FIBER-OPTIC COMMUNICATION FOR VEHICLES, AIRPLANES AND VESSELS

Jan Lubkoll [1], Otto Strobel [2]
[1] Erlangen Friedrich-Alexander University, Schlossplatz 4, 91054 Erlangen, Germany
[2] Esslingen University of Applied Sciences, Flanderstr. 101, 73732 Esslingen, Germany

Introduction

Optical data buses in vehicles are almost exclusively used for infotainment (information and entertainment) applications. The Media Oriented Systems Transport (MOST) [1] is the optical data bus technology currently used in cars with a data rate up to 150 MBit/s.
The integration of more and more multimedia and telematic devices in vehicles led to a large increase in traffic demands. In particular for luxurious classes a huge need for network capacity and higher complexity by integration of various applications have to be taken into account. Although MOST is the optical data bus technology currently used; alternative solutions for higher data rates that satisfy future automotive applications are highly desirable.
Another serious challenge arises in protecting new generation aircrafts particularly against lightning strikes. This is because new airplanes will be built using carbon-fiber to reduce the weight of fuselage. Therefore, these airplanes will lose a lot of protection against lightning, cosmic radiation and other electrostatic effects [2]. A reasonable solution is to use glass or plastic fibers as transmission medium in new airplanes. Since the FlexRay bus protocol [3] is more adequate for avionic applications; it should be adapted for this transmission medium. Thus, this solution is cost-efficient and offers more safety in the aviation domain.
In this paper we propose an improvement for optical data bus systems that may satisfy the requirements of future automotive applications and safety-relevant operations. First, we give an overview on MOST bus systems. Then, the challenges of data transmission that arise in new aircraft generations are presented. In the main paper we propose two alternative solutions for optical data buses in avionic systems. Subsequently we discuss the prototyping results and present open directions for future work.

Most Bus Technology

MOST Corporation was founded in 1998 by automotive manufacturers and several system vendors to establish and refine a common standard for todays and future needs of automotive multimedia networks [1]. MOST is the optical data bus technology currently used in cars with a data rate up to 150 MBit/s. This bus technology offers not only a synchronous transmission for audio and video data, but also makes available the application framework for controlling the system complexity. In particular, MOST specifies interfaces and functions for infotainment applications at a high abstraction level. Different multimedia components can be connected in a ring topology. Furthermore, Bluetooth can be used for wireless devices and diagnosis interfaces [4].
An LED is used as transmitter to convert the electrical signal to an optical one using a driver circuit. The receiver converts the optical signal into an electric current using a Si-photodiode. The third generation MOST150 was specified to satisfy large traffic demands. It is based on an optical physical layer and a data rate of up to 150 Mbit/s. A polymer optical fiber (POF) is used as transmission medium for MOST bus systems.
Conventional POF/LED bus systems are capable to achieve 150 Mbit/s and will preliminary remain the solution for cars [5]. In particular, MOST150 is adequate for optical data transmission in cars enabling the cross linking of onboard video cameras, laptops, GPS and cell phones.
For higher data rates, alternative solutions are considered. Several advanced modulation techniques have been proposed recently that make this step feasible. Especially, by combining multi-carrier modulation with spectrally-efficient quadrature amplitude modulation (QAM), the first demonstration of 1 Gbit/s transmission over 100 m of SI-POF was reported [6]. Alternatively advanced optical components (see Data Buses in Avionic Systems) can be used. As a result, this optical bus technology can be also used for sensor applications including safety-relevant operations like drive by wire, brake by wire and engine management, and might finally lead to autonomous vehicle driving.

Data Buses in Avionic Systems

In order to reduce the weight of new generation aircrafts, design engineers are going to use more and more carbon-fiber fuselage. On one side this technology may reduce the weight of an aircraft up to 30 %, but on the other side it introduces new safety problems and difficulties. A serious problem arises from the fact that many

advantages of a closed metal fuselage get lost. An important advantage is the Faraday cage inherent lightning strike and cosmic radiation protection. Figure 1 shows the typical lightning strike propagation hitting an airplane. In this case the current will propagate through the exterior skin. From Figure 1b it can be seen that the charge channel of lightning hits the nose of the plane, travels along the skin and leaves through the rear. In Figure 1c the return bolt follows the charge channel. This could induce transients into wires or equipments that could be possibly disturbed, or totally damaged. However, these complications and failures can be avoided by system redundancy and special protection effects [2].

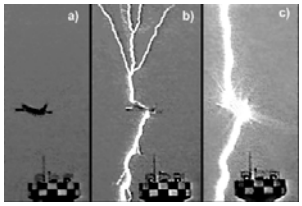

Fig. 1 Lightning strikes an airplane

The situation would be fatal in an airplane without a completely closed Faraday cage. Lightning strikes could possibly take different paths through the plane and thus harm or even destroy several electrical components. These problems can be avoided by complex electrical protections which cause higher costs and increase the weight of the cables. However, a reasonable and cost-effective protection method is the employment of optical wires as transmission medium used in avionic systems based on a mechanism for safety critical systems applying a FlexRay bus protocol.

Contrary to the MOST bus, the LED as transmitters and the POF as fiber could be replaced by VCSEL (vertical surface-emitting laser) and PCS (polymer cladded silica) fiber [7, 8]. Additionally, due to the smaller emitting surface and the smaller output divergence (figure 2) of the VCSEL compared to an LED, the data rates can be extended into the GBit/s-region [9].

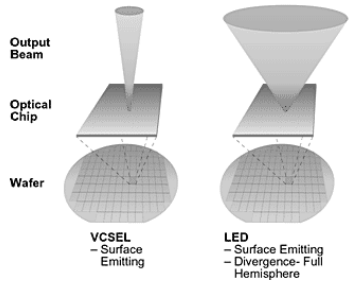

Fig. 2 VCSEL output beam

Conclusions

In this paper we presented the state of the art and next-decade technologies for optical data buses in automotive applications. MOST is the optical data bus technology currently used in cars. MOST150 is the current standard with a bit rate of 150 Mbit/s and it is an adequate solution for optical multimedia data transmission in automobiles. However, to provide the next step to autonomous driving new bus systems with higher data rates are desirable.

Additional challenges arise in new generation aircrafts. Due to safety problems in data transmission, an optical solution for data transmission is highly needed. In particular low attenuation PCS-fibers combined with less temperature critical VCSELs could be a promising solution [9]. This combination paves the way for the new generation aircrafts covered by carbon fiber fuselages, having a much better lightning protection and EMC-compatibility.

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