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Design and Implementation of a Communications Circuit based on LoRa chip

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Abstract

Forest fires are one of the main threats nowadays due to the consequences they have for the society and economy. During a wildfire, to obtain information about the status and evolution of the flames, communications systems become a key aspect in extinguishing the flames.

These communications systems must provide real-time information to be useful. For getting the real-time feature, the sensors which obtain the data must be easy to deploy. This way, the sensors and the communications system will be carried by light mobile units. The communications protocols suitable for light mobile units work in high frequency bands.

However, under rural environmental conditions, these bands have critical fading due to a high vegetation density and the orography. To avoid this fading, a design, and an implementation of a VHF (Very High Frequency) header for a LoRa (Long Range) chip has been presented and implemented in this paper.

1. Introduction

Forest fires are one of the most devasting phenomena which Europe front because of the consequences to the society, economy, and biomass[1]. During wildfires, the people involved in extinguishing the flames need to receive real-time information about the wildfire status and evolution. One proposal to reach these people with such information is to deploy a network of light mobile units equipped with sensors[2].

This network needs a wireless communications protocol to function. In a previous work, the authors compared several protocols to establish the best one for network performance[3]. Their conclusion was that LoRa (Long Range) was the appropriate protocol for the conditions established. A relevant aspect shared by the compared protocols, including LoRa, is that they all operate in high frequency bands[4]–[6].

High frequency communications under rural environmental conditions have difficulties because of the fading. This fading is mainly due to the absorption of high frequencies by the high vegetation density. In addition to absorption, other phenomena exist such as the multipath, caused by orography, or scattering, which also causes losses[7], [8].

In this paper, to avoid this fading related to the high frequency propagation through rural environmental channels, a VHF header was designed and implemented to use the LoRa protocol in a lower frequency band. This way, the VHF header connected to the Semtech SX1272 module[9], the LoRa module, can transmit under the specified conditions.

Firstly, the workflow to get the design was defined. Several topologies and components were analysed before making a final choice on topology and electronic components. Once the topology and components were chosen, the PCB (Printed Circuit Board) was designed. The software used for this was EAGLE[10]. After the PCB design was obtained, the board was fabricated, and the components were soldered on it.

The structure of this paper is as follows: Section 2 describes the process followed to reach the design and its implementation. In Section 3, the design is explained arguing the decision making. In Section 4, the results are shown. Finally, in Section 5 the results are discussed to conclude this paper.

2. Workflow Design

The process undertaken to reach the design the was:

- Service specifications: the frequency bands, the radio channel features, and the power levels are defined.
- Topologies proposal: several topologies to accomplish the service specifications are proposed.
- Topology choice: the best topology among the proposal is selected.
- Frequency study: the frequencies to the mix subcircuit are calculated. Then, the filters features were established.
- Component proposal: several commercial components for each subcircuit are suggested to manage the service specifications.
- Power level study: the power level study accomplishment established are checked by studying the s-parameters and the noise figures of every component.

- Component choice: given the results of the frequency and power studies, the better components among the component proposal are selected.

The design process described above lead to the in-software PCB design and the manufacture afterwards.

3. Design

The very first block diagram of the whole system, as can be seen in Figure 1, has two inputs/outputs.

Figure 1: Block Diagram of the system. The VHF header transmits/receives RF to/from the antenna. VHF header also transmits/receives IF to/from the SX1272 module. VHF header converts RF into IF, and IF into RF.

The service specifications established for the VHF header design are shown in Table 1.

Table 1: Service specifications for the VHF header design

	RF	IF
Input Power (dBm)	[-120 : -65]	[-120 : -50]
Output Power (dBm)	[30 : 33] 0,5 dB steps	0 or 7 or 14
Frequency band (MHz)	[169,05 : 171,15]	[865.05 : 867,15]
Channel Bandwith (kHz)	300	300
Frequency Offset (kHz)	300	300

The channel bandwidth, the frequency offset, the IF output power, and the IF frequency band are established by the SX1272 features. The RF band has been given to the project by the Cabildo de Gran Canaria and the remaining power levels are an estimation.

The topology requires a switching structure to alternate between transmitter (TX) and receiver (RX) functions. So, the topology must have three branches: one for TX, one for RX and a common branch for TX and RX. A topology proposed is shown in Figure 2.

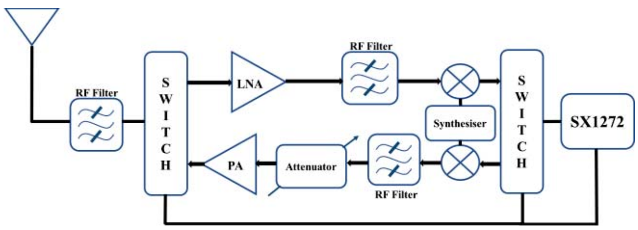

Figure 2. First topology for the VHF header with a mixer per branch and the first filter in the common branch.

This topology has two mixers, one per branch. As these mixers work in TX or in RX, the mixers can be passive or active. On the other hand, the maximum input power of the first filter must be high enough to support the PA (Power Amplifier) output. Another topology is shown in Figure 3.

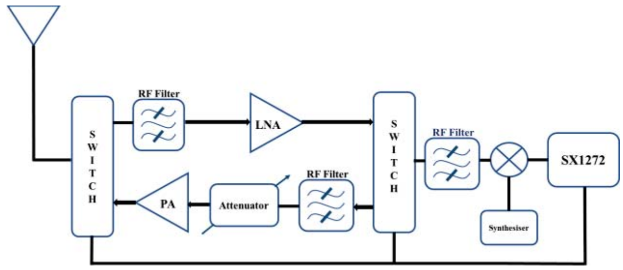

Figure 3. Topology with the mixer in a common branch and the first filter in the RX branch.

This topology has the mixer in the common branch, so it must be a passive mixer. In addition, this topology proposes to place the first filter in the RX branch to avoid exceeding the maximum input power condition. Both topologies have in the TX branch a variable attenuator for the 0.5 dB dynamic range, and SX1272 controls the switching action by a digital pin.

The big difference between the topologies is the mix stage. As in Figure 2, the mixers can be either passive or active, there will be a bigger offer of components than in Figure 3. On the other hand, the complexity of the first topology is higher than the second one. More components mean more wires and an increase in the time necessary in the software design afterwards.

Regarding where the filter is placed, in Figure 2 the filter works in TX as well in RX. In RX, it attenuates the unwanted frequencies and the noise from the antenna. In TX it attenuates the harmonics generated by the amplifier that may interfere with other communications systems. On the other hand, in Figure 3 the filter only works in the RX branch.

The criteria defined to choose a topology was the balance between the cost and the performance. The first topology could get a better performance because the mixer offer is wider. This way, for the first topology, mixers will be found that best meet the service specifications. However, as the first topology is more complex than the second one, its cost will be higher, not only in terms of money but also in terms of time spent.

The improvement that the first topology offers over the second one thanks to the mixers can be achieved by the second topology. For this topology, an appropriate choice of the remaining components can ensure similar performance to the first topology. As the performance can be ensure in both topologies, but the second one is cheaper, the chosen one is the topology which can be seen in Figure 3.

In the frequency study, firstly, the RF and IF bands were defined as follows.

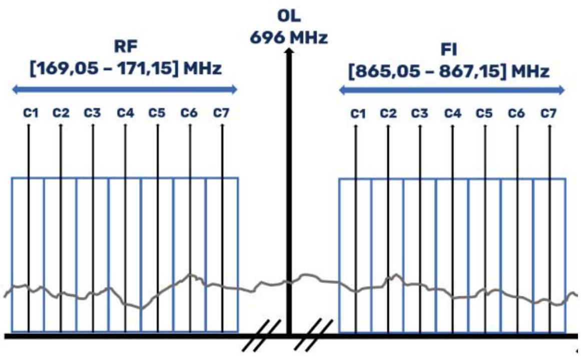

Figure 4. LO, RF and IF frequency bands.

As it can be seen in Figure 4, these bands have seven 300 kHz radiochannels, and its carriers are separated by 300 kHz. The possible LO values for the frequency convert are 696 MHz and 1036.2 MHz. To simplify the synthesiser selection, the lower one was finally chosen. With the 696 MHz, the filter features, the intermodulation products, and the image band were calculated. These values are shown in Table 2

Table 2. Local Oscillator value and RF filter features

	Filter features		
LO (MHz)	Frequency (MHz)	Bandwith (MHz)	Attenuation (dB)
696	170,1	2,1	60
Image Band (MHz)		TX Intermodulation Products (MHz)	
[1561,05 : 1563,15]		[1561,05 : 1563,15]	

As the frequencies of the image band coincide with those of the TX intermodulation products, the three filters are the same. The filters are defined to attenuate 60 dB the first carrier of the image band and the TX intermodulation products.

4. Results

Given the results of the frequency study and the power level values, a proposal for commercial components was made. To reach the RF output power levels, two amplifiers were necessary in the power stage. Also the attenuator must be set to [-7.5:-4.5] dB to obtain the dynamic range. The synthesiser gives a differential clock output, but the mixer needs a sinusoidal unbalanced signal for the LO input. Therefore, a balun and a lowpass filter were connected to the synthesiser and the mixer to unbalance the signal and make it sinusoidal. The components chosen are shown in Table 3 .

To configure the synthesiser, two DIP switches have been added to the software design. This way, LO can be manually set. To measure the PCB, two test points have been added with SMA connectors, and several 0 Ω resistance. This way, by soldering and unsoldering the 0 Ω resistances, the PCB can be measured by stages.

Table 3. Table with the components chosen.

Components	
LNA	MAX2611
PA	MW7IC008NT1
Switch	HMC595AE
Filter	SXBP-169
Attenuator	SKY12347-362LF
Synthesiser	MAX3674
Mixer	ADL5350

The performance obtained with the chosen components is shown in Table 4.

Table 4. Performance of the VHF header

Noise figure (dB)	7,1
IF Input Power (dBm)	[-113,4 : -58,4]
RF Output Power (dBm)	[29,9 : 32,92]

The PCB was designed in EAGLE. The layout obtained is shown in Figure 5

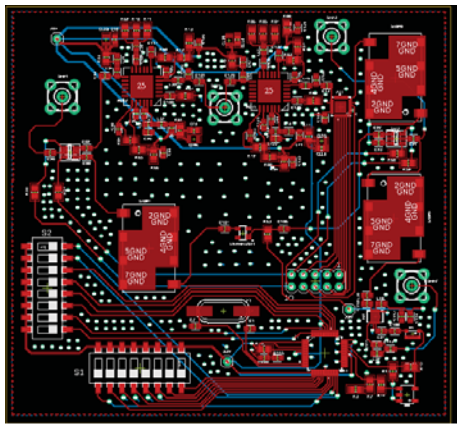

Figure 5. PCB layout

The PCB has a 9 x 10 cm. The circuit, built and soldered is shown in Figure 6

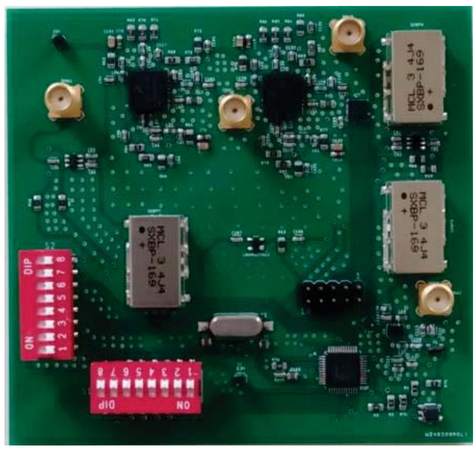

Figure 6. PCB built and soldered

5. Conclusions

VHF header performance, the IF input power and the RF output power, has met the expectations of the service specifications. On the other hand, the noise figure obtained is below a noise figure of 8 dB, which is a typical value in VHF receivers.

Regarding the PCB obtained, it is prepared for measured it thanks to the SMA connectors included. Furthermore, it is easily configurable thanks to the DIP switches and the pins. Finally, the PCB has an appropriate size for a light mobile unit. As conclusion, the VHF header has met all the expectations regarding the design and the first implementation.

6. Acknowledgements

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7. References

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