Geomagnetic disturbances observed at Panagyuriste (PAG) station, Bulgaria on 7-8th of September 2017 during the geomagnetic storm

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Abstract
We report results on the impact of the geomagnetic storm observed on 7-8-th of September 2017 on the geomagnetic field variations in ULF range. We apply FFT filter and spectral analysis on the search-coil geomagnetic data variations (X, Y, Z directions). We obtain the signal distribution at different frequency ranges and dynamical spectra are built. The results reveals that at geomagnetic coordinates 37.02N/ 97.24E and geographic coordinates 42.51N/24.18E the magnitude of pulsations in Pc5 and Pc4 range are more powerful and robust than Pc3, Pc2 and Pc1 range.

Геомагнитни смущения, наблюдавани по време на магнитната буря от 7-8 септември 2017г. в станция Панагюрище (PAG)

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Ключови думи: геомагнитно поле, геомагнитни пулсации, спектрален анализ, станция Панагюрище

Резюме
Докладвани са резултати от влиянието на магнитната буря, наблюдавана на 7-8 септември 2017г. в геомагнитна обсерватория „Панагюрище“, върху вариациите на магнитното поле в ULF диапазон. Върху данните за X, Y и Z компонентите, получени от search-coil магнитометър, е приложен FFT филтър и е извършен спектрален анализ. Намерено е разпределението на сигнала в различни честотни интервали и са построени динамичните спектри. Резултатите показват, че на геомагнитни координати 37.02N/ 97.24E и географски координати 42.51N/24.18E, пулсациите в диапазона Pc5-Pc4 са ясно изразени и с много по-голяма мощност от тези в Pc3-Pc1 диапазона.

Introduction

The investigation of different geophysical fields' parameters as a part of system Lithosphere - Atmosphere-Ionosphere is important to study their interactions. Geomagnetic field variations provide useful information on the behavior of other geophysical fields. Many authors (Fraser-Smith, 2009; Karakelian et al., 2002; Parrot et al., 2016; Parrot and Ouzounov, 2011; Villante et al., 2014, 2004) study potential connections between solar activity, magnetospheric - ionospheric disturbances, ocean temperature, anthropogenic noise and lithospheric processes.
Other authors study ULF pulsations and their latitudinal distribution (Bortnik et al., 2007, 2008b; Marin et al., 2014) in particular long period pulsations which were first detected by Stewart (1861) and categorized as Pc5 oscillations by Jacobs et al. (1964). Geomagnetic micropulsations provide useful information about near-Earth plasma and physical/geophysical interaction fields (Chamati et al., 2011; El-Eraki et al., 2014; Roldugin and Roldugin, 2008). Many of the ULF waves and micropulsations seen at the Earth's surface originate outside the magnetosphere: the solar wind, the magnetopause, the ion foreshock, the bow shock and probably the lithosphere. Geomagnetic disturbances/pulsations are not always connected with magnetosphere/ionosphere processes and their origin is a subject of extensive research (Chamati et al., 2009; Nenovski et al., 2013). Studying their spatial distribution, frequency characteristics, polarization characteristics and correlation with phases of storm, the diagnostic of the space conditions and conductivity structure of the Earth may be achieved (McPherron, 2005).
The geomagnetic storm on 7-8th of September 2017 was the strongest in the solar cycle 24 during the solar minimum due to solar flares with unusually high intensity and/or extremely high energy coronal mass ejections (CMEs). It was characterized by two Dst-index minima and can be considered as a sequence of two storms: the first - with Dstmin = −142 nT at 02 UT on September 8th and the second - with Dstmin = −122 nT and at 15 UT on September 8th (Blagoveshchensky and Sergeeva, 2018).
Here we report the results about ULF geomagnetic pulsation and in particular with periods 150-600s (0.002 – 0.007 Hz) and 45-150s (0.007 – 0.022 Hz) observed in the initial phase and during the magnetic storm at the Geomagnetic Observatory Panagyuriste, Bulgaria. The estimated local K-indices are presented in Table 1.

Time (UT) / Date	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24
07.09.2017	3	4	3	3	2	1	3	6
08.09.2017	7	4	5	5	6	6	5	4

Table 1. Estimated local K-indices, Panagyuriste geomagnetic observatory (PAG), Bulgaria (http://www.geophys.bas.bg/magn_data1/dailymag_en.php)

Measuring instrument and data set

The measuring instrument is located at Panagyuriste Geomagnetic Observatory, Bulgaria. It was installed on May 2003 as a part of South European Geomagnetic Array (Italy, Hungary and Bulgaria). It is three-axial induction (search coil) magnetometer and data acquisition system. The timing is provided via GPS. The station allows to conduct studies on the longitudinal propagation of ULF signal. The data acquisition system was fully upgraded on May 2016. It provides real time measurements at a sampling period of 0.01s. For the needs of our research we use filtered data at sampling period 1s.

Methodology and data analysis

Data analysis include several steps. First, we present the temporal evolution of the signal for the components X-northward, Y-westward, Z-down and we compute the signal power spectra (Fig.1). Second, we construct a band pass filter for each Pc range according to Table 2. After that, to detect the main pulsations peak, spectral analysis is built in the time range 22:00-04:59UT on the 07.09.2017 and 08.09.2017 respectively (Fig. 3(a), Fig. 3(b)).

Analysis and discussion

The temporal evolution of the signal from Panagyuriste Geomagnetic Observatory for the components X-northward, Y- westward, Z- down and it's dynamic spectra are presented on Figure 1. The analyzed time interval starts at 7-th of September 2017, 22:00 UT and ends at 8-th of September 2017, 19:00 UT. The power spectra show a maximum about 23:00 UT which slowly decreases during the next few hours (about 02:00 UT) when Dstmin = −142 nT (Blagoveshchensky and Sergeeva, 2018).
According to the information from Panagyuriste Geomagnetic Observatory the estimated local K indices for the time interval 21-00UT on 7th of September and 00-03UT on the 8-th of September 2017 were 6 and 7 respectively (Table 1).
The most powerful are the pulsations from the X component rather than Y and Z components. In this case the Y component is affected by harmonics with periods 85.3s and 204s. The Z component represents basically periods in Pc3 range (10-45s) which are typically from the dayside and it's harmonics periods are 341s and 113.8s for the time intervals with K=6 and K=7. By means of FFT filter we extract the signal over the ranges from Pc1 to Pc5 (according to the classification in Table 2). The filtered signals are presented on Figure 2, where the upper row are related with the X component at the 22UT, 23UT on 7th of September 2017 and 00UT on 8th of September 2017. The middle and the lower rows are related with Y and Z components, respectively. At the beginning 22:00UT we observe very intensive Pc5 and local Pc4 pulsations for the X and Y components, which remain persistent during the storm. The pulsations for the X component (Northward) are more intensive than these for Y component (Eastward). The Pc5 pulsations have the basic frequencies 48.8 mHz and 29.3 mHz. One hour later the emergence of Pc3 pulsations strongly affect X, Y and Z components during all the analyzed period.
We obtain for ULF wave's multiple harmonics for the X component:
-Pc5 with periods 204.8s and 341s
-Pc4 with periods 51.2s, 64s; 78.8s, 102s and 128s
-Pc3 with periods 12.1s, 15.7s, 19.3s, 23.27s, 25.6s, 32s, 37.9s, 44.5s
-Pc2 with period 6.5s
Detailed analysis by the Welch Power Spectrum Estimate was performed and results are presented on Figures 3a,

3b. The peak of the frequencies is at 23UT for the Pc5-Pc3 ranges for the all components.

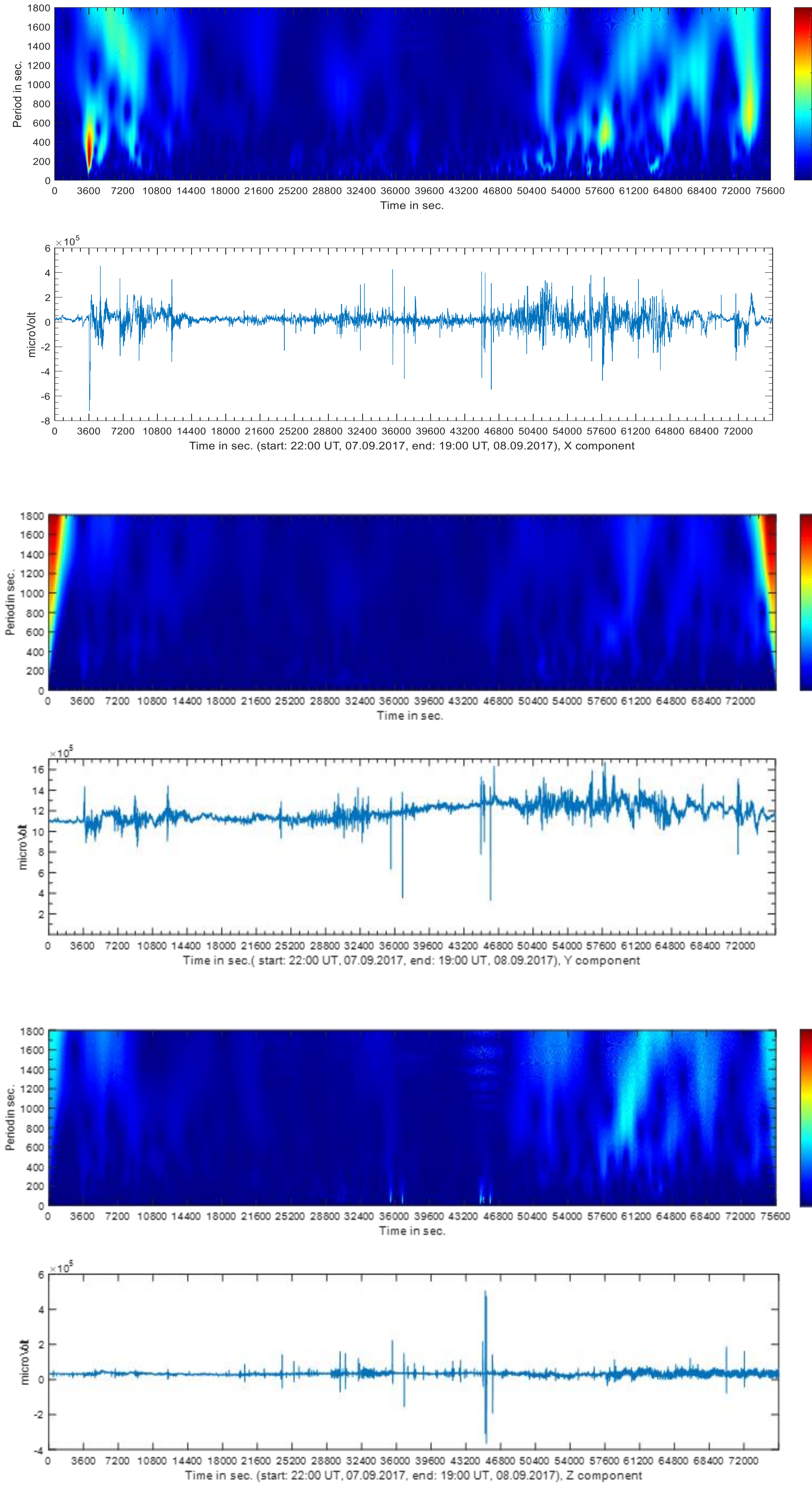

Figure 1. Dynamic spectra, X, Y and Z components

After approximately ten hours, about 12UT on 8th of September 2017 a second storm starts with Dstmin = −122 nT at 15 UT. On Figure 1 we observe pulsations in the range 400-800s (1.25- 2.5 mHz) with lower power than pulsations at 23 UT on 7th September and another pulsation with period in the range 10 – 45s (100 – 22 mHz) clearly visible for X and Z components. Pc4 and Pc3 pulsations remain persistent during the storm. The local K index is 6.

After searching and analyzing data from some INTERNAGNET stations we obtain that Pc4 pulsations have local source and it appears at different stations and different times. Its frequency characteristics are different for each station, where it was detected, for example SGO station, Finland Pc4 with periods 45-150 s and starts 07.09.2017, 04:35UT.

	Pc1	*Pc2*	*Pc3*	*Pc4*	*Pc5*	*Pi1*	*Pi2*
f	0.2-5 Hz	0.1-0.2 Hz	22-100 mHz	7-22 mHz	2-7 mHz	0.025-1 Hz	2-25 mHz
T[s]	0.2-5	5-10	10-45	45-150	150-600	1-40	40-150

Table 2

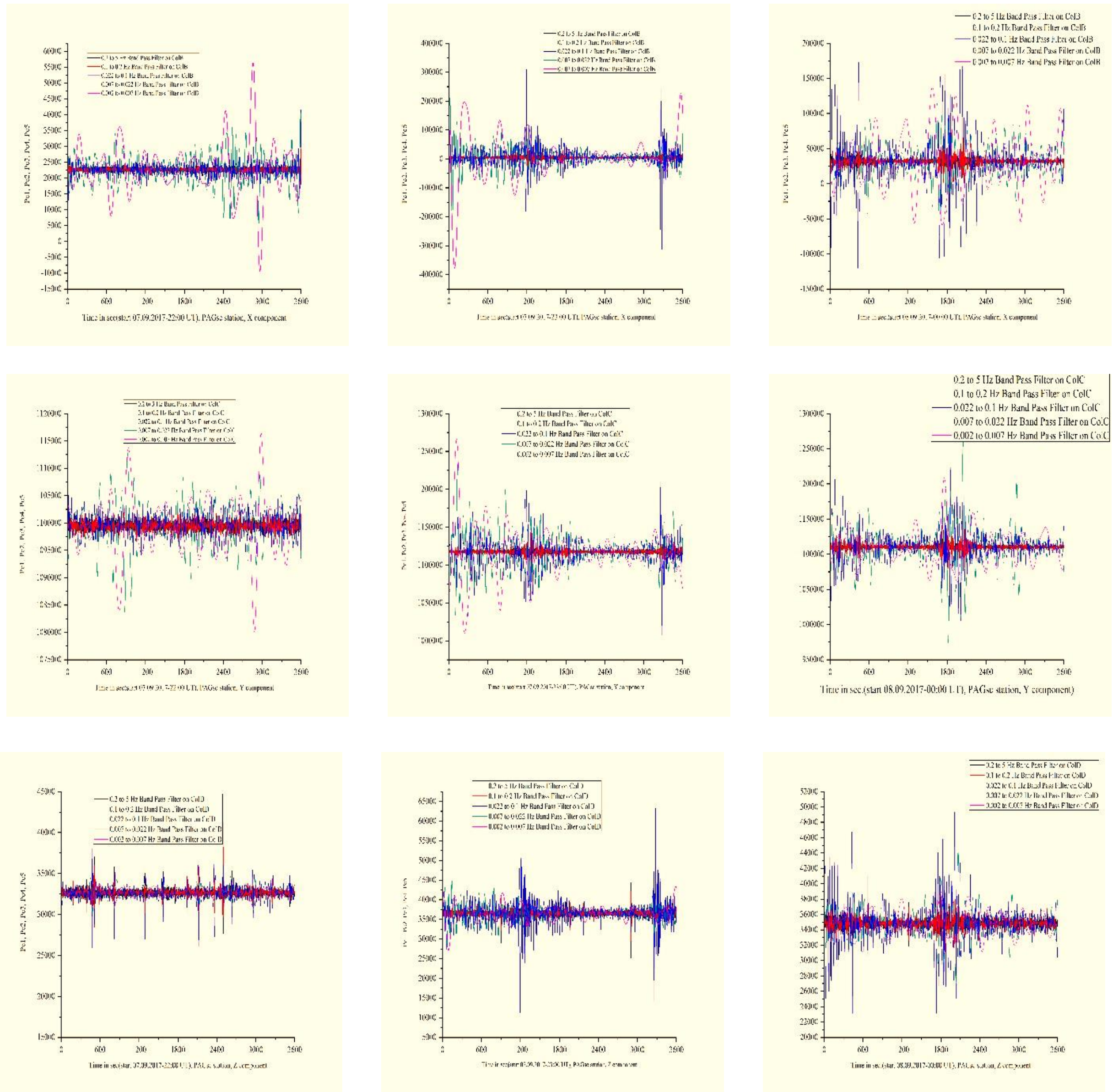

Figure 2. FFT filter

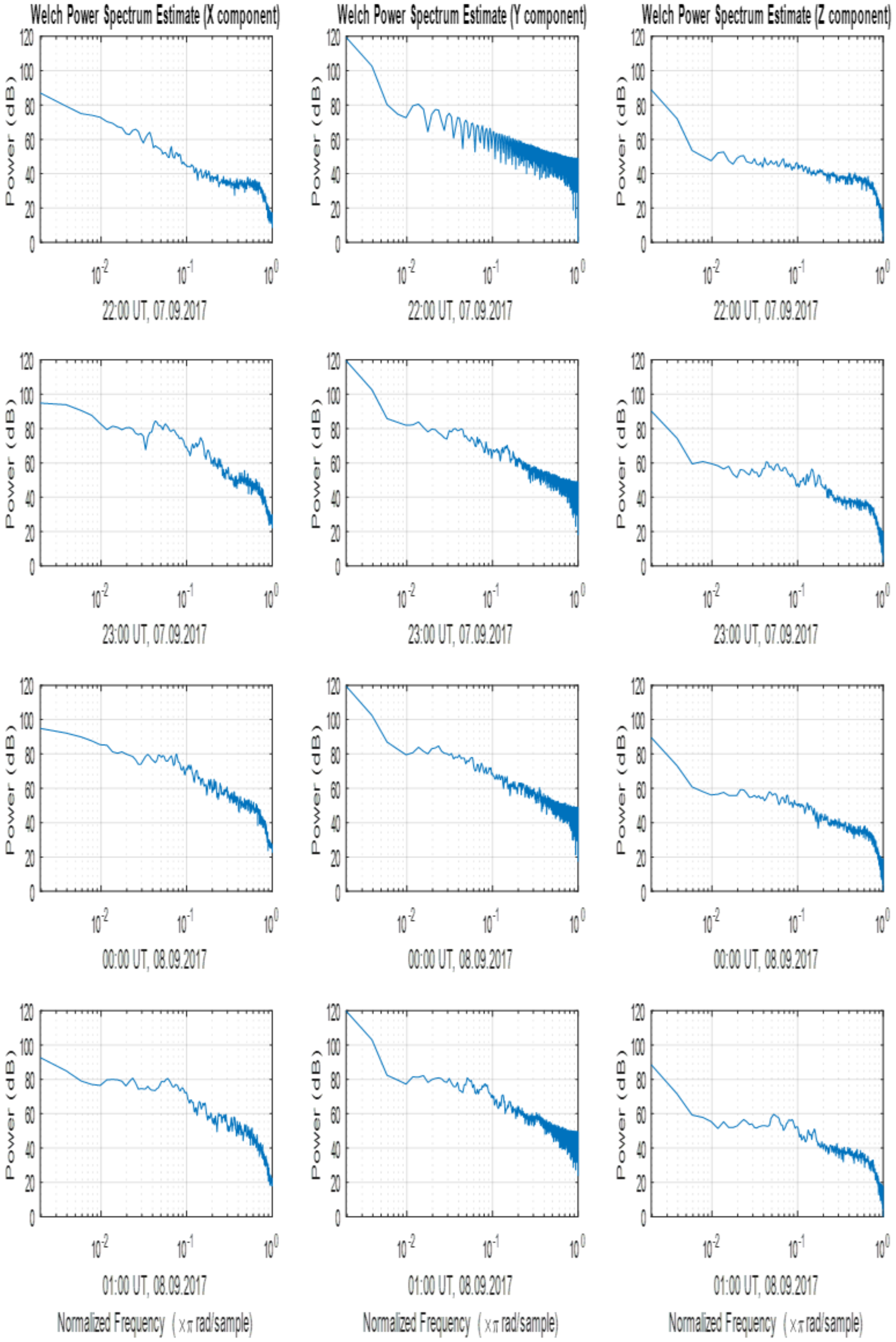

Figure 3a. Power Spectrum Estimate

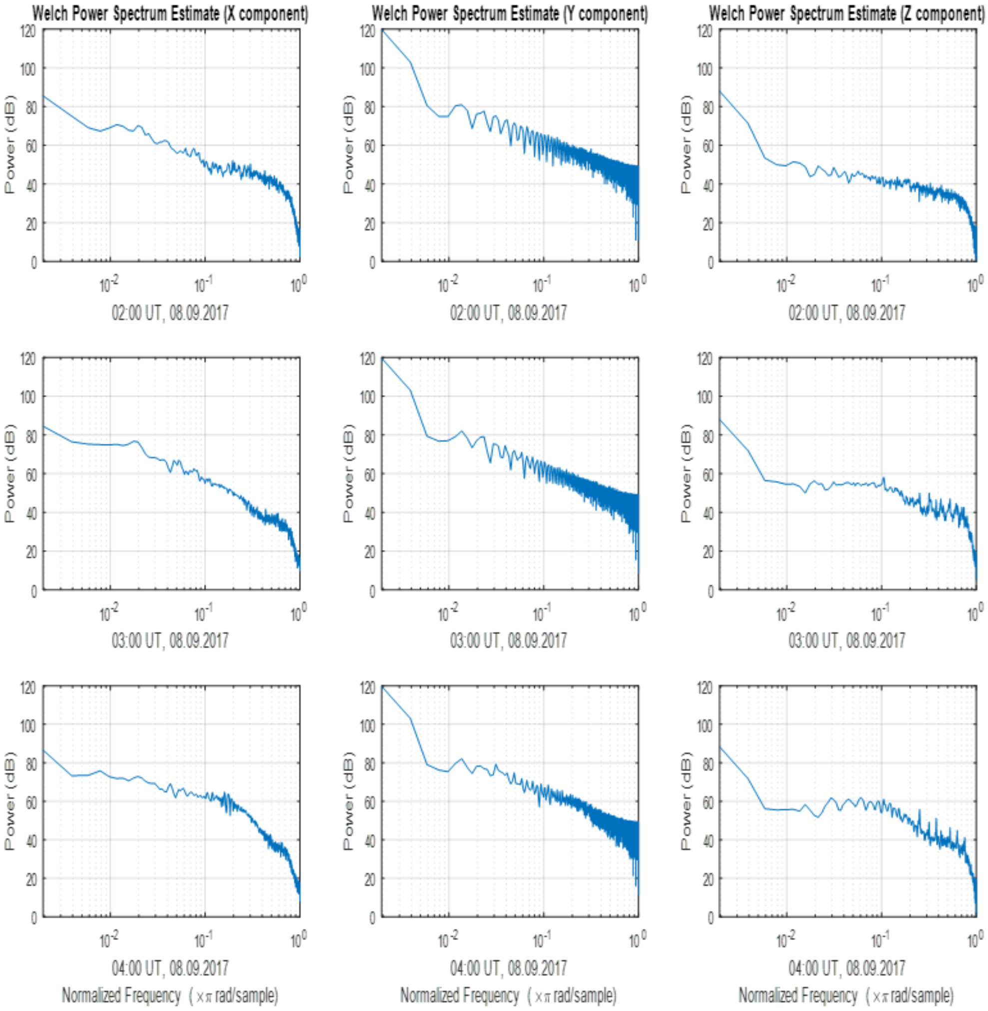

Figure3b. Power Spectrum Estimate

Conclusions

We use data from a search-coil magnetometer located at PAG station, Bulgaria (L=1.6). For our goals we perform spectral analysis to determine dynamical spectrum, temporal and spatial (partly) distribution of the geomagnetic signal, which is registered for the three directions- North, East and down/vertical. We have detected two geomagnetic storms during the 7-8-th of September 2017 at 23UT (first day) and at 12UT second day. We found that most of ULF pulsations appears trough North direction (X component). The signal frequently characteristics are precisely determined. Most harmonics contain Pc3 and Pc4 pulsations and P5 and Pc4 are powerful and robust during the time with K=6 and K=7. Pc4 pulsations have a local source.
Applying a FFT filter and Welch Power Estimate analysis we determine the main periods and peaks of the observed pulsations.

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