AWESOME AND SAVNET INSTRUMENTS IN ECUADOR

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Abstract. In this paper we present in short the Atmospheric Weather Education System for Observation and Modeling of Effects (AWESOME) and the current status of the installation of the South America VLF Network (SAVNET), in Ecuador. These are the first space science sensors introduced in the country for study the equatorial ionosphere and magnetosphere. Equipment designed for detecting very low frequency (VLF) and extremely low frequency (ELF) radio signals which are propagating in the Earth-ionosphere waveguide.

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Introduction

Waves at VLF frequencies are efficiently guided between the Earth and lower ionosphere, travelling very long distance around the globe. These waves are useful on detection and localization of lightning strikes (Wood and Inan, 2004), solar flares-related ionospheric disturbances (Thomson and Cliverd, 2001) and even are associated with strong earthquakes (Cohen, 2010).

Monitoring the D-layer of the ionosphere has been proved to be valuable in atmospheric sciences such as in meteorology, seismology and its related fields.

Stanford University started the Atmospheric Weather Education System for Observation and Modeling of Effects (AWESOME) project, in order to build a global network for monitoring the radio signals propagating in the Earth atmosphere. The sensors are sensitive to Very Low Frequency (VLF) radio transmissions in the range between 3kHz – 50 kHz, emitted from nations to the submarines, as well as Extremely Low Frequency (ELF) natural signals in the radio spectrum between 30–3000 Hz, such those emitted by lightning-induced events and wave-particle interactions in the magnetosphere (sferics, whistlers, chorus, hiss).

As result of the United Nations Workshops on Space Sciences, Ecuador has been interested in hosting space sciences instruments. The representatives of the AWESOME project of Stanford University and the Quito Astronomical Observatory, in kind cooperation of Prof. Umran Inan, came to the agreement for the installation of an AWESOME VLF receiver in the Observatory facilities. The equipment was transported and the installation began in October 2010.

Currently, the Quito VLF station as part of AWESOME network is operating to study the ionosphere and the magnetosphere in the equatorial region, registering electromagnetic waves in ELF/VLF bands. The Quito AWESOME station is providing valuable data to study the VLF phenomena at low latitudes, at places were these kinds of studies have been not realized before.

AWESOME implementation

The equipment was installed and calibrated by the technical personnel of the Quito Observatory following the recommendations given by the researchers of the Space, Telecommunications, and Radioscience Laboratory of the Stanford University. From October 2010 to November 2011 the receiver was located inside the facilities of the Quito Observatory in the Alameda Park. The spectrograms acquired in this site indicate the presence of a strong environmental noise component.

Table 1: AWESOME technical features.

ANTENNA	Area: 1.69m2 Weight: 0.838 Kg Wire: AWG 16, 75.3m Turns:12 Base:2.60m2
RECEIVER	LTC1562 12th order lowpass - 47 KHz cutoff per channel GPS: Motorola M12, FPGA generates 100Kpps RS-232 communication for GPS PCI connection Supply Range from AC 90 V to 240 V Dimension and Weight: 133x210x230mm, 2.6kg
Data acquisition	A/D converter (N/S and E/W interleaved) Data enters 200 samples/s 100kHZ per channel 16 bit resolution +/- 5V

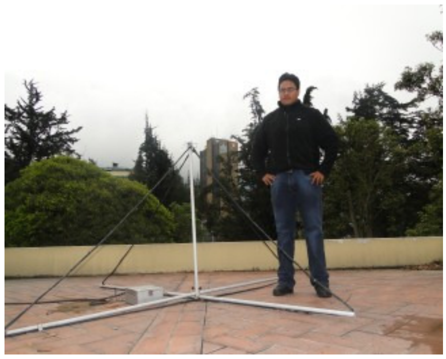

Figure 1: B-Field Antenna on the roof of Electronic Unit of Quito Observatory (LAT: 0°12' 52.98" S; LONG:78°30' 8.79" W; ALTITUDE: 2826 m).

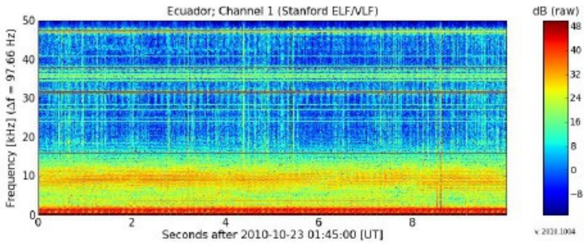

Figure 2: Spectrogram sample acquired in the Quito Observatory site.

Therefore, the receiver has moved to the campus of the Escuela Politécnica Nacional trying to avoid the electromagnetic noise of the surrounding environment. However, the acquired data still show an environmental noise component and certain vanishing of the transmitter signal. This second aspect denotes the existence of troubles with the antenna-preamplifier coupling.

Figure 3: AWESOME antenna in the roof of administration building of Escuela Politecnica Nacional (LAT: 0°12' 41.29" S; LONG: 78°29' 25.70" O; ALTITUDE: 2812m)

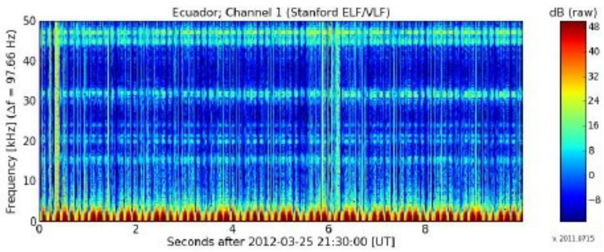

Figure 4: Sample of the spectrogram collected in the Campus of Escuela Politecnica Nacional.

Currently, the VLF receiver continues in the Escuela Politecnica Nacional campus, but its optimal operation is still under study. Actually, we are working on improving the quality of the signal. First, the electronic circuits of the antenna-preamplifier coupling are being modified. Second, we are analyzing the feasibility for relocating the receiver to a site with a low background noise, such moving the equipment to the Jerusalem site where is located the astronomical Station of the Quito Observatory.

Scientific interests

The Quito AWESOME is able to detect radio signal from transmitters used for marine communication. The spectrograms show that we are detecting in the site of localization of the instrument, VLF radio signals in the range of frequencies between 19 kHz to 40 kHz from 8 world-wide transmitters. The table 2 shows the signals detected in Ecuador by the AWESOME receiver.

Table 2: Transmitter signals detected in Ecuador AWESOME receiver

LAT	LONG	FREQ **(Hz)**	SIGN
-21.816	114.166	19800	NWC
21.420	-158.154	21400	NPM
53.079	7.614	23400	DHO
44.646	-67.281	24000	NAA
48.203	-121.917	24800	NLK
46.366	-98.335	25200	NLM
63.851	-22.459	37500	NRK
18.399	-67.178	40750	NAU

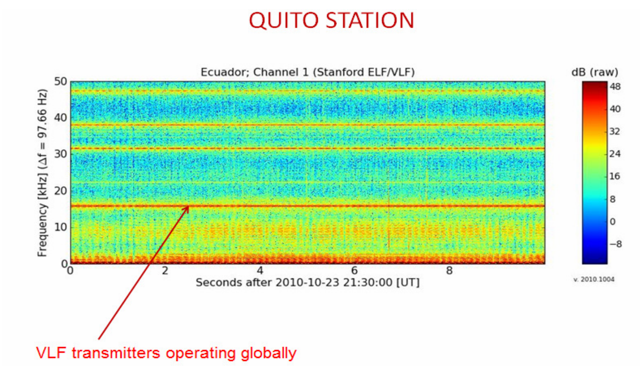

Figure 5: Quito station dynamic spectra showing the global VLF transmitters.

On the other hand, the waves propagating in the Earth atmosphere vary over a wide range of frequencies:

- Ultra low frequency (ULF; 1–30 Hz),
- Extremely low frequency (ELF; 30–3000 Hz),
- Very low frequency (VLF; 3–30 kHz),
- Low frequency (LF; 30–300 kHz),
- Medium frequency (MF; 0.3– 3 MHz),
- High frequency (HF; 3–30 MHz),

and the

- Ultra high frequency (UHF; >30 MHz).

The maximum energy radiated is contained in the ELF/VLF band and the waves are propagating in the atmosphere (ground-ionosphere channel) with a little attenuation (~2–3 dB/1000 km), permitting that the radio waves can propagate very long distances to far from the natural or artificial sources.

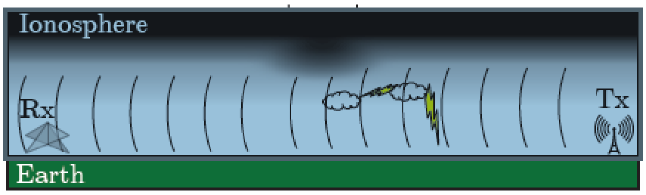

Figure 6: Earth-ionosphere waveguide (Benjamin R. and Cotts T.)

Consequently, radio instruments like AWESOME are powerful remote sensing tools, which beside the waves produced by the electronic transmitter is able to detect the waves propagating in the atmosphere and originated in natural sources. So, ELF/VLF waves can be used to study the ionospheric D-region and its disturbances, caused by various geophysical phenomena: solar flares, lighting induced electron, precipitations (LEP's), cosmic gamma ray flares, effect of geomagnetic storms, earthquake precursors, etc. For these studies, VLF signals are extremely important.

Among the electromagnetic and sound-pressure phenomena that take place in the atmosphere waveguide, specifically, we have interest for studying the occurrence of: **Atmospherics (Sferics)**, radio waves which are propagating thousands of kilometers in the so-called earth-ionosphere waveguide (EIWG). The waves in this case, practically are not dispersed. **Tweeks**, dispersion of signals except near the cut-off frequency of the waveguide. **Whistlers**, produced by lightning strikes (mostly intra-clouds). These waves correspond to audio frequencies ULF (1–30 Hz) with a maximum at: 3 to 5 Hz. A Whistler is essentially a sferic that traveled an even longer distance than a Tweek, with an additional dispersion due to the wave-particle interactions in the magnetosphere. And finally, the **Clorus**, an unexplained phenomenon that appears at sunrise, due to electrons from de Van Allen belts, falling to the Earth surface as audible radio waves.

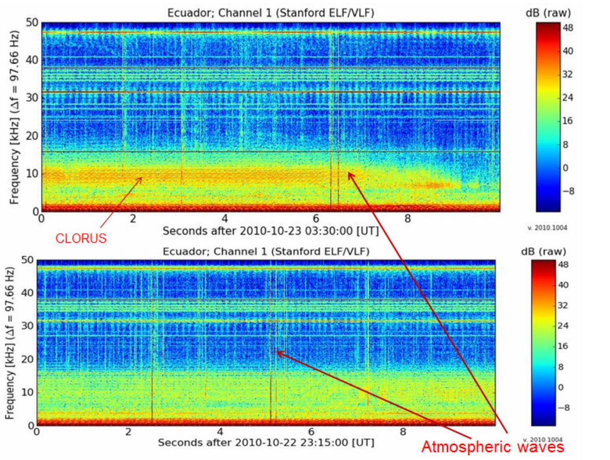

Figure 7: VLF radio waves in the ionosphere

The space sciences instruments like AWESOME, MAGDAS and SAVNET in the new Solar Physics Phenomena division of the Quito Astronomical Observatory will provide the necessary data for carry out these studies in order to understand the physics behind the wave phenomena in close connection with the Sun and its interaction on the Earth-atmosphere.

South America VLF Network (SAVNET)

Once again, the Workshops and meetings organized by the United Nations bring a great benefit and give a valuable opportunity to put in contact researchers around the world, to enter in joint collaboration promoting space science studies. This happens also in the case of the South America VLF Network (SAVNET) collaboration for expanding the net to other regions and in particular to deploy a SAVNET instrument in Ecuador; idea which has been realized in several pass space science meetings.

In the past 2012 UN/Ecuador Workshop, the feasibility for implementation of an SAVNET instrument in Ecuador has been discussed in more detail. The representatives of the Quito Observatory of Ecuador and the Mackenzie University of Brazil came to the agreement for the installation of a SAVNET receiver, in the current year. This instrument will complement the data obtained from the AWESOME receiver and will be operating at a lower bandwidth of frequencies.

Initially, the place assigned to mount the SAVNET system is on the roof of the administration building, where the facilities of the Solar Physics Phenomena division of the Quito Astronomical Observatory are available.

Figure 8: Area designated for the installation of space sciences equipment on the roof of administration building of the Escuela Politecnica Nacional.

Currently, in the Quito Observatory the SAVNET antennas have been constructed and are in the installation and calibration stage. As a result of this process, the best site for the installation of the SAVNET receiver will be defined, avoiding the environment electromagnetic noise to guarantee the best gain signal.

After this work, the equipment will be provided for its installation in Ecuador. We hope that in this year the work will be completed and the SAVNET instrument will be fully operating.

Conclusions and discussion

The international cooperation from the United Nations and Institution as the Stanford University of USA and the Presbyterian Mackenzie University of Brazil make possible to incorporate space sciences studies into the research activities of Ecuadorian universities. In this context, the Quito Astronomical Observatory of the Escuela Politecnica Nacional hosted the AWESOME and SAVNET instruments for monitoring the VLF and ELF radio signals propagating in the equatorial atmosphere. The data corresponding to this region are very important to complement the information from the African equatorial countries, in contribution to understand the physics behind the electromagnetic phenomena that take place in the Earth atmosphere.

The AWESOME receiver in Ecuador will be moved to a new site with less background noise to guarantee the quality of the data. The installation of the SAVNET receiver is in process and the final location will be determined in base of the response of the antennas. We expect to have operating the equipment in this year.

Acknowledgments

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