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Study on Coexistence between Long Term Evolution and Global System for Mobile Communication

Cătălina-Marina Crina [1]

Abstract — The massive development in mobile and personal communications and the emergence of a diversity of radio applications and services has led to an explosion in the number of base station sites and mobile stations and it is emphasizing the necessity for improvements in the way that network operators co-exist. Sustaining future growth is strongly dependent upon the efficiency with which the radio spectrum is used.

The main purpose of this paper is to evaluate the possibility of co-existence between the GSM and LTE systems using a software tool based upon Monte Carlo technique, so called the Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT), identify the potential problems that might occur and eventually draw conclusions and emphasize proper solutions for the occurred problems.

Keywords — co-existence, interference, GSM, LTE Monte Carlo, SEAMCAT

I. INTRODUCTION

Co-location or co-existence in near vicinity of Base Stations may cause interference resulting in performance degradation. In order to minimize this performance degradation to an acceptable defined level, certain decoupling requirements between the systems have to be met. Actual decoupling requirements can be estimated using comprehensive interference analysis techniques.

The most critical co-existence situations occur when the Down Link (DL) of any system (the interfering one) is close to the Up Link (UL) of the concerned victim system. In that case an interfering Base Station (BS) is constantly disturbing a victim system BS probably with high gain antennas on both sides. Mobile Stations (MSs) may also be close to each other and cause interference but this happens only occasionally. BS and MS may also interferer each other in special situations, caused by the near far problems.

The assessment methodology for mobile inter-system compatibility for site co-existence, site co-location and sharing consists in the three main steps:

- Listing the possible incompatibility problems;
- Interference analysis;
- Required decoupling implementation solution.

The scope of this first step is to get a list of possible reciprocal impact of the given systems in terms of interferences. It is desirable (but often impossible) to rank the interference sources upon their impact's severity.

The goal of the second step is to obtain the necessary decoupling value between systems or the probability of interference, depending on the calculation method used.

There are two methods used for interference assessment:

- deterministic calculation, which provides decoupling requirement values which must be implemented between the two systems;
- statistical method based on Monte Carlo simulations, which provides the probability of interference between the two systems.

The last step it consists of considering some case specific solutions:

- improvement of cell planning such as: shrinking the interfering cell, for example by lowering its output power or tilting the antennas of its base station (if feasible),
- increasing the stopband attenuation of the interfering system's transmit filter in the receive band of the victim system,
- increasing the stopband attenuation of the interfering system's transmit filter in the transmit band of the co-located system. This minimizes coupling between the transmitters and the generated IM products in the transmitters.
- increasing the receive filter's stopband attenuation for the interfering transmit frequencies, so that the levels of these transmit signals are lowered below the critical value,
- increasing decoupling between the two systems, either the air decoupling or the decoupling provided by diplexer. This also minimizes coupling between the transmitters.
- other system specific measures such as activating downlink DTX on the traffic channel or activating downlink power control on traffic channels in the case of the GSM system will be lower.

[1] Faculty of Electronics and Telecommunications, Communications Dept.
Bd. V. Parvan 2, 300223 Timisoara, Romania, e-mail first.author@etc.upt.ro

II. SPECTRUM ENGINEERING ADVANCED MONTE CARLO ANALYSIS TOOL (SEAMCAT)

Using Monte Carlo method, in many applications the physical process is directly simulated, hence there is no need to write the differential equations describing the behavior of the system, unlike the classical analysis methods which use differential equations.The only requirement is that the physical or mathematical system to be described using probability and density functions. The result is extracted by averaging a number of simulations for a certain number of cases [2].

The SEAMCAT simulator models a victim receiver which operates in a medium with multiple sources of interference. The interference sources may belong to the same system as the victim receiver, or to another system. The interference sources are randomly distributed around the victim in a manner chosen by the user. Usually a uniform distribution is chosen. Only a specific number of sources of interference are active at a time. In the figure 1, there is presented a simulation scenario with a victim receiver and its sources of interference.

The effect of each source of interference is accounted. Some interference mechanisms are also included: unwanted emissions, receiver blocking, intermodulation products, co-channel and adjacent channel interference [2].

A condition of interference occurrence is that the victim receiver to have a carrier to interference ratio (C/I) smaller than the minimum accepted value for a correct decoding. In order to compute the carrier to interference ratio of the victim, it is necessary to establish both the desired received signal strength (dRSS) and interfering received signal strength (iRSS), [2].

On the left side of the diagram, the situation when no interference occurs is presented, and on the right side the opposite is presented. In the latter case, the additional interference inside the wanted channel band, will increase the noise level, and consequently the C/I ratio of the victim system will decrease. The new C/I ratio is defined by the difference in dB between desired signal strength and the increased noise level. This ratio has to be greater than the minimum accepted in order to obtain a correct decoding, [2].

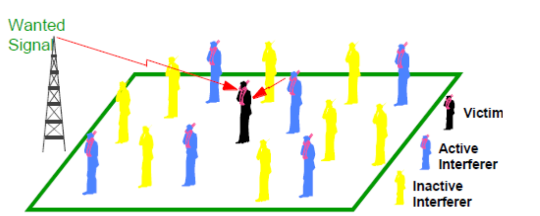

Fig 1 A typical interference scenario for a Monte Carlo simulation, [2].

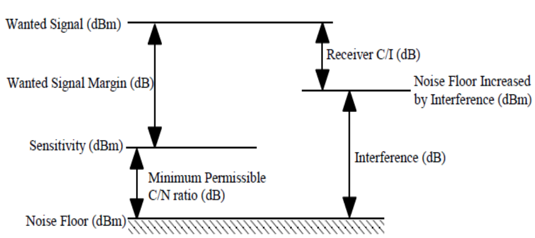

Fig 2 Diagram of the received signals and C/I ratio [2].

The SEAMCAT tool verifies this condition and it registers, for each case, whether interference occurred. The Monte Carlo method considers independent situations in time (or space). For each situation, a scenario is built using a certain number of different variables: the interfering sources position in relation to the victim, the desired signal strength, the channels used by the victim receiver and the interferer, and so on. If a sufficient number of simulations are taken into account, the probability of interference can be computed with a higher precision, [2].

III. STUDY CASE – INTERFERENCE ASSESSMENT BETWEEN LEGACY GSM AND 4G LTE IN 900 MHZ BAND

This study focuses on the main interference problems which may appear with the introduction of new generation LTE, inside the existing GSM 900MHz frequency band in the case in which the GSM BS and LTE BS are co-located. The study will consider both the impact from GSM to LTE as well as from LTE to GSM. The study assumes the case of GSM Operator introducing LTE Base Stations on the already existing GSM sites. The main objective is to evaluate the impact of the interference, determine the interference probability and identify the possible means to mitigate the interference effects: minimum necessary guard band, additional filtering required, and so on.

Channel arrangements in the 900 MHz GSM band:

- 2 x 25 MHz are allocated as Standard or primary GSM 900 Band, P-GSM:

Uplink: 890 MHz to 915 MHz: mobile transmit, base receive;

Downlink: 935 MHz to 960 MHz: base transmit, mobile receive.

- Another 2 x 10 MHz are allocated as Extended GSM 900 Band, E-GSM:

Uplink: 880 MHz to 915 MHz: mobile transmit, base receive;

Downlink: 925 MHz to 960 MHz: base transmit, mobile receive.

In total there are thus 2 x 35 MHz used by GSM900 (Standard GSM and Extended GSM).

Channel arrangements in the 900 MHz LTE band:

Uplink: 880MHz to 915 MHz: mobile transmit, base receive;

Downlink: 925MHz to 960 MHz MHz: base transmit, mobile receive

A. *GSM IMPACT OVER LTE*

1. BS-TO-MS SCENARIO

Since LTE will be introduced in the same GSM 900MHz band, the DL bands of the two systems will be adjacent to each other, with a minimum guard band which has to be determined for the two systems to co-exist without impacting each other. Therefore, there is a concern that potential interference from GSM BS transmitters could interfere with LTE MS receivers. The BS-to-MS interference might cause LTE system DL performance degradation. In order to prevent the affected LTE MS receiver desensitization and blocking, a sufficient isolation between the interfering and affected systems should be achieved.

Impact of mutual interference depends on the interfering GSM BS transmitter emission mask and affected LTE MS receiver characteristics that are functions of the frequency separation between the two systems (guard band).

The tables below show the results of the Monte Carlo simulation for this scenario based on which the recommended minimum guard band is 100 kHz in order to have less than 5% interference probability.

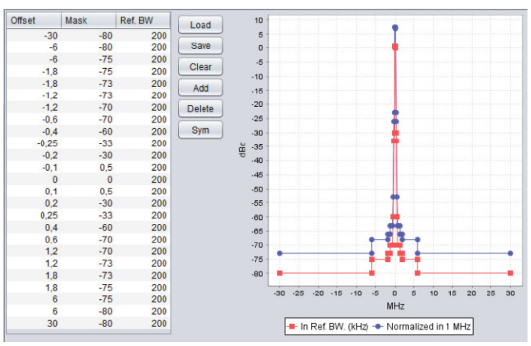

Fig.3 Interfering Transmitter Emission Mask (GSM BS)

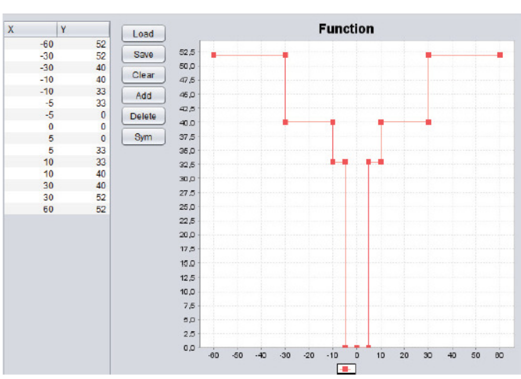

Fig.4 Receiver Blocking Response (LTE MS)

Simulation Parameters

	Victim Link	Interfering Link
Receiver		
Frequency	955 MHz	
Antenna Height	1.5 m	1.5 m
Antenna Gain	2 dBi	2 dBi
Sensitivity	-85.6 dBm	-104 dBm
Reception Bandwidth	10000 kHz	
Noise Floor	-96 dBm	
Cell Range	1 km	
Blocking Response	Rx_Mask_LTE_MS	
Transmitter		
Frequency		949.9 MHz
Antenna Height	30 m	30 m
Antenna Gain	15 dBi	15 dBi
Power Supplied	46 dBm	46 dBm
Cell Range	1 km	
Unwanted Emission		Tx_Mask_GSM_BS

Simulation Results

Table 1 Unwanted Emissions caused Interference Probability vs. Guard Band

Guard band [kHz]	C/I Interference Probability [%]
0	48.72
100	3.01
200	0.28
300	0.04
400	0.05
500	0.05

Table 2 Receiver Blocking caused Interference Probability vs. Guard Band

Guard band [kHz]	C/I Interference Probability [%]
0	4.43
100	4.47
200	4.41
300	4.70
400	4.85
500	4.75

2. MS-TO-BS SCENARIO

Since LTE will be introduced in the same GSM 900MHz band, the UL bands of the two systems will be adjacent to each other, with a minimum guard band which has to be determined for the two systems to co-exist without impacting each other. Therefore, there is a concern that potential interference from GSM MS transmitters could interfere with LTE BS receivers. The MS-to-BS interference might cause LTE system UL performance degradation. In order to prevent the affected LTE BS receiver desensitization and blocking, a sufficient isolation between the interfering and affected systems should be achieved.

Impact of mutual interference depends on the interfering GSM MS transmitter emission mask and affected LTE BS receiver characteristics that are functions of the frequency separation between the two systems (guard band).

Simulation Parameters

	Victim Link	Interfering Link
Receiver		
Frequency	910 MHz	
Antenna Height	30 m	30 m
Antenna Gain	15 dBi	15 dBi
Sensitivity	-88.6 dBm	-107 dBm
Reception Bandwidth	10000 kHz	
Noise Floor	-99 dBm	
Cell Range	1 km	
Blocking Response	Rx_Mask_LTE_BS	
Transmitter		
Frequency		904.9 MHz
Antenna Height	1.5 m	1.5 m
Antenna Gain	2 dBi	2 dBi
Power Supplied	23 dBm	33 dBm
Cell Range	1 km	
Unwanted Emission		Tx_Mask_GSM_MS

Simulation Results

Table 3 Unwanted Emissions caused Interference Probability vs. Guard Band

Guard band [kHz]	C/I Interference Probability [%]
0	76.00
100	12.32
200	2.67
300	2.12
400	1.72
500	1.96

Table 4 Receiver Blocking caused Interference Probability vs. Guard Band

Guard band [kHz]	C/I Interference Probability [%]
0	13.72
100	13.76
200	14.08
300	14.80
400	13.60
500	13.80

The tables above show the results of the Monte Carlo simulation for this scenario based on which the recommended minimum guard band is 200 kHz, in order to have less than 5% interference probability. Based on the 3GPP standard values, the receiver blocking interference probability is higher than 5% even for higher guard bands. In real cases, the actual performances of the LTE BS receiver are better than standard requirements. If this is not the case, additional filtering must be applied. Therefore, based on simulations, the LTE BS blocking response must be improved with 8 dB above 3GPP requirements.

B. LTE IMPACT OVER GSM

1. BS-TO-MS SCENARIO

The BS-to-MS interference might cause GSM system DL performance degradation. In order to prevent the affected GSM MS receiver desensitization and blocking, a sufficient isolation between the interfering and affected systems should be achieved. Impact of mutual interference depends on the interfering LTE BS transmitter emission mask and affected GSM MS receiver characteristics that are functions of the frequency separation between the two systems (guard band).

Simulation Parameters

	Victim Link	Interfering Link
Receiver		
Frequency	949.9 MHz	
Antenna Height	1.5 m	1.5 m
Antenna Gain	2 dBi	2 dBi
Sensitivity	-104 dBm	-85.6 dBm
Reception Bandwidth	200 kHz	
Noise Floor	-113 dBm	
Cell Range	1 km	
Blocking Response	Rx_Mask_GSM_MS	
Transmitter		
Frequency		955 MHz
Antenna Height	30 m	30 m
Antenna Gain	15 dBi	15 dBi
Power Supplied	46 dBm	46 dBm
Cell Range	1 km	
Unwanted Emission		Tx_Mask_LTE_BS

Simulation Results

Table 5 Unwanted Emissions caused Interference Probability vs. Guard Band

Guard band [kHz]	C/I Interference Probability [%]
0	0.18
100	0.10
200	0.17
300	0.13
400	0.12
500	0.13

Table 6 Receiver Blocking caused Interference Probability vs. Guard Band

Guard band [kHz]	C/I Interference Probability [%]
0	0.00
100	0.00
200	0.00
300	0.00
400	0.00
500	0.00

The tables above show the results of the Monte Carlo simulation for this scenario, based on which it results that there are no interference problems because the probability of interference caused by both unwanted emissions and receiver blocking (which is actually 0%) is less than 5%. Therefore, in this case, there is no need for additional filtering or for increasing the guard band between the two systems.

2. MS-TO-BS SCENARIO

The MS-to-BS interference might cause GSM system UL performance degradation. In order to prevent the affected GSM BS receiver desensitization and blocking, a sufficient isolation between the interfering and affected systems should be achieved.
The tables below show the results of the Monte Carlo simulation for this scenario, based on which it results that there are no interference problems because the probability of interference caused by both unwanted emissions and receiver blocking (probability which is actually 0%) is less than 5%.

Simulation Parameters

	Victim Link	Interfering Link
Receiver		
Frequency	904.9 MHz	
Antenna Height	30 m	30 m
Antenna Gain	15 dBi	15 dBi
Sensitivity	-107 dBm	-88.6 dBm
Reception Bandwidth	200 kHz	
Noise Floor	-116 dBm	
Cell Range	1 km	
Blocking Response	Rx_Mask_GSM_BS	
Transmitter		
Frequency		910 MHz
Antenna Height	1.5 m	1.5 m
Antenna Gain	2 dBi	2 dBi
Power Supplied	33 dBm	23 dBm
Cell Range	1 km	
Unwanted Emission		Tx_Mask_LTE_MS

Simulation Results

Table 7 Unwanted Emissions caused Interference Probability vs. Guard Band

Guard band [kHz]	C/I Interference Probability [%]
0	0,73
100	0,73
200	0,72
300	0,65
400	0,68
500	0,67

Table 8 Receiver Blocking caused Interference Probability vs. Guard Band

Guard band [kHz]	C/I Interference Probability [%]
0	0.00
100	0.00
200	0.00
300	0.00
400	0.00
500	0.00

IV. CONCLUSIONS

Each one of the most representative selected scenarios from study treated one mechanism of interference at a time and the final result for the probability of interference was not computed as the cumulative effect from all the interference phenomena present when the 2 systems, GSM and LTE, coexist. Only after solving the problem caused by one interference phenomenon, it can be noticed whether there are still problems caused by other interference phenomena which could be disturbing for the two systems.

From the simulation results, it can be concluded that the GSM system has a greater negative impact upon the LTE system rather than vice versa. However, this impact in not crucial, because with a 200 kHz guard band the probability of interference can be diminished under the accepted value of 5%. The minimum necessary guard band of 200 kHz implies that the GSM operator has to release two carriers, solution which does not affect too much the GSM network.

The simulation results in both studies show that the most impacting scenario out of the four most representative is the MS-to-BS one (the case in which the GSM mobile station is the interferer for the LTE base station). In this case, based on the 3GPP standard values, the receiver blocking interference probability is higher than 5% even for higher guard bands. However, in real cases, the actual performances of the LTE BS receiver are better than the standard requirements. If this is not the case, additional filtering must be applied. Therefore, based on simulations, the LTE BS blocking response must be improved with 8 dB above 3GPP requirements.

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