The secondary radiation of the Earth's ionosphere

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The modernization of the KLAUDIA radiotelescope, used for the detection of the Earth ionosphere's secondary radiation at 40 kHz±200 Hz waves, is presented in the paper. In particular, the scope of the Very Low Frequency receiver's modernization and the construction of the high frequency grounding module is briefly discussed. The most typical features of the radio radiation of the Earth's ionosphere at 40 kHz frequency waves are presented and discussed in detail in the second part of the paper.

The construction and the modernization of the radiotelescope

The radiotelescope KLAUDIA consists of a Very Low Frequency (VLF) receiver supplied with the antenna, a high frequency grounding module, a stabilized power supply adapter and two PC computers, with a special software utility named `Radio-SkyPipe`. It is developed for collecting, processing and visualization of the collected data.

Produced in the USA, the VLF receiver was designed as a device to work with a Long–Wire (LW) type antenna [5]. The LW antenna which is non-symmetric and receives the signal at its whole length, is made up as a single wire, hung in space with one end connected directly to the grounded receiver. The antenna, made from a non-screened wire, negatively influences the quality of the received signal. The part of the antenna which is inside the building, introduces the distortions that come from the electric and electronic installations present in the building. The same situation is related to the grounding, which as a second part of the antenna, receives the signal with all its length too. In order to eliminate harmful disturbances introduced to the receiver by the antenna and the grounding, the decision to modernize the antenna, the grounding line and the receiver was made.

At the frequencies below 30 MHz, the so called "skin effect" is not important. For that reason, the antenna which is designed for receiving 40 kHz frequencies, can be generally built from any kind of the wire. In our case, the receiving part of the antenna, 7.5 m in length, was made up from the steel cord, 1 mm in diameter, brazen in a PCV braid and ended with the ceramic insulators at the binding places. The antenna guys were made of the silk–polypropylene cord, 4 mm in diameter. The antenna was hung under the angle of 30 degrees to the ground level for more circular characteristic and increasing its sensitivity to the signals with horizontal and vertical polarization. The higher end of the antenna was connected to the voltage symmetrizer, which (without using the antenna tuner) enables the connection of the wired antenna to receiver with an instrumentation of a RG 6/U coaxial cable (75 Ω wave resistance). The symmetrizer (balun 9:1), which fits the high impedance of the antenna to the low impedance of the coaxial cable, was made up by trilinear reeling of 11 coils of wire 0.3 wire covered with the gloss paint onto a ferrite ring, type Amidon T 105–2. The whole construction was put into a hermetically closed and screened case, with the mounted F socket. The symmetrizer also creates a galvanic connection of the LW antenna with the coaxial cable's screen, which is connected with the grounding in the receiver, and allows the electrostatic charges, induced in the antenna during the passing of the clouds above it, to be led into the ground. The grounding was made of the galvanized steel pipe, 1.5 m in length, thrust into the ground, to which the 4 mm in diameter cooper lead was connected. The second end was linked with the ground clamp in the grounding tune-up system. Such system composes a balance for the non-symmetric LW antenna. For the high frequency electric currents the grounding wire forms not only the resistance caused by the material resistivity, but also the wave resistance, which is much greater and dependable even on the way of the wire placement. In order to decrease the impedance of the grounding wire, the fitting system consisting of the tuned serial circuit and the meter of the high frequency current, was made. The air coil of the tuned circuit was reeled with the DNE 2.0 wire, 24 reels in total, with detaches between every 2 reels. The air capacitor, of a capacity 500 pF, was isolated from the case. The toroidal transformer, which connects the tuned circuit with the meter circuit, was reeled on the RP $20 \times 12 \times 8$ ferrite ring, made up of F81 material. The whole system was placed into a screened case. The introduction of a tuned resonance circuit into the grounding line and tuning it at a previously determined frequency, becomes a very effective grounding for the high frequency currents. The tuning of the grounding is based on the selection (with an use of a switch) of the proper detachment on a coil and then tuning up the system with an alternating capacitor on a maximum deflection of a meter.

The VLF receiver was factory constructed on a printed circuit board, and the entire system was closed in a metal case, which serves as an anti-distortion screen. Such solution was not completely proven to be useful in practice, because in order to tune the receiver, one should, firstly, remove the upper cover of the receiver (hence the system is left without the screening) and then, using the 50 kΩ set-up potentiometer tune the receiver. In the case of such receiver design, its regulation would be less accurate and very annoying. During the tuning of the system the biggest sources of distortions were the operator's hands, the computer, the monitor and an ambient illumination [2]. To improve the regulation process and in order to reduce the influence of the harmful signal on the quality and the course of the regulation, the case of the receiver was replaced, double screened of the system was used and other constructional changes were introduced. Due to the relatively large inertia of the system, the set-up potentiometer was replaced with the multi-round potentiometer, which enables the precise tuning of the system.

The VLF receiver is originally provided with the analog / digital converter, which allows to transmit the digital signal into the computer via the RS-232 serial port. During the modernization process the receiver was additionally provided with the analog low frequency output, with a help of which the analog signal can be transmitted into the computer via the sound card. The switch of the analog-digital output together with the power switch and the multi-round potentiometer were placed on the front panel of the case. The selected mode of the receiver work is signaled by the proper diodes.

The antenna socket, the power socket, the RS-232 socket, two jack-type sockets and the grounding socket were mounted on the rear panel of the case. This solution has improved the maintenance of the receiver.

Typical changes in the radio radiation's intensity of the Earth's ionosphere

The most typical radio states of the Earth's ionosphere recorded with using the VLF 40 kHz receiver are presented and discussed in the following chapter.

In particular, the changes of the ionosphere's radiation intensity caused by the changes of the solar activity during the period between sunrise and sunset and registered on January, 17 and 21, 2010, are presented in Figures. 1 and 3. It is worth to notice, that the influence of the Sun on the ionosphere is the largest in the morning and in hours before midday, the ionization process takes an advantage in these hours (the density of electrons in D layer is increasing) [3]. The recombination process, that leads to disappearance of the D layer in the night, becomes dominating in hours after noon. The phenomena of ionization, related to the sunrise and the sunset, are presented in Figures 1 and 3 as the increase and the decrease of the intensity of received radio signal.

Figures 2 and 4 present the most interesting details from plots 1 and 3 and are generally explained with the sudden distortion of the ionosphere caused by the solar flashes and the Gamma Ray Bursts (GRB) type flashes. It is worth to underline, that the solar flashes last from few minutes to about one and half hour. Those phenomena are evoked by the rapid replacement of the magnetic field's energy of the Sun by the other types of energy (mostly by the radiant energy, the thermal energy and the kinetic energy of the solar coronae particles). Let us notice, that during the solar flashes, the sunlit side of the Earth's ionosphere is being swept by the ultraviolet radiation and the hard X-ray radiation. This type of radiation penetrates the D layer with easily, thus increasing the rate of ionization process. In the case of the sudden distortion of the ionosphere as a result of the solar flash, the ionization process is observed with a small delay. This delay is equal to about several minutes when counting from the beginning of the flash. The flash duration depends on many factors, which can be: the magnitude of the solar flash, the radiation intensity and the temporary electron density in the ionosphere. The plot presented in Figure 2 shows the recombination process occurring in the ionosphere after the solar flash and persisting for more than 1 hour; the plot in Figure 4 presents slow recombination process occurring in the ionosphere, with the duration equal to about 3 hours.

The GRB flashes last from the few milliseconds to about an hour, occur more or less once per day, originate from out of the galaxy [4]. Such phenomenon is accompanied by the sudden increasing of the gamma radiation intensity on the small area of the sky. Let us notice, that the Earth's atmosphere absorbs the gamma radiation, thus the GRB flashes cannot be directly observed. From the Earth's surface the observation is possible only through the monitoring of the second radiation of ionosphere. In Figures 3 and 4 one can see an "event", which is very short, but energetic enough to significantly change the signal intensity.

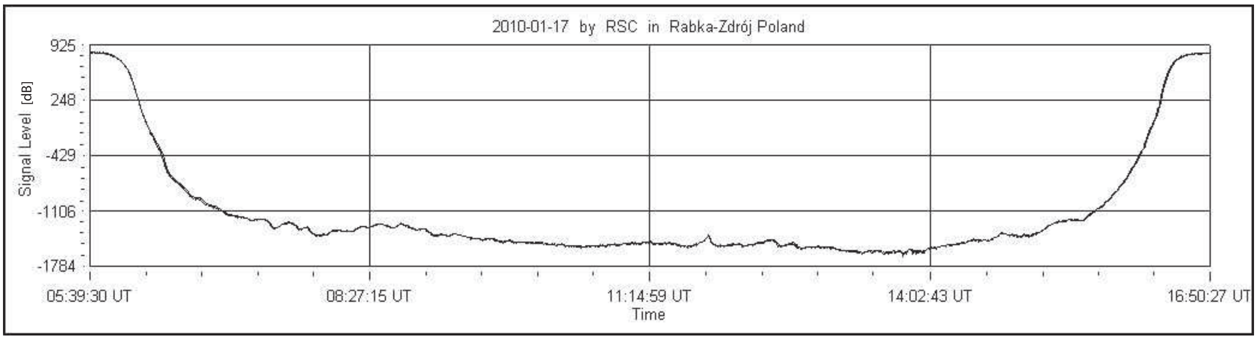

Figure 1: The changes in the ionosphere related to the sunrise and sunset and the changes evoked by the solar flash.

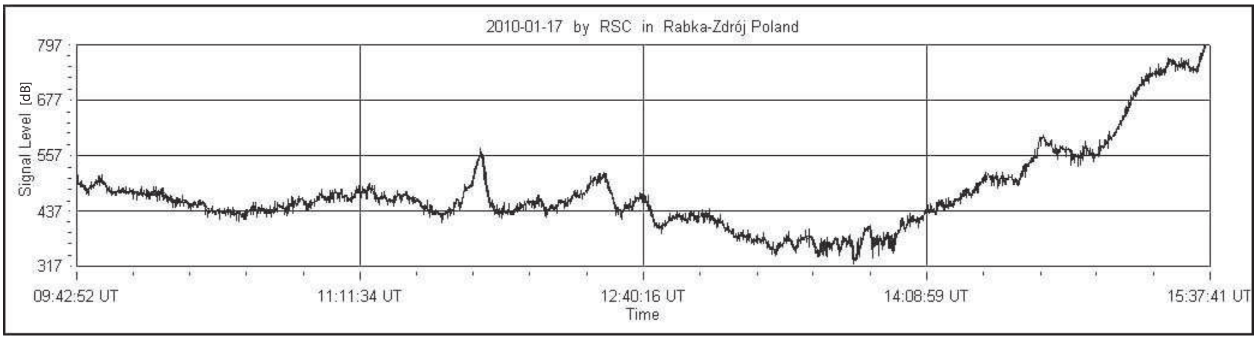

Figure 2: The recombination phase after the solar flash, that lasts for above an hour.

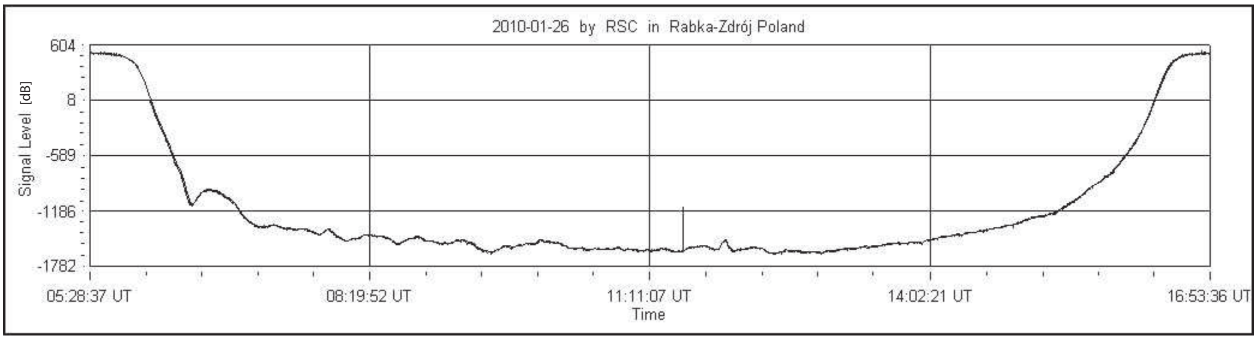

Figure 3: The changes in the ionosphere related to the sunrise and the sunset, and the changes evoked by the solar flash. The characteristic, sharp peak is being also visible on the figure, the most probably it is induced by the strong GRB flash.

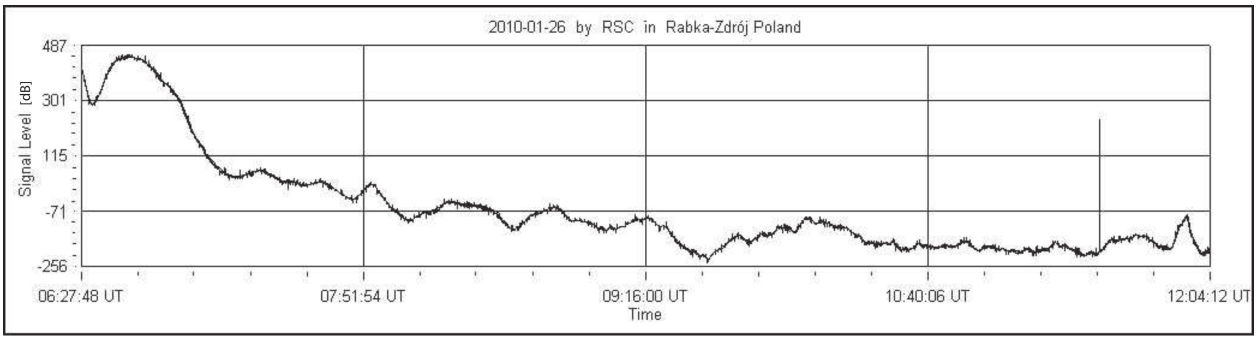

Figure 4: Slow recombination phase, lasting for few hours.

That phenomenon was recorded at 11:31:00 UT, with duration of 0.02 s. Short duration time suggests, that, most possibly, the GRB flash was registered [1].

Summary

The modernization of the KLAUDIA radiotelescope, which serves to register the Earth ionosphere's radiation at 40 kHz frequency, was discussed in detail in the present paper. The investments, that were made, enabled the significant improvement of the quality of the received signal. In the second part of the paper the typical changes in the intensity of the radio radiation evoked by the daily change of the solar activity, unpredictable radio blasts generated by our star and the GRB flash, were presented. The results prove, that the KLAUDIA radiotelescope works correctly after modernization and, in the near future, will serve for the permanent monitoring of the radio activity of the Sun.

References

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