Method for Enhancement of Coexistence Between E-GSM and CDMA Systems in Border Areas

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Abstract— *This paper presents a possible method for enhancement of co-existence of an E-GSM system based network with a CDMA sustem based network, in border area between two countries. Since the frequency bands allocated for the deployment of previous mentioned networks can partially overlap and due to the fact that the downlink frequency band of CDMA system is in the same frequrency band as the uplink of E-GSM system, the co-existence of the systems represents a challenge for the spectrum enineering process. In this paper a method for sharing the frequency band between the two countries under discussion is presented, in order to offer an equitable access to limited spectrum resources. Under this approach, there are settled common technical principles of a coordination procedure between country A and country B.*

Keywords— E-GSM, CDMA, spectrum engineering, co-existence method.

I. INTRODUCTION

In the last years, there is a continuous growth in the request for mobile telephony services due to the evolution of Internet but also due to the growth of user’s mobility.

Natural evolution of mobile communications systems supposed the transition from system based on 2G technologies (GSM) towards actual 4G (LTE) systems, with intermediary steps like 3G (UMTS). Already there are plans to develop 5G systems, which will ensure throughput rates of GB/s.

No matter of the available systems in the market from technical point of view, implementation of those technologies will always depend of the economical factors of the area in which network deployment is planned. So, for sure in areas with less economic/buying power, network operators will be reluctant in implementing new techologies (like 3G or 4G), due to the fact that the needed equipments are still expensive.

Taking into account those mentioned above, GSM based systems are still used in rural areas, ensuring voice communications.

At world-wide level, there are regulations regarding telecom domain, regulations regarding technical parameters of different system, their aim beeing to ensure co-existence of the systems operating in adjacent geographical areas, adjacent frequency bands or the same frequency bands.

Co-location or co-existnce of two of such systems can often lead to interference from one system to the other, interferences which implies a degradation of network’s performances. To minimize this degradation, there is a need for taking measures in order to reduce the values for interfering signal.

A critical situation appears when the downlink of one system is in the band used by the uplink of another system. In this case, the interferer system affects constantly the other system, the interference level beeing very high and due to the fact that the interferer signal is emitted by the base stations with high power from antennas situated on towers/masts of at least 30 meters.

Such a case can be the one from the following scenario, case which will be treated in this paper: an E-GSM based system is deployed in country A simultaneously with a CDMA 2000 based system deployed in country B.

E-GSM allocated frequency bands, according to 3GPP TS45.005[1], are 880-890 MHz for the uplink (UL) and 925 – 935 MHz for the downlink (DL).

CDMA 2000 allocated frequency bands, according to 3GPP2 C.S0057-D[2], are 835.005-844.995 MHz for the uplink (UL) and 880.005-889.995 MHz for the downlink (DL).

To evaluate the compatibility of the systems, in practice, the following steps are taken:

- Identifying the possible compatibility issues;
- Analyzing and evaluating the effects of interferences;
- Implementing solutions in order to reduce the impact of interferences from one system to the other.

II. SPECTRUM ENGINEERING AND SEAMCAT© TOOL

The challenges which spectrum engineering is facing today are those given by the need of increasing penetration of the existing radio applications and introduction of new radio applications whilst taking into account the regulatory, technological and economic considerations, all of those constrained by the requirement for global compatibility amongst many radio systems within a congested radio spectrum.

So, in short, spectrum engineering challenges are to find how new systems can share spectrum with existing (incumbent) services and applications, while there is no more "empty" spectrum.

Thus the need for spectrum engineering to achieve an efficient spectrum use in order to find which existing radio systems are easiest to share with, and then to determine the "sharing rules".

Some of those rules can be: frequency separation of radio systems, geographical separation of radio systems, transmit time sharing or working at different power levels.

Evaluation of the interference's effect cand be done in two approaches:

- A deterministic approach, usually using worst-case assumptions to be in the "safe side" (E.g. Minimum Coupling Loss (MCL) method, to establish the rules for minimum "separation")
- A statistical approach, with parameters represented by random variables in order to cover all possible values for each parameter (E.g the Monte-Carlo method, which allows calculating the probability of interference between two systems for a given deployment).

In the case of the deterministic approach (e.g. Minimum Coupling Loss – MCL), a simulation scenario looks like in Fig. 1

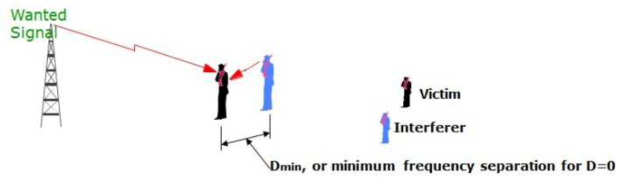

Fig. 1: MCL simulation scenario

The main disadvantage of this approach is that such worst-case assumption will not be permanent during normal operation and therefore sharing rules might be unnecessarily stringent. This will conduct to the conclusion that spectrum use is not necessarily efficient.

In the case of statisitical approach (e.g. Monte Carlo method), a simulation scenaroi looks like in Fig.2.

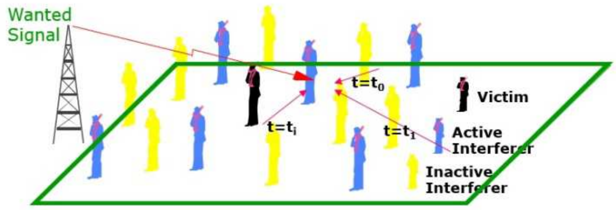

Fig. 2: Monte-Carlo simulation scenario

This kind of analysis implies repeated random generation of interferers and their parameters (activity, power, etc.), and after many trials, not only unfavourable, but also favourable cases will be accounted, the resulting rules beeing more "fair". This will lead to a more efficient spectrum use.

SEAMCAT©[3] is a software based on Monte-Carlo statistical method, for performing sharing and compatibility studies. It is used in many ECC and CEPT Reports, in the same time beeing a reference tool recognised at ITU, having been ment also as an educating tool for new spectrum engineers for their use in administrations, industry or at Universities.

SEAMCAT[3] is designed for co-existence studies between different radio systems operating in the same or adjacent frequency bands and is intended mainly (but not exclusively) for systems operating under terrestrial services. One of its advantages is that can be extended to cellular systems based on CDMA and OFDMA technologies. The outcome of this software is mainly the quantification of probability of interference between radio systems.

III. SIMULATION SCENARIO AND RESULTS

The simulation scenario consisted in defining two systems, E-GSM system belonging to the country A and CDMA 2000 system belonging to the country B. E-GSM system was considered as „victim", while CDMA 2000 system was considered the interferer. This is due to the fact that downlink band of the CDMA 2000 system is used in country A for the uplink of E-GSM system.

Table.1: E-GSM system parameters used in simulation

Parameter	Setting
Noise Floor	-110 dBm
Sensitivity	-103 dBm
Reception Bandwidth	200 kHz
Receiver Noise Figure	4 dB
C/I	9 dB
C/(I+N)	6 dB
Cell Radius	15 km
Operation Frequency	885 MHz
Mobile Antenna Height	1.5 m
Mobile Antenna Gain	0 dBi
Base Station Antenna	30 m

Height	
Base Station Antenna Gain	15 dBi
Operating Frequency	885 MHz

E-GSM BS receiver blocking mask was defined as in Fig. 3.

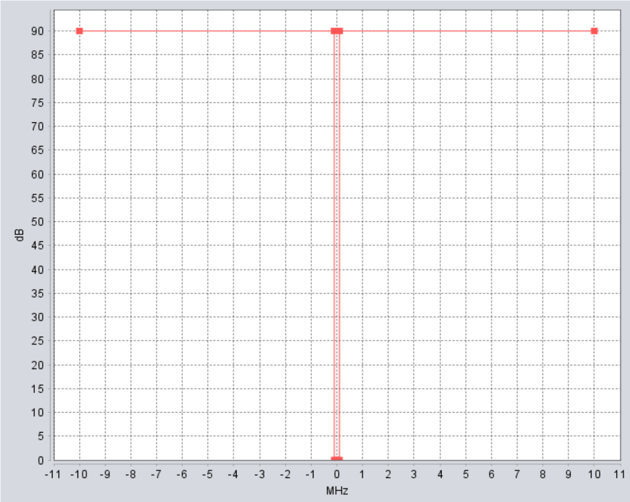

Fig. 3: E-GSM receiver blocking mask

Parameters used for CDMA 2000 system are prezented in Fig. 4

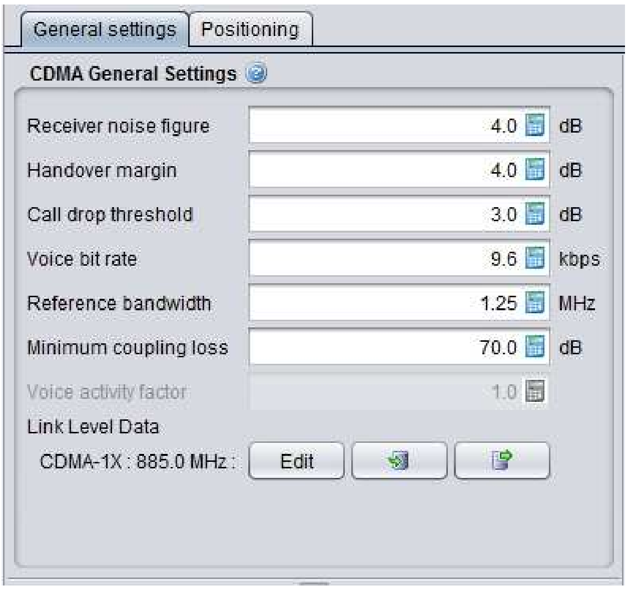

Fig. 4: CDMA system parameters

The probability o f interference was observed for different distances between Interfering system (CDMA 2000) and Vicitm link (E-GSM).

As it can be seen from Fig. 5 and 6, the relation between desired signal and interfering signal shows clearly that there is no possibility of co-existence between those two system in the same frequency band (885 MHz), even though there is a geographical separation.

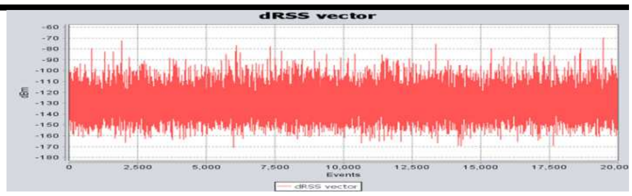

Fig. 5: dRSS Vector

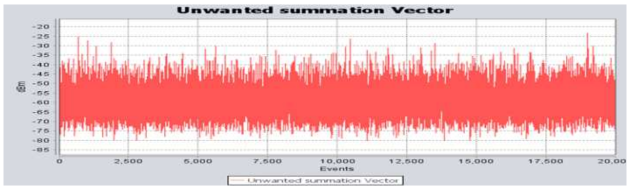

Fig. 6: iRSS Unwanted Vector

In order to allow the deployment of both systems in the neighbouring countries, the intention is to find solutions, equitable for everyone. One possible solution is the one presented in the next chapter.

IV. METHOD FOR ENHANCEMENT OF COEXISTENCE BETWEEN E-GSM AND CDMA SYSTEMS IN BORDER AREAS

We assumed in our scenario that the frequency band 880-890 MHz is used in country A for E-GSM mobile stations (MS) transmission and base stations (BS) reception in accordance with Article 5 of ITU Radio Regulations[4] (Table of Frequency Allocations) while the same frequency band is used in country B for CDMA BS transmission and MS reception in accordance with Table of Frequency Allocations (Article 5, RR).

Due to the fact that as we saw earlier it is impossible for the systems under discussion to function simultaneously in the same band and in the same geographical area, it makes sense to try the following approach:

- Divide frequency band 880-890 MHz into two sub bands.
- Define sub-band 880-885 MHz as preferential sub-band of country B.
- Define sub-band 885-890 MHz as preferential sub-band of country A.

Supplementary to those measures to be taken, the following rules should apply, in order to have an equitable use of the spectrum in border areas:

- Receivers of E-GSM BS from country B, operating in the sub band 880-885 MHz may claim protection if a reference transmitter in compliance with HCM[5] requirement regarding the limitation of protection of receivers located at the site and the height of E-GSM BS receiver produces the field strength which does not exceed 26 dBµV/m/200 kHz at the height of 10 meters above ground level at the border line with country A.

- Receivers of E-GSM BS operating in the sub band 885-890 MHz may claim protection if a reference transmitter in compliance with HCM[5] requirement regarding the limitation of protection of receivers located at the site and height of E-GSM BS receiver produces the field strength which does not exceed 26 dBμV/m/200 kHz at the height of 10 meters above ground level at the distance of 30 km from border line of country B inside the territory of country A.
- Transmitters of CDMA BS from country A may operate in the band 880-885 MHz without coordination with country B if the field strength produced by CDMA BS transmitters does not exceed 17 dBμV/m/1.25 MHz at the height of 10 meters above ground level at the distance of 30 km from border line of country A inside the territory of country B.
- Transmitters of CDMA BS from country A may operate in the band 885-890 MHz without coordination with country B if the field strength produced by CDMA BS transmitters does not exceed 17 dBμV/m/1.25 MHz at the height of 10 meters above ground level at the border line of country B.

For field strength calculations, ITU-R Recommendation P.1546 “Method for point-to-area predictions for terrestrial services in the frequency range 30-3000 MHz”[6] shall be used.(for 10% of time and 50% of locations), using the relevant propagation curves, according to the type of radio propagation path between the transmitter and the referenced points (land path propagation or sea path propagation.

In accordance with the point 4.7.3.4 of HCM Agreement[5], the request for protection of a receiver may only be rejected if the conditions governing the cross ranges of harmful interference as given in Annex 1 to the HCM Agreement[5] are not met. In compliance with Annex 1 to the HCM Agreement[5], for GSM system in the range of 870-960 MHz, permissible interference field strength level is equal to 26 dBμV/m, maximum cross-border range of harmful interference is equal to 30 km and ERP of the reference transmitter is equal to 13 dBW.

Heights of antenna of transmitter for which conditions of Annex 1 of HCM Agreement[5] are estimated were determined using propagation curves from the Figure 10 of ITU-R Recommendation P.1546-4[6] (antenna gain from TABLE 3, f = 885 MHz, land path, 10% time, 50% location) are presented in the TABLE 2.

Table.2:Antenna heights used for calculations

Transmitter antenna height, m	**Radius of service area of reference transmitter, km(for field strength level 26 dBμV/m/200kHz and receiving antenna height 10 m)**		
	Antenna tilt		
	γ =0°	**γ =4°**	**γ = 5°**
10	24	21	17
20	33	28	23
30	39	34	28
37,5	42	37	30
60	50	44	37
75	54	47	40
150	67	60	52

Table.3: Antenna gain

Angle of antenna diagram, degree	**Losses L_a,dB**		**Accounted antenna gain G^*_a, dB**
	Antenna diagram of Kathrein 739 650 (f=870 MHz) in vertical plane	**Calculated diagram of 004LA type in vertical plane (Appendix 1 to Annex 6 of HCM)**	
0	0	0.0	12
1	0.2	0.0	12
2	0.9	0.2	11
3	1.9	1.0	10
4	3.5	3.0	9
5	5.7	8.1	5

* Ga = 15 dB – L - La – antenna gain; L = 3 dB – an average feeder losses;

La = an average attenuation due to antenna tilt (γ = 0°, 4°, 5°).

As follows from the TABLE 2, only up to 20 meters transmitter antenna heights can be used near the border line with confirmed receiver protection. Higher antenna heights values can be used farther from the border line.

Taking into account this fact we will consider the reference antenna height of typical transmitter for which interference level shall be determined equal to 30 meters.

Permissible interference power level in the place of antenna location in this case is equal to:

Pallow = Pin – A – Ga + L + La (1)

where:

Pallow – allowable interference power in the place of antenna location;

Pin = -104 dBm – level of BS sensitivity;

A = 6 dB – interference margin. In case of compatibility of two specific technologies an interference margin is assumed to derive from the generally accepted interference threshold for the mobile service (MS):

I/N = - 6 dB;

Ga = 15 dB – antenna gain;

L = 3 dB – an average feeder loss;

La = 3 dB – an average attenuation due to antenna tilt.

Pallow = -104 – 6 – 15 + 3 + 3 = -119 dBm

Conversion of the power into the field strength is made using the following formula:

E [dBμV/m] = P [dBm] + 20 log F [MHz] + 77.2 (2)

E [dBμV/m] = -119 + 20 log 885 + 77.2 =

E[dBμV/m]=17dBμV/m/200kHz⇔25 dBμV/m/1.25MHz

The obtained value 25 dBμV/m is permissible interference field strength on the input of BS receiver antenna in 1.25 MHz bandwidth at the height of 30 meters above ground.

Conversion of the field strength from antenna height 30 meters to the heights in column 1of Table1 is made using the method from ITU-R Recommendation P.1546-4[6]. The conversion factor is equal K30-10 = 8 dB. Taking into account these factors, permissible interference field strength level at the height 10 meters above ground level is equal:

E [dBμV/m]=9dBμV/m/200kHz ⇔17 dBμV/m/1.25MHz

Obtained value proposes a maximal permissible interference field strength produced by CDMA base station on the border line at the height of 10 meters above ground on preferential GSM channels of country B.

The preliminary obtained parameters of CDMA BS fulfilling this condition are presented in the TABLE 4.

Table .4:CDMA BS height vs. distance

CDMA transmitter* antenna height, m	**Allowable distance from CDMA BS transmitter to the border line, km(for field strength level 17 dBμV/m/1,25MHz at the height 10 m on the border line)**		
	Antenna tilt		
	γ =0°	**γ =4°**	**γ = 5°**
10	42	35	28
20	55	46	37
30	63	53	43
37,5	66	57	47
60	76	66	54
75	80	69	58
150	96	83	71

* The value ERP = 13dBW is assumed to be typical for CDMA BS transmitter and to be equivalent to the ERP of the E-GSM BS transmitter.

In case of country A's preferential channels, the E-GSM BS receivers from country B still need protection from CDMA BS transmitters. HCM method can be used for the obtaining of technical conditions for CDMA BS preferential channels by using the same conditions as previously for the protection of E-GSM receiver. The only change is the place of the usage of the criterion 26 dBμV/m at 10 m on the border line or by shifting this criterion to 30 km inside the territory of country B. Such approach allows obtaining the limitations for E-GSM BS parameters, exactly the allowable distance from the E-GSM BSs to the border line with definite antennas height and tilt. Conversion of the TABLE 2 to such conditions is presented in the TABLE 5.

Table.5:E-GSM BS height vs. distance

Receiver antenna height, m	**Allowable distance from E-GSM BS receiver to the border line, km(for field strength level 26 dBμV/m/200kHz created by the E-GSM BS transmitter at the height 10 m on the border line)**		
	Antenna tilt		
	γ =0°	**γ =4°**	**γ = 5°**
10	24	21	17
20	33	28	23
30	39	34	28
37,5	42	37	30
60	50	44	37
75	54	47	40
150	67	60	52

Limitations for CDMA BS parameters can be obtained by using the E-GSM BS receiver protection criterion 17 dBμV/m at 10 m on the distance 30 km inside the territory of country B. Thus we can get converted data from the TABLE 4 to TABLE 6 relating to the radius of CDMA BS service area.

Table.6:CDMA BS height vs. Cell radius

CDMA transmitter antenna height, m	**Radius of CDMA BS service area, km(for field strength level 17 dBμV/m/1,25MHz at the height 10 m on the 30km distance inside ROU territory)**		
	Antenna tilt		
	γ =0°	**γ =4°**	**γ = 5°**
10	42	35	28
20	55	46	37
30	63	53	**43**
37,5	66	57	47
60	76	66	54
75	80	69	58
150	96	83	71

As follows from the TABLE 6, for example, the CDMA BS with antenna height of 30 meters and antenna tilt 5° can be located on the distance not closer than 13 km from the border line.

V. CONCLUSION

This paper presents a practical approach in order to allow the co-existence of GSM and CDMA systems operating in the same band in different countries.

The equitability condition of spectrum sharing is fullfiled, allowing both networks to be deployed, with constraints in the border area.

Presented approach gives only common technical principles of a coordination procedure between country A and country B.

In reality, the calculation of necessary field strength level is performed with terrain data usage by both concerned sides. Thus the BS data base exchange is required for current coordination procedure.

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