD mobile station => 802.16 TDD Fixed SS	802.16 TDD Nomadic SS => UTRA FDD mobile station	UTRA FDD mobile station => 802.16 TDD Nomadic SS
	Distance = 3.5 m	Distance = 3.5 m	Distance = 1 m	Distance = 1 m
1st adj chan	53.3	53.3	57.3	59.3
2nd adj chan	42.3	43.3	45.3	48.3

Table 24: A summary of the additional isolation needed (in decibels) to protect mobile stations and SSs using standard values. Deterministic analysis from ITU-R M.2113 (Table 2.4-6)

Another aspect that is important to take into account is the possibility of blocking due to interference between terminals. In particular, difficulties may arise as a result of not having a harmonized band plan. If TDD terminals use channels that are within the FDD terminals' pass bands in proximity to FDD terminals then there is a risk for blocking.
The above table shows that a roughly 50 dB isolation is needed to ensure the coexistence. Theoretically, this can be achieved by additional filtering, to improve the ACIR figure. It is noted that improving the ACIR by 50 dB requires improving both the emission filtering (ALCR) and the reception filtering (ACS) by 50 dB.

3.7.2 Summary of MS-MS interference

A deterministic (worst-case) analysis of interference between terminal stations shows that the impact can be severe when they are close to each other. Specifically, for a separation distance of 3.5 m (for fixed TDD subscriber station to FDD mobile terminal) or 1m (for nomadic TDD subscriber station to FDD mobile terminal), an additional isolation of roughly 50 dB is needed. Monte Carlo simulations suggest that interference between terminal stations will have a small or negligible impact on the system capacity when averaged over the system for uniform outdoor-only user densities. Non-uniform user distributions are not studied in this report.

4 CONCLUSIONS

Interference between base stations

Without additional mitigation measures, several scenarios are associated with severe interference problems, especially those associated with macro-macro deployments. Interference is high for both co-located and in-proximity scenarios, when using the parameters of the standards without any interference mitigating techniques.

There are a number of actions that can be taken alone or in combination in order limit the interference between base stations. All actions necessary to avoid implementing a guard band are associated with an increased level of complexity, as there is always a trade off to consider.

The interference limiting techniques considered here are guard bands, additional front-end filters, restricted channels, deployment restrictions and special site engineering (for co-siting case).

The use of guard bands, where appropriate, should not be considered in isolation but in conjunction with other solutions such as additional front-end filters and restricted channels. For the 2nd adjacent channel, additional front-end filters can be expected to give sufficient protection. For the 1st adjacent channel, one may decrease the output power down to 25 dBm EIRP (a “restricted channel”) and add additional front-end filtering. To avoid the need of additional filtering, one could place the base station indoors or without line of sight to the interfered base station, to decrease the interference sufficiently.

For co-siting one may use vertical antenna separation to decrease the interference. Together with additional front-end filters (applied to both macro base stations involved) this gives sufficiently low interference for the 2nd adjacent channel, but not for the 1st.

Interference between base stations and terminals

For the uplink, deterministic analysis show that interference from TDD mobile stations into FDD base stations and from FDD mobile stations into TDD base stations may be severe, in particular cases but they do not represent the average behaviour of the network. It can be mitigated by co-location of base stations or by any of the above mentioned interference mitigating techniques, with the consequence on base station-base station interference as discussed above.
However, a statistical analysis shows that the coexistence problems can be alleviated.

For the downlink, Monte Carlo simulations show that for uniformly-distributed outdoor-only users, base station-mobile station interference will have a small or negligible impact on the system capacity when averaged over the system.

Interference between terminals

A deterministic (worst-case) analysis of interference between terminal stations shows that the impact can be severe when the mobile stations are close to each other. Monte Carlo simulations suggest that interference between terminal stations will have a small or negligible impact on the system capacity when averaged over a system of uniformly-distributed outdoor-only users. Non-uniform user distributions are not studied in this report.

5 REFERENCES

[1] Report ITU-R M.2030, Coexistence between IMT-2000 time division duplex and frequency division duplex terrestrial radio interface technologies around 2600 MHz operating in adjacent bands and in the same geographical area.

[2] .Draft ETSI EN 301 908-3 V3.2.1 (2006-12), Harmonized EN for IMT-2000, CDMA FDD (UTRA FDD) (BS) and ETSI EN 301 908-2 V3.2.1 (2006-12), Harmonized EN for IMT-2000, CDMA FDD (UTRA FDD) (UE).

[3] Draft ETSI EN 301 908-7 V3.2.1 (2006-12), Harmonized EN for IMT-2000, CDMA TDD (UTRA TDD) (BS) and ETSI EN 301 908-6 V3.2.1 (2006-12), Harmonized EN for IMT-2000, CDMA TDD (UTRA TDD) (UE).

[4] Draft ETSI EN 302 544, Broadband Radio Access Networks (BRAN); Broadband Data Transmission Systems in 2500-2690 MHz, Harmonized EN.

[5] CEPT Report 019, Draft Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS.

[6] Report ITU-R M.2116, Characteristics of broadband wireless access systems operating in the land mobile service for use in sharing studies.

[7] Report ITU-R M.2113, Sharing studies in the 2 500-2 690 MHz band between IMT-2000 and fixed broadband wireless access (BWA) systems including nomadic applications in the same geographical area.

[8] 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.

APPENDIX A: TABLES OF CO-EXISTENCE PARAMETERS FOR TDD AND FDD INCLUDING DERIVATION OF NUMBERS BASED ON CEPT REPORT 019

	CEPT Report 019
BS 1st adj ACLR (dB)	Non restricted blocks : Calculated from the BEM (absolute value) = 15,5[4]dBm/5MHz With an EIRP=61 dBm/5 MHz, ACLR = 45,5
	Restricted blocks Calculated from the BEM (absolute value) = -6,5[5]dBm/5MHz With an EIRP=25 dBm/5 MHz, ACLR = 31,5
BS 2nd adj ACLR (dB)	Non restricted blocks : Calculated from the BEM =-45 dBm/MHz =-38 dBm/5 MHz With an EIRP=61 dBm/5 MHz, ACLR = 99
	Restricted blocks Calculated from the BEM (absolute value) = -15 dBm/5MHz With 25 dBm/5 MHz as EIRP, ACLR = 40
MS 1st adj ACLR (dB)	Calculated from the BEM (absolute value) = 1,5[6] dBm/5MHz With TRP = 31 dBm/5MHz, ACLR1 =29.5 With EIRP = 35 dBm/5MHz, ACLR1 =33,5
MS 2nd adj ACLR (dB)	Calculated from the BEM (absolute value) = -10[7] dBm/5MHz With TRP = 31 dBm/5MHz, ACLR1 =41 With EIRP = 35 dBm/5MHz, ACLR1 =45

Table A.1 : TDD parameters used in various contexts

[4] 4 MHz*4 dBm/MHz – 3 dBm/30 kHz*0.8 MHz + 3 dBm/30 kHz*0.2 MHz = 15,5 dBm in 5 MHz
[5] 4 MHz*(-18) dBm/MHz – 25 dBm/30 kHz*0.8 MHz + (-19) dBm/30 kHz*0.2 MHz = -6,5 dBm in 5 MHz
[6] 4 MHz*(-10) dBm/MHz– 15 dBm/30 kHz*1 MHz= 1,5 dBm in 5 MHz
[7] 4 MHz*(-19) dBm/MHz + (-13)dBm/MHz*1 MHz= -10 dBm in 5 MHz

	CEPT Report 019
BS 1st adj ACLR (dB)	Non restricted blocks : Calculated from the BEM (absolute value) = 15,5[8]dBm/5MHz With an EIRP=61 dBm/5 MHz, ACLR1 = 45,5
BS 2nd adj ACLR (dB)	Non restricted blocks : Calculated from the baseline requirement =-45 dBm/MHz =-38 dBm/5 MHz With an EIRP=61 dBm/5 MHz, ACLR2 = 99
MS 1st adj ACLR (dB)	Calculated from the BEM (absolute value) = 1,5 dBm/5MHz [9] With TRP = 31 dBm/5MHz, ACLR1 =29,5 With EIRP = 35 dBm/5MHz, ACLR1 =33,5
MS 2nd adj ACLR (dB)	Calculated from the BEM (absolute value) = -10 dBm/5MHz [10] With TRP = 31 dBm/5MHz, ACLR2 =41 With EIRP = 35 dBm/5MHz, ACLR2 =45

Table A.2: FDD parameters

[8] 4 MHz*4 dBm/MHz – 3 dBm/30 kHz*0.8 MHz + 3 dBm/30 kHz*0.2 MHz = 15,5 dBm in 5 MHz
[9] 4 MHz*(-10) dBm/MHz– 15 dBm/30 kHz*1 MHz= 1,5 dBm in 5 MHz
[10] 4 MHz*(-19) dBm/MHz + (-13)dBm/MHz*1 MHz= -10 dBm in 5 MHz

APPENDIX B : METHODOLOGY TO STUDY TDD BS INTERFERENCE TO FDD BS

This Annex presents a deterministic methodology used to study the interference from a TDD base station (BS) to an FDD base station. For this purpose, the level of isolation, which is required to protect the victim FDD BS receiver from interference caused by the TDD BS, is calculated. Only the far field deployment is addressed where there is no coordination between operators.

The methodology used in the studies is based on minimum coupling loss (MCL) calculations. The assessment criterion is the probability of a victim FDD BS receiver being interfered by the TDD BS transmitter. It is described below how this probability is calculated. The analysis in hand doesn't consider the combined effects of interferer emissions (manifested by ACLR) and the victim sensitivity (manifested by ACS) known as Adjacent Channel Interference Ratio (ACIR) and given by the following equation (in linear terms):

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

Rather, it analyzes the performance of the FDD BS victim receiver (ACS, blocking) and that of the TDD BS interferer transmitter (ACLR, out-of-band emissions) independent from each other. In this way, it is possible to provide a clear picture about the limiting factors in the coexistence scenario, and in addition, to identify on which side, i.e. transmitter or/and receiver, the burden of mitigation techniques should be put. In summary, the methodology consists of two steps:

1. Translate the required MCL isolation into a minimum separation distance required between an FDD BS and a TDD BS at which the interference is at the maximum level by causing an acceptable degradation of the FDD BS performance. The assumptions made to perform these calculations are given below.
2. Establish the probability of the victim FDD BS receiver being interfered by the TDD BS transmitter. This is performed by establishing the likelihood of the TDD BS being closer to the FDD BS than the minimum separation distance calculated above.

B.1: Calculating the minimum separation distance

It is assumed that the level of the TDD BS adjacent channel interference (ACI) is in the order of the thermal noise floor. This results in 3dB FDD BS receiver desensitization. For a UMTS BS, this corresponds to a maximum TDD ACI level –109dBm/3.84MHz.

The maximum transmit power of the TDD BS, denoted by P_{TDD}, is given below according to the CEPT Report 19:

I. P_{TDD} (Restricted 5MHz block) = 25dBm/5MHz (EIRP)

II. P_{TDD} (Unrestricted 5MHz block) = 61dBm/5MHz (EIRP)

III. P_{TDD} (Unrestricted 10MHz block) = 64dBm/10MHz (EIRP)

It is further assumed that antenna gain of the FDD BS is G_{FDD} = 17dBi, where cable loss is included. The antenna gain of TDD BS, G_{TDD}, is already considered in the TDD in-band maximum transmit power P_{TDD} given above. There will be situations in real networks where more than one interfering site will be present, however it is assumed in the present studies that only one interfering site will be dominant.

The BS OOB mask defined in the CEPT Report 19 is used in the present studies to obtain the adjacent channel interference power, P_{INT}, as seen by the victim FDD BS. P_{INT} is determined for the cases that TDD BS is operating in the first adjacent 5MHz restricted block or in the second TDD adjacent 5MHz/10MHz unrestricted block. The calculation of P_{INT} takes the FDD BS receiver filter bandwidth into account. ACLR of the TDD BS can be calculated from the maximum transmit power of the TDD BS and the TDD BS interference power in the FDD BS channel as follows, however this figure is not of direct interest here:

$$ACLR = P_{TDD} - P_{INT} \ .$$

The MCL isolation required to protect the FDD BS receiver can be calculated from the TDD BS interference power in the FDD BS channel and the maximum allowable ACI:

$$MCL = P_{INT} - \max ACI \ .$$

It should be noted that the TDD BS transmit filter attenuation (ACLR) is implicitly considered in the above equation. To calculate the required path loss for the far-field deployment, denoted by PL_{FF}, the antenna gain of the FDD BS should be added to the MCL isolation:

$$PL_{FF} = MCL + G_{FDD} \ .$$

The minimum separation distance, R_{min}, required between FDD BS and TDD BS is calculated according to the dual-slope path loss model defined below (log-normal shadowing is not taken into account):

$$PL_{DS}(r) = \begin{cases} PL_{FS}(r) = 32.45 + 2 \cdot 10 \cdot \log_{10}(r_{km}) + 2 \cdot 10 \cdot \log_{10}(f_{MHz}) & r < r_B \\ PL_{FS}(r) + K \cdot 10 \cdot \log_{10}(r / r_B) & r \geq r_B \end{cases} ,$$

where:

PL_{DS}: Dual-Space median path loss,

PL_{FS}: Free-Space median path loss for line of sight between transmitter and receiver

r: Separation distance between transmitter and receiver,

r_B: Breakpoint after which it is less likely to be line of sight between transmitter and receiver, here assumed to be 200m

K: The slope of path loss model for the non-line of sight portion, here assumed to be 4.

B.2: Establishing the probability of interference

As pointed out before, the metric to assess the interference impact is the probability of interference. This probability gives the likelihood that the FDD BS receiver is 3 dB desensitized. The minimum separation distance obtained above, R_{min}, is used to calculate the probability of interference. This is performed by establishing the likelihood of a TDD BS interferer being closer to a FDD BS than R_{min}.

Different outdoor deployment scenarios are considered here. It is assumed, that urban, suburban and rural networks consist of hexagon cells with a maximum radius of R_{max} and the BS located in the center of the hexagon. For road and rail coverage it is assumed that BSs are located on a line parallel to the route with an inter-base-station distance $2R_{max}$. The radiuses of different cell types are summarised in Table B.1.

It is assumed that each FDD BS will have at least one TDD BS within its coverage area. This is based on the fact that the relative BS densities of TDD and FDD systems are similar if the same frequency band is used. In addition, there is an even probability of an interfering TDD BS being located at any point within the coverage area of the victim FDD BS for a far field uncoordinated network deployment. For urban, suburban and rural cells, the probability of a TDD BS being within a particular radius from a FDD BS is proportional to the area covered by that radius. More precisely, the probability that the FDD BS is interfered corresponds to the probability that a TDD BS lies within a hexagon of radius R_{min}. This is equal to the ratio of the area of the hexagon with this radius to the area of the hexagon with $r = R_{max}$. Because of the congruence of concentric hexagons, the probability is simply given by $Pr = (R_{min} / R_{max})^2$.

For road and rail coverage it is assumed that there is a uniform probability that the dominant interfering TDD BS is located at a point alongside the line covered by the victim FDD BS. The probability that the interferer is located at distance R_{min} or less from the victim FDD BS is simply the ratio of R_{min} to the cell radius of the FDD BS, i.e. $Pr = (R_{min} / R_{max})$.

Network cell type	Cell radius R_{max} (m)
Urban	790
Suburban	2350
Rural	7770
Rural road/rail	7770

Table B.1: FDD network outdoor cell types with corresponding cell radius

APPENDIX C - ABBREVIATIONS

ACIR	Adjacent Channel Interference Ratio
ACLR	Adjacent Channel power Leakage Ratio
ACS	Adjacent Channel Selectivity
BDTS	Broadband Data Transmission Systems
BEM	Block Edge Masks
BER	Bit error ratio
BRAN-TDD	Broadband Radio Access networks
BS	Base station
C/I	Carrier to Interference ratio
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CDMA DS	Code Division Multiple Access
CEPT	European Conference of Postal and Telecommunications Administrations
ECC	Electronic Communications Committee
EIRP	Effective isotropic radiated power
EN	European norm
EPFD	Equivalent Power Flux Density
ETSI	European Telecommunications Standards Institute
ETSI BRAN	ETSI - Broadband Radio Access networks
ETSI TFES	ETSI Task Force for ERM and MSG for Harmonised Standards for
FDD	Frequency Division Duplex
I/N	Interference to Noise ratio
IMT	International Mobile Telecommunications
ITU-R	International Telecommunication Union
LoS	Line of Sight
MAI	Maximum Allowed Interference
MCL	Minimum Coupling Loss
MS	Mobile station
OFDM-TDD-WMAN	OFDM-TDD-Wireless metropolitan area network
PSD	Power Spectral Density
RC	Restricted Channel
S/N	Signal to Noise ratio
TDD	Time Division Duplex
TD-SDCMA	Time Division-Synchronous Code Division Multiple Access
TRP	Total Radiated Power
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
URC	Unrestricted Channel
UTRA	UMTS Terrestrial Radio Access
WAPECS	Wireless Access Policy for Electronic Communications Services
WCDMA	Wideband CDMA
WRC-07	World Radio Conference - 2007
WRC-2000	World Radio Conference - 2000