HIGH THROUGHPUT FREE SPACE OPTICAL COMMUNICATION USING WHITE LED LIGHTING EQUIPMENT

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Abstract

This paper presents a conceptual architecture for high throughput short distance Free-Space-Optical (FSO) communication using white LEDs lighting equipment. Multiple carriers' modulation techniques are used to increase the system bit rate.

Introduction

Among all the theoretical advantages of optical communications, the possibility to use high performances Light Electroluminescent Diodes (LED) lighting system as a source for digital communications becomes one of the most relevant for avionics systems. As the aircraft cabin presents the larger number of nodes to interconnect, free-space optical (FSO) communication appears to be one of the best solutions for weight and power saving solutions. In addition FSO communication systems provide safer operation than radio frequency solutions as they do not interact or affect with the on board communication equipment. High throughput point to multipoint free-space optical links is presented hereafter. The conceptual architecture, main performances and limitations are described and compared with avionics requirements and standards.

Architecture Description

The FSO communication system architecture is based on high performance lighting RGB LEDs and describe on the figure below. A Media Interface Adapter (MIA) is responsible to collecting the electrical input signals according to the protocol they follow that could be for example, 10Base-T Ethernet, ARINC429, MIL-STD-1553 or CAN bus. The MIA output signal is then passed through a digital modulator to create a multi-bit symbol that is used by the LED Driver to generate the optical multi-carrier signal.

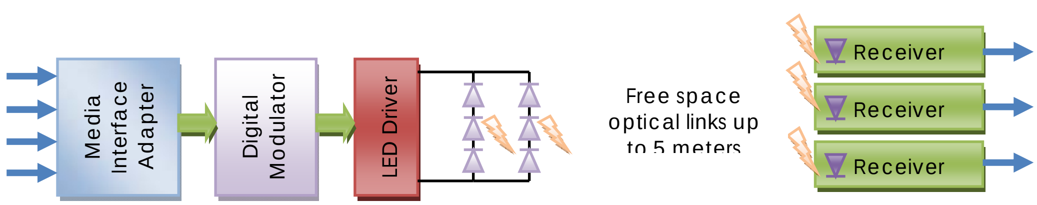


Figure 1. Schematic block diagram of the full-duplex link

The optical signal propagates over the cabin to the receiver which merges and decodes the multiple optical signals and paths to form a single electrical signal that will be demodulate to a protocol independent form. A MIA is therefore used to deliver the received signal in the proper electrical signal (Ethernet, CAN Bus, etc…).

The digital modulator is a multi-bit symbol generator that allows increasing the system bit rate. The symbol generator encode the incoming bit stream into symbols, each symbols are therefore use to modulate one optical carrier. This solution allows to increase the system performances and to add some reconfiguration flexibility, as Optical Code Division Multiple Access (O-CDMA) could be implemented to allow multiple channel communication over the cabin.

RGB LED performances

Among all the advantages of LEDs, the most interesting one is their efficiency and life-time. Due to their low power dissipation, LEDs efficiency, expressed as lumens per watt, are higher than incandescent bubbles and much more reliable with a life time better than 20000 hours. The following graph depicts two different LEDs types, and displays the cost versus energy efficiency ratio: LED offers a very high efficiency, in terms of both cost and energy.

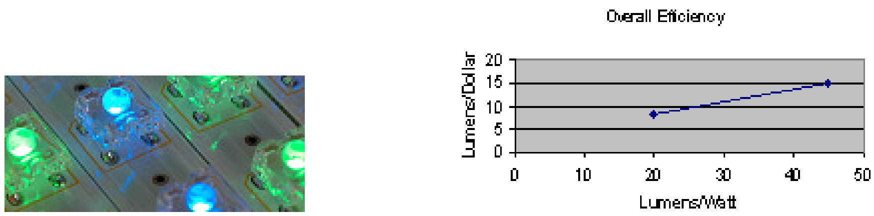


Figure 2. RGB LED front-end details and Cost/efficiency comparison (courtesy of Lunar Accents)

LED also offers modulation capability with typical bit rates up to few megabits and large radiating diagrams that allow a wide covering of the photon over the cabin. This last advantage is particularly interesting to design free space optical communication with no shadow/mask zone.

The optical front-end in charge of the electrical to optical conversion is realized with RGB LEDS as describe on fig. 2, each LED could be modulated with any combination of the three red, green of blue colors to form the optical wavelength coded symbols. The demonstrator is based on 3 symbols, but simulations results demonstrate system operations with 6 or 12 symbols. The higher the number of symbol is the higher overall bit rate will be.

Optical system performances

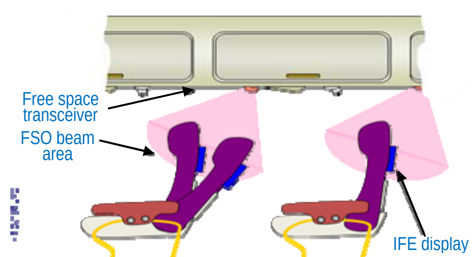
The main limitation of LEDs is there relatively low modulation bandwidth as compared to lasers. However, using multiple carrier techniques compensates for this disadvantage by spreading the high bit rate data onto many lower bit rate carriers. Simulations demonstrate that 100Mbps could be reached using simple few Mbps RGB LEDs. Gigabit rates could be reached with higher performances LEDs.

The cabin multiple optical reflections or paths are collaborative at the receiver level and do not impact the link performances as the communication distances are relatively short (below 10m) and the maximum bit rate per carrier is below the maximum propagation delay.

Masking and/or shadow effects could be negligible using a smart mesh and large number of sources, which is the case for lighting in the cabin as describe in the drawing below.

System Application and integration

As the communication system is based on the use of lighting LEDs it could be use for seat downstream IFE and communications (video and audio broadcasting) without adding extra equipments into the aircraft. This allows removing any high speed wiring to the user IFE system. The system could also be used for rack and intra-equipment communication (board to board synchronization and data exchange, etc…).



Conclusion

The architecture based on the use of existing lighting LEDs seems to be very promising as a considerable weight saving could be realized, and the communication system become cabin arrangement independent. Simulations and experimental results validated through a functional demonstration show that the performances reached are compatible with video broadcasting over the cabin.