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NEURAL NETWORKS TECHNIQUE OF LAYER F2 CRITICAL FREQUENCY FORECASTING ABOVE STATION GAKONA (HAARP) AT THE ACCOUNT OF NEAR-EARTH SPACE PARAMETERS AND GEOMAGNETIC DISTURBANCE

O.M. Barkhatova[1], A.E. Levitin[2]

[1]*Radiophysical Research Institute (NIRFI), Nizhny Novgorod, Russia*
[2]*Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Troitsk, Russia*

Abstract

In these work nonlinear correlation dependences of ionospheric layer F2 critical frequency above station Gakona (HAARP) from a number of solar-magnetospheric parameters are established. For this purpose the special technique based on creation of the "locking" block of an entrance package of the data, directed in Elman artificial neural network (ANN) is developed. As a result of neural network numerical experiments the forecast of critical frequency values for intervals from 0.5 till 2 hours is executed. Maximal effectiveness of ionospheric layer F2 critical frequency forecasting in sub-auroral region at use of the offered method are 93% and 83% for 0.5 and 1 hour forecast, accordingly. For long-term forecast on 1.5 and 2 hours corresponding efficiency are 75% and 67%.

1. Introduction

At the present time the problem of short-term and long-term forecasting of dominant ionospheric parameters (critical and maximum observed frequencies) still remains actual. First of all, it is connected to a problem of ensuring of a continuous radio communication in various ranges of frequencies. The development of neural networks techniques is one of the effective approaches to forecasting of ionospheric parameters and diagnostics of its changes depending on a level of geomagnetic disturbance [1]. Such techniques combine correlation processing with nonlinear transformation of investigated multifactorial sequence.

In the present work the problem solving of critical frequency ionospheric layer F2 forecasting above the high-altitude station Gakona (Alaska) located near of heating test bench HAARP is submitted. Geomagnetic coordinates of this sub-auroral station: 63.54° MLat, 265.69° MLong, geographical coordinates – 62.39° NLat, 214.87° Elong (LT=UT-9h). The region of station Gakona location is near to an auroral oval. It is well-known, that the high-latitude ionosphere is most subject to influence of geomagnetic disturbances caused by Solar-terrestrial connections. Therefore the forecast of critical frequencies in this region can be successful at the account of a number of Solar-magnetospheric parameters making an impact on a state of an ionosphere.

In this work to such parameters have been referred: Solar wind parameters (SWP) and interplanetary magnetic field parameters (IMF), intensity of X-ray and ultra-violet radiation, intensity of a luminescence of the night sky on wave-lengths 6300 Å, 5577 Å, 4278 Å, components of a geomagnetic field (H, D, Z), components of symmetric and asymmetric parts of a low-latitude disturbance field (SYM, ASY), the magnetotail stretching index (bi), a planetary index of global geomagnetic disturbance Kp. Daily features of behavior of an ionosphere also were taken into account at performance of the forecast. For this purpose the full daily interval has been divided into day time and night parts. This division was carried out on value of a Solar zenith angle at height of 250 km above station Gakona. As a result the day time part is accepted for a time interval 14.45-4.00 UT (05.45-19.00 MLT) and a night part – for an interval 04.15-14.30 UT (19.15-05.30 MLT).

2. Data preparation

In the present work the opportunity of forecasting of sub-auroral ionospheric layer F2 critical frequency changes at the account of dominant Solar-magnetospheric parameters was considered in an interval from October, 20 to November, 2, 2005. However during the selected interval in numerical values of critical frequency data were gaps, which connected to an exhaustion of an ionosphere at night. These breaks have been filled with a method of interpolation by a cubic spline (Fig. 1).

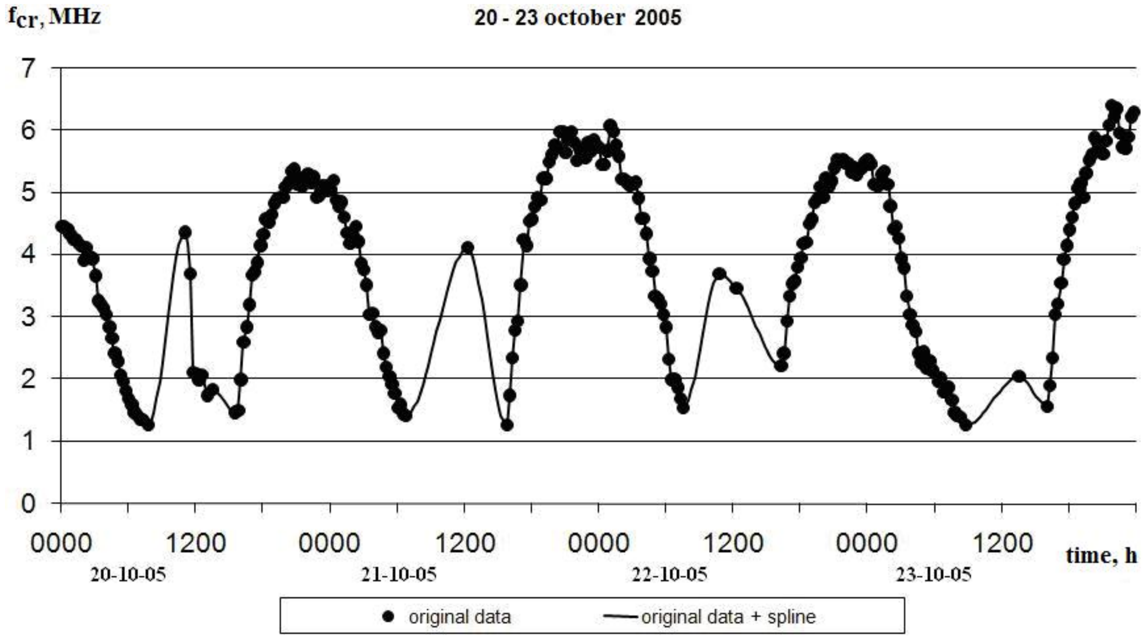

Fig. 1. Interpolation of the critical frequency original data by a cubic spline. Markers make a note of critical frequency original values from Gakona station, the continuous line corresponds to the values interpolated by a method of a cubic spline

3. Forecasting of critical frequency. A "locking" method

For realization of numerical experiments on critical frequency forecasting two-layer recurrent Elman network with the increased number of connections has been developed due to submission of entrance data file on the second hidden layer. Such architecture allows to receive sufficient branching of a network and ladder logic of internal nonlinear memory.

To account for daily features of critical frequency behavior has demanded creation of the additional block which "locks" an entrance data package. For this purpose all entrance data package of Solar-magnetospheric parameters has been divided on "day time" and "night time" parts. Such division was realized proceeding from the general accepted ideas about physical processes in a polar ionosphere. The SWP and IMF data, components of a geomagnetic field and indices SYM and ASY were considered equally effective both for day and night times. The X-ray, ultra-violet radiation data and Solar zenith angle data have been referred to the day time parameters while the data of low energy particles precipitation (intensity of the night sky luminescence), values of indices Kp and bi – to the night time parameters. The block of "locking" in this case represented an original key which allowed using for day time forecasting only "day time" parameters from an entrance file, without recruiting "night time" parameters. Similarly for night time forecasting "night time" parameters are linked up only. The complete architecture of a neural network is submitted on fig. 2.

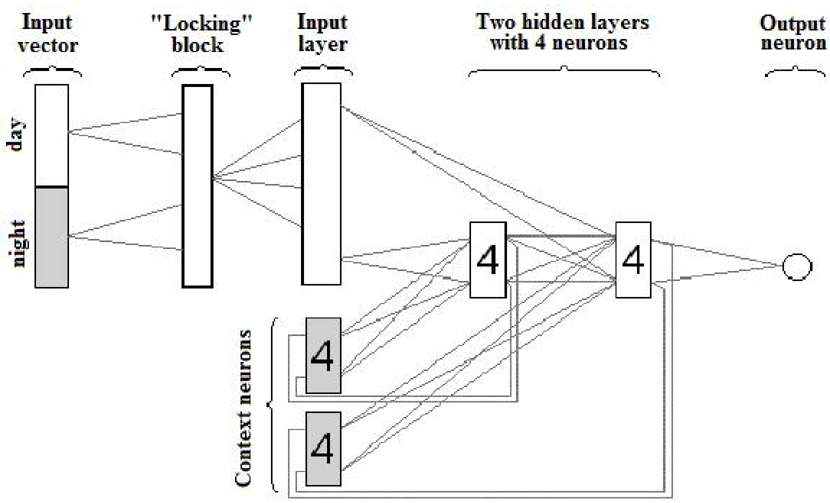

Fig. 2. The architecture of Elman network used in this work

Before direct statement of neural network forecasting experiments for each of Solar-magnetospheric parameters has been determined the delay time of magnetosphere-ionospheric physical process development. The list of parameters and corresponding forestalling times are submitted in Table 1. For the others Solar-magnetospheric parameters used in neural network experiments, the forestalling time was considered equal to zero.

Solar-magnetospheric parameters	**Optimal quantity of forestalling time, hours**
B (IMF magnitude)	2
By (component of IMF)	2
Bz (component of IMF)	2
N (SW concentration)	3
V (magnitude of SW velocity)	2
Vy (component of SW velocity)	3
Vz (component of SW velocity)	2.5
NV^2 (dynamic pressure of SW)	2.5
T (SW plasma temperature)	2.5
H (horizontal component of GF)	1
Angl (zenith angle)	0.5
SYM-D (SYM azimuthal component)	0.5
b2i (the magnetotail stretching index)	2

Table 1. Optimum forestalling times for various Solar-magnetospheric parameters (SW - a Solar wind, GF - a geomagnetic field)

Neural networks experiments on ionospheric layer F2 critical frequency forecasting with using of Solar-magnetospheric parameters was carried out in the following sequence:
1) The fixed day time parameters were exposed and forecasting on a full daily interval with using of parameters for a night time and their combinations was carried out;
2) After definition of their most effective combinations, the search for day time parameters with the fixed combinations for night time was carried out.
Thus, with help of ANN has been determined the parameters exerting the greatest influence on increase of a forecasting effectiveness on day time and night time intervals. Achieved to forecasting effectiveness (PE) (see, for example, [2]) are submitted in table 2.

The forecast, hours	**Average PE, %**	**Combinations of Solar-magnetospheric parameters**	
		Day time	**Night time**
0.5	93	Xr 10	Bz, SYM-D
1	83	N, Angl	Vz, I1
1.5	73	Angl, Bz	By, Vz
2	64	Xrs 10	Vz, NV^2

Table 2. Results of critical frequency forecasting by a "locking" of entrance data sequence. Here Xr10 - ratio of X-ray radiation intensity on wave-lengths 0.05 - 0.4 nm (Xrs10) to intensity on wave-lengths 0.1 - 0.8 nm (Xrl10), UV4 - intensity of ultra-violet radiation on wave-length 28.5 nm, Z and H - vertical and horizontal components of GF, accordingly

4. Conclusions

For the critical frequency forecasting the submitted method of "locking" an entrance data package with using of Solar-magnetospheric parameters is effective enough on intervals from 0.5 to 2 hours. Average forecasting effectiveness at 0.5 and 1 hour are 93% and 83%, accordingly, and at the forecast at 1,5 and 2 hours – 73%, 64%, accordingly. The analysis of received forecasting results has allowed to establish the basic groups of the most effective Solar-magnetospheric parameters which raise the forecast on day time and night time intervals. In the day time a primary role play such parameters as Solar zenith angle, intensity of X-ray radiation, Solar wind and an interplanetary magnetic field parameters. At night time on forecast efficiency is influenced the ratio of luminescences of the night sky intensity and, hence, the energy of precipitation particles, a D-component of index

SYM, dynamic pressure of a Solar wind, component By of an interplanetary magnetic field, and component Vz of a Solar wind velocity.

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