Report on Radio Observation of Meteors (Iža, Slovakia)

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During the period from 1 to 17 August 2014 meteors were experimentally registered using radio waves. This experiment was conducted in the village of Iža, Slovakia. Its main objective was to test the technical equipment intended for continuous registration of meteor echoes, which will be located in the Slovak Central Observatory in Hurbanovo. These tests are an indirect continuation of previous experiments of observation of meteor showers using the technology available in Hurbanovo at the end of the 20th and the start of the 21st century. The device consists of two independent receiver systems. One recorded echoes of the transmitter Graves 143.050 MHz (N47.3480° E5.5151°, France) and the second one recorded echoes of the TV transmitter Lviv 49.739583 MHz (N49.8480° E24.0369°, Ukraine). Apparatus for tracking radio echoes of the transmitter Graves consists of a 9-element Yagi antenna with vertical polarization (oriented with elevation of 0° to azimuth 270°), receiver Yaesu VR-5000 in CW mode, and a computer with registration using the program HROFFT v1.0.0f. The second apparatus recording the echoes of the transmitter Lviv consists of a LP antenna with horizontal polarization (elevation of 0° and azimuth of 90°), receiver ICOM R-75 in the CW mode, and also a computer with registration using HROFFT v1.0.0f. Total of about 78000 echoes have been registered during around 700 hours of registration. Probably not all of them are caused by meteors. These data were statistically processed and compared with visual observations in the IMO database. Planned own visual observations could not be performed due to unfavourable weather conditions lasting from 4 to 13 August 2014. The registered data suggest that in this configuration were performed observations in the back-scatter mode and not in the planned forward-scatter mode. Deeper analysis and longer data sets are, however, necessary to calibrate the observation system and this will be subject of our future work. A realization of a custom radio system similar to the BRAMS system is also being considered.

1 Introduction

Reflections of radio waves from meteor trails were experimentally recorded and registered during the Perseids meteor shower activity in the period from 1 to 17 August 2014 in Iža, near (about 15 km) the Hurbanovo Observatory. A number of meteor showers occured in this period, but they cannot be distinguished using the equipment. All meteors except of the sporadic meteor background are therefore attributed to the Perseids. The distinction of the sporadic background is also difficult due to short record length and long activity period of Perseids. The main objective of the experiment was, besides obtaining data on the Perseids, testing of instruments and software to build a continuous registration of meteors in our observatory. Originally, these observations should be supplemented by the visual and photographic observations, but these observations could not be done because of the bad weather conditions.

2 Description of the Equipment

We used two very similar equipments which registered meteor reflections in two directions, one oriented towards the east and the other towards the west.

Description of the eastward station
(referred hereafter as the 50 MHz station)
A horizontally polarized log-periodic antenna with an operating range from 40 MHz to 1300 MHz with a gain of about 6 dB_d and width of the main lobe (for decrease in 3 dB) of 60° in the horizontal and vertical plane was used. The antenna was oriented towards the azimuth 90° (= east) with elevation of 0°. Given the relatively small height of the antenna, the conductive ground effect cannot be neglected and the beam peak of the antenna has an elevation of about 15°. The analog television transmitter Lviv at 49.739583 MHz (N49.8480° E24.0369°, Ukraine) was used as a source of electromagnetic waves. Of course, it is impossible to exclude the interference of other television broadcasters at this frequency. Since it is a television transmitter, one can assume circular emission characteristics of the transmitter in the horizontal plane. The communication receiver ICOM-R75 was used to detect radio waves. It was tuned to the frequency of 49.73970 MHz with CW modulation. The difference in frequencies between the transmitter and the receiver ensured a low-frequency output in the range between 880 Hz and 940 Hz. A notebook with the Windows XP operating system and the program HROFFT in 1.0.0f was used to register echoes.

Description of the westward station
(referred hereafter as the 144 MHz station)
A vertically polarized 9-element Yagi antenna with gain about 10dB_d with an operating range of 143 - 148 MHz was used. Width of the main lobe of the antenna (for decrease in 3 dB) is approximately 40° in both the vertical and the horizontal plane. Azimuth of the antenna was 270 ° (= west) with an elevation of 0°. Due to the proximity of a conductive ground a shift of emission maxima to the elevation from 12° to 15° can be assumed. The transmitter of the GRAVES radar at 143.050 MHz

(N47.3480° E5.5151°, France) was used as a source of electromagnetic waves. The communication receiver Yaesu VR-5000 was used to detect radio waves. It was tuned to a frequency of 143.05062 MHz with CW modulation. The difference in frequencies between the transmitter and the receiver ensured a low-frequency output in the range between 880 Hz and 940 Hz. A notebook with the Windows XP operational system and the program HROFFT in 1.0.0f was used to register echoes.

A separate notebook was used for each equipment to prevent disruptions of registration at the same time on both stations and to avoid interference of the low-frequency signal and a mutual interference of the registration software. Both antennas were placed under the roof of the house covered by tiles. Walls of the roof are made of lightweight bricks, so that the thickness of material in front of the antenna is only about one third of the wall thickness. Reasons for this solution were difficulties with the installation of antennas above the roof. Considering their size and the fact that it was only a short registration and testing of the equipment, we accepted this solution as sufficient. This placement of antennas caused, however, a decrease in the sensitivity of the whole equipment, the possibility of signal reflections, and worsening of emission characteristics of both antennas.

3 Data Processing

Areas of the atmosphere in which meteors overflights can be observed were identified by the conversion of emission characteristics of antennas. Figure 1 shows the boundaries of areas observed by antennas for the lower and the upper height in which it is assumed that sufficient ionization of meteor trails would cause the reflection of electromagnetic waves. We used the height of 80 km and 120 km, respectively, to calculate the boundaries. This model does not consider the impact of conductive ground to the radiation characteristics of antennas. Small circles mark areas of the highest antenna sensitivity by assuming the conductivity of the ground. Positions of the transmitters and the receiver are indicated in this Figure, too.

A total of about 78000 records was obtained during the experiment. However, probably not all the echoes came from meteors. It can be seen from the hourly values plotted in Figure 3 that there is recorded a relatively high number of echoes, but there are only small changes in the frequency of the records during a day and during the observation period. Here, it would be necessary to analyze the shapes and lengths of echoes and their frequencies for the separation of interference and sporadic meteor background from shower meteors. This would enable us to perform corrections on the non-meteoric component and sporadic meteors. Observations in periods without significant meteor showers are also needed to determine the background more reliably. This was impossible due to the short time frame. In the 50 MHz record, there is a fairly regularly occurring period with saturation of the receiver which can be attributed to the effect of the ionosphere, namely to the sporadic Es layer. A record of hourly moving averages is shown in Figure 2.

During the registration process several gaps occurred, caused

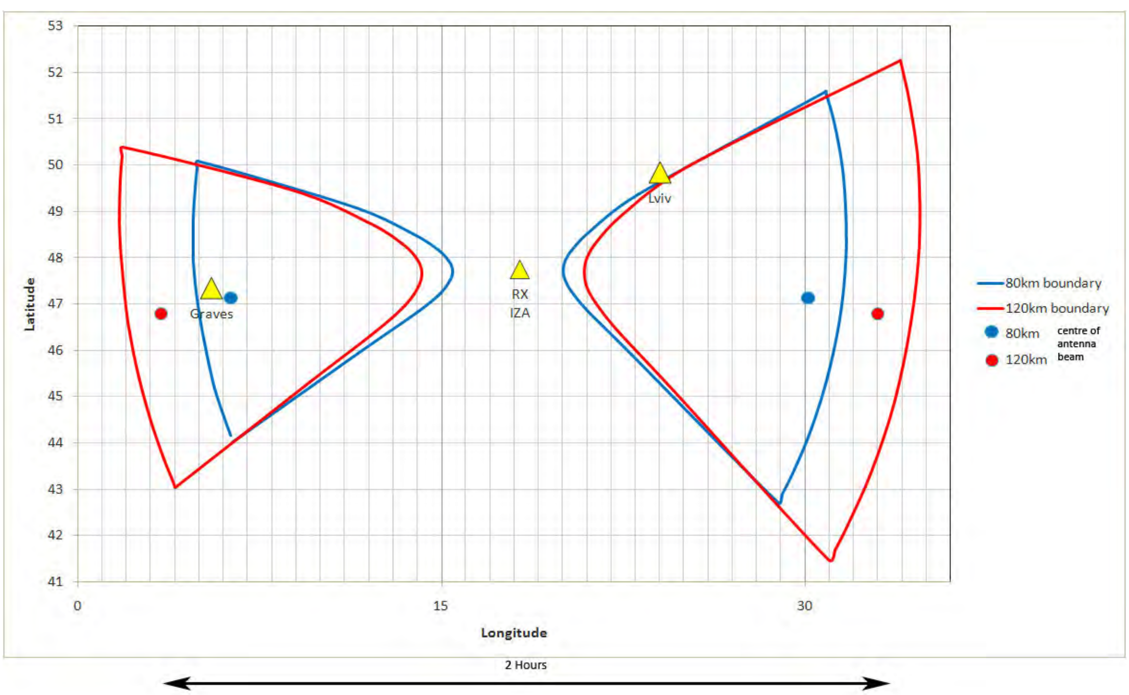

Figure 1- Theoretical field of view of both antennas calculated for the upper (120 km AGL) and the lower (80 km AGL) boundary of detectability of radiometeors.

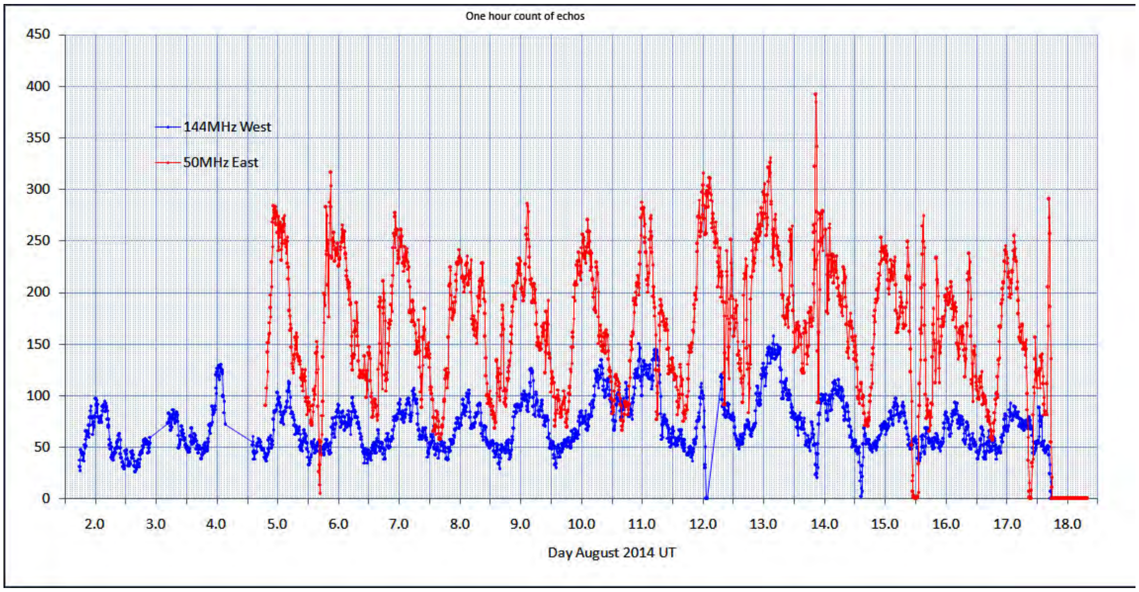

Figure 2- Hourly counts of echoes from both stations.

by either an equipment failure or its deliberate switching off during a thunderstorm. The most serious equipment failure occurred on 12 August 2014 at 144 MHz station for 5 hours due to an operating system failure of the computer. This outage occurred at time of daily maximum in frequency of meteors.

We used the program HROFFT to RMOB v. 3.0 for further processing - analysing the distribution of numbers of meteors according to the level of low-frequency signal. From these hourly data, we selected a part from 4 to 10 August 2014 at levels of 10 db and 20 db, i.e. the range of data without any interruption and without major changes in the daily amplitude in both records. Using the method of cross-correlation, we found the highest correlation between the evolution of the detection at 50 MHz and the 144 MHz for the mutual shift of about 2 hours. The dependence of the correlation coefficient for the mutual shift of records is shown in Figure 3. The correlation coefficient at 20 dB is non-significant and it reaches very low levels. The correlation coefficient reaches the maximum value of 0.73788 at the level of 10 db. By analysing the plot of correlation and by comparing it with the field of view of both antennas, we can conclude that the time difference in local time 2 hours reaches the outermost observation zones. Using calculations, it may be also determined that the maxima occur at the time when the radiant is near the upper culmination in the given area. It is therefore possible to conclude that our experiment used mainly the backscattering method and not the forwardscattering method which we originally anticipated.

Activity of Perseids

The activity of the Perseids meteor shower is evident on the plots of hourly counts of meteors (Figure 2), but it is not as clearly seen as in the plot of visual observations (Figure 4) (http://www.imo.net/live/perseids2014/). It is caused by various factors that have been mentioned above. More consistency of visual and radio observations can be found in the plots of one hour values of the total lengths of echoes in seconds (Figure 5) for both stations, especially at levels 10 and 20 dB. Similar consistency can also be found in hourly numbers of meteors for both stations at levels of 20 and 30 dB (plots are not presented). Outages of registration on 3rd, 4th and 12th August 2014 can be also seen in Figure 5.

4 Conclusion

It was experimentally found that the described equipment is applicable to record the evolution of meteor showers. To ensure continuity of registrations it is advisable to use either a more stable operating system, or double the measuring device. Both receivers need about an hour to stabilize the frequency, but slight variation of receivers is not a defect and can be compensated by changing the frequency ranges of registration. The signal from existing transmitters was discovered not to be fully suitable for meteor registration. We are currently working on an opportunity to build our own transmitter in Slovakia that would be suitable. Since the tested equipment is able to provide at least some basic information about meteoric activity and does not require high costs, we began with the work needed for its installation for continuous registration of meteors in the SCO in Hurbanovo. An extension of this basic assembly is planned, which would allow registration of spectrograms of meteor records and registration of the amplitude of received RF signals.

Acknowledgment

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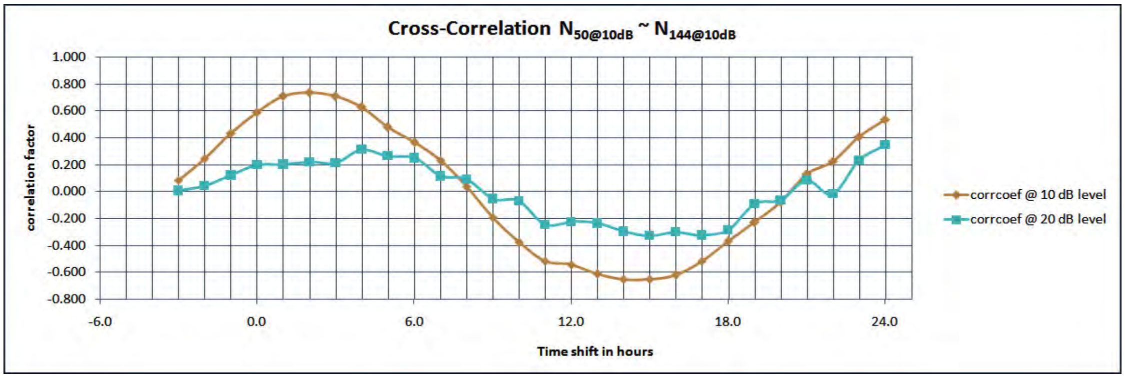

Figure 3- Cross-correlation coefficient between the number of echoes at both the 50 MHz and the 144 MHz registrations at levels of 10 dB and 20dB.

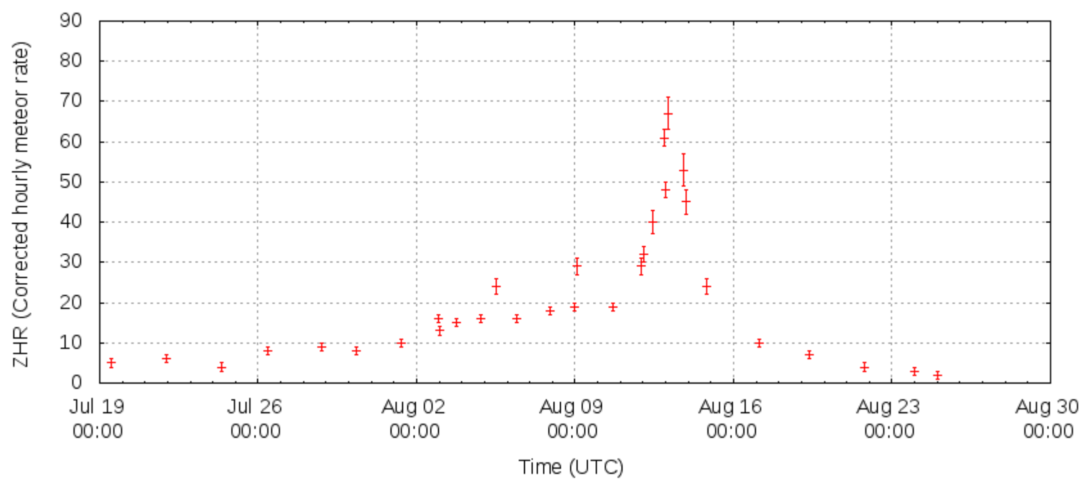

Figure 4- Reduced hourly counts of visual meteors (http://www.imo.net/live/perseids2014/).

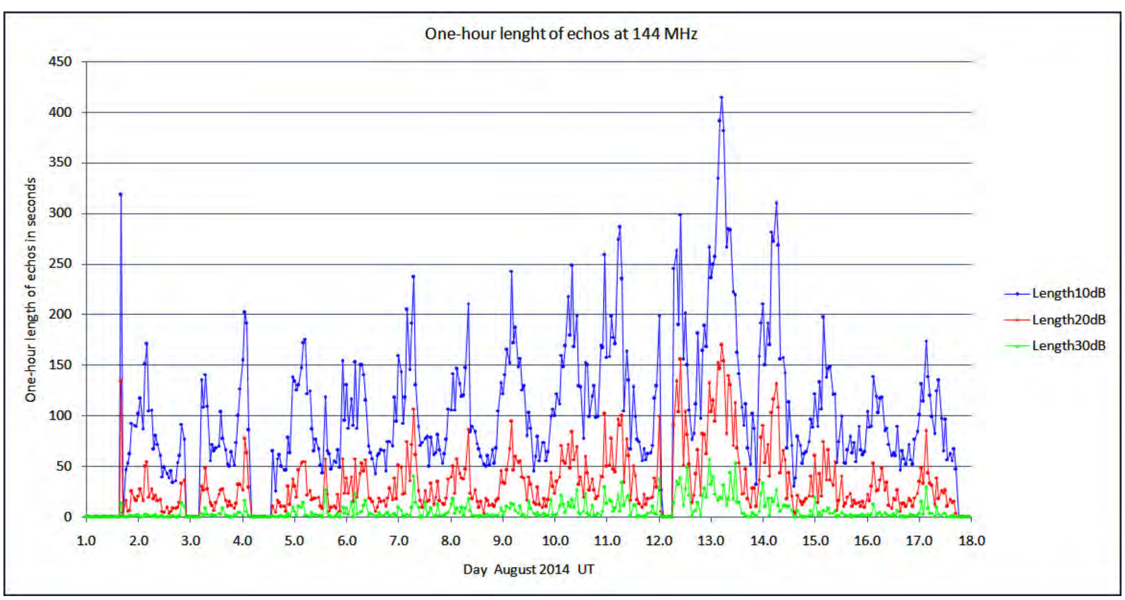

Figure 5- One-hour values of echo length sums for the 144 MHz registration at the levels of 10 dB, 20dB, and 30dB.