[Doc 8F/TEMP/362Rev1]

Working Party 8F

NOTE TO 3GPP AND 3GPP2

COEXISTENCE BETWEEN IMT-2000 TDD AND FDD RADIO INTERFACE TECHNOLOGIES WITHIN THE FREQUENCY RANGE 2 500-2 690 MHz OPERATING IN ADJACENT BANDS AND IN THE SAME GEOGRAPHICAL AREA

Working Party 8F is the ITU-R Working Party responsible for the overall system aspects of IMT-2000 and beyond.

Working Party 8F has completed a Draft New Report ITU-R M.[IMT.COEXT] on the "Coexistence Between IMT-2000 TDD and FDD Radio Interface Technologies Within the Frequency Range 2 500 - 2 690 MHz Operating in Adjacent Bands and in the Same Geographical Area." A further working document toward a draft new report is under preparation to address the potential improvement that can be brought about when mitigation techniques are applied to the results of the aforementioned TDD/FDD coexistence studies. The objective is to finalize this new report at the WP8F meeting in Edinburgh, October 2003.

The present working document, which is currently in an early stage of preparation, is attached for your consideration. Draft new Report ITU-R M.[IMT.COEXT] is also attached for information.

The next meeting of WP 8F will take place from 26 March to 3 April 2003, in Brazil.

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WG Spectrum DG1, Sharing Studies and Related Issues.

Attachments: 2

- Doc: 8F/TEMP/361 (Draft new Report ITU-R M.[IMT.MITIGATION])
- Doc. 8F/623, Attachment 7.12 (IMT.COEXT)

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RADIOCOMMUNICATION
STUDY GROUPS

Document 8F/TEMP/361-E
1 October 2002
English only

Source: Attachment 7.3 to Documents 8F/728, 8F/740, 8F/779

Working Party 8F
(Spectrum DG 1)

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ON MITIGATING TECHNIQUES TO ADDRESS COEXISTENCE BETWEEN IMT-2000 TDD AND FDD RADIO INTERFACE TECHNOLOGIES WITHIN THE FREQUENCY RANGE 2 500-2 690 MHz OPERATING IN ADJACENT BANDS AND IN THE SAME GEOGRAPHICAL AREA

1 Scope

This report provides analyses of the potential improvement that can be brought about when mitigation techniques are applied to the results of the TDD/FDD coexistence studies presented in the draft new report ITU-R M.[IMT.COEXT] shown in reference [3]. That Report identified scenarios where TDD/FDD coexistence was problematic due to Base Station to Base Station (BS-to-BS), Base Station to Mobile Station (BS-to-MS), Mobile Station to Base Station (MS-to-BS) and Mobile Station to Mobile Station (MS-to-MS) interference. In this study we apply various mitigation techniques to those scenarios to qualify and quantify the potential improvements they can bring.

It is recognized that mitigation techniques affect the cost, complexity or performance of the system deployment. As such, there may need to be tradeoffs made between these and the benefits associated with the use of each mitigation technique separately or in combination with others. This report presents the reader with a description of these tradeoffs that may need to be evaluated in selecting which, if any, of these techniques may be implemented economically.

This draft new report specifically addresses techniques that might be applicable for general application when planning deployment of multiple competitive networks operating in adjacent bands and in the same geographical area. As in the related paper, the IMT-2000 technologies considered are the FDD based IMT-2000 CDMA direct spread radio specification and both TDD based CDMA TC modes, more specifically HCR TDD (3.84 Mcps) and LCR TDD (1.28 Mcps).

2 Introduction and summary

Potential coexistence issues between TDD and FDD IMT-2000 radio interface technologies have been identified during studies into how multi-operator networks may be deployed in the IMT-2000 2 500-2 690 MHz band in the most spectrum-efficient manner. Report [IMT.COEXT], [3], concluded that significant interference was likely to be experienced in BS-to-BS scenarios (whether they be co-located or in proximity) as well as in MS-to-MS scenarios where outages would impact user service levels.

Editor's Note – Material needed on the issue of combination of the mitigation techniques. The introduction needs to elaborate on the issue that the not all mitigation techniques are necessarily covered.

3 Review of the previous related work in ITU-R WP 8F

That Report presented results of the consequences of adjacent channel interference on compatibility of a number of scenarios of TDD and FDD air interface technologies operating in adjacent bands and in the same geographical area. The previous study was based on deterministic interference level calculations for BS-BS scenarios and led to required separation distances and/or isolation requirements or supported cell range. The interference from mobile stations into mobile stations and base stations was also analyzed both with deterministic and statistical calculations leading to capacity loss and/or probability of interference.

The scenarios presented in section 3.1 are only the ones that were identified as problematic for TDD/FDD coexistence in [3]. They will be used as the basis for qualifying and quantifying the benefits of using each of the mitigation techniques presented in this Report. The evaluation criteria presented in section 3.2 are the same as those presented in [3], e.g. required separation distances and/or isolation requirements or supported cell range, capacity loss and probability of interference.

3.1 Reference scenarios

The following interference scenarios have been identified in [3] for coexistence of IMT-2000 FDD and TDD systems.

1) FDD BS <–> TDD BS

2) FDD UE <–> TDD UE

3) FDD UE <–> TDD BS

4) FDD BS <–> TDD UE

While the first case was analysed by deterministic methods, statistical analysis was used for cases 3 and 4. Case 2 was analysed by both methods. In this report, case 1 is further analysed through statistical methods for interference level calculations for base stations using adaptive antennas.

In [3], 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.

The problematic cases identified in [3] are described below:

3.1.1 Macro TDD BS – macro FDD BS

In [3], the macro TDD BS – macro FDD BS interference is identified as the most problematic case. Some of the parameter values pertaining to this scenario are repeated in Table 1 below for reference. Given these parameters, the maximum acceptable level of external interference, (I_{ext}), is also obtained from [3].

3.1.2 <Problematic case #2>

3.1.3 <problematic case #3>

TABLE 1

Summary of parameters for the problematic coexistence cases

Type[1]	P_{tx} (dBm)	Antenna Height (m)	ACLR[2] (dB)	ACS[2] (dB)	I_{ext} (dBm)[3]
FDD BS	43	30	45	46	–114 to –106 (rural) –100 to –95 (urban)
TDD BS	43	30	70	46	

[1] FDD BS is WCDMA FDD and TDD BS is HCR TDD

[2] For adjacent channels with 5 MHz carrier separation

[3] The range corresponds to lightly loaded (20%) and highly loaded (75%) systems

In Table 1, ACLR is Adjacent Channel Leakage Ratio and ACS stands for Adjacent Channel Selectivity.

Editor's Note – Table 1 is to be expanded to include the parameters from all of the problematic cases presented in section 3.1

3.2 Evaluation criteria

The evaluation criteria used in this Report are the same as those presented in [3], e.g. required separation distances and/or isolation requirements or supported cell range, capacity loss and probability of interference. Various mitigation techniques are selected and evaluated to determine the amount of improvement they provide to the performance of the reference scenarios in section 3.1, *i.e.* their ability to reduce isolation requirements in terms of separation either in the space or frequency domain, and to reduce the probability of interference.

4 Overview of interference mitigation techniques relevant to TDD-FDD Coexistence

Each of these subsections describes the main attributes of the mitigation techniques. The techniques presented are only those that can be useful in addressing coexistence between TDD and FDD systems operating in adjacent bands and in the same geographical area, recognizing that this may exclude other commonly used techniques in system deployment.

4.1 Site engineering

4.1.1 Antenna coupling and isolation

4.1.1.1 Non-collocated antennas

For interference between two macro base stations

Two macro (over the rooftop) BS antennas that are pointed towards each other in the horizontal plane can exhibit a tight coupling to each other. To mitigate that tight coupling, it is recommended to down tilt the antennas so that they would not be in each other’s respective boresight in the vertical plane.

For interference between a macro and micro base stations

In the case of macro and micro BS antennas, mitigating the strong antenna coupling can be achieved by mounting the antennas at different heights. For example, the macro antenna could be mounted on a pole on the roof, while the micro antenna would be possibly on the building outer wall closer to street level. Thus the effective gain that determines the coupling between the two is less than the algebraic sum of the gains.

4.1.1.2 Collocated antennas

It is possible to achieve significant levels of isolation between two collocating base station antennas through proper placement by taking advantage of the antenna pattern. Cellular antennas normally have vertical beamwidth in the range of a few degrees in either side of the horizontal. Also, sectored antennas typically have horizontal beamwidth in the range of 90 degrees (±45 degrees from boresight) and their pattern falls off rapidly at ±90 degrees off the boresight direction. A high degree of front-to-back ratio could also be used to provide isolation between two collocated base station antennas. Using these characteristics, it is possible to facilitate the coexistence of any two base stations by collocating them on the same tower or rooftop. While it is not always possible to coordinate the collocation process between competing operators, doing so would yield additional isolation over the Minimum Coupling Loss (MCL) assumption in [3]. In those problematic cases identified in [3], this additional isolation can be used to reduce the size of the guardbands between two systems in adjacent blocks/channels. Section 5.1.2 quantifies the potential improvement in coexistence due to collocation. Careful installation techniques allow two antennas that are mounted on the same pole to achieve higher coupling loss of [72] dB.

4.1.2 Use of orthogonal polarizations

It is possible to get additional isolation between two antennas by having them orthogonally polarized to each other. Cellular antennas are typically linearly polarized. Therefore, as an example, using vertical polarization on one antenna and horizontal polarization on the other can reduce the degree of coupling between the two of them. The coupling effect is quantified in terms of an antenna characteristic know as Cross Polar Discrimination (XPD). The collective effect of the XPD from both antennas needs to be taken into account. Section 5.1.3 quantifies the potential improvement in coexistence due to use of orthogonal polarization.

4.2 Use of Adaptive Antennas (AA)

Adaptive Antennas increase the coverage and capacity of the wireless networks and enhance their performance through spatial processing, beam forming, and interference mitigation. The direct effect of AA on coexistence is due to the fact that the RF energy radiated by transmitters is generally focused in specific areas of the cell and is not constant over time. Adaptive antennas can be, therefore, modeled as a narrow angular sector in coexistence simulations, thus affecting the likelihood of interference in coexistence scenarios. Moreover, beam forming with the goal of maximizing the link margin for any given user inside the cell coverage area at any given time, makes the AA beams' azimuth and elevation vary in time. These two factors suggest that the adaptive antenna pattern and gain need to be considered as random variables both in E- and H-plane. While an absolute worst case may look prohibitive, the statistical factor introduced by the use of AA determines the percentage of time that the worst case happens. If this percentage is satisfactorily small, the coexistence rules may be relaxed.

Another effect of the AA on coexistence involving adjacent bands is due to the fact that the gain of the AA is reduced in the antenna-to-antenna coupling due to loss of coherency in out-of-band operation. This reduction in gain further reduces the interference power into AA from other antennas operating in adjacent bands and vice versa. The impact is especially important since direct

AA main beam coupling is the largest contributor to the interference. Simulations point to the fact that the BS-BS direct antenna coupling is the most problematic case for coexistence. With the use of AA, the loss of coherency in out-of-band operations reduces the gain towards the interferers/victims, thus lowering the amount of interference power.

4.3 Improved equipment specifications

4.3.1 Filtering and/or linearization techniques

Editor's Note – Depending upon the resolution of section 5.3.1.2, agreement on the following text can be reached.

[Filtering or linearization or both can be used to reduce the unwanted emissions from one base station to another thus reducing the interference at the victim base station. In a similar manner, receiver filtering may reduce the in band interference to the victim base station. When the overall interference is reduced, base stations could be moved closer to each other, or allowed higher TX power or both while maintaining a desired interference level.

In order to predict a reasonable level of protection for TDD to FDD interference, it is useful to consider recent agreements in 3GPP RAN specifications and assume as an example that similar agreements would be made for equipment that will be designed for 2.5 GHz. According to these agreements, TDD equipment is required to protect FDD equipment. The level of protection depends on if the equipment is intended for deployment in co-location (defined in 3GPP RAN as BS which have an MCL=30 dB) or in the same geographical area (defined in 3GPP RAN as BSs which have physically overlapping service areas) and on the class of TDD base station (local area or wide area). See appendix A for details.

Better FDD receiver protection can be achieved by the incorporation of additional receive filter in the FDD BS receiver. As an example for such filter one may consider a filter such as currently required to protect the FDD in the 1900 MHz band from GSM emissions.]

4.4 Other techniques

4.4.1 Use of power control

Editor's Note – It needs to be resolved as to the manner in which power control was implemented in scenarios presented in the baseline Report ITU-R M.[IMT.COEXT]. Once this is done, then the following text in square brackets can be edited accordingly.

[In TDD systems that do not employ power control, the available BS DL power is usually equally divided between the users in the slot. A typical system design will then consist of budgeting that available power to cover path loss, SIR requirements, an allowed interference level that would be equal at all users antennas and some margin. As the allowed interference is the same for all users, it by necessity has to be small if coverage and or capacity is to be preserved.

To mitigate that interference, power control can be used such that different interference levels that are experienced by different users will trigger an increase in the BS DL power allocated to that user. The net result is that the interference allowed to some users can be increased while maintaining low average interference, and therefore maintaining the capacity and coverage. An additional benefit of the technique is that the interference caused by the TDD DL to the FDD system could also be reduced.

The cost associated with this technique is negligible as it is already part of the UMTS standard design and part of existing equipment.]

5 Effects of the mitigation techniques on the coexistence

In each subsection of this chapter we will address both the benefits and costs associated with each technique for the considered scenarios.

5.1 Effects of using site engineering techniques

5.1.1 Effects based on improving antenna coupling and isolation

5.1.1.1 [Collocating Antennas]

The effect of antenna coupling on interference among base stations can be reduced through collocation and proper placement. Based on the measurements reported to 3GPP, TSG RAN [4] for a variety of typical antennas, it is possible to quantify this effect. There are several placement options, including the following.

a) Vertical separation: Based on [4], it is possible to achieve at least 60 dB of isolation between two 16 dBi vertically polarized, 90^o sector antennas with approximately 3 metres of vertical separation.

b) Side-by-side separation: The measurements in [4] suggest 45 to 50 dB of isolation between two 16 dBi vertically polarized, 90^o sector antennas at approximately 4 to 6 metres of horizontal separation.

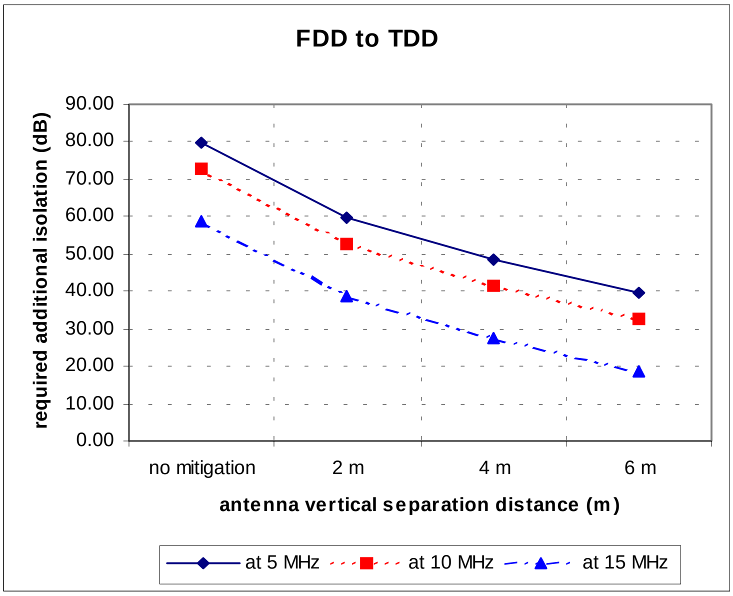
c) Back-to-back separation: The measurements in [4] suggest 65 to 70 dB of isolation between two 16 dBi vertically polarized, 90^o sector antennas at horizontal back-to-back separation distances in the range of 1 to 1.5 metres.

The above isolation is achievable using the antenna patterns only and does not include the use of any additional screening or absorption material.

It is, therefore, possible to facilitate the coexistence of any two base stations by collocating them on the same tower or rooftop. While it is not always possible to coordinate the collocation process between competing operators, doing so could yield, on the average, 60 dB of isolation. This is 30 dB of additional isolation over the 30 dB MCL assumption in [3]. In those problematic cases identified in [3], this additional isolation can be used to reduce the size of the guardband between two systems in adjacent blocks/channels. Using the methodology of section 4.2.1.4 in [3], where adjacent-band FDD and TDD systems are collocated, the amount of additional isolation achieved by the techniques discussed above are shown graphically in the following figures. The initial no mitigation numbers shown in these figures come from [3] and are based on an interference to noise ratio of –6 dB. This applies to a large cell, probably a rural application, where maintaining a low receiver sensitivity is important, i.e., to receive a signal from a mobile user operating at the edge of a large cell. The amount of improvement due to vertical separation of the antennas is depicted in Figures 1 and 2.

FIGURE 1

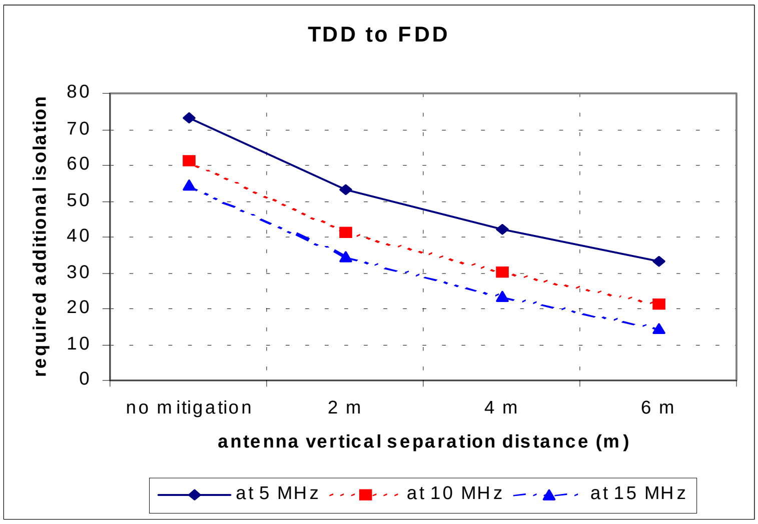
Improvement in required additional isolation due to vertical antenna separation (TDD victim)



Editor's Note – Explanatory text needed on how the graphs were made.

FIGURE 2

Improvement in required additional isolation due to vertical antenna separation (FDD Victim)



The amount of improvement due to horizontal separation of the antennas is depicted in Figures 3 and 4.

FIGURE 3

Improvement in required additional isolation due to horizontal antenna separation (TDD victim)

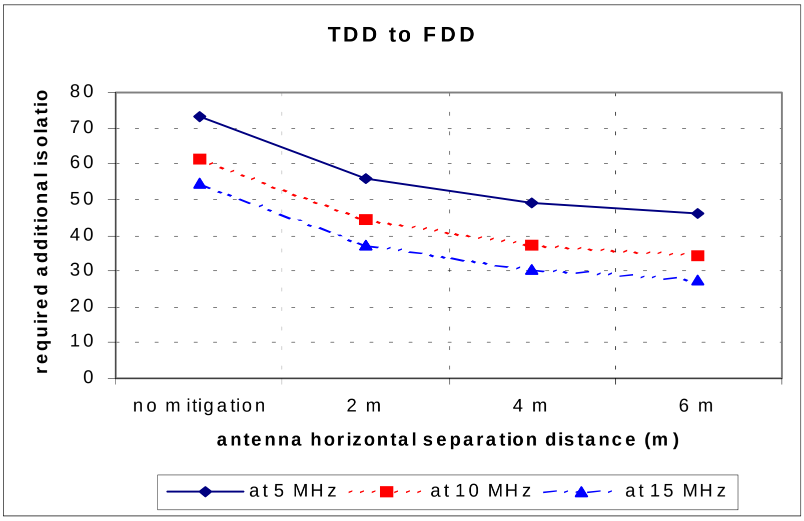
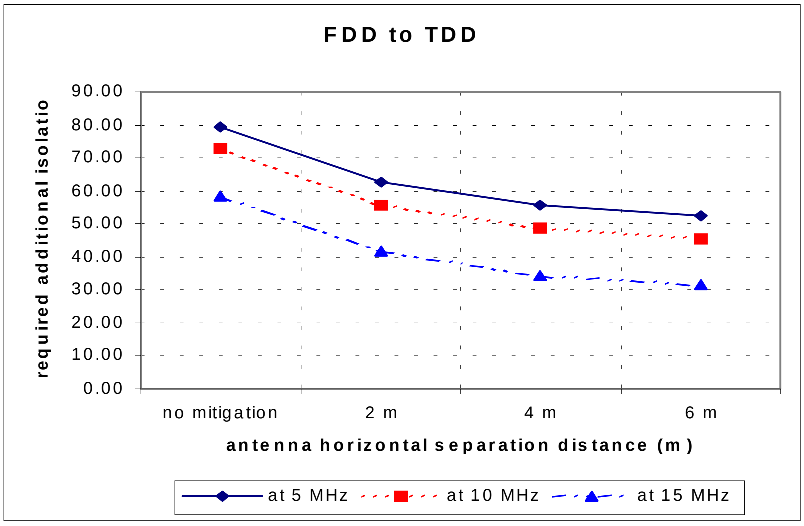


FIGURE 4

Improvement in required additional isolation due to horizontal antenna separation (FDD victim)



The amount of improvement due to back-to-back separation of the antennas is depicted in Figures 5 and 6.

FIGURE 5

Improvement in required additional isolation due to back-to-back antenna separation (TDD victim)

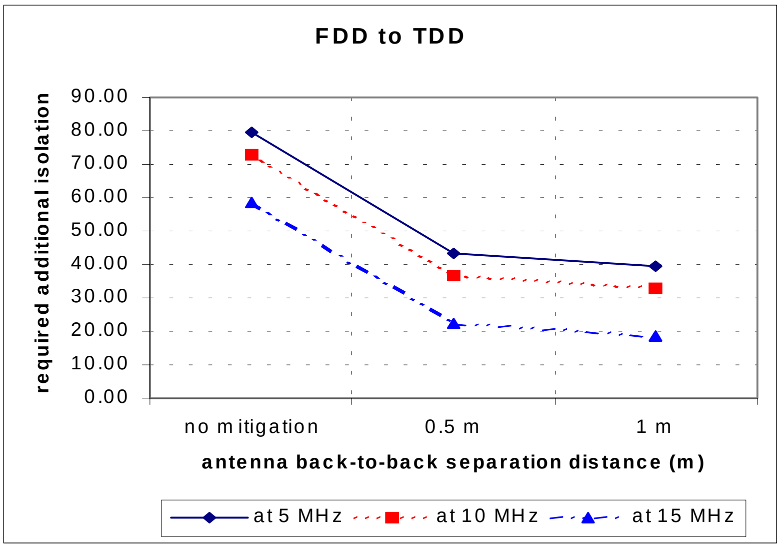
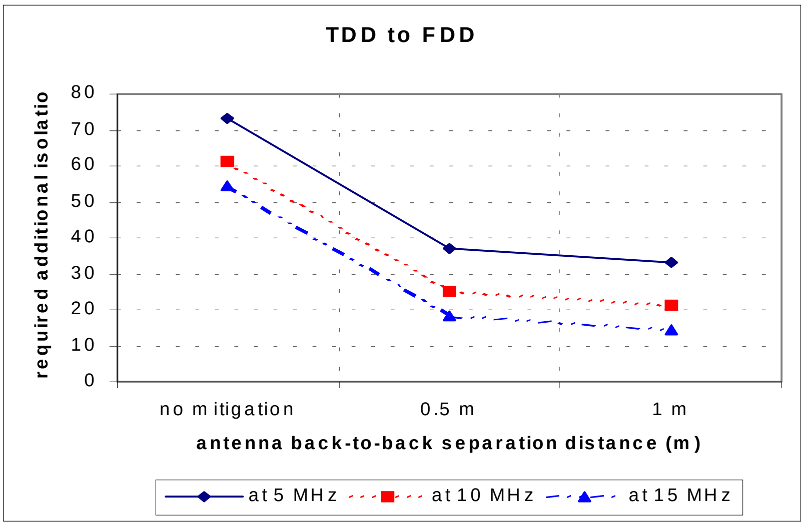


FIGURE 6

Improvement in required additional isolation due to back-to-back antenna separation (FDD victim)



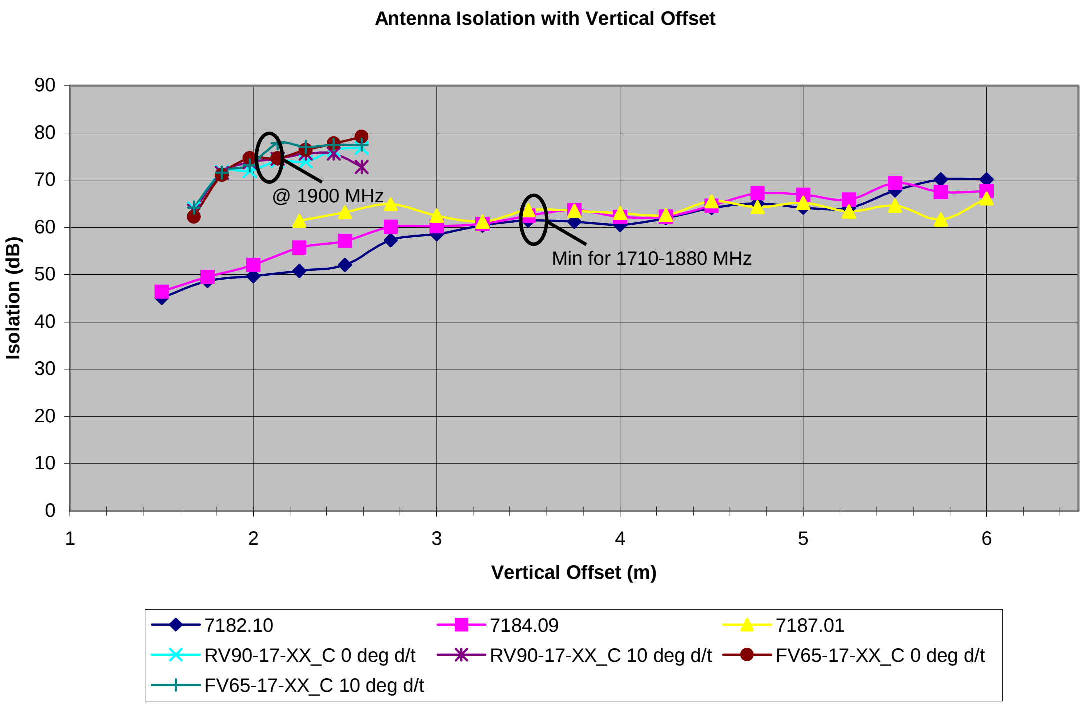
In combination with other mitigation techniques, coordinated antenna placement can potentially remove the need for guardbands in collocation scenarios.

Editor's Note: Explanatory text needed for the graphs.

The following graph was compiled from measurements in [6] and [4] at 1 900 MHz and 1 710-1 880 MHz respectively. The isolation is likely to increase for antennas designed for the 2 500 MHz band and for pole mounted antennas.

FIGURE 7

Antenna isolation with vertical offset



Editor's note: Material needed on the cost and trade off issues. Also, description needed on the graphs.

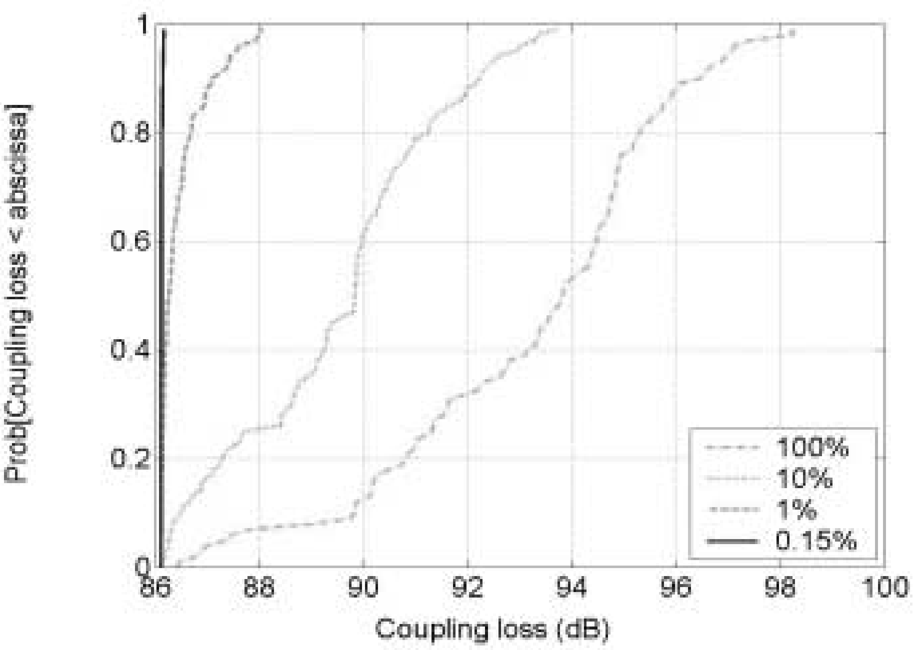
5.1.1.2 Antenna isolation achieved by antenna displacement

5.1.1.2.1 Macro, downtown BS and in building pico BS

Avoiding LOS placement of indoor pico base stations and macro pole mounted antennas achieves an isolation of 86 dB. The isolation is obtained between in building pico BSs located randomly within the buildings of a regular Manhattan type grid and a macro, downtown BS pole mounted on the building located in the centre of the grid (see following graph). The in building pico BSs are distributed in height and building location (See Appendix B for more details).

FIGURE 8

Distribution of the coupling loss between the macro, downtown BS and the most coupled in building pico BS, for different densities of in building pico BSs (100% corresponds 4 BSs per floor, in all floors, in all buildings)



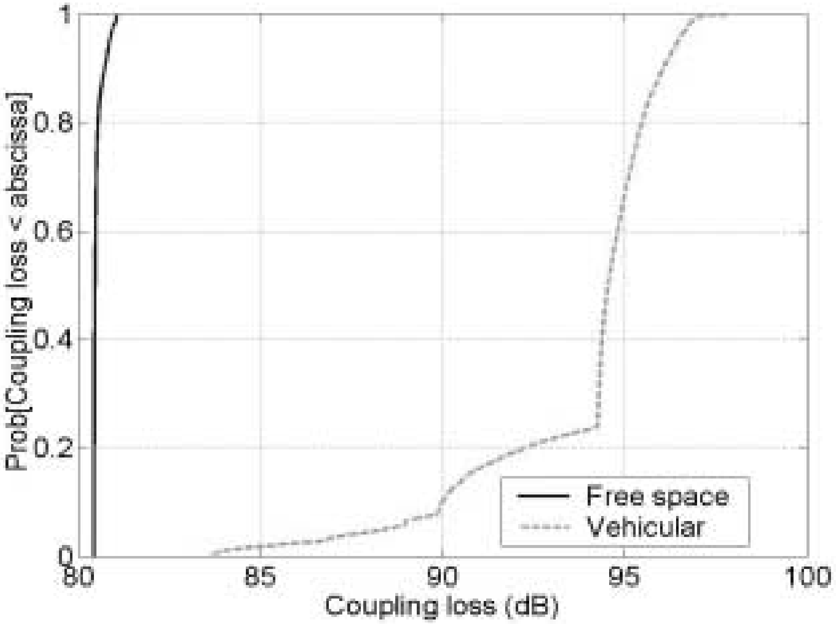
5.1.1.2.2 Macro, downtown BS and outdoor micro BS

Avoiding LOS placement of macro pole mounted and micro antennas can achieve antenna isolation of greater then 80 or 90 dB (depending on propagation model).

The isolation is obtained for >90% of the deployments between in outdoor micro BSs located in a regular rectangular grid and a macro, downtown BS pole mounted in an area at the centre of the grid. (see following graph) The macro, downtown BS is placed randomly with in the centre area. A height difference of 25 m is assumed between the macro, downtown BS and the outdoor micro BSs. (See Appendix B for more details)

FIGURE 9

Distribution of coupling loss between a macro, downtown BS and the most coupled outdoor micro BS



5.1.2 Use of orthogonal polarization

Antenna XPD is defined as the ratio of the received signal level in the wanted polarization to the received signal level in the unwanted polarization. The minimum (i.e., worst case) collective isolation achievable between two orthogonally polarized antennas (XPD_{min}) is related to the XPD of both antennas through the following equation [5].

$$XPD_{\min} = \left[XPD_1^{-\frac{1}{2}} + XPD_2^{-\frac{1}{2}}\right]^{-2}$$

Citing antenna manufacturers' catalogs, it is possible to achieve XPD in the order of 25 to 35 dB for cellular antennas in the frequency range of interest. This parameter is sometimes specified as inter-port isolation in dual-polarized antennas. As an example, using two antennas each having a main-lobe XPD of 30 dB would produce XPD_{min} of 24 dB in main beam coupling situations.

One possible scenario for implementing this technique would be the case of two base station antennas at close proximity, potentially in line-of-sight to each other. While the underlying path loss could be insufficient to provide enough isolation for adjacent or alternate channel operation, additional isolation due to the use of a polarization orthogonal to that of the interferer could potentially solve the problem. It should be noted that the amount of isolation through XPD of the antennas is fully achievable when the two antennas are in the worst-case scenario configuration; i.e., main-beam coupling in line-of-sight, where isolation is needed most. The amount of isolation reduces in side lobe coupling or NLOS situations due to deterioration of the polarization purity of the antennas and depolarization introduced by reflection and diffraction.

This technique can also be combined with other mitigation techniques to remove specific coexistence problems, e.g., additional isolation requirement for collocation of base station antennas.

Editor's note: Text will be added to discuss the availability of orthogonal polarization as a mitigation technique and the extent to which the theoretical results could be achieved in the real world.

5.2 Effects of using adaptive antenna technology

Editor's Note: This is work under development. Further explanation on the analytical approach is needed.

Since the macro TDD BS – macro FDD BS interference was identified as the most problematic case, the analysis reported here is done for this case in both rural and urban areas. Generally, all the assumptions in calculation of the interference levels including antenna heights, Adjacent Channel Leakage Ratio (ACLR), Adjacent Channel Selectivity (ACS), channel bandwidths, receiver sensitivity, etc. are consistent with [1]. The AA pattern and gain are given later in this section. Given these parameters, the maximum acceptable level of external interference, (I_{ext}), is also obtained from [3]. According to the results presented here, it is evident that the use of AA reduces the required additional isolation in less than 2% of the time in rural and urban areas significantly (compare with tables in Section 4 of [3]). The additional isolation needed for coexistence, if necessary, is at a level that can be easily achieved by other coexistence-friendly site engineering practices or better equipment specifications.

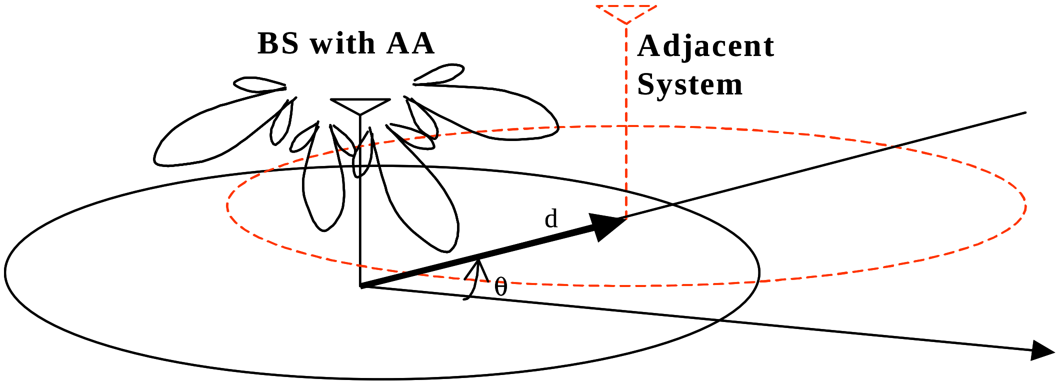
5.2.1 Introduction

Adaptive antennas impact a wireless system in many ways; through coherent combining of the arrived signals, large diversity gains that combat uncorrelated fading among multiple antennas, and interference suppression and mitigation. An adaptive array with M elements is capable of nulling $M-1$ interferers perfectly. This capability of the array, however, has been assumed to be solely used for coping with intra-network interference and is not included in the simulations for inter-network interference.

Direct benefit from the use of AA on the coexistence, however, is due to the fact that the RF energy radiated by transmitters is focused in limited, specific regions of a cell rather than wide sectors. Also, the beam forming capability of adaptive antennas at the base stations creates inherent down tilt in the vertical plane, which is determined by the distribution of users within the cell. Since users are distributed within the cell area, the AA is likely to point its beams at user locations, thus lowering the likelihood of creating/accepting interference to/from other stations, as depicted in Figure 10. This lower likelihood of interference is verified by the results presented here.

FIGURE 10

Distribution of AA beams in time and space lowers the likelihood of interference



Editor's note: informative text needed on the various options on the geometry of the array as it relates to deployment matters, noting that the array geometry was not relevant for the analysis presented.

5.2.2 Propagation models

For macro cells, the following path loss model is recommended in [1].

$$L = 40(1-4\times10^{-3}\Delta h_b)\log_{10}(R) - 18\log_{10}(\Delta h_b) + 21\log_{10}(f) + 80 + FM \qquad (1)$$

FM is the log-normally distributed shadowing margin with standard deviation of 10 dB

f is frequency in MHz

Δh_b is the base station antenna height above average rooftop, and

R is distance in km.

Several propagation models are used in [3] for the purpose of coexistence simulations. However, [3] uses a Dual-Slope model from [10] for the case of macro-cell BS-BS interference. This model is formulated by equation (2) for 2.6 GHz.

$$L_{LOS} = \begin{cases} 40.7 + 20\log_{10}(d) & 1 \le d \le d_{break} \\ 40.7 - 20\log_{10}(d_{break}) + 40\log_{10}(d) & d \ge d_{break} \end{cases}$$
$$d_{break} = \frac{4h_{tx}h_{rx}}{\lambda} \qquad (2)$$

In equation (2), h_{tx} and h_{rx} are the transmitter and receiver antenna height above average rooftop, λ is the wavelength, d is the distance between the transmitter and the receiver, and d_{break} is the breakpoint associated with the first Fresnel zone, all in metre. It should be noted that for typical antenna heights above rooftops and the range of frequencies under consideration for IMT-2000 technologies, this model performs as free space LOS for most deployment distances. This is overly pessimistic for urban deployment scenarios since the effects of the perturbation of the first Fresnel zone by buildings in the vicinity of base stations are ignored. It will be shown later that AA introduces improvements even in case of this overly pessimistic model.

5.2.3 Deterministic analysis without AA

Given the ACIR, Adjacent Channel Interference Ratio, it is possible to calculate the required separation distance from the following example of a TDD BS interfering with an FDD BS [3] without the benefit of AA.

The average output power of the TDD BS, including the activity factor of TDD (assumed as 0.5) is the following.

$$P_{ave} = P_{tx} - 3 = 43 - 3 = 40 \quad dBm$$

The overall resulting gain, assuming both BS antennas are aligned through their maximum gain beams with no downtilt (worst case) is:

$$G = G_{tx} + G_{rx} = 15 + 15 = 30 \quad dBi$$

Given the ACLR and ACS values in Table 1,

$$ACIR = 10\log_{10}\left(\frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}}\right) = 10\log_{10}\left(\frac{1}{\frac{1}{10^{7}} + \frac{1}{10^{4.6}}}\right) = 45.98 \approx 46 \quad dB$$

The required path loss, assuming tolerable adjacent channel interference of –114 dBm [3] is found as follows.

$$L = P_{ave} + G - ACIR - I = 40 + 30 - 46 - (-114) = 138 \quad dB \qquad (3)$$

Using the propagation model given by equation (2), the required separation distance to achieve 138 dB of path loss is calculated to be 9,541 m, which is quite prohibitive.

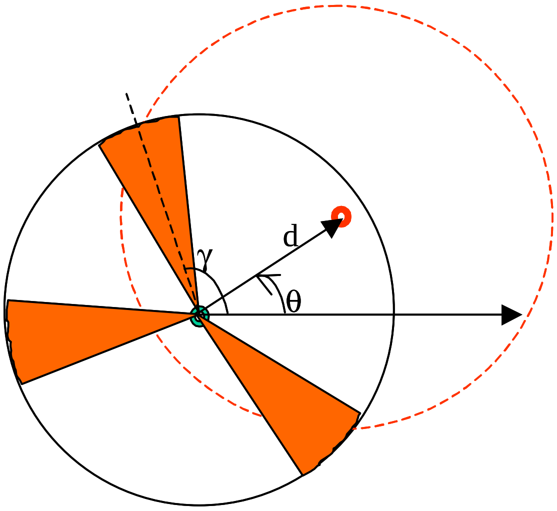
Given distance, equation (3) can also be rearranged to obtain the required ACIR.

5.2.4 Statistical analysis with AA

As described above, implementation of AA at the base station requires statistical analysis. The statistical simulation of AA is performed at snapshots in time. The basic set up for the simulation in the horizontal plane is shown in Figure 11.

FIGURE 11

Simulation in the horizontal plane

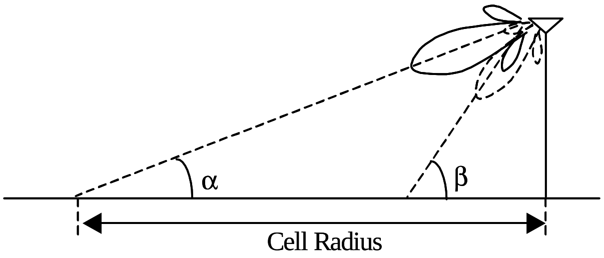


It is being assumed that during any given time slot on any carrier, one downlink beam at the TDD BS with AA illuminates each sector, thus affecting the victim FDD BS, or vice versa, the FDD BS, shown in red, radiates its energy in space, thus affecting the uplink of TDD BS. The distance between the two BS is set to be smaller than the larger of the two cell radii, presumably the FDD cell radius. It is assumed that the TDD base stations are located at random points within the FDD cell area, thus having a random distance *d* and angle θ to the FDD BS. The User Equipment (UE) terminals are assumed to be uniformly distributed within the cell area.

In vertical plane, it is assumed that the AA beams are distributed in the angular area between α and β as shown in Figure 12. α is determined by cell radius and transmitter height while β is assumed as 45^{o}. Both vertical and horizontal beam width of the AA are assumed to be equal to 10 degrees.

FIGURE 12

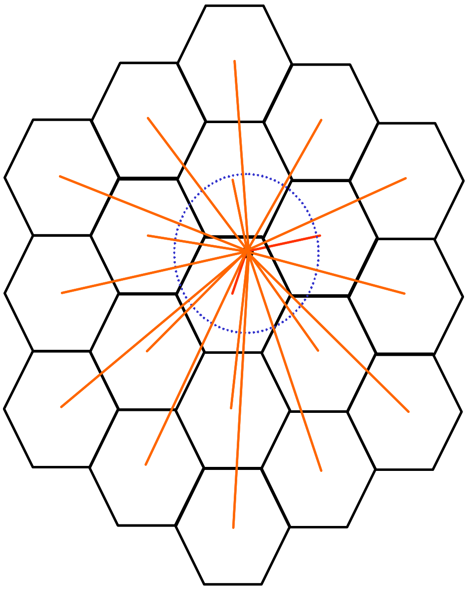
Simulation in the vertical plane



For the purpose of demonstrating the impact of AA on coexistence, a network of 19 cells, as suggested by [1], has been considered. Figure 4 depicts the network of 19 cells being built around a victim station. One such network is simulated for all random points picked within the cell area of the victim BS, the circle in Figure 13.

FIGURE 13

Network of 19 interfering cells



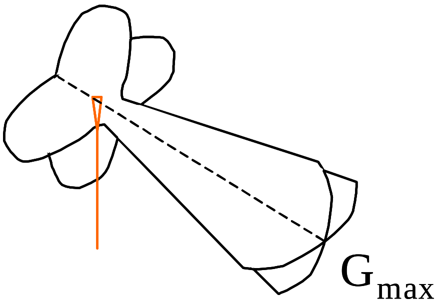
Base station density is based on ETSI Recommendation [9] (cell radius of 4 km for rural and 1.5 km for urban have been assumed). Some comparative simulations were also performed with cell radii as low as 500 m and as high as 9 km. The contribution from interferers beyond the closest 19 is considered to be insignificant. The likelihood of interference is observed by the percentage of the time the victim is protected as suggested by [1].

In all cases, the effect of perfect downlink and uplink power control is taken into consideration. In the downlink, this is implemented by lowering the transmit power of a TDD BS beam as the user moves closer to the BS to take advantage of reduced path loss. For simulations involving FDD network of cells, random values within the power control dynamic range of the FDD BS, as specified in section 6.4.2 of [9], have been assumed. In the uplink, power control is implemented by lowering the transmit power of the UE as it moves closer to the BS.

Throughout the simulation, FDD base stations are considered to have a maximum gain of 15 dBi with some degrees of down tilt such that the gain towards the horizon is reduced by 3 dB. For the TDD base stations utilizing AA, however, each beam is modeled in E-plane and H-plane according to Figure 14.

FIGURE 14

E-plane and H-plane of the AA beam assumed in the analysis



The maximum gain of an AA beam, G_{max}, is generally related to the array parameters as follows.

$$G_{\max} = G_{element} + 10\log_{10} M \qquad (4)$$

In the above formula, M is the number of array elements, $G_{element}$ is the gain of a single array element assumed to be 10 dBi. In nsynchro adjacent channel interference, due to loss of coherency in out-of-band beam-to-beam coupling, the additional array gain over $G_{element}$ is assumed to be $5\log_{10}(M)$ in main beam coupling throughout the analyses. It is also being taken into consideration that despite the random direction of the AA beam and general side and back lobe suppression, the upper side lobes are somewhat larger than other lobes unless highly complicated beam-forming techniques and large arrays are used. If the interferer and the victim share only the horizontal plane (but not the vertical plane), side lobes of the individual array elements affect the interference power. In this case, the gain of the array is assumed to be equal to the gain of the individual element through its side lobes, which is assumed to be 0 dBi. If the victim and interferer share only the vertical plane (but not the horizontal plane), the gain of the array is given by equation (5).

$$G = G_{element} - 10\log_{10} M \qquad (5)$$

If the interferer and the victim share neither planes, the gain is given by equation (6).

$$G = G_{element} - 20\log_{10} M \qquad (6)$$

The results presented in sections 5.2.1 and 5.2.2 were obtained assuming M=10, which corresponds to 10 and 20 dB side-lobe level from equations (5) and (6), respectively. It should be noted that AA are capable of producing much deeper nulls than 10 or 20 dB. These numbers are only used as average over all side lobes.

The simulations were run for various antenna heights. The results reported here, though, reflect the case where both antennas have the same height of 30 m, which creates the most interference. In reality, antennas are not likely to have equal heights, thus there is likely to be lower interference floor than the results of this study indicate.

Broadcast information contained in the logical control channels is meant to be transmitted in downlink to all users. This information is typically transmitted on certain known timeslots that are changed only on a long-term basis. For the stations using conventional antennas, as far as this analysis is concerned, this information can be treated as other information contained in traffic channels. Since the FDD base stations in this analysis are assumed to use conventional antennas, there is no effect on the results of the interference analysis into the uplink of the TDD base stations.

The case of the TDD BS implementing AA in the downlink, however, needs to be looked at separately. There are two possible implementations. One implementation of AA in TDD BS applies beamforming only to the traffic channels and leaves the broadcast channel as omnidirectional, thus creating interference to all surrounding victims in the periods that such information is being broadcast. It is, however, possible, as an alternative implementation approach, to apply beamforming to the broadcast channel, thus focusing even the broadcast information to certain areas of the cell at any given time.

5.2.4.1 First approach

According to 3GPP specifications [11], one out of the 15 time slots in a 10 ms TDD frame is considered for broadcast information such as synchronization or paging. Assuming that there is no coordination between the neighbouring TDD and FDD systems, there is a probability of 1/15 (~0.067) for any given FDD uplink timeslot suffering partially to fully from interference due to broadcast channel of a neighbouring TDD base station. For a given FDD uplink, the existence or nsynchronize of TDD broadcast information can be considered as a Bernoulli random variable, which takes up the values of 1 and 0, with the following statistical characteristics.

$$\begin{aligned} &X : \text{Bernoulli R. V.}, S_X = \{0,1\} \\ &p_1 = p, \qquad p_0 = q = 1 - p \\ &E[X] = p \\ &VAR[X] = pq \end{aligned}$$

In the above expressions, 1 and 0 represent the existence and nonexistence of interference, respectively.

Without AA at the TDD base station, in the worst case the interference into any given FDD frame is present all the time and the results of the deterministic analysis of section 3.1 apply. However, with the implementation of AA, on the average, the interference from the broadcast channel is present only $E[X] = p$ = 1/15 (= 6.7%) of the duration of the FDD frame. This is a 15-times, or almost 12 dB, reduction in the total amount of interference into an FDD uplink frame due to broadcast channel compared to the worst case analyzed in section 3.1. The extra margin of 12 dB may be translated into range. Considering the Dual-Slope path loss model with distance dependency of 40log(*d*), a two-fold improvement in the safe coexistence distance between the TDD and FDD macro base stations is expected. Based on calculations in section 3.1, one can also verify this by computing the new safe distance for broadcast channel as the following.

$$L_{new} = 138 - 12 = 126 \quad dB$$

Using equation (3), and a breakpoint distance of 1,248 m [3],

$$\begin{aligned} &126 = 40.7 - 20\log_{10}(1248) + 40\log_{10}(d_{new}) \\ &d_{new} = 4793 \quad m \end{aligned}$$

thus, the new safe distance of under 5 km for omnidirectional interference from the broadcast channel. The interference from the beam-formed traffic channels needs to be statistically added to the interference from the broadcast channel. This effect is analyzed by introducing a Bernoulli random variable in the interference calculations. If this random variable takes the value “1”, interference from the TDD traffic channel is replaced with the interference from the broadcast channel with omnidirectional configuration. The results are reflected in 5.2.1.

5.2.4.2 Second approach

With this approach, timeslots containing broadcast information should be treated as any other timeslots and broadcast channel will not add any additional interference to neighboring stations. This more favorable approach involves additional complexity and its implementation is the operator’s choice. For the sake of the present analysis, therefore, it has been assumed that simpler approach, i.e. the first approach, is implemented at the TDD BS. It is highly likely, though, that operators implementing AA at IMT-2000 TDD base stations favor second approach due to its superior performance.

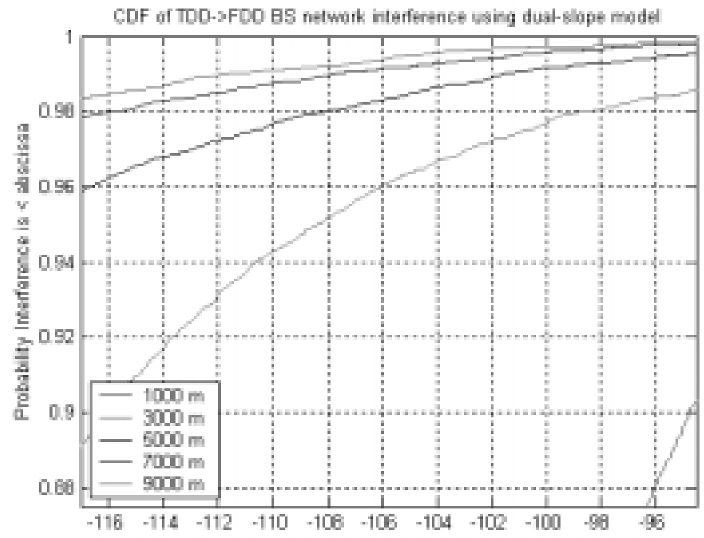
5.2.5 Effect of adaptive antennas in the downlink

Editor's Note: Material needed on the effect of null-steering capabilities of AA used for coexistence purposes. A table needed to show the relationship between safe separation distance and interference levels for each cell radius.

The effects of the AA in the downlink pertain to the case where the TDD base station equipped with adaptive antenna uses downlink beamforming. Therefore, the victim has been chosen to be a single FDD base station and interferers are 19 TDD base stations. Corresponding ACLR and ACS values for 5 MHz channel spacing are being used. It can be seen from Figure 15 that with acceptable interference threshold of –114 dBm (rural areas) being met at least 95% of the time, using AA at the BS causes the safe coexistence distance to be reduced significantly from 9.5 km to about 4 km. In other words, with TDD-FDD base station separation of maximum 4 kilometres, the interference criterion of –114 dBm is met at least 95% of the time. For 98% interference criterion, the safe distances are in the range of below 5 km to below 7 km for the interference threshold levels of –106 to –114 dBm. Also, in urban macrocell situations with maximum tolerated interference level of –95 to –100 dBm, the safe coexistence distance is reduced even further to about 3 km.

FIGURE 15

Likelihood of interference as a function of cell radius due to a network of TDD/AA base stations into a single FDD base station, using dual-slope propagation model

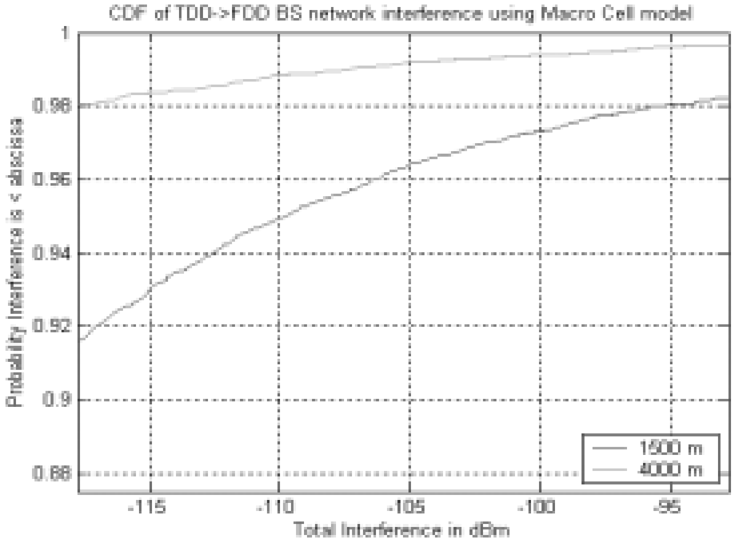


It is important to note that the 9.5 km distance was calculated for a single TDD interferer, while Figure 6 depicts total interference from a network of 19 TDD base stations.

In urban areas, often times base station antennas are mounted to the side of the buildings. The variation in height and orientation of the buildings in urban settings, thus, obstruct the LOS after a few blocks. A more realistic propagation model for non-LOS situations, such as the one introduced in (2), produces the results shown in Figure 16. The improvement introduced by this more realistic model is quite clear. With the same interference protection criterion, safe coexistence is feasible at least 98% of the time for urban cells and for rural cells, the base stations are almost always protected.

FIGURE 16

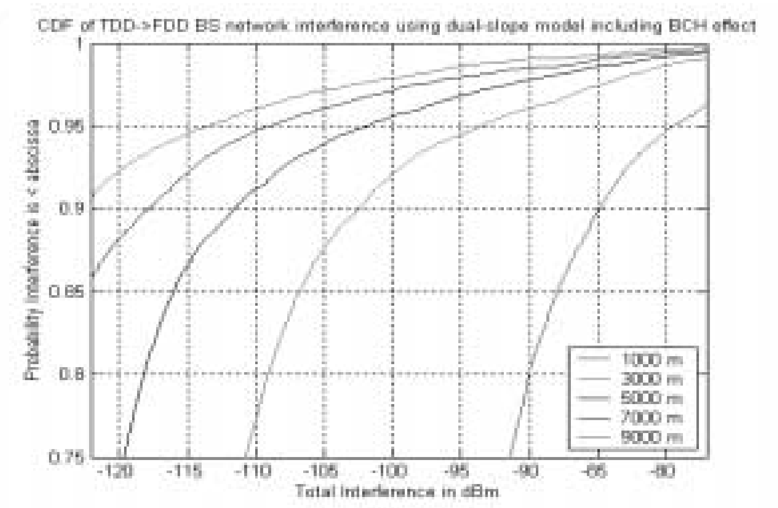
Likelihood of interference as a function of cell radius due to a network of TDD/AA base stations into a single FDD base station, using macrocell [1] propagation model



By introducing a Bernoulli random variable, the effect of the broadcast information in the downlink of the TDD BS on the uplink of the FDD BS is captured in Figure 17 using the Dual-Slope propagation model. As it is apparent from the figure, the omnidirectional interference has a direct effect on the upper tail of the CDF plot. This is due to the fact that, this interference, although present only a fraction of the time, is a strong contributing component to the Monte Carlo simulation. Based on Figure 8, the rural macrocell requirements are met 95% of the time for distances greater than 6 km while urban macrocell requirements are met 95% of the time for distances greater than 3 km. For 98% protection level, urban stations are protected for distances greater than 7 km.

FIGURE 17

Likelihood of interference as a function of cell radius due to a network of TDD/AA base stations, including omni-directional broadcast channel, into a single FDD base station, using dual-slope propagation model



Comparison of Figures 16 and 17 reveals that interference from the TDD system into the FDD system can be significantly reduced specially if the implementation of the AA at the TDD base station follows the second approach with regards to broadcast control channels.

5.2.6 Effect of adaptive antennas in the uplink

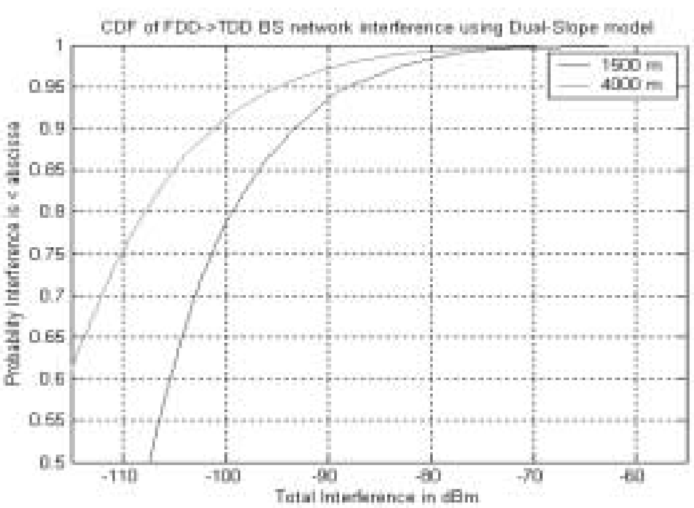
In the case of uplink beamforming at the base station (TDD/AA being the victim), spatial signatures used in the process of forming the beam in the direction of the intended users are uniquely attributed to the propagation environment from the intended user to the base station. These signatures, therefore, could be significantly different from that of an interfering station a distance away, thus the victim being affected by less or no additional gain from the direction of the interferer. This effect, however, has not been introduced in the simulations and full array gain has been applied to the interferer; i.e. worst case.

With the use of AA, in band signals due to out-of-band transmissions by other base stations are not coherently received at the AA. This reduces the gain towards the adjacent band interferers relative to the main beam, thus lowering the amount of interference power into the uplink of the TDD base station.

The effect of an FDD network of 19 cells on a TDD BS with AA was examined. Figure 18 depicts the outcome using dual-slope propagation model.

FIGURE 18

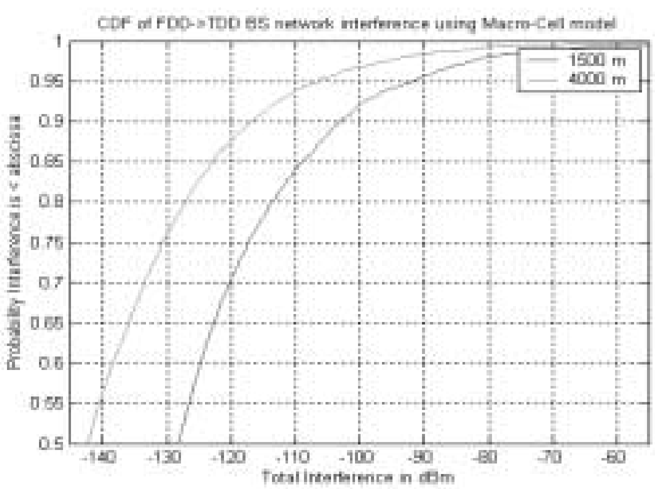
Likelihood of interference as a function of cell radius due to a network of FDD base stations into a single TDD/AA base station, using dual-slope propagation model



A more realistic propagation model for non-LOS situations, such as the one introduced in (2) [1], produces the results shown in Figure 19.

FIGURE 19

Likelihood of interference as a function of cell radius due to a network of FDD base stations into a single TDD/AA base station, using macrocell [1] propagation model



Using the interference protection criterion, safe coexistence is feasible at least 90% of the time for both urban and rural cells.

5.2.7 Conclusion

The following table summarizes the results for macro BS-BS interference and shows the additional isolation required in less than 2% of the time in rural and urban areas using the dual-slope propagation model. The additional isolation needed for coexistence, if necessary, is at a level that can be easily achieved by other coexistence-friendly site engineering practices.

TABLE 2

Summary of macrocell BS-BS interference with AA and additional isolation required

Scenario	Total Interference Power exceeded less than 2% of the time (dBm) for Rural [1]	Additional Isolation Required less than 2% of the time (dB) for Rural [2]	Total Interference Power exceeded less than 2% of the time (dBm) for Urban [1]	Additional Isolation Required less than 2% of the time (dB) for Urban [3]
TDD/AA Downlink	–101	5 to 13	–86	9 to 14
TDD/AA Uplink	–88	18 to 26	–81	14 to 19

[1] Assuming Dual-Slope propagation model

[2] Assuming –114 to –106 dBm maximum tolerated interference level [3]

[3] Assuming –100 to –95 dBm maximum tolerated interference level [3]

In case the adaptive antenna implementation at the TDD BS leaves the broadcast channel as omnidirectional, additional interference is being generated into the uplink of the FDD BS, as captured by section 3.7 and Figure 8. Statistically, this approach to AA implementation increases the level of interference, thus increasing the additional isolation required. The second approach to broadcast channel implementation, however, does not change the results of the above table. Also, the broadcast channel implementation does not affect the FDD BS to TDD BS scenario.

Editor's Note: The section needs cost, complexity and other trade-offs.

5.3 Effect of improved equipment specifications

5.3.1 Effects of filtering and linearization

5.3.1.1 Effects of TDD transmitter specifications on required coupling

A summary of the 3GPP-RAN TDD out of band emission requirements are given below.

TABLE 3

Summary of the 3GPP-RAN TDD out-of-band emission requirements

TDD BS class	Adjacent Carrier spacing of 5 MHz	Alternate Carrier spacing of 10 MHz	Other Carrier spacing of ≥15 MHz
LA	ACLR, –23 dBm	ACLR, –36 dBm	Spurious, –40 dBm
WA	ACLR, –33 dBm	ACLR, –36 dBm	Spurious, –40 dBm

Given the allowed external interference levels in [3], the following MCL is required.

TABLE 4

Required MCL

Scenario	Allowed Iext, dBm	TDD BS class	Carrier Spacing, MHz	MCL range	
				From	To
Macro, rural	–114 to –106	WA	5	81	73
		WA, LA	10	78	70
		WA, LA	≥ 15	74	66
Macro, downtown	–100 to –95 dBm	WA	5	67	62
		LA	5	77	72
		WA, LA	10	64	59
		WA, LA	≥ 15	60	55
Outdoor micro	–97 to –90 dBm	WA	5	64	57
		LA	5	74	67
		WA, LA	10	61	54
		WA, LA	≥ 15	57	50
In building pico	–85 dBm	LA	5	62	62
		LA	10	49	49
		LA	≥ 15	45	45

As can be seen, an MCL of 72 dB in adjacent carriers is sufficient for all deployment in scenarios except for macro rural.

5.3.1.2 Effects of FDD receiver filtering on allowed TDD base station TX power

Editor's Note: This piece of specification is specifically valid in the band 1805-1880 MHz. The numbers in table 5 are counted backwards from the 3GPP specifications. Confirmation of the applicability of this approach from 3GPP would be beneficial.

[For blocking when collocated with GSM 1800, the FDD receiver requires an additional filtering of 31 dB in order to achieve the required blocking of +16 dBm in the 1 805-1 880 MHz frequency band. For a discussion on blocking, please see section 4.2.1.4 in [3]. Therefore, the blocking performance in the TDD bands from 1 900-1 920 MHz would also have additional protection. Therefore in the 1 900-1 920 TDD band, a 3-section filter meeting the GSM requirement would provide an additional attenuation.

TABLE 5

Typical filter attenuation

	Typical filter attenuation (dBc) for 31 dB GSM filter	
TDD Band	3 lower FDD Bands*	2 lower FDD Bands**
1 900-1 905 MHz	15.8	20.9
1 905-1 910 MHz	10.9	14.4
1 910-1 915 MHz	5.0	7.1
1 915-1 920 MHz	1.3	1.8

* FDD Bands 1 920-1 935 MHz

** FDD Bands 1 920-1 930 MHz

NOTE – It is anticipated that his type of filter would become standard for all FDD and TDD equipment independent of operating frequency band. Therefore, this example is expected to be indicative of all future performance. The cost of these filters may be so cost effective, even better filters may be used.

The specified FDD blocking performance for TDD is –40 dBm. With the receiver filter, the blocking performance is increased. Assuming that an MCL of 72 dB exists between the TDD and FDD base stations, the maximum allowed TDD TX power is given in the table below.

TABLE 6

Maximum allowed TDD TX power

	FDD blocking requirement with GSM filter			
TDD Band	3 lower FDD Bands*		2 lower FDD Bands**	
	Max Blocker	**Max TDD TX power**	**Max Blocker**	**Max TDD TX power**
1 900-1 905 MHz	–24.2	> 43	–19.1	> 43
1 905-1 910 MHz	–29.1	> 43	–25.6	> 43
1 910-1 915 MHz	–35.0	37	–32.9	39.1
1 915-1 920 MHz	–38.7	33.3	–38.2	33.8
1 900-1 920 No filter	–40	32	–40	32

* FDD Bands 1 920-1 935 MHz

** FDD Bands 1 920-1 930 MHz

FDD ACS performance in same geographic area with TDD, with GSM FDD blocking improvement filter is given below.

TABLE 7

FDD ACS performance

			TDD TX power, dBm		
	TDD Band, MHz	**FDD ACS/Spurious dBm**	**without FDD RX filter**	**With filter 3 lower FDD Bands***	**With filter 2 lower FDD Bands****
Macro, Rural	1 900-1 905	–51	21	36.8	41.9
(Iext = –114 to –106 dBm)	1 905-1 910	–51	21	31.9	35.4
	1 910-1 915	–51	21	26	28.1
	1 915-1 920	–51	21	22.3	22.8
Macro, Downtown	1 900-1 905	–37	35	> 43	> 43
(Iext = –100 to –95 dBm)	1 905-1 910	–37	35	> 43	> 43
	1 910-1 915	–37	35	40	42.1
	1 915-1 920	–37	35	36.3	36.8
Outdoor micro	1 900-1 905	–34	38	> 43	> 43
(Iext = –97 to –90 dBm)	1 905-1 910	–34	38	> 43	> 43
	1 910-1 915	–34	38	43	> 43
	1 915-1 920	–34	38	39.3	39.8
In building pico	1 900-1 905	–22	> 43	> 43	> 43
(Iext = –85 dBm)	1 905-1 910	–22	> 43	> 43	> 43
	1 910-1 915	–22	> 43	> 43	> 43
	1 915-1 920	–22	> 43	> 43	> 43

* FDD Bands 1 920-1 935 MHz

** FDD Bands 1 920-1 930 MHz

As can be seen, except for the rural macro deployment the TDD TX power is limited by the blocker requirements of the FDD receiver. For all bands except the adjacent band, TDD TX power of +37 dBm or better is possible with 72 dB of MCL without any additional filtering except for the filtering required to coexist with GSM. For adjacent band TDD TX power is limited to +33 dBm but can be raised if MCL is improved.]

5.4 Effects of other techniques

5.4.1 Effects of using power control

6 Considerations for combining mitigation techniques

Editor's Note: This section discusses the issues related to using certain mitigation techniques in combination with others.

7 Conclusions

8 References

[1] ETSI TR 125 942 V4.0.0 (2001-09), Technical Report, "Universal Mobile Telecommunications Systems (UMTS); RF System Scenarios".

[2]

[3] "Draft New Report ITU-R M.[IMT.COXT] on the Coexistence between IMT-2000 TDD and FDD Radio Interface Technologies Operating in Adjacent Bands and in the Same Geographical Area", ITU-R WP 8F, Attachment 7.12 to the Chairman's report of the 7th meeting of Working Party 8F, 27 February to 5 March 2002, Queenstown, New Zealand.

[4] "Antenna-to-Antenna Isolation Measurements", TSGR4#8(99)631, 26 October 1999.

[5] Polarization in Electromagnetic Systems, Warren L. Stutzman, Chapter 7 Dual-Polarized Systems, Artech House, 1993.

[6] "Electronic Isolation of Collocated Horizontally and Vertically Stacked Antennas", EMS Wireless, 1999.

[7]

[8]

[9] ETSI TS 25 104 V4.2.0 (2001-9)

[10] Rappaport, T S, Wireless Communications – Principles and Practice, Prentice Hall, 1996.

[11] 3GPP TS 25.221 V3.10.0 (2002-03), "Physical Channels and Mapping of Transport Channels onto Physical Channels (TDD)", Release 99.

Editor's Note: Appendices A and B have not been reviewed.

Appendix A

Local Area (LA) and Wide Area (WA) base station performance requirements

(From 25.105 v5.1.0, reproduced here for the convenience of the reader)

6.6.2.2.2.1 3.84 Mcps TDD Option

6.6.2.2.2.1.2 Additional requirement for operation in the same geographic area with FDD on adjacent channels

In case the equipment is operated in the same geographic area with a FDD BS operating on the first or second adjacent channel, the adjacent channel leakage power shall not exceed the limits specified in Table 6.8AA.

TABLE 6.8AA

Adjacent channel leakage power limits for operation in the same geographic area with FDD on adjacent channels

BS Class	BS Adjacent Channel Offset	Maximum Level	Measurement Bandwidth
Wide Area BS	± 5 MHz	–36 dBm	3,84 MHz
Wide Area BS	± 10 MHz	–36 dBm	3,84 MHz
Local Area BS	± 5 MHz	–23 dBm	3,84 MHz
Local Area BS	± 10 MHz	–33 dBm	3,84 MHz

NOTE – The requirements in Table 6.8AA for the Wide Area BS are based on a coupling loss of 74 dB between the FDD and TDD base stations. The requirements in Table 6.8AA for the Local Area BS ACLR1 (± 5 MHz channel offset) are based on a relaxed coupling loss of 87 dB between TDD and FDD base stations. The requirement for the Local Area BS ACLR2 (± 10 MHz channel offset) are based on a relaxed coupling loss of 77 dB between TDD and FDD base stations. The scenarios leading to these requirements are addressed in TR 25.942 [4].

If a BS provides multiple non-contiguous single carriers or multiple non-contiguous groups of contiguous single carriers, the above requirements shall be applied to those adjacent channels of the single carriers or group of single channels which are used by the FDD BS in the same geographic area.

6.6.2.2.3 Additional requirement in case of co-siting with nsynchronized TDD BS or FDD BS operating on an adjacent channel

6.6.2.2.3.1 3.84 Mcps TDD Option

6.6.2.2.3.1.2 Additional requirement in case of co-siting with FDD BS operating on an adjacent channel

In case the equipment is co-sited to a FDD BS operating on the first or second adjacent channel, the adjacent channel leakage power shall not exceed the limits specified in Table 6.9AA.

TABLE 6.9AA

Adjacent channel leakage power limits in case of co-siting with FDD on an adjacent channel

BS Class	BS Adjacent Channel Offset	Maximum Level	Measurement Bandwidth
Wide Area BS	± 5 MHz	–80 dBm	3,84 MHz
Wide Area BS	± 10 MHz	–80 dBm	3,84 MHz

NOTE – The requirements in Table 6.9AA are based on a minimum coupling loss of 30 dB between base stations. The co-location of different base station classes is not considered. A co-location requirement for the Local Area TDD BS is intended to be part of a later release.

If a BS provides multiple non-contiguous single carriers or multiple non-contiguous groups of contiguous single carriers, the above requirements shall be applied to those adjacent channels of the single carriers or group of single channels which are used by the co-sited FDD BS.

Co-existence with UTRA-FDD

6.6.3.4.1 Operation in the same geographic area

This requirement may be applied to geographic areas in which both UTRA-TDD and UTRA-FDD are deployed.

6.6.3.4.1.1 Minimum requirement

For TDD base stations which use carrier frequencies within the band 2 010-2 025 MHz the requirements applies at all frequencies within the specified frequency bands in Table 6.16.
For 3.84 Mcps TDD option base stations which use a carrier frequency within the band 1 900-1 920 MHz, the requirement applies at frequencies within the specified frequency range which are more than 12.5 MHz above the last carrier used in the frequency band 1 900-1 920 MHz.
For 1.28 Mcps TDD option base stations which use carrier frequencies within the band 1 900-1 920 MHz, the requirement applies at frequencies within the specified frequency range which are more than 4 MHz above the last carrier used in the frequency band 1 900-1 920 MHz.

The power of any spurious emission shall not exceed.

TABLE 6.16

BS Spurious emissions limits for BS in geographic coverage area of UTRA-FDD

BS Class	Band	Maximum Level	Measurement Bandwidth
Wide Area BS	1 920-1 980 MHz	–43 dBm (*)	3,84 MHz
Wide Area BS	2 110-2 170 MHz	–52 dBm	1 MHz
Local Area BS	1 920-1 980 MHz	–40 dBm (*)	3,84 MHz
Local Area BS	2 110-2 170 MHz	–52 dBm	1 MHz
NOTE* – For 3.84 Mcps TDD option base stations, the requirement shall be measured with the lowest centre frequency of measurement at 1 922.6 MHz or 15 MHz above the last TDD carrier used, whichever is higher. For 1.28 Mcps TDD option base stations, the requirement shall be measured with the lowest centre frequency of measurement at 1 922.6 MHz or 6.6 MHz above the last TDD carrier used, whichever is higher.			

NOTE – The requirements for Wide Area BS in Table 6.16 are based on a coupling loss of 67 dB between the TDD and FDD base stations. The requirements for Local Area BS in Table 6.16 are based on a coupling loss of 70 dB between TDD and FDD Wide Area base stations. The scenarios leading to these requirements are addressed in TR 25.942 [4].

6.6.3.4.2 Co-located base stations

This requirement may be applied for the protection of UTRA-FDD BS receivers when UTRA-TDD BS and UTRA FDD BS are co-located.

6.6.3.4.2.1 Minimum requirement

For TDD base stations which use carrier frequencies within the band 2 010-2 025 MHz the requirements applies at all frequencies within the specified frequency bands in Table 6.17. For 3.84 Mcps TDD option base stations which use a carrier frequency within the band 1 900-1 920 MHz, the requirement applies at frequencies within the specified frequency range which are more than 12.5 MHz above the last carrier used in the frequency band 1 900-1 920 MHz. For 1.28 Mcps TDD option base stations which use carrier frequencies within the band 1 900-1 920 MHz, the requirement applies at frequencies within the specified frequency range which are more than 4 MHz above the last carrier used in the frequency band 1 900-1 920 MHz.

The power of any spurious emission shall not exceed.

TABLE 6.17

BS Spurious emissions limits for BS co-located with UTRA-FDD

BS Class	Band	Maximum Level	Measurement Bandwidth
Wide Area BS	1 920-1 980 MHz	–80 dBm (*)	3,84 MHz
Wide Area BS	2 110-2 170 MHz	–52 dBm	1 MHz
NOTE * – For 3.84 Mcps TDD option base stations, the requirement shall be measured with the lowest centre frequency of measurement at 1 922.6 MHz or 15 MHz above the last TDD carrier used, whichever is higher. For 1.28 Mcps TDD option base stations, the requirement shall be measured with the lowest centre frequency of measurement at 1 922.6 MHz or 6.6 MHz above the last TDD carrier used, whichever is higher.			

NOTE – The requirements in Table 6.17 are based on a minimum coupling loss of 30 dB between base stations. The co-location of different base station classes is not considered. A co-location requirement for the Local Area TDD BS is intended to be part of a later release.

Appendix B

Deployment based MCL calculations

Introduction

The following presents the results of an investigation aiming at determining the appropriate value for the minimum coupling loss between a macro BS and a micro or pico BS in different scenarios:

a) Macro, downtown BS in proximity of in building pico BS;

b) Macro, downtown BS in proximity of outdoor micro BS.

General approach

For the purpose of determining the ACLR requirement of the micro or pico BS, the minimum coupling loss between a macro, downtown BS and a micro or pico BS may be defined as the value that is exceeded with a probability of 90%, recognizing that the remaining cases (where the coupling loss is lower) should be addressed by operator coordination. This probability must take into account the generally higher density of micro or pico BSs compared to macro BSs.

To take this fact into account it is assumed that a Macro, downtown BS is surrounded by a larger number of micro or pico BSs placed at typical distance from each other. The position of the macro BS relative to the arrangement of micro or pico BSs is random. For each position of the macro BS, the smallest coupling loss to any of the surrounding micro or pico BSs is recorded, and a distribution of coupling loss is obtained by varying the position of the macro BS.

Macro, downtown BS and in building pico BS

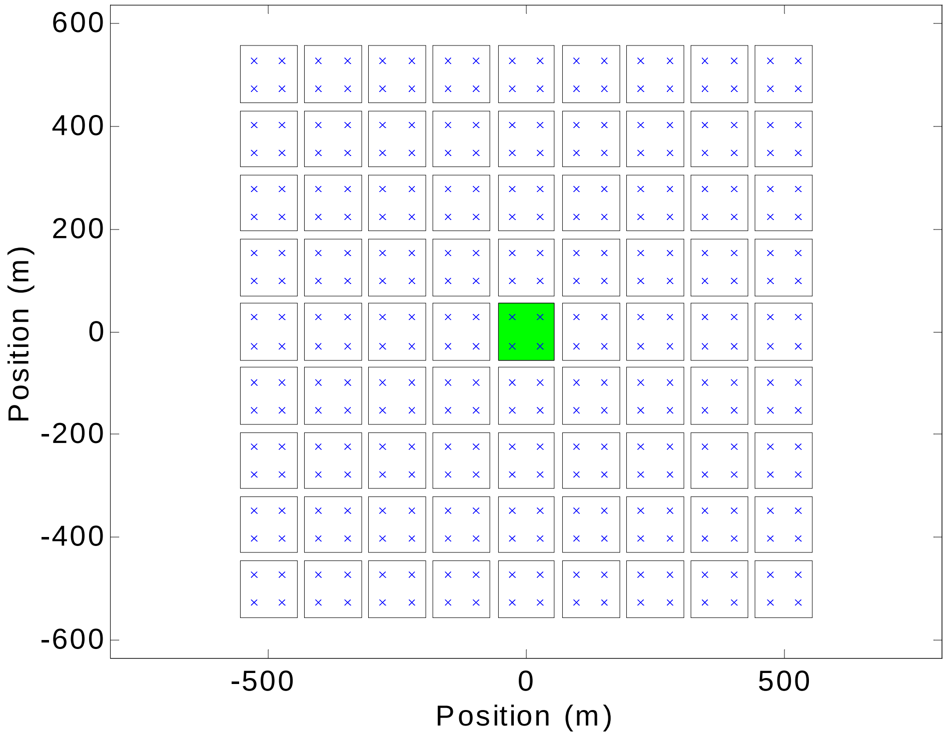
Scenario

This scenario is depicted in the Figure B-1. In building pico BSs are located inside blocks arranged according to a Manhattan grid where the road width is 15 m and the block size is 110 m. The macro, downtown BS is assumed to be located on top of the centre block at a random location within the green (shaded) area. In building pico BSs can potentially be present in every building, and up to the highest floor. There are up to four in building pico BSs per floor, and the height difference between the in building pico BSs on the highest floor and the macro, downtown BS is assumed to be 15 m. It is also assumed that there is another grid of in building pico BS at a lower floor with a height difference of 23 m.

In the calculations there may not be an in building pico BS at every location of the grids. The number of in building pico BSs that are actually present (density) is a parameter. For each trial a subset of locations for the in building pico BSs is randomly selected along with a position for the macro, downtown BS within the green area shown below.

FIGURE B-1

Assumed deployment scenario for Macro, downtown BS and in building pico BS in proximity. The crosses are possible locations for the in building pico BSs. The macro, downtown BS may be anywhere within the green area



Propagation model

Free space propagation loss added to building penetration loss of 10 dB is assumed between the macro, downtown and the in building pico BSs. Frequency is 2.6 GHz.

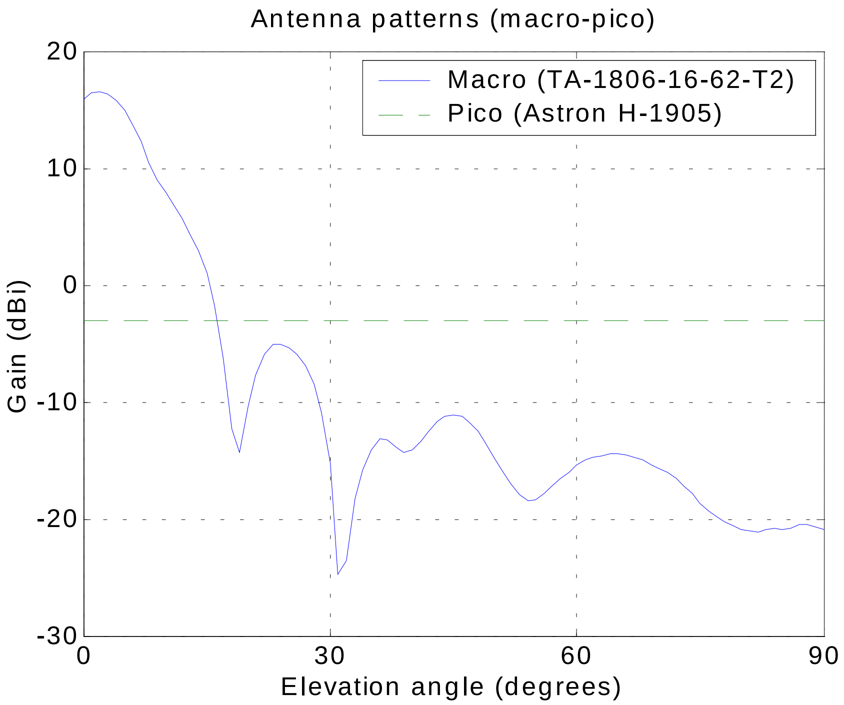
$$PL(d) = 38.1 + 20 \log10(d \text{ in metres}) + 10 \text{ dB}$$

Antenna patterns

Figure B-2 shows the antenna patterns assumed for the analysis. The macro antenna (Tiltek) has a downtilt of 2 degrees and a gain of 16.5 dBi. The pico antenna (Astron H-1905) has a gain of less than –3 dBi for the relevant elevation angles. These data are available from the Internet site of the manufacturers.

FIGURE B-2

Assumed antenna patterns for the Macro, downtown BS/in building pico BS

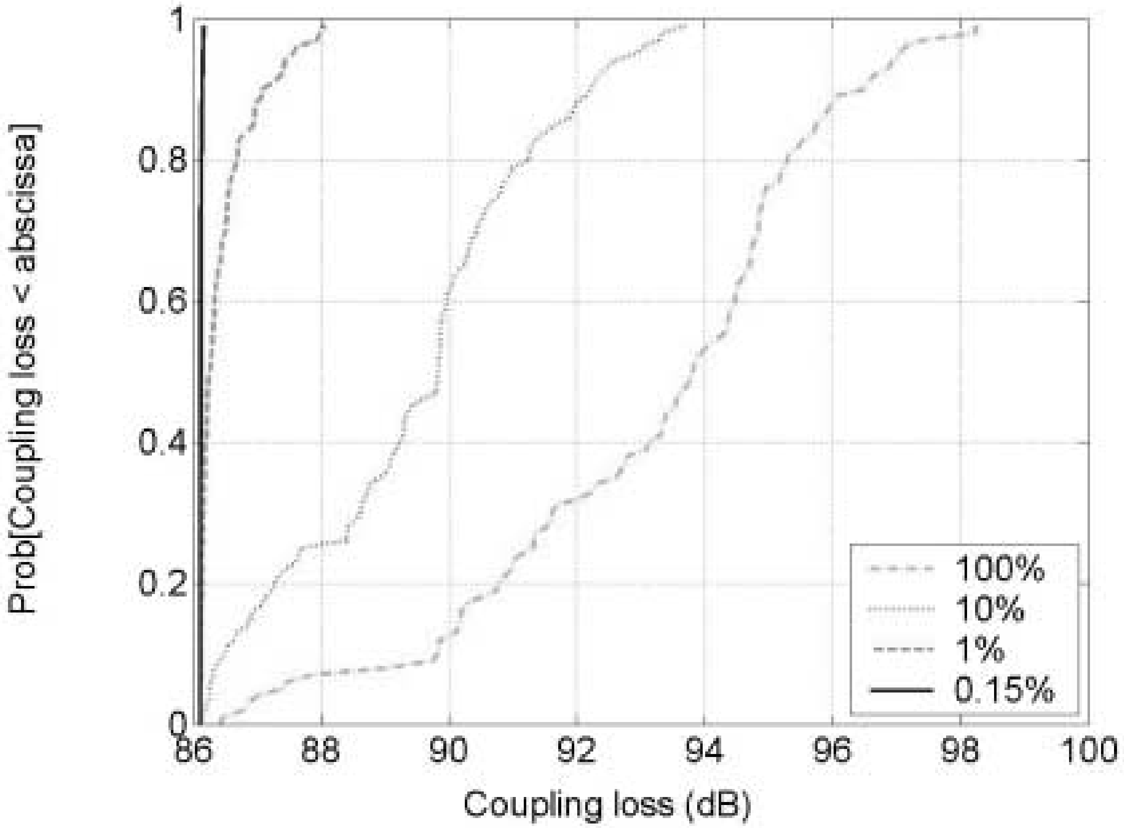


Coupling loss results

Coupling loss between a pair of BSs is obtained by subtracting the gains of the antennas from the feeder losses and propagation loss. Variations in azimuth of the gain of the macro, downtown BS are ignored (i.e. it is assumed that the in building pico BS is always in the direction of the maximum gain in azimuth). Feeder losses are assumed to be 3 dB for both BSs combined. The distribution of the coupling loss between the macro, downtown BS and the most coupled in building pico BS is shown in Figure B-3 below.

FIGURE B-3

Distribution of the coupling loss between the macro, downtown BS and the most coupled in building pico BS, for different densities of in building pico BSs (100% corresponds to a full grid)



The obtained minimum coupling loss is around 86 dB. Assuming feeder losses of 4 dB (instead of 3 dB) would increase that figure by 1 dB.

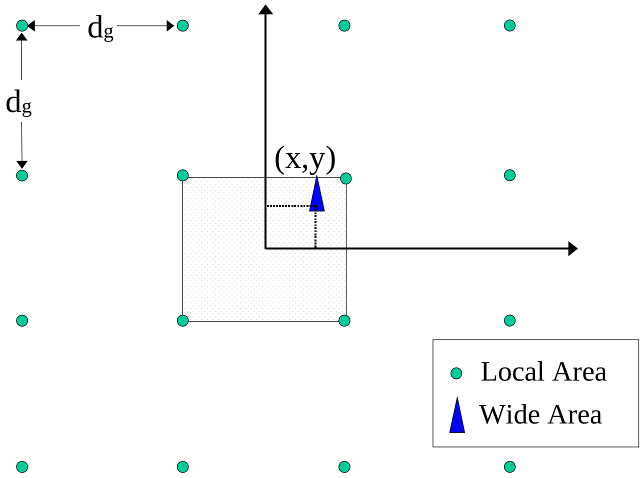
Macro, downtown BS and outdoor micro BS

Scenario

This scenario is represented in Figure B-4 below, where (without loss of generality) the outdoor micro BSs are deployed along a square grid of spacing d_g = 200 m. The macro, downtown BS is located in a certain position (x, y) with respect to the centre of this arrangement.

FIGURE B-4

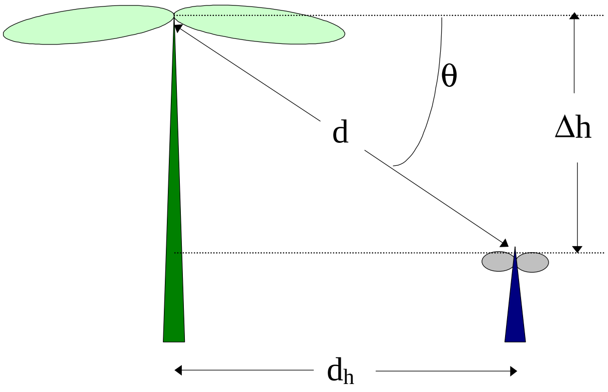
Assumed deployment scenario for Macro, downtown BS and outdoor micro BS in proximity



The situation in the vertical plane is illustrated in Figure B-5. The height difference between the outdoor micro BS and macro, downtown BS antennas is $\Delta h = 25$ m, and these antennas see each other at an elevation angle of $\theta = \arctan(\Delta h / d_h)$ where $d_h = \sqrt{[(x-x_l)^2+(y-y_l)^2]}$ and (x_l, y_l) are the coordinates of the outdoor micro BS.

FIGURE B-5

Illustration of the scenario in the vertical plane



Propagation model

Two path loss models may be considered for this scenario. The simplest model is the free space path loss as in the macro/pico scenario (without penetration loss):

$$PL(d) = 38.1 + 20 \log10(d \text{ in metres})$$

However, it should be recognized that this model might give overly pessimistic results since there is a high probability that the two antennas are not in line-of-sight in an urban environment, even for short distances. For this reason the vehicular test environment path loss model should also be considered:

$$PL(d) = 130.5 + 37.6 \log10(d \text{ in metres}),$$

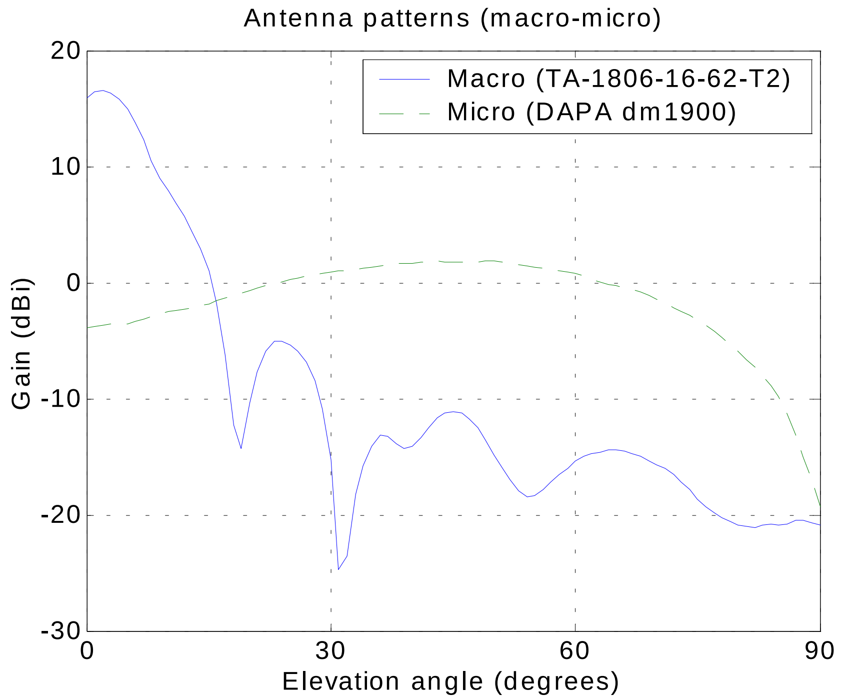
Where it is assumed that the macro antenna is at 15 metres above the average rooftop level, and the frequency is 2.6 GHz.

Antenna patterns

Figure B-6 shows the antenna patterns assumed for the analysis. The macro antenna (Tiltek) is the same as in the previous scenario. The micro antenna (DAPA dm19-00) is omnidirectional. The pattern is available from the Internet site of the manufacturer (www.dapacom.com).

FIGURE B-6

Assumed antenna patterns for the Macro, downtown BS/outdoor micro BS

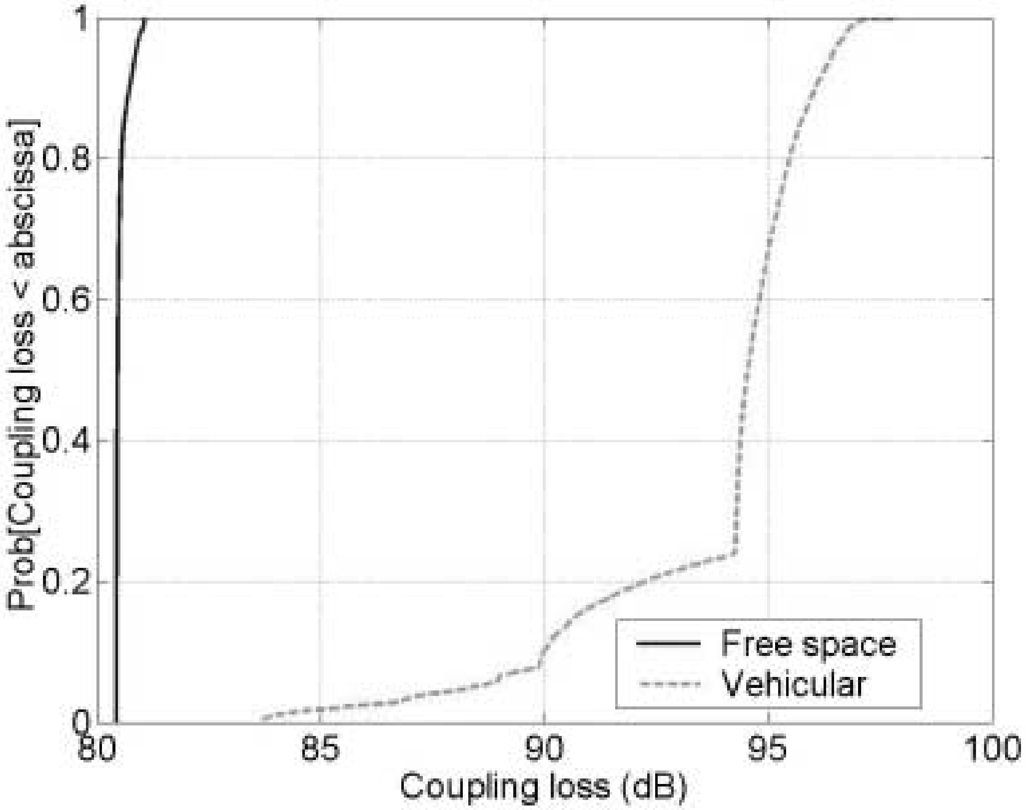


Results

Coupling loss between a pair of BSs is obtained by subtracting the gains of the antennas from the feeder losses and propagation loss. Variations in azimuth of the gain of the macro, downtown BS are ignored (i.e. it is assumed that the outdoor micro BS is always in the direction of the maximum gain in azimuth). Feeder losses are assumed to be 3 dB for both BSs combined. The distribution of the coupling loss between the macro, downtown BS and the most coupled outdoor micro BS is shown in Figure B-7 below for the two considered path loss models.

FIGURE B-7

Distribution of coupling loss between a macro, downtown BS and the most coupled outdoor micro BS



The figure shows that the 10th percentile of the distribution is either 78 dB or 88 dB depending on the propagation model chosen.

ATTACHMENT 7.12

Source: Rev. 1 to Document 8F/TEMP/232

DRAFT NEW REPORT ITU-R M.[IMT.COEXT] ON THE COEXISTENCE BETWEEN IMT-2000 TDD AND FDD RADIO INTERFACE TECHNOLOGIES OPERATING IN ADJACENT BANDS AND IN THE SAME GEOGRAPHICAL AREA

Description

During the Geneva WP 8F meeting (October 2000) it was decided to write a new report on coexistence issues between TDD and FDD systems in the 2 500-2 690 MHz band. MII China, CATT, Ericsson, Siemens and Telia defined a document structure. At the Rabat meeting (February 2001) Siemens and Ericsson had separate contributions on this issue. It was decided that Ericsson and Siemens should cooperate to develop a joint report or recommendation for the Stockholm meeting and that draft versions should be circulated on the WP 8F-share e-mail reflector at ITU, for the review and comment by other interested parties.

The report was scheduled to be finalized in Tokyo, but due to the many contributions to the report it was decided to postpone the finalization until the Queenstown meeting. It was also decided that work on this report would continue in between the Tokyo and Queenstown meetings via the sharing reflector and that suggested changes would be referenced to the report in line in/line out format.

Since the Tokyo meeting there were several recommended changes to the report from that meeting (8F/489, chapter 8, attachment 8.16 (page 410)). Those that were discussed on the reflector and agreed were incorporated into the report (8F/587). Further discussions took place during the Queenstown meeting, and attached is the draft report with revision marks showing changes from the document out of Tokyo. It is submitted to wp 8F for approval[1].

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[1] Note by the Secretariat: following the approval of this document by WP 8F, the revision marks were accepted.

ANNEX

DRAFT NEW REPORT ITU-R M.[IMT.COEXT]

Coexistence between IMT-2000 TDD And FDD Radio Interface Technologies within the frequency range 2 500-2 690 MHz operating in adjacent bands and in the same geographical area

1 Introduction

1.1 Introduction and outline of the paper

In this document the coexistence between IMT-2000 TDD and FDD radio interfaces are investigated. Specifically, the interference properties between CDMA DS (WCDMA or UTRA FDD) and CDMA TC (UTRA TDD) with its two modes High Chip Rate (HCR, 3.84 Mcps) TDD and Low Chip Rate (LCR, 1.28 Mcps) TDD are studied for a large number of scenarios.

The main part of the document describes Base Station to Base Station (BS-BS) interference for both proximity and co-location scenarios. Also Mobile Station to Base Station (MSBS), Base Station to Mobile Station (BS-MS) and Mobile Station to Mobile Station (MS-MS) scenarios are studied for proximity scenarios.

In Sections 2.4-2.5, the transmitter and receiver characteristics are described. In Section 2.8 the relation between the external interference level, and coverage and capacity is discussed. In Section 3.2 the methodology of the deterministic BS-BS and MS-MS scenarios is described. The Monte Carlo methods are described in Sections 3.3. The results are presented in Chapter 4 and conclusions are made in Chapter 5.

An overview of the results can be obtained by reading Chapters 1, 2.1-2.3, and 5.

1.2 Scope

For the purposes of the analysis in this report it has been assumed that TDD and FDD systems at 2.5 GHz will have similar characteristics than those of WCDMA and HCR/LCR TDD as given in ITU-R Recommendation M.1457.

1.3 Summary

This report provides an analysis and present results of the consequences of adjacent channel interference on FDD and TDD compatibility for a number of scenarios. This study is based on deterministic calculations for BS-BS scenarios leading to required separation distance and/or isolation requirements or supported cell range. The interference from mobile stations into mobile stations and base stations is analysed both with deterministic and statistical calculations leading to capacity loss and/or probability of interference.

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 on factors such as propagation conditions, user density and placement, 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.

It is recognised that any potential improvement brought about by mitigation techniques such as site engineering, adaptive antenna, etc… is not covered in this report and should be the subject of further study.

Main results

BS-BS interference: 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 involved duplex method.
- 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 several scenarios large values of separation distances or additional isolation are needed to obtain low interference conditions. Some scenarios have low separation distances and do not require additional isolation.
- In some deployment scenarios separation distances or filtering requirements can be traded off against coverage and higher MS transmit powers in the victim system.
- 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.

BS-BS interference in proximity: WCDMA/3.84 Mcps TDD

The required separation distances are in a range from 1 m to 15 km depending upon the cell types involved and carrier separation used. They are the lowest for pico-to-pico scenarios and the highest for macro-to-macro scenarios.

BS-BS interference in proximity: WCDMA/1.28 Mcps TDD

Based on assumptions for reference separation distances, only the macro-to-macro scenario requires significant additional isolation. For other scenarios, the basic isolation is sufficient.

BS-BS Co-location: WCDMA/3.84 Mcps

- Co-location of base stations will be prevalent in future systems
- When WCDMA and 3.84 Mcps 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.

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 be set on the service level.

2 Assumptions

2.1 Radio interface technologies considered

In this paper the IMT-2000 technologies considered are the FDD based IMT-2000 CDMA direct spread (also known as WCDMA) radio specification and the TDD based IMT-2000 CDMA TC with its two modes HCR TDD (3.84 Mcps) and LCR TDD (also known as TD-SCDMA, 1.28 Mcps).

They are for simplicity referred to as FDD and TDD, respectively, in the sequel where appropriate.

2.2 Interference scenarios

This paper considers the following basic scenarios:

- Interference to FDD BS caused by TDD BS (Deterministic calculations)
- Interference to TDD BS caused by FDD BS (Deterministic calculations)
- Interference to FDD BS caused by TDD UE (Monte Carlo simulations)
- Interference to TDD BS caused by FDD UE (Monte Carlo simulations)
- Interference to FDD UE caused by TDD UE (Monte Carlo simulations)
- Interference to TDD UE caused by FDD UE (Monte Carlo simulations)
- Interference to FDD UE caused by TDD BS (Monte Carlo simulations)
- Interference to TDD UE caused by FDD BS (Monte Carlo simulations)
- Interference to FDD UE caused by TDD UE (Deterministic calculations)
- Interference to TDD UE caused by FDD UE (Deterministic calculations)

The methodology used in the calculations and simulations is described in Chapter 3.

2.3 Involved cell layers

All scenarios should be considered, i.e. Macro, Micro and Pico. However, not all *combinations* of FDD and TDD cell layers have been investigated since some are considered less likely.

Frequency allocation

The study focuses on coexistence in the IMT-2000 band between 2 500 and 2 690 MHz. A principle allocation according to Figure 1 is assumed. This study focuses on interference between TDD and FDD UL as well as TDD and FDD DL. Interference between FDD UL and FDD DL is not considered (because of the frequency separation). No particular assumptions on the sizes if the bands have been made since the focus is on the *border* effects between FDD UL and TDD, and TDD and FDD DL, respectively.

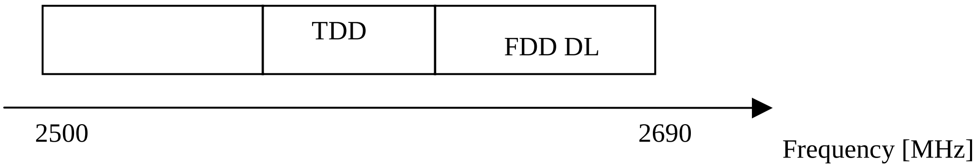

FIGURE 1

Assumed frequency allocation

It is assumed in the calculations that the TDD and FDD bands are separated with a certain amount of bandwidth (possibly of zero width). The carrier separation is defined as the spectral distance between the centre frequencies of the respective bands, including possible guardbands.

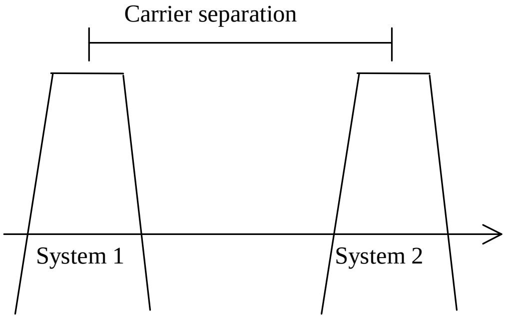

FIGURE 2

Carrier separation

The carrier separation thus consists of half the bandwidth of system 1 plus half the bandwidth of system 2 plus possibly extra guardband. For WCDMA/3.84 Mcps TDD the carrier separation is minimum 2.5 + 2.5 = 5 MHz and for WCDMA/TDSCDMA it is minimum 2.5 + 0.8 = 3.3 MHz.

With 5 MHz extra guardband the carrier separation thus becomes 10 or 8.3 MHz, respectively.

Deployment scenarios and base station position

In this study, different types of base stations (for both FDD and TDD deployment) are considered (macro, micro and pico). A *macro* base station is assumed to be located above rooftop and to be deployed in areas with both high and low user densities. The main objective of the macro base stations is to achieve coverage over a relatively large area.

A *micro* base station is assumed to be located outside below rooftop and are deployed in areas with high user densities. The micro base stations are mainly used to enhance the capacity in areas with high user densities.

The *pico* base station is located indoors and used for indoor coverage only. Typical deployment scenarios are in an office building. The pico base station could in principle be located at any floor within a building. However, it is here assumed that the height of the pico base station is approximately the same as the height of a micro base station.

The assumed heights of the different base stations are summarized in Table 1. Furthermore, the average building height is assumed to be 24 m and thus, the macro base stations are positioned 6 m above the average rooftop.

TABLE 1

Assumed heights of the macro, the micro and the pico base station (both FDD and TDD)

Base station type	Height m
Macro	30
Micro	6
Pico	6

2.4 Transmitter characteristics

The transmitter characteristic includes output power restrictions and transmitter antenna gain.

2.4.1 Output power and antenna gain

The BS maximum output power and antenna gain for FDD and TDD base stations are found in Table 2.

TABLE 2

Maximum output power and Tx antenna gain for the macro, micro and pico base stations (FDD and TDD)

BS type	Maximum output power dBm	Antenna gain (tx) dBi
FDD Macro	43	15
FDD Micro	30	6
FDD Pico	24	0
3.84 McpsTDD Macro	43	15
3.84 Mcps TDD Micro	30	6
3.84 Mcps TDD Pico	24	0
TD-SCDMA Macro	34*	15
TD-SCDMA Micro	21*	6
TD-SCDMA Pico	12*	3*

Note: the transmitter power of TD-SCDMA BS is assumed lower than for 3.84 Mcps because of the use of 8 element smart antenna system employed for TD-SCDMA.

The FDD BS is assumed to transmit continuously whereas the TDD BS is assumed to transmit half of the time (activity factor = 0.5).

The FDD and TDD MS maximum output power and transmission antenna gain are found in Table 3.

TABLE 3

Maximum output power and Tx antenna gain for FDD and TDD MSs

MS type	Maximum output power dBm	Antenna gain (tx) dBi
FDD	21	0
TDD	21	0

2.4.2 Spectrum Masks and ACLR values

The BS ACLR values in Table 4 are from (1) and (2) respectively. For the TDD BS, the ACLR requirement refers to the case of coexistence with other (TDD or FDD) systems.

The below values are valid for 3.84 Mcps TDD. For 1.28 Mcps TDD, see section 2.6.

TABLE 4

FDD and TDD BS ACLR

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

The employed ACLR values 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

2.5 Receiver characteristics

2.5.1 Receiver noise floor and antenna gain (FDD and TDD)

A noise floor of –103 dBm and –99 dBm supposes a noise figure (NF) of 5 and 9 dB respectively (thermal noise power –174 dBm/Hz*3.84 MHz = –108 dBm/3.84 MHz).

The receiver noise floor and the receiver antenna gain for FDD and TDD BSs are found in Table 6. The corresponding values for the FDD and TDD MSs are found in Table 7.

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 kbps 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 Mcps TDD macro	–109
3.84 Mcps TDD micro	–109
3.84 Mcps 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

2.5.3 ACS specifications

The BS ACS values in Table 10 are (indirectly derived) from (1) and (2) except for 15 MHz where an assumption has been made. Furthermore, the FDD and TDD MS ACS are found in Table 11.

The below values are valid for 3.84 Mcps TDD. For 1.28 Mcps TDD, see section 2.6.

TABLE 10

FDD and TDD BS ACS

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

TABLE 11

FDD and TDD MS ACS

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

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 ACIR value according to the following formula:

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

The values have been rounded in the ACIR column.

TABLE 12

FDD to 3. 84 Mcps TDD BS ACIR

Carrier separation MHz	**FDD BS ACLR DB**	**3.84 Mcps TDD BS ACS DB**	**Resulting ACIR dB**
5	45	46	~42
10	50	58	~49
15	67	66	~63

TABLE 13

3.84 Mcps TDD to FDD ACIR

Carrier separation MHz	**3.84 Mcps TDD BS ACLR dB**	**FDD BS ACS DB**	**Resulting ACIR dB**
5	70	46	~46
10	70	58	~58
15	70	66	~64

TABLE 14

TDSCDMA to FDD BS ACIR

Carrier separation MHz	**TDSCDMA 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

NOTE that the TD-SCDMA ACLR values for 8.3 MHz carrier separation has been estimated since there is no specified value for this separation in the standard specification.

2.7 The practical gain of antennas of the interfering station and the victim

With conventional antenna systems, the practical gain of interfering and victim stations are considered to be the sum of the individual antenna gains in the direction from the interfering to the victim stations, including the effects such as difference in height and downtilt angles. In the special case of the direct boresight coupling, this gain would be the sum of the maximum antenna gains and could result in the worst case coexistence scenario. For detailed derivation of the practical antenna gains, please refer to Appendix C.

When TDD systems utilize adaptive antenna (AA) beam forming, the coexistence situation must be analysed differently and determining the likelihood of interference requires statistical analyses such as Monte Carlo simulations. Any potential improvement brought about by the use of adaptive antenna is not covered in this report and requires further study.

Reference separation distance2.8 Relation between acceptable BS degradation and additional interference to the BS

In order to understand the full system impact of a certain interference source (and consequently the required separation distances) it is important to investigate the coverage and capacity losses induced by a certain external interference level.

In this section the impact on coverage and capacity is investigated as a function of the total noise level including both receiver noise and the external interference. Given the acceptable losses this determines the corresponding acceptable interference level. After that the required separation distances can simply be read from the Tables in Chapter 4.

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.

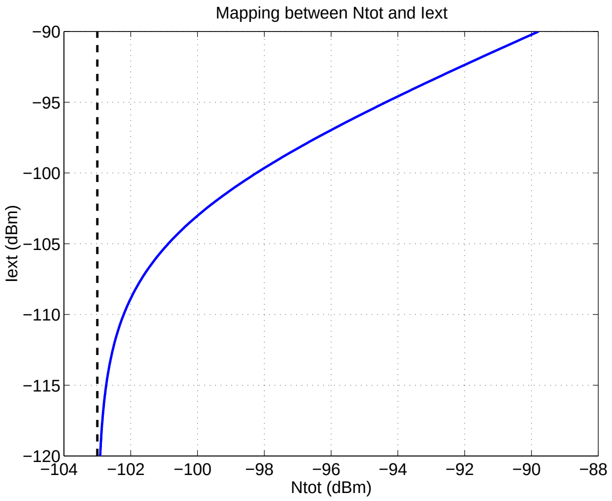

FIGURE 3

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).

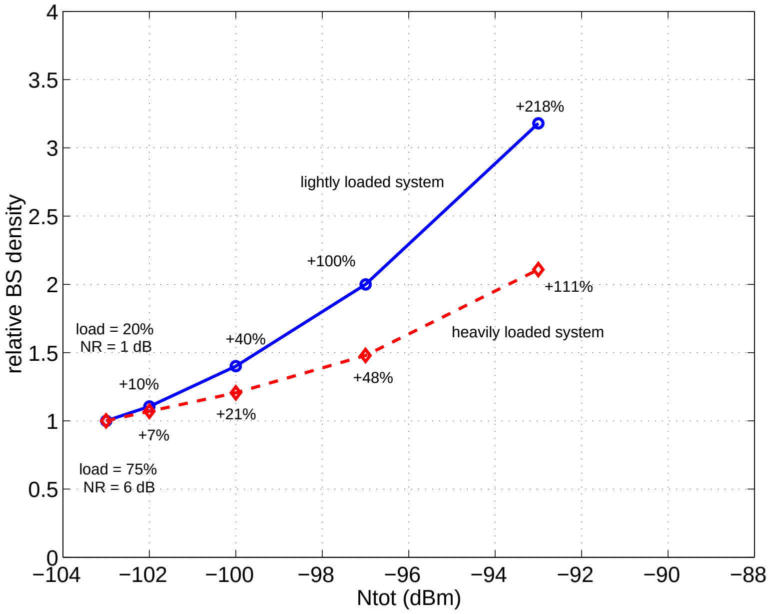

FIGURE 4

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_{acc}, the maximal level of acceptable interference that consequently follows from the cell size criterion.

Thus,

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

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_{acc} 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_{acc} can be larger. Pico cells are intended for small cells with little or no coverage problems and allows for even larger I_{acc}. In the next section this is further examined.

As long as I_{ext} and I_{int} are small enough so that the above inequality holds, I_{ext} 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_{acc} one of the following things must happen when I_{ext} is further increased:

1. The left-hand side grows beyond the limit I_{acc} and the inequality is violated.
2. Reducing the load, that is Iint, in the system compensates the increase of I_{ext}.

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.

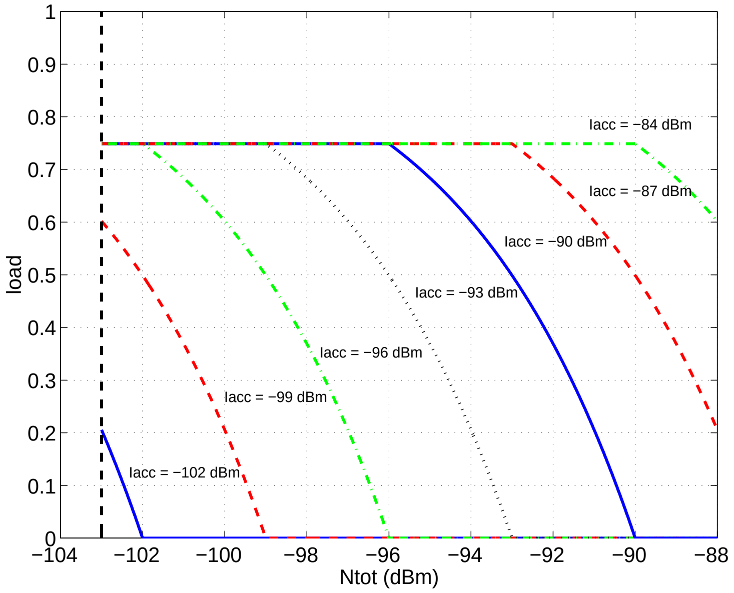

FIGURE 5

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 cell located in between.

The higher values of I_{acc}, 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 sections 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 be 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.

TABLE 15

Maximum tolerated interference levels

	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_{ext} values in Table 15 has been used for the corresponding cell type.

It should be noted that the lower value of tolerable I_{ext}' 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_{ext} values in this table are used in Chapter 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 Interference evaluation methodologies

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 corner 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.

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

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

d is distance in metres.

Path Loss Model for Indoor Test Environment

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

$R =$ 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 a 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.

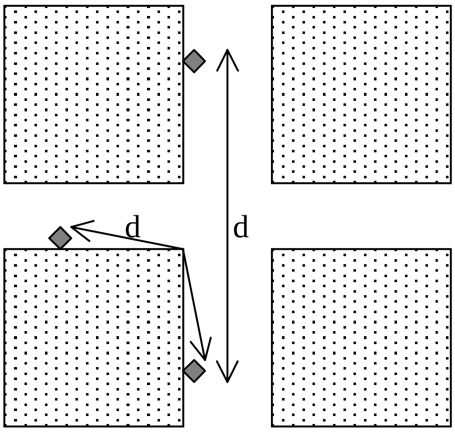

FIGURE 6

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 Tx.

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 Chapter 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

1 *Calculate the efficient output power*

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

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

2 *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 ACIR*

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

(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 propagation 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*

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

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.

TABLE 16BIS

Assumptions for alternative evaluation of BS-BS interference

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, Chapter 6.1.5). The block size is 75 × 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.

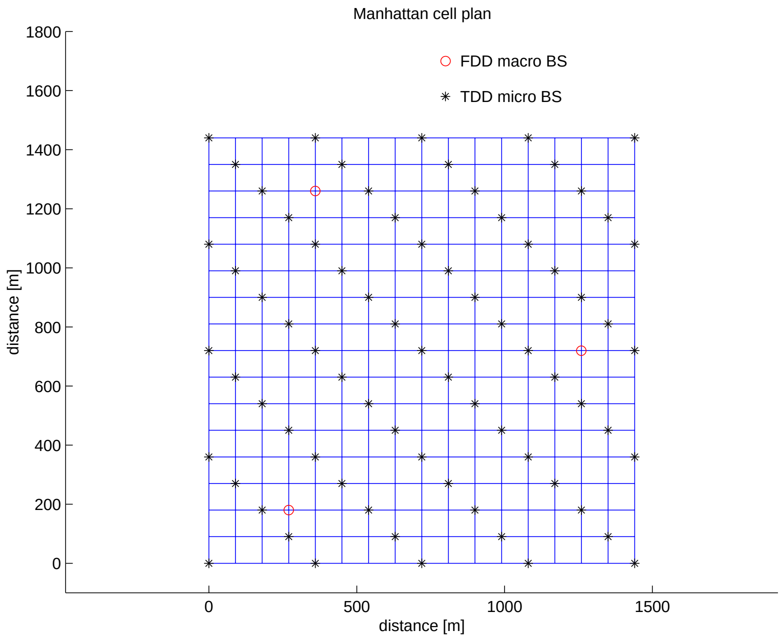

FIGURE 7

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 /3.84 TDD, FDD/1.28 TDD scenarios

The pathloss models and methodology used are very similar to the ones used by Ericsson (see previous section), 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 Mcps 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 bands 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 of capacity.

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 Mcps) 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 network needs to be 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 be avoided in planning. Therefore it will be 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 kbps 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 Chapter 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 gain	0 dBi

TABLE 19

CDMA TDD macro base station (transmit)

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

ACLR and ACS values

Carrier separation (MHz)	FDD MS ACLR (dB)	TDD MS ACS (dB)
5	33	33
10	43	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 Chapter 2, and an overview is given in Table 22 and Table 23. ACLR values for a FDD mobile terminal are given in Table 21.

TABLE 22

W-CDMA FDD mobile terminal (transmit)

Transmit power	21 dBm
Antenna height	1.5 m
Antenna gain	0 dBi
Power control step	1 dB
Power control: Min. 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 Chapter 2. Only the LOS condition is investigated.

4 Calculation examples and Results

4.1 Calculation examples

See Section 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

FDD to TDD interference

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	138/130	**9541/6020**
	15	43	30	63	–114/–106	124/116	**4262/2689**
FDD macro to TDD micro (Vehicular)	5	43	15	42	–97/–90	113/106	**341/222**
	10	43	15	49	–97/–90	106/99	**222/145**
	15	43	15	63	–97/–90	92/84	**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	**436/267**
	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	102/94	**58/37**
	10	24	6	49	–114/–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	–97/–90	91/84	**31/21**
	10	30	6	49	–97/–90	84/77	**21/14**
	15	30	6	63	–97/–90	70/63	**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 Mcps 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**	**Reference separation distance m**	**Pathloss dB**	**Accepted level of I_{ext} at Rx dBm**	**Required ACIR dB**	**Missing Isolation 5 MHz c.s 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)	27	15	50	81.6	–114/–106	**74.4/66.4**	**28.8/20.4**
TDD pico to FDD macro (Outd-to-Ind)	21	15	50	99.4	–114/–106	**50.6/42.6**	**4.6/-3.4**
TDD micro to FDD micro (LOS)	27	12	50	74.7	–97/–90	**61.3/54.3**	**15.3/8.3**
TDD micro to FDD micro (Pedestrian)	27	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	60.7	–85	**45.3**	**-0.7**
TDD pico to FDD pico (Indoor)	21	0	10	85.3	–85	**20.7**	**-25.3**

TABLE 27

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 c.s dB**
FDD macro to TDD macro (LOS)	43	30	100	80.7	−114/−106	**106.3/98.3**	**64.3/56.3**
FDD macro to TDD micro (Vehicular)	43	15	50	81.6	−97/−90	**73.4/66.4**	**31.4/24.4**
FDD macro to TDD pico (Outd-to-Ind)	43	15	50	99.4	−85	**43.6**	**1.6**
FDD micro to TDD micro (LOS)	30	12	50	74.7	−97/−90	**64.3/57.3**	**22.3/15.3**
FDD micro to TDD micro (Pedestrian)	30	12	50	91.9	−97/−90	**47.1/40.1**	**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**	**-1.4/-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**	**-21.3**

4.2.1.3 Required separation distances for TDSCDMA/FDD interference

TABLE 28

TDD to FDD interference

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 Mcps TDD

This section 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 FDD sites would be co-sited (i.e. collocated).

The maximum allowed interference for receiver desensitization is defined by

MAI_Desen (dBm) = Noise floor (dBm) + Receiver Noise Figure – 6 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

The affected interference power received at the receiver input-port of the interfered station is calculated as:

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)

ACIR = 1/(1/ACS+1/ACLR)

MCL = Minimum coupling loss (dBm) = 30 dB.

Table 30 shows interference calculations on both WCDMA and 3.84 Mcps 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).

MAI_Over = 1 dB Compression Point – Safety Margin

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

C_RX_ = C_TX_ - ACIR – MCL

where:

C_RX_ = Total carrier power received at input port of the interfered station (dBm)
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.

TABLE 32

Supported cell range under Worst case antenna tilting

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	138.3	138.3
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	
	15 MHz	125.5	
FDD micro →TDD micro (NLOS)	5 MHz	121.9	
	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 macro – TDD micro

TABLE 33

MS-to-BS interference (uplink)

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

TABLE 34

BS-to-MS interference (downlink)

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

TABLE 37

BS-to-MS interference (downlink)

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

TABLE 38

MS-to-MS interference (downlink)

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.

TABLE 39

3.84 Mcps TDD / FDD

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 Mcps TDD/FDD

victim (receiver)	interferer (transmitter)	rel. capacity loss
FDD BS	1.28Mcps TDD MS (cluster = 1)	<2%
1.28Mcps TDD BS (cluster = 1)	FDD MS	<2%
1.28Mcps TDD MS (cluster = 1)	FDD MS	<2%
1.28Mcps TDD MS cluster = 3)	FDD MS	<3%

4.2.2.3 Outage consequences due to MS-to-MS interference in FDD/3.84 Mcps TDD scenarios

The following sections 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 0.5 km 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%

For the case that the separation distance between the mobile terminals is fixed, the distance between the mobile terminals and their respective base stations will vary. This is incorporated into the Monte Carlo simulation.

TABLE 42

Interference probability for different separation distances

Carrier separation (MHz)	**5**	**10**
Separation distance (m)		
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. Additional to this, 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	7%	4%

TABLE 44

Interference probability for different separation distances

Carrier separation (MHz)	**5**	**10**
Separation distance (m)		
1	73%	54%
3	54%	34%
10	18%	8%
30	3%	2%
100	2%	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 be severe, and coverage may be 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). However, 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 (-11.8 dB) of the time with the speech service in our example, an *instantaneous* value of –10, 0 or 10 dBm, correspond to an *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.

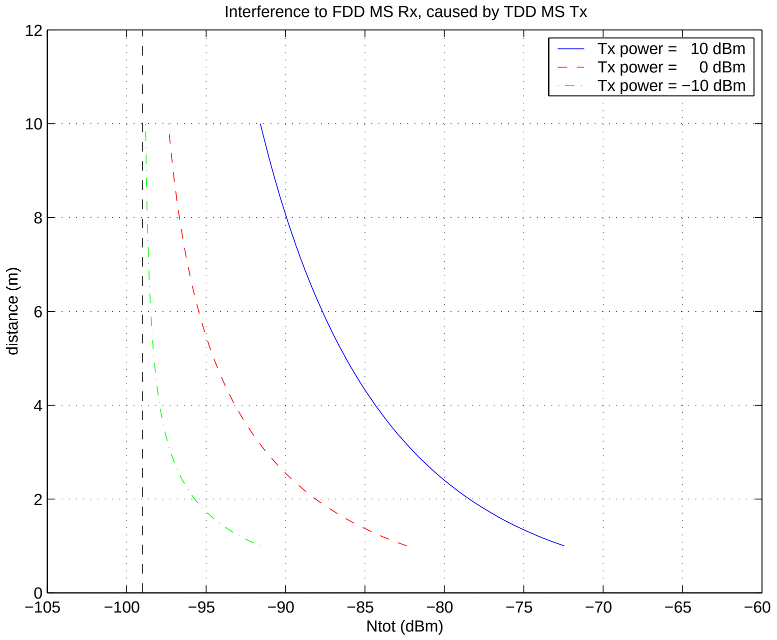

FIGURE 8

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.

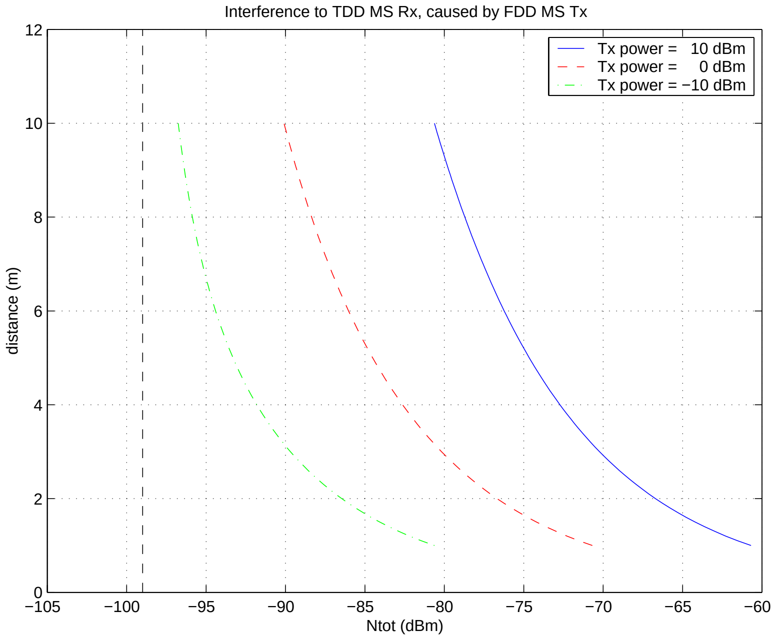

FIGURE 9

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 than 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 involved duplex method.
- •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 several 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 Mcps TDD (See Section 4.2.1.1)

TABLE 45

BS-BS: WCDMA/3.84 Mcps TDD

Scenario	**Carrier sep MHz**	**Required Sep. distance TDD to FDD m**	**Required Sep. 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
Macro-to-micro (Veh)	5-15	48-222	61-341	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
	10-15	9-24	12-52	50	-
Micro-to-macro (Veh)	5-15	58-284	69-341	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	1	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 section 4.2.1.1. Please refer to these tables for the complete set of results.

BS-BS in proximity: WCDMA/1.28 Mcps TDD (See section 4.2.1.3)

TABLE 46

BS-BS: WCDMA/TD-SCDMA

Scenario	Carrier sep MHz	Required Additional Isolation (dB) or not	Reference separation distance m	Required separation distance m
Macro-to-macro	3.5	40.9(YES)	100	2700
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-micro	3.5	-11.4(NO)	50	23.4
Micro-to-pico	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 Mcps (See section 4.2.1.4)

- Co-location of base stations will be prevalent in future systems
- When WCDMA and 3.84 Mcps 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 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 be set on the service level.

References

(1) 3GPP TS 25.104 v3.4.0, "UTRA (BS) FDD; Radio transmission and Reception"

(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.

(8) R4-99653 "Summary of results on FDD/TDD and TDD/TDD coexistence", Siemens.

(9) R4-00-0414 "TDD Capacity Loss Simulation results due to Adjacent Channel Interference", Siemens.

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

(11) R4-00TDD055 "Simulation results for 1.28 Mcps TDD performance requirements", CWTS and Siemens.

(12) Evaluation Report for ETSI UMTS Terrestrial Radio Access (UTRA) ITU-R RTT Candidate, (Sep. 1998), Attachment 5.

(13) TR 101 112 V3.2.0 (UMTS 30.03) "Selection procedures for the choice of radio transmission technologies of the UMTS", ETSI SMG2.

(14) SMG2 UMTS L1 Tdoc 679/98 "Coupling Loss analysis for UTRA - additional results", Siemens.

(15) 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.

(16) TR 25.945 v 2.0.0 "RF requirements for 1.28Mcps UTRA TDD option", TSG RAN4.

(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 1.28Mcps 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 1.28Mcps TDD: First Results

(23) ITU 8F/623, Chairman’s report of the 7th ITU-R WP8F meeting in Queenstown

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

APPENDIX A

ACLR, ACS and ACIR

ACLR	Adjacent Channel Leakage power Ratio
ACS	Adjacent Channel Selectivity
ACIR	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:

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

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

To meet a specific ACIR 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 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 used dual slope LOS model.

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

Pratical 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 1).

2) The practical gain of the antennas is thought to be gain at the direction between the two antennas(see 2 and 3, which 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 below table is valid for both the 1.28 Mcps and 3.84 Mcps 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 (15 dBi)	30	15	15
TDD Micro BS (6 dBi)	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 the 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

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

2 The vertical beam width of Micro BS antenna

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

3 The angle c

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

4 The angle a

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

5 The angle b

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

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 $\theta_{micro}/2$, 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:

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

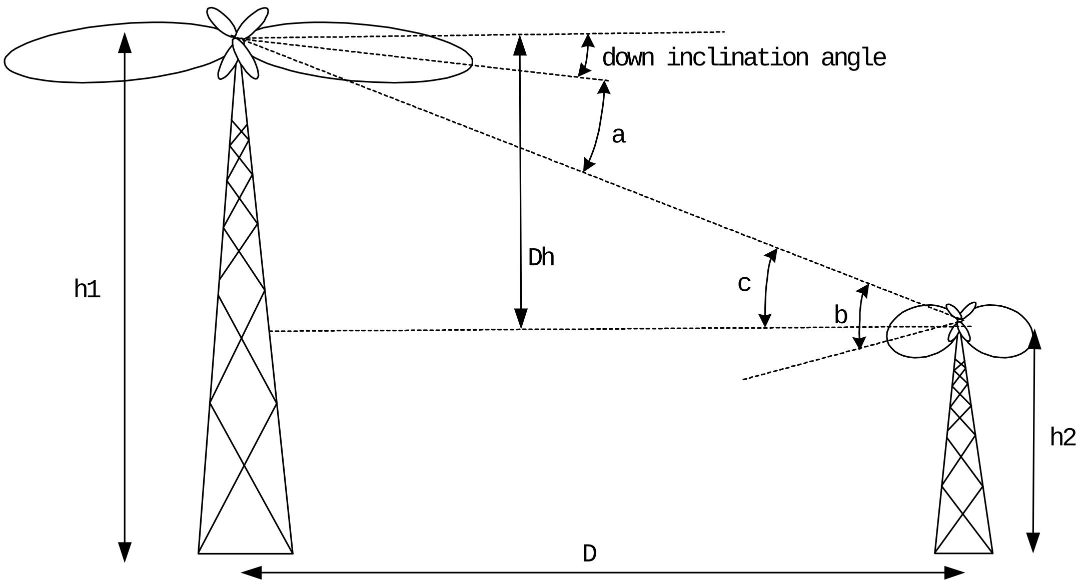

FIGURE C.1

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 ITU-R Rec. 1336-1).

The calculations made here take advantage of the approach proposed in section 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 IUT-R Rec 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 section 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 a 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 :

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

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 section 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 ITU-R Rec. 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)
- ITU-R Rec. 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[2]

	FDD Macro BS (15 dBi)	FDD Micro BS (6 dBi)	FDD pico BS (0 dBi)
TDD Macro BS (15 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

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[2] For detailed curves and results, see document [23].