SPACED-RECEIVER MEASUREMENTS OF IONOSPHERIC SCINTILLATIONS

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1. INTRODUCTION

Irregular fluctuations or scintillations of amplitude, phase and angle of arrival are occasionally observed on radio waves propagating through the ionosphere. These scintillations are caused by ionospheric density irregularities, giving rise to radio wave diffraction [Yeh and Liu, 1982]. Amplitude scintillations over 20 dB peak-to-peak at VHF band are routinely observed in summer nighttime in Japan. Scintillations up to microwave bands occasionally appear during geomagnetic storms [Ogawa et al.,1980; Minakoshi et al.,1981]. It is reported that these scintillations sometimes disturb considerably the satellite operations and communications.

In order to investigate the characteristics of the midlatitude ionospheric scintillations, 136 MHz radio wave from geostationary satellite ETS-II stationed at 130°E has been received continuously. Especially, spaced-receiver scintillation measurements have provided much information on the structures and behaviors of the ionospheric irregularities [Kumagai and Ogawa, 1984]. By means of a correlation analysis of fluctuating radio signals obtained at three closely-spaced antennas, movement, spatial scale size and shape of the irregularities are derived. It has been certified that the ionospheric irregularities causing nighttime scintillations have well-developed field-aligned structures at F-region height. These results are useful for investigating the generation mechanisms of the ionospheric irregularities as well as scintillations.

2. METHOD

Fig. 1 shows the three antenna locations at the Hiraiso Branch, Radio Research Laboratories and the directions of the 136.112 MHz radio paths from the geostationary satellite ETS-II; the elevation and azimuth angles are 47° and 197° (from north to east), respectively. Crossed-Yagi antennas are located at S (south) and E(east), and a helical antenna at W (west). The separation of each pair of antennas is about 200 m. The 136 MHz signal levels received by three antennas were recorded on MT every 0.125 s. In a three-antenna measurement, the movement of the ionospheric irregularities in a plane perpendicular to the radio path (observation plane: S'E'W') can be determined from time lags among three scintillation records.

It is reasonable to assume that a surface of constant correlation coefficient in space (two-dimensional)-time coordinate system is approximately ellipsoidal. Then, for no time difference, a contour of constant correlation coefficient on the observation plane is elliptic. Parameters of the ellipse such as direction of major axis, major-minor axial ratio, and minor radius are also derived from three pairs of auto-correlation and cross-correlation functions of scintillation records [Bramley and Browning, 1978].

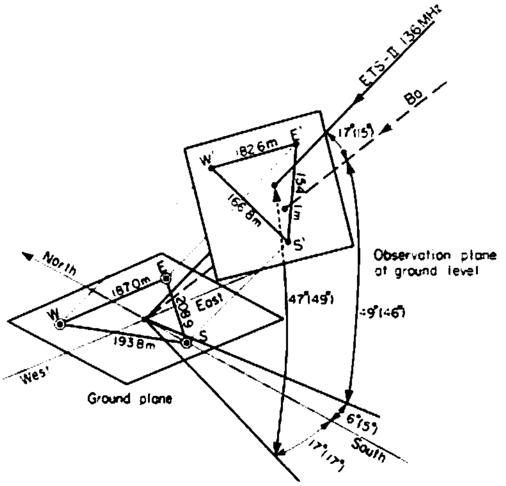

Fig. 1. Antenna locations (S, E, and W), radio propagation path from ETS-II, and geomagnetic field line Bo. Angles of these vectors on the ground (at 300 km height) are indicated. Projection of a triangle SEW onto the plane perpendicular to the radio path makes a triangle S'E'W'.

3. RESULTS

3. 1. Scintillation Event of July 21 - 22, 1982

Time evolution of the 136 MHz scintillation event of July 21 - 22, 1982 is shown in Fig. 2 where, from top to bottom, scintillation signal level, drift velocity (every 8 min) and ellipse representing the constant correlation coefficient (every 16 min) are displayed. Note that both drift velocity and irregularity pattern ellipse represent those in the observation plane.

Strong scintillations started at 1845 LT and lasted until 0500 LT. The maximum amplitude of the scintillations is about 20 dB p-p. From 20 h to 0 h LT, the drifts were essentially directed southwestward and most of the drift velocities are less than 30 m/s. In the postmidnight hours, there are two periods (0000-0032 LT and 0308-0356 LT) for which the drifts are directed northward. Especially, high northward drift velocities (about 100 m/s) in association with the strong and high-pitch scintillations were observed during 0000-0032 LT. It is interesting that the sudden onset of the strong scintillations seems to be initiated by the northward drifts. The northward drifts during 0308-0356 LT have mean velocity of 23 m/s. Outside these periods in the postmidnight, the drifts are directed southward or southwestward with velocities essentially less than 40 m/s.

Most ellipses shown in Fig. 2 have long major axes which are aligned along almost the same direction. Fig. 3 presents a schematic picture showing the relation between the ellipse in Fig. 2 and the ionospheric irregularity configuration. We can observe the projection of the irregularities onto the plane perpendicular to the radio path. The directions of the geomagnetic field lines at 300 km and 500 km heights projected onto the observation plane are indicated in Fig. 2. Most of the major axis directions of the ellipses coincide with the projected geomagnetic field lines, indicating that the irregularities in the ionosphere at F-region heights extend along the geomagnetic field lines. The axial ratio of the ellipse in Fig. 2 amounts to 7 during strong scintillations. In order to obtain the actual axial ratio of the field-aligned irregularities, a factor of 3.9 (=1/sin15°) should be multiplied.

In most cases, the derived drifts are in the directions normal to the elongations of the irregularity pattern ellipses. When the axial ratio of the irregularities is very large, it is impossible to obtain a drift component along the elongation. This is the reason why the derived drifts are predominantly directed southwest-northeast.

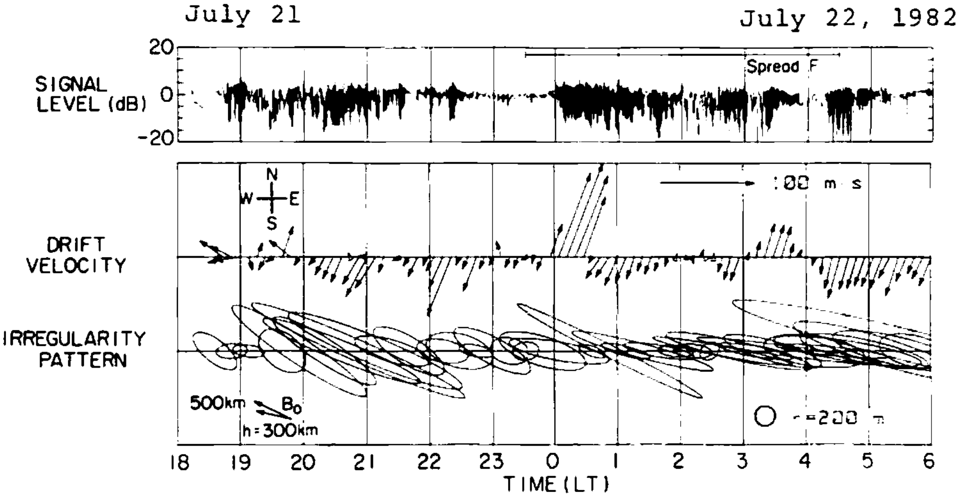

Fig. 2. Time evolution of scintillation event of July 21-22, 1982. From top to bottom, 136-MHz signal level, drift velocity, and irregularity pattern ellipse are displayed.

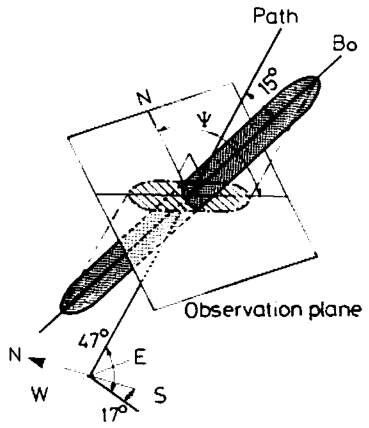

Fig. 3. Relation between actual field aligned irregularity configuration (dotted area) and irregularity pattern projected onto the plane perpendicular to the radio path (hatched area).

3. 2. Characteristics of Irregularity Shape

Using the data obtained for seven scintillation events, characteristics of the irregularity shape are investigated. Fig. 4 shows dependences of the axial ratio and minor radius of the irregularities on S_4 index which represent the scintillation strength. S_4 indices are classified into six groups (every 0.2) and mean (filled circle) and standard deviation (vertical bar) of each data set are shown. The mean axial ratio (Fig. 4a) increases with increasing S_4 until S_4=1.0 where saturation seems to occur. The average of the axial ratio is 6.2, which corresponds to 24 for the actual field-aligned irregularities. The minor radius (Fig. 4b) tends to decrease with increasing S_4. The average of the minor radius is 182 m. Consequently, these results suggest a tendency that stronger scintillations are produced by more elongated irregularities with smaller scale sizes.

The results obtained in the present study are useful for the investigation of the plasma instabilities which generate ionospheric irregularities and of strong radio wave scattering mechanisms.

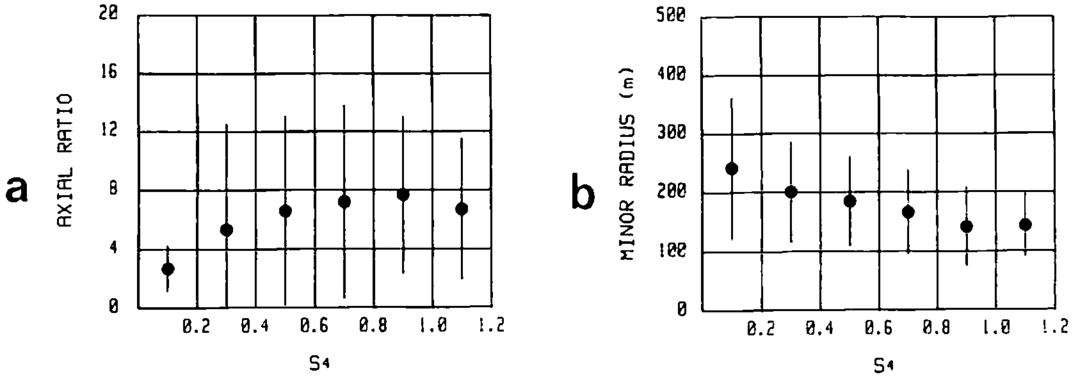

Fig. 4. Dependences of (a) axial ratio and (b) minor radius of irregularities on S_4 index.

REFERENCES

Bramley, E.N. and R. Browning, J. Atmos. Terr. Phys., 40, 1247, 1978.

Kumagai, H. and T. Ogawa, submitted to J. Atmos. Terr. Phys., 1984.

Minakoshi, H., K. Sinno, M. Kan, H. Kurihara, and O. Furuta, J. Radio Res. Labs., 28, 1, 1981.

Ogawa, T., K. Sinno, M. Fujita, and J. Awaka, J. Atmos. Terr. Phys., 42, 637, 1980.

Yeh, K.C. and C.H. Liu, Proc. IEEE, 70, 324, 1982.