Description of scenario (+prop. Model)	Carrier separation MHz	Tx power dBm	Practical antenna gain dBi	ACIR dB	Accepted level of I_{ext} at Rx dBm	Required pathloss dB	Required separation distance m	Required additional isolation
TDD macro to FDD macro (LOS)	3.5 MHz	34	15+15-6=24	45	–106	140	2.7k	40.9 (YES)
TDD macro to FDD micro (NLOS)	3.5 MHz	21	15+6-3=8	45	–97	131	44.7	-1.6 (NO)
TDD macro to FDD pico	3.5 MHz	12	15+0-10=5	45	-91	125	9.8	-9.3 (NO)
TDD micro to FDD macro	3.5 MHz	34	6+15-13=8	45	–106	125	31.6	-7.6 (NO)
TDD micro to FDD micro	3.5 MHz	21	6+6=12	45	–97	116	23.7	-11.4 (NO)
TDD micro to FDD pico	3.5 MHz	12	6+0=6	45	-91	110	3.3	-23.3 (NO)
TDD pico to FDD macro	3.5 MHz	34	3+15-10=8	45	–106	116	6.2	-15.3 (NO)
TDD pico to FDD micro	3.5 MHz	21	3+6=9	45	–97	107	3.3	-23.3 (NO)
TDD pico to FDD pico	3.5 MHz	12	3+0=3	45	-91	101	1.3	-35.3 (NO)

4.2.1.4 Co-location scenarios for WCDMA/3.84 Mchip/s TDD

This § describes and quantifies different sources of interference between adjacent-band FDD and TDD systems when the two systems base stations are collocated. Specifically, this contribution accounts for interference into an FDD base station receiver from a collocated TDD base station transmitter, and interference into a TDD base station receiver from a collocated FDD base station transmitter.

Collocation of multiple operators on the same tower or building is a common practice that will become more prevalent in future systems as the number of operators increases and more cell density is required for greater coverage and capacity. Because of deployment constraints, site acquisition difficulties, and other logistical and engineering issues, it is highly likely that WCDMA TDD and PDD sites would be co-sited (i.e. collocated).

The maximum allowed interference for receiver desensitization is defined by

$$\textbf{MAL\_Desen (dBm)} = \text{Noise floor (dBm)} + \text{Receiver Noise Figure} - 6\ \text{dB}$$

TABLE 29

Calculated thresholds for maximum allowable interference level for receiver desensitization

System	Noise floor	Rx noise figure	MAI (desen)
WCDMA TDD	–108 dBm	5 dB	–109 dBm
WCDMA FDD	–108 dBm	5 dB	–109 dBm

Int@_Rcvr = C_Tx_ – ACIR - MCL

where:

- **Int@_Rcvr** = Affected interference at the receiver input port of the interfered system (dBm)
- C_TX_ = Nominal maximum carrier power level at the TX amplifier output (dBm)
- ACTR = 1/(1/ACS+1/ACLR)
- MCL = Minimum coupling loss (dBm) = 30 dB.

Table 30 shows interference calculations on both WCDMA and 3.84 Mchip/s TDD with carrier separations of **5**, 10, and 15 MHz. In all cases the MAI of –109 dBm is exceeded

TABLE 30

Calculated values of interference between TDD and FDD systems

Interfered system	C_Tx_	ACS of RX	ACLR of TX	ACIR	Int@_Rcvr	Threshold exceeded (–109 dBm)
WCDMA TDD	43 dBm	46 @ 5 MHz	45 @ 5 MHz	42.46	–29.46 dBm	Yes
WCDMA TDD	43 dBm	58 @ 10 MHz	50 @ 10 MHz	49.36	–36.36 dBm	Yes
WCDMA TDD	43 dBm	66 @ 15 MHz	67 @ 15 MHz	63.46	–50.46 dBm	Yes
WCDMA FDD	40.2 dBm	46 @ 5 MHz	70 @ 5 MHz	45.98	–35.78 dBm	Yes
WCDMA FDD	40.2 dBm	58 @ 10 MHz	70 @ 10 MHz	57.73	-47.53 dBm	Yes
WCDMA FDD	40.2 dBm	66 @ 15 MHz	70 @ 15 MHz	54.34	–54.34 dBm	Yes

NOTE - TDD basestation TX output Power = **43** dBm
TDD basestation activity factor = –2.8 dB
C_Tx_ = **43** +(–2.8) = 40.2 for FDD TX power.

Receiver overload

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).

$$\text{MAI\_Over} = 1\text{ dB Compression Point} - \text{Safety Margin}$$

A blocking value of −40 dBm is used as specified in 3GPP. The total received carrier power is defined by

$$\text{C\_RX\_} = \text{C\_TX\_} - \text{ACIR} - \text{MCL}$$

where:

- **C_RX_** = Total carrier power received at input port of the interfered station (dBm)
- MCL = Minimum Coupling Loss (dBm) = 30 dB
- C_Tx_ = Total carrier power transmitted at the output port of the interfering station (dBm)
- ACIR = 1/(1/ACS+1/ACLR).

Using these parameters, the following is obtained:

TABLE 31

Computed values showing interference at the RX of the interfered system

Interfered system	C_Tx	ACS of RX	ACLR of TX	ACIR	C_RX	MAI_Over threshold exceeded? (−40 dBm)
WCDMA TDD	43 dBm	46 @ 5 MHz	45 @ 5 MHz	42.46	−29.46 dBm	Yes
WCDMA TDD	43 dBm	58 @ 10 MHz	50 @ 10 MHz	49.36	−36.36 dBm	Yes
WCDMA TDD	43 dBm	66 @ 15 MHz	67 @ 15 MHz	63.46	−50.46 dBm	No
WCDMA FDD	40.2 dBm	46 @ 5 MHz	70 @ 5 MHz	45.98	−35.78 dBm	Yes
WCDMA FDD	40.2 dBm	58 @ 10 MHz	70 @ 10 MHz	57.73	−47.53 dBm	No
WCDMA FDD	40.2 dBm	66 @ 15 MHz	70 @ 15 MHz	54.34	−54.34 dBm	No

4.2.1.5 Supportable path loss under alternative BS-BS interference evaluation

Table 3 below lists the supportable MS-BS path loss at the edge of a cell under the BS-BS interference evaluation described in § 3.2.2 limited by MS output power and **the** C/I requirement of the particular service. Table 32 shows the supported cell range for worst case tilting of the base station antennas. Table 32bis shows the same under practical antenna tilting (for macro **to** micro or micro to macro BS interference cases). Depending on the envisioned path loss models and the operator requirements this may or may not correspond to acceptable cell sizes.

$$MAI\_Over = 1\ dB\ Compression\ Point - Safety\ Margin$$

A blocking value o f 4 0 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)
MCL = Minimum Coupling Loss (dBm) = 30 dB
C_TX_ = Total carrier power transmitted at the output port of the interfering station (dBm)
ACIR = 1/(1/ACS+1/ACLR).

Using these parameters, the following is obtained:

TABLE 31

Computed values showing interference at the RX of the interfered system

Interfered system	**C_Tx**	**ACS of RX**	**ACLR of TX**	**ACIR**	**C_RX**	**MAI_Over threshold exceeded? (–40 dBm)**
WCDMA TDD	43 dBm	46 @ 5 MHz	45 @ 5 MHz	42.46	–29.46 dBm	Yes
WCDMA TDD	43 dBm	58 @ 10 MHz	50 @ 10 MHz	49.36	–36.36 dBm	Yes
WCDMA TDD	43 dBm	66 @ 15 MHz	67 @ 15 MHz	63.46	–50.46 dBm	No
WCDMA FDD	40.2 dBm	46 @ 5 MHz	70 @ 5 MHz	45.98	–35.78 dBm	Yes
WCDMA FDD	40.2 dBm	58 @ 10 MHz	70 @ 10 MHz	57.73	–47.53 dBm	No
WCDMA FDD	40.2 dBm	66 @ 15 MHz	70 @ 15 MHz	54.34	–54.34 dBm	No

4.2.1.5 Supportable path loss under alternative BS-BS interference evaluation

Table **3** below lists the supportable MS-BS path loss at the edge of a cell under the BS-BS interference evaluation described in § 3.2.2 limited by MS output power and the C/I requirement of the particular service. Table 32 shows the supported cell range for worst case tilting of the base station antennas. Table 32bis shows the same under practical antenna tilting (for macro to micro or micro to macro BS interference **cases).** Depending on the envisioned path loss models and the operator requirements this may or may not correspond *to* acceptable cell **sizes.**

BS-BS Scenario	Carrier spacing	Supported cell range (dB path loss) TDD BS ACLR assumptions: set 1 (see Table 17BIS)	Supported cell range (dB path loss) TDD BS ACLR assumptions: set 2 (see Table 17BIS)
TDD micro →FDD macro	5 MHz	124.2	127.7
	10 MHz	134.8	139 3
	15 MHz	145.5	145.5
FDD macro →TDD micro	5 MHz	90.2	NA
	10 MHz	100.9	
	15 MHz	111.2	
TDD micro →FDD micro (LOS)	5 MHz	117.3	120.7
	10 MHz	127.9	132.3
	15 MHz		
TDD micro→ FDD micro (NLOS)	5 MHz	133.9	137.0
	10 MHz	142.0	143.7
	15 MHz	144.7	144.7
FDD micro →TDD micro (LOS)	5 MHz	105.3	NA
	10 MHz	115.9	
(NLOS)			
	10 MHz	130.0	
	15 MHz	**132.6**	

TABLE 32BIS

Supported cell range under practical antenna **tilting**

BS-BS Scenario	Carrier Spacing	Supported cell Range (dB path loss) TDD BS ACLR assumptions: set 1 (see Table 17A)	Supported cell Range (dB path loss) TDD BS ACLR assumptions: set 2 (see Table 17A)
TDD micro →FDD macro	5 MHz	137.1	140.5
	10 MHz	146.9	150.1
	15 MHz	152.9	152.9
FDD macro →TDD micro	5 MHz	103.2	NA
	10 MHz	113.8	
	15 MHz	123.7	

4.2.2 Results from Monte Carlo simulations

4.2.2.1 Capacity consequences in FDD macro/3.84 TDD micro and FDD micro/3.84 TDD micro scenarios

FDD macrn – TDD micro

TABLE 33

MS-to-BS interference (uplink)

Aggressor		
TDD MS	FDD BS	< 1
FDD MS	TDD BS	<1

TABLE 34

Aggressor	Victim	Capacity loss (%)
TDD BS	FDD MS	1
FDD BS	TDD **MS**	*4*

TABLE 35

MS-to-MS interference (downlink)

Aggressor	Victim	Capacity loss (%)
TDD MS	FDD MS	< 1
FDD MS	TDD MS	2

FDD micro - TDD micro

TABLE *36*

MS-to-BS interference (uplink)

Aggressor	Victim	Capacity loss (%)
TDD **MS**	FDD BS	1
FDD **MS**	TDD BS	< 1

Aggressor	Victim	Capacity loss (%)
TDD **BS**	FDD MS	< I
FDD BS	TDD MS	1

TABLE 38

Aggressor	Victim	Capacity loss (%)
TDD MS	FDD MS	< 1
FDD MS	TDD MS	1

Further Studies

Until now, all evaluations have been performed in a Manhattan environment and for symmetric (circuit-switched) services. **All** users have been located outside. These are particularly beneficial scenarios.

Further studies of interest are e.g. to investigate other environments, like the indoor environment. Indoor coverage should also be studied to see how this affects the performance. Other types of services, e.g. asymmetric, packet-oriented services might also be of interest.

4.2.2.2 Capacity consequences in FDD macro/3.84 TDD macro and FDD macro/1.28 TDD scenarios

In the following the results are summarized.

Interferer/Victim	Macro vs. Macro	Micro vs. Micro	Pico vs. Pico	Macro vs. Micro
FDD MS / TDD BS	< 4%	< 1%	**< 2%**	< **1%**
FDD **MS** / TDD MS	< 5%	< 1%	< 4%	< 1%
TDD MS / FDD BS	< 4%	< **1%**	**< 1%**	< 1%

TABLE 40

1.28 Mchip/s TDD/FDD

Victim (receiver)	**Interferer (transmitter)**	**Rel. capacity loss**
FDD BS	1.28Mchip/s TDD MS (cluster = 1)	<2%
1.28Mchip/s TDD BS (cluster= 1)	FDD MS	<2%
1.28Mchip/s TDD MS (cluster= 1)	FDD **MS**	<2%
1.28Mchip/s TDD MS cluster = **3)**	FDD **MS**	<3%

4.2.2.3 Outage consequences due **to MS-to-MS** interference in **FDD/3.84 Mchip/s TDD** scenarios

The following §s present the calculated level of outage in two distinct ways. Firstly the results are given for uniformly spatially distributed FDD terminals, which shows the effect of increasing the density of FDD terminals over a cell.

Secondly the results are shown for the level of outage occurring when there are fixed separation distances between an FDD and TDD terminal, whilst the distance for each terminal to its respective base station is varied. The results presented illustrate the distance for which the level of interference becomes significant.

4.2.2.3.1 **FDD** macro **- TDD** macro

Table **41** and Table 42 show the results **for** the FDD macro to TDD macro interference scenario.

The maximum number of speech users per sector for FDD is assumed to be 50. For a cell radius of 0.5km this corresponds with a density of 191 users per square kilometre. Other densities are also included to simulate cells that are not fully loaded.

TABLE 41

Interference probability for different interferer densities

Carrier separation (**MHz**)	**5**	**10**
Interferer density (1/km^2)		
50	< 1%	< 1%
100	1%	< 1%
191	1%	< 1%

TABLE **42**

Interference probability for different separation distances

Carrier separation (MHz)	**5**	**10**
1	**24%**	**10%**
3	9%	3%
10	2%	1%
30	1%	< 1%
100	< 1 %	< 1%

4.2.2.3.2 FDD macro – TDD pico

For the FDD macro to TDD pico interference scenario the results are shown in Table **43** and Table 44.

The interference probability for this case is higher than for the TDD macro case. It **is** likely that this is caused by low signal strengths for the desired TDD signal, as the e.i.r.p. of the base station is low and the indoor path loss is high. Additionally, the power controlled transmit power of the FDD mobile terminal will be high, as the path loss to the outdoor base station **will** be high.

TABLE 43

Interference probability for different interferer densities

Carrier separation (MHz)	**5**	**10**
Interferer density (1/km^2)		
50	3%	3%
100	**4%**	3%
191	*1%*	**4%**

Carrier separation (MHz)	**5**	**10**
Separation distance (m)		
1	*13%*	**54%**
3	**54%**	**34%**
10	***18%***	***8%***
	3%	2%

4.2.3 Results from deterministic MS-to-MS interference calculations

Normally, the average capacity loss due to MS-to-MS interference will be small. However, for the ***individual*** **MS**, the effect of MS-to-MS interference may he severe, and coverage may he even lost. The impact depends on many parameters of which some are listed below:

Distance between the two MSs.

Transmission power of the interfering MS

Position in the cell (of the affected MS).

Effects of MS-to-MS interference is normally only noticed when the distance between the MSs is very small. However, if the distance is small, it is a high probability of LOS between the terminals which results in a small pathloss.

The transmission power of the interfering MS depends on the deployment scenario (e.g. in average, the transmission power is higher in a macro scenario where the cells are large compared to a micro scenario with small cells) and the load in the system.

Finally, the effect is smaller if the affected MS is close to its base station. Then, the BS may have a margin to increase the DL power to overcome the interference.

Using the same *methodology* as for the BS-to-BS cases, but using the MS parameters, the relationship between total noise in the MS and the distance between the mobiles have been calculated for different values of aggressor transmission powers.

Figure 8 shows the distance versus the total noise floor N_{tot} in the case of interference from a TDD MS to a FDD MS. LOS propagation is assumed. **A** small separation distance together with a high TDD MS transmission power make N_{tot} high (compare with the noise floor at the MS, –99 dBm). I-lowever, it is difficult to predict the consequence of the increased noise floor since it depends on many different parameters.

However, a large increase of the noise floor (high value of N_{tot}) for which the BS cannot compensate by means of an increased output power, the consequence for the interfered **MS** is lost coverage.

Note that the curves are calculated assuming certain instantaneous transmit powers. For TDD which is active 1/15 (-1 1.8 dB) of the time with the speech service in our example, an *instantaneous* value of –10, 0 or 10 dBm, correspond to a *time averaged* value of –21.8, -11.8, and –1.8 dBm, respectively. For the FDD systems, the average and instantaneous powers are the same.

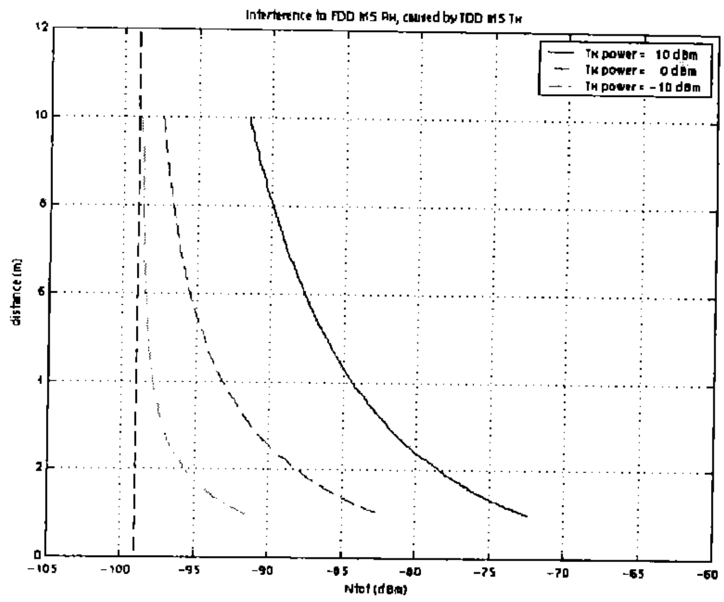

FIGURE 8

Figure 9 shows the opposite situation, i.e. a TDD MS interfered by **a** FDD MS. Because of the higher activity factor of the FDD MS, the effect **is** larger compared to the previous case.

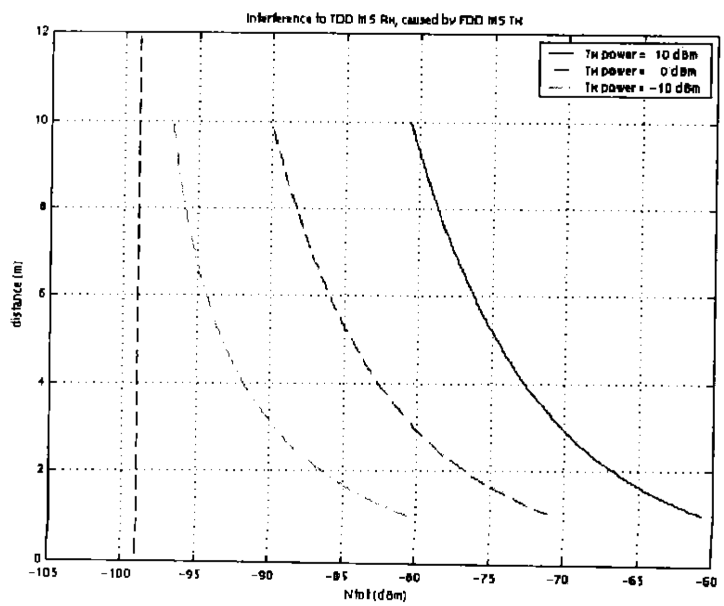

FIGURE 9

It is not difficult to imagine common scenarios where small distances between mobiles combined with medium to high powers and medium to **large** distances to serving **BS** will cause dramatic increases in total noise floor (up to 20-25 dB increase) which the BS cannot compensate, Two mobiles in a bus or a train connected to outdoor micro or macro base stations will likely qualify. The extra interference will often be more tban enough to make the victim MS loose the connection.

It seems that the MS-to-MS interference will have severe consequences for those users that experience it, while other users will not experience any degradation at all.

5 Conclusions

The feasibility of certain scenarios is subject to a trade off between technical, regulatory and economical factors. In the document, 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 document.

BS-BS: General observations

- Several scenarios and parameter settings examined are associated with severe interference problems
- The separation distances have been calculated over an interval of tolerated external interference where the smaller value for separation distance implies high levels of planned tolerated external interference which in turn implies smaller coverage and/or capacity and higher transmit powers for the MS in the victim system.
- There is no fundamental difference in magnitude of interference when considering FDD DL to TDD UL interference or when considering TDD DL to FDD UL for any of the examined scenarios.
- Thus, the potential problems come from the basic fact that DL transmitters are geographically and spectrally close **to** sensitive **UL** receivers, regardless of the duplex method involved.
- Minimum requirements available in 3GPP specifications on transmitter and receiver characteristics are assumed to the maximum extent possible. It could be noted that practical equipment may be better than required in the specifications.
- For scvcral scenarios large values of separation distances or additional isolation are needed to obtain low interference conditions (§ 4.2.1.1, 4.2.1.2). Some scenarios have low separation distances and do not require additional isolation.
- In some deployment scenarios separation distances can be traded off against coverage and higher MS transmit powers in the victim system. (see § 4.2.1.4)

BS-BS in proximity: WCDMA/3.84 Mchip/s TDD (See § 4.2.1.1)

TABLE 45

BS-BS: WCDMA/3.84 Mchip/s TDD

Scenario	Carrier separation MHz	Required separation distance TDD to FDD m	Required separation distance FDD to-TDD m	Reference separation distance m	Required additional isolation dB
Macro-to-macro (LOS)	5-15	2136-9541	2689-14275	100	+49,3
				50	+20.4
Micro-to-micro (LOS)	5	130-290	290-650	50	+8.3
	10	33-73	130-290	50	
	15	16-37	26-60	50	
Micro-to-micro(Ped)	5	33-52	52-80	50	+8.3
				50	-
				100	-
Pico-to-macro (Out-to-Ind)	5-15	15-65	11-58	50	-
Pico-to-micro (Out-to-Ind)	5-15	3-15	6-31	20	-12.4
Micro-to-pico (Out-to-Ind)	5-15	4-10	5-25	20	-11.4
Pico-to-pico (LOS)	5-15	1-9	2-7	10	-0.7
Pico-to-pico **(Indoor)**	5-15	I	1	10	-25.3

The separation distances have been calculated with antenna **gains** given in Table C.1 **in** Appendix C. Table 45 is a sample of results compiled from Tables 24 and 25 in § 4.2.1.1. Please refer **to** these tables for the complete set of results.

BS-BS in proximity: WCDMA/1.28 Mchip/s TDD (See § 4.2.1.3)

TABLE 46

Scenario	Carrier separation MHz	Required additional isolation (dB) or not	Reference separation distance m	Required separation distance m
Macro-to-micro	3.5	-1.6(NO)	50	44.7
Macro-to-pico	3.5	-9.3(NO)	20	9.8
Micro-to-macro	3.5	-7.6(NO)	50	31.6
Micro-to-pic0	3.5	-23.3(NO)	50	3.3
Pico-to-macro (Out-to-Ind)	3.5	-15.3(NO)	10	6.2
Pico-to-micro (Out-to-Ind)	3.5	-23.3(NO)	50	3.3
Pico-to-pico(Ind-to-Ind)	3.5	-35.3(NO)	10	1.3

BS-BS co-location: WCDMA/3.84 Mchip/s (See § 4.2.1.4)

- Co-location of base stations will be prevalent in future systems
- When WCDMA and 3.84 Mchip/s macro base stations are co-located the noise floor of both systems are impacted considerably when considering a 30 dB coupling loss
- Coverage and capacity will be severely affected, if appropriate isolation is not provided between the base stations.
- Based on the existing specifications and Minimum Coupling Loss (MCL) assumptions, even a guard band of 5 MHz and 10 MHz will not remove the problem.
- Continued studies must define needed system specifications and guard bands, as appropriate, considering base station co-location, taking into consideration the fact that some degree of isolation may be achieved in practical systems.

Solution proposals for BS-BS interference

There are a number of basic actions that can be taken alone or in combination in order to combat the BS-BS interference problems. **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.

- Higher performance filters at both transmitter and receiver side.
- 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.
- Appropriate guard bands will need to be considered for several scenarios to allow for flexibility of deployment
- Low power operation of interfering systems reduces the problem but also reduces coverage and flexibility of deployment.
- The exact values of guard bands, filter requirements, etc., will depend on a number of factors and a definitive answer is not given in this document.

- Planning for a higher interference level at the BS receiver taking into account the necessary trade-offs. These include some limits on cell size and the higher mobile transmit power in the victim system and the consequences of these.

MS-BS, BS-MS interference

- For the studied Manhattan scenarios with uniformly distributed outdoor-only users, Monte Carlo simulations suggest that MS-BS, BS-MS interference will have a small or negligible impact on the capacity when averaged over the system.

MS-MS interference

- The Monte Carlo simulations suggest that MS-MS interference will have a small or negligible impact on the capacity when averaged over the system and using uniform user densities (see § 4.2.2.3).
- Deterministic MS-MS calculations suggest that one mobile might create severe interference to another geographically and spectrally close mobile (see § 4.2.3).
- Studies are therefore needed where non-uniform user densities are considered, which are more realistic in real systems in hot spot areas. (see § 4.2.3)
- The outage cannot be reduced much even at the cost of BS density or capacity decrease. Instead, the requirements should he set on the service level.

References

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(2) 3GPP TS 25.105 v3.4.0, "UTRA (BS) TDD; Radio transmission and Reception"

(3) 3GPP TS 25.101 v3.4.0, "UE Radio Transmission and Reception (FDD) "

(4) 3GPP TS 25.102 v3.4.0, "UTRA (UE) TDD; Radio Transmission and Reception"

(5) Recommendation ITU-R M.1225, "GUIDELINES FOR EVALUATION OF RADIO TRANSMISSION TECHNOLOGIES FOR IMT-2000", 1997

(6) 3GPP TR 25.942 v2.1.3 "RF System Scenarios"

(7) Harri Holma, Antti Toskala. WCDMA for UMTS- Radio Access for Third Generation Mobile Communications, John Wiley & Sons, 2000.

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(10) R4-00TDD054 "Simulation assumptions for 1.28 Mchip/s TDD performance requirements", CWTS and Siemens.

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(17) ITU 8F/184, Annex 4 to Attachment 6, Investigation of coexistence between IMT-2000 FDD and TDD radio interfaces

(18) Recommendation ITU-R M.1225, Guidelines for evaluation of radio transmission technologies for IMT-2000

(19) 3GPP TR25.945 v4.0.0, RF requirements for 1.28Mchip/s UTRA TDD option

(20) 3GPP TS25.104 v3.5.0, UTRA (BS) FDD; Radio transmission and reception

(21) 3GPP TR25.942 v2.3.0, RF System Scenarios

(22) 3GPP RAN4#13 meeting Tdoc, R4-00-0607, Siemens, Coexistence Investigations related to 1.28Mchip/s TDD: First Results

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(24) Theodore S. Rappaport, "Wireless Communications - Principles and Practice", Prentice Hall PTR, 1996

APPENDIX A

ACLR, ACS and ACIR

ACLK Adjacent channel leakage power ratio

ACS Adjacent channel selectivity

AClR Adjacent channel interference power ratio

The **ACLR** is the relation between the power transmitted in the own carrier and the power leaking out in the neighboring frequency bands. **ACLR** is thus a measure of the transmitter performance.

Likewise, **ACS** is a measure of the receiver performance. The **ACS** is the suppression of the adjacent channel power (in relation to the power in the own channel).

Together, the **ACLR** and the **ACS** form the protection for adjacent channel interference, The protection is called ACIR and is defined as:

$$AClR = \frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}}$$

where the **ACLR** and the **ACS** are expressed as a ratio and not in dB.

To meet a specific **AClR** requirements, both the **ACLR** and the **ACS** have to be larger than the **ACIR.** If the **ACLR** and the **ACS** are equal, they have to be twice as big as the **ACIR (3** dB if expressed in dB).

APPENDIX B

Derivation of the dual-slope LOS propagation model

The model is constructed as follows:

We assume free space propagation for small distances d- Using equations 3.3 and 3.6 in (24) with f=2.6 GHz gives a path loss of $40.7 + 20 \cdot \log_{10}(d)$ with unit antenna gains.

- At large distances for the reflective model the distance dependency is $40 \cdot \log_{10}(d)$ (see (24), page 89)
- The ground appears in the first Fresnel zone at Fresnel distance (see (24) page 89): $d_{break} = 4 \cdot \frac{h_{tx} \cdot h_{rx}}{\lambda}$

  It is well known that up to the Fresnel distance free space propagation is valid
- A conservative estimate of the break point is to set it equal to the Fresnel distance
- Combining the above gives the dual slope LOS model used.

In reality the attenuation parameter is starting to continuously vary from '20' at the Fresnel distance to be ultimately '40' for sufficiently large distances. By introducing one single break point at the Fresnel distance as above we *overestimate the propagation loss* for distances above the **break** point.

Hence, above the break point the interference power **is** *underestimated* at the victim receiver side Since the model in this report is used for interference studies it can be seen as a very conservative model.

For example in MS-MS scenarios, the distances are well below the break point and the model corresponds to free space propagation.

APPENDIX C

Practical antenna gain of antennas of the interfering station and the victim

There are two main opinions on the practical gain of antennas of the interfering station and the victim.

1) The simple sum of the maximum gain of antennas of the interfering station and the victim is thought to be the practical contributing gain (see I).

2) The practical gain of the antennas is thought to be gain at the direction between the two antennas (see 2 and **3,** where vertical antenna patterns are different).

1 Sum of the maximum gains of antennas of the interfering station and the victim

In general, the resulting antenna gain is dependent on the antenna gain of the transmitter and the receiver as well as the direction of the transmitting and receiving antenna.

If the antennas are located on the same level (height), the resulting antenna gain is assumed to be the sum of the Tx and Rx antenna gains. However, if the heights of the antennas differ significantly, the resulting antenna gain is the gain of the highest located antenna. The resulting antenna gains between different combinations of base stations are presented in Table C.1 (the **Tx** and the Rx antenna gain at a BS is equal). The height of a macro base station is 30 m and the height of a micro and a pico base station is 6 m above the ground. Thus, micro and pico base stations are located at the same height. Macro base stations are located above both the micro and the pico base station.

The table below is valid for both the 1.28 Mchip/s and 3.84 Mchip/s TDD systems.

TABLE C.1

Resulting antenna gain

	FDD macro BS (15 dBi)	**FDD micro** BS(6 dBi)	**FDD pico BS (0 dBi)**
TDD macro **BS**	30	15	15
TDD micro BS	15	12	6
TDD pico BS (0 dBi)	15	6	0

2 Sum of the gains of antennas at the directions of the interfering station and the victim (vertical antenna pattern defined by the 3dB and 10dB angle).

In the following, macro-micro scenarios are employed to analyze the contributing gain of antennas in the practical network.

The practical antenna-to-antenna isolation is a function of the inclination angle, the vertical beam width, and the antenna gain. In practice, to reduce the inter cell interference, the main lobe of antenna is inclined to a given angle, the inclination angle of antenna is affected by the height of antenna, the radius of **cell** and the vertical beam width, and so on. [14]

On the coexistence between TD-SCDMA and FDD systems in adjacent bands and in the same area, the antenna gain is dependent on the directivity diagram of antenna of the interfering station and the victim as well as the inclination angle of both antennas.

Antenna beam width

The 3dB power beam width, θ, of antenna can be estimated as follows:

$$\theta = 180/G$$

Where, G is the maximum gain of antenna.

For engineering calculation, the 10dB power beam width of antenna can be roughly estimated as 2θ.

Practical antennas gain between macro and tbe micro base station.

For the scenarios of micro to macro, the heights of the antennas differ significantly; the practical antenna gain **of** both systems should be calculated with the sum of the **Tx** and Rx antenna gains along the direction from the macro base station to the micro base station, **as** shown in Figure 3.

Assumptions:

Reference separation distance:	D=50 m
Micro BS **Tx** antenna gain:	$G_{A,Tx}$ = 6 dBi
Macro BS Rx antenna gain:	$G_{A,Rx}$ = 15 dBi
Average antenna height of macro cell:	30 m
Average antenna height of micro cell:	6m
Down inclination angle of macro BS antenna:	4.43deg.
Down inclination angle of micro Tx antenna:	2.5deg

1 The vertical beam width of macro BS antenna

$$\theta_{macro} = 180/G_{macro} = 5.7\,\text{deg}$$

2 The vertical beam width **of** micro BS antenna

$$\theta_{micro} = 180/G_{micro} = 45.2\,\text{deg}$$

3 The angle c

$$c = \tan^{-1}((h1 - h2)/D) = \tan^{-1}(Dh/D) = 25.64\,\text{deg}$$

4 The angle **a**

$$a = c - 4.43 = 21.21\text{deg}$$

5 The angle h

$$b = c + 2.5 = 28.14\text{deg}$$

From the above analysis, the angle 'a' is larger than vertical beam width θ_{macro}, so the attenuation of the direction is **10dB** less than its maximum gain. Then the contributing gain of macro BS is less than 5dB (15-10=5).

The inclination angle **b** is larger than the vertical beam width θ_{micro}**/2,** so the attenuation **of** the direction should be 3dB less than its maximum gain.

Then the practical gain of micro BS is less than 3dB (6-3=3)

6 The practical gain of transmitting and receiving antenna can be estimated as:

$$G_{practical} = G_{macro}(a) + G_{miro}(b) < 5 + 3 = 8dB$$

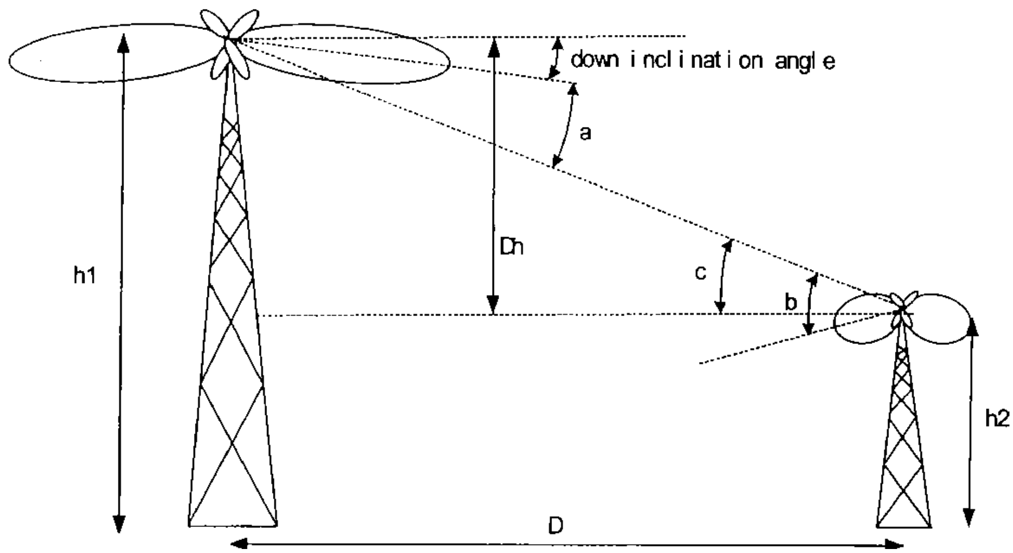

FIGURE C.1

Diagram of the antennas of the base station for macro cell and micro cell

In case the distance of transmitting and receiving antenna increased, the down inclination angle should be decreased, so the practical gain of transmitting and receiving antenna will be increased too. Nevertheless, the path loss of interfering and the victim station will be increased more rapidly than the increasing of contributing gain, thus the total isolation form interfering and the victim station will be increased in case the he distance of transmitting and receiving antenna increased.

Using the method above mentioned, for the scenarios of macro to macro, the antennas are located on the same level, the practical gain of transmitting and receiving antenna should be at least 6dB less than the sum of the maximum gains of the two antennas.

3 Sum of the gains of antennas at the directions of the interfering station and the victim (vertical antenna pattern modelled with Rec. ITU-R F.1336-1).

The calculations made here take advantage of the approach proposed in § 2 and extend it for every possible scenario (as proposed in Table C.1). The vertical antenna pattern of macro and micro cells are here obtained by Rec. ITU-R F.1336-1, using a K shaping factor of 0.2 **for** any tilt angle (2.5° in any cell deployment scenario here), the antennas are supposed 120" sectoral. In the case of pico cells, the antenna is supposed omnidirectional.

This § is in conformity with the Attachment 8.13 of document ITU 8F/489 ("Preliminary draft new recommendation on characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses"),

The assumptions made for the K shaping factor and for the tilt angles may be changed in the near future.

- **Antenna patterns (macro and micro cells)**

Recommendation ITU-R F.1336-1, defines "reference antenna patterns of omnidirectional, sectoral and other antennas in point to multipoint systems for use in sharing studies in the frequency range from 1 to about 70 GHz".

For sectoral antennas, this Recommendation gives the following equations :

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

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

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

where:

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

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

θ = absolute value of the elevation angle relative to the angle of maximum gain (degrees)

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

k = parameter which accounts for increased side-lobe levels above what would be expected **for** an antenna with improved side-lobe performance (typical : k=0.7 between 1 and 3 GHz)

the relationship between the gain (dBi) and the **3** dB beamwidth in the elevation plane (degrees) is, for a sectoral antenna :

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

where φ_S is the 3 dB beamwidth of the sector in the azimuthal plane (degrees).

- **Resulting antenna gains**

The geometry of the scenarios is the same as per § **2,** figure C.1. Using the notations in figure C.1 and the following :

- h1 and h2 the antenna heights (macro : 30m, micro 6m).
- tilt angles for the macro and micro antennas : **2.5 °** down for *tilt1* and *tilt2*

we obtain :

Angle a : $$a = a\sin\left(\frac{h1-h2}{\sqrt{(h1-h2)^2+D^2}}\right) - tilt1$$

Angle b : $$b = a\sin\left(\frac{h1-h2}{\sqrt{(h1-h2)^2+D^2}}\right) + tilt2$$

We have then the resulting antenna gains for two base stations using the gain formulas of Rec. TTU-R 1336-1 (the feeder losses FL_{BS} are 2 dB for all base stations considered):

$$G_{resulting} = G_{BS1}(a) + G_{BS2}(b) - 2.FL_{BS}.$$

- Base Station characteristics

- Antenna gain: 17 dBi (macro), 8dBi (micro), 2 dBi (pico)
- Rec. ITU-R F.1336-1 k-shaping factor: 0.2 (macro and micro), and 1 (pico)
- Sector of the antennas (macro and micro): 120"
- Antenna heights: 30m (macro), 6m (micro), 2m (pico)
- Feeder losses: 2 dB

- The **resulting** table **C.2** would **be** the following

TABLE C.2

Resulting antenna gain[1]

	FDD macro BS (15 dBi)	FDD micro BS (6 dBi)	FDD pico BS (0 dBi)
TDD macro BS (I 5 dBi)	23 dBi	0 - 15 dBi	0 – 15 dBi
TDD micro BS (6 dBi)	0 - 15 dBi	12 dBi	5 dBi
TDD pico BS (0 dBi)	0 - 15 dBi	5 dBi	0 dBi

[1] For detailed curves and results, see document [23]