The Jicamarca acquisition radar system and its first applications to the study of the equatorial ionosphere

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Abstract

The engineers at the Jicamarca Radio Observatory (JRO) have recently developed a new acquisition system based on digital receivers. JARS, which stands for Jicamarca Acquisition Radar System, is an eight-channel reception system that can collect data at a rate of 1 MHz per channel. In this paper, we describe the hardware and software developed for the system and also some of its first applications. JARS is currently being used in imaging experiments at the observatory and it is expected to be used in meteors and ISR experiments in the next months.

1. Introduction

In the past few years, the engineers at the Jicamarca Radio Observatory (JRO) have been working on the development of their own radar acquisition systems based on digital receivers. The first prototype, REX (a two channel acquisition system) was built to be used by the SOUSY radar located at Jicamarca. Due to the success in the results, we have developed a new system, Jicamarca Acquisition Radar System (JARS), with more channels, wider dynamic range, better performance, and more flexibility. This new system will become the principal system for the incoherent scatter radar at the observatory.

JARS is based on AD6620 digital receivers which are the main devices to process the data. In addition, three Complex Programmable Logic Devices (CPLD's) are used to control and configure the entire system taking care of the synchronization and communication between the receiver cards, the radar controller system, and the computer where the data is stored. Additionally, a data acquisition program has been developed to process and save data online. To develop this system, it was necessary to design multilayer boards and to use high knowledge of programming. In addition, it should be noted that the hardware and software of this system has been developed entirely at the JRO installations.

This paper begins with a general description of the system showing its architecture and functionality. Next, the acquisition software is described in detail and examples of radar data taken with JARS in an imaging experiment at Jicamarca are presented. Finally, our conclusions are followed by the description of the radar experiments in which the system will be used in the near future.

2. Overall Architecture

Due to the large number of applications in which this system will be used, JARS was designed in order to allow a large number of possible configuration schemes that depend on the number of channels, bandwidth, number of samples acquired, etc. As mentioned before, JARS has 3 complex programmable logic devices (CPLD) that provide high flexibility in the configuration of system hardware as needed for different applications. These CPLDs communicate with each other and are programmed sequentially following a protocol specially developed for this task.

JARS needs three external input signals to function properly, which are listed below:

- GCLK: A 60 MHz master clock that synchronizes all the system components (ADC's, CPLD's, digital receivers).

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- SYNC: Signal that indicates the beginning of each period
- WIN: Signal that indicates the size of the data to be acquired

It should be noted that these signals are provided by a device named Radar Controller and the signals have Transistor–Transistor logic (TTL) levels, The JARS's architecture is shown in Figure 1.

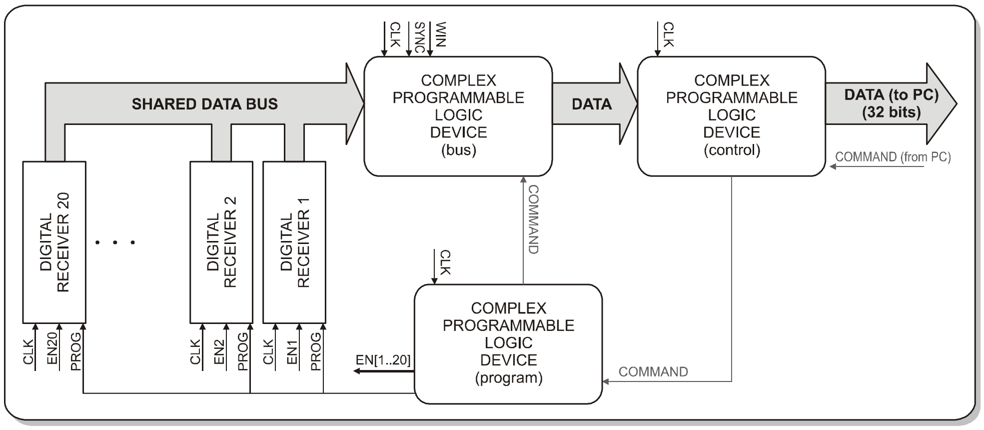

Figure 1. JARS architecture.

The above diagram shows that each CPLD has specific tasks. The CPLD-Control has the function of communicate with the PC. First, it receives commands from the acquisition software for proper configuration of the system, second, sends this information to the CPLD-program and then transfers the acquired data to the PC through a PCI data acquisition card NI-DAQ 6534 from National Instruments. The CPLD-program manages the delivery of the power supply and the programming of the digital receivers depending on the number of channels to be used in order to achieve an efficient use of power consumption. Finally, the CPLD-bus authorizes the use of the shared bus and collects the data from the digital receivers and then transfers this data to the CPLD-control orderly.

2.1 Digital Receivers

Each digital receiver digitizes and processes the signal from an antenna connected to its input terminal. For this purpose, each digital receiver uses the high-speed 14-bit ADC AD6645 in series with the digital signal processor AD6620 both from Analog Devices.

The AD6620 is a digital receiver with a specific architecture designed to perform the frequency translation, quadrature demodulation, decimation, and filtering of the acquired signal. The AD6620 has 3 programmable filters (2 Cascaded Integrator-Comb and 1 FIR) in cascade with decimation stages that decrease the sample rate. In Figure 2, it is shown the diagram of this digital receiver.

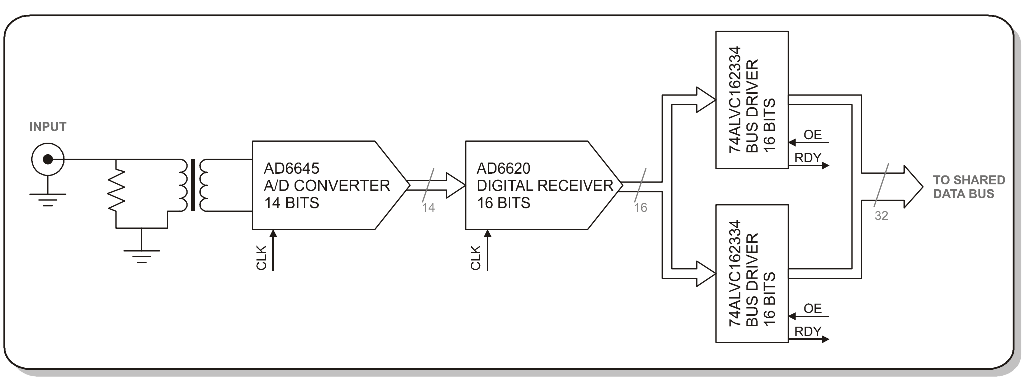

Figure 2. Digital Receiver Architecture.

3. Software

The software developed for JARS acquires, processes and stores the data online. Programmed in C++ using Visual Studio 2008, this software uses a modular programming technique such that each module performs a specific task. In addition, in order to perform some functions that require high processing power (Fourier transforms, correlations, decodifications, etc), the program uses specialized libraries of parallel algorithms as IPP (Integrated Performance Primitives) and TBB (Threading Building Blocks) from Intel. These algorithms make use of the multi-processors of the system PC to improve the data processing performance. The software runs in Windows and exploits the maximum performance of the National Instruments Data Acquisition Card NI-DAQ 6534.

4. Performance Evaluation

- Dynamic Range

To do this test, it was used an Agilent 33250A Signal Generator, as input to the system and 03 preamplifiers with a gain of 45 dB. The system was configured to operate at 1 MHz of resolution and 08 channels. The results are shown in Table 1.

Table 1. Dynamic Range in each channel from JARS.

Channel	**Number of excited bits**	**Minimal signal**	**Maximum signal**	**Dynamic Range**
Ch01	06 bits	-74.1 dBm	6.7 dBm	80.8 dB
Ch02	06 bits	-80.2 dBm	6.8 dBm	87.0 dB
Ch03	06 bits	-82.2 dBm	6.7 dBm	88.9 dB
Ch04	06 bits	-75.2 dBm	8.8 dBm	84.0 dB
Ch05	06 bits	-82.2 dBm	6.8 dBm	89.0 dB
Ch06	06 bits	-74.1 dBm	6.9 dBm	81.0 dB
Ch07	07 bits	-68.1 dBm	6.9 dBm	79.0 dB
Ch08	07 bits	-72.1 dBm	6.9 dBm	82.0 dB

- Maximum Transfer Rate

Currently, JARS has been tested using 08 channels simultaneously and the maximum transfer rate per channel is 1MHz, though if less channels are used, the maximum transfer rate per each channels increases. The maximum transfer rates are shown in Table 2.

Table 2. Maximum transfer rate per channel(s) used.

Number Channels	**Maximum rate per channel**
1	6 MHz
2 to 4	2 MHz
5 to 8	1 MHz

5. Results

Currently, JARS is being used to acquire data from the Jicamarca main antenna in imaging experiments, whose features are shown in Table 3.

Table 3. Main features of Imaging experiments.

Number of Channels	08
Resolution	100 kHz
Data processed	Yes
Date of Experiment	18th January 2011

The results are shown in Figure 3, where a Spread-F image is displayed.

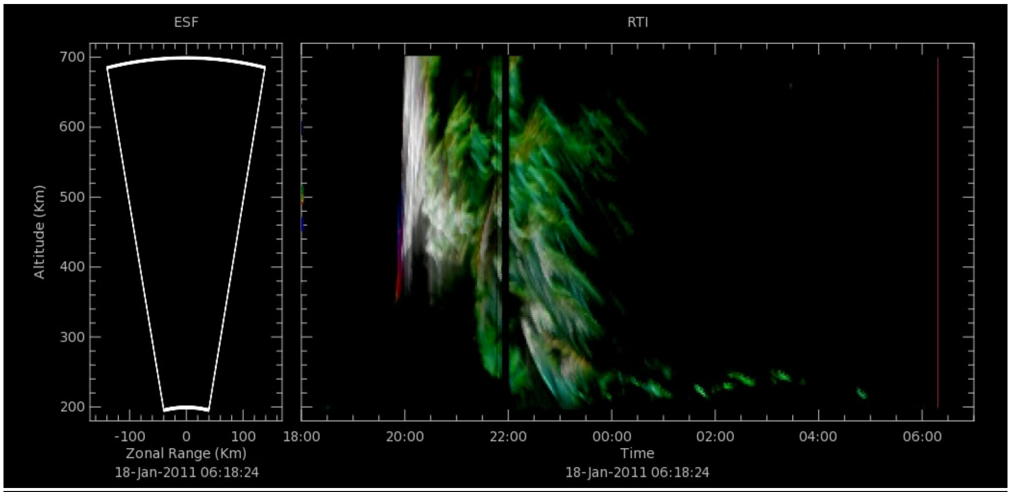

Figure 3. Range time intensity (RTI) plot of spread F on 18 January 2011 measured with JARS.

6. Conclusions

- JARS is a stable and flexible acquisition system easy to configure.
- Since JARS has been entirely developed at Jicamarca, we have full knowledge of the functionally of the system which will allow us to easily configure any type of radar experiment. This will expand further the capabilities of the Jicamarca radar to conduct sophisticated experiments and study in further detail the ionosphere.

7. Future work

Currently, the data acquired by JARS in imaging experiments is being analyzed. In the next 2 months, JARS will be tested in meteor and ISR experiments at the Jicamarca Radio Observatory in order to continue the analysis of its performance. It is expected to obtain results similar to the ones obtained using the old Echotek 214 acquisition system at Jicamarca. Examples of the type of data measured in these experiments are presented in Figure 4.

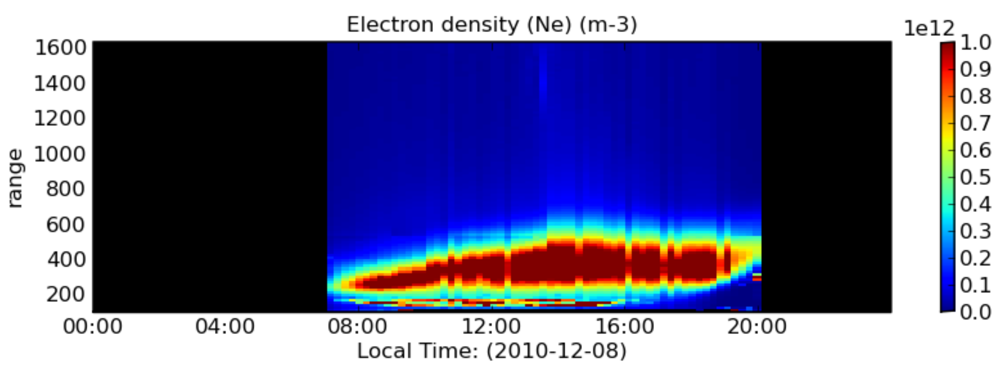

Figure 4. Example of an ISR experiment carried out with the old Echotek 214 system at Jicamarca.

8. Acknowledgments

We thank K. Kuyeng and M. Urco (engineers at the Jicamarca Radio Observatory) for their help during the firsts tests in JARS experiments. We also thank to J. Chau and M. Milla, for their ideas, comments and suggestions during the development of the project. Finally, we thank E. Palpa, A. Belleza and R. Tadeo for their outstanding work in assembling JARS.