THE WILLARD J. VOGEL STUDY

PRELIMINARY REPORT ON MAGNETIC FIELD MEASUREMENTS RECORDED AT SATUS FIRE LOOKOUT - JULY 11, 2001

By David W. Akers, P.E.
Executive Director, The Willard J. Vogel Study
P.O. Box 47236, Seattle, Washington USA
Email: dwa@vogelstudy.org
www.vogelstudy.org

ABSTRACT

A twelve-hour magnetometer recording made at the Satus Fire Lookout on the Yakama Indian Reservation in central Washington, USA, revealed many, 30 mS to 15 S wide magnetic pulses of unknown origin. The characteristics of the pulses suggest that they are of mechanical origin, because of their highly patterned symmetry and amplitude characteristics. The nature of the data and history of the study area further suggest that the pulses may be related to electromagnetic disturbances seen in connection with the appearance of various Anomalous Luminous Phenomena (ALP). The data show similarities to electromagnetic measurements made by ALP researchers in other geographical locations. Since no ALP observations were made during the recording period, there is still the possibility that the source of the pulses may be the result of unknown human activities. This preliminary report discusses the data recorded and presents the results of initial analysis of the data set.

INTRODUCTION

This preliminary report describes the characteristics of magnetic flux variations, recorded over a 12-hour period, at Satus Fire Lookout on the Yakama Indian Reservation in south central Washington state (USA). A 12-bit, three-axis magnetometer - capable of resolving flux changes as small as one or two milliGauss (mG) - was used to acquire the data. The flux changes were sampled at a rate of 100 samples/second, making it possible to resolve waveforms at rates up to about 50 Hz in frequency.

The signals described here are probably related to Anomalous Luminous Phenomena (ALP). Though no observations of ALP were made during the time of the recordings, the history of the study area[1] and similarities to instrument readings made elsewhere[2,3] strongly suggest an ALP connection. Other possible sources for the flux variations, which have not been positively ruled-out, are unknown military or commercial activities.

Additional field work is ongoing to establish a stronger nexus between the magnetic flux variations described here and ALP observed in the study area. In the meantime, this preliminary description and analysis is being presented to point a way toward improved magnetic measurement techniques and discovery of a magnetic “signature” for the flux variations sometimes associated with ALP.

DATA SET CHARACTERISTICS

The data set, acquired on July 11, 2001, consists of a continuous recording of 12 hours and 8 minutes of local magnetic flux variations. Recording began at 1950 Pacific Daylight time (PDT) and continued, uninterrupted until the morning of July 12, 2001 at 0759 PDT. The original recording is 30,600,167 bytes long. The Satus Fire Lookout magnetometer was located at latitude 46° 15.4727' N and longitude 120° 45.2393' W (from GPS).

The magnetometer head was fixed in position during the recording process such that the Y- reading axis pointed towards true North, the X - reading axis pointed to true East, and the Z - reading axis was perpendicular to the earth’s surface. Note that the X axis component of the earth’s horizontal field intensity (H) is usually defined as positive to true north and the Y axis is defined positive to the east (D). Z axis magnitude is also defined as positive-downward. The magnetometer head, an engineering model, inverted the polarity of the flux changes on all three axes from standard geomagnetic definitions. The plotting and analysis done below adjust for these differences and follow the standard definitions.

PRELIMINARY ANALYSIS OF THE DATA

Analog signals from a anisotropic magnetoresistive (AMR) magnetic sensor hybrid (Honeywell HMC2003) were digitized in the magnetometer head module and fed into the serial port of a standard IBM-PC compatible computer. Recording software, running on the PC, synchronized and formatted the magnetometer head data. The raw binary data, along with synchronizing bytes was then recorded on hard disk.

After recording, the data were post processed to synchronize and index frames of data for plotting, Fast Fourier Transform (FFT) generation, and other analysis functions.

A "frame" is defined as a unit of time - one sample interval (10 mS) - in which a sample is acquired and stored. This unit is used to index each sample of data in the recording. The relationship between the frame number (F) and elapsed time (t) is defined by the simple formula:

$$t = 0.01F \text{ (seconds)}$$

Figure 1 shows an overview of the entire 12-hour recording. The plot was made by calculating the average value of every 1000 frames of the original data. The effective sample rate is reduced to one sample every 10 seconds. All three axes are shown in their true amplitude and phase relationships to each other. Normal, diurnal variations in the earth's geomagnetic field are visible in the plot as nearly DC signals. Also visible are the signals of interest, consisting of a series of relatively high level, negative-going pulses, or "spikes," scattered throughout the recording interval.

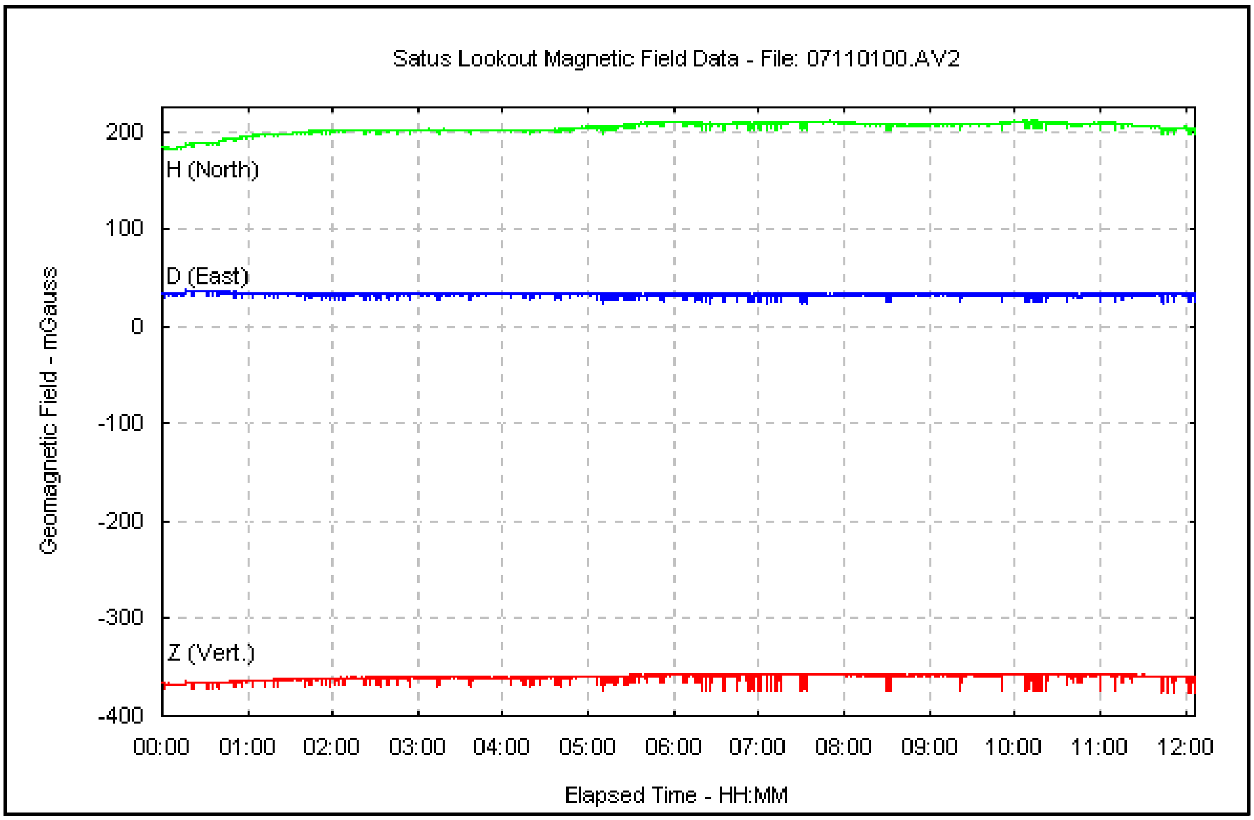


Figure 1. Overall view of entire recording. Start time: 19:50 PDT (0450 UTC)

Note that the spikes increase in number near the center (local midnight) and again towards the end (local sunrise) of the recording. Amplitude suddenly increases near the center of the plot. There is also a tendency of the spike activity to "cluster" around certain points in time. Approximately 845 pulse events of unknown origin were recorded. Details of these signals were clearly preserved in the recording and are described below.

The characteristics of the “signals of interest” which attract attention are the relatively uniform pulse amplitude levels, nearly constant and symmetrical rise and fall times, and wide variation in pulse widths of the waveforms. These features are not typical of “natural” phenomena, such as seismic waves or other forces seen in nature. In addition, the pulses are of relatively high intensity, well above the background noise in the recorded signal.

A closer examination of the raw data indicates that the pulse waveforms on each axis are exactly the same shape - only the amplitude varies. In addition, the signals appear to be in precise phase with each other throughout the recording.

The first step towards a more detailed analysis was to generate a series of simple, graphical plots of the magnetic flux changes in the time domain. Since the waveforms are the same on all axes, only the data for the Z axis - the axis with the best signal-to-noise ratio - were plotted. The results are contained in Appendix A. Each page represents a half-hour time segment, beginning at Frame 0 (19:59:53 PDT on July 11, 2001). Flux magnitude is expressed in milliGauss (mG). (1mG = 100 nT)

The following section classifies the signals in the recording in terms of classic electronics pulse parameters, i.e., amplitude, rise/fall time, and pulse width (Figure 2). The amplitude of a pulse is defined as its peak-to-peak value. Rise and fall times are defined as the time it takes a pulse to increase or decrease from 10% of its initial value to 90% of its final value. The width of a pulse is defined as the difference in time from 50% of its leading edge amplitude to the time at 50% of its trailing edge amplitude. Since most of the pulses seen in the recorded data appear to occur at random, the parameter of repetition rate is not a relevant factor in the analysis.

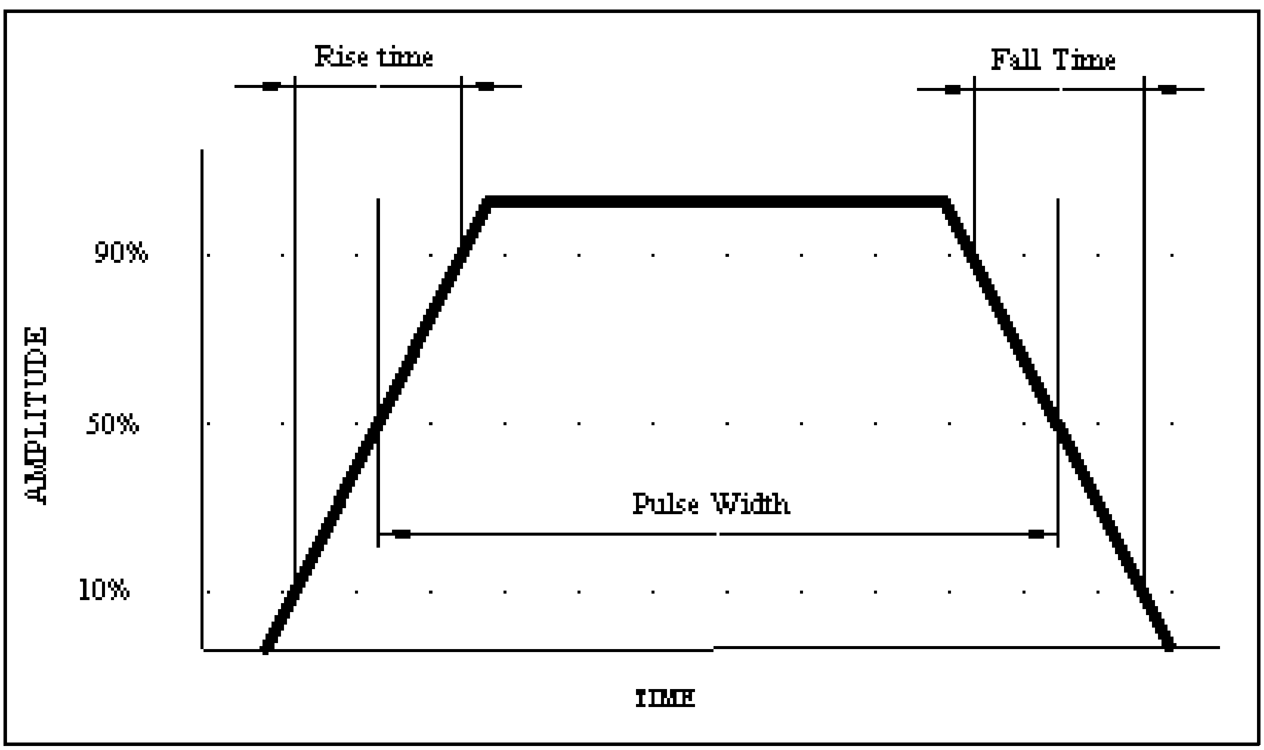


Figure 2. Pulse parameter definitions.

The recording registers only one positive-going pulse near Frame 107,000. This pulse was caused by a rock, holding the magnetometer head in place, shifting position. It should be disregarded. Background noise - 60 Hz power lines, geomagnetic noise, etc. - running at a level of about 2-3 counts (≅2 mG) throughout the recording - can be seen superimposed on the baseline and negative peaks of the signals of interest.

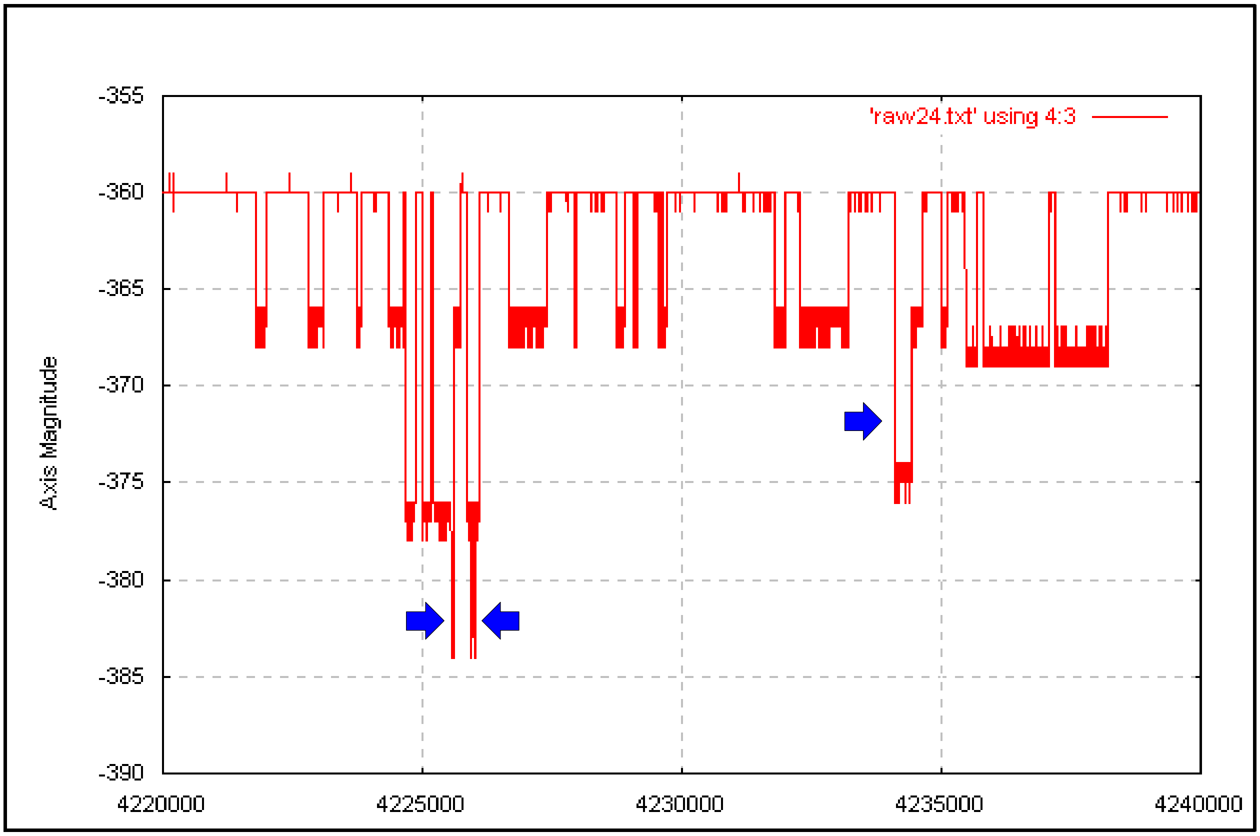


Figure 3. Typical Single and Multi-step waveforms seen throughout the recording (Z Axis).

Figure 3 shows a pulse sequence from the last portion of the recording in greater detail. All types of pulses seen in the entire recording can be seen in this sequence. In general, all pulses recorded were discrete pulses, i.e., they form complete single units.

Each discrete pulse can be further classified as a single or multi-step pulse. A single-step pulse is one which rises to a fixed magnitude - in the current case, a negative value - and stays at that level until returning to its starting level. Multi-step pulses contain step changes in amplitude, before returning to their starting levels. Three of these multi-step pulses are shown in Figure 3 (arrows). Note that, even in the multi-step pulses, amplitude changes are distinctly patterned.

The amplitude characteristics of the recorded pulses are interesting in that they appear relatively constant from pulse-to-pulse over periods of hours. When a change in amplitude occurs, it generally occurs rapidly and in the form of a "ramp." For example, pulse amplitude remains almost constant at 7 mG from frames 0 through 2274000 in the recording (there is one exception in the higher amplitude pulse at frame 1867000). Beginning around frame 2274000, the amplitude suddenly "ramps-up" during one pulse and stabilizes at another, relatively constant level of 14-16 mG in the next sequence of pulses. Figure 4 clearly shows this transition.

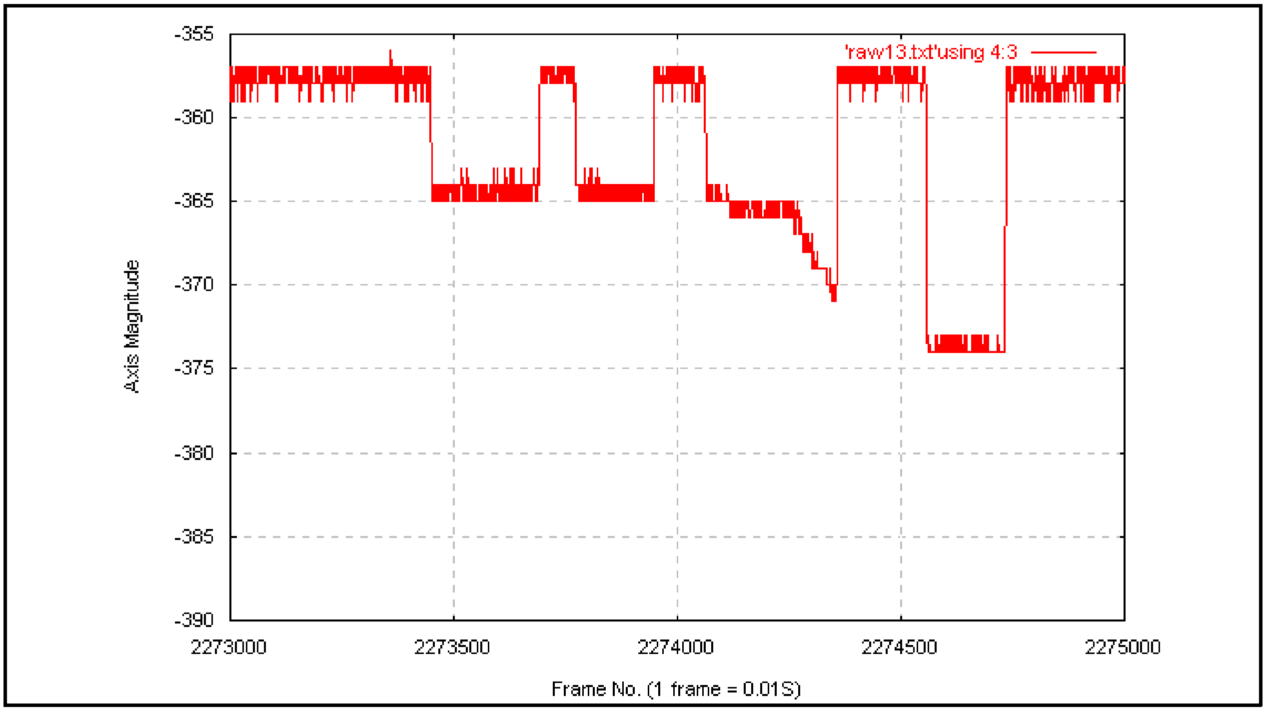


Figure 4. Amplitude transition near middle of recording (Z Axis). 5 Seconds/Division

The rise and fall times for most pulses in the recording are remarkably constant and measure 20 mS or less. The rise and fall times could be faster than reported, since resolution at the 100 Hz sampling rate is only ±10 mS. There are also several occasions where “overshoot” or “ringing” is seen in negative-going portions of the waveforms. These may be artifacts introduced by the magnetometer or frames dropped in the acquisition process.

A few higher amplitude spikes (to 23 mG) occur in the data, mostly towards the end of the recording period (local sunrise). Such transients appear to occur only in multi-step waveforms. Good examples are seen in Figures 5 and 6 (Pulse width times are occasionally included for reference). Other examples can be seen in Appendix A, starting around Frame 3390000.

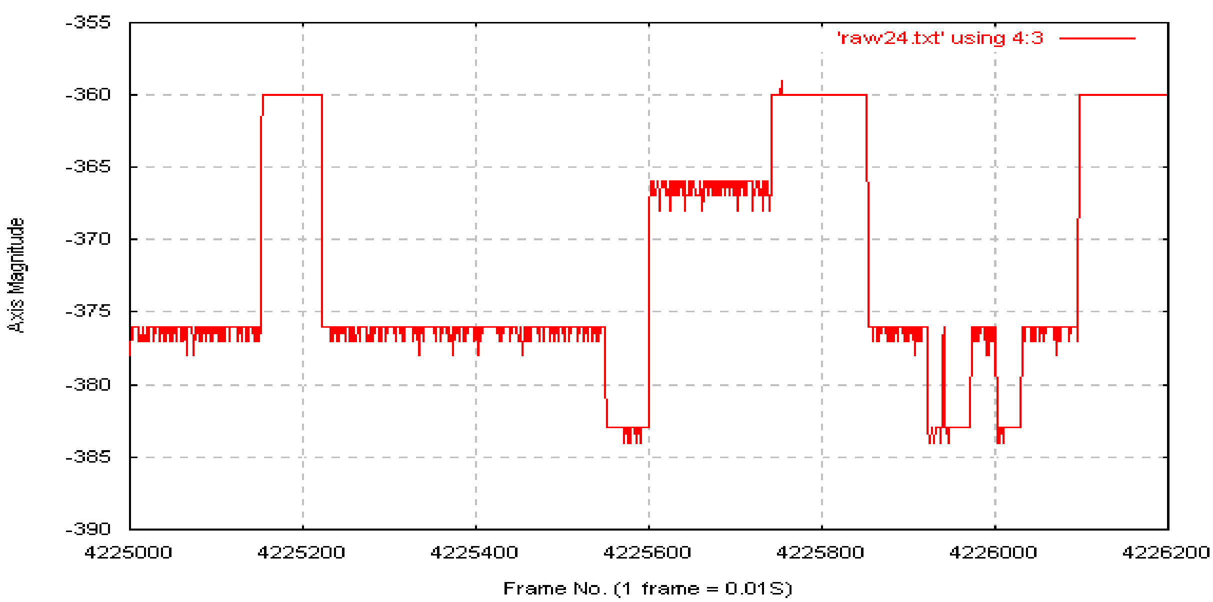


Figure 5. Multi-step pulses (Z Axis). 2 Seconds/Division

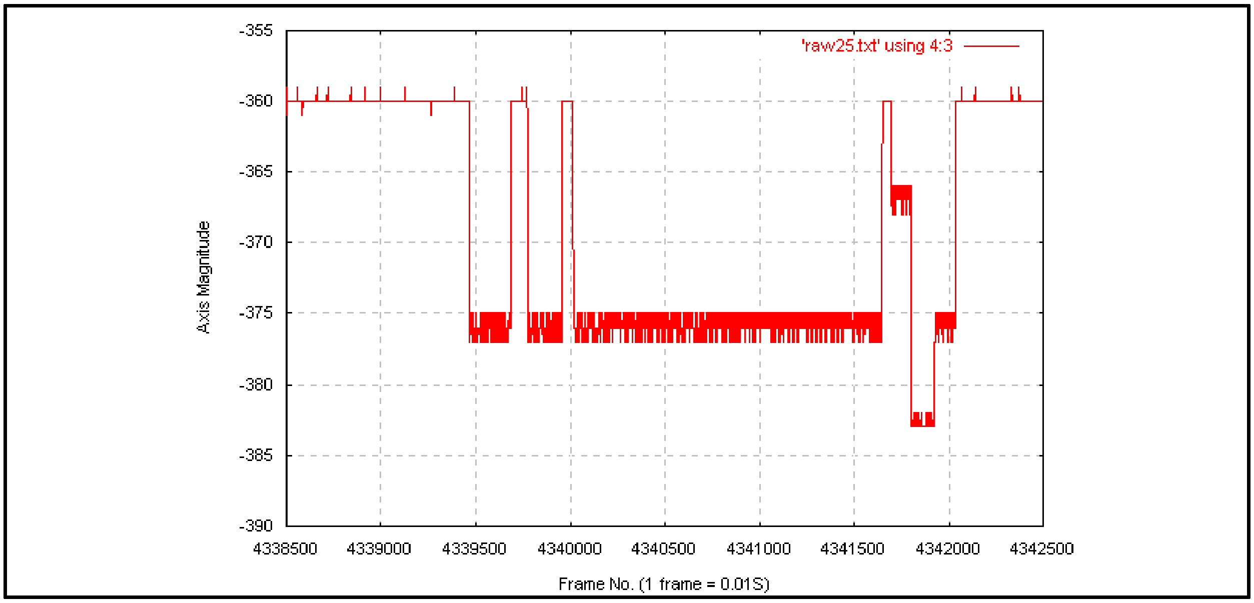


Figure 6. Another multi-step pulse (Z Axis). 5 Seconds/Division

Pulse widths for the discrete pulse events vary widely throughout the recording period: The minimum pulse width detected during the 12-hour recording was 20 mS (Frame 3848061). The maximum pulse width was 15.25 S (Frame 4340000, in Figure 6). This amounts to a pulse-width ratio of about 500:1. Both, the longest and shortest pulses were seen in single-step pulse events.

Another way of looking at the data is to combine isolated pulse events into groups of pulses and apply Fast-Fourier Transform (FFT) or wavelet analysis techniques. Depending upon how we choose the pulse cluster to be examined (our “window”), a different view of the data emerges. Preliminary analysis using FFT’s on single pulses has been done. More work using this technique is being done and will be included in a future report.

The multi-axis capability of the magnetometer used to make the recording also yielded some interesting information regarding the location of the signals of interest. In summary, the origin of the signals appears to be a fixed, point source. A vector magnitude and angle for each axis can be readily calculated from the data (see Appendix B). Since just one location was used for the magnetometer head, only a line-of-position can be calculated. Based on calculations, the source of the signals is either above and southwest or below and northeast of the Satus Fire Lookout. The angles in the geomagnetic, horizontal (H) plane are in a direction either 220° or 40° from true north. Additional recordings from multiple locations should result in a more exact location for the signal source - assuming it does not move.

One additional observation should be included here: A recording made during early testing of the magnetometer hardware and recording software - on August 27, 1998, at 14:01:02 (PDT) at Satus Fire Lookout - captured a 5 second long single pulse which had a magnitude of -300 mG. At the time, the signal was regarded as spurious, since a single, well-formed pulse was not “expected” by the researcher. A recent check of the old data, shows that the recorded pulse had similar properties (rise/fall times and XYZ amplitude/phase characteristics) to the July recording data. A line-of-position calculated from this pulse also nearly matched the line-of-position found in the later, July 11, 2001 recording.

CONCLUSIONS

The signals recorded on evening July 11 and into the morning of July 12 drew attention by virtue of their "unnatural" appearance - namely, their virtually constant rise/fall times and uniform amplitude characteristics. It would be very easy to classify these signals as "machine-made" as opposed to "natural" origins. Indeed, at the time of this writing, the possibility that the signals are produced by human activity has not been positively ruled-out.

On the other hand, several researchers have reported magnetic "pulse" signals, Very Low Frequency (VLF) radio emissions and varying electrostatic fields associated with (and without) ALP in other locations[4]. If the signals are "man-made," their purpose is unclear based on the current data set. If the signals were intended for routine human communication purposes, experience suggests that some regularity in the pulse widths and/or amplitude patterns would be seen. Pulse-amplitude modulation (PAM) and Pulse-width modulation (PWM) are common in human electronic communication protocols, but the combination of both is unusual.

Another possibility, with regard to the intended "purpose" of the pulses, is that the source generating the pulses could be controlling some kind of machine process. In typical machine control systems, either PWM or PAM would be used, but the two would generally not be used together.

A striking characteristic of the current recording is that, while the signals have the outward appearance of being "machine-made," examinations of the details of the signals reveal some unusual characteristics.

For example, the single-step pulses appear to vary randomly in width from unit-to-unit. In addition, there are the multi-step pulses, which appear to have highly patterned, but random sequences. Also, the sequences of pulses - the pulse "trains" - appear to occur randomly.

Another unique feature appears to be the apparently fixed, point source location of the signals. Further measurements should make it possible to exactly locate the source of the emissions. Knowledge of the exact location will yield a great deal of information about the "generator" of the signals.

At the present time, there are no known man-made devices in the air or in the ground, near the Satus Fire Lookout which would generate the strong magnetic flux variations of the nature recorded. The study area is closed to almost everyone but registered Yakama tribal members. The Satus Fire Lookout is well within the boundaries of the closed area. There are radio repeaters and microwave relay stations co-located at the site where the readings were made, but none of the signals seen in the magnetometer recordings appeared to be related to these installations.

The features of the magnetic flux variations recorded in July would almost certainly be associated with concurrent moving electrostatic fields and, consequently, the generation of VLF or perhaps Extremely Low Frequency (ELF), radio waves. This fact is the basis for the assertion that the current measurements made at Satus Lookout could be connected to ALP observations and ELF measurements made by other researchers[5], specifically, at Hessdalen in Norway and (much earlier) in Missouri in the USA[3].

In summary, the following features distinguish the signals of interest seen in the July 11, 2001 recording:

1. Pulses occur in individual units, with single or multiple-step characteristics.

2. Pulse amplitudes show strong patterning and vary in more or less regular “steps.”

3. Pulse amplitudes range between 7 and 23 mG (300 mG in an earlier recording).

4. Pulse rise and fall times are constant - at 20 mS or less - in almost every instance.

5. Pulse widths vary widely and apparently randomly - from 30 mS to 15 S.

6. Pulses appear to come from a fixed, point source - located either above and southwest or below and northeast of the Satus Fire Lookout.

7. Most of the energy in the pulses appears on the vertical, Z axis - perpendicular to the earth’s surface.

Additional field work is being performed to further characterize the signals recorded and described in this preliminary report. Future, long term recording sessions are planned for several locations around the Satus Fire Lookout. A major thrust of the work will to determine the exact location of the source of magnetic flux variations and whether they are truly anomalous or simply man-made signals. If they prove to be anomalous, further work will be done to correlate the magnetic variations with observed luminous phenomena. Additional instrumentation will be deployed as available funding and human resources allow.

REFERENCES

1. Akers, David W., **Report on the Investigation of Nocturnal Light Phenomena at Toppenish, Washington, August 1972,** http://www.vogelstudy.org

2. Strand, Erling, "**Project Hessdalen 1984 - Final Technical Report**", http://www.hessdalen.org/reports/hpreport84.shtml

3. Rutledge, Harley, **Project Identification: The First Scientific Field Study of UFO Phenomena,** Prentice Hall, New Jersey, 1981. (Out of print.)

4. Teodorani, M., Montebugnoli, S., Monari, J., The EMBLA 2000 Mission in Hessdalen, Italian Committee for Project Hessdalen, http://www.itacomm.net/PH/default.htm , August, 2000.

5. Teodorani, M., Strand, E., Hauge, B., EMBLA 2001: The Optical Mission, Italian Committee for Project Hessdalen, http://www.itacomm.net/PH/default.htm

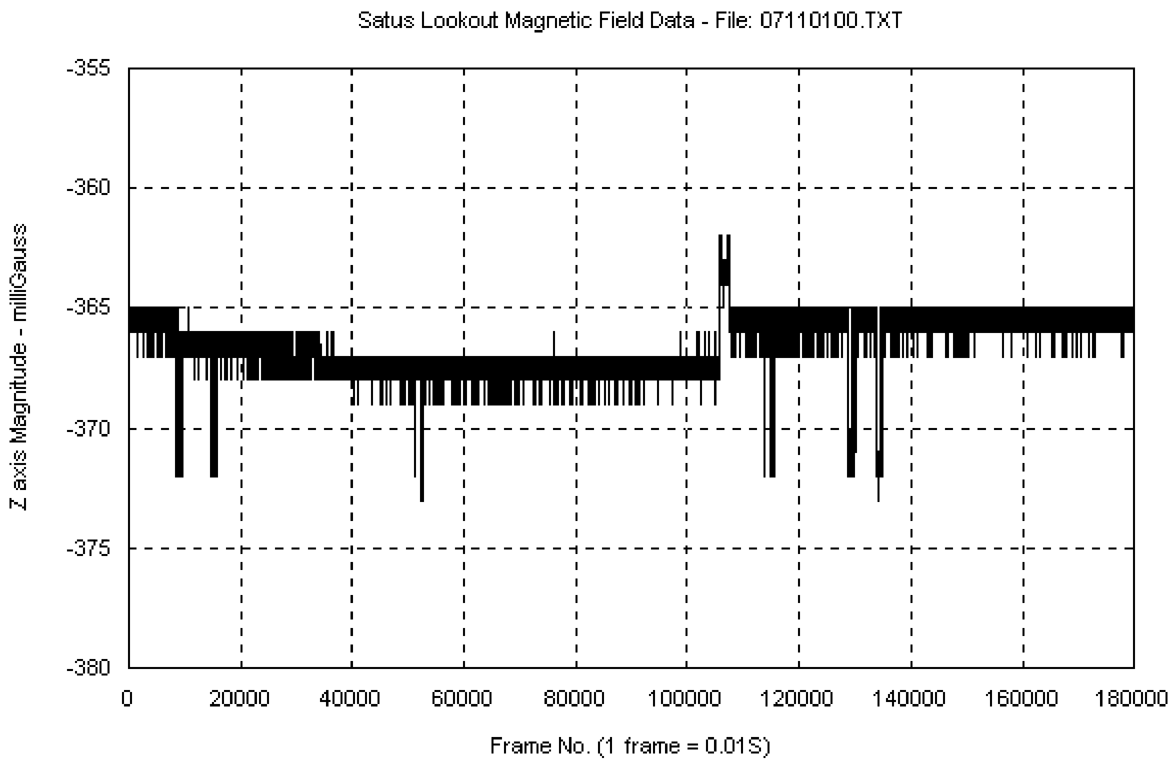
ACKNOWLEDGEMENTS

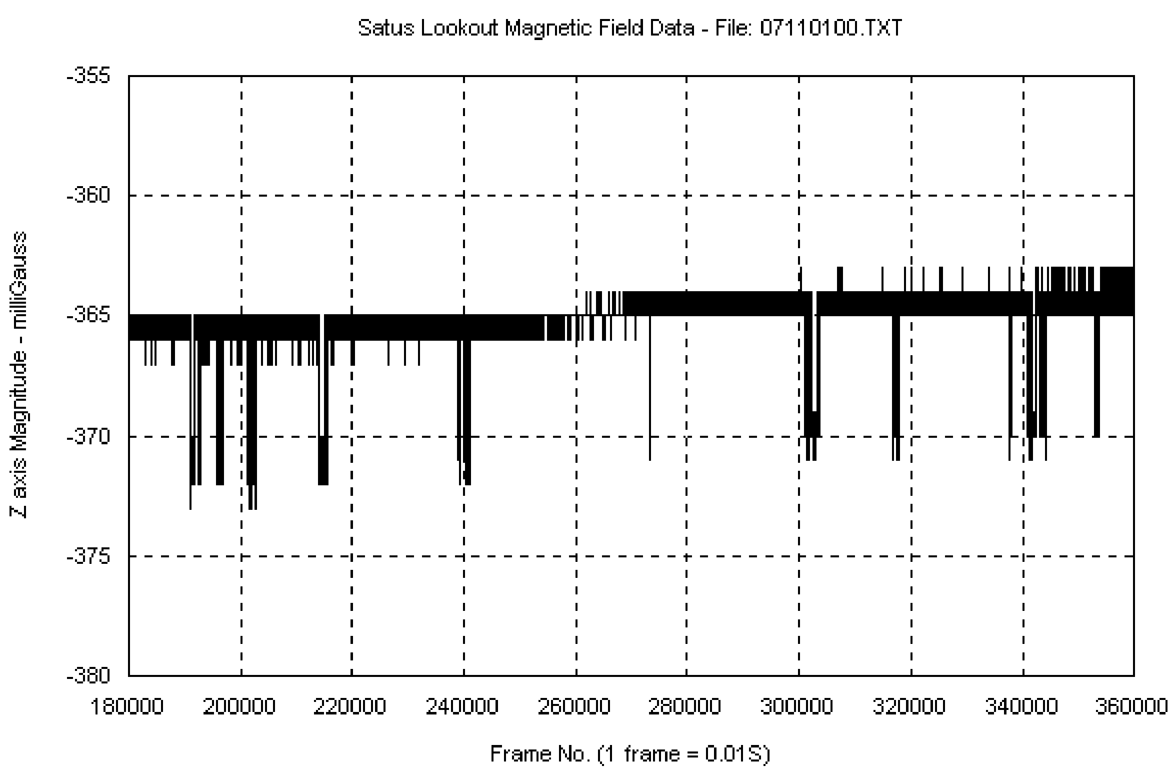
Thanks to the Yakama Indian Nation and the Yakama Indian Tribal Council for permission to perform parts of this research on their sovereign lands. Thanks also to the many people working on the Reservation and surrounding areas for their kindness and assistance in facilitating this work.

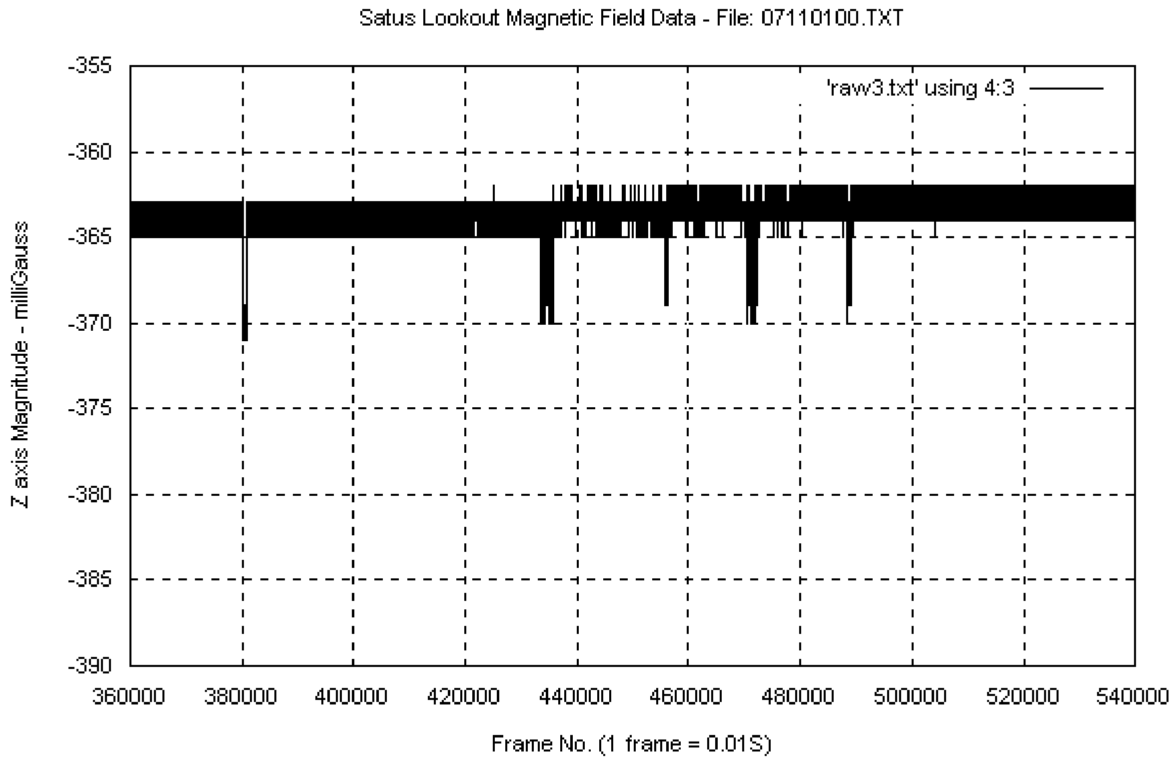
APPENDIX A. Plots of Z Axis Data vs. Elapsed Time by Half Hour Segments

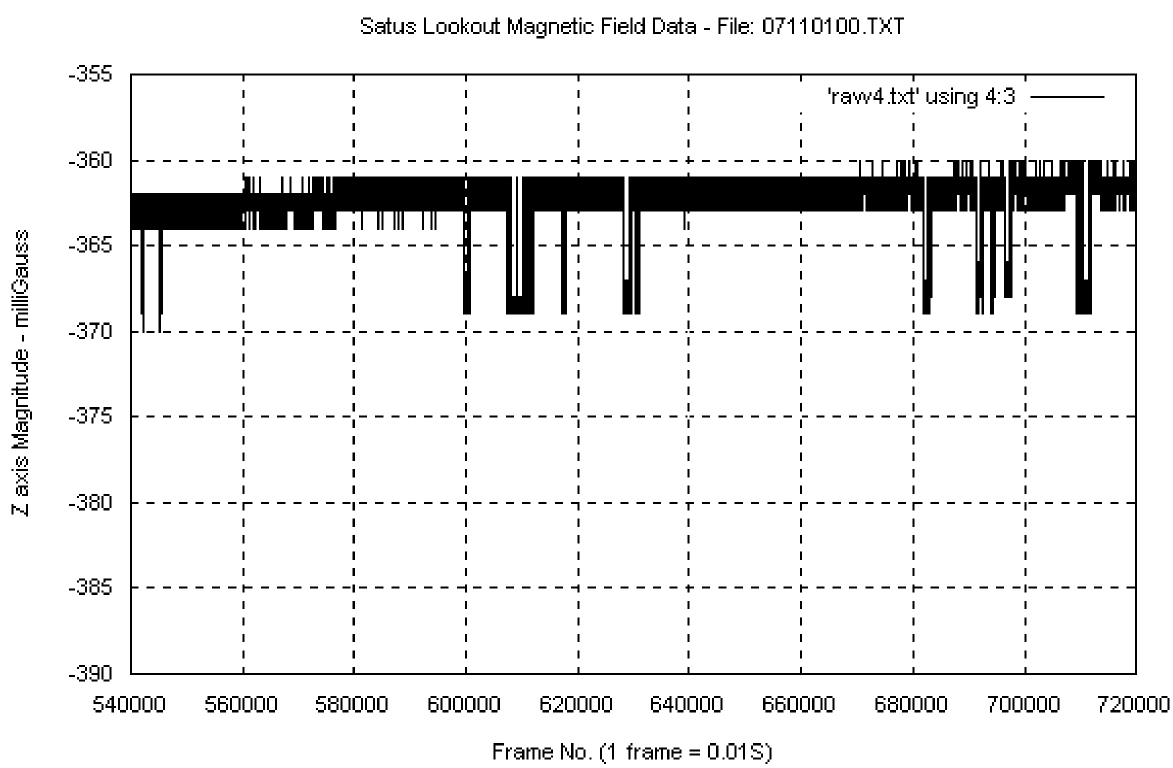
The following pages show plots of the Z Axis data from the July 11, 2001 recording in half-hour segments. Magnetometer data have been adjusted to conform with standard geomagnetic definitions.

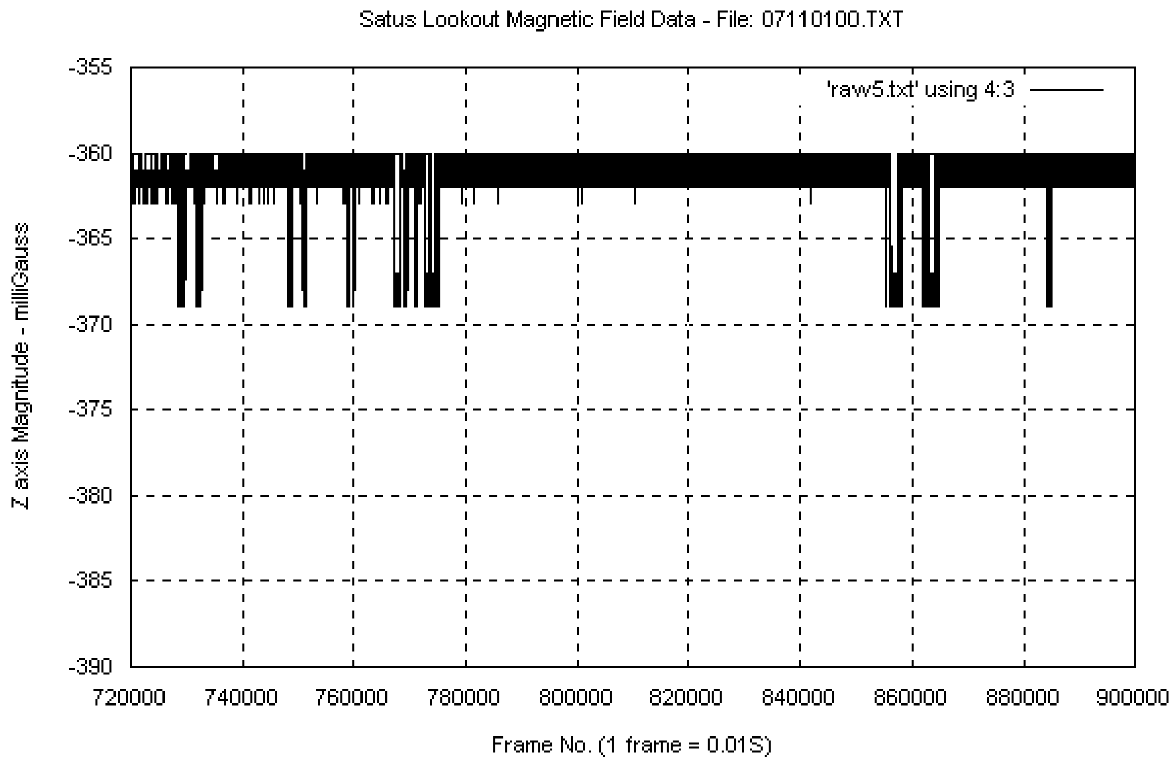
Elapsed time, on the X axis, is displayed by frame number (Each division on the grid represents 200 Seconds).

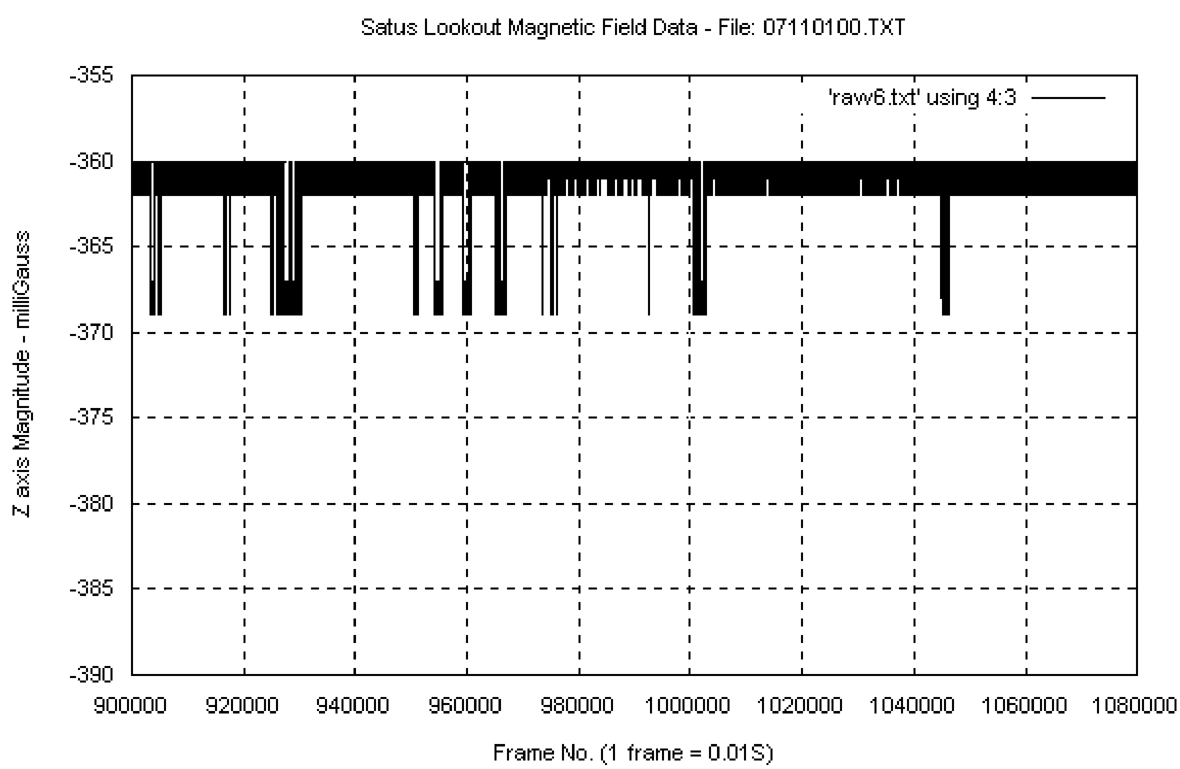

Satus Lookout Magnetic Field Data - File: 07110100.TXT
-355
-360
-365
-370
-375
-380
Z axis Magnitude - milliGauss
0
20000
40000
60000
80000
100000
120000
140000
160000
180000
Frame No. (1 frame = 0.01S)

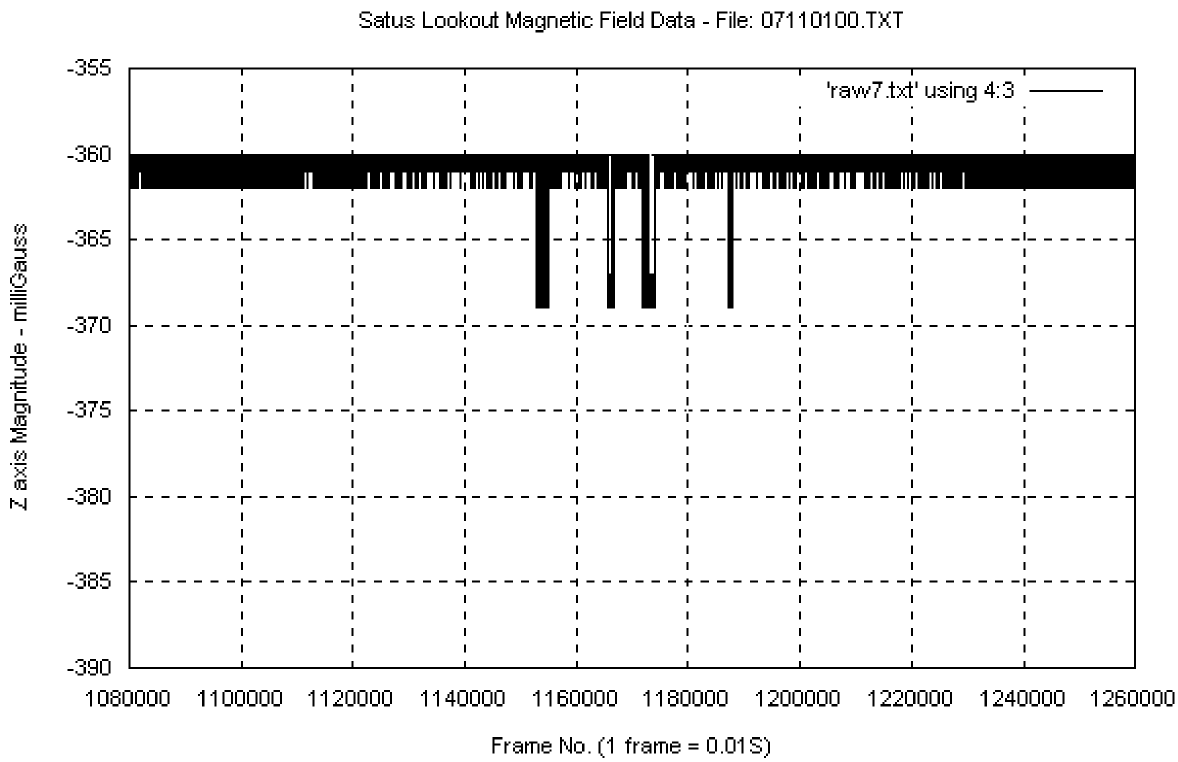

Satus Lookout Magnetic Field Data - File: 07110100.TXT
-355
-360
-365
-370
-375
-380
Z axis Magnitude - milliGauss
180000
200000
220000
240000
260000
280000
300000
320000
340000
360000
Frame No. (1 frame = 0.01S)

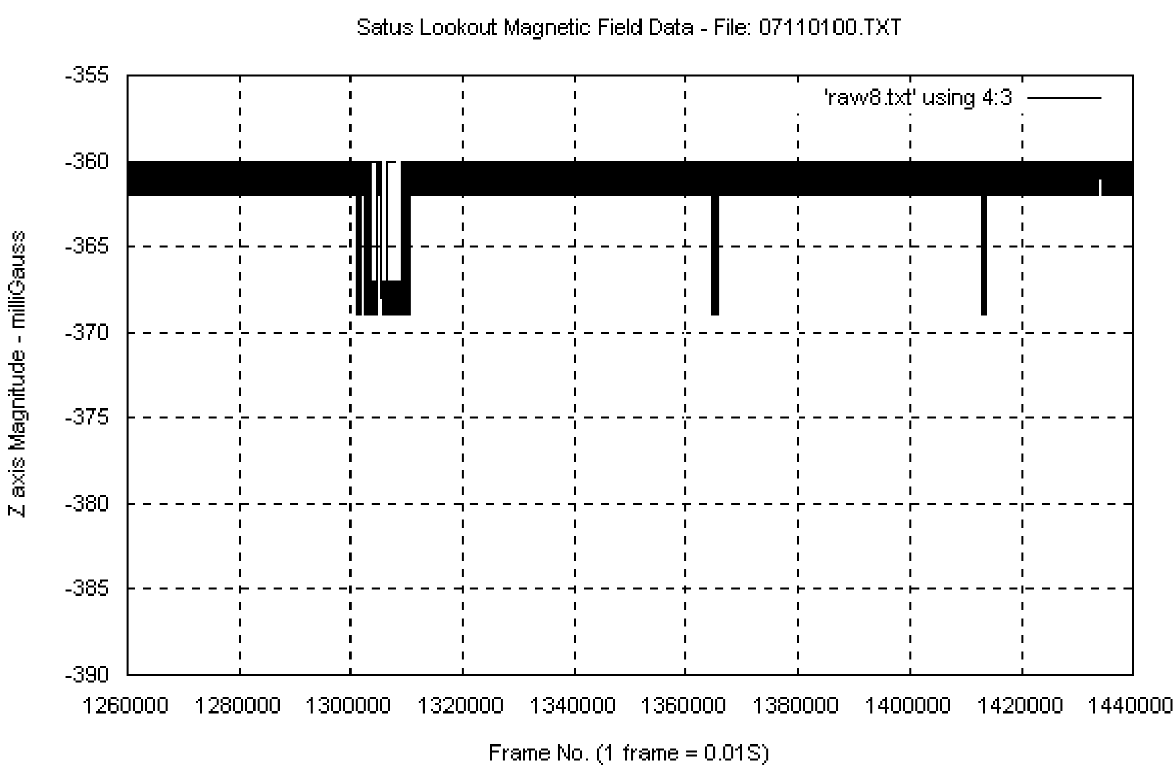

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw3.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
360000
380000
400000
420000
440000
460000
480000
500000
520000
540000
Frame No. (1 frame = 0.01S)

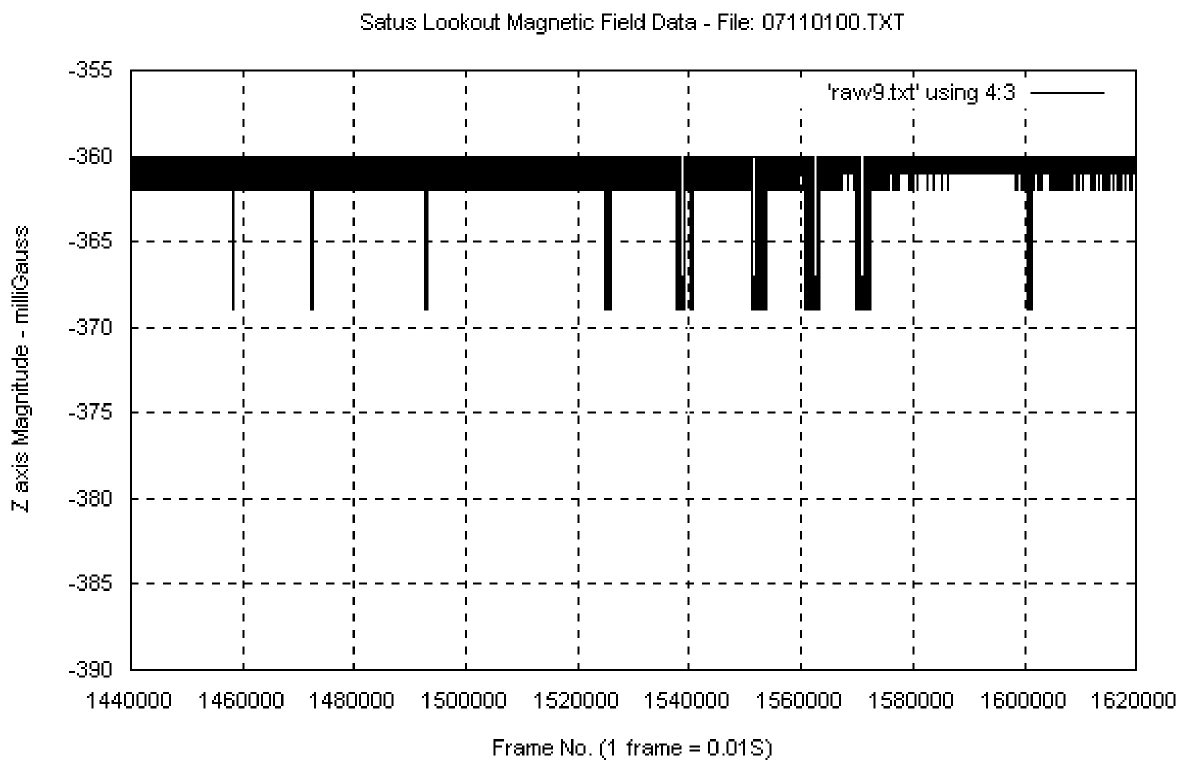

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw4.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
540000
560000
580000
600000
620000
640000
660000
680000
700000
720000
Frame No. (1 frame = 0.01S)

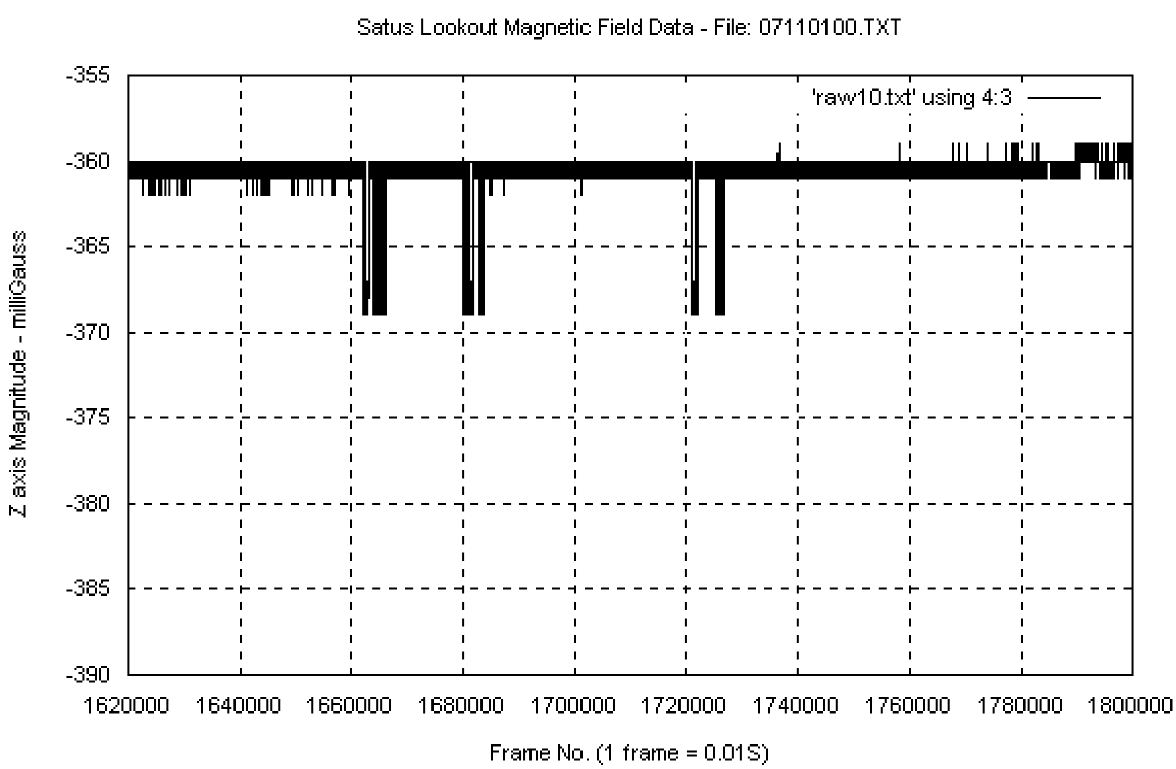

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw5.txt' using 4:3
-355
-360
-365
-370
-375
-380
-385
-390
720000
740000
760000
780000
800000
820000
840000
860000
880000
900000
Z axis Magnitude - milliGauss
Frame No. (1 frame = 0.01S)

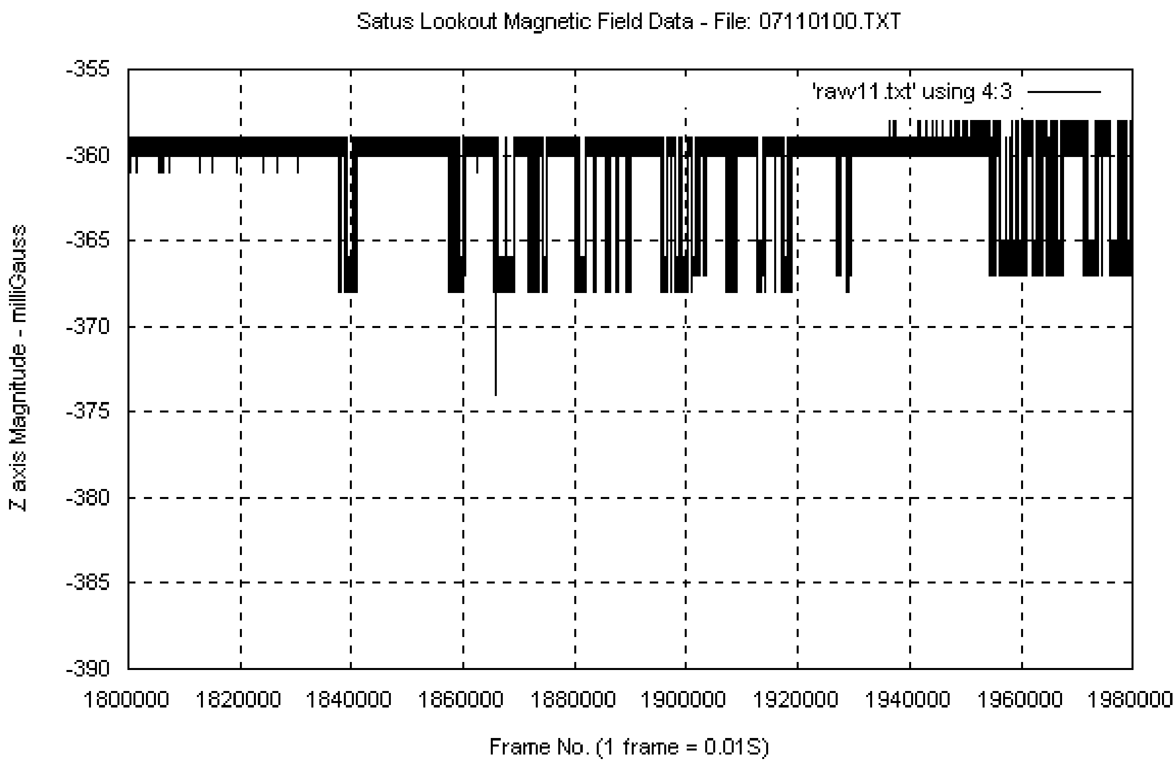

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw6.txt' using 4:3
-355
-360
-365
-370
-375
-380
-385
-390
900000
920000
940000
960000
980000
1000000
1020000
1040000
1060000
1080000
Z axis Magnitude - milliGauss
Frame No. (1 frame = 0.01S)

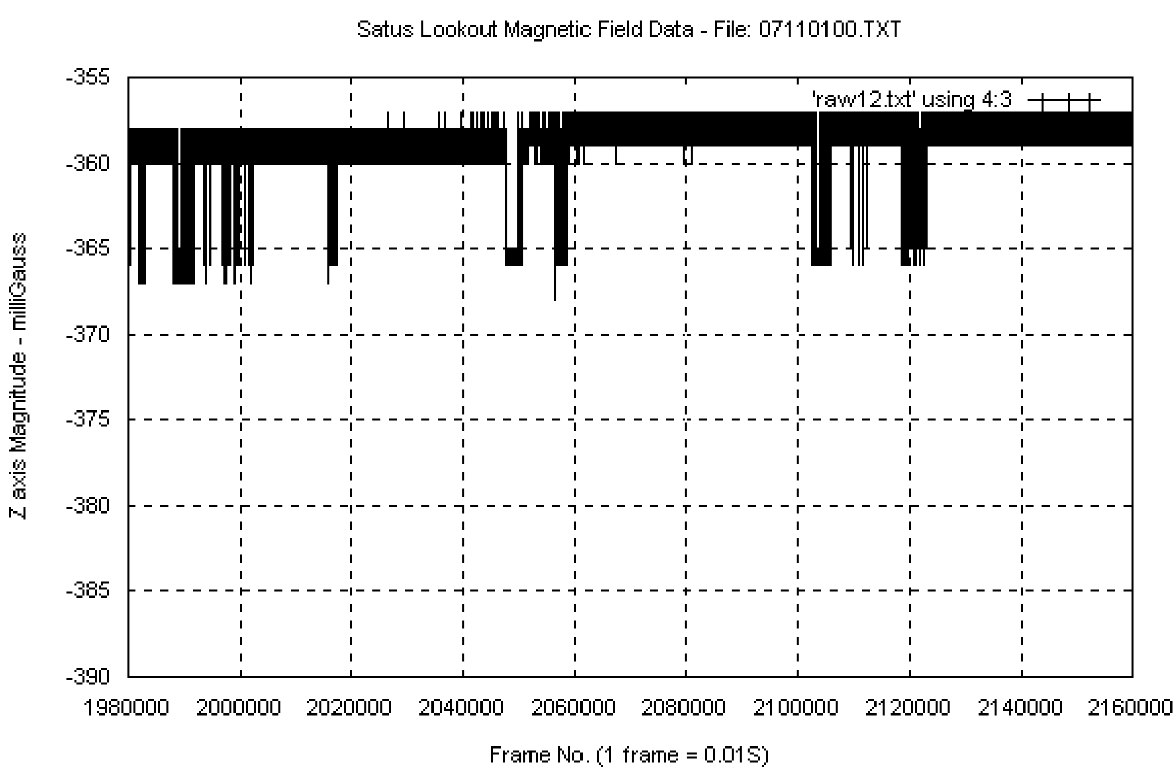

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw7.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
1080000
1100000
1120000
1140000
1160000
1180000
1200000
1220000
1240000
1260000
Frame No. (1 frame = 0.01S)

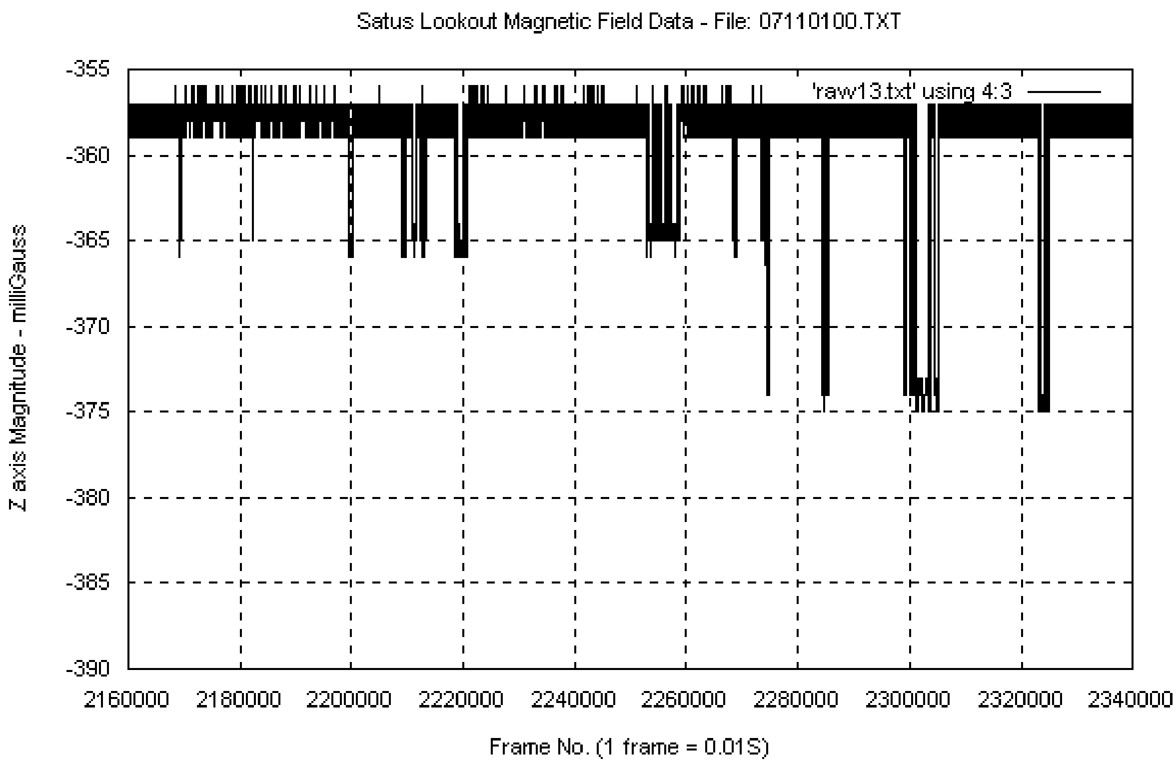

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw8.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
1260000
1280000
1300000
1320000
1340000
1360000
1380000
1400000
1420000
1440000
Frame No. (1 frame = 0.01S)

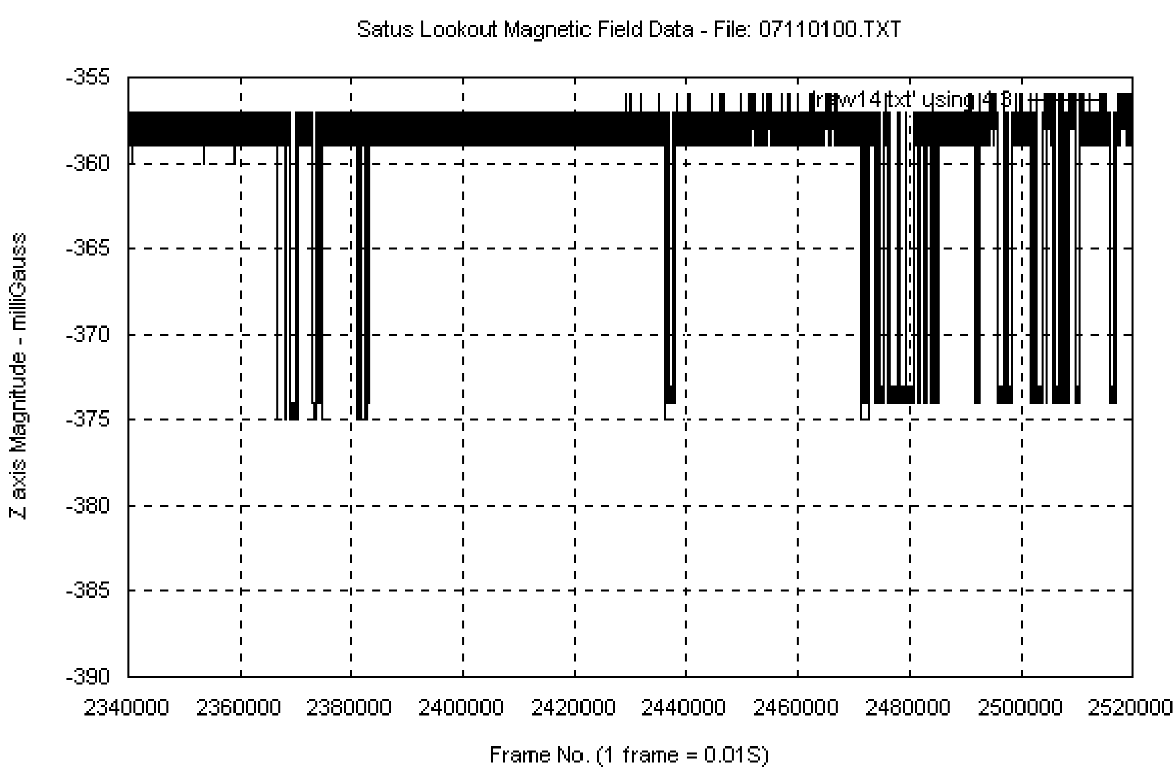

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw9.txt' using 4:3
-355
-360
-365
-370
-375
-380
-385
-390
Z axis Magnitude - milliGauss
1440000
1460000
1480000
1500000
1520000
1540000
1560000
1580000
1600000
1620000
Frame No. (1 frame = 0.01S)

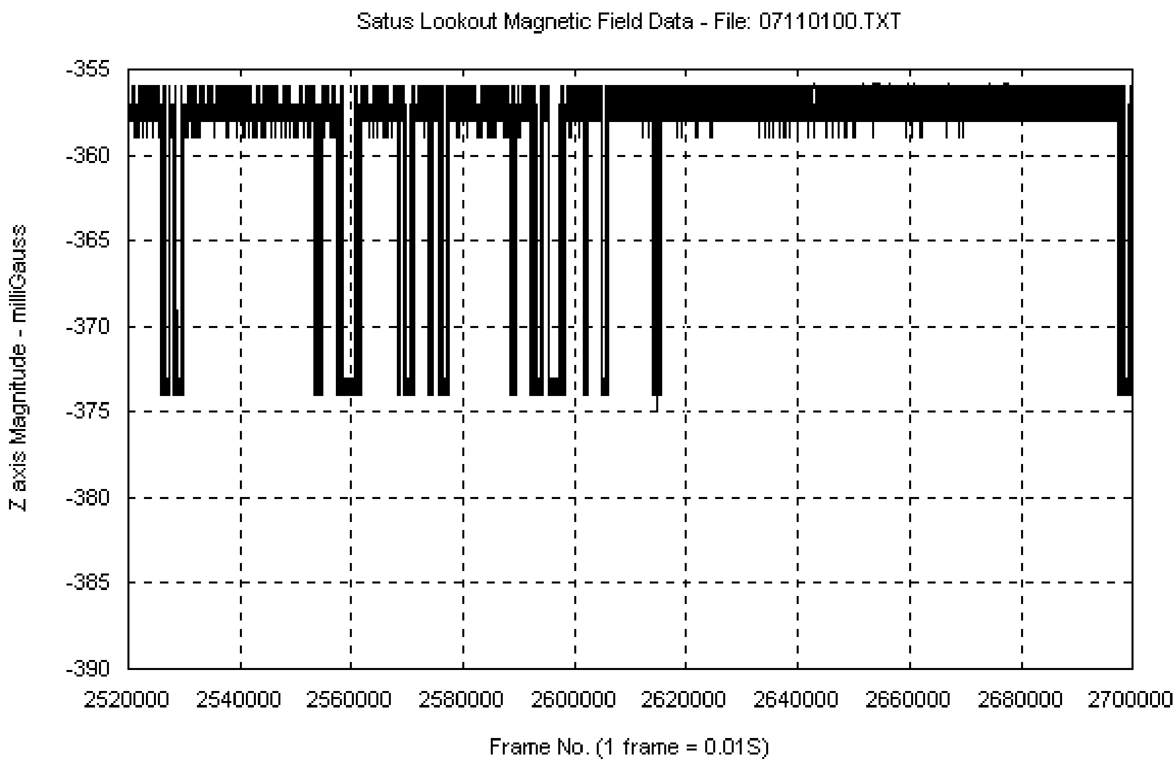

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw10.txt' using 4:3
-355
-360
-365
-370
-375
-380
-385
-390
Z axis Magnitude - milliGauss
1620000
1640000
1660000
1680000
1700000
1720000
1740000
1760000
1780000
1800000
Frame No. (1 frame = 0.01S)

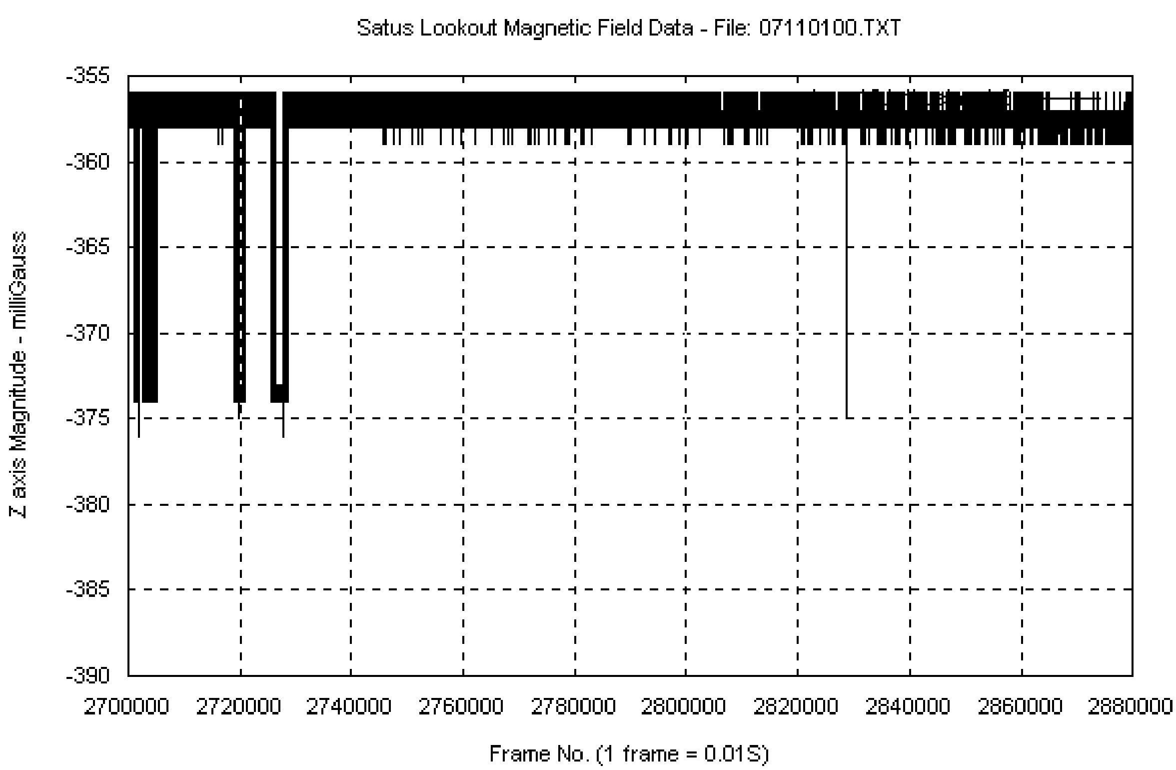

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw11.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
1800000
1820000
1840000
1860000
1880000
1900000
1920000
1940000
1960000
1980000
Frame No. (1 frame = 0.01S)

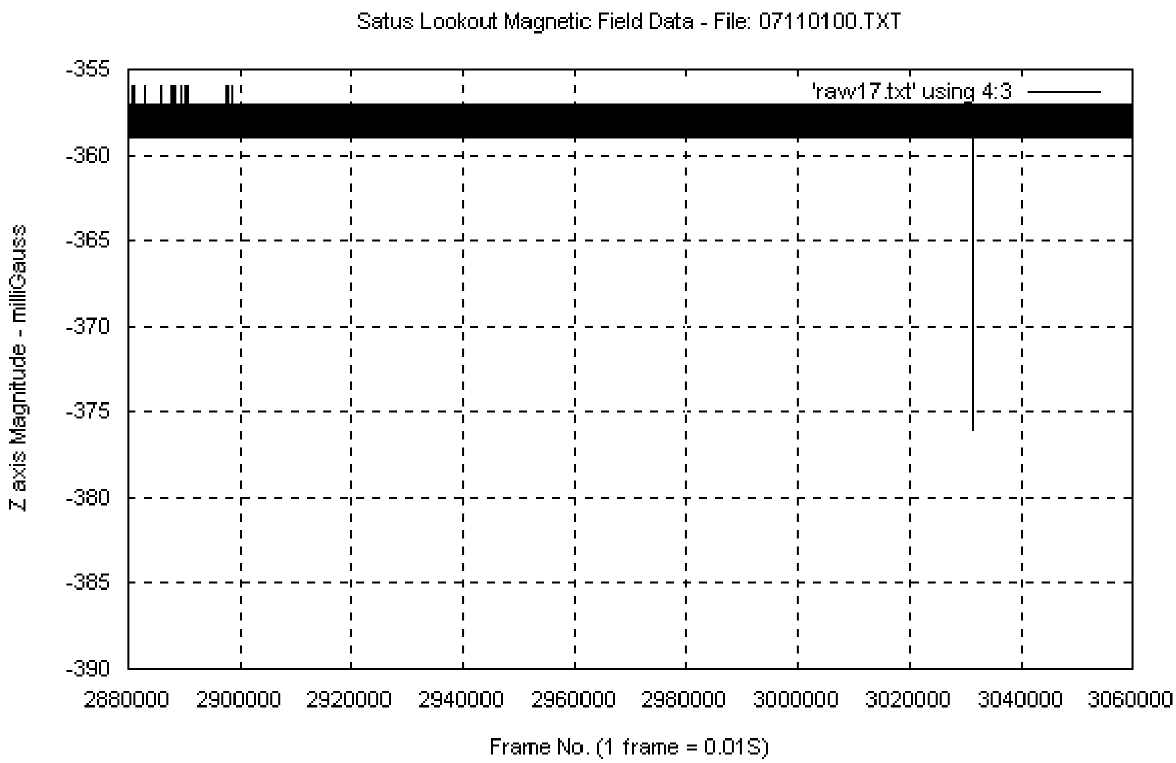

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw12.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
1980000
2000000
2020000
2040000
2060000
2080000
2100000
2120000
2140000
2160000
Frame No. (1 frame = 0.01S)

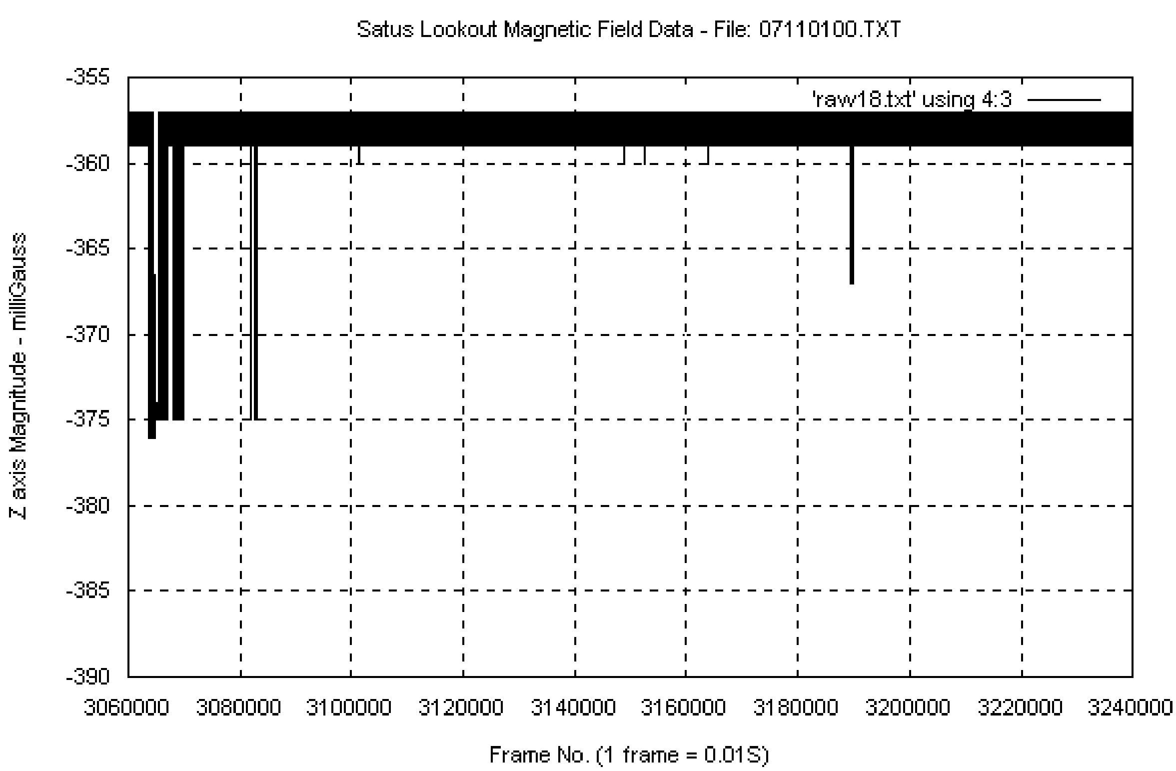

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw13.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
2160000
2180000
2200000
2220000
2240000
2260000
2280000
2300000
2320000
2340000
Frame No. (1 frame = 0.01S)

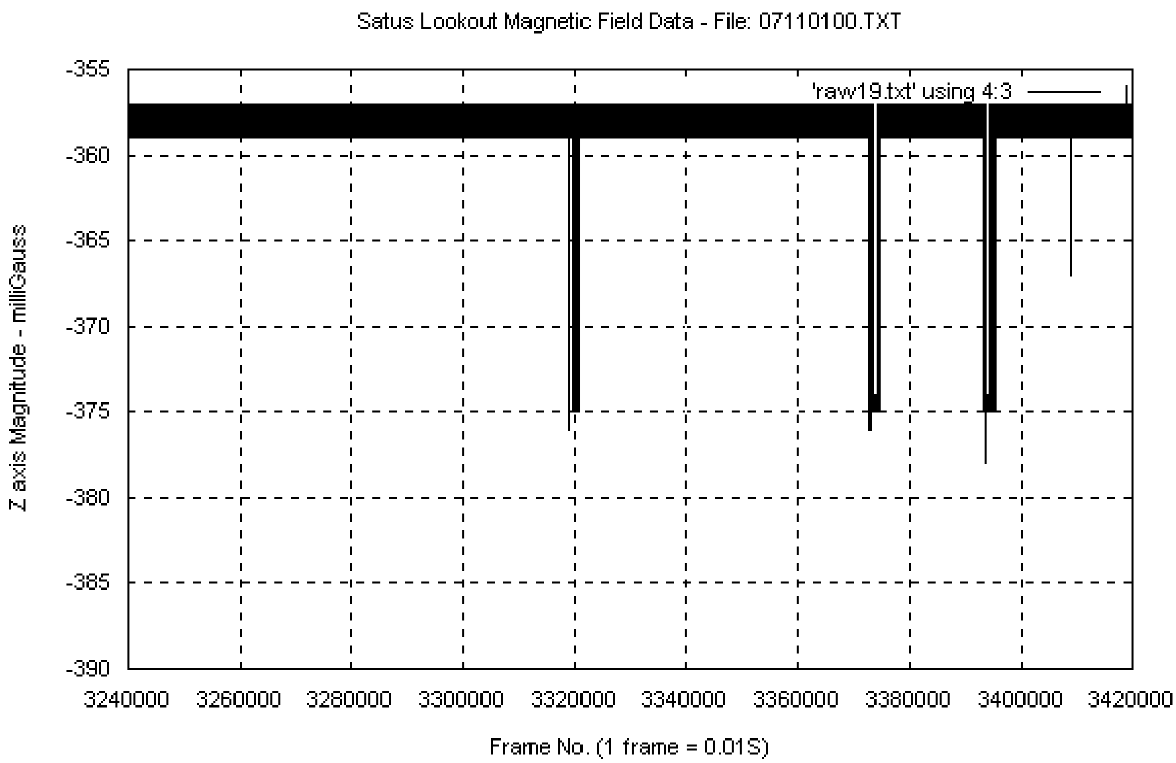

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw14.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
2340000
2360000
2380000
2400000
2420000
2440000
2460000
2480000
2500000
2520000
Frame No. (1 frame = 0.01S)

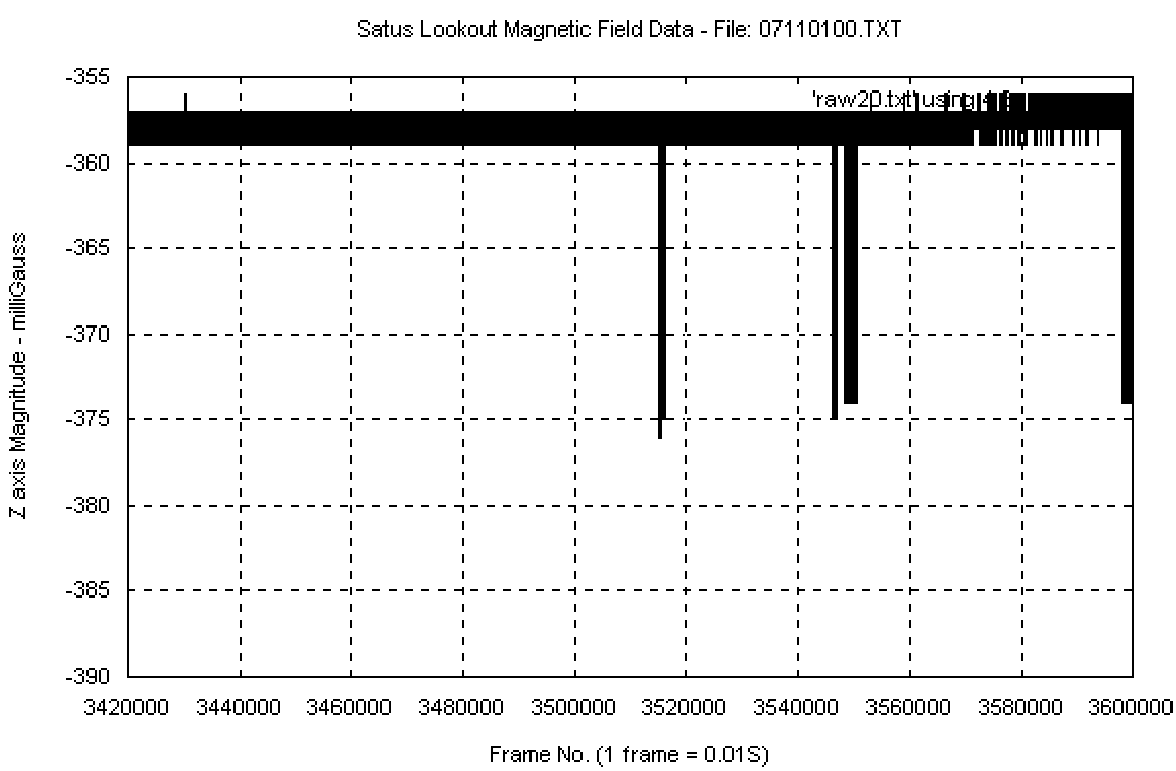

Satus Lookout Magnetic Field Data - File: 07110100.TXT
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
2520000
2540000
2560000
2580000
2600000
2620000
2640000
2660000
2680000
2700000
Frame No. (1 frame = 0.01S)

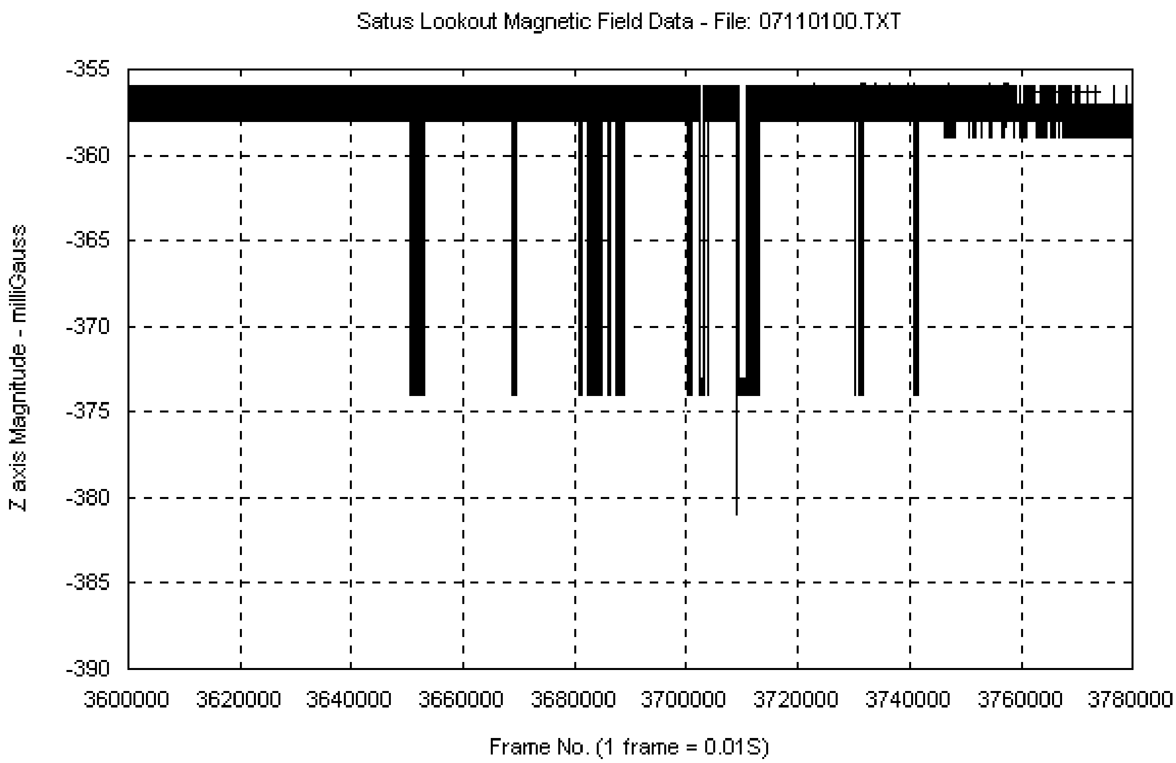

Satus Lookout Magnetic Field Data - File: 07110100.TXT
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
2700000
2720000
2740000
2760000
2780000
2800000
2820000
2840000
2860000
2880000
Frame No. (1 frame = 0.01S)

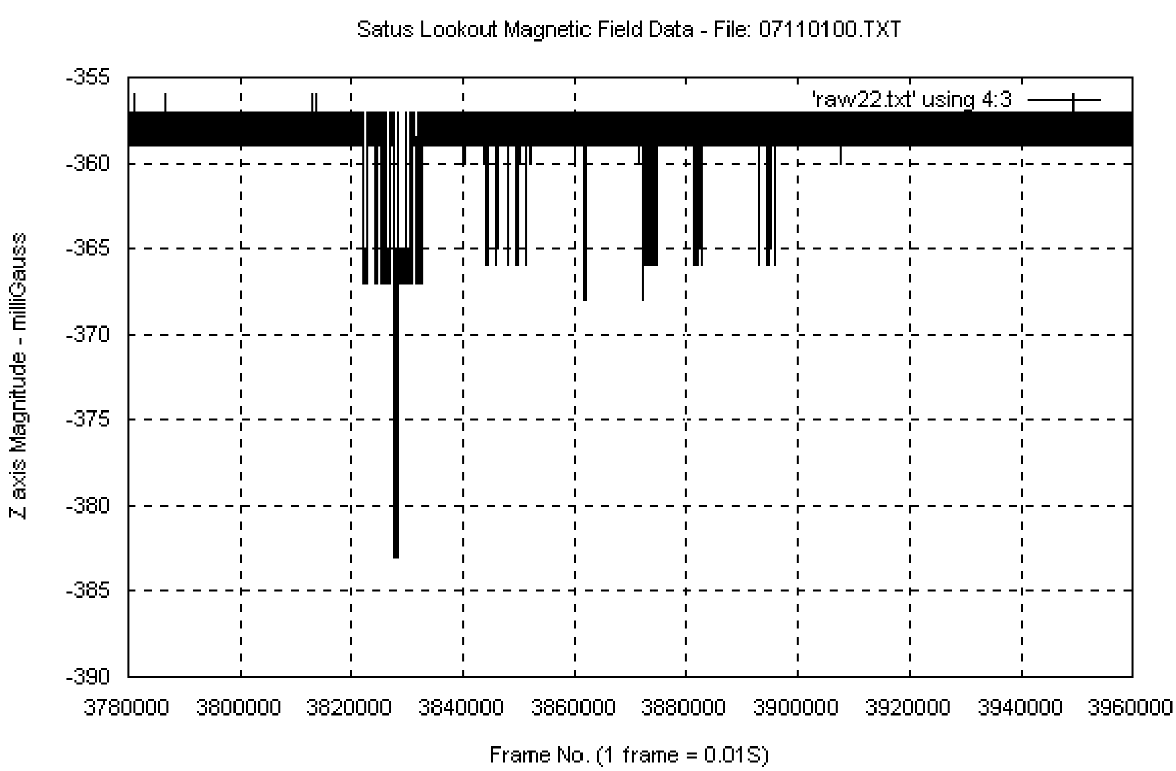

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw17.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
2880000
2900000
2920000
2940000
2960000
2980000
3000000
3020000
3040000
3060000
Frame No. (1 frame = 0.01S)

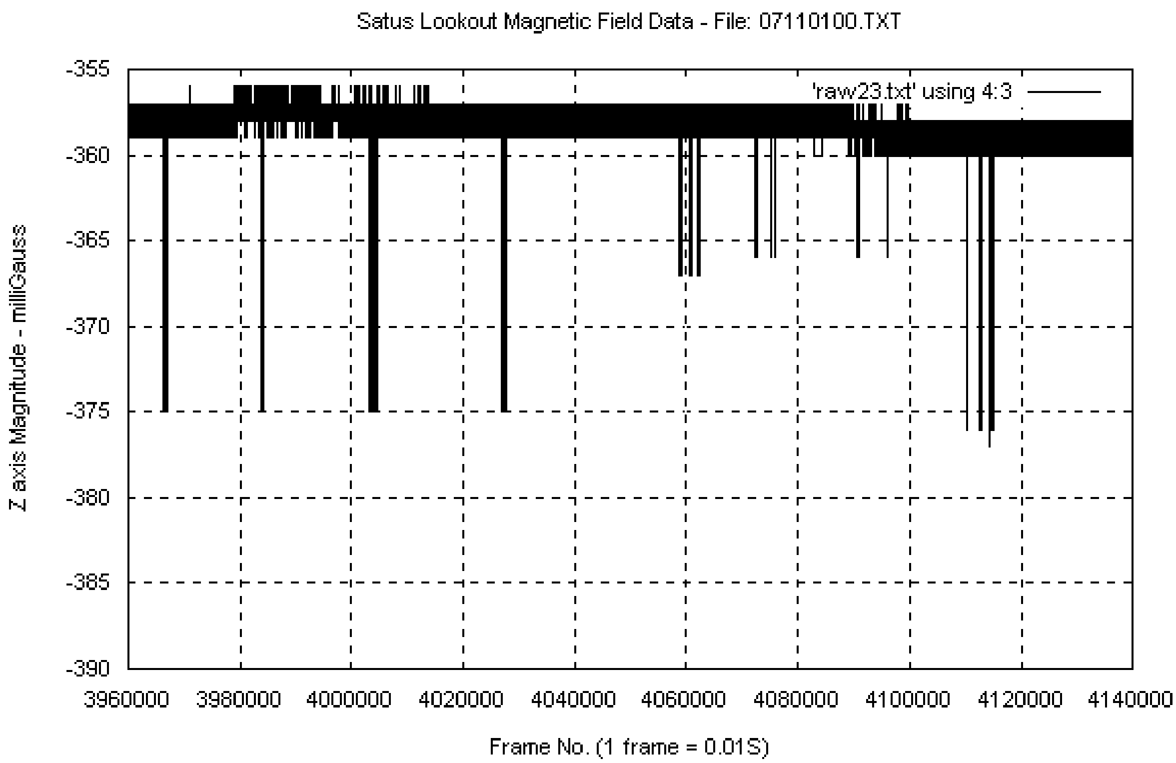

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw18.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
3060000
3080000
3100000
3120000
3140000
3160000
3180000
3200000
3220000
3240000
Frame No. (1 frame = 0.01S)

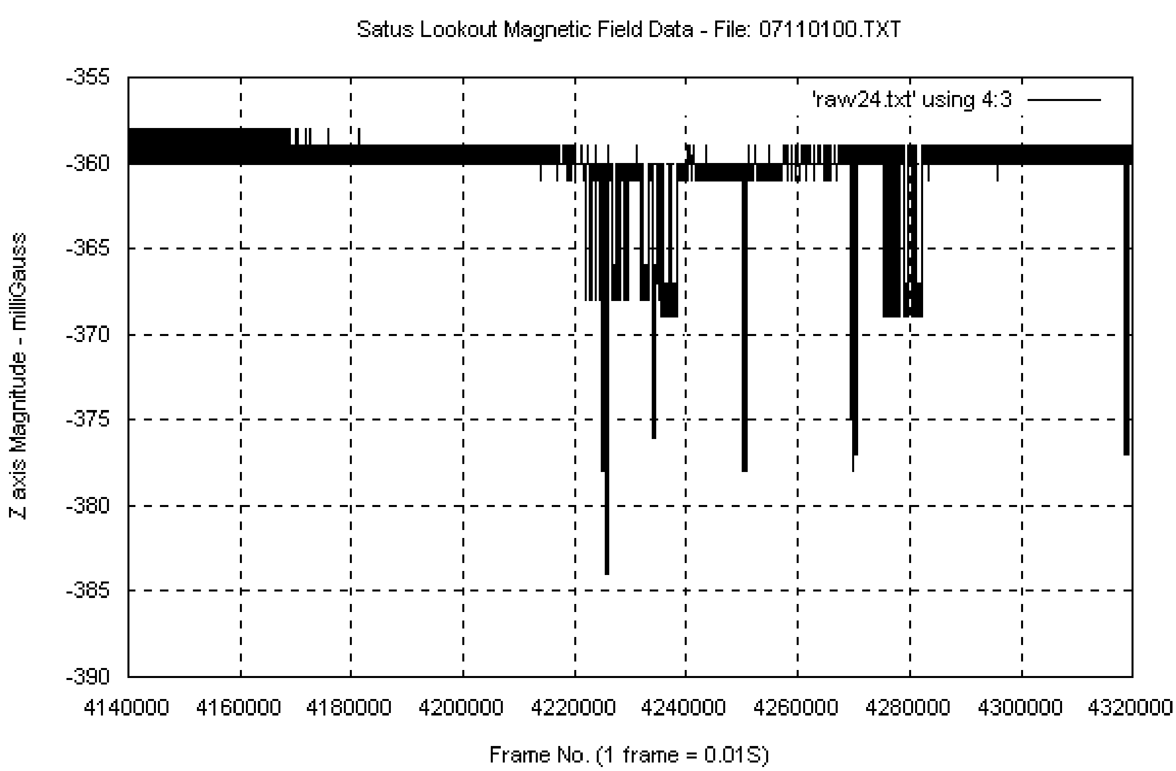

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw19.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
3240000
3260000
3280000
3300000
3320000
3340000
3360000
3380000
3400000
3420000
Frame No. (1 frame = 0.01S)

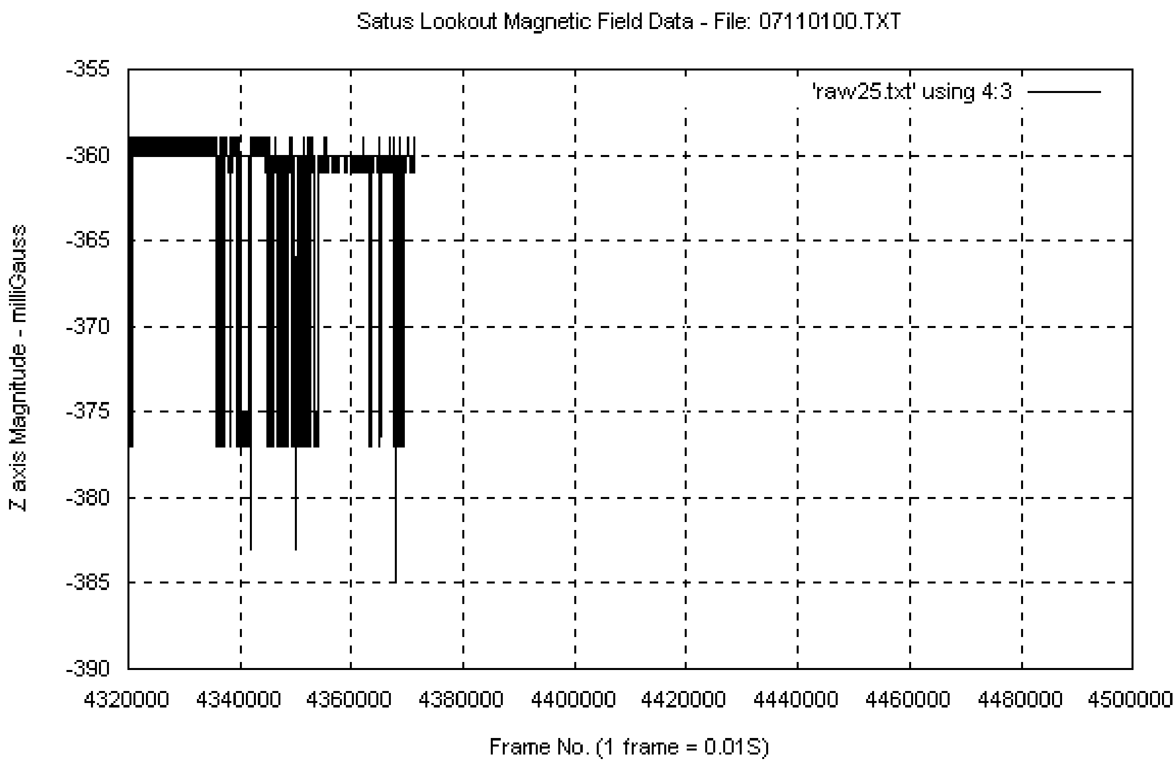

Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw20.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
3420000
3440000
3460000
3480000
3500000
3520000
3540000
3560000
3580000
3600000
Frame No. (1 frame = 0.01S)


Satus Lookout Magnetic Field Data - File: 07110100.TXT
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
3600000
3620000
3640000
3660000
3680000
3700000
3720000
3740000
3760000
3780000
Frame No. (1 frame = 0.01S)


Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw22.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
3780000
3800000
3820000
3840000
3860000
3880000
3900000
3920000
3940000
3960000
Frame No. (1 frame = 0.01S)


Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw23.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
3960000
3980000
4000000
4020000
4040000
4060000
4080000
4100000
4120000
4140000
Frame No. (1 frame = 0.01S)


Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw24.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
4140000
4160000
4180000
4200000
4220000
4240000
4260000
4280000
4300000
4320000
Frame No. (1 frame = 0.01S)


Satus Lookout Magnetic Field Data - File: 07110100.TXT
'raw25.txt' using 4:3
Z axis Magnitude - milliGauss
-355
-360
-365
-370
-375
-380
-385
-390
4320000
4340000
4360000
4380000
4400000
4420000
4440000
4460000
4480000
4500000
Frame No. (1 frame = 0.01S)

APPENDIX B. Calculation of Magnitude Vector from Three-axis Data.

Directional information can be derived from the magnetometer data using the following process:

1. Derive pulse amplitude for each axis manually from numerical data, or use the DCSTRIP software utility.

2. The magnitude of the three-axis vector: $\mathbf{A} = \sqrt{Z^2 + H^2 + D^2}$. (Eq. 1)
   Where: Z = vertical amplitude, H = North amplitude, D = East amplitude (Declination)

3. Angle from vertical to north: $\theta_1 = \tan^{-1}(H/Z)$. (Eq. 2)

4. Angle from vertical to east: $\theta_2 = \tan^{-1}(D/Z)$. (Eq. 3)

5. Angle between north and east (horizontal plane): $\theta_3 = \tan^{-1}(H/D)$. (Eq. 4)

Example:

From the ASCII data for the pulse extending from Frame # 4340014 to Frame # 4341500:

$Z = 376-360 = 16$, $D = 33-26 = 7$, $H = 203-197 = 6$ (Pulse amplitudes)

Application of Equations 1- 4 yields the following results:

$\mathbf{A} = 18.47$ mG, $\theta_1 = 20.56°$, $\theta_2 = 23.63°$, and $\theta_3 = 40.60°$

Since, by definition the Z component of the magnitude is positive downward, the resulting vector is downward at an angle of about 20.6° to the north and 23.6° to the east. The line of position therefore puts the source of the pulses under ground to the north and east of Satus Lookout, or above and to the southwest of the lookout.

Note that the above calculations make several assumptions: Perhaps the most critical is that the magnetometer head was positioned very accurately, H-to-true north and Z-to-vertical. Another is that the calibration for each magnetometer channel is accurate. An estimate for the instrument used and its placement during the recording is that the absolute readings are accurate to within ±20%.