Lightning Warning System

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ABSTRACT: This study presents a warning lightning system that has been developed by the University of São Paulo in order to detect intra-cloud (IC) and cloud to ground (CG) lightning activity and then predict the probability of CG occurrence. The system designed is based on a slow-antenna that is integrated with microcontroller and a single board computer. The system has a firmware that can be updated anytime, and in the present moment an algorithm identifies the strokes and provides the thunderstorm warning system. By doing that, it will be possible to have a compact and low cost system that can be updated with more lightning signatures and other tasks.

INTRODUCTION

Lightning flash counters (LFC) are devices designed to detect the lightning activity in the vicinity of a given location. By analyzing the electric field changes in time, LFCs have been employed as a warning system in addition to study the nature of the thunderstorms. LFCs like the International Radio Consultative Committee (CCIR)[*Horner*, 1960], which were designed to respond mainly to the radiation field of a return stroke and the Conseil International des Grands Réseaux Électriques (CIGRÉ) [*Prentice*, 1972] counters are examples of such instruments. Based on these flash counters *Mackerras* [1985] developed a class of lightning sensors called CGRx that enable the evaluation of intra-cloud to cloud-ground lightning ratio because of its capability to discriminate between these two types of lightning, as well as the polarity of the ground flashes [e.g., *Prentice and Mackerras*, 1977].

The Companhia Energética do Ceará (COELCE) runs a lightning warning system that relies on STARNET long range lightning detection network (*Morales et al.* [2011]) and GOES satellite images. The system monitors in real-time the lightning occurrence over the State of Ceará and it displays on the screen of its operational center at headquarters the cities and the power company features (transmission lines, substations and etc) that have been hit by lightning strokes. As this system does not predict the occurrence of lightning, the University of São Paulo (USP) proposed to built a sensor that could detect both IC and CG to predict the thunderstorm activity, based on the argument that the maximum IC flash rate anticipates the CG activity (*Goodman et al.* [1988]).

For this study, we present the main concept of a Lightning Warning System (LWS) and its first preliminary results to respond the previous action. The LWC has been implemented in a modern single-board computer and a low-cost and high performance DSC (Digital Signal Controller), which is a novel concept that integrates a general-purpose MCU (Microcontroller) plus a DSP (Digital Signal Processor) in a single chip. By using DSP techniques and firmware implementation that incorporates a stroke signature analysis it's possible to gain flexibility because it is not difficult to implement the different lightning characteristics observed, thus maximizing the flash counting and thunderstorm forecast capability.

In the next sections we present a description of the warning system and preliminary results obtained.

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SYSTEM DESCRIPTION

The system developed by the University of São Paulo can be divided in 3 components: a) slow antenna, b) signal processing and c) LWS-IAG

a) Slow antenna

The slow antenna is a 3 meters vertical whip antenna with a coupling circuit working as an integrator for the signal from the antenna (figure 1). In addition to the signal integration, the circuit has a low pass frequency response designed to reduce the requirements of the anti-aliasing filter.

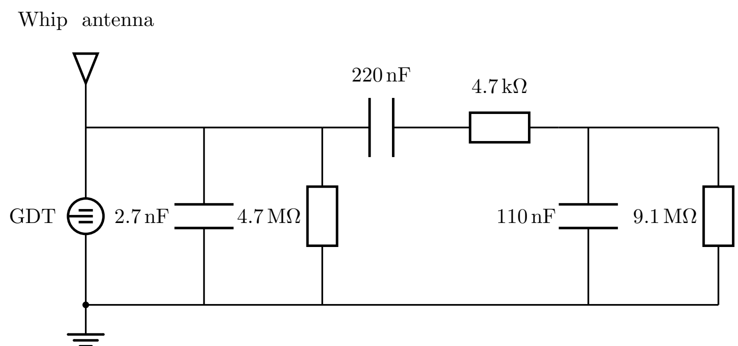

Figure 1: Passive network coupling circuit designed for integrating the signal from the whip antenna.

The coupling circuit has been set with a time constant of $\approx$ 1 s and a frequency response similar to CCIR, CIGRE and CGR4 systems, whose response are shown in figure 2.

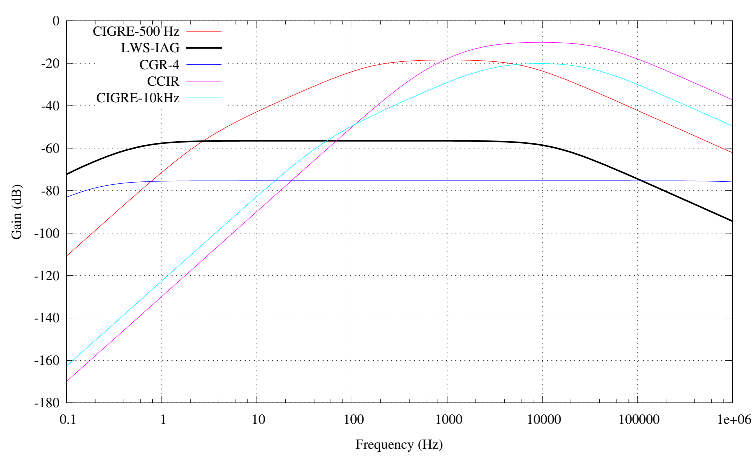

Figure 2: Frequency response of the coupling circuit designed for the LFC (LWS-IAG) compared to other approaches for lightning detection.

b) Signal processing

The heuristic for the identification of the lightning flashes is based on the analysis of the waveform in the time domain, thus imposing a requirement on the anti-aliasing filter with relation to the transient response. The Bessel realization was chosen due its linear phase response and low overshoot to step inputs. The trade-off of employing this type of filter is the less steep transition zone from cutoff to stop frequency, which implies in the use of higher sampling rate in order to have the Nyquist frequency in the stopband of the filter. With the present design parameters, the sample rate is about 46 kS/s and in order to reduce the digital processing requirements the signal is decimated in the Data Capture Module bringing the sample rate to 11.5 kS/s.

c) LWS-IAG

The lightning warning system developed by University of São Paulo is summarized in the flow chart of figure 3, that presents the Message Sequence Chart designed for the LWS-IAG. Also it shows how we expect to broadcast the warning system to COELCE and the community.

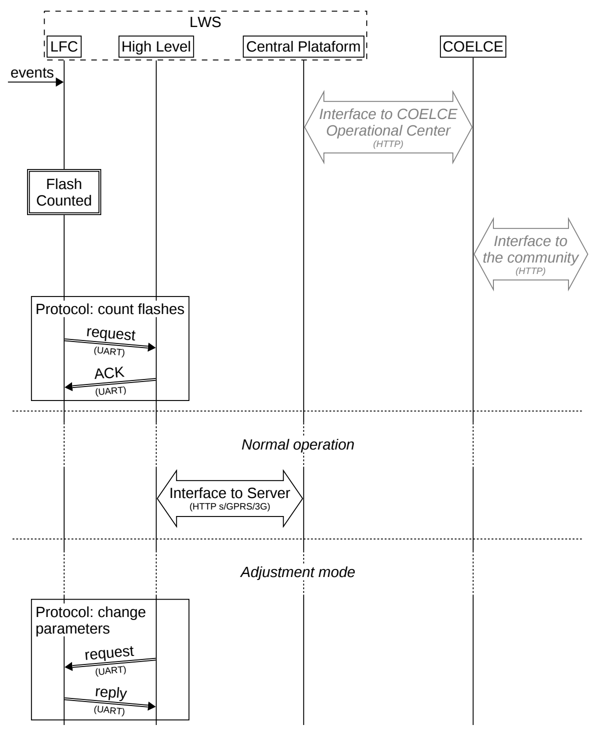

Figure 3: Message Sequence Chart showing the high level view of the communication protocol among the several modules of the LWS-IAG.

The LWS-IAG system is composed of 3 computational subsystems that are described below:

1. *Central Platform:* A server computer that centralizes the information from the LFC stations via TCP/IP connection and works as a HTTP server for warning dissemination.

2. *High Level Module:* Single Board Computer (Raspberry Pi) running an embedded Linux operating system. It is responsible for execution of communication protocols with the central platform, GPS

time synchronization, MODEM GPRS/3G data transferring, and execution of application programs that identifies strokes and provide thunderstorm phase warning.

3. *Data Capture Module:* Module built around a Kinetis FRDM-K20D50M board, which makes use of the DSC embedded in this board, thus allowing for real time processing of the electric field measurements sampled by the internal ADC. The module receives the electric field signal conditioned by the slow antenna, filters the signal than it sends via UART to the High Level Module.

PRELIMINARY RESULTS

Before integrating the LWS-IAG system, we integrated the slow antenna with a National Instruments data acquisition system (NI-6361) and the Garmin GPS18, which was used to synchronize the samples with a Universal time. The first test was performed on 2014/01/22 21:54:55 UTC (figure 4) at University of São Paulo (São Paulo, Brazil). At the same time of such test a High-Speed video camera with 10,000 frames per second (*Schumann et al.* [2014]) and a fast antenna (*Schulz et al.* [2005]) were also recording the same events. For the event of figure 4, the fast antenna electric field measurements (not shown) indicated a positive CG flash. By inspecting figure 4 it is possible to observe several features of the electric field changes associated with this flash: a) return stroke (RS); b)continuing current (CC) c) followed by several recoil leaders in a spider lightning (IS). For comparison purposes, Figure 5 shows a frame of the high-speed video where it is possible to identify the CG flash.

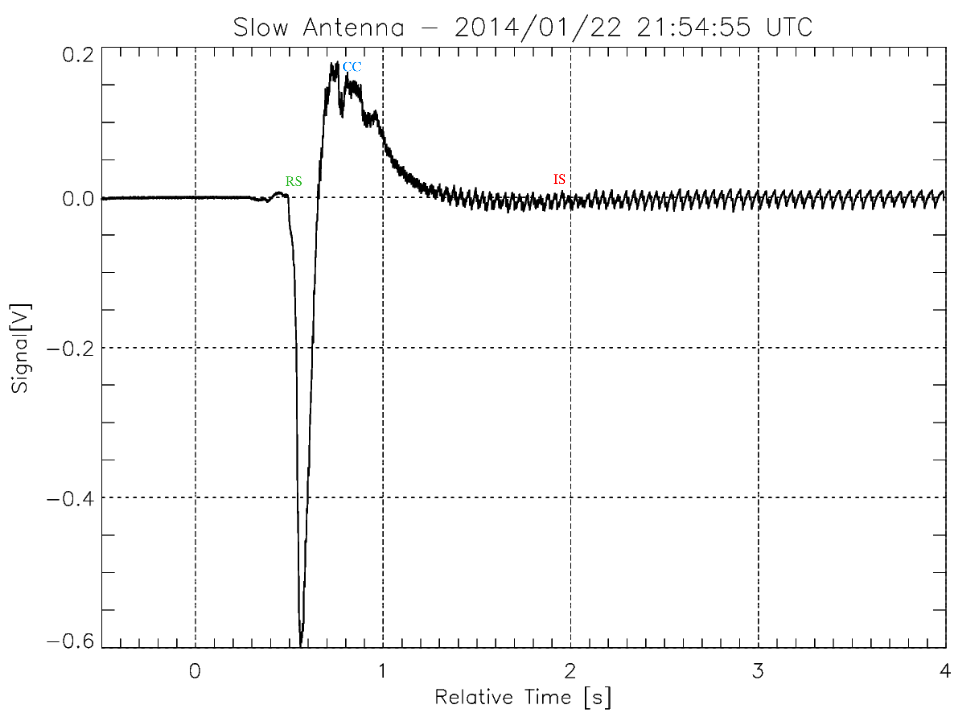

Figure 4: Signal acquired by the slow antenna system of the LFC showing features of a positive CG followed by a spider lightning.

Figure 5: Frame recorded at 2014/01/22 22:54:55.591 UTC by the high-speed video camera showing the CG flash.

CONCLUSION

This study presented the prototype of a lightning warning system developed University of São that has been name LWS-IAG. The designed LWS-IAG incorporates the recent electronics and computers advances in order to make a small and low-cost system. The preliminary results showed that the antenna is capable to detect the lightning features. During the conference we will present the results of the integration of the antenna with LWS-IAG to check if the heuristic proposed is able to detect and classify the lightning flashes properly.

ACKNOWLEDGMENTS: This study is funded by the COELCE Research & Development Project #0039-0040/2010. The authors would like to thank Dr. Marcelo Saba for providing the high-speed video and fast-antenna measurements.

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