RESEARCH OF THE FRACTAL AND SCALING PROPERTIES OF TROPOSPHERIC AND IONOSPHERIC TURBULENCE WITH ARTIFICIAL PERTURBATIONS

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Abstract. Application of fractal-scaling analysis methods to the investigation of thermal radio radiation in the millimeter radio waves range and with presence of artificial perturbations of ionosphere has been considered in this work.

1. Introduction

Troposphere and ionosphere of Earth is in fact two huge natural research laboratories of turbulence including it artificially created case [1 – 5]. Lets consider two radio physical cases hereinafter.

Radio thermal radiation of the troposphere is a particular case of thermal (temperature) emission. The last one represent electromagnetic radiation emitted a mater and occurred due to its internal energy. The thermal radiation spectrum is limited by frequencies occupied by radio waves, i.e. by the frequencies from 3 kHz up to 6000 GHz. Special attention is paid to the frequency range of millimeter waves (MMW) 30 – 300 GHz. The reason is that the MMW actively interact with atmospheric gases especially with oxygen and water vapour as well with hydrometeor formations such as rainfalls, clouds, snowfalls etc. As a result the MMW are strongly absorbed and scattered in the troposphere [1].

Lets turn now to ionosphere. Interaction of starting and flying space rockets (SR) with environment was the subject of many researches. In particular it is found that the interaction character is significantly dependent on height h, rocket fuel components and other factors It is accepted to consider a rocket and environment interaction in three areas: in ionosphere ($15 < h < 30$ km), lower ionosphere (60–70 $< h < 120$ km) and upper ionosphere (120 – 450 km).

The numerous researches shows that basic wave processes stimulated by SR is connected to acoustic–gravity waves in ionosphere, acoustic waves in atmosphere, phenomena’s in optical and quazi–

optical range, low–frequency electromagnetic oscillations generation, geofield perturbations and forming of ionospheric holes.

Note that following processes lead to ultra–long waves generation:

- spontaneous electrical charges emergence on a rocket shell;
- MHD effects of conducting volumes;
- acoustic (vibration) oscillations of plasma in rocket torch;
- induced particles eruption.

Within this work experimental researches of fractal characteristics of real processes radio thermal radiation for wavelength of 8.2 mm. are carried out and also some experimental results for fractal–scaling methods of detection and identification of artificial ionosphere perturbations are presented.

2. Experiment

Radio thermal troposphere radiation intensity characterized as radiobrithness temperature T_I was measured by radio metrical method at wavelength λ = 8.2 mm. The radiometer was made using the modulation scheme with superheterodine receiver at input had sensitivity 0.5K and provided noise signal measurement in the frequency band Δf = 400 MHz by main and mirror channels at intermediate frequency 250 MHz.

Signal modulation with frequency 1000 Hz was curried out using ferrite switch. The horn with directivity pattern $9^0 \times 1^0$ was used as antenna. The internal calibration derive at receiver input included a waveguide switch, matched loadings at temperature of environment and liquid nitrogen, a switch electromechanical drive and its position sensors. The switch observation angle was equal to 90^0 .

The fragments of obtained measurements results of radio thermal radiation at λ=8.2 mm are given on Figure 1. There were analyzed 5 series of records produced under different meteoconditions.

The obtained data were used for phase portrait reconstructed for every series and constructed autocorrelation function of the studied series.

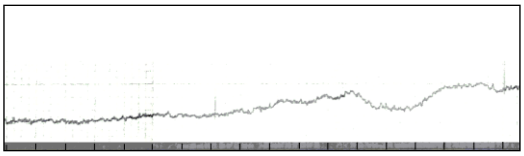
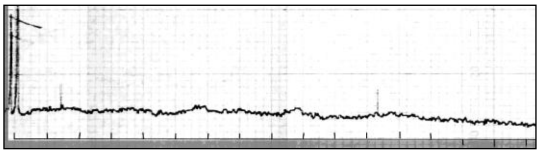
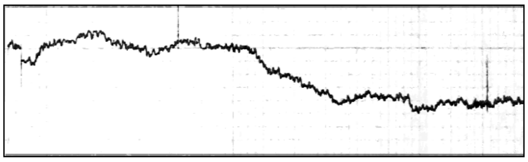
No 1. Pure Troposphere	
No 2. Cumulus Clouds.	
No 3. Cumulus Clouds Layered.	

Figure 1. Results of measurements of radio thermal radiation on $\lambda = 8.2$ mm.

3. Results and Analysis

The empirical probability distributions of radio thermal radiation values constructed at different series of experimental data differ weakly between them. Statistical characteristics analysis of radio thermal radiation was carried out with help of the Pearson diagram [1]. The Pearson diagram is shown on Figure 2 with the points corresponding to measurements series considered. On the diagram the division boundary is shown higher of which the distributions may not exist. One can see that statistical characteristics of the series No 1 and No 2 are grouped in the region of distribution law close to the Gaussian one. From the other side, the series No 3 - 5 are in the field of power law with heavy tails. It follows from this fact that it is just expedient the fractal processing.

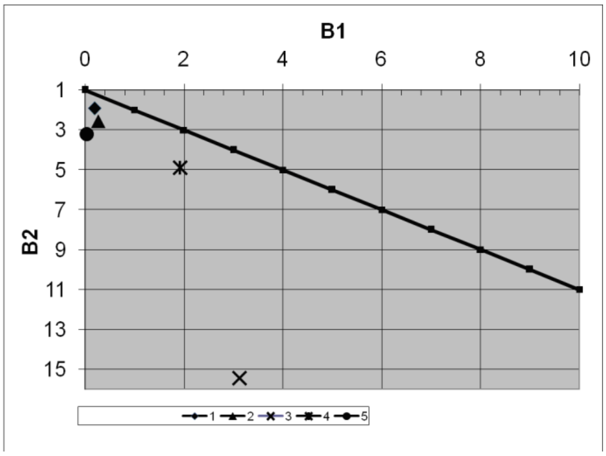


Figure 2. The Pearson diagram for series of radio thermal measurements.

The fractal dimension and Hurst index were measured [2]. Analysis made using the graphs $D_C = f(M)$ and $\log\frac{R}{S} = f[\log(t)]$ where D_C - correlation dimension, M - enclosure dimension, R/S - ratio of swing to dispersion, t - "time" (record number at time axis). Estimated of correlation dimension D_C and Hurst index are given in table 1.

Table 1.

Fractal characteristics of radio thermal radiation in MMW range.

Series number	Correlation dimension D_C	Hurst index H
1	1,976	0,024
2	3,549	0,451
3	6,573	0,427
4	3,466	0,534
5	2,894	0,106

The following is some experimental results of fractal methods of artificial ionosphere perturbations detection and identification [3, 4]. Fractal data processing was being held on measurement series of about 5 min. duration. During the processing fractal dimension *D* and also enclosure phase portrait dimension of measurement series were defined [2, 6].

Fractal dimension was being defined basing on correlation index slope angle:

$$C(r) = \frac{1}{N^2} \sum_{i,j=1;i\neq j}^{N} \eta(r - |X_i - X_j|), \quad D_C = \frac{\log(C(r)) - const}{\log r},$$

when $\eta(z)$ is Heaviside function, N is number of samples, r is distance between points pair, X_i, X_j is sample elements, D_C is correlation fractal dimension. In this case number of samples was equal to 500, i.e. dimension was defined by sliding window of 500 measures.

The enclosure dimension was defined via Grassberger-Procaccia algorithm.

4. Conclusions

Effectiveness of radio physical researches may be increased significantly due to accounting wave phenomena fractality which is developing during all stages of radiation, scattering and wave distribution in different environment. Radical distinction between fractal–scaling and classical method is connected to principally different approach to main components of signal and field [1 – 6]. It allows to move on new level of information structure of real non–Markovian signals and fields.

In this work for the first time, the fractal characteristics of radio thermal troposphere radiation in the MMW range were measured. The positions given in the work will be widened in the future. It is obvious that estimate of parameter H current value can be lightly introduced now into theory and practice of classical processing of radar data on noise background. Considerable changes of acting radio system schemes are not required.

We clearly see scaling of turbulence and it’s fractality at non–Gaussian distributions in radio thermal radiation scale. Here far correlation model must work and hence super diffusion and sub diffusion modes must exist and stable distribution functions with informative “tails” must be observed.

Results obtained in report shows prospects of fractal–scaling information processing use in scientific and applied tasks of troposphere and ionosphere investigation by use of modern radiophysics methods.

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