TSG RAN Working Group 4 (Radio) meeting #8
26-29 October 1999
Sophia Antipolis

Agenda Item:

Source: **Siemens**

Title: **Summary of results on FDD/TDD and TDD/TDD co-existence**

Document for: **Discussion**

1. Introduction

In order to determine ACIR resulting from co-existence of either multi-layers or multi-operators, many simulations have been carried out on the relationship between ACIR and system capacity loss for FDD/FDD and TDD/TDD coexistence. The results of the simulations are described in [1].

On the other hand in order to confirm the possibility of FDD/TDD and TDD/TDD coexistence, different cases of the simulations have been carried out considering the 1920MHz border, which were described in [2], [3] and [4].

This contribution is what collects and summarises the results of the simulations for FDD/TDD and TDD/TDD coexistence and aims to be included in [1].

2. Description of Simulation

2.1 General

As mentioned in the introduction the implemented method is not exactly the same as in [1].

Different main parameters, which are independent of the simulated environment, are as follows, and are assumed for both TDD and FDD mode.

- Application of a fixed carrier spacing of 5 MHz in all cases
- Spectrum masks for BS and MS
- Maximum transmit powers for BS and MS
- Receiver filters for BS and MS
- Power control

Concerning a service assumption all stations have used speech service.

2.1.1 Spectrum mask

WG4 agreed a definition to characterise the power leakage into adjacent channels caused mainly due to transmitter non-linearities. The agreed definition is:

Adjacent Channel Leakage power Ratio, ACLR = The ratio of the transmitted power to the power measured after a receiver filter in the adjacent RF channel. Both the transmitted power and the received power are measured within a filter response that is nominally rectangular, with a noise power bandwidth equal to the chip rate.

Following the above definition, the ACLR for the spectrum masks for BS and MS are given in Table 1.

Table 1. ACLR used in the simulations

Reference	Station	Macro		Micro		Pico		HCS	
		ACLR1	ACLR2	ACLR1	ACLR2	ACLR1	ACLR2	ACLR1	ACLR2
Tdoc [2]	MS	45.39 dB	-	40.38 dB	-	45.39 dB	-	-	-
	BS	60.39 dB	-	55.35 dB	-	60.39 dB	-	-	-
Tdoc [3], [4]	MS	32 dB	42 dB	-	-	-	-	32 dB	42 dB
	BS	45 dB	55 dB	-	-	-	-	45 dB	55 dB

2.1.2 Maximum transmit power

The maximum transmit powers for BS and MS are given in Table 2.

The figures are defined according to the three environments assuming that a speech user occupies one slot and one code in TDD and one frame and one code in FDD.

Table 2. Maximum transmit power used in the simulations

Cell structure		Macro	Micro	Pico	HCS
TDD	MS	30 dBm	21 dBm	21 dBm	21 dBm
	BS	36 dBm	27 dBm	27 dBm	27 dBm
FDD	MS	21 dBm	14 dBm	14 dBm	21 dBm
	BS	27 dBm	20 dBm	20 dBm	27 dBm

2.1.3 Receiver filter

On the receiver side, in the first step an ideal RRC filter (α = 0.22) has been implemented and in the second step a real filter has been implemented

WG4 agreed on an Adjacent Channel Selectivity (ACS) definition as follows:

Adjacent Channel Selectivity, ACS: Adjacent Channel Selectivity is a measure of a receiver's ability to receive a signal at its assigned channel frequency in the presence of a modulated signal in the adjacent channel. ACS is the ratio of the receiver filter attenuation on the assigned channel frequency to the receiver filter attenuation on the adjacent channel frequency. The attenuation of the filter on the assigned and adjacent channels is measured with a filter response that is nominally rectangular, with a noise power bandwidth equal to the chip rate.

Following the above definition, the ACS becomes infinity with the ideal RRC filter. The ACS with the real filter are given in Table 3.

Table 3. ACS used in the simulations

	ACS with the real filter
MS	32 dB
BS	45 dB

2.1.4 Power control

Simulations with and without power control (PC) have been done.

In the first step a simple C based power control algorithm has been used. The PC algorithm controls the transmit power in the way to achieve sensitivity level at the receiver.

In the second step a C/I based power control algorithm has been used.

The model for power control uses the Carrier to Interferer (C/I) ratio at the receiver as well as the receiving information power level as shown in the following figure.

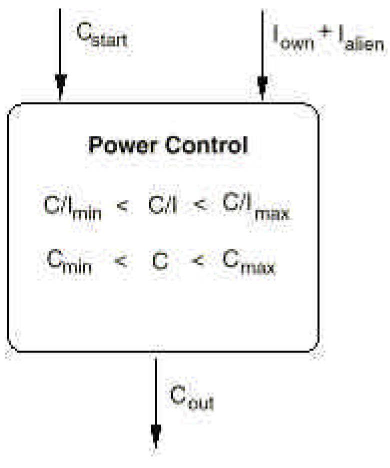

Figure 1 C/I based Power Control algorithm

The model considers the interference caused by alien systems as well as the intra-system interference. The control algorithm compares the C/I value at the receiver with the minimum required and the maximum allowed C/I value. In order to keep the received C/I in its fixed boundaries the transmission power is controlled (if possible). Consequently the most important value during power control is the C/I. If the C/I is in the required scope, the transmission power is varied to keep the received power in its fixed boundaries, too. Figure 2 shows an example of the power algorithm. The axis of ordinate contains the C/I threshold and the axis of abscissa contains the C-thresholds.

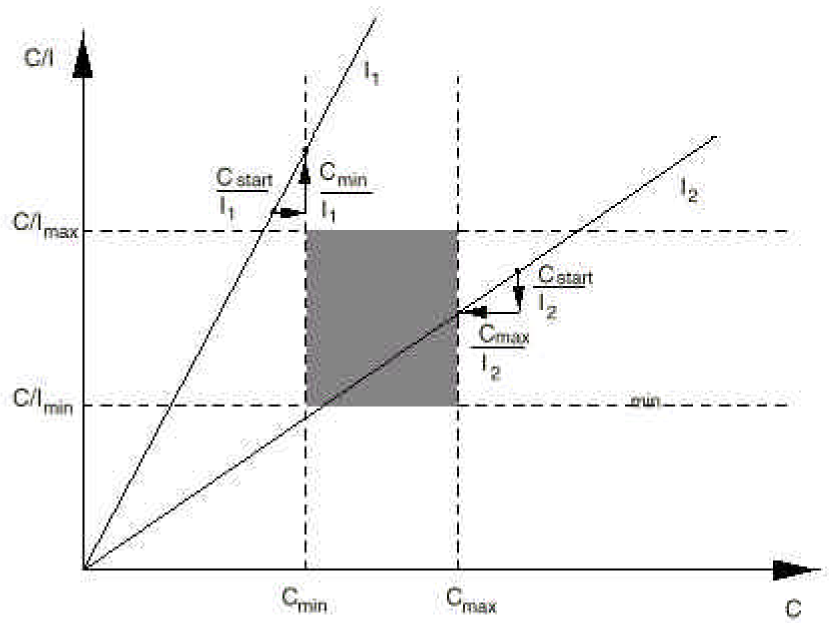

Figure 2 Example of power algorithm

The two straight lines include all possible values for C/I(C) for a received interference power I_1 and I_2. The area defined by the thresholds is marked with grey. The control of the corresponding station's transmission power should get the point on the straight line into the marked area. Regarding the interference I_1, the transmission power must pulled up until the minimum receiving power is reached. The upper C/I threshold demand cannot be fulfilled here. Concerning I_2, the grey marked area can be reached.

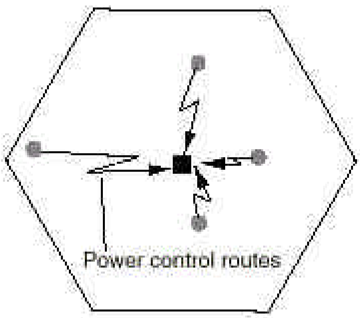

Figure 3 Power control in UL

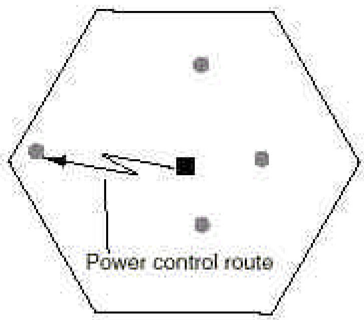

Figure 4 Power control in DL

It has to be remarked that the power control strategy in CDMA systems is different for uplink and downlink. In the uplink, each mobile has to be controlled in the way that the base station receives as low as possible power while keeping C/I requirements. Therefore the pathloss for each connection has to be considered. Concerning the downlink, the base station transmits every code with the same power regardless of the different coeval active connections. Consequently the power control must consider the mobile with the lowest receiving power level to ensure a working connection for each mobile.

The power control range is assumed as given in Table 4.
The power control step size is 1 dB for both MS and BS.

Table 4. Power control range used in the simulations

Reference		Tdoc [2]	Tdoc [3], [4]
TDD	Uplink	80 dB	80 dB
	Downlink	30 dB	30 dB
FDD	Uplink	80 dB	65 dB

2.2 Macro cell scenario

2.2.1 Evaluation method

Since for the macro scenario a hexagonal cell structure is assumed, a Monte-Carlo method has been chosen for evaluation. Each Monte-Carlo (MC) calculation cycle starts with the positioning of the receiver station (disturbed system) by means of an appropriate distribution function for the user path. The interfering (mobile) stations are assumed to be uniformly distributed. The density of interferers is taken as parameter. To start up we assume that only the closest user of the co-existing interfering system is substance of the main interference power. However to judge the impact of more than the one strongest interferer, some simulation cases are performed with the 5 strongest interferer stations. In simulations behind it was shown that taking into account more than 5 will not change the simulation results. In addition a transmitter station in the disturbed system and a receiver station in the interfering system are placed, i.e. communication links in both systems are set up. At each MC cycle the pathloss between the disturbed receiver and the next interfering station as well as the pathloss for the communication links are determined according to the pathloss formula given in the next section. Depending on the use of power control the received signal level C at the receiver station in the disturbed system is calculated. Finally the interference power I is computed taking into account the transmit spectrum mask and the receiver filter. C/I is then substance to the staistical evaluation giving the CDF.

2.2.2 Pathloss formula

The pathloss formula for the **Macro Vehicular Environment Deployment Model** is implemented to simulate the MS ↔ BS case (10 dB log-normal standard deviation, see B.1.6.4.3 in [5]). Both 2000m and 500m cell-radii are considered. The simulation does not support sectorised antenna patterns so an omnidirectional pattern is used.

However [5] was generated before the evaluation phase of different concepts for UTRA, which were all FDD based systems. Therefore [5] does not name propagation models for all possible interference situations. E.g. considering TDD the mobile to mobile interference requires a model valid for transmitter and receiver antennas having the same height. In order to cover this case the outdoor macro model in [3] was used. The model is based on path loss formula from H. Xia considering that the height of the BS antenna is below the average building height. This is seen as reasonable approximation of the scenario. Furthermore it has to be considered that mobiles might be very close to each other, i.e. in LOS condition, which leads to considerably lower path loss. To take this effect into account LOS and NLOS is randomly chosen within a distance of 50m (100m) for MS – MS (BS – MS) interference whereas the probability for LOS increases with decreasing distance. Details can be found in [3].

2.2.3 User density

The user density of the TDD system is based on the assumption that 8 slots are allocated to DL and UL, respectively. Considering 8 or 12 codes per slot this yields 64 / 96 channels per carrier corresponding to 53.4 / 84.1 Erlang (2% blocking). Taking into account that users are active within only one slot and that DTX is implemented we reach effective user densities of 5.14/km² / 8.10/km² for the 500m cell radius (cell area = 0.649 km²) and 0.32/km² / 0.51/km² for the 2000m cell radius (cell area = 10.39 km²), respectively. Note that these figures “sound” rather small, since we concentrate on one slot on one carrier. However if an average traffic of 15mE per user is assumed, these figures lead to 5484 real users per km² / 8636 real users per km². It should be emphasised that this investigations regards user on a single carrier at adjacent frequencies, since users on the second adjacent frequency will be protected by higher ACP figures. In addition one TDD carrier per operator is a very likely scenario at least in the first UMTS start-up phase.

The user density of the FDD system is based on the ITU simulation results given in [6]. For the macro environment 88 Erlang per carrier lead to an effective user density of 4.23/km² and 67.7/km² for the 200m cell and 500m cell respectively. Note that in FDD all users are active during the entire frame.

2.3 Micro cell scenario

2.3.1 Evaluation method

For the **Micro Pedestrian Deployment Model**, a Manhattan-grid like scenario has been generated. A 3x3 km² area with rectangular street layout is used. The streets are 30m wide and each block is 200m in length. This is in accordance to B.1.6.4.2 in [5].

In the microcellular environment evaluation a detailed event-driven simulation tool is used. A street-net is loaded into the simulator (according to [5]). A given number of mobiles is randomly distributed over the street-net with a randomly chosen direction. These mobiles move with a maximum speed of 5 km/h along the streets. If they come to a crossing there is a probability of 0.5 for going straight across the crossing and a probability of 0.25 for turning left and right respectively. If there is another mobile in the way, a mobile slows down to avoid a collision. This results in a distribution of the speed that comes close to the one described in [5]. Mobiles coming from the right may cross a crossing first. The model simulates the behaviour of cars and pedestrians in a typical Manhattan-grid layout. Based on the observed coupling loss the received signal C and the interference power I are determined in the same way as described for the macro scenario.

2.3.2 Pathloss formula

Using the propagation model presented in [7] by J.E.Berg, only one corner is considered, i.e. propagation along more than one corner results in an attenuation above 150 dB and is therefore negligible. The log normal standard deviation used is 10 dB.

2.3.3 User density

Starting again from 64 and 96 users per slot for TDD, we reach an effective user density of 129.36 per km² and 203.73 per km², respectively (e.g. 64 users → 53.4 Erlang → 6.675 Erlang per slot → 258.72 Erlang per km² (cell area = 0.0258 km², due to 72 BSs covering the streets) → 129.36 effective users (DTX)). Assuming on average 25mE per user this will lead us to 82791 and

130388 users per km², which might be slightly too high in a real scenario. For that reason simulation cases for 10000, 5000 and 1000 user per km² are added.

2.4 Pico cell scenario

2.4.1 Evaluation method

The third scenario studied is the **Indoor Office Test Environment Deployment Model**. This scenario is referenced as the **Pico**-scenario. It is implemented as described in B.1.6.4.1 of [5]. The office rooms give in principle a cell structure similar to the macro environment case, because only one floor without corridors is implemented. For that reason the evaluation method used is the same as in macro based on Monte-Carlo simulations.

2.4.2 Pathloss formula

The indoor path loss formula given in [5] was implemented (log-normal standard deviation 12dB). However it is taken care that the coupling loss is not less than 38 dB, which corresponds to a 1m free-space loss distance.

2.4.3 User density

Some reasonable assumptions have been made on the user density in the pico cell scenario. If we take straight forward the ITU simulation results based on [5] e.g. for FDD, we reach 220000 active users per km² (88 Erlang per BS, BS serves two rooms, i.e. 2*10m*10m = 0.0002 km² with DTX = 0.5 → 220000 active users per km²). Assuming further on average 300mE per user, there should be 29.333.333 users per km², which is not very realistic. For the simulations we added a 10000 active users per

Starting from a realistic scenario we assumed that each user in a room occupies 10m² yielding 10 user per room or 100000 user/km². For TDD we get 100000/8 *0.5 (DTX) = 6250 users per slot, which leads under the assumption of 100mE per user to 625 active users per km². This is the lowest user density referred to in the simulation results section. To judge the impact on the results the user density is increased up to almost 10000 active users per km².

2.5 HCS scenario

The scenario is a multi-operator layout with a microcell TDD and a macrocell FDD system. The microcell layout has 20x20 Blocks of 75m width separated by streets with 15m width. In an evaluation area of 12x12 blocks in the middle of the manhattan grid 72 BSs are placed in every second street junction. The FDD macrocells are placed with a distance of 1000m. Antenna hights are 10m for TDD and 27m for FDD BSs. (see Fig. 5)

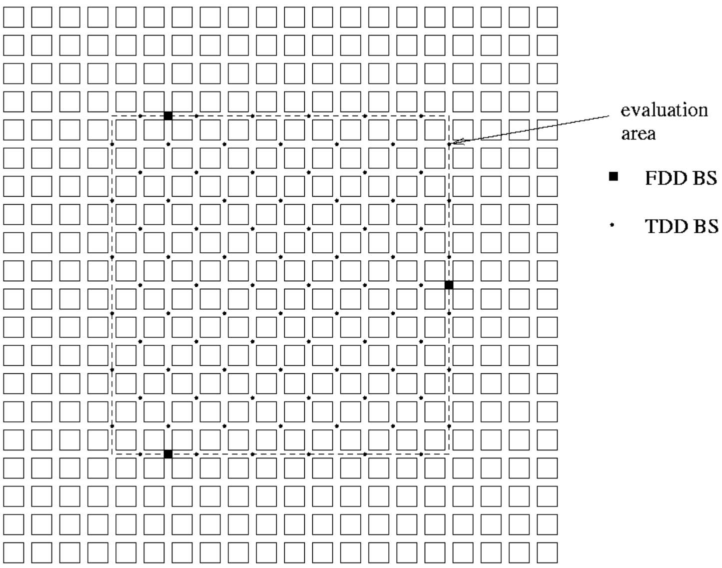

Figure 5: Multi-operator HCS scenario

The evaluation of interference has been done by Monte Carlo simulations where mobiles have been placed randomly on the streets and connected to their best serving BS. The user density in the FDD system has been 44 transmitting users per cell. All mobiles have been power controlled depending on the actual receive power and on the actual interference situation which in the case of a victim station consisted of a randomly chosen co-channel interference and the calculated adjacent channel, inter-system interference. In each snapshot, the adjacent channel interference power of the 30 strongest interferers has been summed up and evaluated.

3. Simulation Results on FDD/TDD co-existence

The results corresponding to the individual parameters in the FDD/TDD co-existence simulations that are based on general assumptions described in section 2 are shown in Table 5.

Table 5. Description of results and the individual parameters used in the FDD/TDD co-existence simulations

No		individual parameters							Results		Required C/I
		Scenario	Cell structure	Cell radius	Receive filter	Power control type	User density in interfering system (/km^2)	# of the strongest interferer	Reference to Tdocs including figures	Probability of C/I less than requirement	
1	1	TDD MS perturbs FDD BS	Macro to Macro	500m	Ideal RRC (α=0.02)	None	5.14	1	[2]	1.5%	-21dB
	2						8.10			2%	
	3						12.64			2.5%	
	4					C based	5.14			0 %	
	5						8.10			0 %	
	6						12.64			0 %	
	7					None	5.14	5		2%	
	8						8.10			3%	
	9						12.64			4%	
	10					C based	5.14			0 %	
	11						8.10			0 %	
	12						12.64			0 %	
	13				Real filter	None	5.14	30	[3]	8%	
	14					C based				1.3%	
	15					C/I based				2.2%	
	16			2000m	Ideal RRC (α=0.02)	None	0.32	1	[2]	1.5%	
	17						0.51			2%	
	18						0.79			2.5%	
	19					C based	0.32			1 %	
	20						0.51			1.5 %	
	21						0.79			2%	
	22				Real filter	None	0.32	30	[3]	1.6%	
	23					C based				1.6%	
	24					C/I based				0.7%	
	25		Micro to Micro	-	Ideal RRC (α=0.02)	None	1.563	1	[2]	0 %	
	26						7.813			0 %	
	27						15.625			0 %	
	28						129.36			0 %	
	29						203.73			0 %	
	30						224.08			0 %	
	31					C based	1.563			0 %	
	32						7.813			0 %	
	33						15.625			0 %	
	34						129.36			0 %	
	35						203.73			0 %	
	36						224.08			0 %	
	37		Pico to Pico	-	Ideal RRC (α=0.02)	None	1E,625	1	[2]	0 %	
	38						1.43E,2187			0 %	
	39						2.36E,3437.5			0 %	
	40						3.05E,5937.5			0 %	
	41						3.39E,9281.3			0 %	
	42						1E,13475			0 %	
	43					C based	1E,625			0 %	
	44						1.43E,2187			0 %	
	45						2.36E,3437.5			0 %	
	46						3.05E,5937.5			0 %	
	47						3.39E,9281.3			0 %	
	48						1E,13475			0 %	
2	1	FDD MS perturbs TDD MS	Macro to Macro	500m	Ideal RRC (α=0.02)	None	67.7	1	[2]	0.3 %	-5.6dB
	2					C based				0 %	
	3				Real filter	None		30	[3]	4.5 %	
	4					C based				0.22 %	
	5					C/I based				2.4 %	
	6			2000m	Ideal RRC (α=0.02)	None	4.23	1	[2]	0.5 %	

	7					C based				0.5 %	
	8				Real filter	None		30	[3]	0.8 %	
	9					C based				0.4 %	
	10					C/I based				0.5 %	
	11		Micro to Micro	-	Ideal RRC (α=0.02)	None	196	1	[2]	0 %	
	12						393			0 %	
	13						1179			0 %	
	14						2984			0 %	
	15					C based	196			0 %	
	16						393			0 %	
	17						1179			0 %	
	18						2984			0 %	
	19		Pico to Pico	-	Ideal RRC (α=0.02)	None	1E,220000	1	[2]	0 %	
	20						3.54E,9156			0 %	
	21					C based	1E,220000			0 %	
	22						3.54E,9156			0 %	
	23					None	1E,220000	5		0 %	
	24						3.54E,9156			0 %	
	25					C based	1E,220000			0 %	
	26						3.54E,9156			0 %	
	27		HCS	-	Real filter	C/I based	67.7	30	[4]	0 %	
3	1	FDD MS perturbs TDD BS	HCS	-	Real filter	C/I based	67.7	30	[4]	0 %	-8dB

4. Simulation Results on TDD/TDD co-existence

The results corresponding to the individual parameters in the TDD/TDD co-existence simulations that are based on general assumptions described in section 2 are shown in Table 6.

Table 6. Description of results and the individual parameters used in the TDD/TDD co-existence simulations

No		individual parameters							Results		Required C/I
		Scenario	Cell structure	Cell radius	Receive filter	Power control type	User density in interfering system (/km^2)	# of the strongest interferer	Reference to Tdocs including figures	Probability of C/I less than requirement	
1	1	TDD MS perturbs TDD BS	Macro to Macro	500m	Ideal RRC (α=0.02)	None	5.14	1	[2]	2 %	-8dB
	2						8.10			3 %	
	3						12.64			4 %	
	4					C based	5.14			0.5 %	
	5						8.10			0.7 %	
	6						12.64			1.3 %	
	7				Real filter	None	5.14	30	[3]	10 %	
	8					C based				1.2 %	
	9					C/I based				3 %	
	10			2000m	Ideal RRC (α=0.02)	None	0.32	1	[2]	2 %	
	11						0.51			3 %	
	12						0.79			4 %	
	13					C based	0.32			1.3 %	
	14						0.51			1.5 %	
	15						0.79			2 %	
	16				Real filter	None	0.32	30	[3]	1.5 %	
	17					C based				1.5 %	
	18					C/I based				0.9 %	
	19		Micro to Micro	-	Ideal RRC (α=0.02)	None	1.563	1	[2]	0 %	
	20						7.813			0 %	
	21						15.625			0 %	
	22						129.36			0 %	
	23						203.73			0 %	
	24						224.08			0 %	
	25					C based	1.563			0 %	
	26						7.813			0 %	
	27						15.625			0 %	
	28						129.36			0 %	
	29						203.73			0 %	
	30						224.08			0 %	
	31		Pico to Pico	-	Ideal RRC (α=0.02)	None	1E,625	1	[2]	0 %	
	32						1.43E,2187			0 %	
	33						2.36E,3437.5			0 %	
	34						3.05E,5937.5			0 %	
	35						3.39E,9281.3			0 %	
	36						1E,13475			0 %	
	37					C based	1E,625			0 %	
	38						1.43E,2187			0 %	
	39						2.36E,3437.5			0 %	
	40						3.05E,5937.5			0 %	
	41						3.39E,9281.3			0 %	
	42						1E,13475			0 %	
2	1	TDD MS perturbs TDD MS	Macro to Macro	500m	Real filter	None	5.14	30	[3]	0.1 %	-5.6dB
	2					C based				0.06 %	
	3					C/I based				0.03 %	
	4			2000m		None	0.32			1 %	
	5					C based				0.2 %	
	6					C/I based				0.2 %	

5. Summary and Conclusion

Many simulations for FDD/TDD co-existence and TDD/TDD co-existence on HCS and one layer environment considering either the ideal filter or the real filter and C/I based power control have been investigated.
The results in the realistic condition, which are chosen from those in Table 5, are shown in the following table.

Table 7. The simulation results for FDD/TDD co-existence in the realistic condition

No	Scenario	Cell structure	Results (Probability of C/I less than requirement)	Required C/I	Remarks
1	TDD MS perturbs FDD BS	Macro (Radius=500m)	2.2%	-21dB	Real receive filter C/I based power control 30 strongest interferer
2		Macro (Radius=2000m)	0.7%		
3	FDD MS perturbs TDD MS	Macro (Radius=500m)	2.4 %	-5.6dB	
4		Macro (Radius=2000m)	0.5 %		
5		HCS	0 %		
6	FDD MS perturbs TDD BS	HCS	0 %	-8dB	

The results in the realistic condition, which are chosen from those in Table 6, are shown in the following table.

Table 8. The simulation results for TDD/TDD co-existence in the realistic condition

No	Scenario	Cell structure	Results (Probability of C/I less than requirement)	Required C/I	Remarks
1	TDD MS perturbs TDD BS	Macro (Radius=500m)	3 %	-8dB	Real receive filter C/I based power control 30 strongest interferer
2		Macro (Radius=2000m)	0.9 %		
3	TDD MS perturbs TDD MS	Macro (Radius=500m)	0.03 %	-5.6dB	
4		Macro (Radius=2000m)	0.2 %		

It is obvious from the above results that the C/I requirements are met with high probability for all given scenarios in the most realistic conditions.
We propose:

- to include a new section 7.1 "Evaluation of FDD/TDD interference" in [1]
- to include section 2 in this Tdoc in section 7.1.1 "Description of Simulation" in [1]
- to include section 3 in this Tdoc in section 7.1.2 "Simulation results on FDD/TDD co-existence" in [1]
- to include section 5 (table 7) in this Tdoc in section 7.1.3 "Summary and Conclusion" in [1]
- to include a new section 8.2 " Evaluation of TDD/TDD interference" in [1]
- to include a new section 8.2.1 "Description of Simulation" in [1], while in this section a reference to section 7.1.1. will be sufficient
- to include section 4 in this Tdoc in section 8.2.2 "Simulation results on TDD/TDD co-existence" in [1]
- to include section 5 (table 8) in this Tdoc in section 8.2.3 "Summary and Conclusion" in [1]

6. References

[1] TSG RAN WG4 TR 25.942 V 2.0.0 (1999-10) “RF System Scenarios”
[2] TSG RAN WG4#3 Tdoc 96/99 “TDD/FDD co-existence – summary of results”, Siemens
[3] TSG RAN WG4#6 Tdoc 419/99 “Simulation results on FDD/TDD co-existence including real receive filter and C/I based power control”, Siemens
[4] TSG RAN WG4#7 Tdoc 568/99 “Interference of FDD MS (macro) to TDD (micro)”, Siemens
[5] ETSI TR 101 112 V3.2.0 UMTS30.03
[6] Evaluation Report for ETSI UMTS Terrestrial Radio Access (UTRA) ITU-R RTT Candidate (September 1998), Attachment 5
[7] J.E. Berg, ”A Recursive Model For Street Microcell Path Loss Calculations”, International Symposium on Personal Indoor and Mobile indoor Communications (PIMRC) ’95, p 140 – 143, Toronto