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GEOMAGNETIC ORIENTED ELECTROMAGNETIC RADIATION IN THE IONOSPHERE

by

C. U. Benton, H. M. Fowles, and P. K. Goen

ABSTRACT

Strong bursts of electromagnetic radiation were observed in the ionosphere during the Waso rocket Electromagnetic Pulse (EMP) experiment. The pulses have a frequency content from below 20 MHz to above 70 MHz. They vary in duration between 5 μ s and 2 ms and in peak-amplitudes of 2 mV/m to greater than 200 mV/m. These pulses show a high degree of geomagnetic correlation and are of unknown origin.

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I. INTRODUCTION

One of the objectives of the Waso Electromagnetic Pulse (EMP) experiment was to measure the electromagnetic background in the ionosphere. A Terrier Sandhawk rocket system with a 22.9-cm-diam payload, 351 cm long, was used. The payload reached an apogee of 405.5 km at 319 s. Data were taken continuously on most systems from launch to reentry at 612 s. The Langmuir probes and the scan converter took data only when the payload was above 90 km.

II. INSTRUMENTATION

The EMP instrumentation consisted of three EMP antennas, two of which drove three filter channels each. The six filter channels continuously recorded the electromagnetic fields seen by the payload. Each channel had 6-MHz bandwidth and the center frequencies were spaced at 10-MHz intervals from 20 through 70 MHz. The envelope of the received signal was continuously telemetered to the ground on an S-band carrier.

The third antenna furnished signals to a scan converter system which had a 3-db bandwidth from 1 MHz to 300 MHz. The scan converter provided a time domain record of 3.3- μ s length of any signal above a preset threshold that arrived when

the scan converter was armed. After being triggered, 5 s were required to transmit the received signal before the scan converter was automatically rearmed.

Supporting instrumentation included dual Langmuir probes to measure in situ electron densities; a magnetometer to provide information on rocket orientation; two S-band telemetry systems; an electronic sequencer; a fire-module system; a radar transponder; a payload recovery system which included a C-band beacon.

Ground station equipment consisted of two tracking radars, two S-band receivers with tracking antennas, three tape recorders, a time code system, a scan converter base station, launch control, prelaunch payload control, and a 2-mV pulser.

III. PREFLIGHT INVESTIGATIONS

The 2-mV pulser was located 300 m from the launcher and produced a nominal peak field of 4.8 kV/m at 100 m. The radiated field was mapped in azimuth and elevation using a calibrated sensor suspended 100 m below a helicopter. Tests were conducted to insure safety of the rocket motors and initiators located nearby. The pulser was operated at various intervals in the 24-h day for a 3-wk period and ionograms taken before, during, and after the pulser operation in order to search for possible ionosphere modification effects. No significant effects were found, (i.e., changes that could not have been caused by other means).

IV. FLIGHT SUMMARY

Prior to launch day, full systems tests indicated proper operation of all systems. Prelaunch tests began 2 h before launch and the rocket was launched on schedule at Barking Sands, Kauai, Hawaii at 1400 UT on May 9, 1975. The rocket performance during the flight was smooth and followed closely the predicted trajectory. Apogee was at + 319 s at an altitude of 405.5 km. Coning angle of the payload was $\pm 2.8^\circ$ and the payload roll rate was 4.4 rps. Normal noise was experienced on all telemetry channels during the burn phase of the first and second stages. All telemetry channels returned to normal at + 35 s at an altitude of 94 km when the Langmuir probes were deployed. The scan converter operation began at about the same time. Data were obtained until + 612 s at an altitude of 41 km.

The 2-mV pulser was operated in approximately 16-s intervals beginning at + 58.475 s and continued until + 639 s. The payload was recovered in a normal fashion and all equipment was found to operate properly except the magnetometer and Langmuir probes which were destroyed on reentry.

V. ANALYSIS SUMMARY

All telemetry, radar data, time codes, and voice commentary were tape recorded in real time. Immediately after splashdown, oscillograms were made at slow speed from the tapes. Proper operation of the system during the flight was indicated. The Langmuir probe data were reduced to give electron density (N_e) profiles of a weak, stable ionosphere. The N_e profile from the Langmuir probes compared very closely with predicted Ionosonde derived profiles (Figs. 1 and 2).

Short pulses were observed on the filter channels which did not correlate with pulses from the pulser. The scan converter triggered repeatedly within 10 ms after arming. None of the scan converter data resembled pulses from the 2-mV pulser and trigger-times were not correlated with pulser firing. Many of the scan converter traces display an apparent monochromatic or CW-like signal in the VHF range or possibly of higher frequency. The observed signals correspond to a field of ~ 100 mV/m which is higher than previously reported estimates of ionospheric EM background.¹⁻³

Fig. 1. Calculated Electron Density Profile.

Fig. 2. Measured Electron Density Profile.

VI. GEOMAGNETIC ORIENTATION OF RANDOM PULSES

The short pulses observed on the filter channels appeared to be correlated with magnetic north or south when compared to the magnetometer trace. Of the 570 characteristic sets of pulses observed, most occurred above 90 km. Pulses were counted only when they simultaneously occurred in two or more channels, and then as a one-pulse count. The frequency of occurrence was random with some occurring in bursts of two or three sets of pulses separated by about 0.8 s, 60% of which occurred in the 50-, 60-, and 70-MHz channels. At times the pulses were seen simultaneously in all channels, and at others in only a few of the channels. There were instances when a pulse was seen in one high-frequency channel and in one low-frequency channel only. The amplitude of about 80% of the pulses was between 80 mV/m and 100 mV/m. The pulse duration was usually between 5 μ s and 400 μ s with some as long as 2 ms. When the magnetometer indicated north or maximum, the antenna for the three lower frequency filter channels was pointed 45° counterclockwise as viewed from the bottom of the payload. Figure 3 is a histogram showing the orientation of the pulses from all filter channels with respect to the magnetometer trace. Figure 4 shows the location of either antenna with respect to magnetic north for all pulses. If an antenna was pointed east or west, and a pulse of electromagnetic energy was traveling down a field-line in the polar direction, the sensor system would have a 56-db gain over the time when the antenna was pointed north and a 24-db gain over the time when the antenna was pointed south. We have no way of determining the direction of propagation of the pulse if indeed the pulse was traveling down a field-line as is strongly indicated from these data.

Fig. 3. Pulses Vs Magnetometer.

Fig. 4. Antenna Degrees from North or South Vs Pulse Sets.

The probable radio-propagation conditions at the time of the rocket flight are such that signals of about 20 MHz or less could have been propagated by ionospheric refractions from remote points on the earth while propagation at 30 MHz or higher could have been restricted to near line-of-sight distances. If this was the case, the number of signals from terrestrial radio transmitters in the 20-MHz channel would have been much greater than the number of such signals in the higher frequency channels, while the rocket was below the F-region peak of the ionosphere. The 20-MHz signal from WWVH which is located about 8 km from the launch site is identifiable in the 20-MHz filter channel when the rocket is below the peak of the F-region. The measured amplitude of the WWVH signal up to about 200 km is in reasonable agreement with signal estimates obtained from NBS publication 236 (NBS Frequency and Time Broadcast Services). The 20-MHz channel also shows some signals which tend to vanish high in the ionosphere. The other filter channels show much less variation with altitude. Near apogee, the signals in all channels are about the same in amplitude. It is believed that all channels were working properly during the flight, and that the pulses are not due to p-static or space-charging,⁴ or internal malfunctions.

VII. CONCLUSIONS

The data examined strongly suggest that there are short bursts of electromagnetic energy traveling along the earth's magnetic-field-lines in the ionosphere. The amplitude of these pulses is significant and contains a frequency content at least from 17 MHz to 73 MHz. The VHF radiation present in the ionosphere is expected to consist of galactic noise, thunderstorm noise, and the signals from all radio transmitters roughly within line-of-sight distance of the rocket payload. The continual background noise when the rocket was above 300 km observed in the data was about 4 mV/m or less peak-to-peak. All six filter channels saturated at about 200 mV/m peak and many of the channels were saturated at times by these short pulses. Missile charging and static discharge can be ruled out. Direct solar radiation could not have illuminated the rocket during the flight, so a direct solar source is doubtful. Galactic sources appear doubtful. This leaves ionospheric storms or an indirect solar source as the possible source. Without further supporting evidence, the source of these pulses is unknown at present.

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