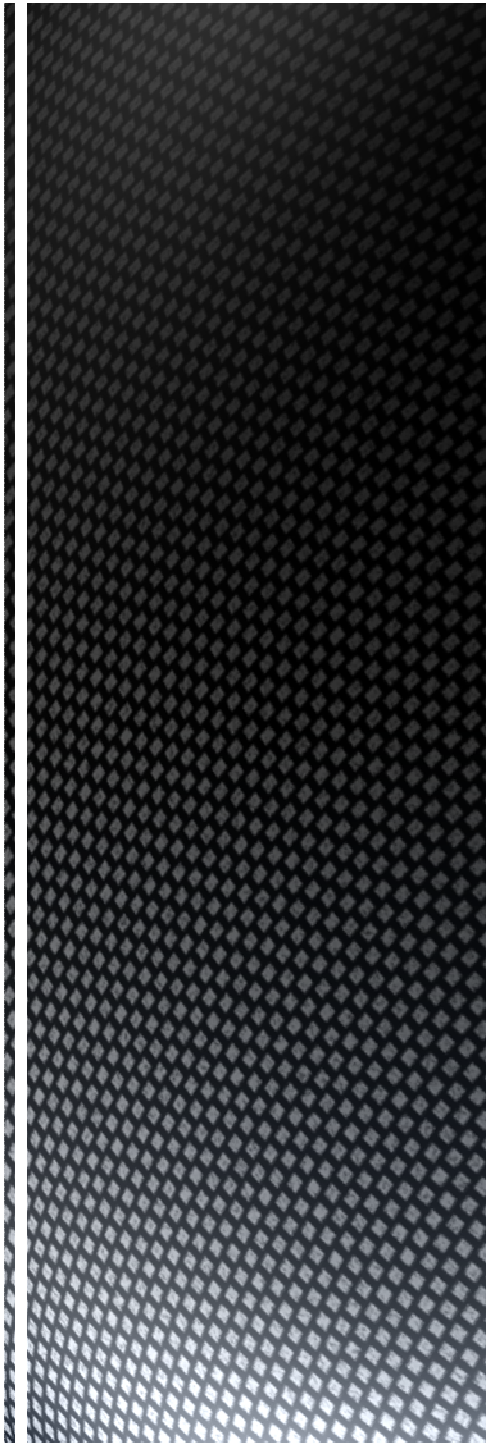
Programme for Research-Development-Innovation for
Space Technology and Advanced Research - STAR

Experimental Weak Radio Signals Monitor for Ionospheric Disturbances Analysis

RAMA

Presenter: Paul DOLEA, BITNET CCSS

Romanian Space Week , 12-16 May 2014, Bucharest, Romania



- Coordinating organization: BITNET CCSS SRL www.bitnet.info
- Project manager: Octavian CRISTEA, octavian.cristea@bitnet.info
- Partner organization: TECHNICAL UNIVERSITY of CLUJ-NAPOCA
- Partner team leader: Tudor PALADE, tudor.palade@com.utcluj.ro

- Space weather (SWE) refers to the environmental conditions in Earth's magnetosphere, ionosphere and thermosphere. These conditions are mostly due to the solar activity. Of particular interest is the monitoring and analysis of solar flares induced events.

- **The purpose of this project** is to design and experiment a low cost research grade radio system, able to detect solar flares and measure their impact on ionospheric radio wave propagation in different frequency bands.

- **Objectives**
  - Deployment of an experimental passive radio instrument able to monitor solar flares induced disturbances in low ionospheric layers
  - Experimentation of some passive radio monitoring techniques for high ionospheric layers propagation anomalies monitoring
  - Acquisition of original data sets regarding solar flares induced ionospheric radio propagation disturbances measured in Romania, especially during the solar maximum activity.

- **Estimated results**

  - RAMA will lead to the first Sun originated ionospheric radio propagation disturbances monitoring facility in Romania.
  - The project is an opportunity for the Romanian scientific community to develop knowledge in the field of ionospheric research and to participate to international space weather related programs (ESA, FP7, COST, NATO STO).

  - END PRODUCTS
    - An experimental portable low-cost research grade ionospheric disturbances radio monitoring instrument which can be made available to other interested research groups.
    - Original data sets regarding Solar flares and observed radio interferences in Romania during the solar maximum activity.

- **Human resources involved**: 40 person-month

- **Start date of the project / End date of the project**: 19.11.2012 / 19.11.2014

Work plan of the project

The project work plan is broken down into five phases covering the radio system deployment and ionospheric disturbance data sets acquisition.

Phase list

Phase no.	Phase title	Involved partners	Start month (1 ... n-1)	End month (2 ... n)
1	VLF ionospheric disturbances monitor – design and preliminary tests (TRL 2)	CO P1	1	2
2	VLF ionospheric disturbances monitor – laboratory model (TRL 3)	CO P1	3	6
3	VLF ionospheric disturbances monitor – function oriented model (TRL 5)	CO P1	7	12
4	Multi-band ionospheric disturbances monitor – function oriented model (TRL 5)	CO P1	13	18
5	Instrument demonstration and analysis of solar flares induced ionospheric disturbances as measured by RAMA in 2013-2014 (TRL 7)	CO P1	19	24

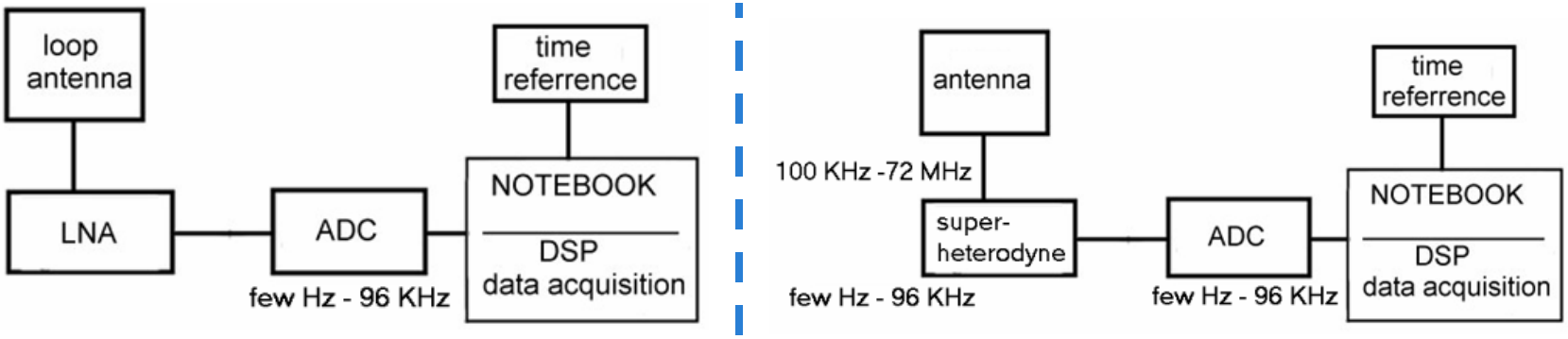
ongoing

Implementation status of the project and results

I. THE RAMA INSTRUMENT – function oriented model

(start TRL=2, achieved TRL 5)

Basically, RAMA is a very high resolution software defined spectrum analyzer, for very weak non-stationary radio signals monitoring.



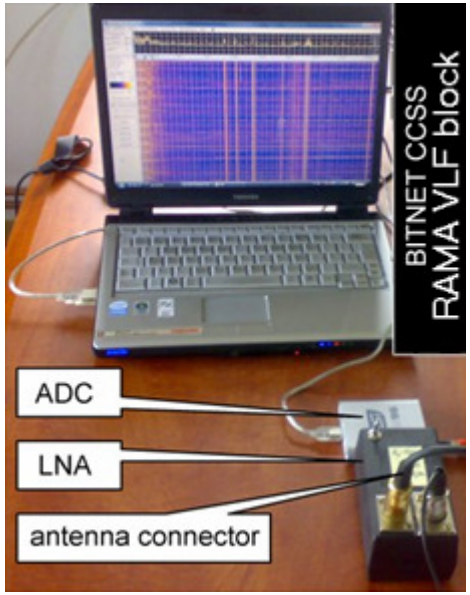
Block-diagram of the RAMA receiver:

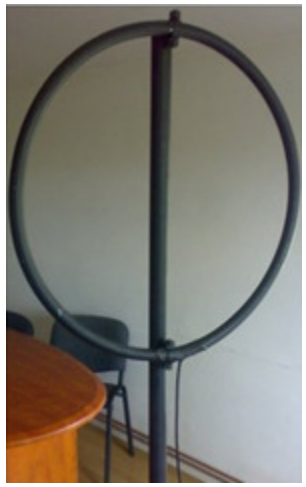
LEFT: the VLF block (few Hz-96 KHz).

RIGHT: the LF-HF block (100 KHz-72 MHz)

It is a software defined spectrum analyzer with 24 bits resolution.

Some pictures containing <u>hardware RAMA VLF blocks</u>, including some loop antenna prototypes. The large antenna is for very week radio signals measurement (especially at extreme low frequencies - ELF).





Actually, the measured and saved parameter is the peak power of a spectral line and the corresponding frequency, in a specified frequency window. Several frequency windows are monitored simultaneously. Some of them cover artificial VLF broadcasts received through ionospheric reflections in Cluj.

The dynamics of the power of these spectral lines is ionospheric propagation conditions dependent.

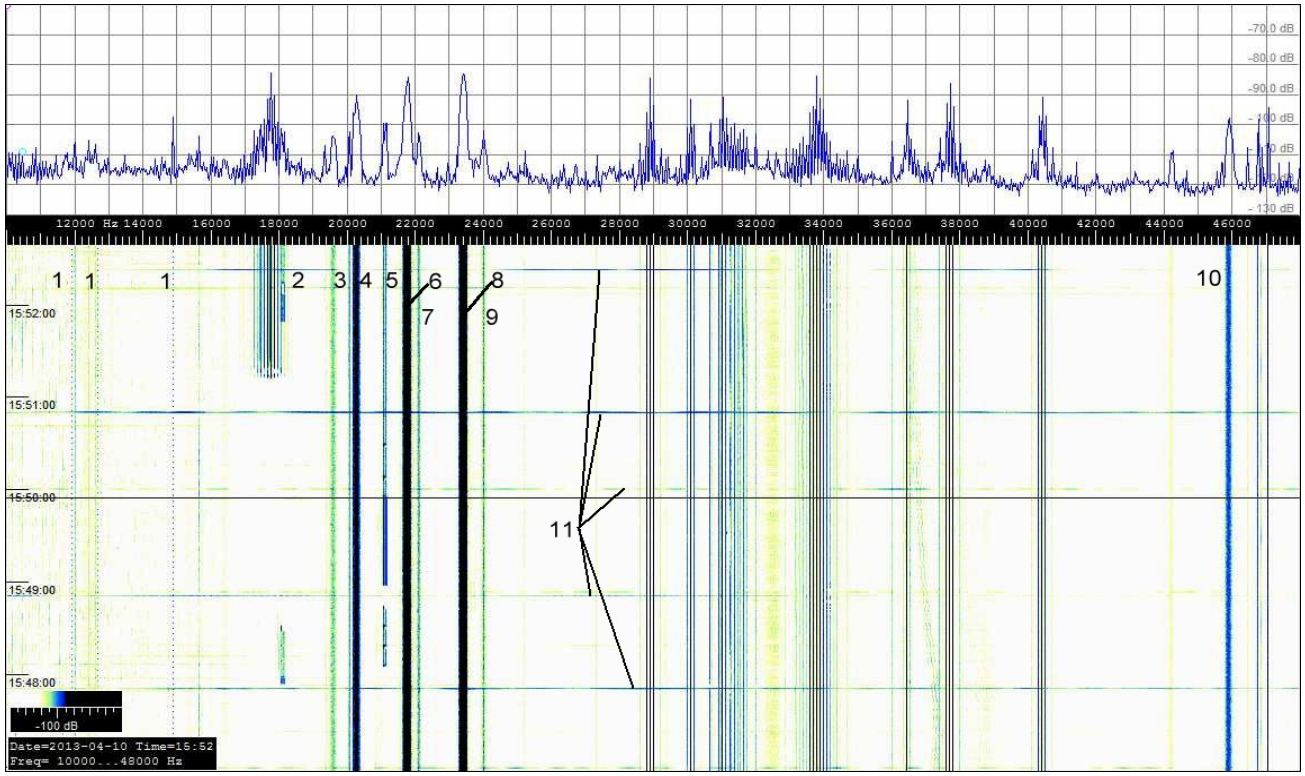
The main data acquisition related software blocks are:

- ADC control;
- spectrum analysis using FFT algorithms;
- spectrum graphical representation such as amplitude/power versus frequency, amplitude/power versus frequency and time (waterfall);
- instant or average parameters measurement (peak, noise, etc. in a given frequency band).

Data are saved in ASCII files at predefined time intervals with time stamp, for post-processing and correlation with data provided by other sensors, such as GOES X RAY FLUX.

In this configuration, the receiver has an estimated detection limit of VLF magnetic fields in the range of few tens of femtotesla.

The data acquisition related software is mostly based on open-source programs developed by third parties. The post-processing mathematical models and algorithms are developed by BITNET CCSS.

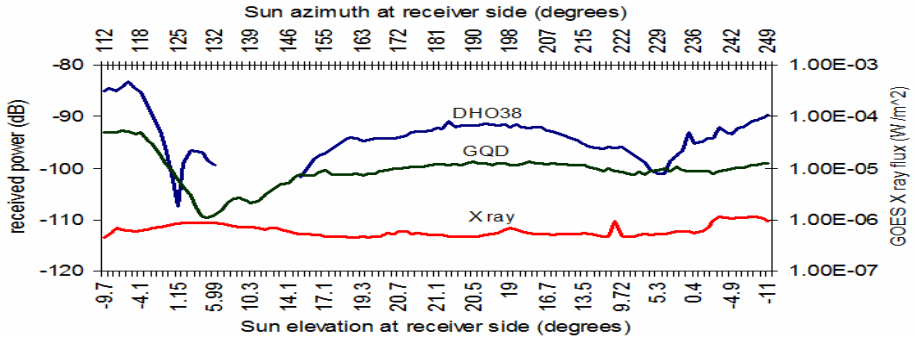


Typical (0 – 48 KHz) spectrum sample as seen on the RAMA graphical monitor. Some strong signals are received in Cluj from distant transmitters for submarines. All of them can be used for monitoring ionospheric propagation. Horizontal lines represent lightnings.

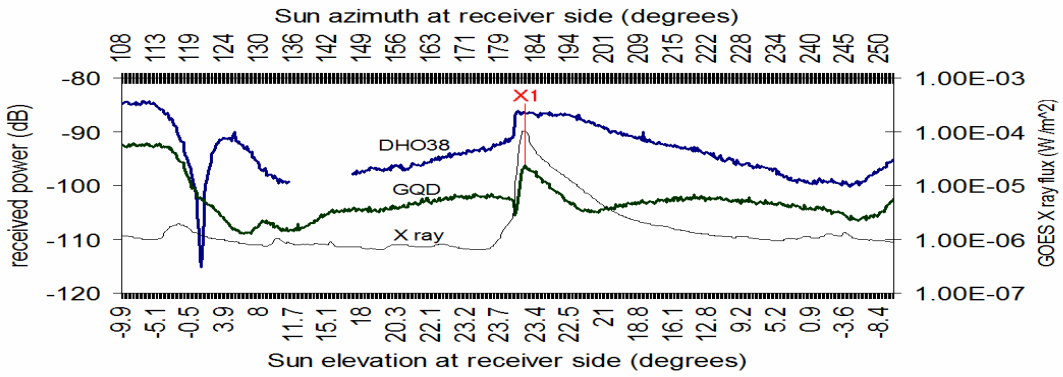
Legend: 1-Alpha (RUS); 2-RDL (RUS); 3-GBZ (UK); 4-ICV (I); 5-FTA (F); 5-FTA (F); 6-HWU (F); 7-GQD (9UK); 8-DHO38 (D); 9-NAA (USA); 10-NSY (I);

II. Acquisition of original data sets regarding solar flares induced ionospheric radio propagation disturbances

Sample propagation data sets acquired with the RAMA instrument.



Influence of Sun elevation and azimuth on the received power from 2 distant VLF (DHO38 and GQD) emitters during quiet Sun.



Influence of Sun elevation, azimuth and an X1 class X-ray flare on the received power from 2 distant VLF emitters (DHO38 and GQD).

SUMMARY OF OBTAINED RESULTS

- Experimentation of some passive radio monitoring techniques for low ionospheric layers propagation anomalies monitoring: √ **DONE**
- Deployment of the RAMA instrument: √ **DONE**
- Acquisition of original data sets regarding solar flares induced ionospheric VLF/LF radio propagation disturbances: ~ **Partially DONE** (work in progress, several months of propagation data sets already available).

OTHER WORK IN PROGRESS:
• Post-processing of acquired propagation data sets
• Development of new (proprietary) post-processing algorithms for ionospheric propagation disturbances forecast purposes.

- **Risk analysis and contingency plan (lessons learned)**

It is not the case few months before the end of the project.

The project objectives are almost accomplished.

But, since the project has been funded starting with the end of 2012 (late compared with the Solar cycle), and taking into account some 1 year for developing the RAMA instrument, we missed some large solar flares in 2013.

Project's contribution to the goal of the STAR Programme

BITNET is interested in developing high value-added prototypes and services in the field of SSA.

RAMA is a prototype instrument which can be integrated in the ESA Space Weather network of ground-based sensors. This might be of particular interest since actually there is no such sensor in SE Europe (at least not in an ESA country).

Dissemination activities (SELECTION)

- Octavian Cristea, Paul Dolea and Tudor Palade, **“Influence of Sun Elevation, Azimuth and X-ray Bursts on Long Distance VLF Radio Propagation”**, IEEE Proc. COMM 2014 International Conference, Bucharest, May 29-31, 2014 (in press).

- Octavian Cristea, Paul Dolea, Vlad P. Dascal, Tudor Palade, "**PRELIMINARY RESULTS IN DEVELOPING A ROMANIAN RADIO PROPAGATION STATION FOR X-RAY FLARES INDUCED IONOSPHERIC DISTURBANCES MONITORING**", Proceedings 19th International Conference "The Knowledge-Based Organization" - Applied Technical Sciences and Advanced Military Technologies, Sibiu, Romania, 2013, ISSN 1843-6722, pp. 66-71.

- Paul Dolea, Vlad P. Dascal, Octavian Cristea, Tudor Palade “**In-situ measurements regarding LF radio wave propagation using DCF77 time signal transmitter**” IEEE Proc. of 11th International Conference on Telecommunication in Modern Satellite,Cable and Broadcasting Services -TELSIKS 2013, Nis, Serbia

- Octavian CRISTEA, “**Romanian SSA Related Interests & Activities**”, NATO STO SCI 229 (Space Environment Support to NATO Space Situational Awareness) Meeting, Rome, 22-24 Nov. 2012.

CONCLUSIONS

- ✓ Deployment of the RAMA instrument (software defined spectrum analyzer with 24-bit resolution and frequency range: few Hz – 72 MHz): **DONE**

- ✓ The ability to monitor ionospheric propagation disturbances induced by the Sun activity: DONE

- ✓ Acquisition of original data sets regarding solar flares induced ionospheric VLF/LF radio propagation disturbances: **Partially DONE** (work in progress, several months of propagation data sets already available).

- ✓ OTHER ONGOING WORK: post-processing of acquired propagation data sets and development of new (proprietary) post-processing algorithms for ionospheric propagation disturbances forecast purposes.

Thank You for Your Attention!