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Enhanced performance analysis of inter-aircraft optical-wireless communication (IaOWC) system

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ABSTRACT

In this paper, we have presented analysis of inter-aircraft optical-wireless communication system with different parameters and reported the improved performance by usage of a square root module (SQRT). A distance of 80 km was achieved with the same performance representing an enhancement of 63% when compared to the traditional detection.

1. Introduction

The present aircraft communications system uses microwave technology for space-to-ground. In the future system, the aircraft to ground links would remain in the microwave regime but aircraft to aircraft communication will be governed by optical-wireless links [1]. Laser communication is now able to send information at data rates up to several Gbps and at a distance of thousands of kilometers apart. This has opened up the idea to adapt optical-wireless communication technology into aircraft technology; hence inter-aircraft optical-wireless communication is developed. Laser communications require clear optical line-of-sight between transmitter and receiver [2]. Given the distinct probability of line-of-sight blockage due to clouds or other obstructions, multiple redundant data transfer pathways supported by a network of airborne, ground and satellite assets is desired for a reliable data service. Air-to-ground, air-to-air, and air-to-satellite optical links will be required to support such a network. Here [3] deals with one of the building blocks of such a high bandwidth optical communications network namely, the laser communications terminal for the airborne. The plan of research and development of high speed optical communication technology for observed data transmission from satellite/airplanes is explained [4]. The field of low-power communication systems from the avionics engineering perspective has been discussed [5]. A brief overview of the current military communication infrastructure and highlighting terrestrial laser communication technology is also presented [6]. Further improvement in inter-satellite transmission links using square root module is reported [7].

In this work, we presented simulation investigation of inter-aircraft optical-wireless communication system. The simulation setup is reported in Section 2 followed by the simulation results discussion in Section 3. The conclusion is drawn in Section 4.

2. System description

The IaOWC system consists of three main communication parts which are transmitter, propagation channel and receiver as shown in Fig. 1. Where the transmitter is in the first aircraft and the receiver is in the second aircraft. The free space between two connecting aircraft is considered as OWC channel, which is the propagating medium for the transmitted light. The IaOWC transmitter receives data from the aircraft's air traffic control (ATC) system of the aircraft works along with its counterparts located in the aircraft control earth station. The electrical signal from ATC system and optical signal from the laser are modulated by an optical modulator before it is transmitted out to space. The output light-pulses from the optical modulator are transmitted in the transmission medium (OWC) to the receiving aircraft. The receiving end of the inter aircraft optical wireless communication signal consists of a photodiode and a low pass filter.

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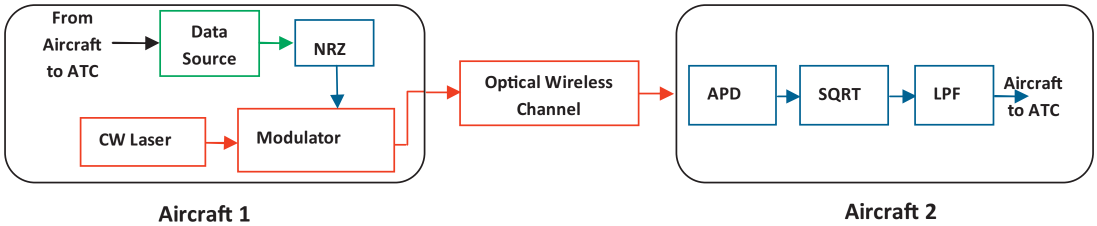

Fig. 1. Design of inter-aircraft optical-wireless communications systems.

3. Results and discussion

The analysis in this paper is going to be performed by observing two cases: Case (i) described the analysis of inter-aircraft optical-wireless communication systems and Case (ii) gave us improved analysis of inter-aircraft optical-wireless communication systems.

3.1. Case (i): Performance analysis of inter-aircraft optical-wireless communication system

The parameters used in this case are transmission length 100 km, wavelength 1550 nm, transmitter power 60 mW, transmitter aperture diameter 10 cm, beam divergence 0.25 mrad, transmitter pointing error 1 μrad, attenuation 0.4 dB/km, additional losses 1 dB, index refraction structure $5e^{-015}$ $m^{-2/3}$.

Fig. 2(a)–(d) depicts the measurement of SNR at aircraft 2 at different space-difference between the two aircrafts with different attenuation, transmitter pointing error, transmission power and with and without Intensity Scintillation. In the attenuation case as shown in Fig. 2(a), it is observed that SNR reduces from 92 dB to 20 dB in the range of space-difference 10–80 km between the two aircrafts at an attenuation of 0.4 dB/km. Alternatively; SNR varies in the range of 88–20 dB in the range 10–50 km at an attenuation of 0.8 dB/km. It means that as we move to higher attenuation, range of two aircraft reduces.

In other case the transmitter pointing error is used as shown in Fig. 2(b). It has been observed that SNR reduces from 92 dB to 20 dB in the range of space-difference 10–80 km between the two aircrafts at a transmitter pointing error 1 μrad. Alternatively; SNR varies in the range of 76–20 dB in the range 10–50 km at transmitter pointing error 5 μrad. It means that as we move to higher transmitter pointing error, range of two aircraft stands reduced.

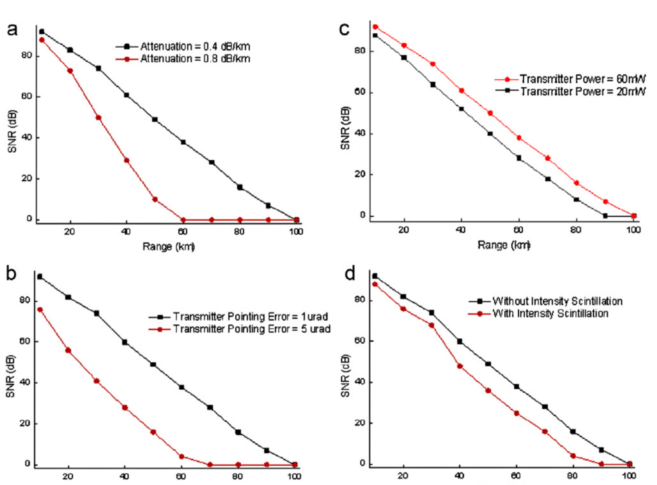

Fig. 2. (a) Evaluation of SNR (dB) versus range with different attenuation. (b) Evaluation of SNR (dB) versus range with different transmitter pointing error. (c) Evaluation of SNR (dB) versus range with different transmitter power. (d) Evaluation of SNR (dB) versus range with an without Intensity Scintillation.

In another case transmission power is used as shown in Fig. 2(c). It has been observed that SNR reduces from 92 dB to 20 dB in the range of space-difference 10–80 km between the two aircrafts at a transmission power of 60 mW. Alternatively; SNR varies in the range of 88–20 dB in the range 10–70 km at transmission power of 20 mW. It means that as we move to higher transmission power, range of two aircraft increases. Further in case where scintillation is used as shown in Fig. 2(d), it has been observed that SNR reduces from 92 dB to 20 dB in the range of space-difference 10–80 km between the two aircrafts without Intensity Scintillation. Alternatively; SNR varies in the range of 88–20 dB in the range 10–70 km with Intensity Scintillation. It means that with Intensity Scintillation, range of two aircraft reduces.

The eye diagram of inter-aircraft optical-wireless communication system in the absence of SR module the achievable Q Factor is 4.78292 and BER $8.6e^{-007}$ at bit rate 1.25 Gbps for 80 km transmission range is shown in Fig. 3.

3.2. Case (ii): Improved analysis of inter-aircraft optical-wireless communication system

In this next analysis we will consider the SQRT module following the APD to compensate for its square law response [8] resulting in improved performance of the linear equalizer [9].

In Fig. 4, the SNR of the inter-aircraft optical-wireless communication system is also plotted against transmission range. The SNR is computed approximately as 88–48 dB in the range of 20–100 km with SR module. Further, the SNR decreasing continuously from 83 dB to 20 dB in the range of 20–80 km without using SR module. The percentage improvement in SNR is achieved 17% at 30 km and at 100 km it was 48%. It means that an efficient improvement in SNR ratio is achieved with SR module, which further helps in increasing the transmission length of inter-aircraft optical-wireless communication system.

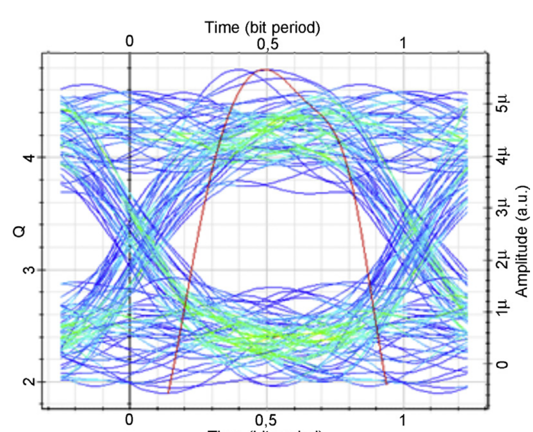

Fig. 3. Eye diagram of IaOWC system at 80 km.