Development of a radiofrequency signal generator for ionosonde radar transmitter using low-cost SDR

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Abstract

The Jicamarca Radio Observatory (JRO) is an Instituto Geofísico del Perú (IGP) facility, dedicated to monitor the upper atmosphere with different instruments such as radars, GNSS receivers, magnetometers, among others. Ionosonde is a type of HF radar that uses multiple frequencies to survey the ionosphere and obtain estimates of electron density. In this poster we present the development of a low-cost radiofrequency signal generator for a ionosonde radar transmitter based on the Red Pitaya development board with a sampling frequency of 250 Msps, and the ability to transmit modulated signals with a frequency sweep ranging from 1 MHz to 60 MHz, providing the possibility of using it with other CW radars.

2. FPGA internal architecture

For the design, Vivado development environment from Xilinx-AMD was used. The hardware synthesis was based on the VHDL hardware description language, using a behavioral description style for the modules, such as the SPI controller, register map, numerically controlled oscillator (NCO), OOK modulator, multiplexer, synchronization module with a 10 MHz GPS clock input, and trigger for signal transmission initiation. Subsequently, all the mentioned modules and IP Core Clocking Wizard were integrated using the structural description style in the Vivado software.

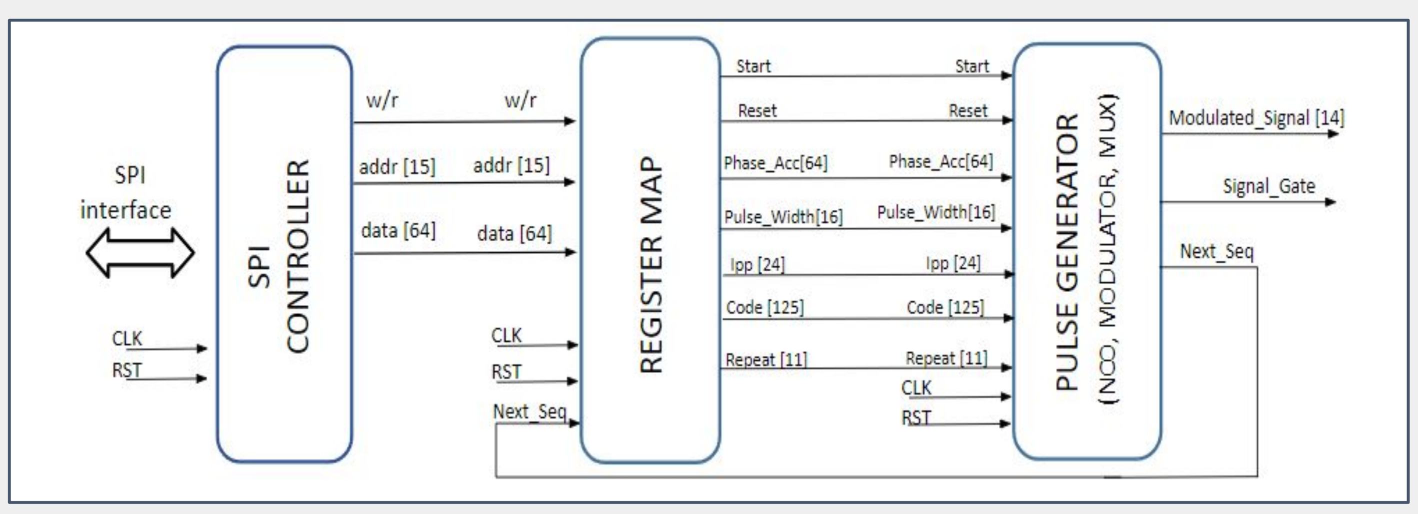

Figure 1. Block design.

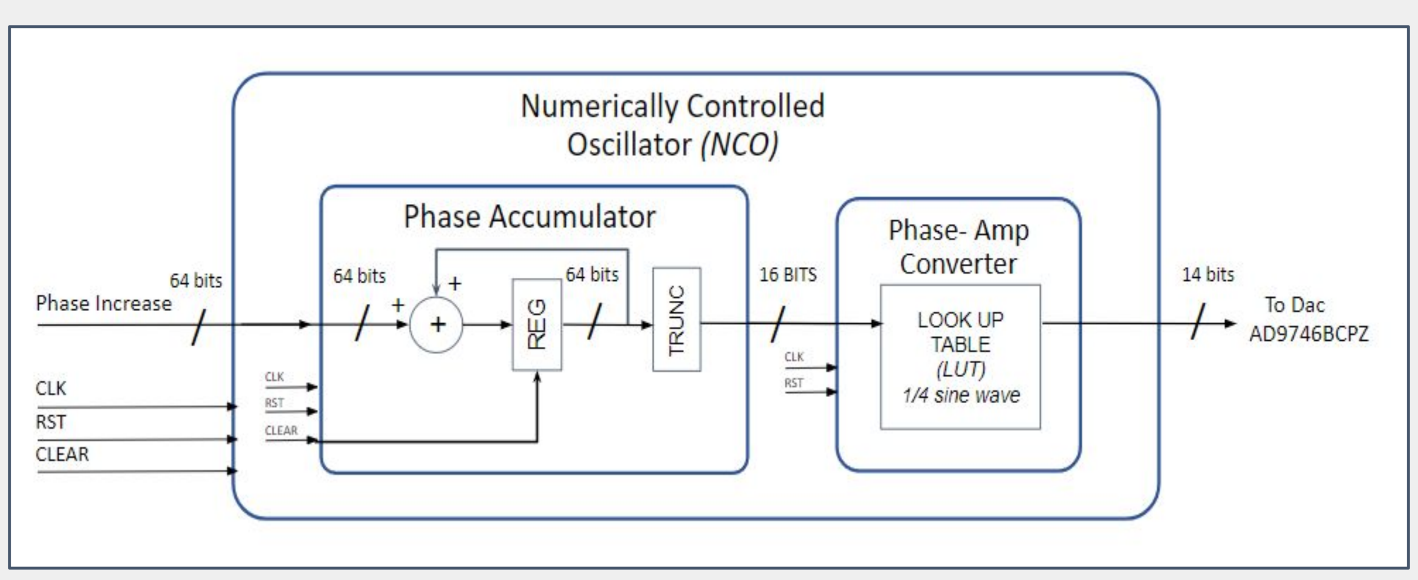

Figure 2. Numerically controlled oscillator.

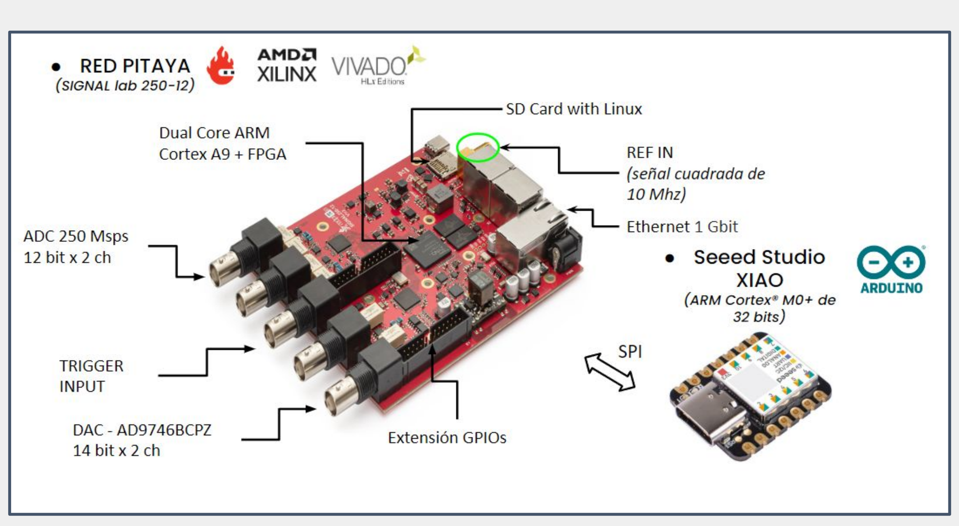

Figure 3. Hardware.

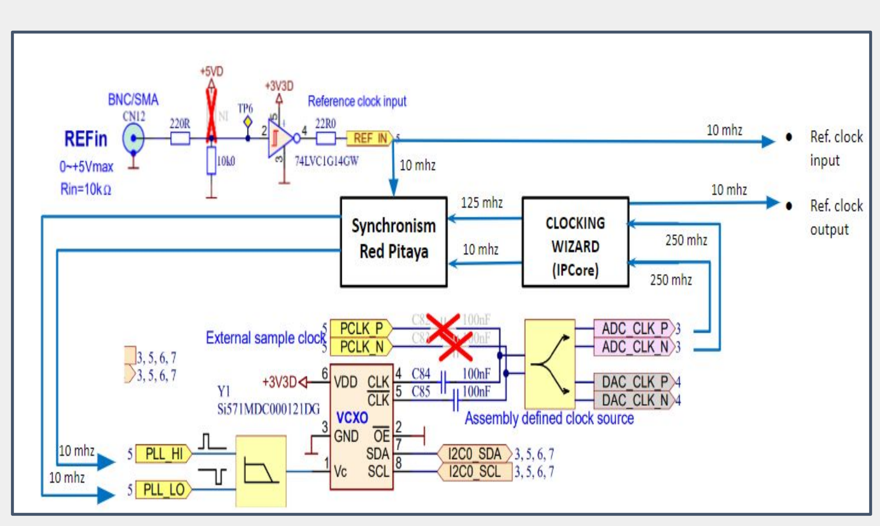

Figure 4. Synchronization module.

3. PCB

Red Pitaya requires a 10 MHz square signal for the reference clock. For this reason, a PCB was design to converts the sinusoidal signal from the GPS receiver into a square signal. In addition a Seeeduino microcontroller is used to configures the frequency using SPI.

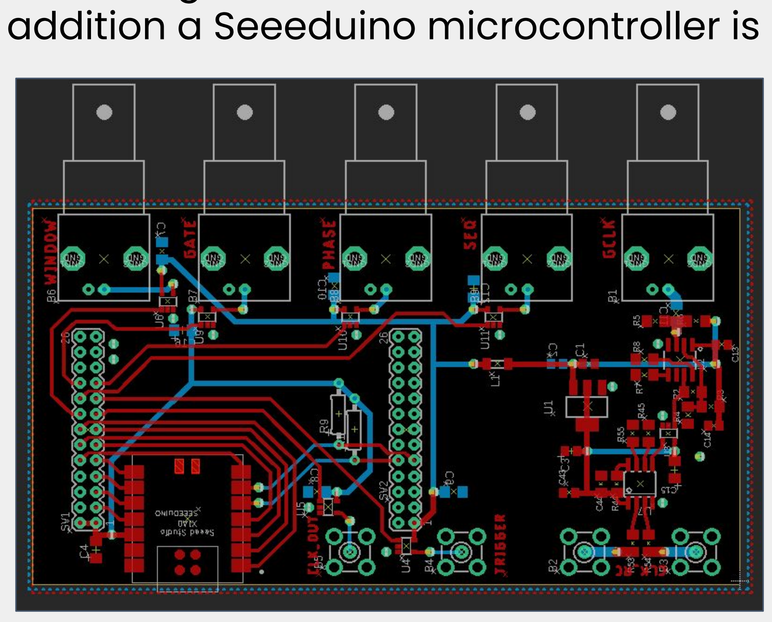

Figure 5. Schematic of the electronic board.

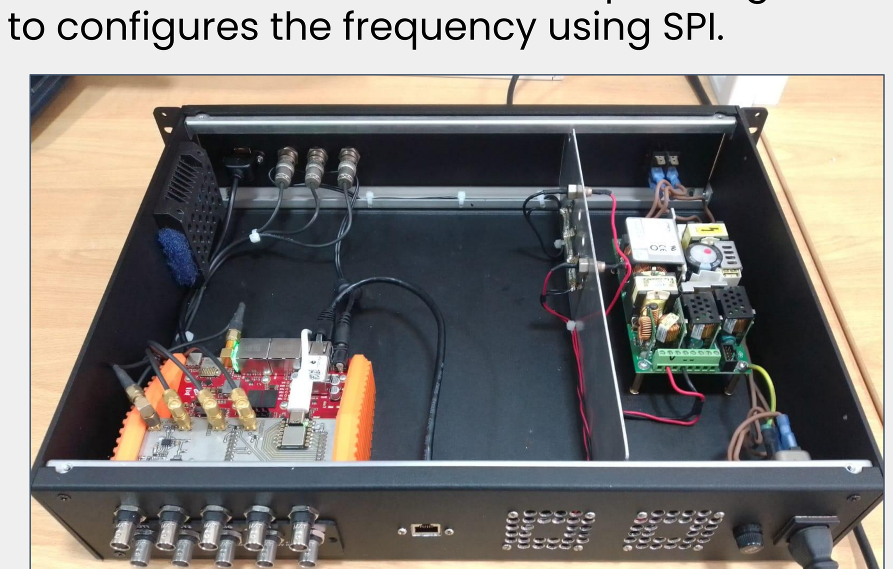

Figure 6. RF Signal Generator Rack.

1. Introduction

Currently, the Jicamarca Radio Observatory has the Vertical Incidence Pulsed Ionospheric Radar (VIPIR) as a scientific facility, which has the capacity to acquire vertical ionograms of the equatorial ionosphere. To monitor the ionosphere at a regional level and expand our capabilities to conduct observations related to space weather events in Peru we need a low-cost HF survey network in Peru. This work is the initial step and we propose to implement a radiofrequency signal generator for ionosonde radar transmitter using Red Pitaya based on SoC FPGA Zynq-7020.

4. Synchronization and trigger

The phase difference between the 10 MHz GPS signal and the 10 MHz signal generated by the system remains under 500 ps. The frequency sweep happens when it detects the rising edge of the trigger signal.

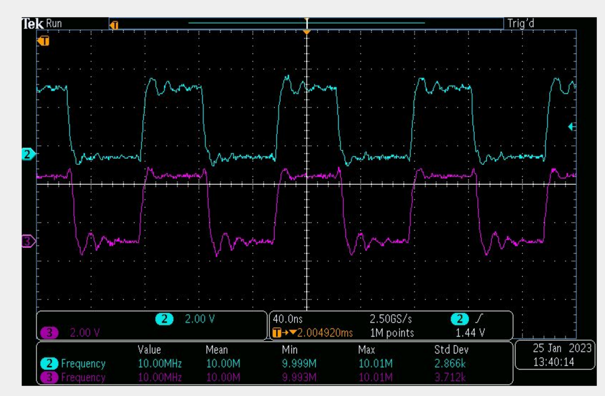

Figure 7. Synchronization between the GPS signal and that generated by the system.

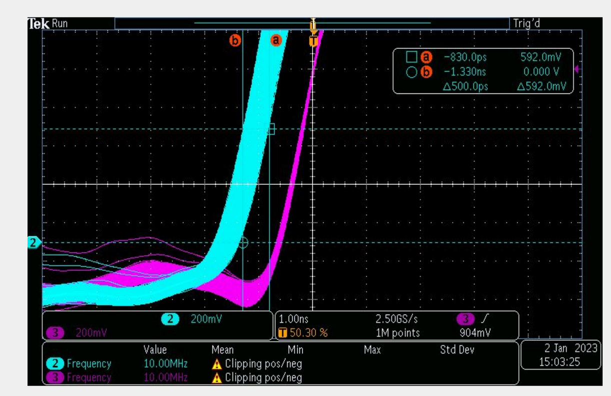

Figure 8. Phase shift of synchronization signals.

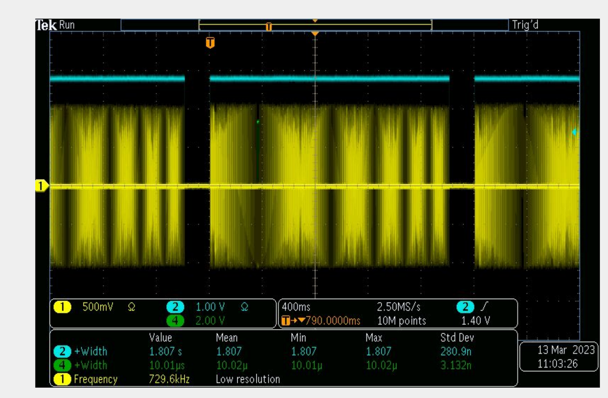

Figure 9. Frequency sweep.

5. Results

The initial tests were carried out using the Vertical Incidence Pulsed Ionospheric Radar located at the IGP-JRO, where pulsed signals were successfully transmitted using the radiofrequency signal generator. Ionograms were obtained using the VIPIR receiver.

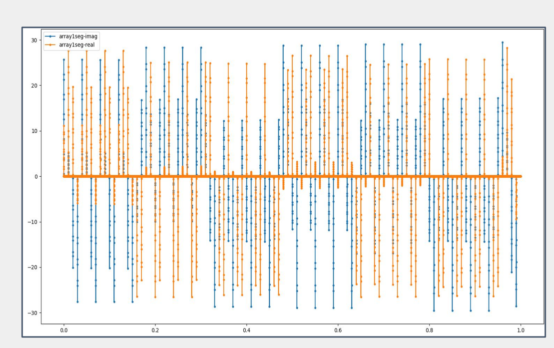

Figure 10. Copper ball.

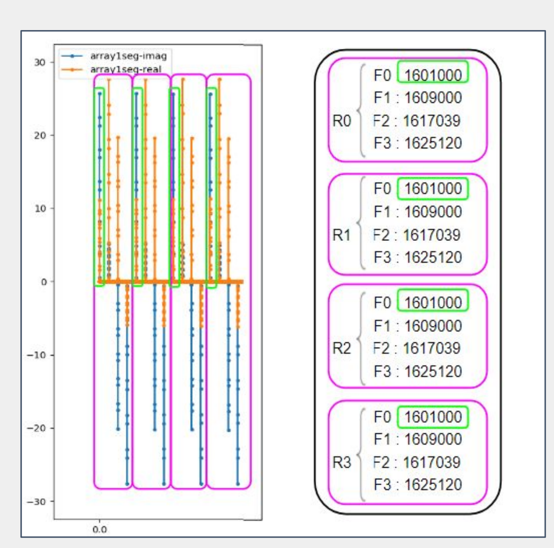

Figure 11. Frequency repetitions.

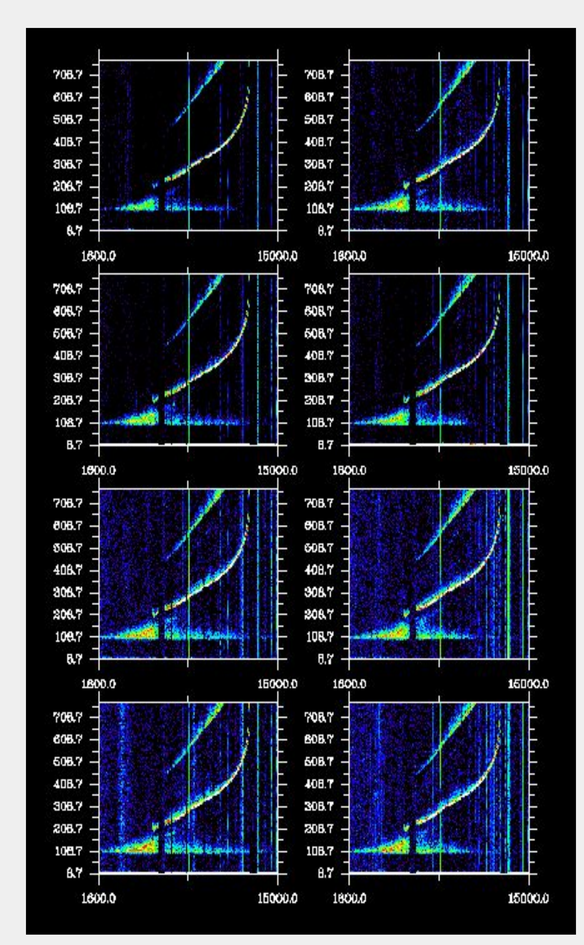

Figure 12. Receiving echoes with VIPIR, 23-05-2023, 16:43 pm.

CHARACTERISTICS	VIPIR	NEW GENERATOR
Number of pulses	1808	32768
Pulse width	60 us	1 - 120 us
IPP	10 ms	1 - 67 ms
frequency steps	8 Khz	0.1 Hz
frequency sweep	1 - 15 Mhz	1 - 60 Mhz

Figure 13. Features of the new generator

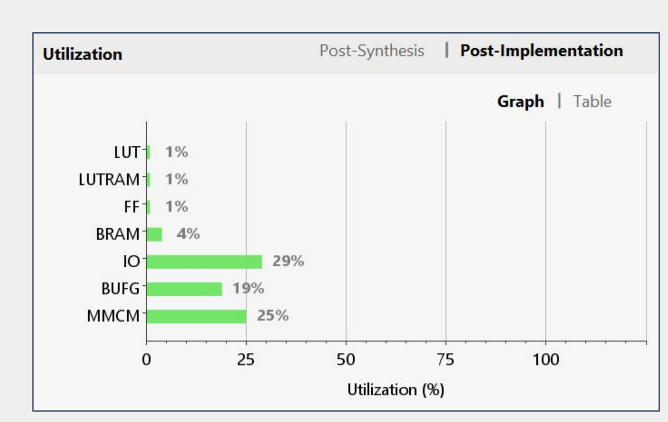

Figure 14. Resources used

6. Conclusions and Future Work

- The correct generation of RF signals has been validated.
- Synchronization was achieved with the 10 MHz signal from the GPS receiver.
- Vertical echoes were received with the VIPIR receiver.
- As part of future work, hardware synthesis of the BPSK modulator will be carried out to generate coded signals.

7. Acknowledgments

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8. References

[1] Barona J. (2017), Implementation of an Electronic Ionosonde to Monitor the Earth's Ionosphere via a Projected Column through USRP.

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