



Electronic Communications Committee (ECC)  
within the European Conference of Postal and Telecommunications Administrations (CEPT)

**BORDER CODE COORDINATION BETWEEN CDMA2000 SYSTEMS IN 450 MHz BAND**

**Vienna, October 2007**

**0 EXECUTIVE SUMMARY**

This report has been completed to complement existing ECC Report 97 “Cross Border Interference for Land Mobile Technologies” and ERC Recommendation T/R 25-08 “Planning Criteria and Coordination of Frequencies in the Land Mobile Service in the Range 29.7-921 MHz” and addresses the issue of code coordination between CDMA systems based on CDMA 2000 interface. The guidance in this report is directed to Administrations wishing to develop such CDMA systems in their countries.

The report studies applicability of the code coordination approach used in ERC Recommendation 01-01 “Border Coordination of UMTS/IMT-2000 Systems” to CDMA systems based on CDMA2000 interface. Due to similarity of CDMA interfaces the same code allocation scheme could be used for CDMA-PAMR and CDMA-450 systems coordination tacking into account CDMA2000 codes hierarchy. The threshold levels of the predicted mean field strength for coordination are deduced from ECC Report 97 “Cross Border Interference for Land Mobile Technologies” and analysis provided in this report. ECC Report 97 contains the results of Monte Carlo simulations of CDMA-PAMR networks using SEAMCAT software.

This report is relevant only for cases when neighboring Administrations use or plan to use CDMA2000 networks on their territory and their frequency plans coincide. For other cases ERC Recommendation T/R 25-08 should be referenced.

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## **Border Code Coordination between CDMA-PAMR Systems**

### **1 INTRODUCTION**

This report addresses the issue of cross border coordination between CDMA2000 systems with code coordination procedure. The guidance in this report is directed to Administrations wishing to develop CDMA systems based on CDMA 2000 interface in their countries. This report is applicable only for code coordination between CDMA2000 systems which frequency plans coincide.

Recommendation and report have addressed the issue of cross border coordination for Land Mobile service:

- ECC Report 97 "Cross Border Interference for Land Mobile Technologies";
- ERC Recommendation T/R 25-08.

ECC Report 97 "Cross Border Interference for Land Mobile Technologies" and ERC Recommendation T/R 25-08 provides procedures and thresholds for coordinated cases, for preferential and non-preferential allocation cases for different Land Mobile technologies including CDMA-PAMR. However data presented in these documents considers the case for CDMA networks when both systems use aligned frequencies with already coordinated codes. But uncoordinated case with CDMA systems using aligned frequencies isn't considered in any ECC document. To investigate this case and provide possible variant of code coordination procedure this report is prepared. The baseline for such procedure could be found in ERC Recommendation 01-01 where code coordination between UMTS systems is described. For code coordination it is proposed to deduce threshold levels partly from ECC Report 97 "Cross Border Interference for Land Mobile Technologies" and partly from the proposed simplified model of uncoordinated CDMA networks.

### **2 CODE ALLOCATION SCHEME**

For code coordination each base station shall use a unique time offset of the pilot pseudonoise (PN) sequence to identify a Forward CDMA Channel. Time offsets may be reused within a CDMA cellular system. Distinct pilot channels shall be identified by an offset index (0 through 511 inclusive). This offset index specifies the offset time from the zero offset pilot PN sequence in multiples of 64 chips. The same pilot PN sequence offset shall be used on all CDMA frequency assignments for a given base station. To distinct signals with PN sequence offsets all base stations should be time synchronized but such synchronization is mandatory requirement for CDMA2000 standard.

Administrations should agree on a repartition of these offset indexes on an equitable basis. In any case, each country can use all codes in the most important part of its own territory.

In border areas, codes will be divided into 6 "index sets" containing each one sixth of the available offset indexes. Each country is allocated three index sets (half of the indexes) in a bilateral case, and two index sets (one third of the indexes) in a trilateral case.

Four types of countries are defined in a way such that no country will use the same index set as any one of its neighbours. The following lists describe the distribution of European countries:

Type country 1: BEL, CVA, CYP, CZE, DNK, E, FIN, GRC, IRL, ISL, LTU, MCO, SMR, SUI, SVN, UKR, AZE, SRB.

Type country 2: AND, BIH, BLR, BUL, D, EST, G, HNG, I, MDA, RUS (Exclave), GEO

Type country 3: AUT, F, HOL, HRV, MKD, POL, POR, ROU, RUS, S, MLT

Type country 4: ALB, LIE, LUX, LVA, MNE, NOR, SVK, TUR.

For each type of country, the following tables and figure describe the sharing of the indexes with its neighbouring countries, with the following conventions of writing:

	Preferential index
	non-preferential index

	Set A	Set B	Set C	Set D	Set E	Set F
<b>Country 1</b>	2..83	88..168	173..253	258..338	343..423	428..509
Border 1-2						
Zone 1-2-3						
Border 1-3						
Zone 1-2-4						
Border 1-4						
Zone 1-3-4						

	Set A	Set B	Set C	Set D	Set E	Set F
<b>Country 2</b>	2..83	88..168	173..253	258..338	343..423	428..509
Border 2-1						
Zone 2-3-1						
Border 2-3						
Zone 2-1-4						
Border 2-4						
Zone 2-3-4						

	Set A	Set B	Set C	Set D	Set E	Set F
<b>Country 3</b>	2..83	88..168	173..253	258..338	343..423	428..509
Border 3-2						
Zone 3-1-2						
Border 3-1						
Zone 3-1-4						
Border 3-4						
Zone 3-2-4						

	Set A	Set B	Set C	Set D	Set E	Set F
<b>Country 4</b>	2..83	88..168	173..253	258..338	343..423	428..509
Border 4-1						
Zone 4-1-2						
Border 4-2						
Zone 4-2-3						
Border 4-3						
Zone 4-3-1						

Figure 1

Because of time shifting mechanism for code generation, the situation when propagation delay may lead to synchronisation of two different base stations signals occurring in some parts of service area. The average diameter of such correlation areas could be up to 245 meters (one chip duration multiplied on light speed). To prevent such situations in border areas it is recommended not to use some codes and to introduce 4 exclusion codes between neighboring index sets what gives 78.125 km propagation path before possible correlation area appears. This precludes any real synchronisation and reduction of code space less than on 5% only in border areas won't affect network planning.

All codes are available in areas away from the border where the field strengths into the neighbouring country are below the relevant trigger levels.

A two countries code sharing should be applied or used by base stations that exceed the relevant trigger level (Item 3) of only one neighbouring country. A three countries code sharing should be applied or used by base stations that exceed the relevant trigger level (Item 3) of two neighbouring countries.

In certain specific cases (e.g. AUT/HRV) where the distance between two countries of the same Type number is very small (< few 10s km), it may be necessary to address the situation in bi/multilateral coordination agreements as necessary, and may include further subdivision of the allocated codes in certain areas.

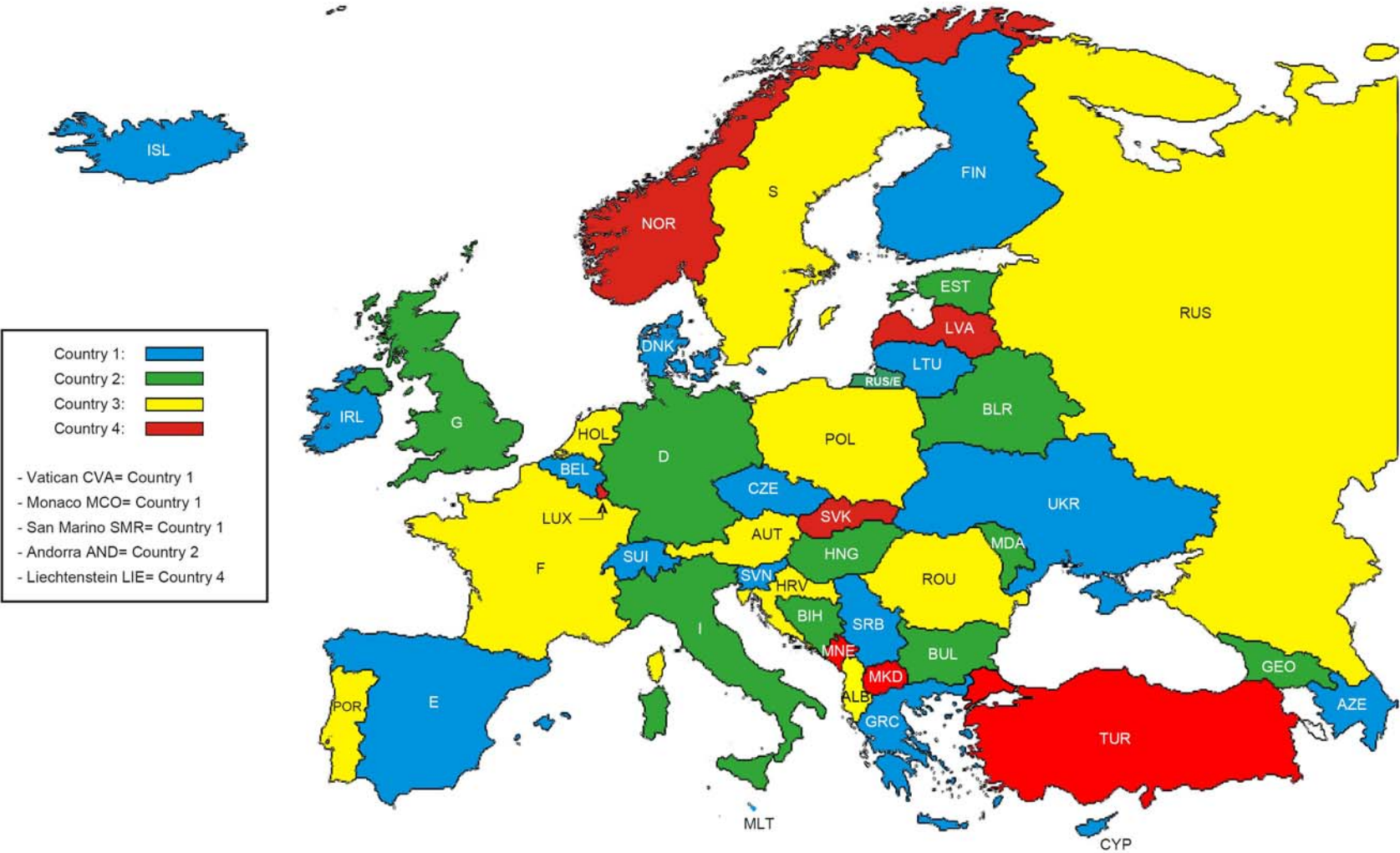


Figure 2

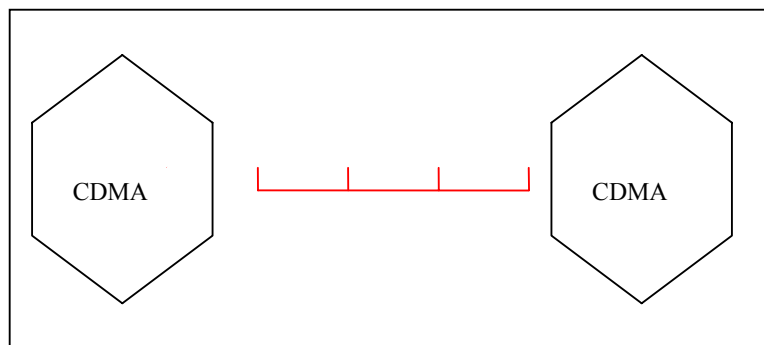
### 3 COORDINATION THRESHOLDS

Two types of thresholds should be specified:

- trigger level of the predicted mean field strength on the border to perform code coordination for exact base station, which also correspond to maximum permitted level of the mean field strength on the border for base stations using non-preferential codes;
- maximum permitted level of the mean field strength on the border for base stations using preferential codes.

ECC Report 97 provides maximum permitted level of the mean field strength on the border for CDMA-PAMR base stations for coordinated case when both systems use aligned frequencies and preferential codes. It is proposed to use this level as the maximum permitted level for the case of BS using preferential codes. The deduction layout from ECC Report 97 relevant to this issue is explained below.

To define threshold level for cross border operation of CDMA systems in coordinated case a new principle was proposed which states that a network should not be protected to a greater extent than it would be from its own continuously rolled out network. The studies were undertaken using Monte Carlo modelling. The two CDMA systems were modelled at separation distances which were progressively increased.



**Figure 3**

The outage of users in reference cell with permanent capacity was taken as the criteria of coexistence. Nominal outage and nominal capacity was obtained from the modelling of the cell in the completely rolled out network. Then the network was divided in two and only one part was left what caused reduction of self-interference and consequently reduction of outage. Interfering network is situated such way that produces the exact level of interference to return outage to its nominal value. The power level in the middle of separation distance is taken as threshold on the border. Only downlink to downlink case was considered as the worst case.

The permissible interference for duplex technologies was measured in a bandwidth of 25 kHz at a height of 3 metres in 50% of time. The result shown in the study for two CDMA systems is -104.1 dBm. Modelling was undertaken at 450 MHz but the results are applicable over the range of frequencies used by CDMA2000 based systems below 1000 MHz. For the studies in ECC Report 97 the Extended Hata model for subrural environment was used.

Thresholds for duplex systems should be based on the power measured in a 0 dBi antenna, these may be converted to field strengths (as dBuV/m) at the appropriate frequency. The use of a 0 dBi antenna, as a standard for comparison, represents a worst case, particularly at lower frequencies, where 0 dBi antennas are less common. The formula for the conversion of dBm to dBuV/m is:

$$F_{\text{dBuV/m}} = P_{\text{dBm}} + 77.21 + 20\lg(f_{\text{MHz}})$$

where  $P_{\text{dBm}}$  is the power in dB microwatts.

The calculation of relevant field strength level in case of aligned frequencies and preferential codes for CDMA2000 in 450 MHz band is presented below:

Central frequency of downlink band	Threshold field strength level on the border (rounded)*	Overall CDMA BS signal strength on the border**
465 MHz	26.5 dBuV/m/ 25 kHz	43.5 dBuV/m/ 1.25 MHz

**Table 1**

\* - measured in a bandwidth of 25 kHz at a height of 3 metres in 50% of time.

\*\* - measured in a bandwidth of 1250 kHz at a height of 3 metres in 50% of time (recommended).

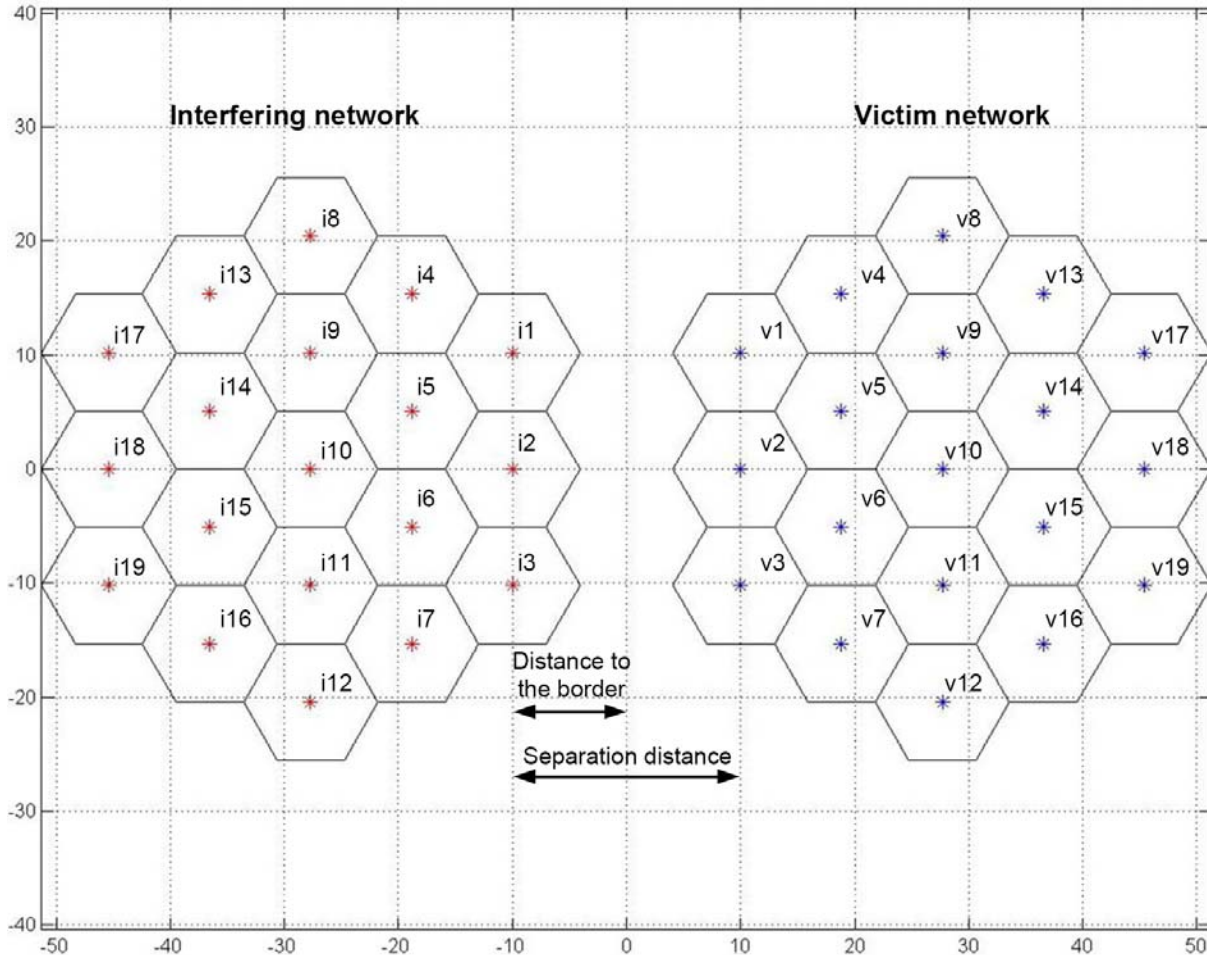
SEAMCAT model, which was used for cross border studies, is not applicable for uncoordinated case with aligned frequencies because each CDMA receiver in SEAMCAT applies processing gain only to its wanted signal. It is difficult to define accurately real correlation zones because of multi-pass propagation when different delays could occur. Theoretically it could occur almost at any location within victim cell. But to estimate the impact of possible correlation between different BS signals on network performance simplified model is proposed with line-of-sight conditions. To find areas of possible correlation the geometrical problem should be solved. The areas where the following conditions are true should be defined as:

$$R_i - 15.625 - 0.120 \leq R_v \leq R_i - 15.625 + 0.120 \text{ (correlation with the adjacent PN offset)}$$

$$R_i - 2 * 15.625 - 0.120 \leq R_v \leq R_i - 2 * 15.625 + 0.120 \text{ (correlation with the second adjacent PN offset)}$$

$$R_i - 3 * 15.625 - 0.120 \leq R_v \leq R_i - 3 * 15.625 + 0.120 \text{ (correlation with the third adjacent PN offset)}$$

Where  $R_i$  is the distance from interfering BS and  $R_v$  is the distance from investigated victim BS. All areas are limited to victim cell circle. The case of same PN offset interference is possible only for overlapping cells which is improbable for cross border situation and not defined in the above conditions. The geometrical networks representation for estimating such areas is shown below. 5.9 km cell radii and omni antennas were considered which is in agreement with parameters used in cross border study.



**Figure 4**



Different interfering cells create different impact in victim cells. For one fixed separation distance there could be up to  $19 \times 19 = 361$  different area projections. Some examples of such potential correlation areas for 20 km separation are presented below.

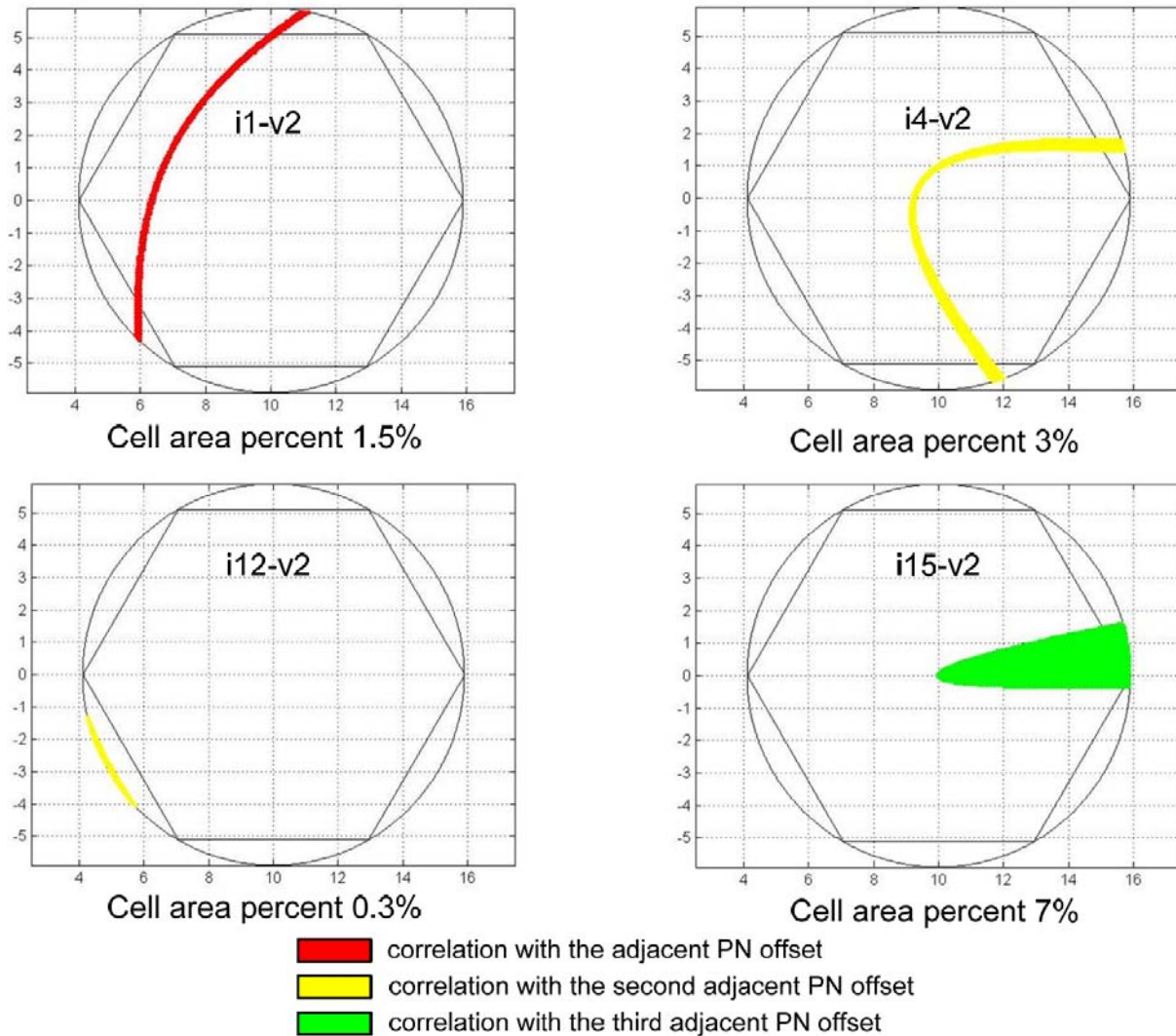


Figure 5

To provide wide range of results for different separation distances it is easier to present only cell area percent relevant to correlation zone (100% correspond to the circle area defined by cell radii). Set of tables for all combination of interfering and victim cells for separation distances from 12 to 50 km is attached in the Annex 1.

Next step is to look on the impact in terms of propagation. It is likely to have harmful interference at the edge of the cell and unlikely to have any interference near wanted BS. Also the magnitude of the impact is very dependent both on path losses between wanted Tx and victim Rx and path losses between interfering Tx and victim Rx. It is proposed to look at the worst case when path loss between wanted BS and victim Rx is approximated with Hata suburban model and path loss between interfering BS and victim Rx is approximated with Hata rural model. Actual area where correlation causes harmful interference could be defined from pilot signal levels difference and processing gain value. In coordinated case wanted pilot signal should be amplified on processing gain value compared to interfering pilot signal from neighbor cell and at the edge of the cell wanted pilot-to-interfering pilot ratio would be close to 21 dB (Processing gain =  $10 \cdot \lg(1250/9.6) = 21$  dB). Therefore it is proposed to define correlation area as area where wanted pilot-to-interfering pilot ratio is lower than 21 dB. All radio parameters were taken from cross border study ECC Report 97. The effect of propagation on correlation area percentage is illustrated below. Colorbar provides grade for wanted pilot-to-interfering pilot ratio, interfered areas are colored in blue tones and non-interfered in red and yellow tones.

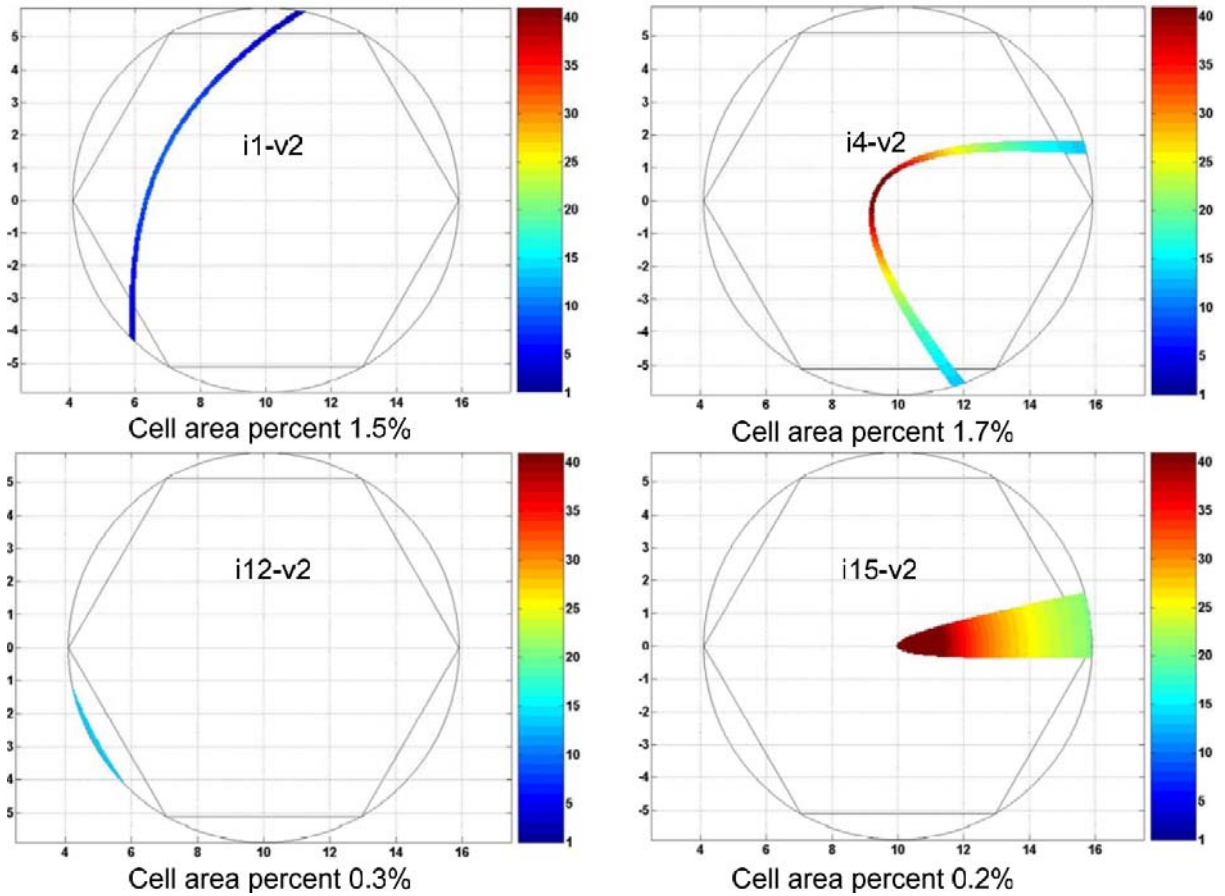


Figure 6

The calculation results of correlation area percentage with regard to propagation are presented in Annex 2. Because interference could occur inside the network and not only on the edge the criterion used in cross-border study can't be applied. The separation distance which corresponds to the threshold is defined as minimum distance when 1% or less of cell area could be interfered by uncoordinated BS.

The analysis in Annex 2 showed that interfered area become lower than 1% with the separation distance between 40 and 42 km. In more detailed analysis it was found that 41 km almost exactly corresponds to 1% of correlation area. The cell correlation area variant for 41 km separation distance is presented below.

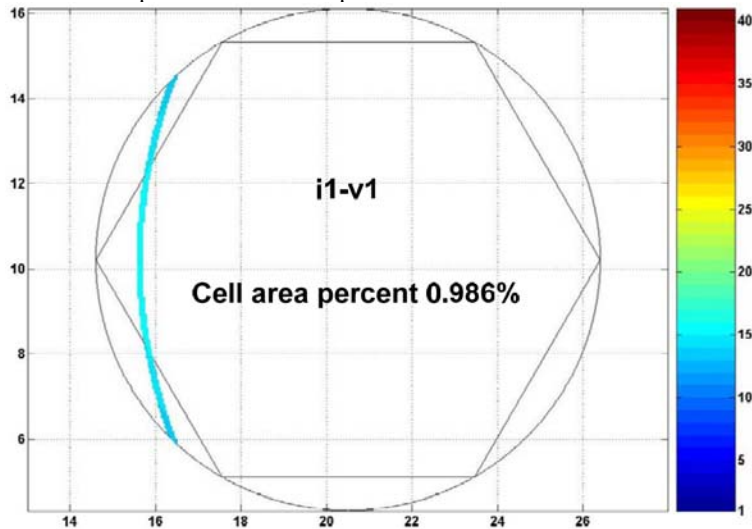


Figure 7

For this distance the threshold level is defined using SEAMCAT, the exact way it was defined in ECC Report 97. To provide permitted level on the border 25 kHz band receiver on a height of 3 meters was modeled in SEAMCAT 3 on a distance of 20.5 km from the closest BS in CDMA cluster. The modeled case and the correspond level -107.5 dBm shown on the figure below. Yellow point denotes measuring receiver location on the border and red points denote interfering CDMA BS cluster, blue point have no physical meaning for the study and just obligatory for SEAMCAT simulation.



Figure 8

This level is 3.5 dB less than level received for coordinated case and proposed to be used as a maximum permitted level for uncoordinated networks. The calculation of relevant field strength level for uncoordinated networks case in 450 MHz band is presented below:

Central frequency of downlink band	Threshold field strength level on the border (rounded)*	Overall CDMA BS signal strength on the border**
465 MHz	23 dBuV/m/ 25 kHz	40 dBuV/m/ 1.25 MHz

Table 2

\* - measured in a bandwidth of 25 kHz at a height of 3 metres in 50% of time.

\*\* - measured in a bandwidth of 1250 kHz at a height of 3 metres in 50% of time (recommended)

#### 4 CONCLUSIONS

To provide maximum coverage in border areas where concerned Administration using CDMA systems based on CDMA2000 interface with coincident frequency plans to prevent mutual harmful interference it is strongly recommended to use code coordination what leads to higher permitted levels of maximum field strength on the border. The procedure for allocation of preferential and non-preferential codes is provided in this report. 5% or even less of codes should be excluded from border areas to prevent any possibility of correlation between base stations of different Administration.

The threshold level 43.5 dBuV/m is proposed for the case of two coordinated CDMA networks in 450 band using aligned frequencies and preferential codes. For uncoordinated networks and when there is no exact information about CDMA networks frequency plans the level of 40 dBuV/m is proposed. If the network operators on both sides of the border are prepared to accept higher levels of interference than the coordinated level to work closer to the borders with some impact on the loss of service it is even more important to perform code coordination to prevent higher probability of correlation between neighboring networks signals.

## **5 BIBLIOGRAPHY**

- [1] ECC Report 97 "Cross Border Interference for Land Mobile Technologies"
- [2] ERC Recommendation T/R 25-08 "Planning Criteria and Coordination of Frequencies in the Land Mobile Service in the Range 29.7-921 MHz"
- [3] ERC Recommendation 01-01 "Border Coordination of UMTS/IMT-2000 Systems".
- [4] 3GPP2 C.S0002-C "Physical Layer Standard for cdma2000 Spread Spectrum Systems"





Separation distance 28 km

Table with 19 rows (i1-i19) and 39 columns (v1-zone to v19-zone) for a separation distance of 28 km. Values are generally 0.3, 0.4, 0.8, 1.0, 1.2, 1.3, 1.4, 1.7, 2.0, 2.1, 2.2, 2.6, 3.0, 3.7, 4.0, 4.3, 4.6, 5.0, 5.4, 5.7, 6.0, 6.4, 6.7, 7.0, 7.4, 7.7, 8.0, 8.4, 8.7, 9.0, 9.4, 9.7, 10.0, 10.4, 10.7, 11.0, 11.4, 11.7, 12.0, 12.4, 12.7, 13.0, 13.4, 13.7, 14.0, 14.4, 14.7, 15.0, 15.4, 15.7, 16.0, 16.4, 16.7, 17.0, 17.4, 17.7, 18.0, 18.4, 18.7, 19.0, 19.4, 19.7, 20.0.

Separation distance 30 km

Table with 19 rows (i1-i19) and 39 columns (v1-zone to v19-zone) for a separation distance of 30 km. Values are generally 0.8, 1.0, 1.3, 1.4, 1.7, 2.0, 2.1, 2.2, 2.6, 3.0, 3.7, 4.0, 4.3, 4.6, 5.0, 5.4, 5.7, 6.0, 6.4, 6.7, 7.0, 7.4, 7.7, 8.0, 8.4, 8.7, 9.0, 9.4, 9.7, 10.0, 10.4, 10.7, 11.0, 11.4, 11.7, 12.0, 12.4, 12.7, 13.0, 13.4, 13.7, 14.0, 14.4, 14.7, 15.0, 15.4, 15.7, 16.0, 16.4, 16.7, 17.0, 17.4, 17.7, 18.0, 18.4, 18.7, 19.0, 19.4, 19.7, 20.0.

Separation distance 32 km

Table with 19 rows (i1-i19) and 39 columns (v1-zone to v19-zone) for a separation distance of 32 km. Values are generally 0.9, 1.0, 1.3, 1.4, 1.7, 2.0, 2.1, 2.2, 2.6, 3.0, 3.7, 4.0, 4.3, 4.6, 5.0, 5.4, 5.7, 6.0, 6.4, 6.7, 7.0, 7.4, 7.7, 8.0, 8.4, 8.7, 9.0, 9.4, 9.7, 10.0, 10.4, 10.7, 11.0, 11.4, 11.7, 12.0, 12.4, 12.7, 13.0, 13.4, 13.7, 14.0, 14.4, 14.7, 15.0, 15.4, 15.7, 16.0, 16.4, 16.7, 17.0, 17.4, 17.7, 18.0, 18.4, 18.7, 19.0, 19.4, 19.7, 20.0.

Separation distance 34 km

Table with 19 rows (i1-i19) and 39 columns (v1-zone to v19-zone) for a separation distance of 34 km. Values are generally 1.2, 1.3, 1.4, 1.7, 2.0, 2.1, 2.2, 2.6, 3.0, 3.7, 4.0, 4.3, 4.6, 5.0, 5.4, 5.7, 6.0, 6.4, 6.7, 7.0, 7.4, 7.7, 8.0, 8.4, 8.7, 9.0, 9.4, 9.7, 10.0, 10.4, 10.7, 11.0, 11.4, 11.7, 12.0, 12.4, 12.7, 13.0, 13.4, 13.7, 14.0, 14.4, 14.7, 15.0, 15.4, 15.7, 16.0, 16.4, 16.7, 17.0, 17.4, 17.7, 18.0, 18.4, 18.7, 19.0, 19.4, 19.7, 20.0.



















