Proc. NIPR Symp. Upper Atmos. Phys., **1**, 199–203, 1988

IONOSPHERIC DISTURBANCE EFFECT ON NNSS SATELLITE POSITIONINGS AT SYOWA STATION

Kiyoshi IGARASHI, Tadahiko OGAWA, Hideo MAENO and Yasukazu KURATANI

Radio Research Laboratory, 2–1, Nukui-kitamachi 4-chome, Koganei-shi, Tokyo 184

Abstract: An experiment for investigating a relation between geomagnetic disturbance and satellite positioning error in the polar region was carried out at Syowa Station, Antarctica, in 1985 and 1986 with a two-wave (150 and 400 MHz) NNSS receiver. From the analysis of positioning data of about 10000 passes over 245 days, it is clearly found that the position determination error increases with increasing geomagnetic disturbance level (local *K*-index) and the number of passes on which the position determination is succeeded decreases by one or two per day when *K*-index is large. These results suggest that when the ionosphere is highly disturbed the 150 and 400 MHz radio waves from the satellites are strongly scattered by ionospheric irregularities and/or spatial gradients of the electron density associated with ionospheric disturbances.

1. Introduction

The Navy Navigation Satellite System (NNSS) receiver installed at Syowa Station has been used as a standard clock and/or a positioning equipment for geophysical studies in Antarctica (SHIBUYA and KAMINUMA, 1982; SHIBUYA *et al.*, 1982). Success in the NNSS positioning depends on both the maximum satellite elevation angle and the duration of receiving signals. In a recent paper, SHIBUYA (1985) has reported a comparative experiment made at mid-latitude (Tokyo) and high-latitude (Syowa Station) in order to clarify the receiving conditions in high latitudes. He has founded that the occurrence number of "insufficient positionings (which means that positioning is impossible though the maximum elevation angle of satellite is in the range 15°–75°)" at Syowa Station were larger than those at Tokyo and attributed this result to more disturbed ionosphere conditions at Syowa Station than at Tokyo. MEDHURST (private communication, 1987) has noted a correlation between the quality of Doppler data from JMR NNSS receiver and the corresponding ionospheric condition (sunspot number).

In this paper, ionospheric disturbance effect on the satellite positioning is quantitatively examined in detail by deriving some empirical relations between positioning errors and geomagnetic disturbances from the positioning data over 245 days obtained at Syowa Station in 1985 and 1986. Our experiment also aimed to investigate traveling ionospheric disturbances and ionospheric scintillations; the former study will appear in a separate paper in this issue by OGAWA *et al.* (1988).

2. Observations

A commercial two-wave (150 and 400 MHz) NNSS receiver JLE-923 (Japan Radio Co. Ltd.) was used for the present experiment. The receiving antenna was set on the roof of the Ionosphere Observatory at Syowa Station. The NNSS receiver determines the position and provides UT time, the broadcast ephemeris and orbital parameters of the satellite. These are printed out on a paper-chart and also stored in a floppy disk of a personal computer. A total of 9565 positioning results were recorded during periods of April 4 to May 27, 1985 and July 3, 1985 to January 11, 1986, with the average of 39 passes a day. Six NNSS satellites were in operation during the above observation periods.

3. Results

Figure 1 shows a scatter plot of measured positions in the geophysical coordinates, where the center is the averaged position derived from the whole set of data (9565 passes). The mean radial distance of the whole data is 149.8 m. Most of the measured positions (95.2%) are located in a circle with a radius of 500 m from the mean position. The latitude of the mean position is 69°00′19.41″±0.03″S and the longitude 39°34′41.26″±0.03″E. The standard deviation is 3.89″ (121 m) in latitude and 1′06.14″ (735 m) in longitude. The large longitudinal error may stem mainly from that the determination of position is made with the algorithm of the hyperbolic-

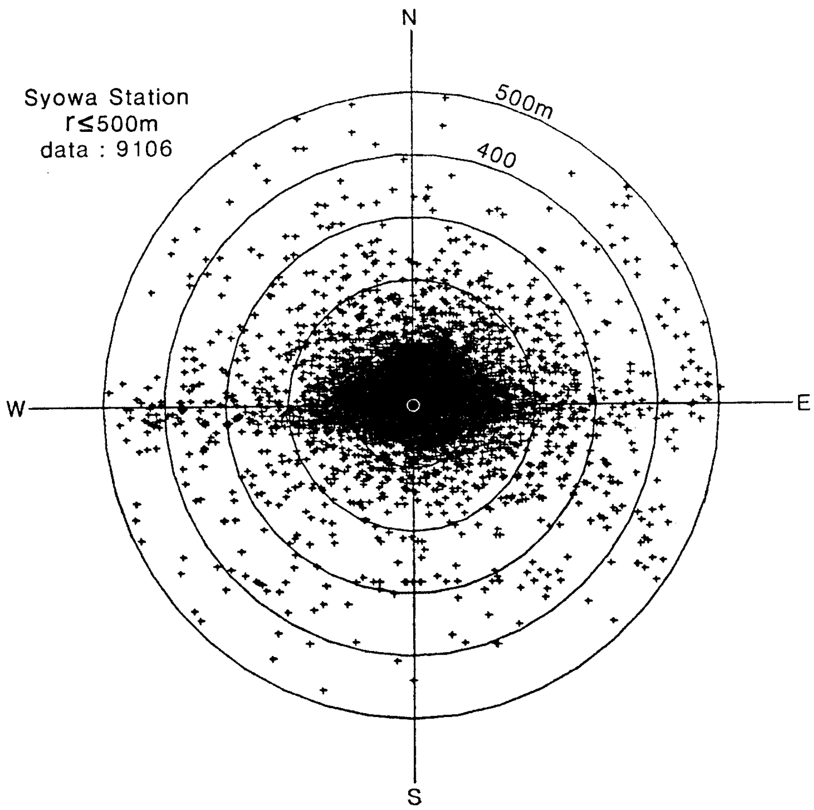

Fig. 1. Scatter plot of positionings ($r \leqq 500$ m) around the mean position (center in the figure).

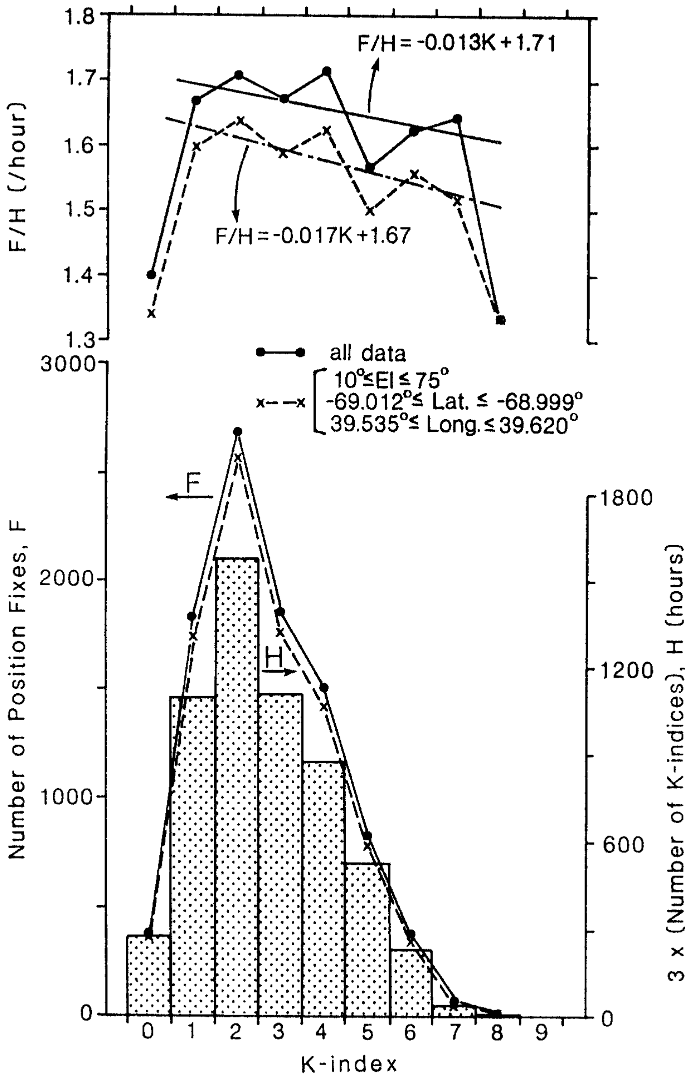

Fig. 2. Distributions of the number of position fixes (F) and 3×(number of K-index) (H) as a function of K-index for two data sets indicated in the figure (lower part) and positioning rate per hour (F/H) (upper part). Two regression lines are drawn by using data for 1≦K≦7.

navigation system using polar-orbiting satellites.

One possible cause for many "insufficient" positioning occurring in the polar region is ionospheric disturbances such as scintillations and steep spatial gradients of the electron density. Here, we adopt tentatively a three-hour K-index obtained at Syowa Station as a measure of ionospheric disturbance level.

The lower panel in Fig. 2 shows the distribution of K-indices and number of position fixes (F) during the observation period as a function of K-index. The position determination rate per hour can be defined as a ratio of F to 3×(number of K-indices), H. The result is shown in the upper panel in Fig. 2. In both panels, the solid circles were derived from all the data while the crosses were derived from the data having limited maximum satellite elevation angles (EL), longitudes and latitudes as indicated in the figure.

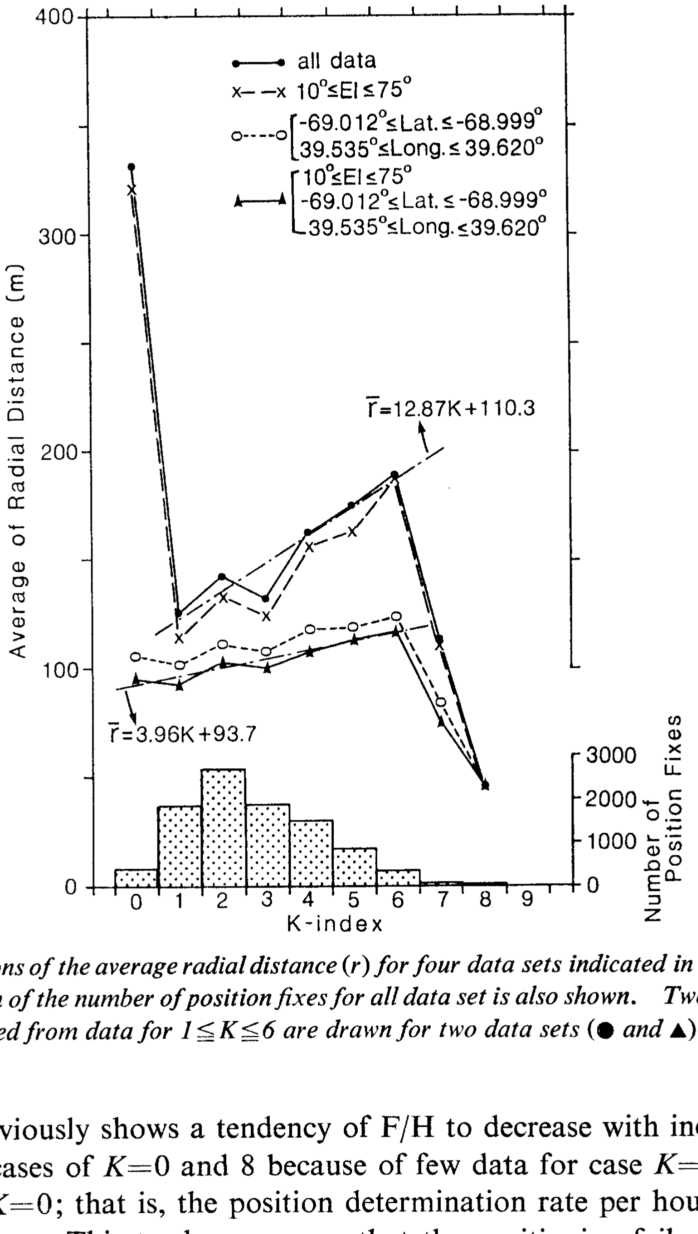

Fig. 3. Variations of the average radial distance (r) for four data sets indicated in the figure. Distribution of the number of position fixes for all data set is also shown. Two regression lines calculated from data for $1 \leqq K \leqq 6$ are drawn for two data sets (● and ▲).

Figure 2 obviously shows a tendency of F/H to decrease with increasing K-index except extreme cases of $K=0$ and 8 because of few data for case $K=8$ and unknown factor for case $K=0$; that is, the position determination rate per hour decreases with increasing K-index. This tendency means that the positioning failure occurs one or two times per day more frequently on the disturbed day than on the quiet day.

Figure 3 shows the averaged radial distances ($\bar{r}$) of scattered position shown in Fig. 1 as a function of K-index. In the figure the data is classified into four sets according to the elevation angles, latitudes and longitudes. It is obvious that $\bar{r}$ increases with increasing K-index ($K=1$–6). Large values of $\bar{r}$ at $K=0$ for two data sets (all data and $10° \leqq \mathrm{El} \leqq 75°$) are due to that two data points having very large deviations from the mean position are included, and the declining trends at $K=7$ and 8 are due to the small number of data.

4. Conclusion

Positioning data over 245 days were obtained by a two-wave NNSS receiver at

Syowa Station, Antarctica. From these data, empirical relations between positioning errors and geomagnetic disturbances (*K*-indices) are examined, and the following results are obtained:

(1) The mean position of the Ionosphere Observatory at Syowa Station is 69°00′19.41″±0.03″S and 39°34′41.26″±0.03″E. The standard deviations of the latitude and longitude are 3.89″ (120.6 m) and 1′06.14″ (735 m), respectively. The larger standard deviation in longitude may be caused by that the NNSS satellite has a polar orbit.

(2) The average radial distance ($\bar{r}$) between measured positions and the mean position is 149.8 m. Of the whole set of determined positions, 72.7, 87.5, 91.7, 93.9 and 95.2% are located within 100, 200, 300, 400 and 500 m, respectively.

(3) The position determination rate (F/H) per hour is given by $-0.013K+1.71$ where K represents the local *K*-index at Syowa Station. Statistically, the position cannot be determined for one or two passes per day when the degree of geomagnetic disturbance is large.

(4) The $\bar{r}$ increases with increasing *K*-index, and is given by $12.87K+110.3$ m.

From the above results (3) and (4), it is concluded that geomagnetic disturbance affects considerably the position determination using the NNSS satellites. As far as we know, experimental results showing clearly the ionospheric disturbance effect on the positioning error have not been published yet. In a two-wave NNSS receiver the propagation delay due to electrons in an ionosphere is corrected in pre-processing stage. However, we have found the geomagnetic disturbance effect. These results suggest that the 150 and 400 MHz waves are strongly scattered by ionospheric irregularities, strong gradients and others associated with ionospheric disturbances.

Acknowledgments

It is a pleasure to acknowledge all the members of the wintering party of the 26th Japanese Antarctic Research Expedition for their kind support in making the observations at Syowa Station. The authors wish to express their thanks to Mr. K. AIKYO of the Radio Research Laboratory for supporting this study and his useful discussions.

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(Received May 25, 1987; Revised manuscript received August 18, 1987)