TRANSMISSION OF DIFFERENTIAL GPS SIGNALS OVER FIBER FOR AIRCRAFT ATTITUDE DETERMINATION

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Introduction

The Daphne project has been addressing the adoption of an optical fiber infrastructure for future aircrafts. Beyond the obvious motivation of reduced weight and electromagnetic interference, the availability of a huge amount of bandwidth makes the optical fiber well suited to transport Radio Frequency (RF) signals transparently, while avoiding cumbersome dedicated RF cabling. An integrated optical network may be exploited to transport radio signals from diverse aircraft antennas ranging from satellite/earth communications, collision avoidance, GPS signals for positioning and attitude determination, weather/detection RADAR to corrosion sensors. Such network can also support passenger infotainment and mobile communication services, such as cellular GSM/UMTS/LTE, broadband Wi-Fi (IEEE 802.11) and Ultra-Wide-Band Wimedia/WiGig. Specifically, the optical fiber infrastructure may provide connectivity from external antennas (through remote nodes) to RF transceivers installed in the cockpit and avionics bay (head-end nodes); in the context of the present paper, the transmission of differential GPS signals used to provide aircraft attitude information will be discussed. The use of GPS for aircraft attitude determination has been under discussion for more than 20 years [1]. It consists in performing carrier-phase differential processing of measurements from GPS antennas affixed to the frame of the aircraft, which yields centimeter- or millimeter-level accuracies, provided that integer phase ambiguities are resolved [2]. The attitude algorithm consists in a highly accurate real time kinematic (RTK) technique, given the short baseline distance between antennas, in which the main antenna acts as a Base station and two auxiliary antennas as Rovers. In the present experiment, we used a setup consisting of two-antennas (Base and Rover), which is enough to evaluate the RTK performance. A particular aspect of concern stems from the fact that the transmission of optical signals through a complex optical fiber network is subject to the occurrence of reflections in the multitude of connectors spanning the path between a remote node and a head-end node. Therefore, we will focus our analysis on the performance impact of optical reflections affecting the power level stability of the optical source.

Experimental setup

The experimental setup is shown in Fig. 1, and specific details in Fig. 2 and 3. Two Septentrio PolaNt dual-frequency GPS antennas were used, which are high precision geodesic grade antennas, incorporating high-gain low-noise amplification. They were placed with a clear sky view, in the rooftop of INESC building. Two RF cables were routed to a remote module box, which contains two electro-optic conversion devices, consisting of 1550 nm directly modulated vertical cavity surface emitting lasers (VCSELs), biased at 6mA, pigtailed into single mode fiber (SMF). Two 150-meter cables of SMF were used to transport the optical signals to the laboratory, where two photo-receivers converted the optical signals back to RF signals, which were then fed into two Septentrio PolaRX GPS receivers. The used dual frequency GPS system uses both L1 (1575.42 MHz) and L2 (1227.6 MHz) frequencies, allowing the receivers to precisely compute ionospheric delay errors. In order to assess the impact of optical reflections, the experimental setup shown in Fig. 4 was included in the Base path (between antenna 2

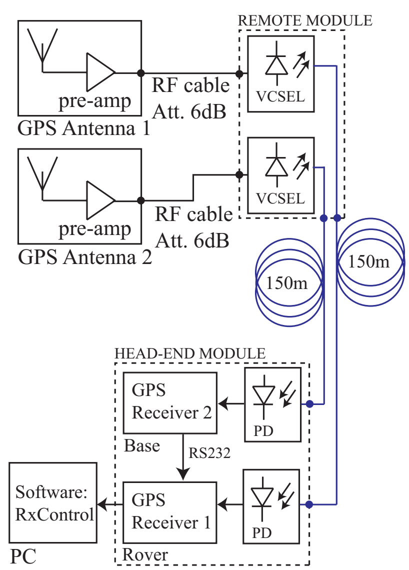

Figure 1. Experimental GPS setup

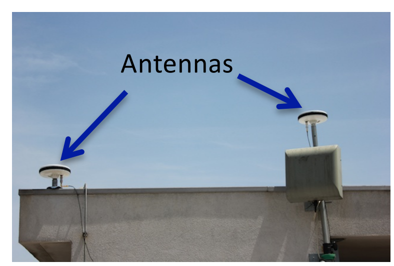

Figure 2. Antennas on rooftop

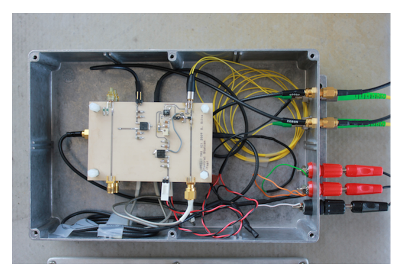

Figure 3. Remote module box

and receiver 2) of the general setup of Fig. 1, where a 3 dB coupler, variable optical attenuator (VOA) and optical multi-meter were used, with the purpose of controlling the amount of induced reflection. The choice of the Base path was deliberate in order to decrease the precision of differential corrections being fed into the Rover receiver.

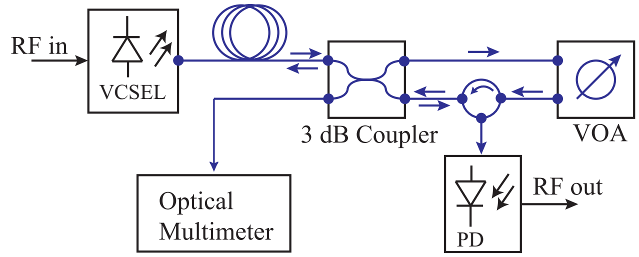

Figure 4. Experimental setup for reflection emulation

Experimental results

The occurrence of optical feedback due to back-reflection is known to affect the laser Relative Intensity Noise (RIN) [3]. Fig. 5 shows the measured RIN as a function of optical return loss (ORL), for three different frequencies near the GPS L1 central frequency. This measurement was obtained using a spectrum analyzer at the “RF out” port (instead of the GPS receiver), and with no signal applied at the “RF in” port. The ORL is defined as the ratio of laser transmitted power to the returning (reflected) power. For reference, the corresponding calculated Noise Figure is shown on the right axis, whose value depends on RIN, received optical power and also on the optical source modulation efficiency [4]. A significant increase in RIN is observed, especially for reflections above -16 dB, which is strongly dependent on frequency, due to perturbations caused by optical feedback in the laser cavity. This dependency is shown clearly in Fig. 6. Finally, Fig. 7 shows the mean time required to obtain a fix of phase ambiguities of the GPS signal, counted from the restart of the algorithm (implemented in RxControl); Additionally, the maximum and minimum time required is also shown in error-bars. We can observe that a level of ORL of -25dB or less is required for a time to fix below 50 seconds, which translates into a required RIN value at the receiver better than -140dB/Hz and a link noise figure below 25dB.

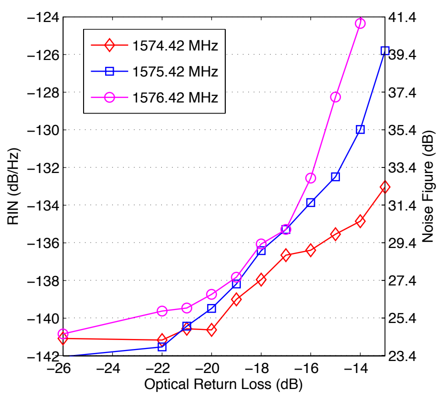

Figure 5. RIN and noise figure versus optical return loss

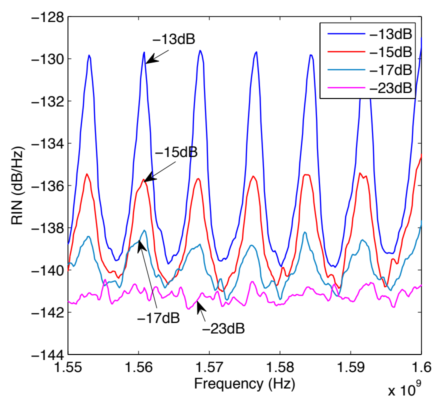

Figure 6. Measured RIN level versus frequency for different values of ORL

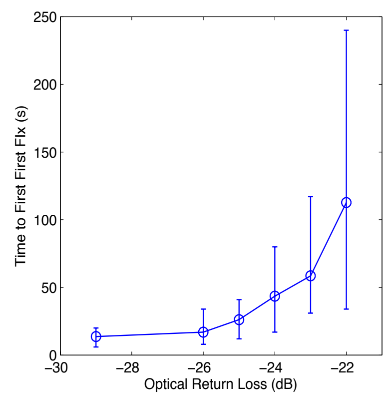

Figure 7. Time to first fix of phase ambiguities.

Conclusion

We have successfully demonstrated the transmission of differential GPS signals over fiber. We concluded that a maximum ORL of -25 dB is required in order to achieve a fix of phase ambiguities in less than 50 s. We also verified that optical reflections could also affect the GPS receiver due to multipath. This will be the subject of future work.

Acknowledgments

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