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Research of power LEDs for mobile communication

Abstract. *The passengers' safety, the decrease of mortality on European roads, the increase of individual transport and reducing of CO2 emission are important concepts, which coming to the fore in automotive industry at the present time. The only solution of the aspects mentioned above is establishment of informative-communicative (cooperative) systems. The International Organizations (Car2Car Communications Consortium, GeoNET) had built the core of problems solution of informative-communicative systems construction on wireless communication in range of radio frequency (802.11p WAVE, CALM M5). Thanks to the significant advance in the quality of vehicles lighting, in the form of implementation of LED technologies, and development of adaptive lighting systems, shows the car communication systems based on optical free space networks that are next developmental milestone in the construction of informative-communicative (cooperative) systems V2V2I (Vehicle-to-Vehicle-to- Infrastructure).*

Streszczenie. *Bezpieczeństwo pasażerów, spadek liczby wypadków śmiertelnych na drogach Europy, wzrost liczby pojazdów i ograniczenie emisji CO2 to ważne wyzwania stojące dzisiaj przed przemysłem samochodowym. Jedynym rozwiązaniem wszystkich tych problemów jest wykorzystanie systemów informacyjno-komunikacyjnych. Organizacje międzynarodowe (Konsorcjum Car2Car, GeoNet) tworzą narzędzia informacyjno-komunikacyjne bazujące na komunikacji bezprzewodowej dla częstotliwości (802,1p WAVE, CALM M5). Dzięki istotnemu rozwojowi jakości oświetlenia samochodowego, m.in. wdrożenia systemów LED i adaptacyjnych, możliwe staje się wprowadzanie systemów komunikacji pojazdów opartych na otwartych sieciach optycznych, co w dalszej kolejności umożliwi wprowadzenie informacyjno-komunikacyjnych systemów V2V2I.* ***(Zastosowania LEDów w komunikacji samochodowej).***

Keywords: power LEDs, V2V2I, optical free space networks, optical communication channel.
Słowa kluczowe: diody elektroluminescencyjne, V2V2I, otwarte sieci optyczne, kanał komunikacji optycznej.

Introduction

For the past 30 years the automotive industry became “the engine” of many European countries. The research of new technologies for cars grows every year. An availability of car purchase brought an increase of traffic on roads, along with increased number of accidents caused by man. The accidents on the roads and motorways in the European Union's claimed the life of 39 thousand people in the year 2008 [1]. The annual losses in the consequences of traffic accidents are around 160 billion of Euros, which is equivalent of 2% of EU GDP. Based on this alarming news, the EU decided to support research and implement measures to reduce the number of traffic accidents involving fatalities on half in 2010, compared to the situation of 2001 [2]. The result of this research is the implementation of informative-communicative systems on the principle of information exchange among vehicles (road users) and also between vehicle and infrastructure along the road. These systems are in shortcut called V2V2I (Vehicle-to-Vehicle-to-Infrastructure). The International Organizations (Car2Car Communications Consortium, GeoNET) had built the core of problems solution of informative-communicative systems construction on wireless communication in range of radio frequency (802.11p WAVE, CALM M5). The present development in LED technology and adaptive lighting systems shows advantages of using alternative communication systems based on optical free space networks.

Intelligent cooperative systems V2V2VI

The intelligent cooperative systems are based on the communication link vehicle-vehicle (V2V), vehicle-infrastructure (V2I) and traffic control centre-infrastructure (DRC2I). These systems show promise to change the current situation and meet the EU requirements to reduce the road accidents. The intelligent cooperative systems increase the time horizon, quality and reliability of information provided to the driver about his surroundings, other vehicles and other road users. Moreover, these systems allow a better management conditions leading to greater safety and more efficient and comfortable mobility. According to the international organization Car2Car Communications Consortia, the services V2V2I can be divided into three basic groups [3]:

- services related to the safety,
- services associated with optimal using of traffic infrastructure,
- services related to additional applications.

The general scheme is shown on fig. 1 [11].

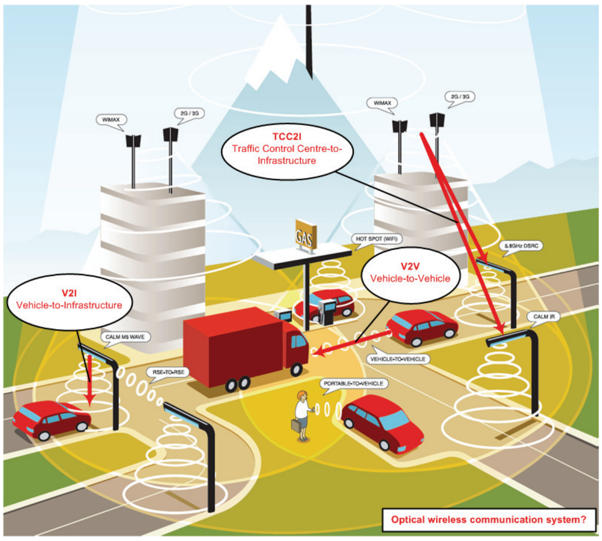

Fig. 1. Intelligent cooperative systems V2V2I

Intelligent cooperative systems V2V2I allocated by the European telecommunications standardization institute (ETSI) on the frequency band 5.9 GHz (the frequency region from 5.875 to 5.925 GHz). This zone was derived from today available communication system IEEE 802.11. This derived technology is called IEEE 802.11p (WAVE) and is referenced in the related documents such as WLAN or CALM M5. The subject of standards CALM is to provide standardized set of protocols of wireless interface and parameters for long and medium range, high-speed connections ITS using one or more media, with harnesses and network protocols and upper layer protocols. Other defined ICT technologies except of IEEE 802.11p are [4]:

- cellular systems: GSM / HSCSD / GPRS (2/2.5G) and UMTS (3G),
- Wireless Systems in 60 GHz band,
- Communication in the infrared optical spectrum,
- Wireless LAN (WLAN) at 5 GHz.

Implementation of LEDs in the automotive industry

The optical communication systems in the visible and infrared spectrum are an alternative to technologies based on radio waves. The massive implementation of LEDs in automotive industry speaks for using of these systems. LEDs consume only a third of energy in providing the same level of light as traditional light sources. An energy saving plays a big role for their application. Based on assessing the U.S. Department of Energy in 2003 the energy saving with application of LED was up to 49% against to the traditional lighting of automobiles [5]. LEDs occur not only in luxury cars in the present time. LEDs are used in the various forms of tail lights, but some car factories came with their application to the front lights as well. The implementation of LEDs products in the Japanese and European automobile factories is around 40% of global resources, the massive application could be expected around the year 2011. In this year, the European Commission (EC) decided to enact mandatory DRL (Daytime Running Lights - fig. 2) light on new cars in all EU countries [6].

Fig. 2. DRL – Daytime Running Lights

This type of day lights should immediately emit light at the start of engine. Thanks to the rapid development of LEDs we can assumed that the traditional bulbs disappear completely from new cars during 10 years. The advantage of LEDs against to traditional light bulbs is obvious. For LEDs to achieve maximum performance are 3 ms enough, compared with traditional light bulbs the value is of 200 ms. It is obvious advantage for stop lights where this time mean saving of 5 m of stopping distance at the speed of 40 km/h . The possibility of using LEDs to transmit information without the burden on surrounding electromagnetic smog and the risk of interference is another advantage.

Optical free space networks using power LEDs

The exchange of relevant information between vehicles (V2V) is major step in the field of road traffic safety. An example might be when the vehicle A is transmitting to vehicle B moving behind vehicle A information such as the abrupt reduction of speed, speed, road conditions, information from the system ESP and steering angle (see fig. 3). This information can alert the driver of the vehicle B by acoustic signals, light signals or in other steps the information may be processed by independent information management functions. These temporarily created optical free space networks could significantly eliminate the reaction time of man, which is around 1 s [6]. The estimated bit rate for the transmission of all important information is around the value of 400 kbps [7]. The measurements showed that the power LEDs have bandwidth high enough to support data transmission in the range of MBps.

Unlike radio communication technologies such as IEEE 802.12p, which are able to communicate from 500 m up to 800 m depending on the obstacles, the microcellular optical networks always require a direct ray between transmitter and receiver side. The worst conditions for these systems are also very sunny days, resulting in a high value of ambient light. This value is independent on the distance between vehicles. The value of the light flux with the square of the distance reduces at optical communications and received optical power fluctuates 5 decades up to 100 m for the use of a photodiode at the receiver with a spectral filter (FWHM = 50 mm). Receivers therefore require a wide dynamic range, high sensitivity and effective suppression of ambient light.

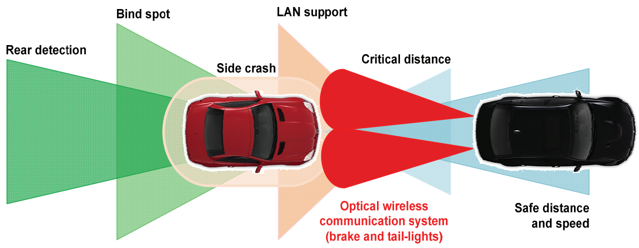

Fig. 3. Communication V2V

The problems of communication in optical free space networks

The ensuring of sufficient optical power at the receiving side is very important for creation a fast and reliable transmission connection (optical channel). Network connection can be therefore characterized by the performance of optical communication and BER factor. The information transmitted in the optical channel requires some form of modulation to be encoded in a physical parameter. Parameters are mostly intensity, frequency and polarization of the emitted light. Power LEDs can be described as almost perfect Lambert's sources; therefore the intensity modulation is the only possible modulation. LEDs transmitting in the visible spectrum are mostly produced for lighting and their rate of change of status is relatively low. In the case of optical free space networks injected into intelligent cooperative system V2V2I this would be an optical system using direct detection of intensity changes and the subsequent transfer to an electrical current. Effect of ambient light noise is described by specifying the ambient noise power P_{amb} :

(1) $$P_{amb} = N_{amb} \cdot B_W ,$$

where: P_{amb} – ambient noise power, N_{amb} – surrounding radiation, B_W – bandwidth photodiode.

The electrical current with direct component is formed by influence of ambient noise I_{DC}:

(2) $$I_{DC} = R \cdot P_{amb},$$

where: R – sensitivity of photodiode, B_W – photodiode bandwidth.

Photodiodes also produce dark current in units of nA that can be neglected for these applications. Transimpedance involvement used in receivers of optical signal for converting of the generated current on the voltage, shows sensitivity by relation (3) [8]:

(3) $$V_{PP} = R \cdot P_{tot},$$

where: V_{PP} – generated voltage (peak-peak), P_{tot} – total power of optical signal and ambient noise.

The involvement of optical free space communication channel for the experimental measurement is shown in fig. 4.

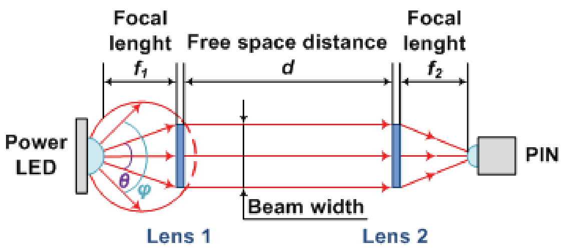

Fig. 4. Optical free space communication channel

As shown in fig. 4 power LED and PIN are placed in the focal of lens. Optical beam in fig. 4 (Beam width) is a non-divergent, which corresponds to experimental measurements in the laboratory. The optical beam with exact divergence is required in a practical application of the automotive industry (see fig. 5). The final product could integrate the lens together with the LED / PIN. In the PIN the received optical power P is expressed as [9]:

(4) $$P = P_t \cdot \frac{(m+1)}{2\pi d^2} \cos^m(\phi) \cdot T_S(\psi) \cdot \cos(\psi), \quad 0 \le \psi \le \Psi_C$$

where: P_t – optical power of power LED, ϕ – angle of optical beam focused by lens, d – distance between receiver and transmitter block, $T_S(\psi)$ – transmit filter, $g(\psi)$ – gain concentrated beam, Ψ_C – field of concentrated beam.

The half-angle m corresponding to Lambert's radiation source means for the power of the radiation source [9]:

(5) $$m = \frac{-\ln 2}{\ln(\Psi_{1/2})},$$

where: $m = 1$ pro $\Psi_{1/2} = 60°$.

For arrangement shown on fig. 4 we suppose equality of angles $\phi = \psi$. In this case concentrator of the beam is the lens, which improves received power at the PIN. In the next step of experiment the lens on the side of power LED was removed - see fig. 5. The reason was an approximation to the real situation in the implementation of the optical free space system into vehicle (eg V2V).

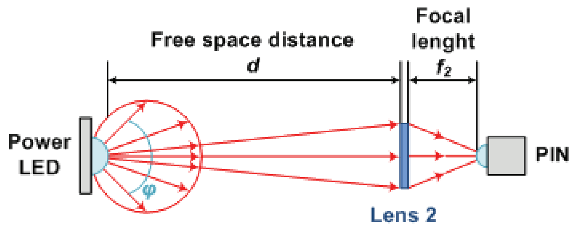

Fig. 5. Optical free space communication channel without lens 1

Optical output power measured at power LED and PIN and the corresponding effective coupling is then calculated as a percentage of power values, see in tab. 1, and parameter V_{PP} indicates the amplitude of voltage on the power LED on a square wave. The resulting sensitivity is determined by the equation (3). Module Thorlabs DET10A with a rise time of 1 ns and working at the wavelength range 200-1100 nm was used at the receiving side in actual measurements. The oscilloscope LeCroy WaveRunner 204MXI was used for processing signals from the photodetector. Positional changes on the receiving side for the basic configuration according to fig. 4 (fig. 5) are shown in fig. 6 (fig. 7)

Table 1. Optical power depending on frequency of modulation

Freq [kHz]	100	500	1000
V_{PP} [mV]	653	540	421
P_{LED} [mW]	4550	4279	4030
P_{PIN} [mW]	1138	984	809
Efficiency [%]	25	23	20
R [V/W]	0,57	0,55	0,52

Power LED is not primarily intended for communication, but for the lighting purposes. This corresponds to the bandwidth in the range of units of Mbps that can provide (the maximum frequency used in the experiment was 1000 kHz).

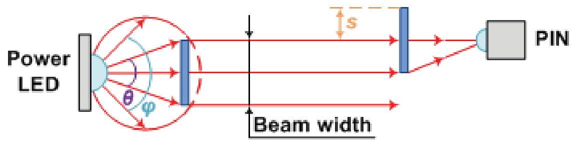

Fig. 6. Repositioning of the receiving part by the parameter s according to fig. 4

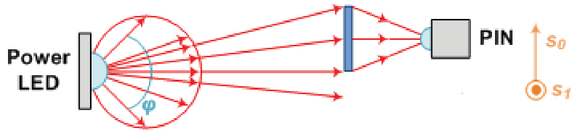

Fig. 7. Repositioning of the receiving part by the parameter s according to fig. 5

In the case of situation of experimental measurements, depicted on the Fig. 6, was only a positional change in relation to the width of the beam - a parameter s. The distance between the receiving and transmitting side (parameter d) was 2 m. The results of the measurements for different offsets *s* are shown in fig. 8.

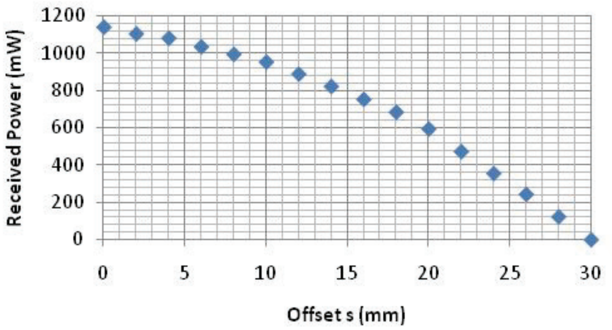

Fig. 8. The results of the measurements for different offsets *s*

The experimental measurements shown in Fig. 7, in which the situation is closest to the real deployment of optical free space networks into the automotive industry, were implemented positional change in all directions of the horizontal position (reduction of the parameter and the displacement of the transceivers-receiver axis). The result of measurements was again carried out for different offsets *s*, and it is shown in fig. 9.

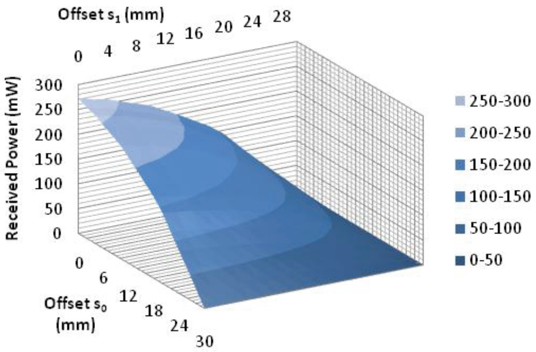

Fig. 9. The results of the measurements for different offsets s_0 *and* s_1

From the results, presented on fig.8 and fig. 9, is evident that it is possible to consider the application of power LEDs in the intelligent and cooperative systems to the automotive industry. General advantage of LEDs is shorter time to achieve maximum performance, unlike traditional bulbs, and longer life time. The results showed that the power LEDs meet the requirements on the bit rate of the estimated value of around 400 kbps. In the case that the higher speed was required, it would be necessary to proceed to other solutions, for example replacement power LEDs by panel of super-shine SLEDs, which can handle higher bit rates [7]. The advantage of power LEDs is their potential using in the cars adaptive lighting systems.

Conclusion

Optical free space communications are an alternative to radio technology on the field of information exchange V2V. According to the organization GeoNet, C2C-CC and CVIS that dealing with technology application of 802.11p in the automotive industry in V2V and V2I, it is obvious that the radio system itself leads to congestion and interference of free channels at high density traffic. Solution is in the form of performance-controllable adaptive algorithm D-FPAV [10], but it seems to be preferable optical free space networks for unicast communication. Therefore V2V2I system should be hybrid. Dominant technology ensuring communications V2V and V2I should be technology IEEE 802.11p, but in situations of long string of cars, traffic jams or two near behind moving vehicles the primary information would have to be the data from short-time optical free space network between vehicles. For creating a meaningful system it is obvious that the transfer and evaluation of information received through the optical free space system should be in a very short term. As a solution are increasingly promoting the fiber-optic systems in cars under the system MOST (Media Oriented System Transport) or IDB-1394 standard, AMI-C, which already fully use the advantage of the optical fiber (concretely the plastic optical fibers - POF).

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