RF Front End for an SDR-based Community Network in the 700 MHz Band

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***Abstract*— This paper presents the design of an RF front end for a base transceiver station implemented with a commercial general purpose software defined radio board. This front end helps to decrease the total cost of deploying community networks and the contribution of this paper is to disclose its project and simulation results, as well as discuss the aspects that influenced its design decisions.**

***Keywords*— RF front end, LTE, Rapid Prototyping**

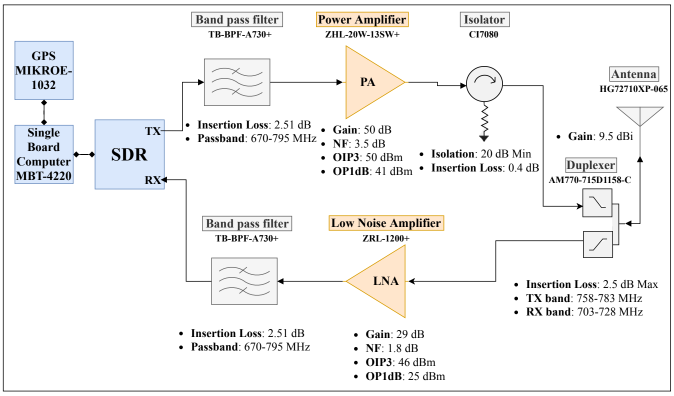

Fig. 1: Adopted radio system structure.

I. Introduction

Despite the development of the telecommunications field, many communities around the world still do not have access to internet technologies easily found in urban centers. This is particularly true in Amazon's sparsely populated areas due to lack of interest from commercial mobile operators [1].

Some works have been using low cost and easy-to-deploy software defined radio (SDR)-based community networks [1], [2]. One of the motivations for the SDR-based community network is that general purpose SDR boards available in the market have a relatively low cost, open-source community and flexibility thanks to software implementation in comparison to proprietary radio systems [3]. A drawback of the SDR boards is its low power capability. Thus, if we want to cover large areas we need to use an appropriate RF front end.

The community networks previously cited typically focus on voice services and use legacy radio access technologies (RATs), such as GSM. Expanding these networks to use more advanced RATs like LTE would require to adapt the software part of the SDR, as well as the RF front end due to the available spectrum license for the new RAT.

In this context, this paper details the design of an RF front end for an SDR-based base station in the 700 MHz band with 5 MHz of channel bandwidth. The goals is to provide coverage with LTE technology with frequency division duplexing (FDD). The remaining of this paper is organized as follows: Section II shows details of the proposed architecture for the SDR system, including the RF front end, Section III shows the simulation tool used to design and verify the performance of the system in terms of RF parameters.

II. Adopted Architecture

The goal in the system's development was to establish a rapid prototyping design. For that, we deployed a modular design based on commercial components, which allowed designing the front end without using a printed circuit board design. The system should meet the power and frequency requirements shown in Table I and Anatel's specifications for spurious emissions presented in Table II [4].

Fig. 1 shows the hardware structure of the adopted RF system, with emphasis on the building blocks of the RF front end. This design was developed to solve limitations of SDR boards that prevent them from being complete cellular base stations alone [3]. The software part of the SDR system is based on OpenAirInterface (OAI) software [5], which is compatible with several SDR boards, such as Ettus USRP B210 and LimeSDR. Both devices have similar specifications in the 700 MHz frequency, although with a slight difference in transmit power, where the B210 can output at least +10 dBm [6] while the LimeSDR board has an output power between 0 to 10 dBm [7].

Different types of RAT require high clock accuracy, which can be achieved with a GPS-synchronized clock reference, so the GPS MIKROE-1032 was used due to its small size and ease of assembly [8]. Since the project focus on FDD LTE, the base station will transmit and receive signals at the same time, which requires an RF duplexer to be placed among the receive (RX) chain, transmit (TX) chain and antenna [3] as presented on Fig. 1.

On the TX chain the main parameters evaluated were the output 1 dB compression point (OP1dB), output third order intercept points (OIP3), gain, output power, and consumed power. The OP1dB specifies the output signal level that causes the gain to drop by 1 dB [9] from ideal curve and it is useful to identify how much power the amplifier can deliver without saturation. Thus, the higher the OP1dB the higher output the devices can provide. The OIP3 is the output power in which

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the power of the third order intermodulation products (IMD3) becomes equal to the power of the fundamental, so high values of OIP3 are preferable because they indicate less out-of-band emission [9].

On the RX chain, the main parameters evaluated were noise figure (NF) and power gain. The former indicates the degradation of signal to noise ratio (SNR) between the input and the output of the system and represents how noise influences the signal chain [10].

Parameter	Specification
Maximum Output power	40 dBm (10W)
Expected Power	30 - 37 dBm (1 - 5 W)
Uplink Frequency	703 - 708 MHz
Downlink Frequency	758 - 763 MHz

TABLE I: System's requirements.

Frequency offset (edges of the block)	Maximum power level	Resolution range for measurement
0,05 – 5,05 MHz	- 7 dBm -1,4x(f_offset -0,05) dB	100 kHz
5,05 – 10,05 MHz	- 14 dBm	100 kHz
10,05 – 15,05 MHz	- 13 dBm	100 kHz

TABLE II: Limits for undesirable emissions by the base station.

On the transmit chain, a band pass filter was used to attenuate the intermodulation products produced by the SDR's transmitter amplifiers. The TB-BPF-A730+ was selected due to its modularity and low insertion loss. A power amplifier (PA) was needed for the signal to reach longer distances, so we opted for the ZHL-20W-13SW+ due to its high gain, good OP1dB and OIP3, and its availability in modules in plug-and-play style. There is also the CI7080 RF isolator to protect the PA from signal reflection as well as limiting the emission band.

On the receiver chain, the ZRL-1200+ low noise amplifier (LNA) was picked due to its modular design and low NF. there is also another band pass filter (TB-BPF-A730+) to filter any out-of-band spurious signals.

The RF duplexer AM770-715D1158-C was used due to its good trade-off between insertion loss, maximum input power and bandwidth. When selecting the antenna the objective was to find an outdoor one with a gain close to 10 dBi, low height to minimize its exposition to wind, and a good trade-off between these parameters and price. Thus, we opted for the HG72710XP-065 panel antenna. It has a 9.5 dBi gain, 65°cross polarization, weatherproof design, and 698-2700 MHz range, which satisfies the system's requirements.

III. Signal Chain Calculation

To assess the RF parameters of the front end we used Analog Devices' ADIsimRF signal chain calculator [11] software to obtain an estimation of signal levels, distortion, noise, and power consumption for the TX and RX chains and compare them with the requirements shown in Section II. The software considers the cascaded components' individual parameters exhibited in Section II and their insertion losses, providing a reliable evaluation of the overall RF system's performance.

Parameter	TX	RX
Output Power (dBm)	34.09	-64
OP1dB (dBm)	47.6	24
IP1dB (dBm)	-5.5	-11
Power Gain (dB)	54.09	36
Noise Figure (dB)	6.01	0.42
SNR (dB)	81	6.6
OIP3 (dBm)	56.6	46
IIP3 (dBm)	2.5	10
IMD3 (dBc)	-51	-226
Power Consumption (W)	67.2	6.48
Input RX Sensitivity (dBm)	-	-106.6

TABLE III: Simulation results.

Table III shows the results acquired with the software by employing an input power of -20 dBm on TX, -100 dBm on RX and a bandwidth of 5 MHz. On the TX chain the output power of 34.09 dBm and IMD3 of -51 dBc (-16.91 dBm) meet the ANATEL regulations exposed in Table II. On the RX chain the power gain of 36 dB, low NF of 0.42 dB and SNR of 6.6 dB are the most important parameters to consider for having an appraisal of the signal reception. It is important to note that when implementing this system there will be more signal losses ascribed to SMA cable connections.

IV. Conclusions

This paper presented the design of an RF front end for an SDR-based LTE community network. The work aims to show an alternative solution that combines the flexibility of SDR boards with the rapid prototyping obtained with the use of modular components. We used the ADIsimRF software to predict the system's performance as well as in the evaluation of different components and their influence in the overall performance. The results found in simulations will be compared with measurements after the implementation of the system.

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