ANALYSIS OF DOPPLER SCINTILLATION DATA OF JAPANESE DEEP SPACE PROBE "SAKIGAKE"

Zen-ichi YAMAMOTO, Gaku TORIYAMA and Haruto HIROSAWA
The Institute of Space and Astronautical Science, Japan

1.INTRODUCTION

Tracking signals of deep space probes will be affected by solar wind blowing acrross the ray-pathes, and their Doppler frequences will fluctuate. The magnitude of Doppler scintillation of a tracking signal is assumed to be proportional to the product of electron density fluctuations and solar wind velocity [1][2]. So we can obtain some informations of solar wind properties by the analysis of deep space probe tracking data. In this paper, we present the results on the determination of the passing points of the shock waves observed on February 7, 1986 by the analysis of the tracking data of Japanese first deep space probe "SAKIGAKE".

2.CROSS-CORRELATION BETWEEN DOPPLER SCINTILLATION AND SOLAR-FLUX

The magnitude of Doppler scintillation of a deep space probe tracking signal is assumed to be proportional to the product of electron density fluctuations and solar wind velocity, whitch is called "Solar-Flux". Therefore, we can obtain some informations of solar wind properties by the analysis of deep space probe tracking data. We have extracted the Doppler scintillation data of "SAKIGAKE" by digital signal processings with least-squaring filters. The Doppler scintillation data of "SAKIGAKE" on February, 1986 are shown in Fig.1. We have choiced the data of this period for the analysis, since strong shock waves had been detected by earth-based obsevations. Here we use Kp-indices data as Solar-Flux data. Actually, the Solar-flux is the quantity from Kp-indices which are proportional to solar wind velocity alone. However in this study, we could not take the effect of plasma density fluctuations into account since we could not obtain any adequate data of plasma density fluctuations for this period. Kp-indices are known to be the quantities to reveal the fluctuations of earth magnetophere, and are assumed to be proportional to solar wind velocities alone. Kp-indices data in February, 1986 are shown in Fig.2 [3]. Comparing Fig.1 with Fig.2, we can see that there is a good correlation between them. So we have calculated the cross-correlation function between them. The result is shown in Fig.3. Fig.3 indicates that there exists a good correlation between them and that there is a peak at t=0. Therefor, we can see that the time difference between them is less than a day. This result is very reasonable, since the position of "SAKIGAKE" was comparatively near the earth in this period. Considering velocities of solar wind, the time difference should be in the order of hours or minutes. Therefore, in order to guess physical phenomena from the cross-correlation between two data, it is necessary for us to examine the cross-correlation in the order of minutes or hours. It means that we should take the Doppler scintillation data every hour or every minute.

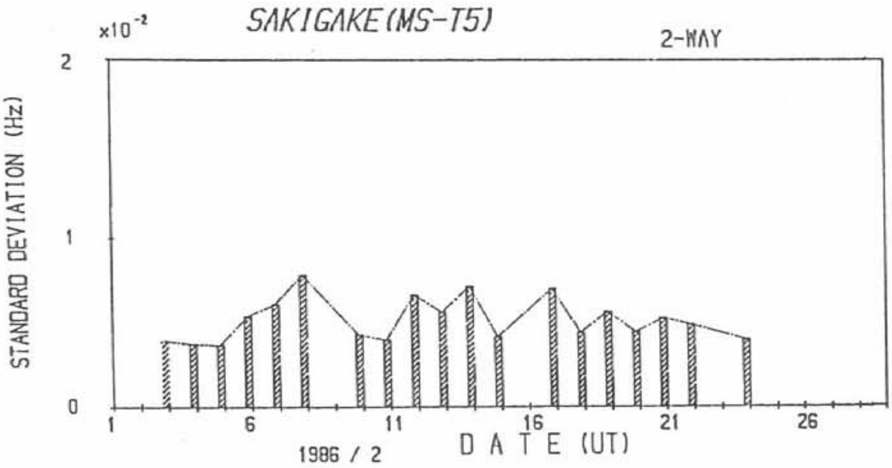

Fig.1. Doppler Scintillation Data of "SAKIGAKE" in Feb., 1986.

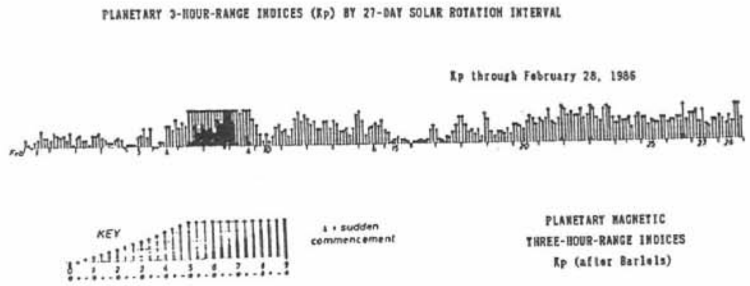

Fig.2. Kp-indices Data in Feburuary, 1986.

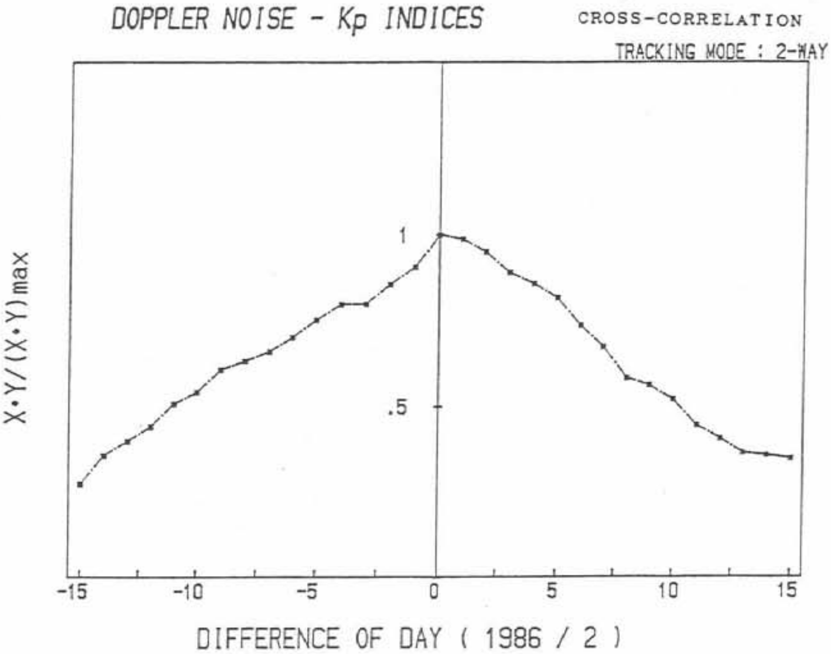

Fig.3. Cross-Correlation Between Doppler Scintillation and Kp-indices.

3.DETERMINATION OF PASSING POINTS OF SHOCK WAVES

According to the abobe conclusion, we have obtained and analyzed Doppler scintillation data of "SAKIGAKE" on February 7, 1986 every minute. The total duration of the Doppler scintillation data is two hours. We show the results in Fig.4. We can see some similar parts that appear with time lags. However, it is difficult for us to discriminate the fluctuations by shock waves. Therefore, we have culculated running deviations of the Doppler scintillation waveform. We show the results in Fig.5. From this figuer, we can see that the deviation varies as a function of time. Generally, plasma densities of shock waves are greater than that of solar wind. So we can consider that shock waves passed across the ray-path at the points with large fluctuations. We can assume that shock waves passed ray-path of up-link and down-link simultaneously (see Fig.6). Since the range of "SAKIGAKE" at this time was about 1.31×10^8 kilometers, the round-trip time Trt is about 14.5 minutes. In this case, we should be able to see the echoes of shock waves within 15 minutes. And we can guess the passing point of a shock wave on the ray-path from the following equation.

$$d = t \cdot c \;/\; 2 \qquad \text{(a)}$$

where, t is the time difference between a shock and its echo, and d is the distance between "SAKIGAKE" and the passing point of the shock wave.

In the case of point (1) on Fig.5, we get t=5 minutes. So we get $d=4.5\times10^7$ km. Similary in the cases of points (2) and (3), we get $d=6.3\times10^7$ km. And in the case of point (4), we get $d=5.4\times10^7$ km. We have plotted these points on the ray-path of "SAKIGAKE" (see Fig.7). From this figuer, we can see that the passing points are distributed around the same place on the ray-path. These results are very reasonable from the properties of shock waves.

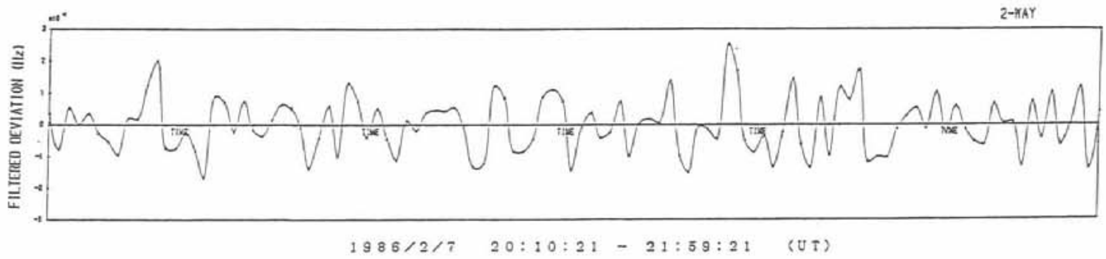

Fig.4. Doppler Scintillation Data on Feb. 7, 1986 (2 hours).

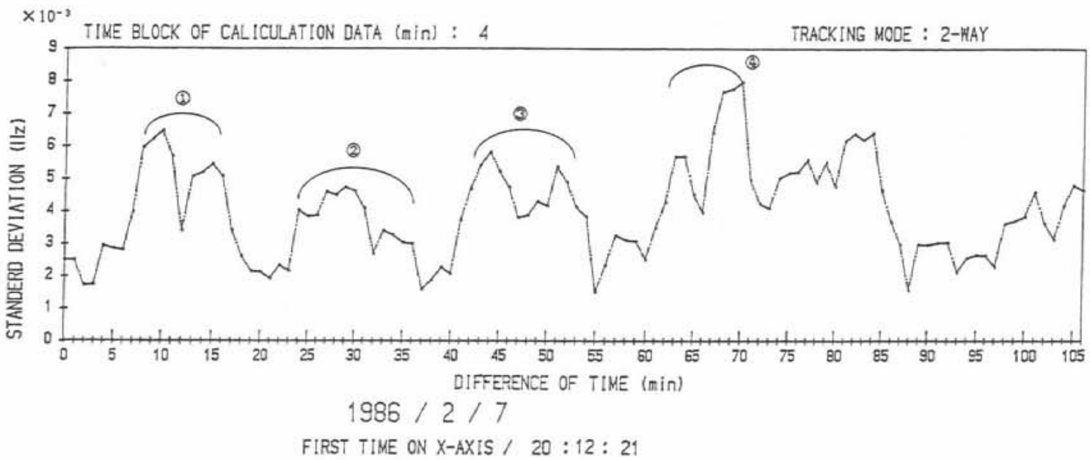

Fig.5. Running Deviations of Doppler Scintillation Waveform.

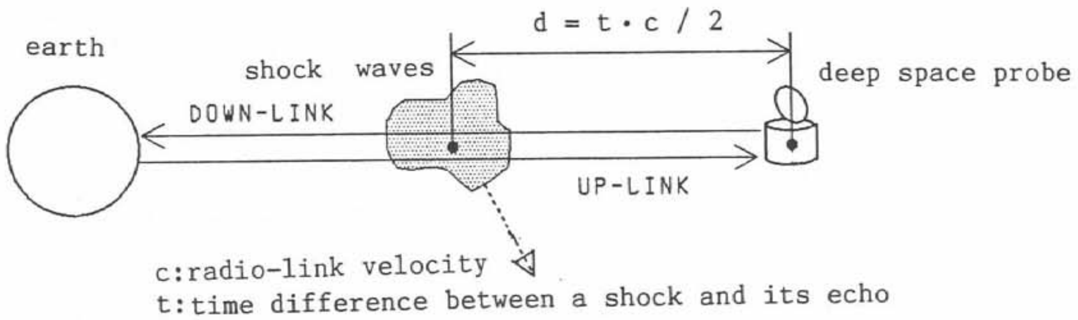

Fig.6. Relation of Earth, Shock Wave and Deep Space Probe.

4.CONCLUSIONS

From the analysis of the Doppler scintillation data of "SAKIGAKE" for the detection of shock waves, we found that it is necessary to get Doppler scintillation data every minute. So we have actually analyzed the Doppler scintil-lation data of "SAKIGAKE" on February 7, 1986 every minute, and we could determine the passing points of shock waves on the ray-path. The results turned out to be very reasonable from the properties of shock waves.

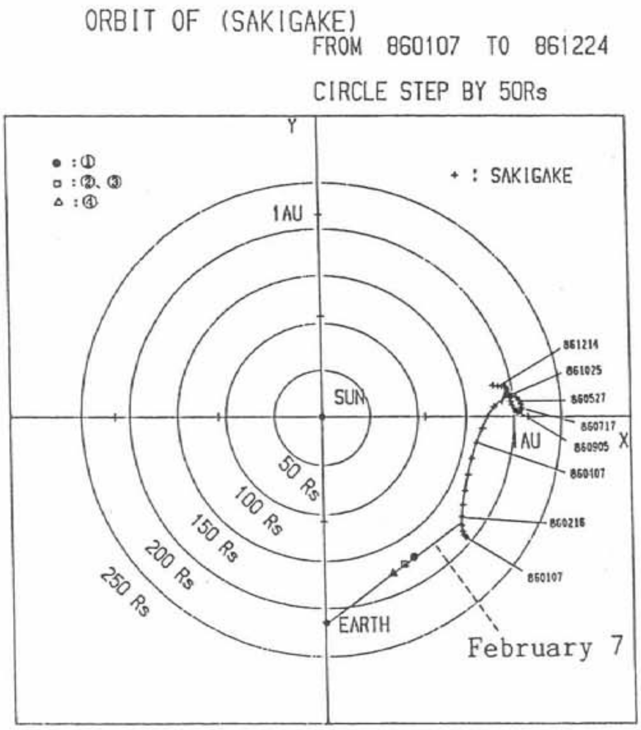

Fig.7. Passing Points of Shock Waves on Ray-path (Feb. 7, 1986).

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