# ATTITUDES OF THE ANTARCTIC SOUNDING ROCKET VEHICLES

Fumio TOHYAMA and Iwao AOYAMA

*Faculty of Engineering, Tokai University, Kitakaname, Hiratsuka 259-12*

***Abstract:*** The attitudes of the 12 sounding rockets which were launched at Syowa Station in Antarctica from May 1972 to August 1973 were determined by geomagnetic aspect sensors.

The attitudes of the latest launched sounding rockets, S-210JA-22 and S-310JA-1 were also determinated. The three-dimensional orientation of the S-210JA-22 rocket axis was obtained by the geomagnetic aspect sensors and the solar aspect sensor. The result shows that the precessional motion of the S-210JA-22 vehicle included the geomagnetic field line.

The spin frequency of these 14 vehicles was mostly in the range from 1.1 to 1.3 Hz and their conical (precessional) half angle was mostly from 20 to 60 degrees, with the conical rotational period mostly from 50 to 120 seconds.

## 1. Attitudes of the Two Latest Vehicles

### *1.1. Attitude of the S-210JA-22*

The rocket was fired at 02h20m (45°EST) on January 26, 1976, with the azimuth angle of 315° (north-west direction), and the elevation angle of 82°. This azimuth is the same as the declination of the geomagnetic field at Syowa

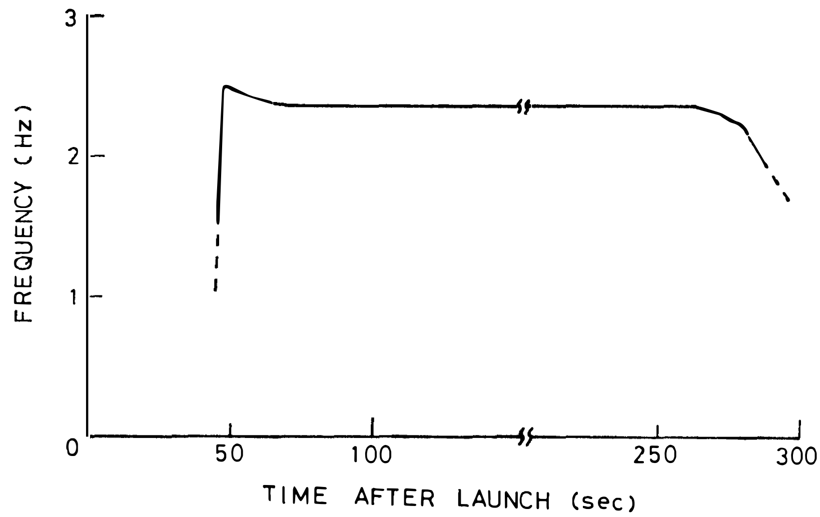


*Fig. 1. Time dependency of the S-210JA-22 spin frequency.*

Station, while the inclination of the geomagnetic field line at Syowa is about 66°. Therefore, it is likely that the rocket's precessional motion included the geomagnetic field line through Syowa.

The spin frequency after the nose-cone removal was 2.36 Hz as shown in Fig. 1. This frequency is high as compared with that of other rockets. Fig. 2 shows the angle between the vehicle axis and the geomagnetic field line during the flight. In this figure, it is found that the conical half angle is 13° or 39°. The solar aspect sensor showed that the precessional motion of the rocket included the geomagnetic field line through Syowa. Therefore, it is found that the true half angle is 39°. The precession period of the vehicle is about 74 seconds.

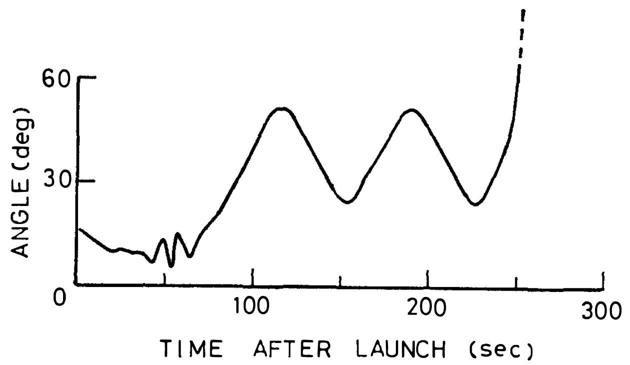


*Fig. 2. The angle between the S-210JA-22 vehicle axis and the geomagnetic field line during the flight.*

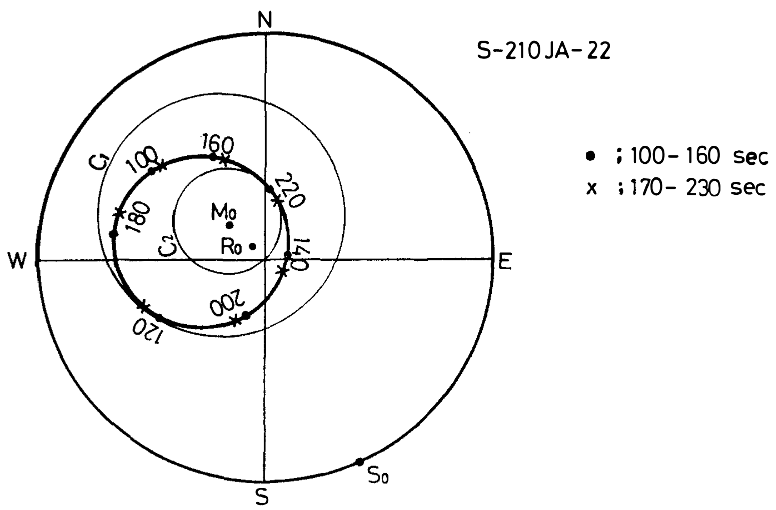


*Fig. 3. Time dependency of the absolute orientation of the S-210JA-22 spin axis between 100 and 230 seconds after launch, referring Wuff's stereographic projection. The points of $M_0$, $R_0$ and $S_0$ correspond to the directions of the geomagnetic field line, of the vehicle launching and of the sun at the time of the firing, respectively.*

Fig. 3 shows the time dependency of the orientation of the vehicle spin axis between 100 and 230 seconds after launching. It is referred to Wuff's stereographic projection. The center of the circle is the zenith at Syowa Station and the circumference corresponds to the horizon. It is found that a precessional motion shows a circle on the Wuff's projection. Circle $C_1$ is 52° distant and $C_2$ is 25° distant from the geomagnetic field line respectively in the figure. The vehicle's conical circle is located between $C_1$ and $C_2$.

### *1.2. Attitude of the S-310JA-1*

The first rocket of the S-310 type was launched at 12h45m on February 13, 1976. The time dependency of the vehicle's spin frequency is shown in Fig. 4. The spin frequency is slowed down to 1.05 Hz by a yo-yo despinner at 50 seconds after the launching. The conical half angle is 15° or 22° and the period is 180 seconds (*cf.* Fig. 5). Rockets of this type seem to have better stability in

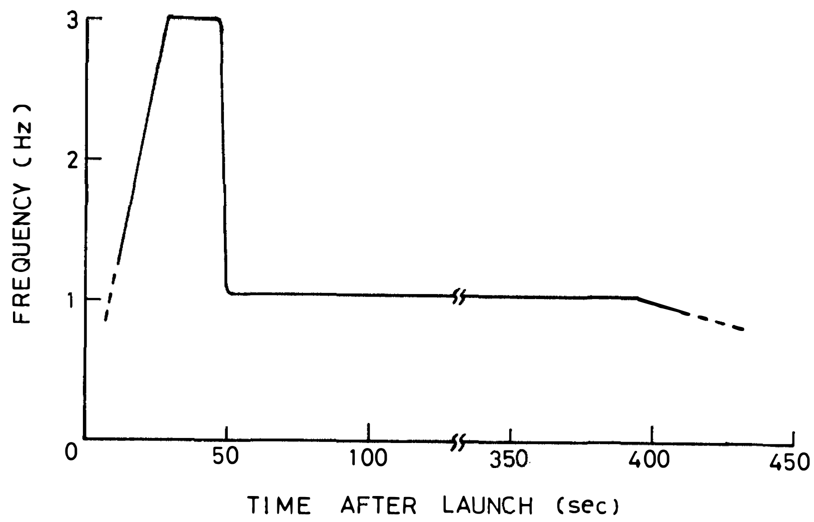


*Fig. 4. Time dependency of the S-310JA-1 spin frequency.*

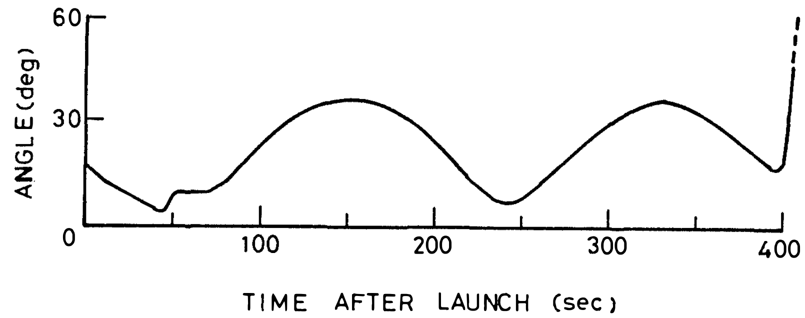


*Fig. 5. The angle between the S-310JA-1 vehicle axis and the geomagnetic field line during the flight.*

attitude than the S-210 type rockets.

A solar aspect sensor was not installed in the S-310JA-1 payload, so that we could not determinate the three-dimensional attitude. However, this rocket was launched along the geomagnetic field line with the azimuth angle of 315° and the elevation angle of 80°. Therefore, it is probable that the precessional motion included the geomagnetic field line. If the precessional motion includes the field line, the true conical half angle is 22 degrees.

## 2. Summary of Attitudes of 14 Rockets Launched at Syowa

The attitudes of rockets which were launched at Syowa Station are summarized in Table 1. These attitudes were detected by geomagnetic aspect sensors or

*Table 1. Summary of rockets attitudes determined by geomagnetic aspect sensors. The half angles in the bracket ( ) are somewhat uncertain owing to noisy data. The determination of three-dimensional attitude are marked with asterisk.*

| Rocket | Launching | | Attitude results | | |
|---|---|---|---|---|---|
| | Time (45°EST) | Azimuth (deg.) | Rolling frequency (Hz) | Coning | |
| | | | | Half angle (deg.) | Period (sec) |
| S-210JA- 7 | 0023 Dec. 14, 1972 | 315 | 1.10 | 21* | 88 |
| S-210JA- 8 | 0401 Aug. 11, 1972 | 135 | 1.20 | 52 | 58 |
| S-210JA- 9 | 0213 May 14, 1972 | 135 | 1.10 | 36 | 123 |
| S-210JA-10 | 0202 May 16, 1972 | 315 | 1.12 | (13) | 20 |
| S-210JA-11 | 0445 Aug. 7, 1972 | 315 | 1.20 | 50 | 57 |
| S-210JA-13 | 2320 June 10, 1973 | 315 | 1.32 | (34) | 95 |
| S-210JA-14 | 2347 Mar. 25, 1973 | 315 | 1.21 | (7) | 20 |
| S-210JA-15 | 0011 June 12, 1973 | 315 | 1.15 | 20 | 52 |
| S-210JA-16 | 0245 Feb. 15, 1973 | 135 | 1.20 | 46 | 45 |
| S-210JA-17 | 0254 Apr. 23, 1973 | 135 | 1.05 | 67 | 77 |
| S-210JA-18 | 0353 Aug. 23, 1973 | 315 | 1.32 | 45 | 70 |
| S-210JA-19 | 2209 July 15, 1973 | 135 | 1.56 | 42 | 100 |
| S-210JA-22 | 0220 Jan. 26, 1976 | 315 | 2.36 | 39* | 74 |
| S-310JA- 1 | 1245 Feb. 13, 1976 | 315 | 1.05 | 15 | 180 |

magnetometers. The three-dimensional attitudes of S-210JA-7 and 22 rockets were obtained by means of geomagnetic aspect sensors together with solar aspect sensors. More than half of the rockets were launched in the same direction as the declination of the geomagnetic field at the launching site. Therefore, it is likely that the precessional motion of these vehicles included the geomagnetic field line.

The spin frequency of the rockets was from 1.1 to 1.3 Hz mostly and the period of precessional motion was mostly in the range from 50 to 120 seconds.

## 3. Problems in Attitude Determination

Attitude information of sounding rockets has become very important with progress of rocket-borne instrumentations. Especially, it is indispensable to determine a three-dimensional attitude of vehicle in space in order to elucidate the relationships among various kinds of geophysical phenomena.

It is necessary to use the geomagnetic aspect sensors together with other kinds of aspect sensors, such as solar aspect sensor, moon aspect sensor, horizontal aspect sensor and so on. If these aspect sensors are developed and improved, it will become possible to determine the three-dimensional attitudes of rockets in any launching condition.

One of the problems for the geomagnetic aspect sensor is an effect of magnetic deviation, which is due to magnetic fields from the instruments on board the rocket and due to magnetization of the instruments and the rocket body. We have solved these problems by demagnetizing the magnetized parts and by extending the dynamical range of measurement.

## Acknowledgments

The authors wish to express their thanks to all members of the 17th wintering party of Japanese Antarctic Research Expedition for their support and co-operation in the launching operations at Syowa Station in Antarctica. These rocket experiments were supported by the National Institute of Polar Research.

(*Received May 16, 1978*)