Ofcom

OFFICE OF COMMUNICATIONS

Low-power concurrent use in the spectrum bands 1781.7 – 1785 MHz paired with 1876.7 – 1880 MHz

Study of coordination between low-power GSM and low-power CDMA

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Contents

Section 1

Summary

1.1 This further technical study ("Technical Study") has been prepared by Ofcom, in connection with the award of wireless telegraphy licences to use the spectrum bands 1781.7 – 1785 MHz paired with 1876.7 – 1880 MHz (the “Spectrum Bands”). It is referred to in the Auction of spectrum 1781.7 – 1785 MHz paired with 1876.7 – 1880 MHz Information Memorandum also published today.

1.2 The Technical Study is intended solely for information purposes only. This Technical Study is not intended to form any part of the basis of any investment decision or other evaluation or any decision to participate in the award process for the Spectrum Bands, and should not be considered as a recommendation by Ofcom or its advisers to any recipient of this Technical Study to participate in the award process for the Spectrum Bands. Each recipient of this Technical Study must make its own independent assessment of the potential value of a Licence after making such investigation as it may deem necessary in order to determine whether to participate in the award process for the Spectrum Bands. All information contained in this Technical Study is subject to updating and amendment.

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Coordination between users of GSM and CDMA low-power systems

1.4 A Monte Carlo analysis of interference into CDMA 1X pico cells from GSM pico cells transmitting within the occupied bandwidth of the CDMA system in neighbouring office buildings with no obstructions between them indicates that 97% probability of call success in the CDMA system could be achieved with 800m separation, where the GSM system operates on three transmitters or less. At a separation of 400m and with five GSM pico cell interferers, call success on the CDMA system is over 90%. On the basis of these results, coordination between users of low power GSM and CDMA in these spectrum bands may be necessary.

Section 2

Introduction

2.1 In July 2005 Ofcom published a consultation on proposals for the award of a limited number of low-power wireless telegraphy licences to use the spectrum bands 1781.7 to 1785 MHz and 1876.7 to 1880 MHz. Alongside the Consultation Document, Ofcom published a document[1] that considered interference scenarios, coordination between licensees and power limits in the spectrum bands.

2.2 This study considers the effects of interference into a low-power code division multiple access (CDMA) system from one or more low-power GSM pico cells in an adjacent building. For the purposes of this study, low-power is defined as being a maximum mean equivalent isotropically radiated power (EIRP) density of 0dBm/kHz and the CDMA system characteristics are based on CDMA 1X.

Methodology

2.3 The two buildings modelled are assumed to be separated by a street or free space. The distance between victim receivers and interferer transmitter was varied from 50m to 800m.

2.4 Two scenarios were considered

2.4.1 Interference from 1 to 5 floors of GSM into a single CDMA pico cell

2.4.2 Interference from 1 to 5 floors of GSM into a CDMA system occupying 5 floors

Quality assurance

2.5 On completion of the study a peer review within Ofcom was used to verify the methodology and conclusions of the work and provide an internal quality assurance check.

[1] Ofcom, 28 July 2005. Low-power concurrent use in the spectrum bands 1781.7 – 1785 MHz paired with 1876.7 – 1880 MHz. Interference scenarios, coordination between licensees and power limits.

Section 3

Analysis of call success for a CDMA system with interference from GSM

3.1 The aim of these calculations is to calculate the probability of call success on a CDMA pico cell system when it is subject to co-channel interference from a nearby GSM pico cell system.

System characteristics

3.2 Calculations were based on pico cell deployments in office buildings. The pico cell base station characteristics used in the calculations were

- Frequency used for path loss calculations: 1880 MHz
- CDMA cell service radius: 70m
- GSM maximum base station power: 23dBm EIRP
- CDMA maximum base station power: 31dBm EIRP

3.3 In each case the maximum base station power is equivalent to 0dBm/kHz within the occupied bandwidth of the system.

Methodology

3.4 CDMA calls are considered unusable when the Ec/Ior success ratio is not met. This figure is normally 0.5 dB and is shown in Annex B.

3.5 Two factors may cause this parameter to fail to be achieved. The interference may be so great that the individual link is unable to achieve the required Ec/Ior due to the limitation on the CDMA maximum traffic channel power. Alternatively it might fail because the interference to the cell affects so many mobiles so severely that it is impossible to achieve the required Ec/Ior on all mobiles without exceeding the maximum power of the CDMA base station. Both of these parameters are shown in Annex B.

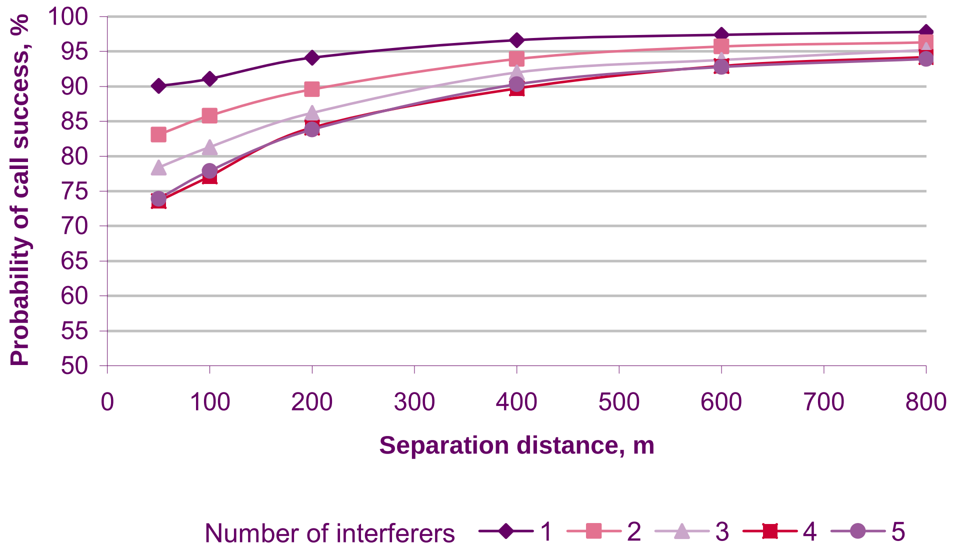
3.6 The power control process within CDMA is iterative and is normally studied using computer based Monte Carlo models. The European Conference of Postal and Telecommunications Administrations (CEPT) supports a Monte Carlo modelling tool called SEAMCAT. SEAMCAT 3 is the version which models CDMA technologies but it does not support the modelling of in-building technologies. For this study a simplified Monte Carlo model was constructed in order to study this problem.

3.7 The Monte Carlo model was run with between 1 and 5 floors of interfering GSM pico cells and the separation distances ranged from 50 metres to 800 metres. All simulations ran for 4,000 iterations so that results were obtained from 140,000 mobile terminal positions. A detailed description of the calculations is contained in Annex A and a list of parameters is provided at Annex B.

Results

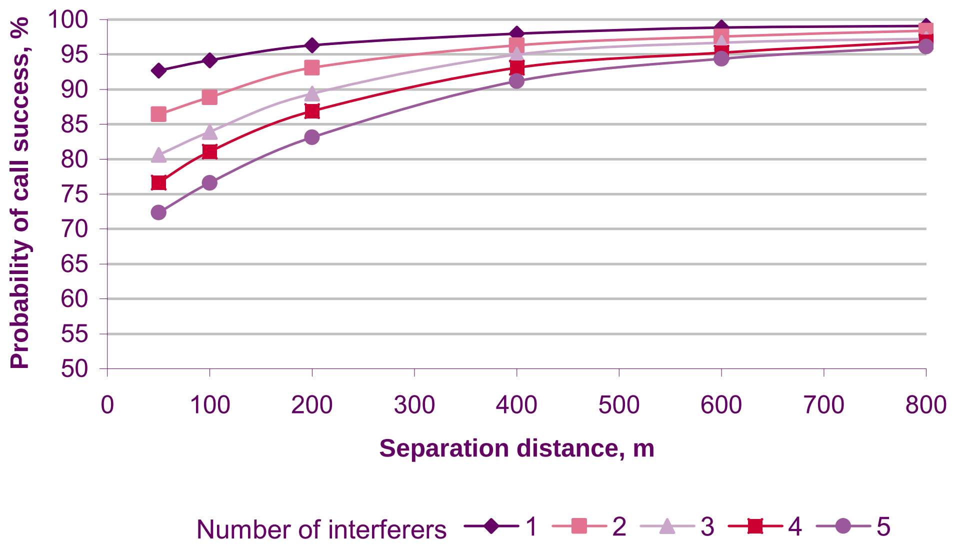
3.8 Results for the Monte Carlo study were provided in terms of call success probability for a range of distances between buildings. Figures 1 and 2 below show this graphically.

Figure 1. Probability of call success for a single CDMA pico cell



3.9 The figures indicate that to achieve 97% probability of call success, one interfering GSM transmitter may share the same frequency band as that occupied by a single CDMA pico cell if the buildings are separated by a distance of 600m.

Figure 2. Probability of call success for a CDMA system occupying five floors (one pico cell per floor)



3.10 The figures indicate that to achieve 97% probability of call success, one interfering GSM transmitter may share the same frequency band as that occupied by the five floor CDMA system if the buildings are separated by a distance of 400m; two interfering GSM transmitters may share the same frequency band if the buildings are separated by a distance of 600m and three interfering GSM transmitters may share frequency with a CDMA system at a building separation distance of 800m.

3.11 The model was analysed in order to determine the reason that the 5 floor scenario yields a better performance than the single floor scenario. Two factors were found to affect the performance. The probability that a small proportion of the mobiles will find a lower path loss to a base station on another floor was found to contribute to the performance in the 5 floor case.

3.12 Whilst it was also expected that the additional noise from base stations on other floors would reduce the effect of the reduced path loss, when this factor was studied it was found that the CDMA soft handover feature reinforced the preference for the multi floor scenario to a greater extent than the additional noise reduced it.

Section 4

Conclusion

4.1 On the basis of this study Ofcom sees no need to alter the previous conclusion that neighbouring office pico cell systems will need coordination.

Annex A

Calculation of call success probability

A1.1 This annex describes the calculation of the call success probability on a CDMA pico cell system when it is subject to co-channel interference from a nearby GSM pico cell system.

System characteristics

A1.2 The pico cell base station characteristics used in the calculations were

- Frequency used for path loss calculations: 1880 MHz
- CDMA cell service radius: 70m
- GSM maximum base station power: 23dBm EIRP
- CDMA maximum base station power: 31dBm EIRP

A1.3 In each case the maximum base station power is equivalent to 0dBm/kHz within the occupied bandwidth of the system.

A1.4 Other parameters used in the study are listed in Annex B.

Propagation model

A1.5 Within the building the field strength will be reduced by diffraction, where the first fresnel zone is obstructed (due to building layout and office furniture). Recommendation ITU-R P.1238-3 provides the following equation to calculate the propagation losses within buildings:

$$L_{total} = 20 \log_{10} f + N \log_{10} d + L_f \ (n) - 28\text{dB}$$

where:

Ltotal : total propagation loss
N : distance power loss coefficient
f : frequency (MHz)
d : separation distance (m) between the base station and portable terminal (where d ≥ 1m)
Lf : floor penetration loss factor (dB)
n : number of floors between base station and portable terminal (n ≥ 1).

A1.6 Recommendation ITU-R P.1238-3 indicates that the typical value for N within an office building is 30 (losses within a building due to floor penetration are not considered).

A1.7 Additional losses of wall partitions are to be included. This study assumed a loss of 4dB per wall that is every 10m. This loss value is taken from COST 231.

A1.8 The in-building propagation loss equation becomes:

$$L = 20 \log_{10} f + 30 \log_{10} d + 0.4d - 28 \qquad \text{dB}$$

where

d : separation distance (m) between the base station and portable terminal (where d ≥ 1m)

Methodology

A1.9 CDMA calls are considered unusable when the Ec/Ior success ratio is not met. This figure is normally 0.5 dB and is shown in Annex B.

A1.10 Two factors may cause this parameter to fail to be achieved. The interference may be so great that the individual link is unable to achieve the required Ec/Ior due to the limitation on the CDMA maximum traffic channel power. Alternatively it might fail because the interference to the cell affects so many mobiles so severely that it is impossible to achieve the required Ec/Ior on all mobiles without exceeding the maximum power of the CDMA base station. Both of these parameters are shown in Annex B.

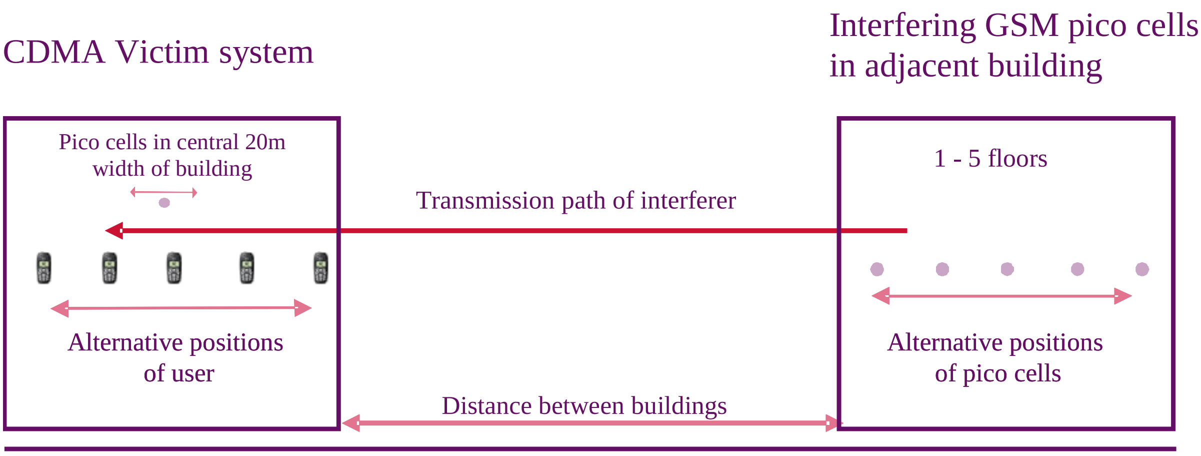
A1.11 The power control process within CDMA is iterative and is normally studied using computer based Monte Carlo models. The European Conference of Postal and Telecommunications Administrations (CEPT) supports a Monte Carlo modelling tool called SEAMCAT. SEAMCAT 3 is the version which models CDMA technologies but it does not support the modelling of in-building technologies. For this study a simplified Monte Carlo model was constructed in order to study this problem. The model employs the power control processes which have been defined for SEAMCAT 3. The source code of the simplified computer model used in this study is available from Ofcom.

A1.12 For this model it was assumed that each CDMA pico cell served a single floor of a building. The number of floors in the model was configurable and scenarios of one floor and five floors were selected for the study. It should be noted that modelling the CDMA power control process requires a scenario that includes at least three CDMA cells.

A1.13 It is possible for up to 6 GSM channels to interfere with a single CDMA 1X channel. For this model a range of numbers of interfering GSM channels from one to five were selected.

A1.14 The office scenario in the first technical study envisaged a 120 metre building with a 50 metre zone of coverage around the GSM pico cell base station. For the purposes of this study, the scenario was converted to a 120 metre wide by 50 metre deep building with the CDMA pico cell base station being placed anywhere within the central 20 metres of the width. To simulate the interference into the CDMA receiver a deployment of GSM pico cells in an adjacent building is modelled. The interfering signal exits from the adjacent building through the wall, crosses the intervening space then enters through another window to reach the victim CDMA user terminal. This is shown in Figure A.1.

Figure A.1. Interfering signal path



The losses for each part of this path are:

$$L_{FreeSpace} = 20 \log_{10} f + 20 \log_{10} d - 28$$
$$L_{Inbuilding} = 20 \log_{10} f + 30 \log_{10} d + 0.4d - 28 + 4$$
$$L_{BuildingOnly} = L_{Inbuilding} - L_{FreeSpace} = 10 \log_{10} d + 0.4d + 4$$

A1.15 $L_{Inbuilding}$ has an additional loss of 4dB caused by the interfering signal exiting or entering each building via the windows.

A1.16 The simulation was run using a range of separation distances between the buildings. The GSM pico cell system was modelled with a single base station on each floor The GSM pico cells were set to a common frequency in the model. The frequency of the interfering GSM channel is estimated to make a small (0dB to 3dB) difference to the impact on the CDMA channel but this effect was not considered to be significant in view of the results obtained.

A1.17 The CDMA system permitted a maximum radio channel power of 31dBm. The number of downlinks was fixed as 7, which is equivalent to 14 active calls, each with a voice activity factor of 50%. The simulation was performed for a single CDMA pico cell and for a five floor installation with one CDMA pico cell per floor.

A1.18 In order to test the system the program was run without interference with up to 15 downlinks (equivalent to 30 active calls, each with 50% voice activity factor). The low levels of loss of service were in line with theory. Without external interference the CDMA power control process settled consistently within 4 cycles.

A1.19 When the GSM interference was switched on significant loss of service was found. All forms of loss of service in CDMA modelling are assumed to be the result of inadequate Ec/Ior (the ratio of the average transmit energy per chip for different fields or physical channels to the total transmit power spectral density), the factor which is calculated by the program.

Results

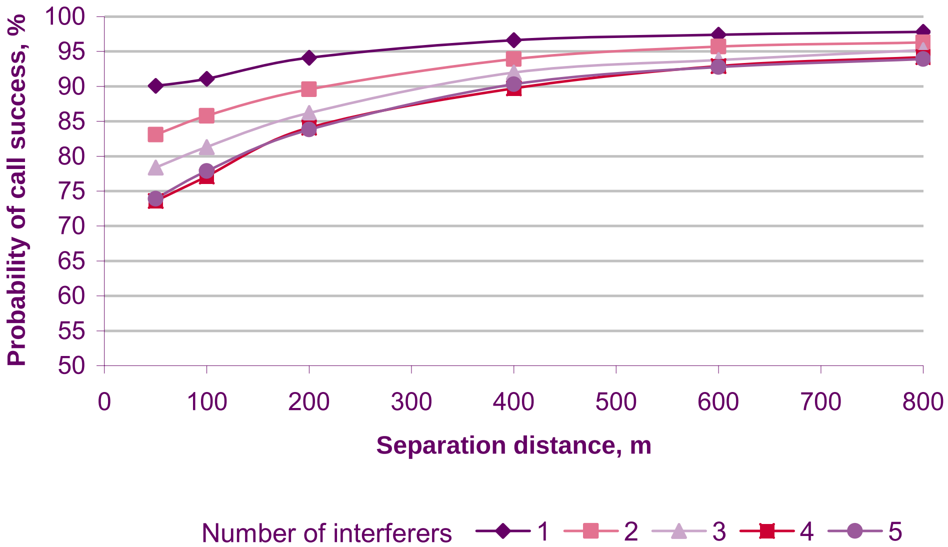
A1.20 The model was run with between 1 and 5 floors of interfering GSM pico cells and the separation distances ranged from 50 metres to 800 metres. All simulations ran for 4,000 iterations so that results were obtained from 140,000 mobile terminal positions.

Table A.1 shows the probability of call success for a CDMA pico cell covering one floor, with the results displayed graphically in Figure A.2.

Table A.1. Probability of call success for a single CDMA pico cell

Separation Distance	Probability of call success – Number of interferers (GSM pico cells) 1	2	3	4	5
50m	90.1%	83.1%	78.4%	73.6%	73.9%
100m	91.1%	85.8%	81.3%	77.1%	77.9%
200m	94.1%	89.6%	86.2%	84.1%	83.8%
400m	96.6%	93.9%	92.0%	89.7%	90.3%
600m	97.4%	95.7%	93.8%	92.9%	92.8%
800m	97.8%	96.3%	95.2%	94.2%	93.9%

Figure A.2. Probability of call success for a single CDMA pico cell



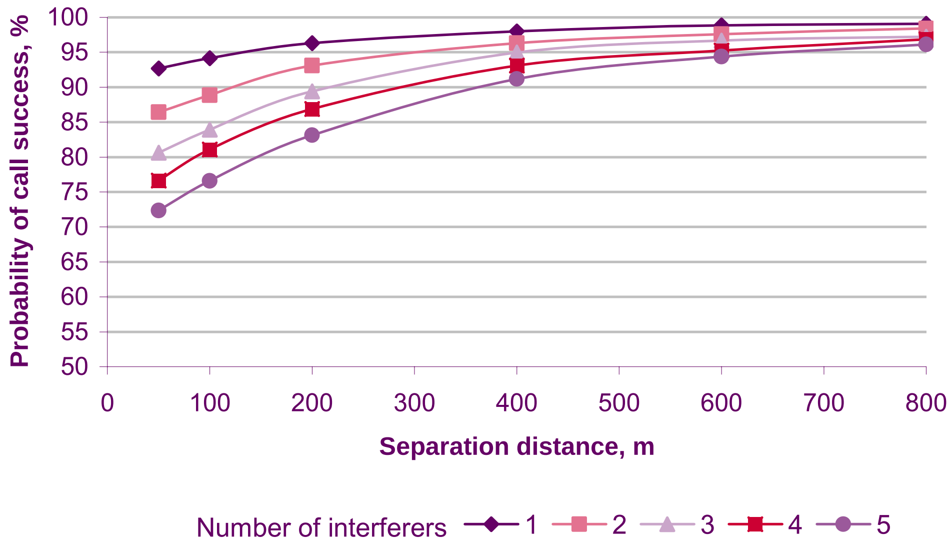
A1.21 The figures indicate that to achieve 97% probability of call success, one interfering GSM transmitter may share the same frequency band as that occupied by the CDMA system if the buildings are separated by a distance of 600m.

A1.22 Table A.2 shows the percentage probability of call success for a CDMA system occupying five floors, and the results are displayed graphically in Figure A.3.

Table A.2. Probability of call success for a CDMA system occupying five floors

Separation Distance	Probability of call success				
	Number of interferers (GSM pico cells)				
	1	2	3	4	5
50m	92.7%	86.4%	80.6%	76.6%	72.4%
100m	94.2%	88.8%	83.9%	81.1%	76.6%
200m	96.3%	93.1%	89.4%	86.9%	83.1%
400m	98.0%	96.3%	95.0%	93.1%	91.2%
600m	98.9%	97.6%	96.7%	95.3%	94.4%
800m	99.1%	98.4%	97.2%	96.8%	96.1%

Figure A.3. Probability of call success for a CDMA system occupying five floors



A1.23 The figures indicate that to achieve 97% probability of call success, one interfering GSM transmitter may share the same frequency band as that occupied by the CDMA system if the buildings are separated by a distance of 400m; two interfering GSM transmitters may share the same frequency band if the buildings are separated by a distance of 600m and three interfering GSM transmitters may share frequency with a CDMA system at a building separation distance of 800m.

A1.24 The percentage interference is higher in the single CDMA cell scenario than in the five floor scenario and is a consequence of the lack of soft handover procedure used in that scenario.

Annex B

Parameters used in the model

Parameter	Value
Width of both buildings	120m
Depth of both buildings	50m
Clear space between the buildings	variable
Vertical distance between the user and the picoBS.	1.5m
Vertical distance between floors	3m
Number of floors in the CDMA installation	1 or 5
Number of floors in the GSM installation	variable between 1 and 5
Maximum power of GSM base station	23dBm
Maximum power of the CDMA base station	31dBm
Antenna gain of GSM base station	0dBi
Antenna gain of CDMA base station	0dBi
Maximum power of the GSM mobile	33dBm
Maximum power of the CDMA mobile	23dBm
Power control range of a GSM mobile	20dB
Power control range of a CDMA mobile	30dB
Power control set point for GSM	-84dBm
Frequency used for path loss calculations	1880 MHz
Standard deviation of the path loss inside the building	10dB
Standard deviation of the path loss between the buildings	8dB
Mean loss through an external wall or window	4dB
Percentage of time CDMA voice is active	50%
CDMA call drop threshold	4dB
CDMA E_c/I_{or} success threshold	0.5dB
CDMA pilot fraction	15% or -8.2dB
CDMA overhead fraction	5% or -13dB
CDMA soft handover margin	4dB
CDMA maximum traffic channel power	20% or -7dB
Thermal noise in the CDMA bandwidth	-113.1dBm
Noise factor for a CDMA mobile	7dB
Number of iterations that the model runs	1,000
Number of simultaneous calls per CDMA floor	7