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The adaptation of the Becker VHF AM airborne radio for the compatibility with the night vision imaging system green B – a proof of the concept

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The concept and preliminary results of the airborne radio lighting system adaptation to the compatibility with night vision imaging system (NVIS) green B is presented in this paper. The lighting system has been changed according to the civil DO-275 standard (*DO-275 Minimum Operational Performance Standards for Integrated Night Vision Imaging System Equipment)*. Moreover, different methods of the NVIS green B cockpit internal lighting system compatibility ensuring are shown and discussed.

Keywords: airborne, night vision imaging system (NVIS), night vision goggles (NVG), night vision, green B, civilian aviation.

1. Introduction

The night vision imaging system (NVIS) permits to improve the awareness and operational capabilities of pilots during night operations [1]. The main part of the NVIS system is the night vision goggles (NVG) which enables the amplification of the low ambient night light, *e.g.*, from the moon or stars [2] reflected from a terrain. Such light is next visualized to a user on a phosphor screen [3]. It has to be borne in mind that the NVIS system cannot change night to day and has many limitations, *e.g.*, a risk of pilot's spatial disorientation, a lower field of view, circa 40° instead of 180°, lighting halo effects [4]. Moreover, various external effects can decrease the usefulness of the NVG, *e.g.*, weather conditions, terrain, external aircraft lighting or cockpit lighting incompatibility [4, 5]. The internal and external aircraft lighting incompatibility occur when a lighting does not fulfil the rigorous avionic standards and this situation is very hazardous for an aviation safeness. If a near IR radiance is too high it can make the NVG glaring or even damage an image intensifier system [6]. It was proved that light incompatibility is the main reason of 30% of military night flights accidents [4].

Therefore, it is clear that the NVIS is not a panacea which will solve all night flight mission problems, but this system gives good perspectives for further improving of night flights safeness [1]. However, cockpit and external aircrafts lights have to be compatible with the NVG [6].

The NVIS was adopted by the US Army for the military aviation in 1971. The concept has been spreading to a civil sector from late 1980s [3]. At the begging of this century it was found that the efficient and safe implementation of the NVIS in a civil aviation has to be standardized to protect the market from NVIS incompatible solutions [1, 3]. The integration of the NVIS technology into the civil aircrafts is described by three Radio Technical Commission for Aeronautics, Inc. (RTCA), standards: *DO-268 Concept of Operations, Night Vision Imaging System for Civil Operators* [3], *DO-275 Minimum Operational Performance Standards for Integrated Night Vision Imaging System Equipment* [7] and *DO-295 Civil Operators' Training Guidelines for Integrated Night Vision Imaging System Equipment* [8]. However, *DO-275 Minimum Operational Performance Standards for Integrated Night Vision Imaging System Equipment* [7] is the most important from the lighting designer point of view. The standard describes the requirements that has to be fulfilled to meet the NVIS lighting compatibility.

Recently, many researches on the NVIS light compatibility have been launched and some producers of an avionic equipment offer such products. The goal is to design and produce the NVIS compatible LEDs [9], LCDs [10] and whole lighting systems [4]. The NVIS lighting compatibility is also interesting from material sciences point of view. Proper nanocrystals engineering permits the fabrication of LED diodes in the wide range of emitting spectra. Until now, QD-LEDs meeting NVIS requirements without any additional optical filters have been reported [6], unfortunately they are not a commercial product.

The Becker is one of the top world producers of the airborne transceivers equipment for an avionic communication and navigation. The goal of this work has been to propose a solution which ensures the compatibility of civilian NVIS green B standard [7] to Becker radio lighting systems. The proof of this concept has been analyzed based on the Becker VHF AM airborne radio front panel. The additional requirement has been the adaptation which should be carried out using only commercially available components with possibly high reliability. Both the concept and achieved preliminary results are presented and discussed in this paper. Additionally, a general market overview of NVIS green B compatible lighting components has been carried out and is as well shown in this paper.

2. NVIS green B solutions and commercially available lighting components

The NVG are still quite expensive hence there are not too many commercial suppliers which are able to provide a wide range of the NVIS compatible lighting components. The products which are available can be divided into two main groups: the specialized optical filers and the lighting components with integrated optical filters. A possibility of using LED diodes with proper spectral characteristics is an alternative, as it was said in the introduction. However, this solution is very risky, especially when the influence of temperature changes on diodes spectral radiance, luminance and chromaticity would be taken into account. The spectral properties of the optical filters or diodes with integrated optical filters are much more resistant to temperature changes in the comparison to standard LEDs. Therefore, only the application of external filters or filters integrated with LEDs can be considered on this stage, because of the night flights safeness.

The properties of some NVIS compatible filters are presented in Table 1 (where NR_B – NVIS radiance requirements for class B equipment). The NVIS compatible optical filters are available in two main types of sheets and bathtubes. The first type is typically utilized in an adaptation of LCD backlight to the compatibility with NVIS. The second one is typically used for the ensuring the NVIS compliant of LED diodes. However, a transmittance of the filters decreases significantly a brightness of LEDs, moreover, the filters shall be utilized in a combination with LEDs which exhibit proper spectral characteristics. An additional problem is a filter dimension which has to be included in the PCB (printed circuit board) design.

T a b l e 1. Properties of NVIS green B optical filters.

Filter type	Producer	Dedicated LED color	Transmittance [%]	Chromaticity CIE 1976		NR_B	Thickness [mm]
				u'	v'		
WBF	Wamco	White	20	0.105	0.580	7.5×10^{-12}	0.03
LBI	Wamco	White	16	0.110	0.575	4.0×10^{-12}	1
CTL-R068	Consolite	White	30	0.1409	0.5686	1.68×10^{-11}	1
PN 35086-001	Esterline	Green 532 nm	15	0.125	0.579	–	>1

Using the filters integrated with diodes is a safer way to provide proper spectral characteristics of the lighting, because suppliers ensure that they choose proper lighting sources for particular filters. Some NVIS compatible LEDs are presented in Table 2 (where NR_A – NVIS radiance requirements for class A equipment). All of them have in some manner integrated optical filters. However, Wamco diodes have these filters directly deposited on the diode lenses and Lumitron uses an additional bathtube like filter according to the market overview. Moreover, Wamco is offering both surface and side emitting diodes.

The adaptation of LCD backlight to the NVIS green B compatibility can be carried out by two main methods described in Table 3. At this stage it was decided that the most reliable solution will be to utilize the NVIS green B LEDs with an optical filter integrated with diode lens. Such components can be bought from Wamco as it was written before. These LED diodes provide LCD and keys backlights to be the NVIS green B compatible without the application of any additional filters. Unfortunately, these diodes exhibit lower brightness in the comparison to the Lumitron diodes. How-

T a b l e 2. Comparison of available NIVS compatible LED diodes.

Filter type	Producer	Brightness [mcd]	NVIS color	Chromaticity CIE 1976 u'	Chromaticity CIE 1976 v'	NR_A	NR_B
FP-0905SMD-WB2	Wamco	30	Green B	0.105	0.580	–	$<1.0\times10^{-10}$
LED FP-1204SMD-WB2*	Wamco	30	Green B	0.105	0.580	–	$<1.0\times10^{-10}$
L-66199-B0805-003	Lumitron	50	Green B	0.131	0.623	–	$<1.7\times10^{-10}$
L-66199-B1206-003	Lumitron	60	Green B	0.131	0.623	–	$<1.7\times10^{-10}$
L-65196-A1206-003	Lumitron	60	Green A	0.088	0.543	$<1.7\times10^{-10}$	–
L-65648-W1206-003	Lumitron	100	White	0.190	0.490	$<1\times10^{-9}$	–
HSMQ-C120**	Avago	45–145	NVIS incompatible				

*Side emitting diode.
**This diode was given as an comparison to NVIS compatible.

T a b l e 3. Methods of LCD adaptation to NVIS compatibility.

Method	Advantages	Disadvantages
Additional optical filter between disperser and LCD matrix	– Backlight diodes do not have to be changed – Very simple	– A risk of an unfiltered light emission between filter and LCD package – A necessity of using a thin optical filter – A risk of a filter and a filtered diode light incompatibility
Changing side emitting LEDs to NVIS compatible LEDs in backlight	– A sureness of emitted light compatibility with NVIS – A lack of an unfiltered light emission – No additional filter needed	– A necessity of diodes changing – More complicated – A necessity of finding NVIS compliant side emitting diodes

ever, still Wamco LED brightness is higher than a brightness of standard LEDs with an external NVIS filter. It can be observed by multiplying a brightness of Avago NVIS incompatible LED diodes (Table 2) by the NVIS filters transmittances (Table 1). Moreover, Wamco is the only company which provides the NVIS green B side emitting LEDs. Because of low brightness of these LEDs, fulfilling the demanded luminance range requirement by a standard could be impossible. Therefore, there was a need to verify if this adaptation method will permit to get a range of a luminance restricted by the DO-275 standard.

3. Experiment

The measuring procedures described in DO-275 standard cover several testes [7]. The most important requirements that have to be fulfilled are as follows.

– Lighting leakage – any unwanted emission of light from a device cannot occur.

– Luminance range – a smooth regulated proper range of this parameter is required.

– Luminance uniformity – all panel components shall exhibit a uniform luminance to the maximum extent possible.

– Chromaticity measurements – a color of the backlight is strictly defined, this requirement does not have to be met for LCD, a value of this parameter is guaranteed by Wamco.

– Radiance measurements – a spectrum of radiated energy is also limited, diodes cannot radiate in a near-IR range, a value of this parameter is guaranteed by Wamco.

At this stage, only three first measuring procedures were verified. The measurements were conducted using a photometer CS-200 Konica Minolta, its parameters are given in Table 4. The equipment has a low accuracy for very low luminance measurements however, for the concept proof analysis it was enough precise.

4. Preliminary results and discussion

The first problem has been found at the very beginning of the investigation and is presented in Fig. 1. The front panel of the tested device is fabricated using some sort of an epoxy resin. This resin is later covered with white and black paints. The white

T a b l e 4. Parameters and settings of a photometer CS-200 Konica Minolta [11].

Parameter	Value
Observer	2° OBS
Color space	Luminance, u', v'
Measuring time	60 s
Measuring angle	1°
Distance	22 cm
Accuracy (measuring angle 1°)	0.01–0.5 cd/m^2: luminance ±0.02 cd/m^2 ±1 digit
	0.5–1 cd/m^2: luminance ±0.02 cd/m^2 ±1 digit
	1–10 cd/m^2: luminance ±2% ±1 digit

Fig. 1. First front panel version – lighting leakages.

Fig. 2. Second front panel version – no light leakages.

paint is partially transparent for a backlight and black paint shall not pass any wavelengths from a backlight. However, if white or black paints are scratched as it can be observed in Fig. 1 a strong light leakage occurs (see a backlight of keys). Such phenomenon is unacceptable from the DO-275 requirements point of view. These light leakages would decrease significantly a performance of the NVG aided flights. Hence the front panel has been changed to another one with much better deposited paints. The second panel version is presented in Fig. 2. In this case, any light leakages have not been observed.

The LEDs brightness influences the luminance of keys and LCD. Therefore a very low brightness of Wamco LEDs could be a next big problem. It was possible that because of it the highest luminance limit which is defined by DO-275 would be impossible to achieve. The backlight of keys in such a case would demand adding of the extra LEDs to increase luminance. The most critical situation would be in the case of LCD backlight. The additional LEDs in LCD backlight would demand the redesign of the inner parts of the display. Hence it would significantly increase the costs of the chosen NVIS adaptation solution and probably would discriminate this concept. The required luminance ranges of LCD and keys are 0.171–5.826 cd/m^2 and 0.0343–4.45 cd/m^2, respectively, according to DO-275. Fortunately the proposed concept of the lighting adaptation enabled to meet these luminance ranges. The calibration curves for keys and LCD backlights are presented in Figs. 3 and 4, respectively.

Both luminance curves are linear and describe retaliation between a luminance and a pulse width modulation (PWM) duty cycle. A PWM was used to regulate the luminance of the diodes with a good precision. Based on the presented results, a smooth regulation of a luminance was achieved. A chromaticity of the keys backlight also met the required limit ($u' = 0.131$, $v' = 0.623$, $r = 0.57$). The chromaticity measurements do not have to be conducted for LCD according to DO-275. It has to be remembered that a light which is emitted from LEDs passes through an epoxy resin and a white paint

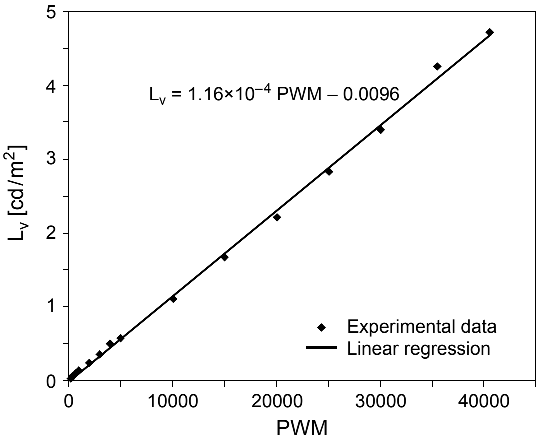

Fig. 3. Keys luminance *vs*. PWM duty cycle.

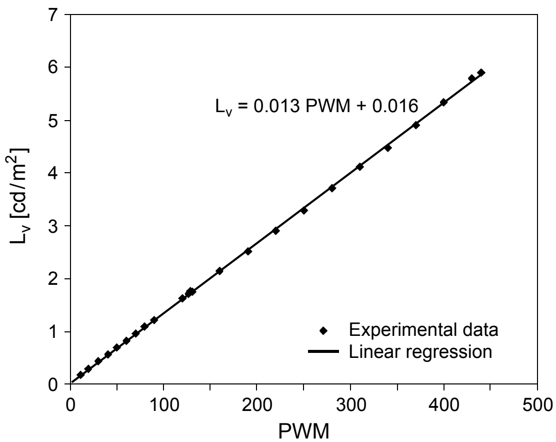

Fig. 4. LCD luminance *vs*. PWM duty cycle.

deposited on the front panel. Hence, an epoxy resin and a white paint thicknesses as well as the properties of these materials can affect the spectral lighting characteristics and surely will affect an amount of a transmitted light. Therefore, any changes of the properties of these two materials would demand the conduction of the additional spectrophotometric measurements. Only after that the NVIS green B compatibility can be guaranteed for the such new constructions.

The second version of the airborne radio front panel fulfilled the initial requirements of the NVIS green B compliance. However, a transparency of the epoxy resin of the front panel was quite low. Hence, higher limit of the NVIS luminance was provided for a high PWM duty cycle. Because of this problem, higher power consumption of the device was needed and long term reliability of the LED diodes was reduced. This drawback can be eliminated by using more transparent epoxy resin for the fabrication of the airborne radio front panel. Hence, the third version of the front panel was

Fig. 5. Third front panel version taken at a dark room.

fabricated and visually inspected (Fig. 5). The quality of the paint deposition and the light transparency are much better in the comparison with the second front panel version. Hence, much lower power consumption will be needed to ensure a backlight luminance required by the DO-275, which will also increase diodes long term reliability. Much more even thickness of the paint films permits to get better lighting uniformity on the entire panel. The additional tests will be conducted using the third version of the panel in the next iteration, *e.g.*, the spectral lighting radiance measurements in a range from 380 to 930 nm, more accurate luminance measurements, the verification of a luminance uniformity.

5. Conclusions

The concept of the NVIS compatible Becker airborne radio lighting system was proposed. Both the side and surface emitting Wamco NVIS green B LEDs provide lighting characteristics which meet the civilian avionic NVIS green B requirements for the used front panel and LCD type.

The NVIS LED power consumption can be reduced by the utilizing of a front panel which is fabricated using a more transparent epoxy resin. This solution also permits the reduction of the PWM duty cycle, hence it will improve the lighting system long term reliability. The next version of the front panel has been prepared for further measurements. The final device will be also used to verify if Wamco diodes implemented in the investigated panel have proper spectral radiation required by DO-275.

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