Communications

An Interpretation of Anisotropic Parameters of Small-Scale Ionospheric Irregularities in the Presence of TIDs

S M PRADHAN
All India Radio, New Delhi 110001
and
K SINGH
Electronics & Radiophysics Laboratory, Banaras Hindu University, Varanasi 221005

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Full correlation analysis for the Mitra type fading records in the presence of the travelling ionospheric disturbances (TIDs) has been done to study the anisotropic parameters of small-scale irregularities. The results show that the apparent drift velocity of the small-scale irregularities and the horizontal phase velocity of the corresponding TID lie almost in the same direction if the TIO is moving in the southward direction. However, the direction of movement of the TID and small-scale irregularities differ significantly for eastward moving TIDs. The axial ratio, the orientation of the characteristic ellipse and the ratio of characteristic velocity to true velocity do not show significant dependence on the direction of movement of the TID. Further, the horizontal phase velocity of the TID moving towards east is almost comparable to the horizontal drift velocity of the small-scale irregularities.

The simultaneous records of amplitude and phase path changes of radio waves reflected from the ionosphere have been used by many workers to study the ionospheric irregularities. Usually, the amplitude records are analyzed by the correlation method to determine the drift and anisotropic parameters of the small-scale irregularities. Recently, it has been shown with the help of Fourier analysis of the fading records that the wave-type irregularities may also be responsible for the fading of radio signals. However, some of the workers have raised doubts about the validity of the cross-spectral analysis. The phase path change records, on the other hand, directly reveal the presence of wave-type irregularities. Also, it has been shown theoretically by Hines and Rao that the observed fading patterns can be explained on the basis of 'phase screen model' in the presence of wave-type irregularities induced by gravity waves at the level of reflection. It is, therefore, interesting to perform correlation analysis for the fading records, when the phase path records reveal the presence of travelling ionospheric disturbances (TIDs), to study the physical significance of the characteristics of small-scale irregularities. It has been shown by other workers that the correlation analysis detects the gravity wave induced winds.

The principles of observation of the amplitude and phase path patterns of three close-spaced aerials are same as that of Mitra and Findlay, respectively. However, certain modifications to improve the automatic switching of aerials and the receiver characteristics have been incorporated in the equipment used in the present investigation. The records correspond to nighttime only and have been classified into two categories, one showing random phase path and the other showing regular phase path changes. The cumulative phase path changes in case of regular variations in a typical case are shown in Fig. 1. The undulations in the cumulative phase path changes have been attributed to distortion in isoionic contour caused by gravity waves. The simultaneous amplitude records are also shown in Fig. 1. The amplitudes are averaged over a period of 1 min. The burst in amplitude corresponding to peaks (concave mirror-like shape) of the TID has been attributed to the focussing of radio waves.

With the help of simultaneous phase path records the presence of a gravity wave induced irregularity at the level of reflection can be ascertained. The record (Fig. 1) which shows a period of 15 min for the second TID is divided into 10 parts (between 1957 and 2007 hrs) leaving the first two and the last three minutes, for the simple reason that the pattern at the beginning and at the end of this wave might have been contaminated by other effects. The auto- and cross-correlations for each minute of the record are determined and different anisotropic parameters have been computed.

The auto- and cross-correlations curves for 1 min record between 2005 and 2006 hrs have been shown in Fig. 2. Fig. 2 shows that the correlation curves have
fluctuations about the time axis. Also, the secondary peaks of all the three auto-correlation curves occur after the same time lag and the peaks of cross-correlation curves show the same time shifts systematically for the three sets of cross-correlation curves. Down and Maude have shown that correlation curves will be sinusoidal in the case of a sinusoidal irregularity at the level of reflection and cross-correlation curves will show symmetrical time shifts due to the movement of the ionospheric irregularity. Down and Maude have observed cross-correlation curves similar to those in Fig. 2 and associated them with the wave-type irregularities. In our case, however, it is directly known from the phase path records that a wave-type irregularity (TID) is present at the level of reflection.

The anisotropic parameters of small-scale irregularities determined for each 1-min record of the amplitude for the TID event are also shown in Fig. 1. It may be seen that the apparent drift speed, direction and orientation of the characteristic ellipse do not depend on the phase of the TID. The ratio of the characteristic velocity \( V_c \) and true velocity \( V \), i.e. \( V_c/V \), however, becomes minimum corresponding to the peak of the TID. This may be explained in terms of focussing of radio waves due to which the steady power of the reflected signal increases near the peak of the TID. The increase in the steady power causes the decrease in the random changes and hence in \( V_c/V \).

The horizontal speed of the TIDs and direction of movement have been determined by the methods of Whitehead and Reddi and Rao, respectively. Table 1 summarizes the results of analysis corresponding to nine TID events. The five cases (2nd to 6th) of Table 1 show that the TIDs move towards south within ±20°. The remaining four events correspond to TIDs moving approximately in the eastward direction. It may be seen that the apparent direction of movement of small-scale irregularities (\( \phi_a \)) is almost the same in case of TIDs moving in southward direction. However, the directions of movement of TIDs and small-scale irregularities differ significantly for eastward moving TIDs. Other parameters like the axial ratio (\( \gamma \)), the orientation of characteristic ellipse (\( \psi \)) and the ratio of characteristic velocity to true velocity \( V_c/V \), do not show much dependence on the direction of movement of TIDs. It is also seen that the values of \( V_c/V \) are slightly higher for the case of TIDs moving towards east and the characteristic ellipse is also oriented more towards west in the case of eastward propagating TIDs. This analysis demonstrates that for TIDs
moving towards south, the directions of movement of small-scale irregularities and TIDs are the same. Further, the horizontal phase speed of the TID is always higher than the apparent drift speed of small-scale ionospheric irregularities. In the case of eastward propagating TID, the apparent drift speed and horizontal phase speed of the TID are almost the same.

It is difficult to draw any firm conclusion on the basis of this analysis made for only a few TID events. However, it seems that if such analysis is extended to a large number of TID cases moving along the geomagnetic lines of force and perpendicular to them, the usefulness of correlation analysis of fading records in the case of TIDs can be evaluated.

**References**
