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Assesment of selected risk conditions affecting the function of eCall system

Abstract. *The emergency call system is a system using GSM network, which is designed for automatic transfer of information about a car accident to an emergency call center to ensure first aid for injured persons promptly. This transfer, unfortunately, may be disrupted under certain conditions, which are experimentally evaluated in this article.*

Streszczenie. *Opisano system bezpieczeństwa wykorzystujący sieć GSM zaprojektowany do automatycznego przesyłu informacji o wypadku samochodowym. Analizowano możliwe przypadki zakłócenia lub przerw w komunikacji,* ***Ocena wybranych zakłóceń funkcjonowania systemu eCall***

Keywords: car accident, emergency call, road safety
Słowa kluczowe: system bezpieczeństwa eCall, zakłócenia system komunikacji GSM

Introduction

Traffic accidents can be considered from the perspective of constantly developing road transportation networks as its unfavourable, but unfortunately also irrepresible part. In some traffic accidents its participants get into a situation, in which they are unable to use a mobile phone to call for emergency services, e.g. due to injuries, or they aren't able to give exact location of the accident. Both of these situations lead to a possible delay in providing first aid to the injured persons, which can cause fatal consequences. [10,11]

In-vehicle system eCall is an emergency call system, which is designed for automatic transfer of information about a traffic accident via the GSM network to an emergency call center to ensure the first aid to injured persons as soon as possible. Activation of the eCall system could be realized in two different ways – automatically by signal comming from airbags unit, if a car crash occures with a deceleration exceeding predefined limit resulting in airbag activation (technical standard CSN EN 16072 allows alternative ways of automatic activation), or manually by passengers, if they get stuck in an emergency situation. [1,2,3]

Under the head of the E-MERGE project has been performed a study based on evaluation of benefits that eCall system carries out, primarily focused on reduction of delays between a car accident occures and arrival of rescuers. Results are shown below:

- reduce the response time to the accident of about 50% in non-urban areas and 40% in urban areas;
- reduce injuries within EU25 of about 15% to save up to 2 500 lives per year. [5, 12]

At the moment of the traffic accident, the eCall system is activated (manually or automatically) and immediately starts to dial up an emergency call, which is able to transmit besides the voice also other information about the accident to the nearest public-safety answering point (PSAP) through the emergency line E112. The voice call enables passengers to communicate with the eCall operator and at the same time a minimum set of data (MSD) is sent to the operator. MSD, which shall not exceed 140 bytes, contains detailed information about the accident – its exact location, time, vehicle information, eCall status and information about service provider. The transmission of the MSD and/or voice call is supposed to be realized via at least 2G network (or better, if available and supported by OBU). [1, 6, 7, 8]

To ensure reliable function of eCall system it is necessary to assess possible risk conditions that may occure in real traffic and cause disruption of its function, which may mean potentional threat for seriously injured passengers.

Equipment and methods

As was stated in the previous chapter, function of the eCall system may be, under certain conditions, limited or completely interrupted. For the process of identifying risk conditions, hereinafter refered to as risk factors, which may cause these disruptions, Ishikawa's cause-and-effect diagram was used, see Figure 1. These risk factors were divided into two categories according to their characteristics – procedural and structural. The first category contains factors, which are affected by human activities, the second one are mostly caused by objects or surrounding properties.

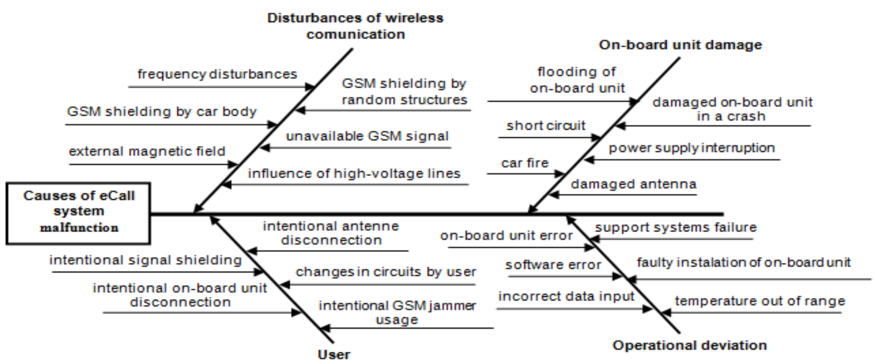


Figure 1: Ishikawa's cause and effect diagram with identified risc factors.

After the step of identifying factors by Ishikawa diagram, Saaty Method of quantitative pair comparison was applied on its output to obtain quantitative information showing the severity of the negative effects of risk factors affecting disruptions of eCall system function. This method is commonly used in analyzing multi-factor evaluation or multi-attribude decision-making problems. Its principle is based on comparisons of all atributes - in this case risks - with each others and according to significance of the risks in currently assessed pair is assigned value from Saaty's scale with the scale of significance 1 - 9 to them. These values are inscribed into Saaty matrix afterwards and processed by the respective formulas. [4]

$$Ri = \left(\prod_{j=1}^{m} s_{ij} \right)^{1/m} \quad (1)$$

$$v_i = \frac{R_i}{\sum_{i=1}^{m} R_i} \quad (2)$$

where: R_i - preferential number of risk, v_i - weight of risk, s_{ij} - risk lying in i-row, j-column, m - count of risks in matrix.

The table below shows the output from Saaty matrix with calculated preferential numbers R_i and weight indexes v_i, where:

- R_i - expresses relative weight of the risk ilustrates its relative significance compared with other risks;
- v_i - is weight of the risk ilustrates its absolute significance compared with other risks, where the value lies within the interval <0,1>.

Table 1: Saaty method output.

Order	Risk type	R_i	v_i	Risk
1.	S	5,63	0,208	Unavailable GSM signal
2.	S	4,20	0,155	GSM shielding by random structures
3.	S	3,78	0,140	Frequency disturbances
4.	P	3,25	0,420	Intentional signal shielding
5.	P	2,95	0,380	Intentional GSM jammer usage
6.	S	2,82	0,104	GSM shielding by car body
7.	S	1,47	0,054	Damaged antenna
8.	S	1,24	0,046	Damaged on-board unit in a crash
9.	S	1,17	0,043	Flooding of on-board unit
10.	S	1,00	0,037	Faulty installation of on-board unit
11.	S	0,91	0,034	On-board unit error
12.	S	0,87	0,032	Power supply interruption
13.	P	0,81	0,100	Intentional antenne disconnection
14.	S	0,74	0,027	Temperature out of range
15.	S	0,69	0,025	Support systems failure
16.	S	0,63	0,023	Short circuit
17.	P	0,50	0,060	Intentional on-board unit disconnection
18.	S	0,47	0,017	Software error
19.	S	0,43	0,016	Incorrect data input
20.	S	0,38	0,014	Car fire
21.	S	0,32	0,012	Influence of high-voltage lines
22.	S	0,30	0,011	External magnetic field
23.	P	0,26	0,030	Changes in circuits by user

Both categories of risks - procedural as well as structural assessed by Saaty Method - were sorted according to the values of preferential numbers Ri.

Both of the previous steps with application of principle 60:40 enable to determine the treshold of the risk severity. According to this, risks lying above the treshold have been assessed as the most severe and were therefore subjected to further experimental investigation. Conversely, risks lying under the treshold were excluded from the investigation because of their low severity and also potentialy low influence on the eCall function.

The main objective of experiments, which have been performed, was to verify or refute theoretically obtained data by risk analysis. Because the threshold had been determined, only five out of twenty three highest severity risks were investigated, as shows Table 1 above.

All the measurements were performed on ONI System monitoring on-board unit, see figure 2. This OBU is capable of sending an SMS at the moment of an accident containing MSD and also supports sending real time data, such as average or instant speed, acceleration in directions of x, y, z axis, GSM signal availability, GPS coordinates, etc. through GPRS to the internet (if available). This feature, which is not supported by standard OBU, was used during all experiments for real time monitoring of collected data.

Figure 2: ONI system on-board unit.

Table 2: ONI system on-board unit specifications.

OBU specifications	
Supported frequencies	GSM 850, EGSM 900, DCS 1800, PCS 1900
Supported GSM standards	2G, 3G
Module recieve sensitivity	- 109 dBm (typical)
Ambient temperature	-30°C to +80°C
Antenna gain	2 dBi
Antenna radiation	H-360°, V-30°

Figure 3: The GSM jammer used for the third experiment.

Table 3: GSM jammer specifications.

Jammer specifications	
Jammed spectrum	850-894MHz, 925-960MHz, 1805-1880MHz, 1900-1980MHz, 2110-2170MHz
Output power	0,5 W
Effective range	2 - 8 m

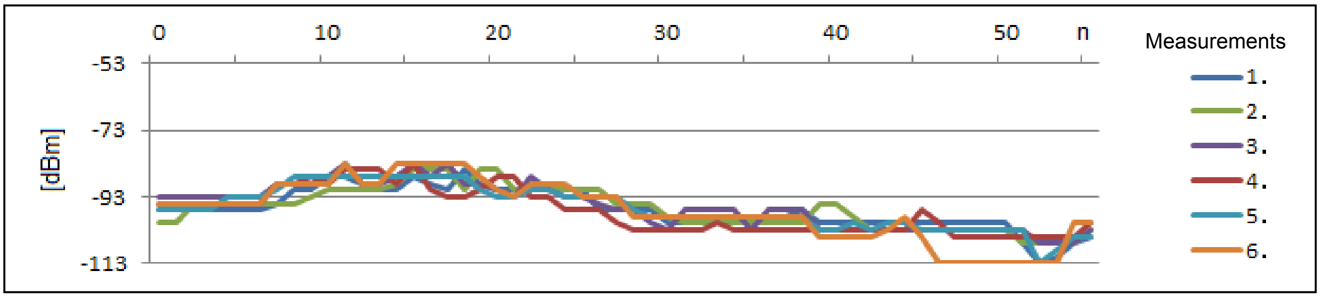
Results

This chapter describes process of every single experiment focused on investigation of the most severe risks, mentioned above and shows its results. Outputs obtained from experiments should allow to verify data acquired from risk analysis and to suggest appropriate corrective measures if possible. Every experimental measurement was run under real conditions corresponding to the real environment, where eCall system is supposed to be used.

The first experiment was performed to determine the level of the negative impact on eCall system when the car equipped with OBU is passing through a route located in a geographical area without guaranteed GSM network coverage - the route has been selected according to the information about the availability of the signal obtained from mobile network operators and verified by an ordinary mobile phone. Total lenght of this route was about 6km and an average speed of measuring vehicle was set to 40km/h.

During this experiment on-board unit was used to measure values of current GSM signal intensity (units: dBm) in specified intervals set by GPS coordinates. That means every measured value of GSM intensity was assigned to the exact coordinates, which enables to track progression of the signal availability on the route and also enables to find exact location of signal loss, where some random shielding structures might be found.

Within the first experiment there were 6 measurements performed overall, collecting 390 values of GSM intensity which were statistically processed and placed into the graph 2. All units describing intensity of the GSM signal are in *dBm.* The lowest intensity takes the value -113dBm (= unavailability), the highest intensity takes up to -51dBm.

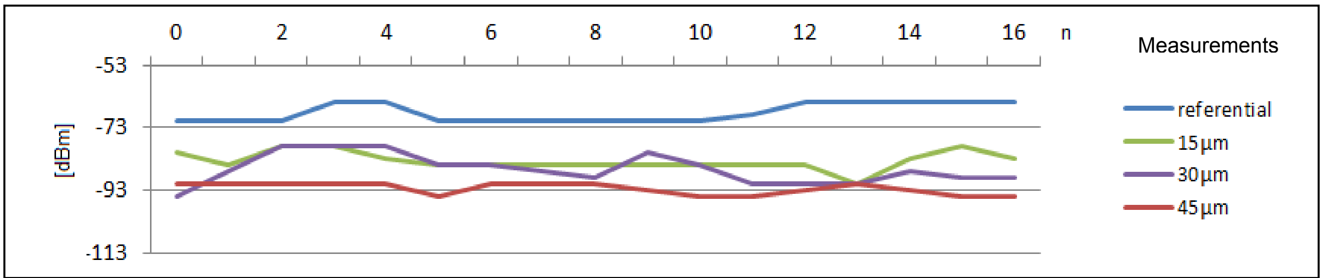


Graph 1: Progress of the GSM signal availability on the selected route.

The second experiment was carried out to evaluate the possibility of disruption of eCall system function by intentional GSM signal shielding caused by a user (driver). One of the most probable ways to create a shielding barrier at home conditions is to use the principle of Faraday cage. For this reason common materials were chosen, as cardboard for creating a supporting structure and aluminum foil with thickness of 15 μm for ensuring its shielding effect. The whole body of the OBU has been closed into this cage and measuring of the GSM signal availability could start.

Within this experiment, four measurements were performed. The first one was used to collect referential values of the GSM signal intensity at selected area. During the second, the third and the fourth measurement values of the intensity while shielding OBU by the aluminum foil of thickness 15 μm, 30 μm and 45 μm were collected. Outcomes from these measurements are shown in the graph 2. The blue line ilustrates referential values of the GSM signal intensity at selected area.

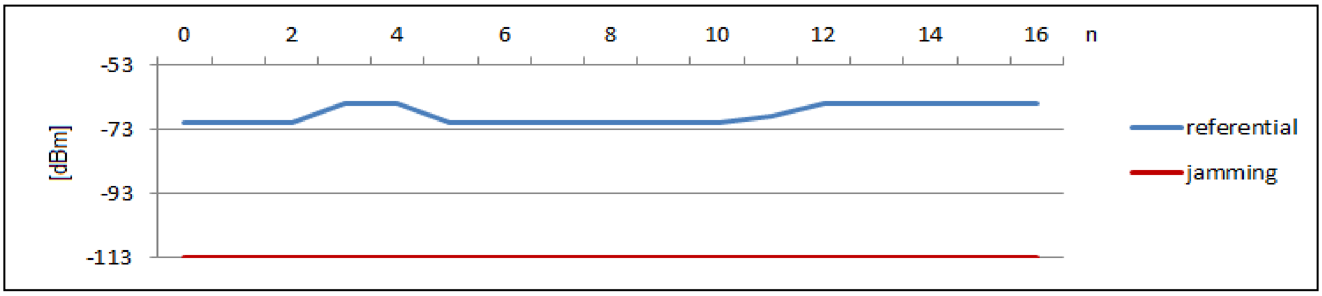
Note: To successful shielding of a mobile phone the thickness of 15 μm aluminum foil is sufficient.



Graph 2: Dependence of the GSM signal availability on the shielding structure properties.

The third experiment was performed to evaluate the possibility of intentional GSM signal jamming by a device (see figure 3) generating disturbing low-power signals in the spectrum of frequencies equal to mobile phone network. Such device prevents the communication between the on-board unit and an emergency call center, so at the moment of a traffic accident it is not possible to transfer any information about the situation, even though the capability of on-board unit to detect the accident stay retained. Moreover, usage of the jammer may also cause malfunction of mobile phones in the vicinity of an accident, which could make it impossible to call emergency services even by witnesses of the accident.

During this experiment there were only two measurements performed due to expected and clear results. Referential values of the signal intensity at selected area were taken over from the previous experiment because it ran under the same conditions. Other values were collected in two different arrangement of OBU and jammer. At first, both devices were placed next to each other, which may be taken as an example of a situation, when the driver knows, where the OBU is hidden in the car's interior. Subsequently, the OBU with its antenna was placed close to widescreen and the jammer was positioned between the front seats, which may illustrate a situation, when the exact position of OBU is unknown. Measured values are shown in the graph 3.



Graph 3: Influence of signal jamming on its availability.

Conclusion

The data recorded during all experimental measurements show that some of the investigated risk factors can have significant negative effect on eCall system, resulting in restriction or even complete disruption of its clutch function.

The most significant negative effect was noticed in the third experiment, representing an intentional usage of jamming device or unintentional frequency disturbances caused by random sources. In this case, the on-board unit was completely out of order all the time because its reciever was overwhelmed by disruptive signal, as illustrates graph 3. It is also important to note the jammer, placed in a vehicle, may disrupt function of all passengers' mobile phones as well as it may cause unavailability of GSM signal of nearby the vehicles. This should be seen as a potential threat if an emergency situation occures.

As a possible way, how to reduce such negative influence of signal jamming on eCall function, may be application of high quality shielding of OBU's body and its antenna cable and also installation of an external antenna on the top of a car body. What should be also kept in mind is that using a GSM jammer is illegal in most of the european countries, but still there are many opportunities to purchase it on the market.

Slightly less severe results were obtained from the second experiment, where the possibility of an intentional signal shielding was investigated. A closer look to the graph 2 suggests that shielding construction used in this experiment didn't cause any signal loss, but significantly lowered its intensity. The difference between a referential value and a value while shielding reaches up to 99,6% after conversion of these values from logarithmic scale (dBm) to linear scale (mW). That means if the referential signal intensity was lower, e.g. about -95 dBm, then the same shielding structure may cause some serious signal losses. Moreover, if any of more sophisticated shielding ways were used, like a packing made of lead sheets, then a signal loss may occure independently of the actual signal intensity.

To prevent a possibility of OBU shielding or shielding its antenna, countermeasures should be done primarily based on OBU design – its shape and/or possitioning in the car's interior. It is possible to integrate OBU into other electronic car parts, e. g. airbag units, which is often hidden under the middle of the dashboard, or place the OBU separately into construction of the dashboard. Due to such placement of OBU or/and its antenna, it should be way more difficult to make an effective shielding. [9]

As the least severe risk factors might be considered missing / unavailable GSM signal and GSM shielding by random structures due to the first experiment output, even though these risks were assessed as the most severe during the risk analysis. The reason of different results is most likely caused by conditions set for the first experiment – parameters of the selected route and the measurement method.

The graph 1 shows progression of the signal intensity on the route, where six measurements were performed in total. Even though the signal coverage was not guaranteed and was proven by mobile phone measurements, OBU was able to keep relatively stable communication with the network. Only during 3 out of 6 measurements some signal losses were detected, where the longest one lasted for tens of seconds, other ones didn't exceed a few seconds. But it is important to keep in mind that these measurements were carried out at low speed around 40 km/h, which means these signal losses were in terms of distance at least around 15 meters long. Such a length is enough to be potentially dangerous if an accident occures in it, because its detection may not be successful.

At this point it would be difficult to suggest any countermeasures due to technological limitations. The on-board unit, used for all experiments mentioned in this article, has proved its ability to operate with very low intensity signal due to an external antenna and high sensitive GSM reciever. However, there still cannot be given any guarantee of no signal losses, because of landscape character and partially inhomogeneous signal coverage (relates to the Czech Republic), which is fortunately still improving.

Contents of this article showed evaluation of some risk factors of eCall system based on an experimental basis, which may occure in real taffic and should be taken into account before eCall will be put into live operation, which is scheduled for the beginning of the year 2017.

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