TABLE **4**

Carrier separation MHz	FDD BS ACLR dB	TDD BS ACLR DB
5	**45**	70
10	50	70
15	67	70

The ACLR values employed for FDD and TDD MSs can be found in Table ***5***. The values are taken *from* **(3)** and (4) except for 15 MHz where an assumption has been made.

TABLE 5

FDD and TDD MS ACLR

Carrier separation MHz	FDD MS ACLR dB	TDD MS ACLR dB
5	33	33
10	**43**	**43**

TABLE 6

FDD and TDD BS receiver noise floor and antenna gain

BS type	Receiver noise floor dBm	Antenna gain (rx) dBi
FDD macro	–103	15
FDD micro	*–103*	6
FDD pico	–103	0
TDD macro	–103	15
TDD micro	*–103*	6
TDD pico	–103	0

TABLE 7

FDD and TDD MS receiver noise floor and antenna gain

MS type	Receiver noise floor dBm	Antenna gain (rx) dBi
FDD	–99	*0*
TDD	–99	0

2.5.2 Receiver sensitivity

The BS reference sensitivity levels in Table **8** (specified for a **12.2** kbit/s service, BER must not exceed 0.001) are taken from (1) and **(2).**

TABLE 8

BS reference sensitivity for FDD and TDD BSs

BS type	BS reference sensitivity level dBm
FDD macro	–121
FDD micro	–121
FDD pico	–121
3.84 Mchip/s TDD macro	–109
3.84 Mchip/s TDD micro	–109
3.84 Mchip/s TDD pico	–109

The MS receiver sensitivity values presented in Table 9 are from **(3)** and (4), respectively

TABLE 9

FDD and TDD MS receiver sensitivity

MS type	BS reference sensitivity level dBm
FDD	–117
TDD	**–105**

Carrier separation MHz	**FDD BS ACS dB**	**TDD BS ACS dB**
5	46	46
10	**58**	**58**
15	66	66

Carrier separation **MHz**	**FDD MS ACS dB**	**TDD MS** ACS **dB**
5	33	33

2.6 Resulting adjacent channel interference ratios

The adjacent channel selection (ACS) and adjacent channel leakage ratios have been taken form the 3GPP specifications for 5 and 10 MHz carrier separation and have been estimated for 15 MHz carrier separation.

The above ACLR and ACS values result in an AClR value according to the following formula:

$$AClR = \frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}} \quad \text{(in linear terms)}$$

The values have been rounded in the ACIR column

Carrier separation **MHz**	**FDD BS** ACLR **DB**	**3.84 Mchip/s TDD BS** ACS **DB**	Resulting AClR **dB**
5	**45**	46	**-42**
10	50	**58**	**-49**
15	67	66	**-63**

TABLE 13

3.84 Mchipls TDD to FDD ACIR

Carrier separation	**3.84 Mchipls TDD BS ACLR dB**	**FDD BS ACS DB**	Resulting **ACIR dB**
	70	46	**–46**
	70	*58*	*–58*
15	*70*	66	***-64***

Carrier separation MHz	**TD-SCDMA BS ACLR dB**	**FDD BS ACS dB**	Resulting **ACIR dB**
3.3	*50* (in the spec. a value of 50 dB for **3.2** MHz c.s **is** used also here)	**46**	**–45**
8.3	65 (estimated)	*58*	–57

Two different approaches are taken to study the impact of an increased noise floor in the UL of an FDD cell: the impact on coverage and the impact on capacity.

In the first approach, the required number of **base** stations (or the base station density) is calculated for different values of the total noise floor (BS receiver noise + external interference) and for two different user densities. This to show the effect on the required BS density of an increased noise floor in lightly and heavily loaded macro systems. The method is described in (7).

In the second approach, the impact of an increased noise floor is studied in a network with fixed base station positions. Here, the increased noise floor results in a lower system capacity.

Although only the FDD system impact has been investigated, the same principles apply also for the TDD system and similar losses will be experienced.

2.8.1 Definitions and basic relations

The receiver noise floor due to thermal noise is denoted N_{BS} and is assumed fixed $N_{BS} = -103$ dBm.

The internal interference in the victim system consists of both intercell and intracell interference and is denoted I_{int} while the external interference from the aggressor system is denoted I_{ext}.

The total noise floor experienced in the victim system is defined as

$$N_{tot} = N_{BS} + I_{ext}.$$

The mapping between N_{tot} and I_{ext} with a fixed $N_{BS} = -103$ dBm is shown in Figure 3 below.

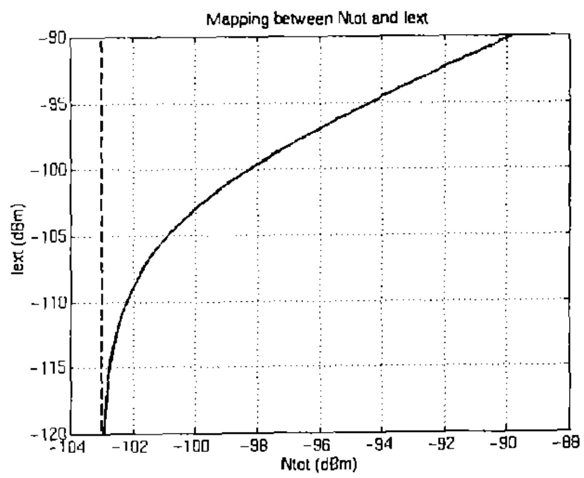

FIGURE 3

Mapping between N_{tot} and I_{ext}

In a system without external interference **the** total receiver noise floor is Ntot = N_{BS}= –103 dBm

The total interference I consists of three components:

$$I = N_{BS} + I_{ext} + I_{int} .$$

2.8.2 Impact on the BS density for a given user population

The impact of an increased noise floor (caused e.g. by external interference) on the FDD UL is shown in Figure 4. The base station density is plotted as a function of the "total noise floor" at the FDD BS receiver.

The reference point is derived for a known area with a known user density. A FDD macro cellular system should cover the area and provide service to the users using a certain QoS criterion. To minimize the costs, as few base stations as possible should be used. Since the users are power limited it is usually the UL that limits the coverage in macro cells.

The leftmost ends of the curves in Figure 4 correspond to an isolated system where no external interference is present. With the introduction and increase of external interference, N_{tot} rises successively, which leads to tighter required cell plan in order to fulfil the QoS criterion. The relative increase in number of BS compared to the reference case is plotted in Figure 4.

'Two systems are studied, one lightly loaded system where the load = 20% of pole capacity and one heavily loaded system where the load = 75% of pole capacity. This corresponds to a noise rise (NR) of 1 and 6 dB, respectively.

As can be seen, the impact is more severe in the lightly loaded system (planned mainly for coverage) than in the heavily loaded system (planned also for high capacity).

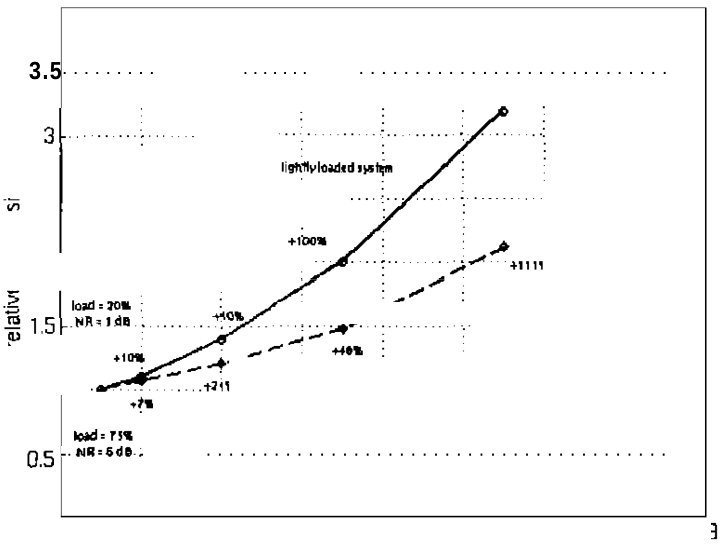

FIGURE 4

Relative BS density as a function of the receiver noise

2.8.3 Impact on the system capacity with a given cell plan

In this scenario it is assumed that the BS density cannot be affected by tighter cell plan. Instead the external interference will have consequences on the system capacity. It will be shown that the UL capacity loss is dependent on the deployment scenario and the system plan.

The system must satisfy the constraints that the UL service must meet a certain C/I target; and that the MS must **use** a power level less than the peak power limit up until the designed cell border, Thus, the total interference, I, at the BS receiver must not exceed a certain value I,,,, the maximal level of acceptable interference that consequently follows from the cell size criterion.

Thus,

$$I = N_{BS} + I_{ext} + I_{int} \leq I_{,,,} \text{ must hold.}$$

The noise floor experienced in the victim system is as before

$$N_{tot} = N_{BS} + I_{ext}.$$

In addition to the above inequality there is the further stability constraint that I_{int} cannot be more than 6 dB higher than the total noise floor N_{tot} which corresponds to a load of 75% of the pole capacity.

For macro cells and micro cells planned also for indoor coverage I, must be fairly small since the BS must be able to detect a weak MS signal at the faraway cell border (or indoor behind walls) with given C/I. For micro cells with street only coverage I,,, can be larger. Pico cells are intended for small cells with little or no coverage problems and allows for even larger **I,,,.** In the next § this is further examined.

As long as I_{ext} and I,,, are small enough so that the above inequality holds, I,,, and I_{int} can increase without harming either coverage or capacity. When I_{ext} (and thus N_{tot}) increases also I_{int} must increase since the C/I requirements must be fulfilled in the system.

However, when the left-hand side of the inequality equals I,,, one of the following things must happen when I,,, is further increased:

1. The left-hand side grows beyond the limit **I,,,** and the inequality is violated.
2. Reducing the load that is lint, in the system compensates the increase of I,,,.

The first option reduces the coverage and creates holes in the cell plan and is not investigated further. The second option keeps the cell plan but reduces the capacity. It is the target of the following investigation to quantify this effect.

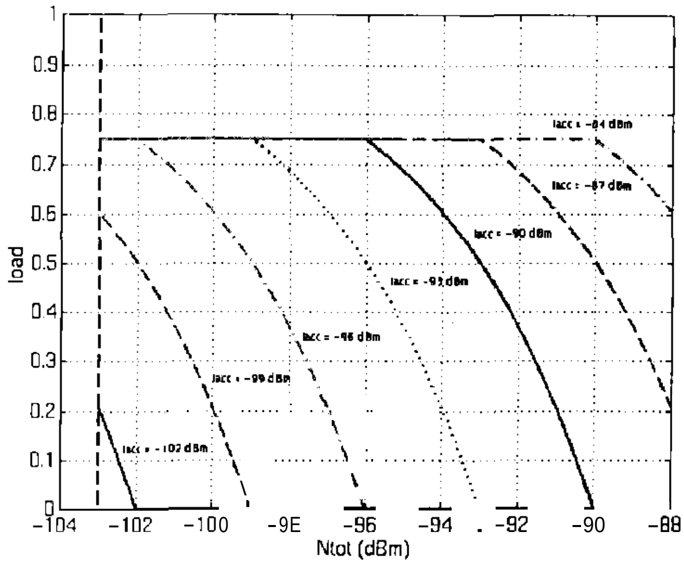

FIGURE 5

Capacity **loss as** a function **of** the **FDD BS** noise **floor N_{tot}.**

Figure 5 shows the load that can be handled **as** a function of the total receiver noise N_{tot}. Since the maximum load is limited to 75% for stability reasons there are horizontal segments of the curves. Each curve is plotted under a certain assumption of I_{acc} and will all share the first **part** of the horizontal segment.

Note though that for values of $I_{acc} < -97$ dBm the maximum load is below 75% since the system sensitivity is limited by $N_{BS} = -103$ dBm even when there is no external interference present. The leftmost curves are relevant for macro cells while the rightmost curves **are** relevant for pico cells with the curves relevant for micro cells located in between.

The higher values of I,,, the longer the horizontal segment of the curve becomes, and thus, the more external interference can be tolerated without a capacity degradation. Once the external interference reaches a critical point, the capacity drops since the only way to maintain coverage is to reduce the internal interference in the system **by** throwing out users.

2.8.4 Acceptable levels **of** degradation

From the previous §s the following conclusions are drawn on the amount of total interference that can be tolerated for different cell types, and the total amount of noise that can he tolerated in order to suffer acceptable capacity losses.

Table 16 indicates typical ranges of the allowed maximum levels of external interference for different types of cells. Furthermore, the relation to capacity loss and BS density according to the methods in (23) are shown (except for pico cells). See (23) for details,

	I_{ext} proposal (dBm)	I_{acc}		Resulting increase of base stations density	
		With no capacity loss (dBm)	With 5% relative cap. loss allowance	With no capacity loss	With 5% relative cap. loss allowance
Macro rural	-114 to -106	-101.6 to -100.2	-101.6 to -100.2	3% to 21%	3% to 21%
Macro downtown	-100 to –95	-95.1 to –91	-95.1 to –91.5	52% to 129%	52% to 117%
Outdoor micro	-97 to –90	-90.5 to –84.1	-90 to –83.6	60% to 183%	46.5% to 170%
In-building pico	-85	No result	No result	No result	No result

In the result tables in this document, the range of I_{acc} values in Table 15 has been used for the corresponding cell type.

It should be noted that the lower value of tolerable I_{acc} the more accentuated is the potential interference problem while a higher value means that the victim system is more robust against external interference. A low value is necessary in deployment scenarios where high sensitivity is desired, for example in coverage limited systems or micro systems planned for indoor coverage. The system can be planned for a higher value to the price of more base stations and sometimes a lower capacity as is indicated in the above Sections. Also, the transmitted powers for all MS in the victim system will increase.

The I_{acc} values in this table are used in § 4 to estimate required separation distances or required ACIR.

2.8.5 Reference separation distances

What separation distance between base stations is acceptable or not depends on the cell types considered but also on what kind of restrictions of deployment or cooperation is possible on the particular market. Below we list distances that have been used to evaluate the effects of performance. They seem reasonable in order to give the two operators as much freedom as possible to deploy the way they want independently of each other, but other distances can be considered as well. Larger separation distance might be possible in markets where co-planning between operators is possible.

Table 16 is used in two ways in this document. The distance is used as an assumed criterion when the required ACIR is calculated. When a fixed ACIR is assumed, the calculated separation distance can be compared with Table 16 to see if the distance requirement is fulfilled.

TABLE 16

Reference separation distances

Scenario	Reference separation distance m
Macro-macro	100
Macro-micro	50
Micro-micro	50
Macro-pico	50
Micro-pico	20
Pico-pico	10

3 ıterfere

3.1 Propagation models

All employed propagation models are according to (6) except the dual-slope LOS propagation model. Furthermore, all models are adapted to a frequency of *2.6* GHz.

The propagation models only take the average behaviour into account. Variations around the mean, due to fading, are not considered in the propagation models. Furthermore, the propagation models are originally used for propagation between base stations and mobile stations. In this study, however, also base-to-base and mobile-to-mobile propagation must be considered. If possible, the same propagation models are deployed as for base-to-mobile propagation.

The following models **are** employed:

Path loss model for vehicular test environment (see **(6))**

Path loss model for outdoor to indoor test environment (see (6))

Path loss model for pedestrian test environment (see **(6))**

Path loss model for indoor test environment (see *(6))*

Dual-slope LOS propagation model (see (Appendix B and (24))

Path **loss** model for vehicular test environment

$$L = 130.5 + 37.6 \cdot \log_{10}(R)$$

R is distance in kilometres.

Path **loss** model for outdoor **to** indoor test environment

$$L = 151.4 + 40 \cdot \log_{10}(R)$$

R is distance in kilometres.

Path **loss** model for pedestrian test environment

One comer of 90 degrees is assumed to be in-between the transmitter and the receiver. Further, the height of the transmitter and the receiver is assumed to be significantly less than the height of the surrounding buildings.

$$L = 20 \cdot \log_{10}(\frac{4 \cdot \pi \cdot d_n}{\lambda})$$

$$d_n = \frac{d}{2} \cdot \left(2 + d \cdot \frac{q}{2}\right)$$

d is distance in metres

Path Loss Model for Indoor Test Environment

$$L = 37 + 30 \cdot \log_{10}(R) + 18.3 \cdot n^{\left(\frac{n+2}{n+1} - 0.46\right)}$$

$R =$ distance in metres

$n =$ number of floors in the path

Dual-slope **LOS** propagation

The dual-slope LOS propagation model assumes free-space propagation until the breakpoint (d_{break}). After the breakpoint, the attenuation is increased because of reflections on the ground.

$$L^{LOS} = \begin{cases} 40.7 + 20 \cdot \log_{10}(d) & 1 \le d \le d_{break} \\ 40.7 - 20 \cdot \log_{10}(d_{break}) + 40 \cdot \log_{10}(d) & d \ge d_{break} \end{cases}$$

d is distance in metres

The breakpoint is calculated as: $d_{break} = 4 \cdot \frac{h_{tx} \cdot h_{rx}}{\lambda}$

where h_{tx} and h_{rx} is the height (over the reflecting surface) of the transmitter and the receiver. λ is the wavelength. The breakpoint is assumed to appear at the distance where the first Fresnel zone is tangent to the ground (reflecting surface). The formula for breakpoint calculation above approximates this.

Example: assuming a height of 6 m of both the transmitter and the receiver, the breakpoint becomes 1 248 m (a frequency of 2.6 GHz corresponds to a wavelength of 0.1154 m).

See Appendix B for more details about this model.

3.2 Deterministic calculations

3.2.1 **BS-to-BS** interference

FDD macro – TDD macro

In proximity: The dual slope LOS propagation model is employed to calculate the pathloss between a FDD macro and a TDD macro BS.

Co-located: no path loss model is used. A coupling loss of 30 dB is used.

FDD macro – TDD **micro**

The Vehicular pathloss model is employed to model the propagation between a FDD macro and a TDD micro BS. This assumes that the height of the FDD BS is above rooftop and that the height of the TDD BS is significantly lower than the surrounding buildings.

FDD macro – TDD pico

The outdoor *to* indoor propagation model is employed *to* calculate the pathloss between a FDD macro and a TDD pico BS. The pico BS is assumed to be located inside **a** building and furthermore, there is no LOS between the **two** base stations (LOS could, e.g., appear when a pico BS is located high up in the building close to a window that faces the macro BS).

FDD micro – **TDD** micro

For FDD micro – TDD micro, two scenarios are considered. The BSs are assumed to be located either in the same street or in different streets. Location in the same street implies LOS-propagation. If the BSs are located in different streets, it is assumed that there is only one corner (of 90 degrees) between the BSs and that the distance from to the base to the corner is the same for both BSs. The scenarios are depicted in Figure 6.

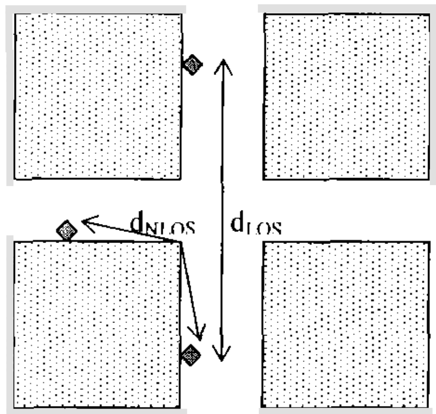

FIGURE **6**

Propagation between **2** micro base stations in the same **and** in different streets

The dual slope LOS propagation model is employed for the case when the BSs are located in the same street. The pedestrian path loss model is used if the BSs are located in different streets.

FDD micro – **TDD pico**

The outdoor to indoor path loss model is used in this scenario. NLOS is assumed between the BSs (LOS could e.g. be caused **by** a window between the BSs).

FDD pico – **TDD** macro

Not considered.

FDD pico – **TDD** micro

Outdoor to indoor path loss model (see also FDD micro – TDD pico above).

FDD pico – TDD pico

Both the FDD and the TDD BSs are assumed to be located inside the same building but separated by one floor.

Calculation example, interference to macro **FDD BS Rx,** caused by macro **TDD BS Tm.**

First we give an example how the required separation distance is calculated when the ACIR is given, and then how to calculate the required ACIR when the distance is given. In § 2 and Appendix C, all values of resulting antenna gains and ACIR are tabulated as well as the relevant interval of tolerated external interference.

Input:	TDD BS output power	P = 43 dBm
	TDD BS activity factor 0.5	$\alpha = -3$ dB

TDD BS **Tx** antenna gain	$G_{A,Tx} = 15$ dBi
TDD BS ACLR	ACLR = 70 dB
FDD BS Rx noise floor	Rxnoise = –103 dBm
FDD BS Rx antenna gain	$G_{A,Rx} = 15$ dBi
FDD BS ACS	ACS = 46 dB

I Calculate the efficient output power

The efficient output power is the average transmitted power, i.e. the output power plus the activity factor.

$$P_{average} = P + a = 43 + (-3) = 40 \text{ dBm}$$

7 Calculate the resulting antenna gain

Here, **2** macro base stations at the same height are considered. The resulting antenna gain is the sum of the **Tx** and the **Rx** antenna gain.

$$G_A = G_{A,Tx} + G_{A,Rx} = 15 + 15 = 30 \text{ dBi}$$

3 Calculate the AWR

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

(ACLR, ACS) = (70, 46) dB implies that ACIR = 45.98 dB ≈ 46 dB

4 Define the maximum tolerable adjacent channel interference. e.g.

According to Table 15, N_{tot} should be at most –102.7 dBm which for N_{BS} = –103 dBm implies that ACI_{max} = – 114 dBm.

5 Calculate the required path loss

$$L = P + G_A - ACIR - ACI_{max} = 40 + 30 - 46 - (-114) = 138 \text{ dB}$$

6 *Convert the path loss to a required separation distance (according to the propagalion formula)*

$$L^{LOS} = \begin{cases} 40.7 + 20 \cdot \log_{10}(d) & 1 \le d \le d_{break} \\ 40.7 - 20 \cdot \log_{10}(d_{break}) + 40 \cdot \log_{10}(d) & d \ge d_{break} \end{cases}$$

The attenuation at the breakpoint at 1 248 m is 102.6 dB. Thus, the searched distance is after the breakpoint ($d > d_{break}$). The required separation distance d_{sep} = 9 541 m.

When the separation distance is instead given, and the required ACIR is the sought value, instead steps 5 and **6** are slightly changed into:

7 Calculate the required ACIR

$$ACIR = P + G_A - \mathbf{L} - ACI_{max}$$

where (according to the propagation formula) **L** is a function of the propagation model (LOS in the example) and given distance *d*:

$$L^{LOS} = \begin{cases} 40.7 + 20 \cdot \log_{10}(d) & 1 \le d \le d_{break} \\ 40.7 - 20 \cdot \log_{10}(d_{break}) + 40 \cdot \log_{10}(d) & d \ge d_{break} \end{cases}$$

If d= 100 m

ACIR= $40 + 30 - (40.7 + 20*\log_{10}(100)) - (-114) = 103.3$ dB

3.2.2 BS-BS interference, alternative evaluation

The methodology used in the evaluation of the BS- BS interference above can be used to establish a tradeoff between the transmit power that is needed for coverage and the power that is available for overcoming external interference. Thus the supportable path loss at cell edge is determined assuming the fulfillment of C/I requirements and a 6dB cell noise rise over the external interference.

Three cases are considered:

TDD and FDD in micro deployment, without line of sight between base stations ("NLOS").

TDD and FDD in micro deployment, with line of sight between base stations ("LOS").

TDD in Micro and FDD in macro deployment.

Two cases are considered for the combined antenna gain for macro-micro combination. Under the worst-case assumption, the results are calculated assuming that the antennas of the victim **BS** and the aggressor BS were looking at each other in the direction of their maximum gain. In that case the combined gain of the two antennas is 21 dB since we assume a macro BS with 15 dBi gain and a micro BS with a ***6*** dBi gain.

However, as shown in Appendix C (Practical antennas gain between macro and micro base station), the combined gain of the transmitting and receiving antennas, when they are close to each other, is less than (or equal to) 8 dB.

The difference in the level of interference between the two assumptions is (21-8 dB = 13 dB). Consequently, the supportable cell range difference is the same amount (slightly less than 13 dB, because of the contribution of thermal noise).

In most cases the parameters assumed for the analysis above were kept. Changed parameters are listed in Table 16bis below. Regarding the ACLR parameters of the TDD **BS,** two sets of values are used. The first set corresponds to the minimum requirements defined in (2), while the second set corresponds to the values shown in Table 4. The increase of the ACLR (at **5** MHz and 10 MHz) to 70 dB decreases the level of interference from the aggressing base station to the victim base station, hence the supportable cell range increases.

Parameter		Micro-micro, **NLOS**	Micro-micro, **LOS**	Micro-macro
BS transmit duty ratio		1		
Voice activity factor		–2.8 dB		
TDD BS (Set 1)	ACLR1	45		
	ACLR2	55		
	ACLR3	70		
TDD BS (Set 2)	ACLR1	70		
	ACLR2	70		
	ACLR3	70		
ACLR1 (FDD BS)		45		
ACLR2 (FDD BS)		55		
ACLR3 (FDD BS)		67		
Coupling distance, m		50		
Coupling, dB		89	72	79

3.3 Monte Carlo simulation

3.3.1 Capacity consequences **of** MS-to-BS, **BS-to-MS, MS-MS** interference in **FDD macro/3.84 TDD** micro scenarios

Environment and propagation models

The used cell plan is a regular Manhattan environment, see Figure 7. The environment configuration is similar to what is proposed in **(6,** § 6.1.5). The block size is *75* x *75* m and the street width is 15 m. TDD is only modelled as a micro system, comprising ***73*** base stations. The FDD system is assumed to be either a macro (above rooftop) or a micro system. 12 macro systems are modelled, however, as shown in Figure 7, only **3** are used in the performance evaluation. The surrounding 9 base stations are used only to avoid border effects. FDD micro base stations are modelled in the same way as TDD micro base station. The TDD and the FDD micro base stations are however not co-sited, instead always located one block away from each other.

Users are located outside in the street and randomly distributed in the area.

The vehicular pathloss model is applied to describe the radio propagation between a macro base station and a user. Between a micro base station and a user and between two users, the pedestrian pathloss model is used.

Table 17 presents the most important simulation parameters.

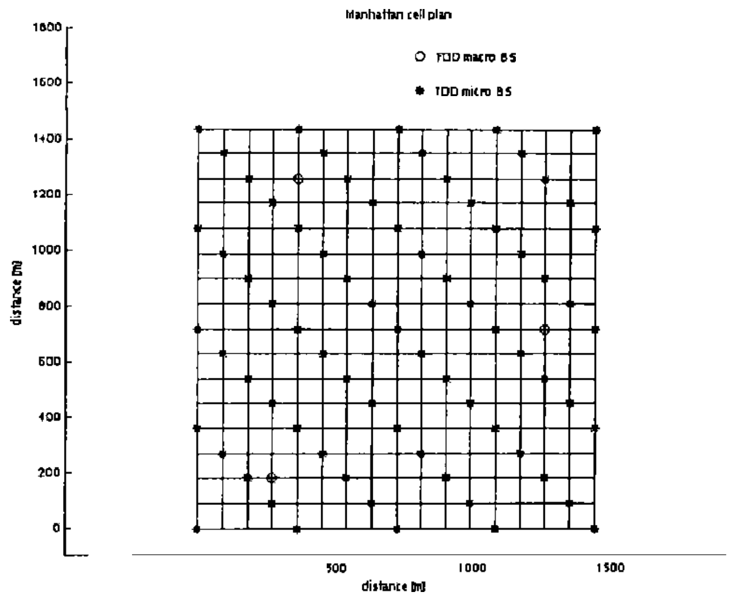

FIGURE 7

The employed cell pattern

TABLE 17

Required C/I and assumed asymmetry

	Power control type	Required C/I	Number of time slots per frame (TDD only)
FDD DL	C/I-based	–21	–
FDD UL	C/I-based	–21	–
TDD DL	C/I-based	–3	8
TDD UL	C/I-based	–5	7

Performance measures

Outage and blocking are used as performance measures. Outage occurs when a user cannot reach the C/I target (and is expressed in relation to the total number of users). Blocking occurs when a user cannot enter the system because there are not enough resources at the base stations (e.g. when all channels are busy).

The capacity is defined as the maximum traffic load at which the outage is below 5% and the blocking rate is below 2%.

All evaluations are performed for 5 and 10 MHz carrier separation

MS-to-BS **interference**

Here, the case when TDD **terminals** interfere with an FDD BS is described. The opposite case, FDD terminals interfering with TDD base stations, is setup equivalently.

The TDD users are randomly distributed within the system area. Based on this, the pathloss, including shadow fading, can be calculated to the TDD and the FDD base stations. The TDD users connect to the closest TDD base station (in terms of path loss) and are randomly allocated to one of the uplink channels (time slot/code combination).

Furthermore, the required TDD MS output power is calculated such that, if possible, the required C/I is achieved at the receiver side. According to the output power of all TDD terminals, the ACI can be calculated at the FDD BS receivers. The ACI is calculated for each TDD UL time slot and averaged over the radio frame.

The ACI at each base station, which causes a rise of the FDD BS receiver noise floor, is input to the evaluation of the quality in the FDD system and a similar procedure to what has been described above is now performed in the FDD system. The users are randomly distributed in the system, the pathloss to the FDD BSs is calculated and each user connects to one or several base stations (according to the soft handover criteria). Furthermore, the FDD uplink power is set such that, if possible, the required C/I at the FDD receiver side is achieved. Finally, the system performance is evaluated by means of outage (and blocking) calculations.

BS-to-MS **interference**

Evaluated equivalently to the MS-to-BS interference scenario described above, however, here the aggressor is a BS (TDD or FDD) and the victim is a MS (FDD or TDD).

MS-to-MS **interference**

Evaluated equivalently to the MS-to-BS interference scenario described above, however, here the aggressor is a MS (TDD or FDD) interfering with another MS (FDD or TDD).

3.3.2 Consequences of MS-to-BS and MS-to-MS interference in FDD 13.84 TDD, FDD/1.28 TDD scenarios

The pathloss models and methodology used are very similar to the ones used by Ericsson (see previous §), so only a brief description is given here. The focus **of** the simulations is on coexistence **of** macro cells considering a vehicular environment (case 3: 120km/h) with 8 kbit/s speech users only

The simulation is a Monte-Carlo based snapshot method calculating CDFs for C/I for large numbers ("trials") of stochastic mobile distributions over cells (including power control).

No kind of synchronization or coordination between the different systems is assumed.

The goal of simulation procedure is to determine the relative capacity loss of a victim system for a considered link (uplink or downlink) due to the presence of a second system – the interfering system. The reference for the capacity loss is the capacity of the victim system alone without the interfering system.

3.3.3 Outage consequences due to MS-to-MS interference in FDD/3.84 Mchipls TDD scenarios

To evaluate a particular frequency arrangement in a band, it is necessary to determine what guardbands between the two systems are necessary, and what effects remain on the channels near the border.

If there is a reduction in capacity in channels near the border, this need not necessarily be a reason to preclude this arrangement. However, this is different for changes to existing hands as opposed to planning for new bands. If a band is already in use, capacity reduction due to the changed use of an adjacent band is more of a problem than when a new band comes into use with two coexisting systems. This is because in the second case it is known from the start that capacity reduction will occur.

The choice of **radio** access technology in a particular spectrum band depends on the outage probability that is achievable in the band and surrounding channels using a realistic deployment. If the frequency arrangement does not allow for satisfactory minimum outage in a practical deployment, the arrangement should not be used.

For the purpose of choosing frequency arrangements it is usual to perform coexistence studies. The result from such a study will be how effectively the spectrum can be used. There are two measures for expressing the merits of a spectrum arrangement. One is minimum outage and the other is loss ofcapacity.

Problems with unsatisfactory minimum outage can be avoided by using guardbands between different systems. Adding and/or planning sufficient base stations can deal with the problem of capacity reduction.

Frequency arrangements for FDD (WCDMA) and TDD **(3.84** Mchipis) in adjacent bands can result in interference problems due to the fact that TDD employs both uplink and downlink direction in the same band. On the border between TDD and FDD, it may be necessary to use a guardband and the overall capacity of the TDD and FDD systems may be reduced due to interference.

3.3.3.1 Monte Carlo simulation based on minimum outage

Outage occurs when a user cannot reach the C/(I + N) target, resulting in a connection with the network that cannot be set up or maintained. The outage in general will depend on the combined effects of noise, co-channel interference and adjacent channel interference.

If there is no interference, lack of signal strength will limit the coverage. Interference due to other co-channel users can also cause outage if so many users are present that the interference is too high, so that the number of users accessing the networkneeds to he limited. Interference from adjacent frequencies can also cause outage that can be resolved for certain scenarios, e.g. BS-to-BS. Of particular importance is the effect of the **ACI** for mobile-to-mobile interference, where outage can occur that cannot he avoided in planning. Therefore it will he necessary to determine the appropriate size of the guardband in order to prevent an unacceptable outage occurring.

As a measure of the level of interference the term interference probability is often used in this context, and is the same as the outage percentage, i.e. the percentage of users for whom the interference (+noise) level is too high.

The objective of these simulations is to determine outage due to adjacent channel interference. The focus is on outage that cannot be avoided by appropriate planning of the network.

3.3.3.2 Methodology of simulation

The methodology and tool used to calculate outage is essentially the same as used for Monte Carlo simulation of capacity reduction. The level of the desired signal and the interfering signals are evaluated for each configuration (based on the random distributions) to determine whether the C/(I + N) target is reached or not. The results presented differ from capacity reduction in that the outage is calculated as opposed to assuming an acceptable outage to calculate the level of capacity reduction.

The calculations make use of a victim link and an interfering link (or possible multiple interfering links) that are between a mobile terminal and a base station. The relative positions of the mobile terminals and base stations are defined using distributions.

The effect of co-channel interference is not included. **As** a result of this, the interference probability in this simulation will be lower than for a loaded system. However, as it is difficult to obtain a good estimate of the load, choosing to model only the adjacent channel interference is an appropriate decision.

In the simulations, users do not move around and no connections are added or removed. Therefore, the point at which a connection is lost is at set up, because the environment will not change. **As** a result of this, a connection that is set up successfully will be completed successfully. In a realistic network users will move around, therefore a user who does not suffer from outage at the start of a call, may come into an area with high interference, where the call will be dropped.

3.3.3.3 MS-to-MS interference, FDD macro – TDD macro/pico

The MS-to-MS interference is evaluated by Monte Carlo simulation **for** 5 and 10 MHz carrier separation. The simulation assumes that the spectrum below 2 550 MHz is FDD uplink, and the spectrum above 2 550 MHz is TDD. The FDD system is macro only, for TDD both macro and pico deployment are considered. Note that the macro and pico deployments are considered in separate simulations.

The service considered is 8 kbit/s speech for both TDD and FDD

3.3.3.4 Victim system

The victim system is either a TDD macro-cell or a TDD pico-cell. These two possibilities are considered as two different scenarios. In this scenario the downlink is considered, as it is the mobile terminal that receives interference.

For the macro-cell scenario, all TDD mobiles are assumed to be outdoor. For the pico-cell scenario, the TDD base station and mobile terminal are both indoor.

The specifications are given in Table 18, Table 19 (macro) **and** Table 20 (pico). These correspond with the specifications given in § 2. **ACS** values for a TDD mobile terminal are given in Table 21. The TDD base station is not power controlled and transmits using a fixed power.

The total transmit power of the base station is shared between users. A maximum number of 12 users per timeslot is assumed, resulting in the transmit power available per user as given in Table 19 and Table 20.

TABLE 18

CDMA TDD mobile station (receive)

C/I	–5 dB
Noise floor	–99 dBm
Sensitivity	–105 dBm
Antenna height	1.5 m
Antenna pain	0 dBi

TABLE 19

Transmit power, total for base station	43 dBm
Transmit power, available for one user	32.2 dBm
Fixed coverage radius	0.5 km
Antenna height	30 m
Antenna gain	15 dBi

TABLE 20

CDMA TDD pico base station (transmit)

Transmit power, total for base station	24 dBm
Transmit power, available for one user	13.2 dBm
Fixed coverage radius	0.05 km
Antenna height	6 m
Antenna gain	0 dBi

TABLE 21

Carrier separation (MHz)	FDD MS ACLR (dB)	TDD MS ACS (dB)
5	33	33
in	A?	43

3.3.3.5 Interfering system

The interfering system is an FDD macro-cell. In this scenario the uplink is considered (mobile terminal transmit). The mobile uses power control, and the power control is modelled as ideal. The power control adjusts the received power to a fixed pre-set receiver sensitivity value (C-based power control).

For the case that the victim system is TDD macro, all FDD mobiles are assumed to be outdoors. For the TDD pico case, all FDD mobiles are assumed to be indoor. The specifications are as given in § 2, and an overview is given in Table 22 and Table 23. ACLR values for a FDD mobile terminal are given in Table 21.

Transmit power	21 dBm
Antenna height	1.5 m
Antenna gain	0 dBi
Power control step	1 dB
Power control: nun. received power	−121 dBm
Power control dynamic range	70 dB

TABLE 23

W-CDMA FDD base station (receive)

Antenna height	30 m
Antenna gain	15 dBi
Receiver sensitivity	−121 dBm
Fixed coverage radius	0.5 km

3.3.3.6 Path **loss** models

Path loss is modelled using mean path loss and slow fading (log-normal). For the macrocell outdoor environment, the model used depends on the separation distance between the two mobiles. Free space path loss is used for distances up to 40 metres and the Hata model (with modifications) is used for distances above 100 metres. Between these limits an interpolation of free space and Hata is used. The Hata model is adapted for use at frequencies up to **3** GHz, **and** for situations with both transmit and receive antenna below rooftops.

The outdoor-indoor propagation model is the same as the outdoor only model with an extra loss factor added for attenuation due to external walls. The indoor only propagation model uses free space path loss, to which extra loss is added for attenuation due to internal walls and floors.

It is also possible that propagation occurs from inside one building to inside another. If both the transmitter and receiver are in an indoor environment, but their separation distance is large, it is assumed that the transmitter and receiver are in different buildings. **A** different propagation model than for the “pure” indoor case is then used. The path loss is then the sum of 1) the attenuation due to an external wall for the transmission out of the building; 2) the Hata model as described above for path loss between the buildings; 3) the attenuation due to an **external** wall for the transmission into the other building. The total path loss is therefore the Hata path loss plus two times the penetration loss of an external wall.

3.4 *MS-to-MS* (Deterministic)

The same methodology is used as for BS-to-BS interference (see 3.2) but with the MS transmitter and receiver parameters as defined in § 2. Only the **LOS** condition is investigated.

4 Calculation examples and Results

4.1 Calculation examples

See § 3.3.1.

4.2 Calculation results

4.2.1 Results from deterministic BS-to-BS interference calculation

4.2.1.1 Required separation distances for WB TDD/WCDMA interference

TABLE 24

TDD to FDD interference

Description of scenario (+prop. model)	Carrier sep. MHz	Tx power (inc activity factor) dBm	Effective antenna gain dBi	ACIR dB	Accepted level of I_{ext} low/high dBm	Required pathloss dB	Required separation distance m
TDD macro to FDD macro (LOS)	5	40	30	46	−114/−106	138/130	**9541/6020**
	10	40	30	58	−114/−106	126/118	**4782/3017**
	15	40	30	64	−114/−106	120/112	**3385/2136**
TDD macro to FDD micro (Vehicular)	5	40	15	46	−97/−90	106/99	**222/145**
	10	40	15	58	−97/−90	94/87	**107/69**
	15	40	15	64	−97/−90	88/81	**74/48**
TDD macro to FDD pico (Outd-to-Ind)	5	40	15	46	−85	94	**37**
	10	40	15	58	−85	82	**18**
	15	40	15	64	−85	76	**13**
TDD micro to FDD macro (Vehicular)	5	27	15	46	−114/−106	110/102	**284/174**
	10	27	15	58	−114/−106	98/90	**136/83**
	15	27	15	64	−114/−106	92/84	**94/58**
TDD pico to FDD macro (Outd-to-Ind)	5	21	15	46	−114/−106	104/96	**65/41**
	10	21	15	58	−114/−106	92/84	**33/21**
	15	21	15	64	−114/−106	86/78	**23/15**
TDD micro to FDD micro (LOS)	5	27	12	46	−97/−90	90/83	**290/130**
	10	27	12	58	−97/−90	78/71	**73/33**
	15	27	12	64	−97/−90	72/65	**37/16**
TDD micro to FDD micro (Pedestrian)	5	27	12	46	−97/−90	90/83	**52/33**
	10	27	12	58	−97/−90	78/71	**24/14**
	15	27	12	64	−97/−90	72/65	**15/9**
TDD pico to FDD micro (Outd-to-Ind)	5	21	6	46	−97/−90	78/71	**15/10**
	10	21	6	58	−97/−90	66/59	**7/5**
	15	21	6	64	−97/−90	60/53	**5/3**
TDD micro to FDD pico (Outd-to-Ind)	5	27	6	46	−85	72	**10**
	10	27	6	58	−85	60	**5**
	15	27	6	64	−85	54	**4**
TDD pico to FDD pico (LOS)	5	21	0	46	−85	60	**9**
	10	21	0	58	−85	48	**2**
	15	21	0	64	−85	42	**1**
TDD pico to FDD pico (Indoor)	5	21	0	46	−85	60	**1**
	10	21	0	58	−85	48	**1**
	15	21	0	64	−85	42	**<1**

TABLE 25

Description of scenario (prop. Model)	Carrier separation MHz	Tx power (incl activity factor) dBm	Effective antenna gain dBi	ACIR dB	Accepted level of Iext dBm	Required pathloss dB	Required separation distance m
FDD macro to TDD macro (LOS)	5	43	30	42	–114/–106	145/137	14275/9007
	10	43	30	49	–114/–106	1381130	9541/6020
	15	43	30	63	–114/–106	1241116	4262/2689
FDD macro to TDD micro (Vehicular)	5	43	15	42	–971–90	113/106	341/222
	io	43	15	49	–971–90	I06199	221114s
	15	43	15	63	–97/–90	92184	94/61
FDD macro to TDD pico (Outd to Ind)	5	43	15	42	–85	101	55
	10	43	15	49	–85	94	37
	15	43	15	63	–85	80	16
FDD micro to TDD macro (Vehicular)	5	30	15	42	–114/–106	117/109	4361267
	10	30	15	49	–114/–106	110/102	284/174
	15	30	15	63	–114/–106	96/88	121/74
FDD micro to TDD micro (LOS)	5	30	12	42	–97/–90	97/90	650/290
	10	30	12	49	–97/–90	90/83	290/130
	15	30	12	63	–97/–90	76/69	60/26
FDD micro to TDD micro (Pedestrian)	5	30	12	42	–97/–90	97/90	80/52
	10	30	12	49	–97/–90	90/83	52/33
	15	30	12	63	–97/–90	76/69	21/12
FDD micro to TDD pico (Outd-to-Ind)	5	30	6	42	–85	79	25
	10	30	6	49	–85	72	10
	15	30	6	63	–85	58	5
FDD pico to TDD macro (Outd-to-Ind)	5	24	6	42	–114/–106	102194	58/37
	10	24	6	49	–1141–106	95/87	39/25
	15	24	6	63	–114/–106	81/73	17/11
FDD pico to TDD micro (Outd-to-Ind)	5	30	6	42	–971–90	91184	31/21
	10	30	6	49	–971–90	84/77	21/14
	15	30	6	63	–971–90	70163	9/6
FDD pico to TDD pico (LOS)	5	24	0	42	–85	64	7
	10	24	0	49	–85	57	4
	15	24	0	63	–85	43	2
FDD pico to TDD pico (Indoor)	5	24	0	42	–85	64	2
	10	24	0	49	–85	57	1
	15	24	0	63	–85	43	<1

4.2.1.2 Required ACIR for 3.84 Mchipls TDD/FDD interference

The required ACIR is independent of the carrier separation. However, the missing isolation compared to the reference cases are not. In the last column the missing isolation compared to the assumed ACIR from table 13 in the TDD-to-FDD case, and from Table 12 in the FDD-to-TDD case. For simplicity only the figures for 5 MHz carrier separation is given

TABLE 26

TDD to FDD interference

Description of scenario (+prop. model)	Tx power (incl activity factor) dBm	Effective antenna gain dBi	Refcrcnce separation distance m	Pathloss dB	Accepled 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
TDD micro to FDD macro (Vehicular)	21	15	50	81.6	–1141–106	74.4/66.4	28.8/20.4
TDD pico to FDD macro (Outd-to-Ind)	21	15	50	994	–114/–106	50.6/42.6	4.6/-3.4
TDD micro to FDD micro (LOS)	21	12	50	74.7	–97/–90	61.3/54.3	15318.3
TDD micro to FDD micro (Pedestrian)	21	12	50	91.9	–97/–90	44.1/37.1	-1.9/-8.9
TDD pico to FDD micro (Outd-to-Ind)	21	6	20	83.4	–97/–90	40.6/33.6	-5.4/-12 4
TDD micro to FDD pico (Outd-to-Ind)	27	6	20	83.4	–85	34.6	-11.4
TDD pico to FDD pico (LOS)	21	0	10	h0.7	–85	453	-0.7
TDD pico to FDD pico (Indoor)	21	0	10	85.3	–85	20.7	-253

TABLE 21

FDD to TDD interference

Description of scenario (+prop. model)	Tx power (incl activity factor) dBm	Effective antenna gain dBi	Reference separation distance m	Pathloss dB	Accepted level of I_{ext} at Rx dBm	Required ACIR dB	Missing isolation 5 MHz carrier separation dB
FDD macro to TDD macro (LOS)	43	10	100	80.7	–I 141–106	106.3198.3	64.3/56.3
FDD macro to TDD micro (Vehicular)	43	15	S0	81.6	–97/–90	73.4/66.4	31.4124.4
FDD macro to TDD pico (Outd-to-Ind)	43	I5	50	99.4	-85	43.6	1.6
FDD micro to TDD micro (LOS)	30	12	50	74.7	-971-90	64.31573	22.3/15.3
FDD micro Io TDD micro (Pedestrian)	30	I2	50	91.9	-971-90	47.1140.1	5.1/-1.9
FDD micro to TDD pico (Outd-to-Ind)	30	6	20	83.4	-85	37.6	-4.4
FDD pico to TDD micro (Outd-to-Ind)	21	6	20	83.4	–97/–90	40.6/33.6	-1.41-8.4
FDD pico to TDD pico (LOS)	21	0	10	60.7	–85	45.3	3.3
FDD pico to TDD pico (Indoor)	21	0	10	85.3	-85	20.7	-213

4.2.1.3 Required separation distances for TD-SCDMA/FDD interference