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Evidence Concerning Instabilities of the Distant Geomagnetic Field: Pioneer I

C. P. SONETT, D. L. JUDGE, AND J. M. KELSO

Space Technology Laboratories, Inc.
Los Angeles 45, California

Abstract—The search-coil magnetometer carried on Pioneer I has yielded evidence of complex geomagnetic behavior at great distances from the earth. This paper is intended to report only some preliminary observations; in particular, what appears to be directional instability in the field. A comprehensive statistical analysis, to be reported later, is still in progress.

Preliminary results of the flight of Pioneer I* have indicated that certain instabilities apparently occur in the geomagnetic field at great distances from the earth. A comprehensive statistical analysis of the data is in progress. Since the results of this analysis are pending, it was considered desirable to present qualitatively some of the characteristics of the data at the present time.

The magnetometer which was used to obtain the data consisted of a search coil wound about a nickel-iron alloy core. The emf generated by the search coil was applied to an amplifier which had a center frequency of 2 cps and a passband 2 cps wide. The dynamic range of the amplifier was approximately 3000. The 2-cps spin rate of the vehicle was utilized to generate the emf, the coil being fixed in the vehicle's frame of reference.

As a consequence of the low frequency, the narrow passband, and the large amount of automatic gain control, the transient response for the amplitude excursions highly modified the data. On the other hand, the phase transient response time was considerably shorter than the time associated with a number of phase shifts which have appeared in preliminary examination of the data. The geometry for the apparatus is indicated in Figure 1 where *XYZ* is an inertial frame centered in the vehicle and X′Y′Z is a rotating frame fixed in the vehicle.

Since the rocket was spin stabilized, the orientation of the spin axis was fixed inertially. The distance from the center of the earth for the particular discontinuity which is shown in Figures 2 and 3 is 84,000 km. The geocentric latitude was 5° and the orientation of the spin axis was approximately 85° to the dipole field di-

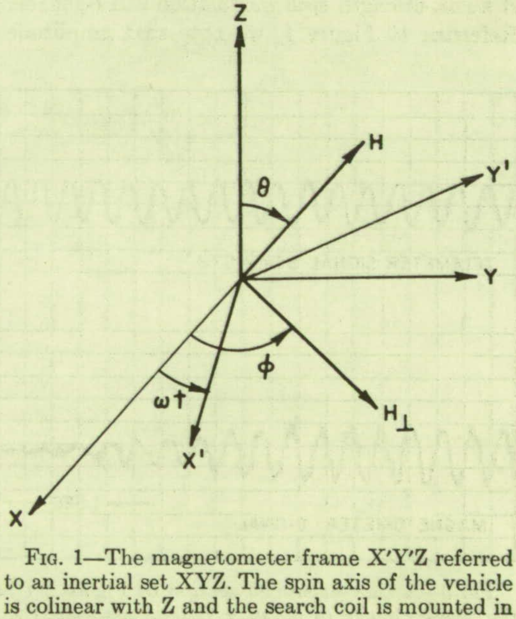

FIG. 1—The magnetometer frame X′Y′Z referred to an inertial set XYZ. The spin axis of the vehicle is colinear with Z and the search coil is mounted in the plane X′Z.

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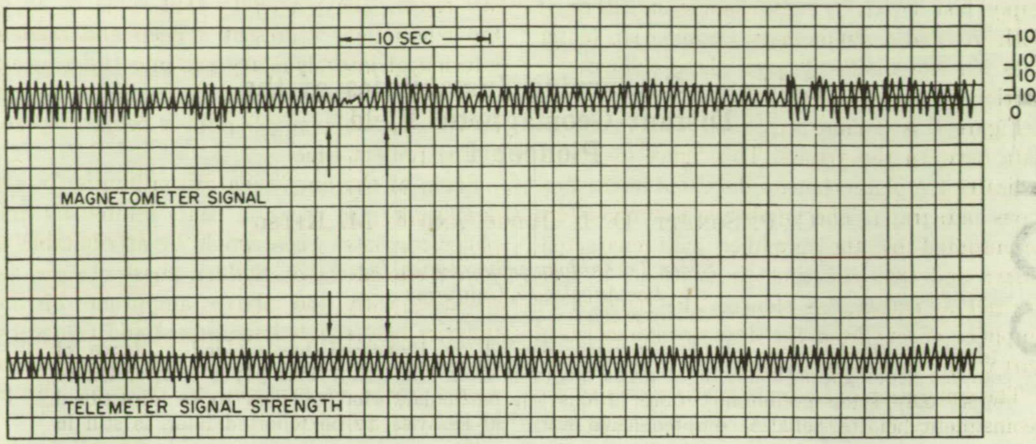

FIG. 2—A typical magnetometer recording showing a signal zero associated with large phase change (between arrows), signal oscillations, and rapid changes in signal level. The magnetometer trace shows a characteristic spin rate. The telemeter rf signal strength is shown below, so as to serve as a phase reference for the magnetometer. The scale for the magnetic field is indicated at the right-hand side, the units being oersted (emu). This record represents the signal at approximately 86,300 km from the earth's surface.

rection; thus, within the error assignment for the experiment, the magnetometer, at this distance, measured the total field. The velocity of the vehicle at this time was 2.2 km/ sec.

The received data shown in Figures 2 and 3 consists of the spin-rate sinusoid corresponding to $\mathbf{H}_\perp$. Comparison of the phase of $\mathbf{H}_\perp$ with the rf signal-strength spin modulation can be made. Referring to Figure 1, we note that amplitude excursions of $\mathbf{H}_\perp$ would be explained by changes in $|H|$, the polar angle θ, or a combination of the two. In Figure 2, the arrows isolate a zero with which is associated a phase change (rotation of ϕ) of about π radians. Because of the amplitude zero, this appears to be a combination of a rotation of $\mathbf{H}$ through the spin axis coupled with a change in $|H|$. The asymmetric form of the signal to the right of the zero would

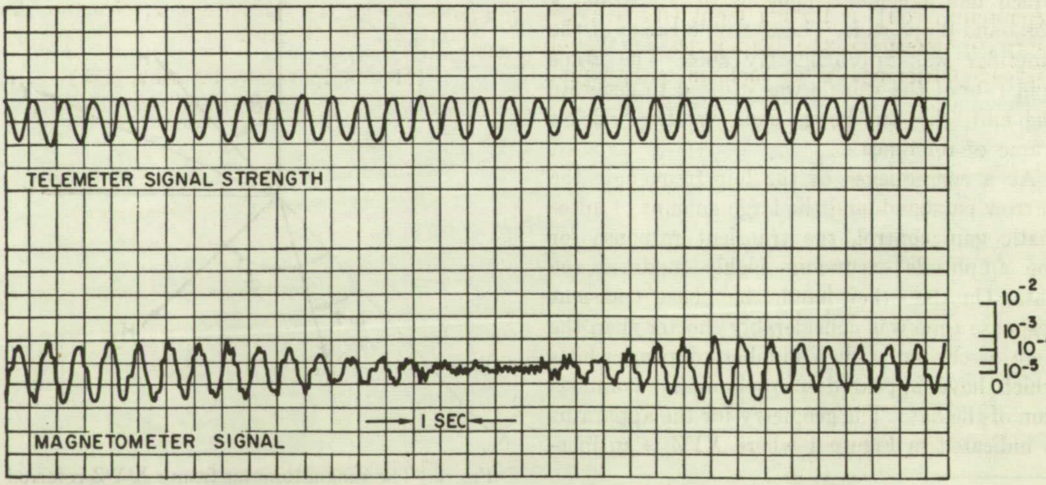

FIG 3—A time-expanded section of Figure 2 (the region about the indexing arrows) showing clearly the phase change of about π radians associated with the zero. The scale at the right of the diagram is the same as for Figure 2.

imply fast ($\tau < \frac{1}{2}$ sec) changes in either or both $|H|$ and θ. Preliminary examination of the data has not disclosed large phase changes occurring in this time.

Figure 3 is a more expanded version of the data between the arrows. This figure distinctly indicates the phase changes discussed in the previous paragraph. The amplitude excursions are accentuated by the amplifier gain characteristics; and thus the time fluctuations, if real, are not as extreme as shown. The removal of amplifier effects from the data is planned as a part of the computer program.

The generation of hydromagnetic waves at the geomagnetic field termination due to a magnetic instability associated with a coronal wind has been proposed by both *Biermann* [1957] and *Hoyle* [1956]. Slow variations in amplitude are seen in Figure 2. The periods were typical for the region of 13 to 15 earth radii. The day of firing (October 11, 1958) was extremely quiet magnetically. A proton magnetometer at Palo Alto disclosed surface fluctuations of about 10^{-6} gauss rms (A. J. Dessler, private communication). Extrapolation of these values to about 13 earth radii would yield wave amplitudes consistent with those obtained [*Dessler*, 1958]. It has been suggested that 10 earth radii represent a suitable geomagnetic-field coronal-wind interface for a quiet day, though the region of instability sampled by Pioneer I is much broader than that suggested by J. A. Simpson (private communication). A further flight will be necessary to determine the boundaries of the observed phenomena, if, in fact, an outer boundary exists. The possibility that some or all of the fluctuations represent a deep and random infusion of interplanetary gas into the geomagnetic field is being explored. A detailed statistical analysis of the available data is being prepared at the present time.

Some of the amplitude discontinuities in the data appear to occur in times limited by amplifier response. These would be attributable to compressional waves. Sudden phase changes associated with the above amplitude discontinuities may enable longitudinal and transverse wave motion to be sorted out, since Alfvén waves would be expected to show an abrupt phase discontinuity.

The following conclusions can now be drawn:

1. Rotations of the magnetic intensity vector, through both large and small angles, appear for the distant field. At least some of those associated with large angular excursions have characteristic times of the order of 10 seconds.

2. Almost periodic oscillations in amplitude occur (sometimes accompanied by rotational changes) having lifetimes of 2 to 5 cycles and periods of the order of 10 seconds.

References

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