FREQUENCY DEPENDENCE OF THE IONOSPHERE
SCINTILLATION PARAMETERS ON THE OBSERVATIONS OF
COSMIC RADIO SOURCES AT THE DECAMETER WAVE RANGE

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ABSTRACT. When signal from radio source propagates through irregularity layer in the ionosphere it has fluctuations of the amplitude (scintillations) which time spectrum has power form with index $a = 3$. It was shown that such form of the time spectrum of amplitude fluctuations caused by power form of the spatial spectrum of electron concentration ionosphere irregularity with index $p = a + 1$, i.e. $p = 4$. Based on theoretical preconditions for such form of the spatial spectrum the frequency dependence of scintillation index $m$ (scintillation intensity characteristic) was obtained in form power function: $m \propto f^{-n}$, $n = (p + 2)/4$, thus $n = 1.5$. Similar frequency dependence of the scintillation index was observed experimentally for case of weak scintillations ($m < 0.5$). In this work the frequency dependence of scintillation parameters was analyzed on long-term observations of power cosmic radio sources on radio telescope URAN-4 at 20 and 25 MHz. The results were compared with results of earlier carried out investigations.

Key words: radio sources: ionosphere scintillations, decimeter range, frequency dependence.

1. Introduction

When signal from cosmic radio source propagates in the inhomogeneous ionosphere it has fluctuations of intensity or scintillations. Scintillation effect can be characterized by scintillation index and time spectrum of fluctuations. Scintillation index defines as (Liu et al., 1986): $m = \sqrt{(I^2 - \langle I^\rangle^2)/(\langle I^\rangle^2)}$, where $I$ – intensity of the received radio signal, angle brackets are the time averaging. Time spectrum of the intensity fluctuations has power shape with exponent $a = 3$ and caused by the power form of the spatial spectrum of the ionosphere plasma irregularities $\Phi_{\text{AN}}(k) \propto k^{-p}$ ($k$ – wave number) with index (Yeh, 1982): $p = a + 1$.

Scintillations on the medium irregularities can originate under the conditions of strong and weak wave scattering (Franke, 1987). If $m \approx 1$, then scintillations are strong, saturated and if $m \ll 1$, (usually $m < 0.5$) then scintillations are weak. The single scattering of the radio signal occurs at weak scintillations and radio signal suffers multiple scattering in a case of the saturated scintillations. Data interpretation complicates by absence of the analytic decisions for strong scintillations, the approximate methods are use in this case.

Ionosphere scintillations were observed in the range from 10 MHz up to 6 GHz (Wu, 1983). For weak scintillations the frequency dependence was obtained as (Liu et al., 1986): $m \propto f^{-n}$. Thus scintillation effect is more significant as wave length of radio signal is larger.
Results and their discussion

Histograms of the spectral indices calculated from scintillation indices obtained from observations of power radio sources at frequencies 20 and 25 MHz were carried out.

2. Observation data

Ionosphere scintillation parameters were obtained from observations of power cosmic radio sources – 3C144, 3C274, 3C405, 3C461 which were carried out on the radio telescope URAN-4 during 1998-2007 at 20 and 25 MHz. Observation method and processing technique were considered in the works (Derevyagin et al., 2005; Panishko et al., 2019).

Index $\alpha$ can be determined on the slant part of the time power spectrum received from observation. Index $n$ can be derived on the index $\alpha$ from equation (1) and also index $n$ can be obtained from the scintillation index measured at two frequencies (equation (2)) as (Yeh et al., 1982):

$$n = (p + 2)/4.$$ (2)

In such case for power form of the spatial spectrum $n \approx 1.5$. In the present work the analysis of the ionosphere scintillation spectral indices calculated from scintillation indices obtained from observations of power radio sources at frequencies 20 and 25 MHz was carried out.

Table 1. Mean values of the scintillation parameters

| Source   | $m_1$ | $m_2$ | $n$  | $p_1$ | $p_2$ | $p$  |
|----------|-------|-------|------|-------|-------|------|
| 3C144    | 0.29  | 0.42  | 1.8  | 3.7   | 3.4   | 5.4  |
| 3C274    | 0.19  | 0.25  | 1.2  | 3.1   | 3.4   | 2.8  |
| 3C405    | 0.20  | 0.28  | 1.6  | 4.6   | 4.6   | 4.3  |
| 3C461    | 0.18  | 0.28  | 1.9  | 4.0   | 4.1   | 5.4  |

4. Conclusions

From the observations of 4-th power radio sources on RT URAN-4 at 20 and 25 MHz the values of the spectral index were obtained during 1998-2007. Frequency dependence differs for each source that means different conditions of scintillation occurrence. Interpretation of this data requires the attraction of many factors which influence on the results including multiple radio wave scattering and geometry of the scintillation effect.

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