Optical front-ends for USRP radios

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We present the design of infrared optical front-ends for USRP radios. The front-ends are validated with a demonstration of an optical audio car entertainment system created with GNU Radio Companion.

Keywords: Infrared optical communications, optical front-ends

1 Introduction

Optical wireless communications have several advantages compared to RF transmissions. Firstly, the infrared spectral region offers a virtually unlimited bandwidth that is unregulated worldwide. This is a big advantage compared to the overcrowded RF spectrum. In addition, infrared communications are generally confined to the room where they are operated, which is a definitive advantage in the case of secure communications. Moreover, in the context of health monitoring, they represent a mean to avoid interferences with RF operated devices and are known to have less influence on the human body than RF technologies [1]. Infrared (IR) optical communications can be performed using either analog or digital modulations schemes and include error correcting schemes. As for classical RF communications, modulation and coding is done in baseband and the evaluation of different schemes for different scenarios and applications deserves the flexibility of software defined radio. This is the reason why we decided to design infrared optical front-ends for Ettus USRP radios. Indeed, this type of equipment offers an open interface for different daughter boards with the possibility to design a custom one.The rest of this paper is organized as follows. Section II discusses the design of 10MHz bandwidth infrared optical front-ends for USRP radios. In section III, to validate the design, we present an infrared audio transmission system for car entertainment using our front-ends and a GNU Radio application. Finally, section IV concludes the paper.

2 Design of 10MHz IR front-ends for USRP radios

In order to implement several IR transmission schemes, a target transmission bandwidth of 10 MHz has been chosen as a first approach. When designing an IR link several constraints have to be taken into account. The first one is that the link may work in baseband. Indeed, it is the IR LED (transmitter) and the photodiode (receiver) which perform the up/down conversions to/from the IR wavelength. For that purpose, Ettus LFTX and LFRX daughterboards [2] have been selected as they allow communications between 0 and 30MHz.

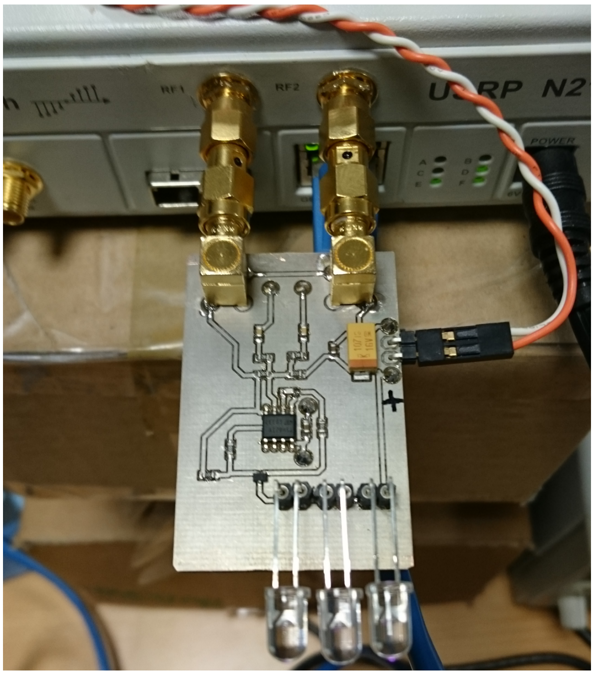

Figure 1: IR TX Front-End fitted on USRP N210

The other constraints can be divided in two parts. The first one concerns the TX IR front-end. The LFTX board outputs a voltage between 0 and 3.3V. This has to be converted to a 0-100mA current into the IR LEDs. The function is implemented thanks to a high speed, high current operational amplifier (opamp). Without the use of a DC-DC converter, the maximum voltage supply from the USRP is 6V which allows to use up to 3 IR LEDs (see Fig. 1) in series on the TX front-end (each LED has a maximum forward voltage of 1.7V). Figure 1 shows a picture of the realized TX front-end when connected to an USRP

N210 + LFTX. The second constraint concerns the RX front-end which uses a PIN photodiode. This device converts IR light photons into a current. However, this current is very small, in the order of 10 μA and it has to be converted to a reasonable voltage value (typically 1V). This can be accomplished by special types of opamps having very low input bias currents (a few pA) and very high gain-product bandwidths (over 1GHz) configured as transimpedance amplifiers. Special care has to be taken when routing printed circuit boards for these devices [3].

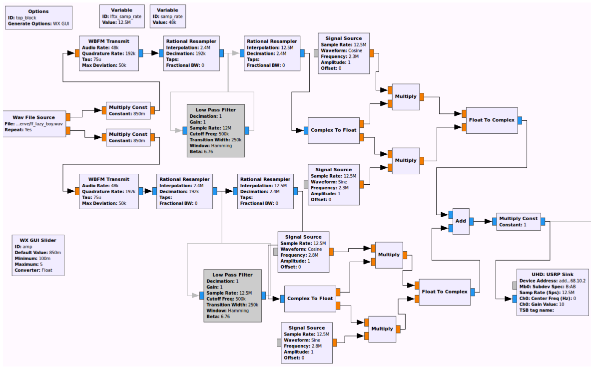

Figure 2: GNURadio screenshot of the car audio modulation system.

3 Demonstration: IR car audio transmission system

To validate our design we have used GNU Radio to create an IR audio link such as those found in car entertainment systems. The passengers use IR wireless headsets to listen to the music. This system uses analog FM to encode audio information. It modulates two carriers at 2.3 and 2.8MHz for respectively the left and right audio channels. As shown on Figure 2, it is quite straightforward to design such a system with the available blocks in GNU Radio Companion. The only tricky part was the simultaneous generation of the two carriers. This lead to constraints on the sampling rate since they could not be directly generated by the board digital up-converter. The system has been validated with commercial headsets and will be presented during the French GNU Radio days in Lyon.

4 Conclusion

USRP radios offer a wide range of RF daughterboards. However, the FPGA + ADC/DAC mainboard is not limited to the RF spectrum. The daughterboard interface is quite generic and allows to design front-ends for optical systems like the one presented in this paper. This is really a big advantage in terms of flexibility. Indeed, one can use the large number of available GNU Radio libraries to design efficient optical IR wireless communication schemes which can include different types of analog and digital modulations and error correcting codes as well as classical synchronization blocks. Moreover, the system presented in this paper costs less than 50€ and has been tested on N210 and X310 radios. The hardware design files will be made available to the community.

References

[1] A. Julien-Vergonjanne, S. Sahuguède, L. Chevalier, *(2016)Optical Wireless Body Area Networks for Healthcare Applications*, In: Uysal M., Capsoni C., Ghassemlooy Z., Boucouvalas A., Udvary E. (eds) Optical Wireless Communications. Signals and Communication Technology. Springer, Cham

[2] `https://www.ettus.com/product/category/Daughterboards`

[3] J. Ardizzoni, *A Practical Guide to High-Speed Printed-Circuit-Board Layout*, Analog Dialogue, Vol. 39, Sep. 2005.