An Information-Communication System for Early Warning and Collision Avoidance in Road Traffic

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Abstract – **The presented system takes the advantage of information-communication technology, ICT and introduces wireless networks' methodology into vehicles and road infrastructure for a significant enhancement of road traffic safety. Warning signals are transmitted to the back of column of vehicles and it enables the distant drivers to stop in time or to make such operation automatically. Large-scale simulations for different traffic conditions have been carried out. They show that in a pile-up scenario the number of collisions decreases from nearly 100% to zero as the penetration of new system (i-radar) increases from 0 to 100%. Even at 50% penetration almost all heavy collisions are excluded and the other collisions reduced twice.**

Index Terms - **Road traffic, wireless networks, collision avoidance, simulations.**

I. INTRODUCTION

Automotive safety, in terms of fatalities/injuries per kilometer driven, has been steadily improving. Despite this trend, the situation on roads is far from satisfactory. Only in USA about 5 million accidents are registered a year, which account for $200 billion in damage property, 3 million of injuries and 40 thousands of killed. The picture in Europe is similar (see, Appendix A).

In order to further reduce the number of road accidents the communication-based active safety is viewed as the next logical step towards what is called the proactive or ICT systems. They provide an extended horizon of information to warn the driver or vehicle of potentially dangerous situation much earlier.

The first communication-based safety system was the automotive radar [1]. It is still applied, mainly in form of Adaptive Cruise Control (ACC) in luxury automobiles like BMW, AUDI, HONDA and others. There are several versions of auto- radars operating in bands 24, 40, 63 and 76/7GHz. Hence, recently the integration trials has been undertaken [2].

The common limitation of the front-end auto-radar is its high cost and short range of control, which practically does not exceed the distance to the preceding vehicle (~100m). If the inter-vehicle spacing in column (platoon) is comparable with the brake distance, the operation of this radar is correct. But, routinely, this is not the case. Hence, the conventional auto-radar can not guarantee the safety in column drive, because the accident of one vehicle in column drive affects the other vehicles.

The more consistent approach from this point of view present the ICT-based radars (i-radars), which use wireless networks for continuous control of long columns of vehicles up to 1000m [3], [4], [5]. The sensor module of such network, connected to the vehicle's on-board computer, monitors the status in the vicinity of a vehicle and can, therefore, detect potentially harmful situations like an abrupt slow-down, airbag explosion or an overturn. Similar sensor modules can be attached to the immobile objects along the road and even to pedestrians.

Location of vehicles is determined by the navigation system (Galileo), which can also provide communication means for rescue action incase of heavy accident.

Several manufacturers in USA, Europe and Japan developed prototypes of complete equipment operating on the basis of moving wireless networks [3], [6], [7]. There are, however, no field tests, nor simulation data (except for some promotion news), which would show the impact of new technology. The present paper tries to fill this gap. We have carried out large-scale statistical simulations for different traffic scenarios and i-radar designs. The numerous results are included and discussed through this paper. A model of collisions is based on the dissertation thesis [7] and its elements are patented [8].

The rest of the paper contains the concept and assumptions of the i-radar system (sec.2), the first- and second-order models of collisions (sec.3), discussion of obtained simulation results (sec.4), new communication technologies and algorithms (sec.5), conclusion (sec.6)

II. CONCEPT AND ASSUMPTIONS

The model of traffic applied in this paper assumes that a driver obtains in time the essential information on his predecessors at a distance up to 1000m. The subject of the special interest is an abrupt stop of the leader of column. New locations of vehicles in result of such a stop are defined by the equation

$$\begin{aligned}&New\ \ location = \\&Old\ \ location - Reaction\ \ time * Speed - Brake\ \ distance\end{aligned} \qquad (1)$$

At the starting point we are not strongly interested in the brake distance, but rather in the reaction time of a driver. This is because the proposed i-radar system practically cancels the reaction time. This way the new deployment of the column after an abrupt stop of the leader can be treated as an exact copy of its previous deployment except for the brake distance

$$New\ \ deployment\ = Old\ \ deployment\ - Brake\ \ distance \quad (2)$$

Incase of identical vehicles there is no space for collisions, because each vehicle is advanced for the same brake distance, Fig.1a. If, however, no i-radar is used, the equation (1) goes in force and the new deployment depends on the reaction time and speed of each vehicle. Hence, for different vehicles, different reaction times and different inter-vehicle spacing, many collisions may occur, particularly at the end of column, Fig.1b.

The quantitative explanation of the collision mechanism is illustrated in Fig.2. Here, three identical vehicles drive with speed of 30m/s, at inter-spacing 30m and reaction delay 1s.

At the moment t=0 the first vehicle, No 0, comes across an obstacle and a second later it starts to brake, i.e. at t=1s. The deceleration is assumed -6m/s^2. So, this vehicle covers a distance of 75m and stops at L=105m.

The next vehicle, No 1, does not see the obstacle and realize the situation upon the stoplights of the predecessor. So, it starts to brake at t=2s and reaches the same point on road, L=105m, but in a second later. The third vehicle, No 2, undertakes similar actions at t=3s.

As we can see from Fig.2, the trajectories of all three vehicles merge at the distance 105m. This is the boundary case. If we take into account the finite dimensions of vehicles, this boundary will simply mean multiple crash.

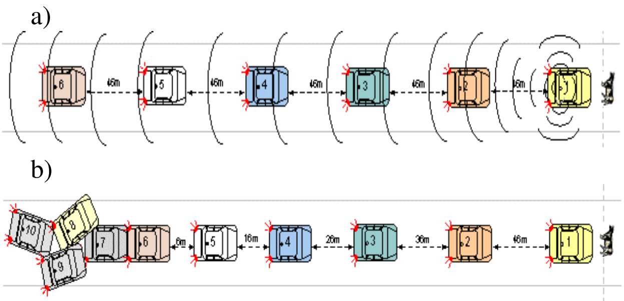

Fig.1. Deployment of vehicles after an abrupt stop of the leader (1) for the case of i-radar used (a) and not used (b)

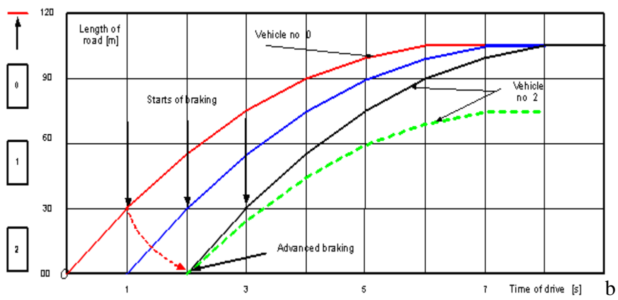

Fig.2. An illustration of the impact of i-radar system: the vehicle 2 receives a warning signal from vehicle 0 at t=1s and starts to brake at t=2s along the dotted trajectory and avoids a collision

The first collision will take place at $t_1 \approx 7$s and the second - at $t_2 \approx 8$s, both in the same place. The similar effect will occur, if we increase the speed or the reaction delay.

The situation is diametrically changed when i-radar is used. The driver in vehicle 2 obtains the warning signal from vehicle 0 at the moment it switches on the stoplights (t=1s). Then, a second later, this vehicle starts to brake. The trajectory, it draws, is shown in Fig.2 by the dotted line. It locates itself far from other trajectories. Hence, the potential collision is moved away.

We have created many models of collisions and carried out many simulations to find out the most representative set of collision parameters. The latest set is as follows:

- the road - straight, single lane, friction coefficient f=0.5
- column of vehicles – composed of 20 different vehicles, mainly cars
- distribution of vehicles' length – exponential (truncated), min=4m, max≈20m, Fig.3a
- speed of column – constant, V=30m/s (108km/h)
- cause of collisions – an abrupt stop of a leader
- distribution of inter-vehicle spacing – uniform, next correlated, mean=30m, Fig.3b
- distribution of reaction time – normal (truncated), mean=1s, variance=1s^2, Fig.3c
- penetration of i-radar – typically 50% (also other values are used, from 0 to 100%)
- brake distances – identical ($H=V^2/2fg$, g= 9.81m/s^2, H≈ 90m)
- total delay (latency) in delivery of warning signals – negligible

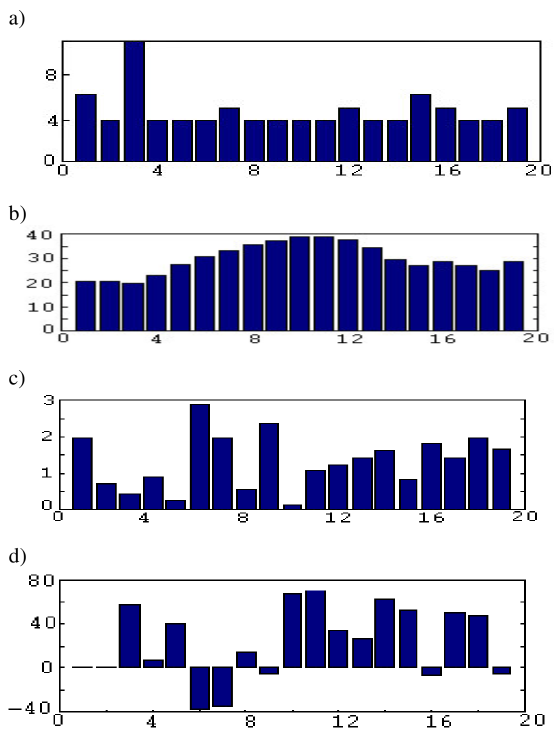

Fig.3. Examples of model parameter distributions: (a) vehicles length, (b) inter-vehicle spacing, (c) reaction delay time, (d) inter-spacing after the stop of leader – negative bars mean collisions (strictly – their depth).

- probability of successful communication in radio channel in absence of overlapping, P=0.5
- reaction of drivers upon i-radar warning – 100%
- definition of a collision: negative distance between neighboring vehicles, Fig.3d.

The above specification can be used as the reference base for comparison of different i-radar systems.

III. Model of Collisions and Preliminary Results

An example of deployment of a group of vehicles after an abrupt stop of a leader is shown in Fig.4. It is obtained as follows: each vehicle is advanced by the distance equal to the reaction delay multiplied by the speed, or it is not advanced at all, if the i-radar is used, eq.(1-2).

Some vehicles in Fig.4 are deliberately placed outside the lane to enable the step-by-step analysis of collisions. In curse of this analysis we form the list of so-called first-order collisions, $d_f(n)-d_r(n-1)<0$, where d_f and d_r are the front and rear ends of n and $n-1$ vehicles, respectively.

The case of the first negative difference (starting from n=3) is considered and the vehicles of number n and $n-1$ are merged and shifted ahead by some distance D (see further). This negative difference is called the depth of a collision (the lacking distance to stop).

The effect of shifting the vehicles is next checked, whether they cause the second-order collisions, $d_f(n-1) - d_r(n-2) < 0$. If the answer is positive, the given collision is registered and no further shift is made.

Then, the next case of negative difference $d_f(n+1)-d_r(n)$ is considered and so forth until the last vehicle in column. The number of statistical scenarios is chosen in accordance with the required accuracy (repeatability) of the given experiment. In any case this number does not fall below 1000, and usually is 10000.

Typical results of simulations are shown in Fig.5a and 5b. They present the distribution of collisions down their depth (placed along abscissa) and down the position of a vehicle in column (expressed by color bars). The Fig.5a refers to the case of no i-radar used and Fig.5b – to the case of i-radar used randomly in 50% of vehicles.

In both figures the depth distribution resembles the exponential low, however, the slope of curve in case of 50% i-radar penetration is more sharp and the density of collisions - twice as low as in case of no i-radar used.

The distribution down the vehicle's position in column can be characterized as follows: for the case of no i-radar used the most of heavy and moderate collisions occur at rear end of the column, Fig.5a (brown bars), while the most of light collisions occur at the front end, Fig.5c (blue bars).

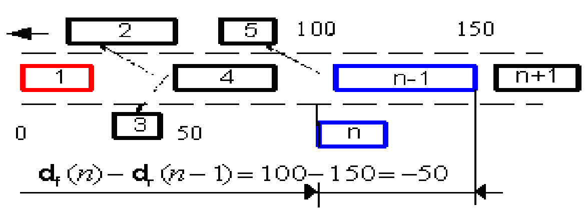

Fig.4. An illustration of definition of the collision depth: $d_f(n)-d_r(n-1)$

For 50% i-radar penetration the light collisions follow the uniform distribution, Fig.5d

The simulation program calculates the mean, maximal and standard depth and the total number of collisions of the first- and second-order (primary and secondary collisions). The shift distance D is calculated due to the first-order depth and length l of the hitting vehicle, e.g.

$$D = \sqrt{d_r(n-1) - d_f(n)} + \sqrt{l(n)}, \quad if\ l(n) \geq l(n-1), \qquad (3)$$
$$otherwise\ D = 0$$

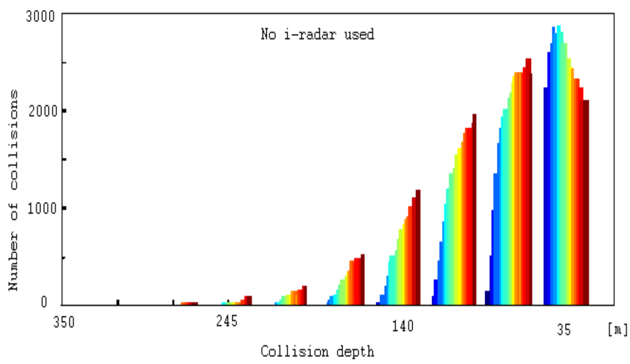

Fig.5a. Distribution of collisions down their depth and vehicle's position in column. No i-radar used. Number of scenarios 10000

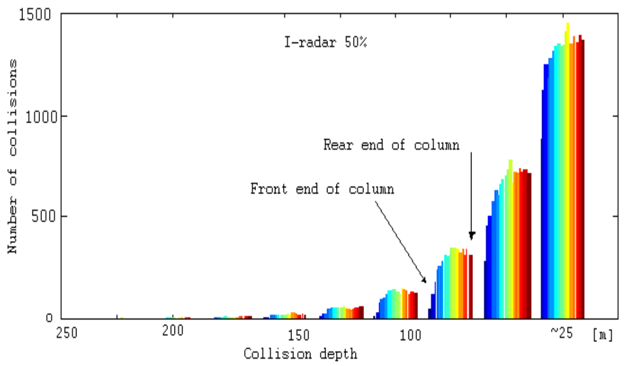

Fig.5b. Distribution of collisions down their depth and vehicle's position in column. I-radar penetration 50%. Number of scenarios 10000

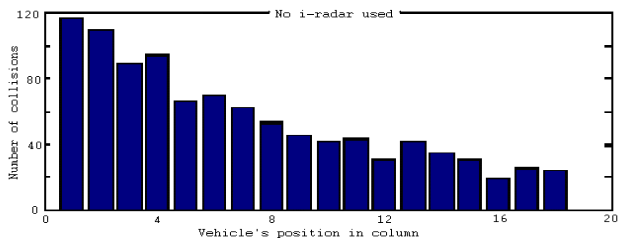

Fig.5c. Distribution of light collisions for the case of no i-radar used

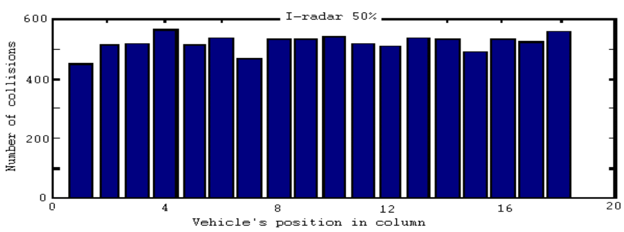

Fig.5d. Distribution of light collisions down the position in column. Penetration of i-radar 50%

IV. Detailed Simulation Results

The behavior of the model under small changes of principal input factors such, as speed, separation distance and reaction delay are given in Table I. This may support or may not, the suitability of the model.

We can see, that mitigation of the input factors by 10% results in sharp decrease of all outcomes. The highest reduction is observed for the secondary collisions - over 20%, the lowest – for the primary collisions, beneath ~10%. This is correct, because the number of secondary collisions is a symptom of road conditions. This number falls down very fast as the road conditions get better, see Table II (row 3).

The last column in Table I refers to the simplified model, in which only primary collisions are considered and no shift of the collided vehicles is provided. We can see that this model reveals the higher number of primary collisions (Δ=715) and prolongs their maximal depth (Δ=63m).

The advanced model presents, instead, 3744 secondary collisions (first column in Table I). They are usually not very serious, so the exchange of 3744 light collisions for 715 heavy collisions may be treated as an equivalent energy exchange. Hence, the conclusion is: both models portrait the same situation, but in more or less detail.

The smaller number of primary collisions in advanced model can be explained as follows: the collided vehicles are shifted ahead, then a distance to the next, potentially hitting vehicle, is prolonged and a collision may not come into effect. Instead, the secondary collision can appear as a result of shifting ahead the two early collided vehicles.

The detailed results of i-radar impact on the safety parameters are given in Table II. Please, note, that the percentage measure is used. It refers to the total number of events 18000 (18 vehicles, 1000 random scenarios).

Table I
IMPACT OF INPUT FACTORS ON OUTPUT SAFETY PARAMETERS.
REFERENCE DATA: I-RADAR 50%, SPEED 30m/s, SPACE 30m, REACTION DELAY 1s, SECONDARY COLLISIONS - RESPECTED

Input factors → Output data ↓	Speed 30m/s	Speed 27m/s	Space 33m	Delay 0.9s	Only primary collisions
Primary collisions [-]	**7946**	6925	7048	7038	8661 Δ=715
Secondary collisions	**3744**	2993	3083	3074	0
Mean depth [m]	**34.6**	28.2	31.6	28.7	41.4, Δ=6.8
Maximal depth [m]	**230**	191	212	194.1	293.4, Δ=63

Table II
PERCENTAGE OF COLLISIONS AND THEIR PARAMETERS VERSUS I-RADAR PENETRATION. STATISTICAL ERROR <1%

Output data	I-radar penetration [%]							
	0	25	50	75	90	95	100	50
Primary col. [%]	88.8	68.7	39.1	20.6	7.7	3.7	0	7946
Secondary col.	59.0	40.3	20.8	6.7	1.8	0.8	0	3744
Light collisions	5.9	8.8	8.6	5.3	2.1	1.0	0	870
Heavy collisions	24.9	7.1	1.46	0.15	.02	0	0	263
Mean depth [m]	73.9	47.8	34.5	27.0	23.8	23	0	34.6
Standard deviation	50.8	37.7	28.9	22.4	18.7	18	0	28.9

At the first glance we notice that the level of collisions in case of no i-radar used is extremely high, up to ~90%. It resembles a pile-up, and, this is really the case. The leader of column have to stop abruptly, no safety means are used, the column consists of 20 different vehicles with different inter-spacing (30±10m), the reaction delay is high, 1±1s and the speed 108km/h. Please, note, that if 100% i-radar is used, all these collisions are avoided!

It is seen from the Table II that all the safety parameters are systematically improved as the penetration of i-radar is growing. The most significant decrease is observed for the heavy collisions. In this case the difference between the state of 0% i-radar penetration and 50% is expressed by the number of 17 (24.9/1.46). This means that the fatal crashes, involving human victims, can be reduced by this number.

The confirmation of this observation is done in Fig.6. We can see, that the heavy collisions decrease, approximately, due to exponential low, while other parameters – nearly inversely proportional to the penetration of i-radar. The number of primary collisions can be expressed by an empirical formula

$$N \approx 100 - p \quad [\%] \tag{4}$$

where p- penetration density of i-radar [%].

The curios is the state of zero-collisions for p=100. It is, naturally, theoretical value, forced by constraints, namely by the identical brake distance. If one vehicle in column is a light car with a good brake system and the following vehicle - a big truck with an out of order brake system, then in emergency a collision may occur despite both drivers use i-radar. We took in the model the same brake distances, because in normal situation they differ not much at constant speed ($H \approx V^2/2fg$) and because there is already one variable - reaction time, which causes similar effects and can express small brake differences.

If only 50% of vehicles is equipped with i-radar, the heavy collisions (>100m) are practically excluded. Then, we can say that i-radar reduces the mean number of collisions approximately twofold, but heavy collisions – by much higher value. This is very promising feature.

The presented data refer to the simulation model. In the real environment some constraints may not be fully satisfied, e.g. 100% reaction on warning signals, the signaling without latency, the identical brake distances etc. This may cause, that the concrete values of experiment will differ the simulation data.

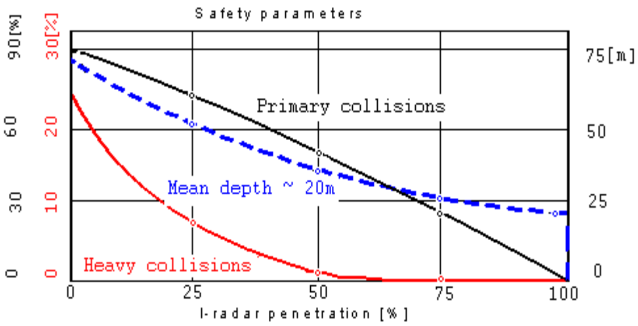

Fig.6. Main parameters of collisions versus penetration of i-radar

However, the ratios of improvement will not change much, because the conditions for both experiments - i-radar used and not used - are the same. This shall guarantee the comparability of the simulation results and the test probes.

V. Communication Technologies and Algorithms

This section has been included to the paper because the modern technologies and advanced communication really define the figures of merit of the i-radar system. The essential problems from the view point of communications are: speed, range and reliability. The full time of transfer the warning signal, from occurrence of the danger to appearing its replica on the receiving monitor, shall be as small as possible, hopefully 0.1s. The communication should cover a large enough area of the order of 1000m within a sector of ~30^0. The probability of successful reception of individual warning signal should be as high as possible. We estimated it for 0.5. The higher values are, naturally, desired, but 0.5 is simply the real expectation in the hostile road environment. The other intelligent means have been taken to raise it up.

The most severe is the problem of communication range. It could not be summed up in several hops as it is usually done [3], [5], [6]. The reason lies in losses of reliability and speed. The range depends mainly on the antennae height. Basing on the Fresnel theory we can estimate the range up to 800m for typical heights of antennae 2m and the frequency band 5.8GHz,. To prolong this range, the MIMO system (multiple input - multiple output) and/or directional antennae should be used (see further).

Serious problem is also with the access to frequency medium and interference. In the literature there are many sophisticated access protocols [3] [5], [6], [13] but we incline to the simplest pure ALOHA. It is bandwidth ineffective, but remains two important features - speed and reliability. The ineffectiveness can be mitigated by limiting the capacity of the message. The typical warning packet contains 100 bytes [3], hence, it takes no more than 100µs when transmitted with 8 Mb/s.

In the sequel the technological basis for both issues – MIMO and medium access – is shortly described .

A. Multiple-antenna system

We will consider the simple system composed of two transmit and two receive antennae, MIMO2x2. The scheme is shown in Fig.7. The message stream at the transmitting point is divided into two sub-streams. Every second bit, say even bit, is sent by the antenna 0, and the odd bits - by the antenna 1. At the receiving point they are retrieved through the combining process on the resulting four individual channels. The typical Rayleigh flat fading and AWGN are assumed. The current values of the transfer functions $h_{0\text{-}3}$ for channels 0-3 are obtained via adaptation process carried on the special pilot signals.

Having done the functions $h_{0\text{-}3}$, the useful signals s_0, s_1 and the noise $n_{0\text{-}3}$ we can write the following equations for the received signals in the channels from 0 to 3 [10].

$$r_0 = h_0 s_0 + h_1 s_1 + n_0,\quad r_1 = h_0(-s_1^*) + h_1 s_0^* + n_1,$$
$$r_2 = h_2 s_0 + h_3 s_1 + n_2,\quad r_3 = h_2(-s_1^*) + h_3 s_0^* + n_3 \qquad (5)$$

where s_0, s_1- transmitted signals, e.g. s_0=1, s_1=-1

$$h_0 = \alpha_0 \exp(j\theta_0),\ h_1 = \alpha_1 \exp(j\theta_1),$$
$$h_2 = \alpha_2 \exp(j\theta_2),\ h_3 = \alpha_3 \exp(j\theta_3) \qquad (6)$$

As the noise is AWGN, we can use the maximum likelihood (ML) criterion of reception

$$d^2(\tilde{s}_0, s_i) \le d^2(\tilde{s}_0, s_j),\quad d^2(\tilde{s}_1, s_i) \le d^2(\tilde{s}_1, s_j)\quad \forall i \ne j \qquad (7)$$

where d^2 – Euclidian distance; $\tilde{s}_{0,1}$ - estimates of useful signals.

$$d^2(x, y) = (x - y)(x^* - y^*) \qquad (8)$$

$$\tilde{s}_0 = h_0^* r_0 + h_1 r_1^* + h_2^* r_2 + h_3 r_3^*,$$
$$\tilde{s}_1 = h_1^* r_0 + -h_0 r_1^* + h_3^* r_2 - h_2 r_3^* \qquad (9)$$

Usually the channels are treated as the independent entities [10], [11]. We introduce the controlled cross-correlation between them via mixing the given channel function h_k with some reference function h_r. This way, using previous equations and correlation coefficients $r_{12}=r_{13}=\ldots=r_{34}=r$, we obtain the BER curves as shown in Fig.8. It is worth to note that there is much gain of MIMO system in respect to the individual Rayleigh channel even at high cross-correlation coefficient, $r=0.5$. Hence, it will substantially improve the range of signaling.

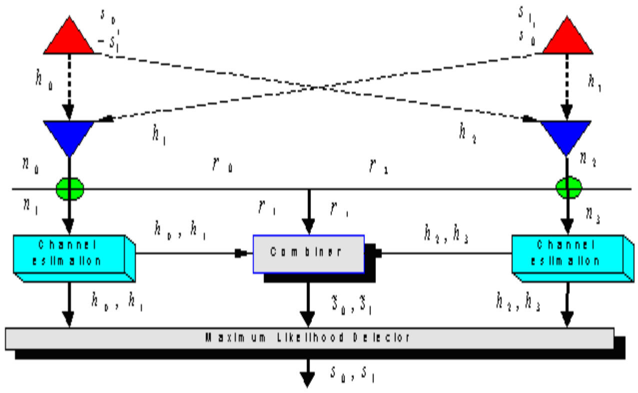

Fig.7. Main factors of the reception process in MIMO2x2 system

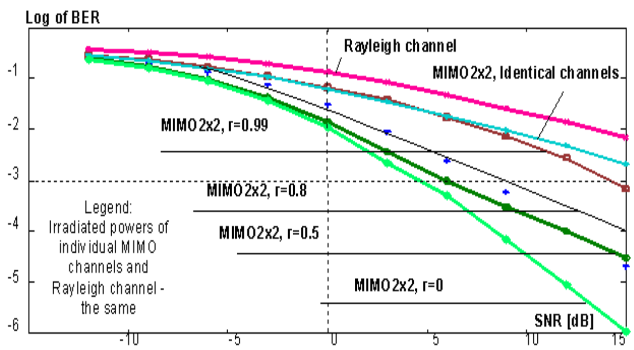

Fig.8. BER vs. SNR for MIMO2x2 system with- and without channel cross-correlation

B. Medium access and interference

In typical scenario a group of vehicles have to send a series of warning packets to the receivers of approaching vehicles. To limit the number of mutual interference the transmitters are restricted in the mean emission rate. It is done by a random go-no-go gate. Receivers accept only non-overlapped packets. Hence, for the Poisson stream the probability of reception is [12]

$$P = \exp(-2\tau\lambda N) \qquad (10)$$

where N - number of transmitters (Tx); λ - mean emission rate; τ - time duration of a packet.

It is easy to show that an optimal probability exists, P_0=1/2e. Then

$$\lambda_{opt} = -\ln(1/2e)/2N\tau \qquad (11)$$

For N=10 and τ=100us, we obtain λ_{opt}=862 packets/sec/Tx. The mutual interference and the throughput are then the highest and $P_0 \approx 0.16$.

An illustration of the emission process is done in Fig.9. There are 1000 slots, each of 10μs. So, the analyzed period is 1000x10μs=0.01s. The packets, each of 100μs, are emitted fully randomly. Because of overlaps the real number of non-interfered transmission is approximately 16 pckets/0.01s/10Tx. If we increase the time of packet delivery to 0.1s, the mean rate increases to 16 packets/Tx. The probability of reception is then

$$P = 1-(1-P_n)^{16} \qquad (12)$$

where P_n - probability of signaling in absence of overlaps.

If P_n is only 0.5, the overall probability of delivery of at least one packet in 0.1s is P=0.9999. In real environment the number of senders may be larger than 10. For three-lane road with inter-vehicle spacing 30m and communication range 1000m the number of 100 senders can be expected. To hold the high probability of packets delivery we have to loose the time constraint, e.g. to take T=0.5s. Hence, the probability of delivery of at least one packet among 100 senders will obtain the value of P=0.996. This is still a satisfactory number.

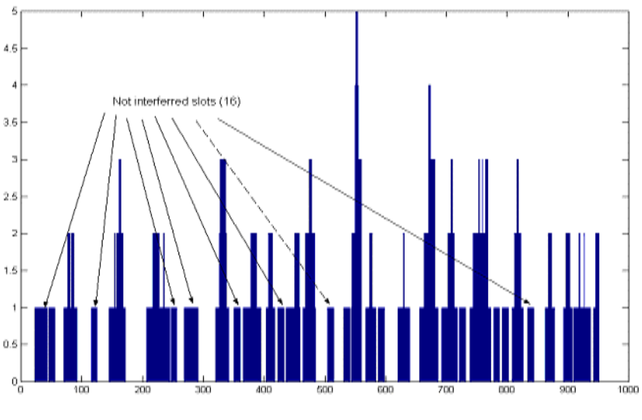

Fig.9. Distribution of overlaps in random generation of warning packets by 10 transmitters – an example

Some authors raise the problem of interference from the same useful packets received several times and from non-useful packets generated by the opposite stream of vehicles [3].We think that the first issue depends on the display design. The packets may be cancelled or may not, if for example, they are used to draw the trajectory of the slow down. The important thing is to assign the packets with the data on kind of danger and its location. The last function will be carried out by Galileo or GPS system.

The packets emitted by the opposite stream of vehicles will be attenuated by the gain of directional antennae and can be cancelled completely by using the special Doppler-effect circuit, which differs the signals propagating along the drive and in opposite direction.

Flat fading will be mitigate by MIMO system, the selective fading – by proper choice of wireless standard with OFDM[1]. No other interference seems to appear in the special channel assigned for safety purposes only.

VI. CONCLUSION

An idea of integrated information-communication system (i-radar) for early warning and collision avoidance in road column traffic was presented and the numerous results of its simulation were included. Currently, these functions are carried out - to some extent - by special automotive radars, mainly ACC (adaptive cruise control). This is, however, an expensive solution not particularly suitable for the column drive control, because of the short range of front-end radar. ACC fails, if an abrupt slow-down appears and the inter-vehicle spacing in column is shorter than a brake distance, which is routine situation.

The i-radar is free of this limitation. It is highly advanced product of the emerging technologies. I-radar controls the traffic over the distance of 1000m and warns the vehicles within a bit of a second. This way it enables to keep extremely short distance between vehicles and, even though, guarantees high level of safety. The simulation shows that if only 50% of vehicles are equipped with i-radar, the number of collisions in typical scenario is reduced twofold and nearly all the heavy collisions, involved human victims, are excluded. This is unique and highly promising property of this new technology.

Theoretically the column fully-equipped with i-radar reveals no collisions even at zero inter-vehicle spacing.

The paper presents also an analysis of the radio communication subsystem, which is responsible for the efficiency and reliability of the total system. The directional antennae, MIMO2x2 combiner and the special ALOHA protocol are the new hits in this scope. The directional antennae and MIMO design guarantee the communication range, while modified ALOHA algorithm – its reliability.

The novelty of the paper consists in new concept of the system: one hope signaling, modified ALOHA protocol, MIMO technology. The new is also the model of collisions and simulation data.

[1] OFDM – Orthogonal Frequency Division Multiplexing

APPENDIX A. STATISTICS OF ROAD COLLISIONS IN EUROPE

TABLE IA
MEAN FATALITY INDEX FOR THE LARGEST EUROPEAN COUNTRIES IN THE PERIOD 1996-2006

Country	Poland	Spain	France	Italy	Germany	UK
Fatalities	6107	5283	7264	6365	7009	3550
Vehicles x10^6	8.32	13.97	23.4	26.8	35.6	20.8
Quotient,10^{-6}	**733**	378	310	238	197	170

TABLE IIA
THE MOST COMMON CAUSES OF THE FATAL CRASHES, 1998-2006

Causes	1998	2000	2002	2004	2006
Driver (total)	47176	44835	43066	41605	37129
- not matched speed/space	**18292**	**12471**	**11905**	**12082**	**10987**
- alcohol	10956	8012	6577	6929	5151
Pedestrian (total)	13180	10776	9159	8041	6719
- careless road intrusion	5912	6199	5138	4454	4230

TABLE IIIA
MEAN NUMBERS OF COLLISIONS, NUMBERS OF FATALITIES AND INJURIES AND THEIR ID-S FOR INDIVIDUAL EUROPE COUNTRIES, 1996-2006

Country	Colli-sions	Fatali-ties	Injuries	Veh. ID[1]	Fatal. ID[2]	Injur. ID[2]
Germany	**364060**	**7009**	**476912**	432	197	13381
UK	229691	3550	245380	347	170	11797
Italy	221241	6365	294607	458	238	14171
France	107582	7264	142203	384	310	6077
Spain	95686	5283	140984	325	378	10088
Poland	54818	6107	68799	218	733	8261
Belgium	46753	1310	64733	367	343	16964
Portugal	43538	1787	45620	277	614	**17148**
Austria	41341	943	49901	402	286	15122
Holland	35246	988	41896	331	183	7758
Czech Rep.	26463	1400	34074	284	483	11750
Greece	20088	1882	26903	241	702	10038
Hungarian	19539	1319	25705	201	650	12663
Sweden	16685	529	23754	360	163	7332
Rumanian	14036	2556	5738	**111**	1060	2380
Slovenia	9167	299	1263	352	425	1794
Slovakia	8551	646	1219	184	650	**1226**
Bulgarian	8019	988	8509	210	603	5195
Ireland	7155	407	10821	281	353	9393
Finland	6806	399	8811	311	247	5449
Denmark	6286	441	8491	283	288	5549
Lithuania	6041	729	7306	254	845	8465
Latvia	4562	537	5574	193	**1209**	1255
Cypr	2544	107	3522	310	493	1623
Estonia	1868	213	2398	260	585	6588
Malta	1117	**15**	**1027**	407	**93**	6340
Luxembourg	**861**	58	1318	**503**	230	5241
Total	**1399744**	**53131**	**1747468**	**-**	**-**	**-**

[1] Vehicle ID -number of vehicles per 1000 inhabitants, Fatalities ID –number of fatalities per number of vehicles x10^6, Injuries ID- number of injuries per number of vehicles x 10^6

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