Magnetic Field Measurement by a Rocket

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ロケットによる地球磁場測定

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要旨: オーロラ・エレクトロジェット電流を間接的に測定するため，地球磁場の高度変化の観測を行った．その結果，ロケット上昇時と下降時に観測された磁場分布の顕著な差異から，オーロラ・ジェット電流の幅がかなりせまく，局在していることが結論できた．

***Abstract*:** The S-210JA-7 sounding rocket was launched from Syowa Station, Antarctica to measure the magnetic field of the electrojet current at 0023 local time on December 14, 1972.

Preliminary results show that there were remarkable differences between the upward and the downward profiles of the magnetic field. These profiles indicate that the current system of the electrojet is quite narrow and localized.

1. Instrumentation

Included on the payload were three-component hybrid digital fluxgate magnetometers and a solar aspect sensor for determining vehicle attitude. Figure 1 shows one of the magnetometer systems which can measure the magnetic field with a wide dynamic range and at a high sensitivity. The main loop consists of a digital system. The output is supplied to the comparator in which the quantified level is from -300 to $+300$ gammas and the comparator output controls gates. The digital signal is converted into an analog current which is applied to the sensor coil for cancelling the field within one quantified level. Therefore, the field in the sensor is always kept within 300 gammas, even if any field change occurred. On the other hand, the input of the comparator is measured in analog form. The value obtained by subtracting the digital value from the observed one, that is within 600 gammas, is detected in analog form. The digital counter output is 8 binary bits and the analog voltages of 0 and 5 volts are -300 and $+300$ gammas, respectively.

Figure 2 shows the geometry of the sensor system, the direction of the magnetic field and the rocket axis. The magnetometer used has three sensors, one of which

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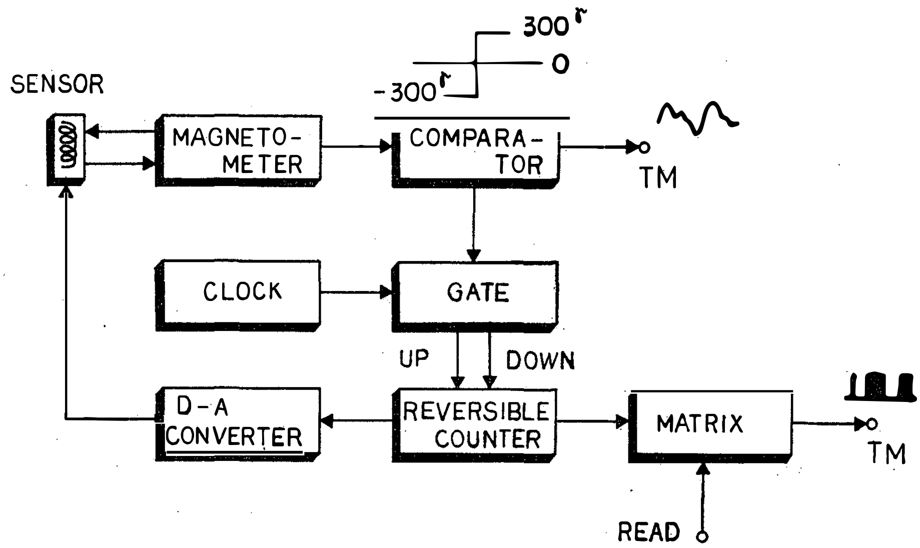

Fig. 1. Block diagram of hybrid digital fluxgate magnetometer.

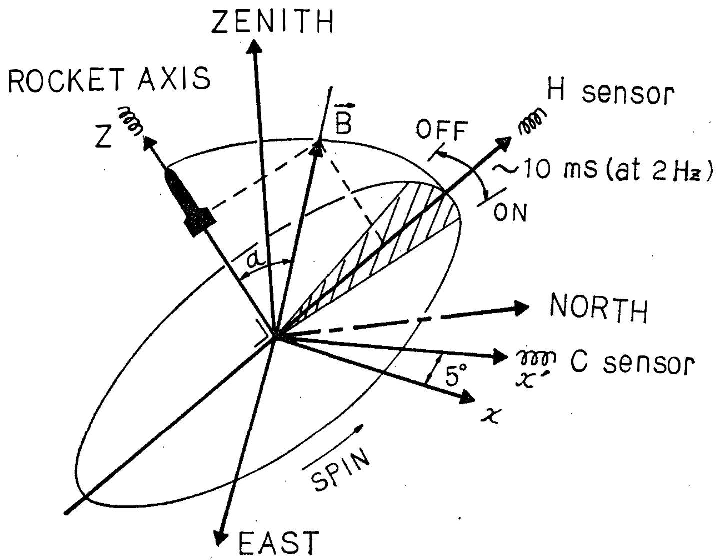

Fig. 2. Schematic diagram showing vehicle co-ordinates and sensor systems.

is mounted so as to be aligned with the rocket axis (Z sensor) and the other two are perpendicular to the rocket axis (H and C sensors). The H sensor rotates in the plane that is perpendicular to the rocket axis corresponding to the rocket's rotation. Therefore, this sensor produces a signal that is proportional to the projected magnitude in the direction of the H sensor in this plane and consequently, the magnitude of the H sensor corresponds to the rocket's rotation. The C sensor is mounted on the same plane as the H sensor but separated in alignment from the H sensor by 85 degrees. When the C sensor crosses a zero field intensity as it rotates in the plane, the H sensor is aligned near the direction of the maximum field intensity. At this time, the output of the C sensor is used to open a gate and the reversible counter starts to count. After about 10 ms, the gate is closed automatically. The digital information is held until the subsequent gate opening, so that a constant cancelling field is applied to the sensor coil. Consequently, the measurement is made on the shaded region in the figure, and the residual field is detected by an analog technique. The field azimuth can be determined by comparing the time of the maximum intensity with the position of an independent reference object like the sun or the moon. The signals for telemetry are 8 serial binary bits which correspond to 0 to 76,000 gammas and 600 gammas full scale in analog form.

2. Analysis and Results

The rocket performance was normal with an apogee of 126 km at 171 seconds after launch, and all the instruments functioned well during the flight. The trajectory of the rocket was obtained by radar tracking. The orientation of the rocket axis was measured by a solar aspect sensor and the magnetometer which gave the attitude for the geomagnetic line of force.

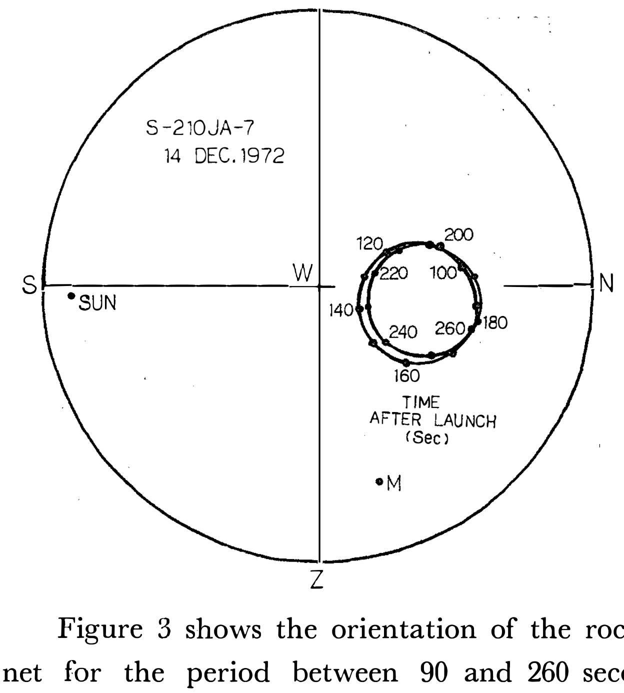

Fig. 3. The orientation of the rocket axis described on a stereographic net for the period between 90 and 260 s after the launching.

Figure 3 shows the orientation of the rocket axis described on a stereographic net for the period between 90 and 260 seconds after the launching. The origin corresponds to the west at the launching point, and "M" and "Sun" correspond to the direction of geomagnetic field and of the sun at the time of the firing, respectively. The half-coning angle was 21 degrees up to 190 seconds after launch and 19 degrees thereafter until 260 seconds after launch.

Magnetograms of Syowa Station at the time of launching are shown in Fig. 4. They are, from the top, horizontal component, declination and vertical component,

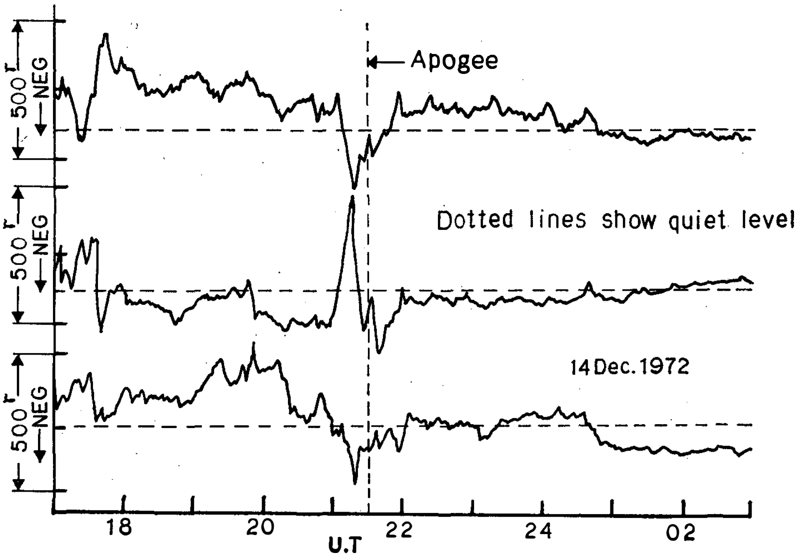

Fig. 4. Magnetograms of Syowa Station (geomagnetic latitude: 66.7°S, geomagnetic longitude: 72.5°E) at the time of the S-210JA-7 launching. From the top, they are horizontal component, declination and vertical component.

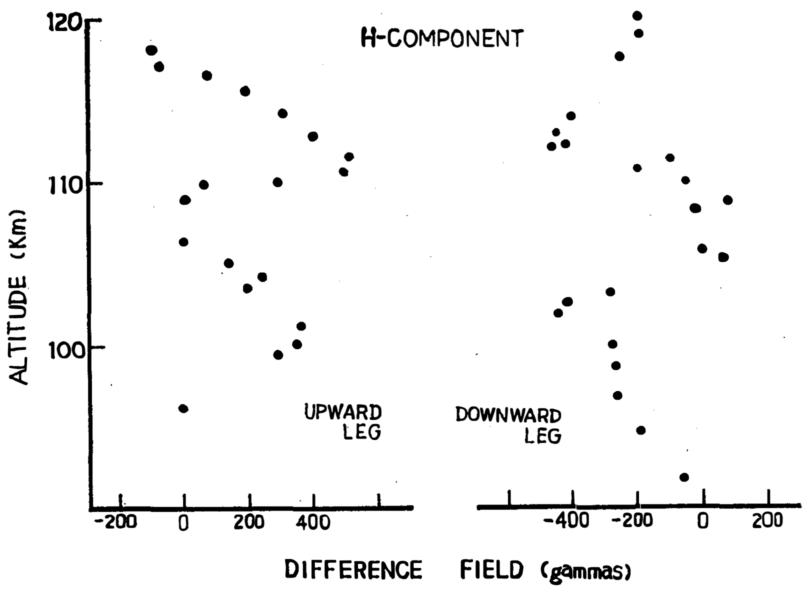

Fig. 5. The horizontal component difference field between the measured and the calculated magnitude on the upward and downward legs, as a function of altitude.

respectively. The dotted line represents the quiet level of each component. The rocket was launched during a bay disturbance which showed a decrease of about 200 gammas in the horizontal component.

The magnitudes of the horizontal and the vertical components of the magnetic

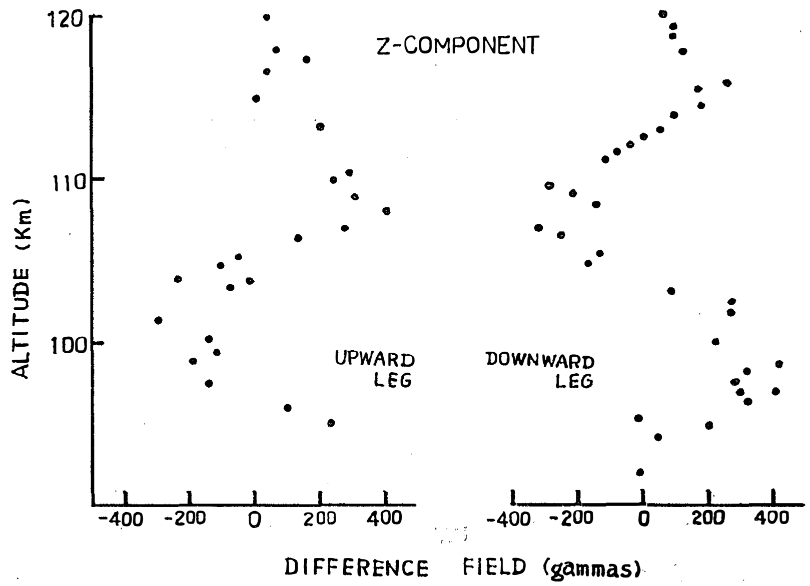

Fig. 6. The vertical component difference field between the measured and the calculated magnitude on the upward and downward legs, as a function of altitude.

field along the rocket trajectory were calculated from the coefficient of a spherical harmonic expansion and were substracted from that of the measured magnetic field. The difference fields of the horizontal and vertical components on the upward leg and downward leg of the flight are shown in Fig. 5 and Fig. 6, respectively.

In Fig. 5, the difference field of the upward leg gradually decreases until about 108 km, then increases until 112 km, and then decreases again. On the other hand, the profile on the downward leg shows the opposite behavior from the upward profile. In the Fig. 6, these two field profiles are different from each other.

These difference fields of the upward leg of the rocket trajectory show the existence of a magnetic field due to an electrojet flowing in an altitude range of 105–107 km, the current system of the electrojet is localized. The intensity of the flowing current is calculated to be about 4.5×10^5 amperes and it may have produced the negative bay disturbance. There appear to be localized currents having different directions during the measurements in the upward leg of the flight and the measurements in the downward leg. The intensity of the filament current is calculated to be about 7.5×10^3 amperes. The current model is 5 km wide and 1 km thick according to the approximation for the upward leg at the altitude of 100–110 km. At the altitude of 100 km, the rocket position of the upward leg was about 55 km away from that of the downward leg. It is suggested that these localized currents appear and disappear repeatedly within a short period of time.

Acknowledgments

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References

CLOUTIER, P. A., H. R. ANDERSON, R. J. PARK, R. R. VONDRAK, R. J. SPIGER and B. R. SANDEL (1970): Detection of geomagnetically aligned currents associated with an auroral arc. J. Geophys. Res., **75**, 2595–2600.

KATO, Y., I. AOYAMA and F. TOHYAMA (1974): Result of rocket experiment at Syowa Station (magnetic field). Nankyoku Shiryo (Antarctic Rec.), **49**, 32–37.