A 60GHz digital link with GNU Radio and USRP radios

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In this communication we present a 60 GHz radio link for Ettus USRP radios. The link is built around dedicated integrated circuits from Analog Devices. The transmission chain is validated with a 100Mbps OFDM system designed with GNU Radio.

Keywords: Millimeter wave communications, RF front-ends

1 Introduction

Most Ettus USRP SDR equipments can be fitted with RF daughter boards featuring different radio ranges and bandwidths. The maximum RF frequency available for Ettus boards is currently 6 GHz. Due to the overcrowded RF spectrum and to enable very high data rates (i.e. several Gbps) millimeter wave bands are being envisaged for 5G telephony. The forecasted bands are 26, 40 and 60GHz. Millimeter wave bands have specific characteristics which have to be evaluated in real transmission conditions. It is therefore necessary to have measurement equipments able to work in these bands. The goal of this paper is twofold. Firstly, to present the constraints associated with millimeter bands and to look for existing solutions adaptable to USRP radios. Secondly, to design an affordable 60GHz transceiver solution based on available off-the-shelf integrated circuits (IC). The rest of this paper is organized as follows. Section 2 presents the constraints associated with the design of printed circuit boards (PCB) for millimeter wave radio communications. In section 3, a USRP based 60 GHz radio link is detailed and validated with the help of an OFDM transmission chain built with GNU Radio. Finally, section 4 concludes the paper by giving evolution possibilities of the current demonstrator.

2 Electronics design constraints for millimeter wave bands

In recent years, the design and the realization of transceiver solutions up to about 6 GHz have been simplified by the availability of relatively low cost dedicated chips and measurement equipment. Moreover, the manufacturing of PCB even for more than two signal layers is relatively easy and low cost. Nowadays, it is no longer necessary to be a member of a specialized firm or lab to take advantage of RF PCB manufacturing. Several Chinese firms provide this service for a relatively low cost. For example, a lot of 10 pieces of 50 mm x 50 mm FR4 4 layer boards would cost you about 50$ [1].

Up to a frequency of 10 GHz the PCB design process is relatively easy. But what about millimeter wave bands applications? As you may know, pushed by the 5G mobile telephony potential market, things are changing rapidly so that dedicated ICs and suitable measurement equipment will be easily available in the next few years. As far as measurement equipment is concerned, the cost is definitely going to be a problem for amateurs. Again, this problem can be overcome by the Software Defined Radio (SDR) technology. The only problem that remains is the availability of millimeter wave front-ends for off-the-shelf SDR hardware. It is possible to build one using frequency mixers and gain blocks available from manufacturers like Mini-Circuits but it is going to be bulky, costly and currently the maximum frequency achievable is 40 GHz [2]. After some research, I found an interesting IEEE paper about an open source SDR frontend for the 60 Ghz band by Zetterberg et al [3]. Unfortunately, the Hittite ICs they used have been phased out. In the meantime, Hittite was acquired by Analog Devices (ADI). Frequently in the past, I used to have several good ideas with no facilities to implement them, but was finally lucky to find their realization by ADI. Again, I dreamt about a 60 GHz transceiver solution and ADI did it!

3 A HMC6300/6301 60 GHz link with USRP radios

The HMC6300/6301 Systems on Chips (SoC) from ADI are an evolution of the HMC6000/6001 from Hittite. Their main characteristics are summarized in Table 1. Figure 1 presents a block diagram of the HMC6300 SoC. ADI provides an evaluation kit for the HMC6300/6301 for about 3500$. This kit allows the user to set up a half-duplex link but does not include the antennas. In order to obtain a link budget of more than 100m we decided to fit the boards with 23dBi horn antennas from SAGE [4]. The total price of this setup is around 5700$.

HMC6300/6301
Frequency range: 57 GHz to 63 GHz
Frequency steps: 250MHz, 500MHz or 540MHz
RF signal bandwidth: 1.8GHz
Universal analog IQ baseband interface
3 wire SPI interface for configuration
HMC6300 P1dB: 15dBm
HMC6301 NF: 8dB

Table 1: HMC6300/6301 specifications.

The last operation to perform is to connect the kit to the USRP radios. This is easily accomplished thanks to LFTX/LFRX or BasicTX/BasicRX daughter boards from Ettus. These boards can transmit/receive baseband data to/from the evaluation board as long as the user provides a differential/non differential adapter (balun transformer or Fully Differential Amplifier) to the IQ interface of the HMC6300/6301. The testbench has been successfully tested over a 100 m link with a 100 MSymb/s OFDM chain designed with GNU Radio. The transmit power was set to 10dBm. Figure 2 shows a picture of the transmitter section.

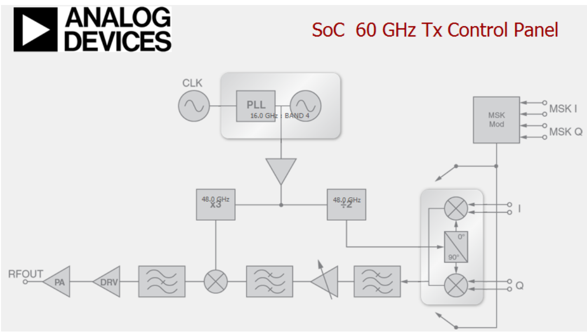

Figure 1: Block diagram of the HMC6300 SoC.

4 Conclusion

The daughterboard interface of N210 and X310 radios is quite generic and allows to easily connect user designed boards like the 60 GHz evaluation kit presented in this paper. We are currently working on a cheaper and a better integration of ADI 60 GHz SoCs with USRP radios. This requires the design of a PCB integrating an HMC6300/6301 eval board and a 71.42857 MHz ECL oscillator circuit needed by the HMC6300/6301 synthesizers. The setup of the SoC transmission parameters (e.g. output power, carrier frequency) is made via an SPI interface which can be implemented with the available GPIO pins on the LFTX/RX or BasicTX/RX daughter boards. The working testbench and its evolutions will be presented at the European GNU Radio Days in Besançon and the design files will be shared with the community.

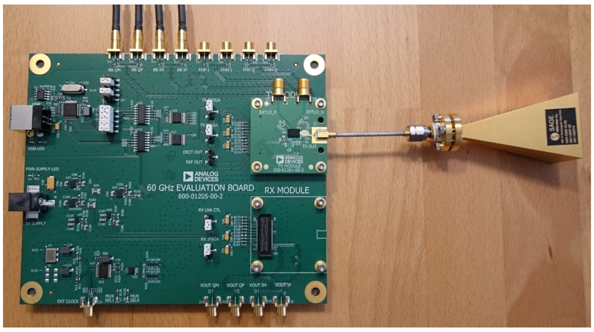

Figure 2: HMC6300 TX front-end fitted with SAGE horn antenna.

References

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