

ASSESSMENT OF NOISE IMPACT ON UWB SIGNALS IN R-EAM BASED OPTICAL LINKS

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Introduction

The combination of information and entertainment services in future avionics systems will require high-bandwidth RF networks on board. The wireless channel between a mobile station (MS) and a Base Station (BS) can be transparently extended to the Central Station (CS) by the Radio-over-Fiber (RoF) concept, providing the potential for delivering different services in these networks. It has been experimentally demonstrated that RoF networks are well suited to simultaneously transport several wireless standards like IEEE 802.11 wireless local area network, global system for mobile communications (GSM), WiMAX and ultra-wide band (UWB) [1]. Here we assess the uplink (worst case) signal-to-noise ratio (SNR) performance of a reflective electro-absorption modulator acting as a BS, as a function of the reverse bias voltage and incident optical power, for UWB signals. We also analyze both zero biased and optimum bias as modulator cases.

Reflective EAM evaluation in RoF

The schematic of the uplink path is shown in the Figure 1. The wireless signal transmitted by the UWB MS, emits an average power denoted by $\langle P_{tx} \rangle$, and a maximum Effective Isotropic Radiated Power (EIRP) of -41.3 dBm/MHz, according to the ECMA 368 standard [2]. After the wireless channel attenuation of L , a weak RF signal arrives to the BS antenna, being converted to the optical domain by the R-EAM through a reflected fraction ($P_{O,D}$) of the incident optical power, P_I , generated by a continuous wave (CW) laser. The conversion efficiency of this process is denoted by the modulator slope efficiency, s_{ea} . The modulated optical signal travels through a short length of optical fiber (hundreds of meters) being detected by a photo-detector (PD) in the CS, having a responsivity of r_d . The UWB receiver sensitivity at 480 Mbit/s specified in the standard [2], corresponds to a minimum SNR of 7.5 dB at the optical front end. Figure 2 shows the measured reflected optical power as a function of the R-EAM (*60G-R-EAM-1550*) reverse bias for three different incident optical powers. The s_{ea} was previously measured for the same range of reverse bias and incident optical powers [3].

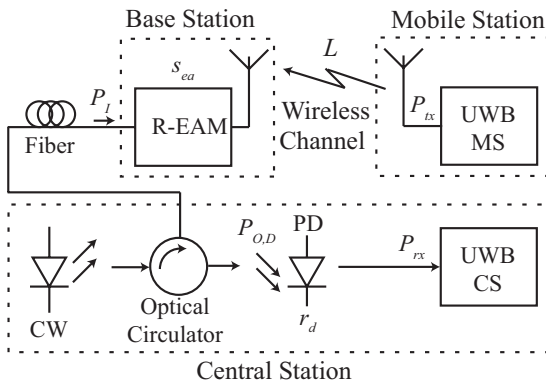


Figure 1. R-EAM RoF uplink scheme

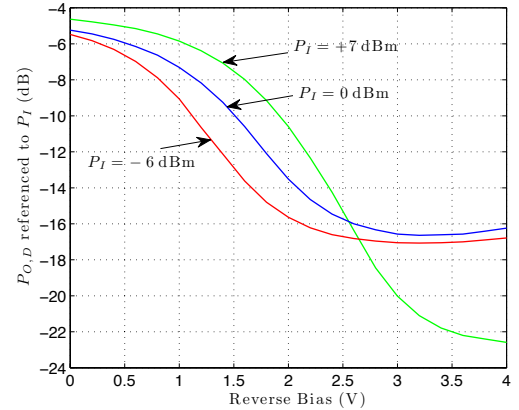


Figure 2. R-EAM reflected power

The signal to noise ratio (SNR) of the RF signal arriving at the central station can be written as:

$$\text{SNR}_{rx} = \frac{\langle I_{rx}^2 \rangle}{\sigma_n^2} = \frac{\langle I_{tx}^2 \rangle g_i}{\langle i_{rin}^2 \rangle + \langle i_{sn}^2 \rangle + \langle i_t^2 \rangle} = \frac{(\langle P_{tx} \rangle / \Delta f) s_{ea}^2 r_d^2 L / R_{tx}}{r_d^2 \langle P_{O,D} \rangle^2 10^{\frac{RIN}{10}} + 2qr_d \langle P_{O,D} \rangle + 4kT / R_L}$$

where $\langle I_{rx}^2 \rangle$ and σ_n^2 denote the mean square of the electrical current and the variance of the noise terms at the receiver, respectively, and $\langle P_{tx} \rangle = \langle I_{rx}^2 \rangle R_{tx}$. The noise terms are referred to the photodiode output, and stem from 3 main components: the relative intensity noise (RIN) from the laser source (proportional to the square of $\langle P_{O,D} \rangle$), the shot noise (proportional to $\langle P_{O,D} \rangle$), and the last term is the thermal noise from the photodiode load (R_L), where k is Boltzmann's constant and $T=290$ K. The thermal noise from the electrical transmitter can be neglected, due to the low total gain of the link (g). The optical power detected by the photodiode ($P_{O,D}$) is expected to have a significant impact on the noise contribution at the receiver. In the presented results, the wireless channel attenuation (L) was not considered, the fiber is considered ideal, $\langle P_{tx} \rangle / \Delta f = -45.3$ dBm/MHz (allocating ~ 4 dBi for the MS antenna gain), $R_L=1000 \Omega$ and $R_{tx}=50 \Omega$. The results in Figure 3 (a) show the SNR as a function of the reverse bias. As expected from the $P_{O,D}$ shown in Figure 2, the RIN and shot noise increase with P_I and the corresponding impact on the SNR can be seen for lower values of reverse bias. A maximum SNR is obtained at 1.8 V reverse bias for an optical input power of $P_I=+7$ dBm. The further increase in the bias voltage decreases the SNR due to the decreasing modulation efficiency, s_{ea} . In Figures 3 (b) and (c) the SNR is obtained as a function of P_I , for both zero and optimum bias cases, respectively. At zero bias, a maximum margin of 10 dB (at $P_I = 0$ dBm) compared to the UWB SNR limit is obtained with a laser RIN of -150 dB/Hz, whereas for a RIN of -160 dB/Hz the performance becomes limited by shot noise, allowing for a SNR margin of ~ 14 dB. An equivalent SNR limit that considers a wireless link length of 0.5 m is also shown in the results. However, the results indicate that such limit is not achievable at zero bias, because of both RIN and shot noise limitations. At optimum bias, 28.5 dB of margin is obtained at the maximum P_I , for a RIN of -160 dB/Hz and $r_d=1$ A/W, allowing for a wireless link distance of approximately 0.5 meter. Furthermore, by reducing the UWB throughput, a maximum distance of ~ 1.2 meter could be achieved at 53.3 Mbit/s.

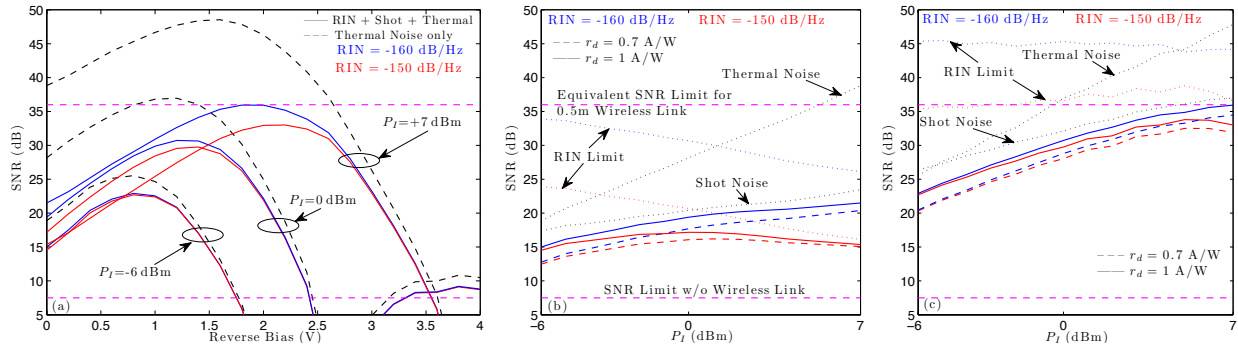


Figure 3. SNR as a function of (a) reverse bias; (b) P_I for zero bias; (c) P_I for optimum bias.

Conclusion

The measured characteristics of a R-EAM, acting as a base station, were used to assess the performance of a radio-over-fiber uplink for possible provision of wireless services within aircrafts. The specific case of deployment of UWB signals was analyzed. We conclude that laser RIN is a performance degradation factor that imposes a limit on the achievable SNR, especially for a zero biased modulator. A laser RIN of -160 dB/Hz would be required in order to avoid the RIN limitation. Additionally, in this case the performance becomes limited by shot noise. Although the zero bias case seems limitative, the R-EAM can be optimum biased using a small battery, which can last for several months, allowing the base-station to operate as a passive device.

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