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BIAS EFFECTS ON POSTFLIGHT DATA

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Mathematical Physics Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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PROJECT APOLLO

BIAS EFFECTS ON POSTFLIGHT DATA

By Richard K. Osburn and Gary A. Ransford
Mathematical Physics Branch

October 4, 1968

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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BIAS EFFECTS ON POSTFLIGHT DATA

By Richard K. Osburn and Gary A. Ransford

SUMMARY

A study was made to provide the postflight analyst with a means of correlating residual patterns in earth orbit unified S-band (USB) data with errors in station location or time tagging. To accomplish this, an arc of perfect data was generated. The station locations were then perturbed and residual plots based on the new locations were obtained. These plots, together with a knowledge of the geometry of the data arc, provide a means for the postflight analyst to identify the sources of many common residual patterns.

INTRODUCTION

The exclusive use of unified S-band data for coming Apollo missions has created a need to eliminate all inherent inaccuracies from the USB system. The major error sources in the system at present appear to be errors in time tagging the measurements and station locations. It is, thus, highly desirable that a means for identifying errors of these types be available.

The residual plot is one of the strongest tools of the postflight analyst. A residual is defined as $\phi - C$, where C is the computed value of an observable (range, X_{30}-angle, Y_{30}-angle, or Doppler) and ϕ is the value observed by the tracking radar. The computed value is obtained by the orbit determination program through the following process:

1. The epoch vector input to the program is integrated forward or backward in time to obtain a trajectory which includes all times at which data was obtained.

2. From the trajectory the position and velocity of the spacecraft is obtained at the time of each observation.

3. Utilizing the position and velocity information in addition to information on station position and the earth-moon-sun ephemerides, the computed value for the observable is obtained.

The residuals obtained by differencing the observed and computed values of the observables may then be used to correct the vehicle state vector. The residuals obtained from the converged state vector should be zero if all parameters and errors were known perfectly.

ANALYSIS

The second revolution of the Apollo 5 mission (AS-204/LM-1) was chosen as the reference trajectory for the study. Figure 1 is a ground-track of the second revolution. Noise-free data from the following USB 30-ft antennae were simulated using the MSC/TRW task A-132 orbit determination program, HOPE: Carnarvon, Guaymas, Bermuda, Ascension, Merritt Island, Hawaii, and Texas.

Of interest in the study were the effects of errors in station latitude, longitude, and height, and in data time. Computer runs were made with these parameters perturbed as follows:

1. Perturb the latitude of each station -0.0005°.

2. Perturb the longitude of each station -0.0005°.

3. Perturb the height of each station -50 ft.

4. Perturb the time tag of the data from each station by -0.025 seconds.

RESULTS AND CONCLUSIONS

Figures 2 through 8 present the results of the runs described in the previous paragraph, arranged by station. From these figures and a knowledge of the geometry involved in each pass, it should be possible for the analyst to correlate patterns in USB residuals with the errors which cause them. Note that positive biases on the parameters will result in plots which are mirror images about the time axes of those caused by the negative biases presented in the figures.

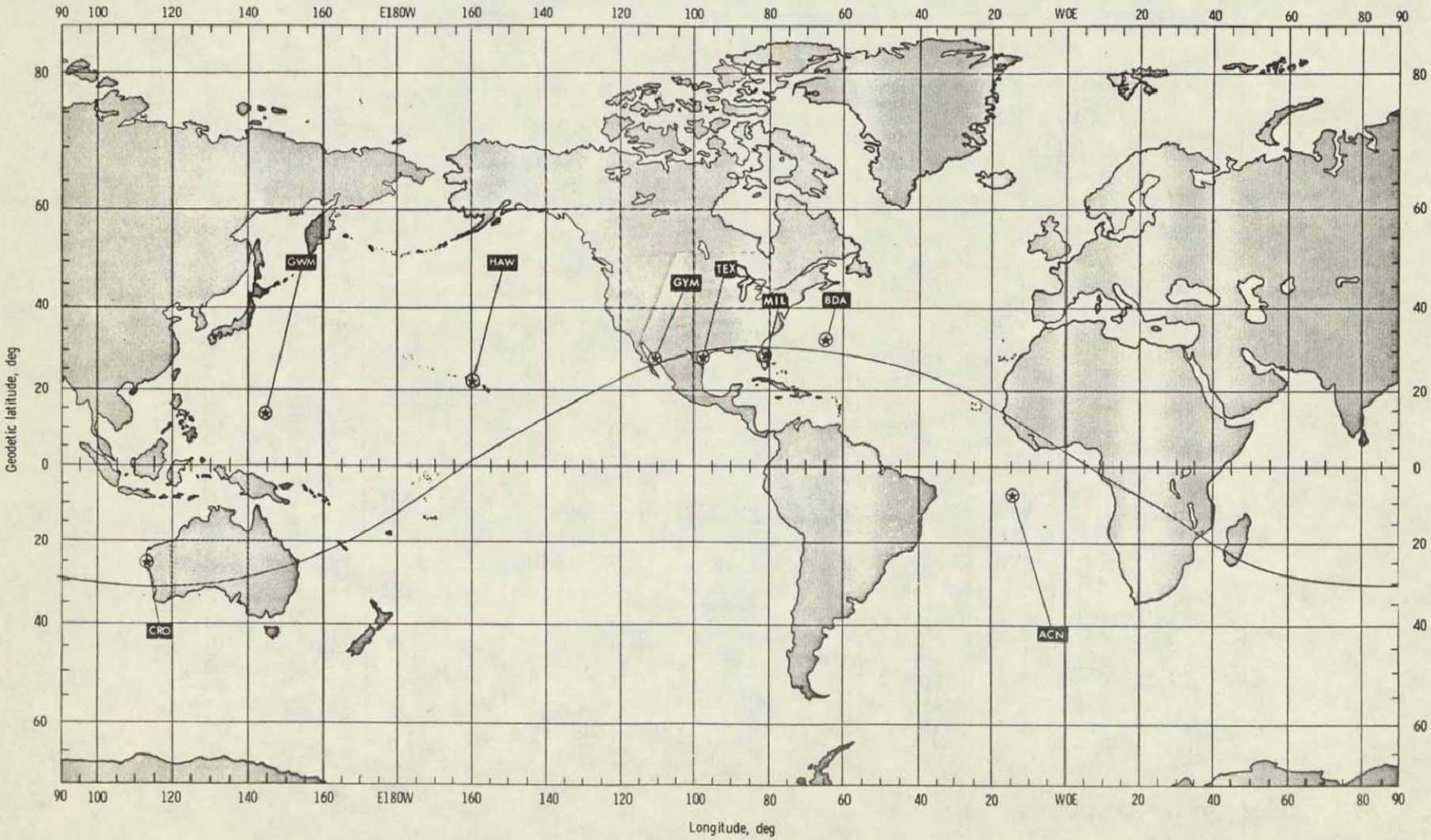
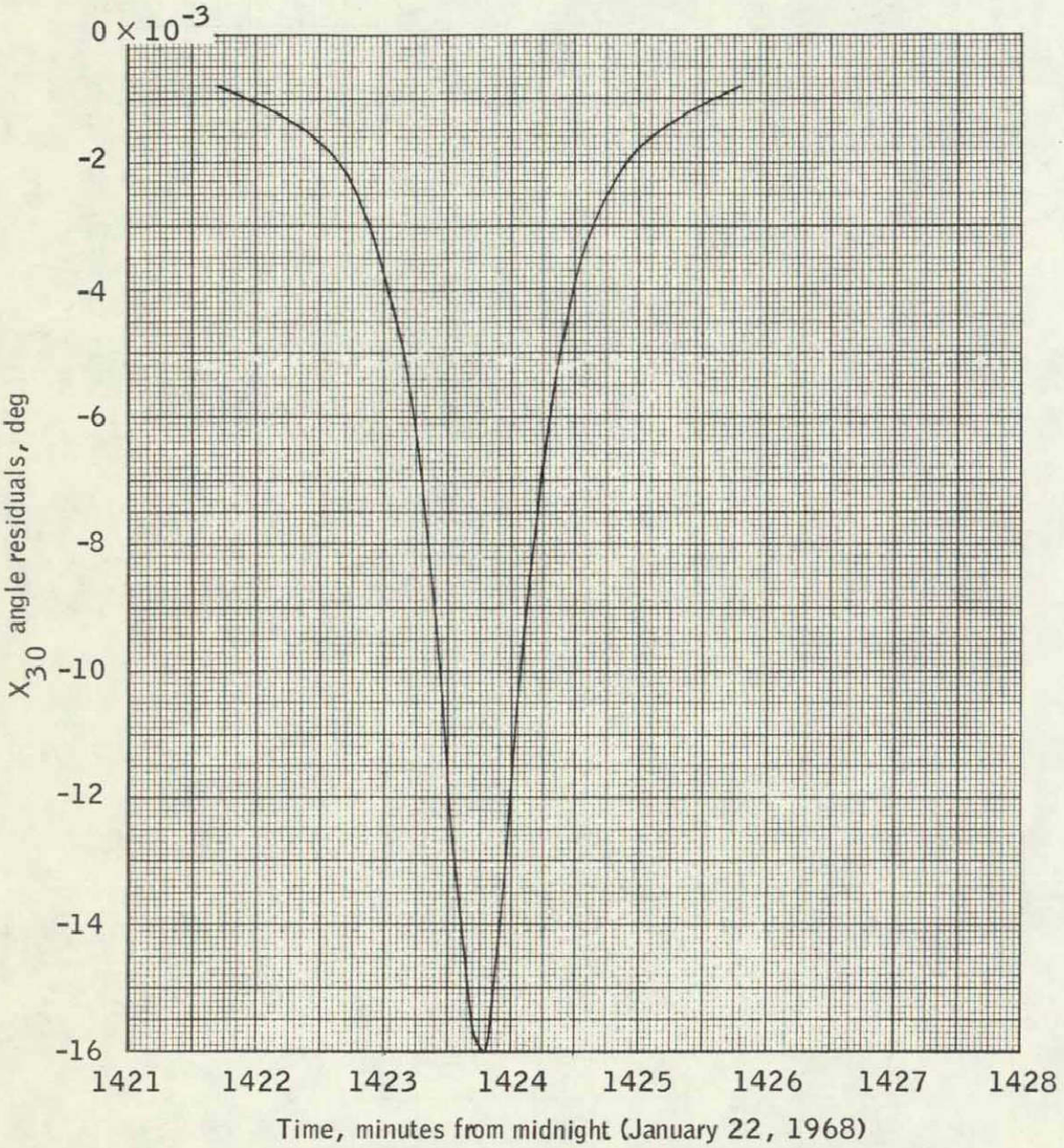
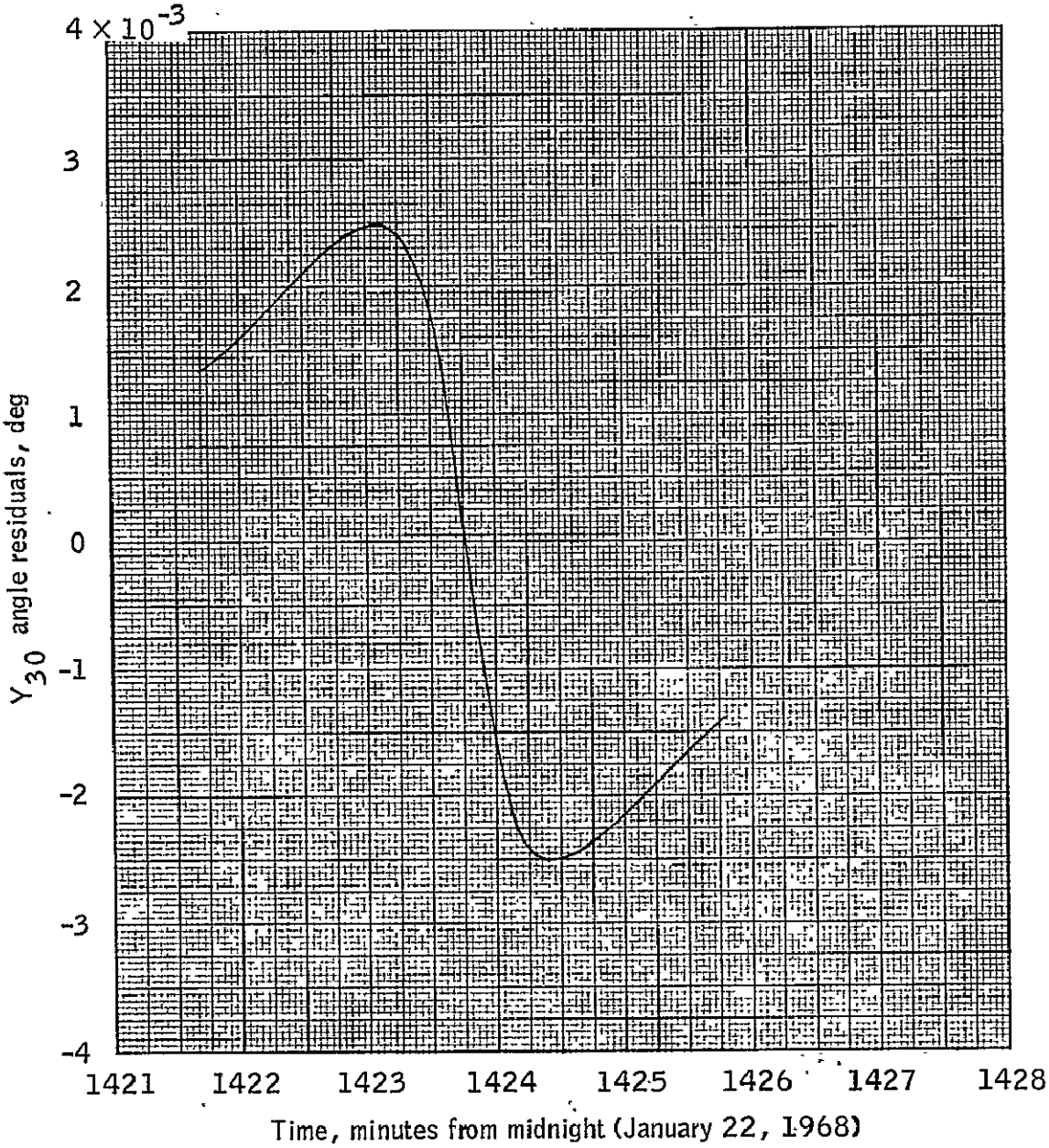


Figure 1. - Ground track of the second revolution of the Apollo 5 mission.



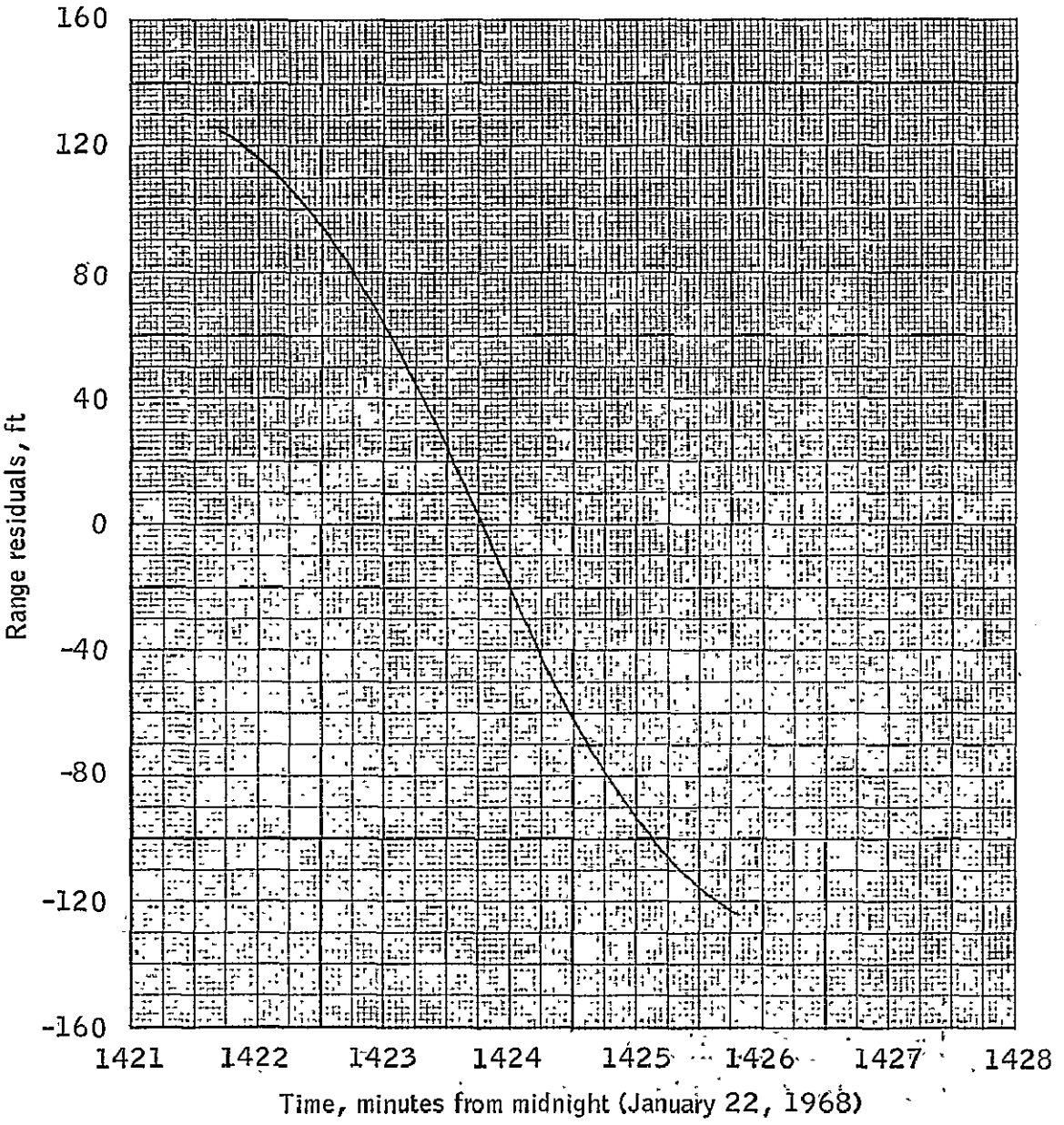
(a) X_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 2.- Residual patterns in USB data from the Carnarvon tracking station.



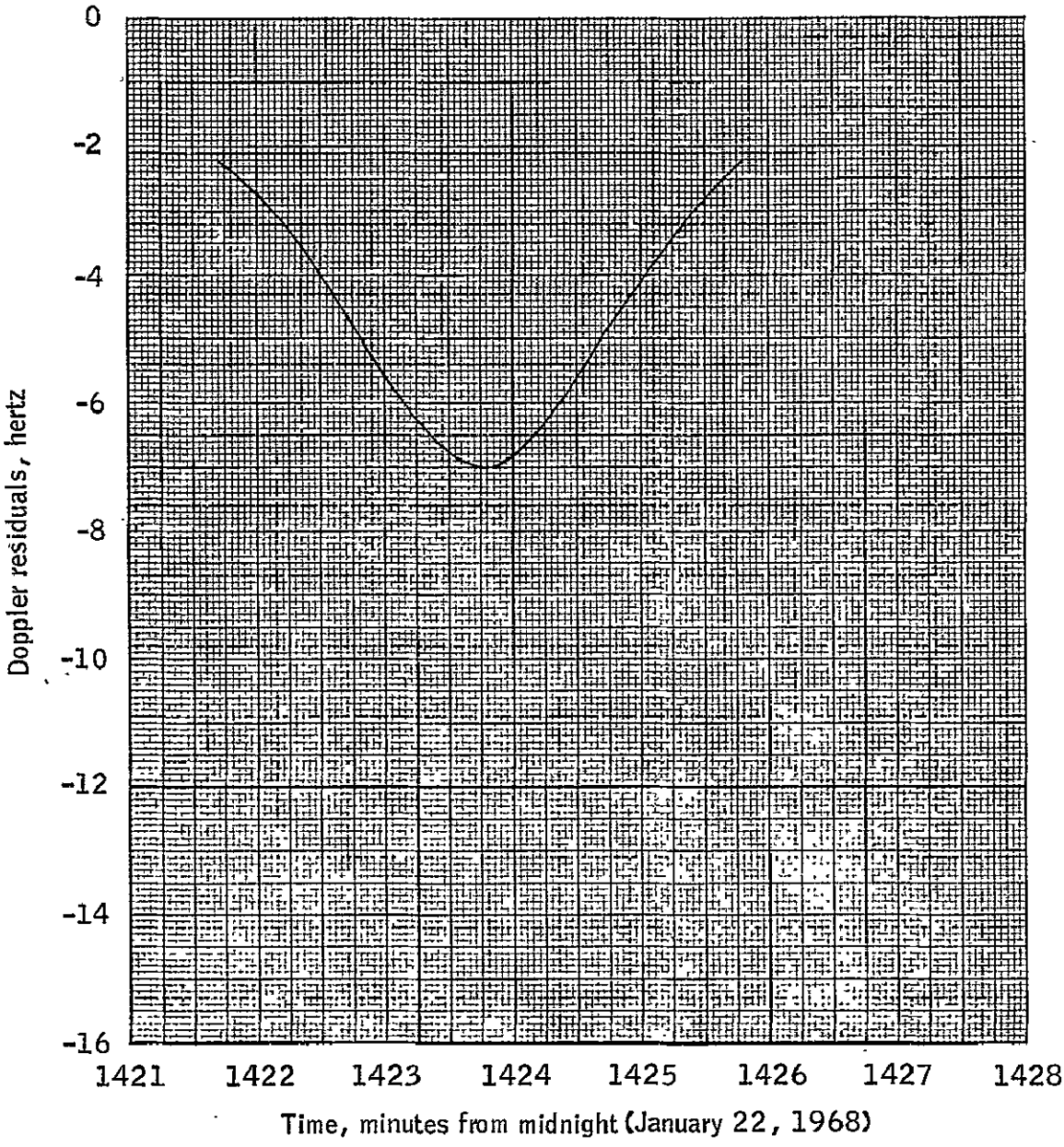
(b) Y_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 2.- Continued.



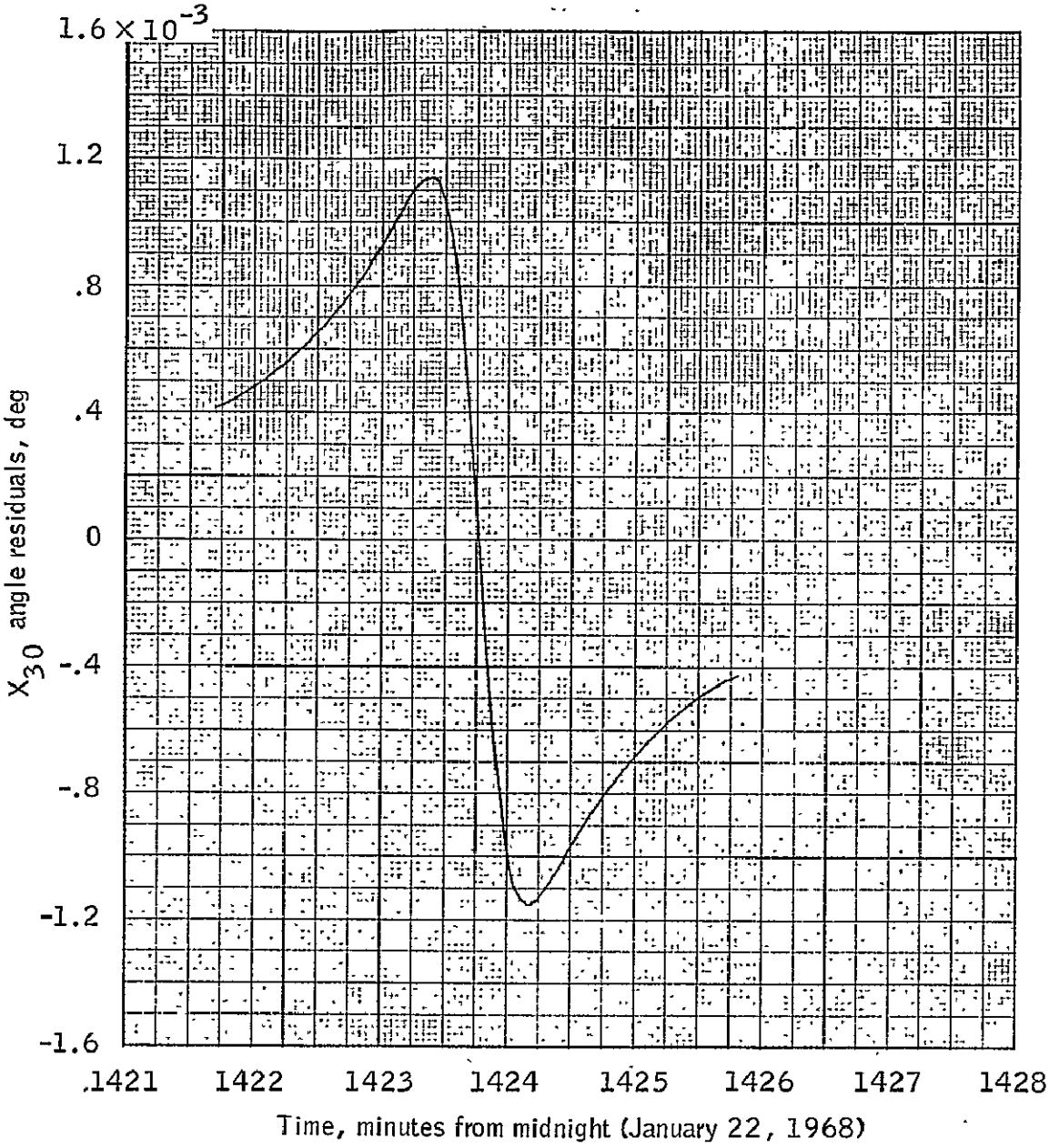
(c) Range residuals for -.0005-degree perturbation of longitude.

Figure 2.- Continued.



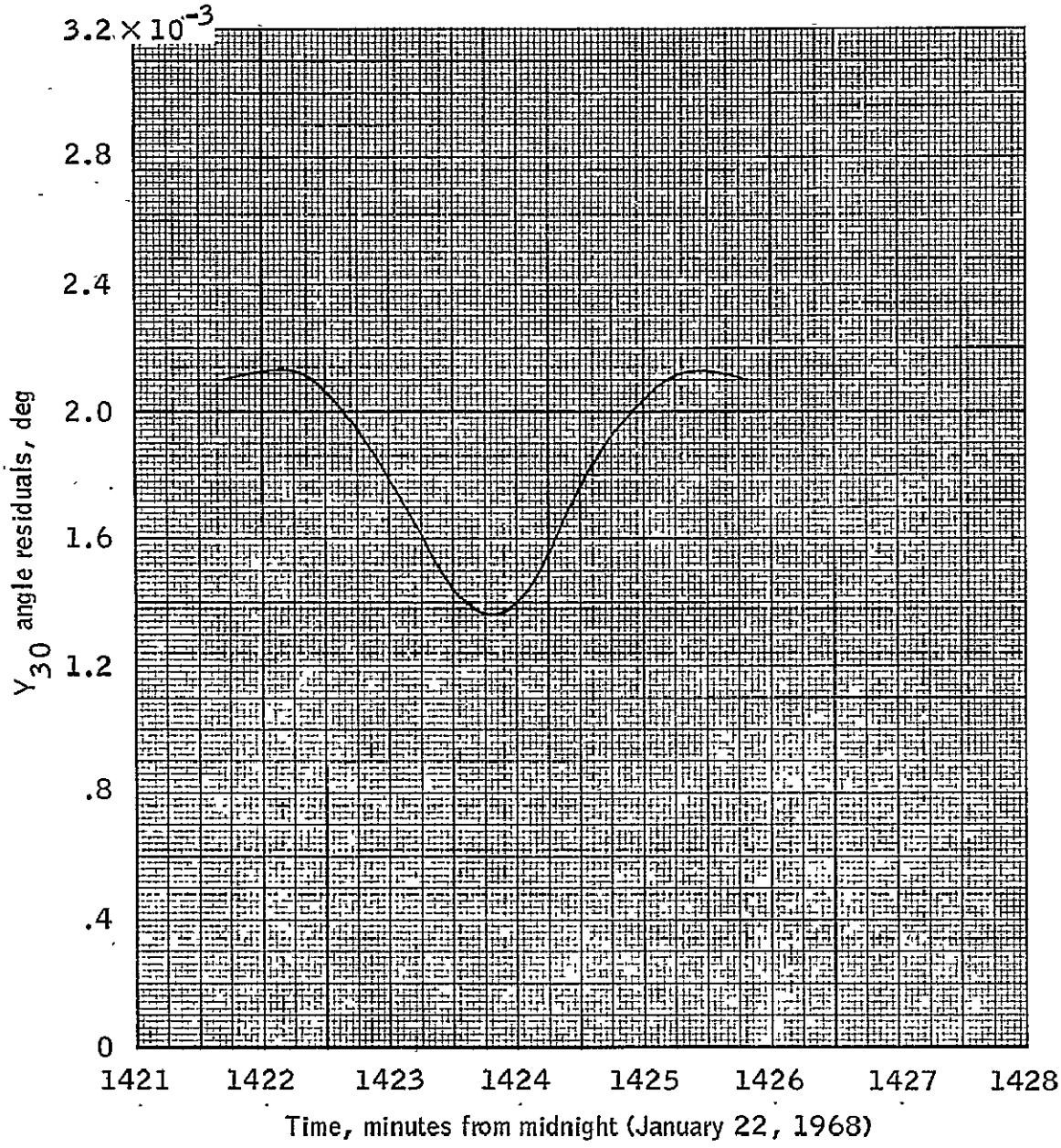
(d) Doppler residuals for -.0005-degree perturbation of longitude.

Figure 2.- Continued.



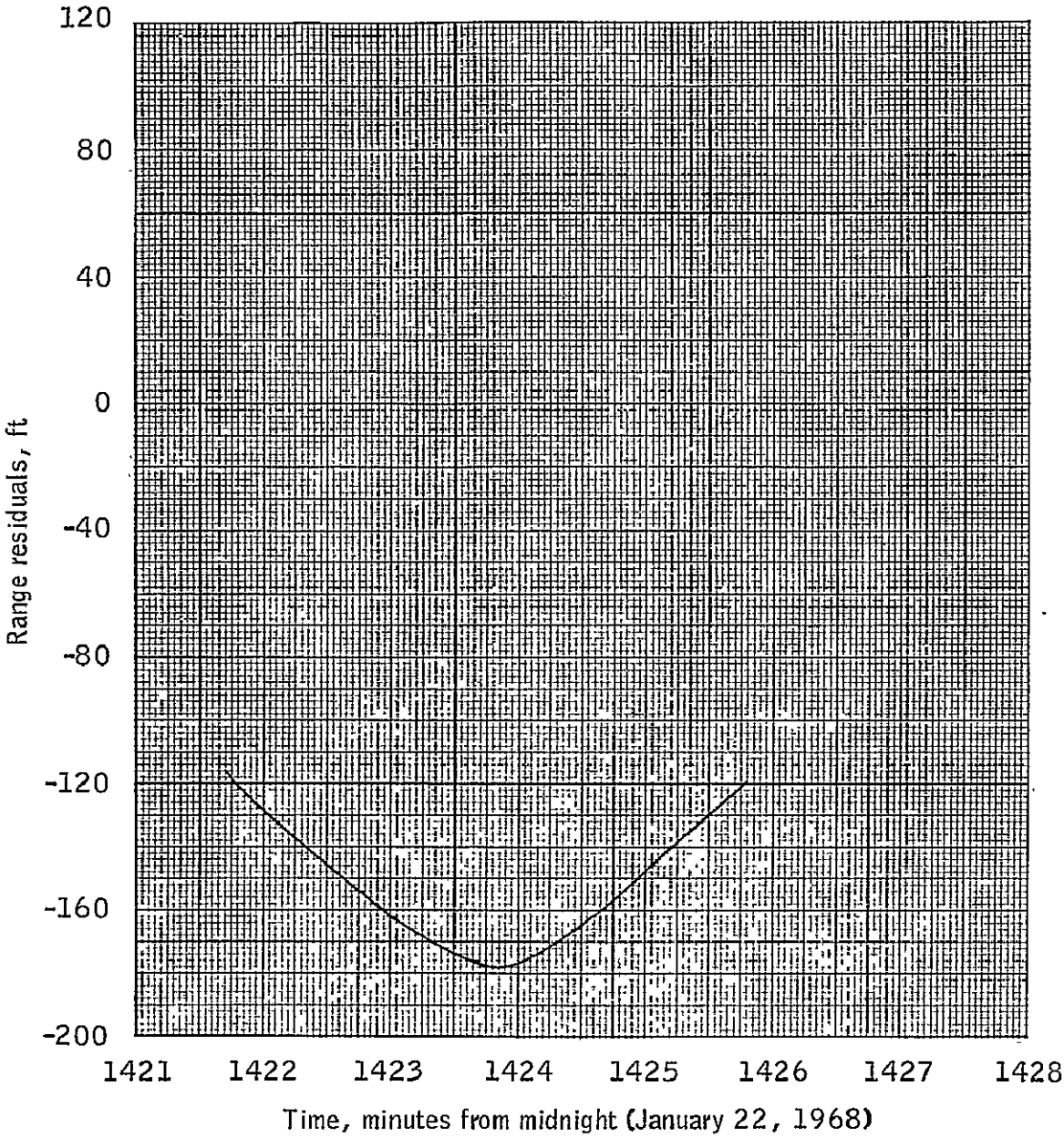
(e) X_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 2.- Continued.



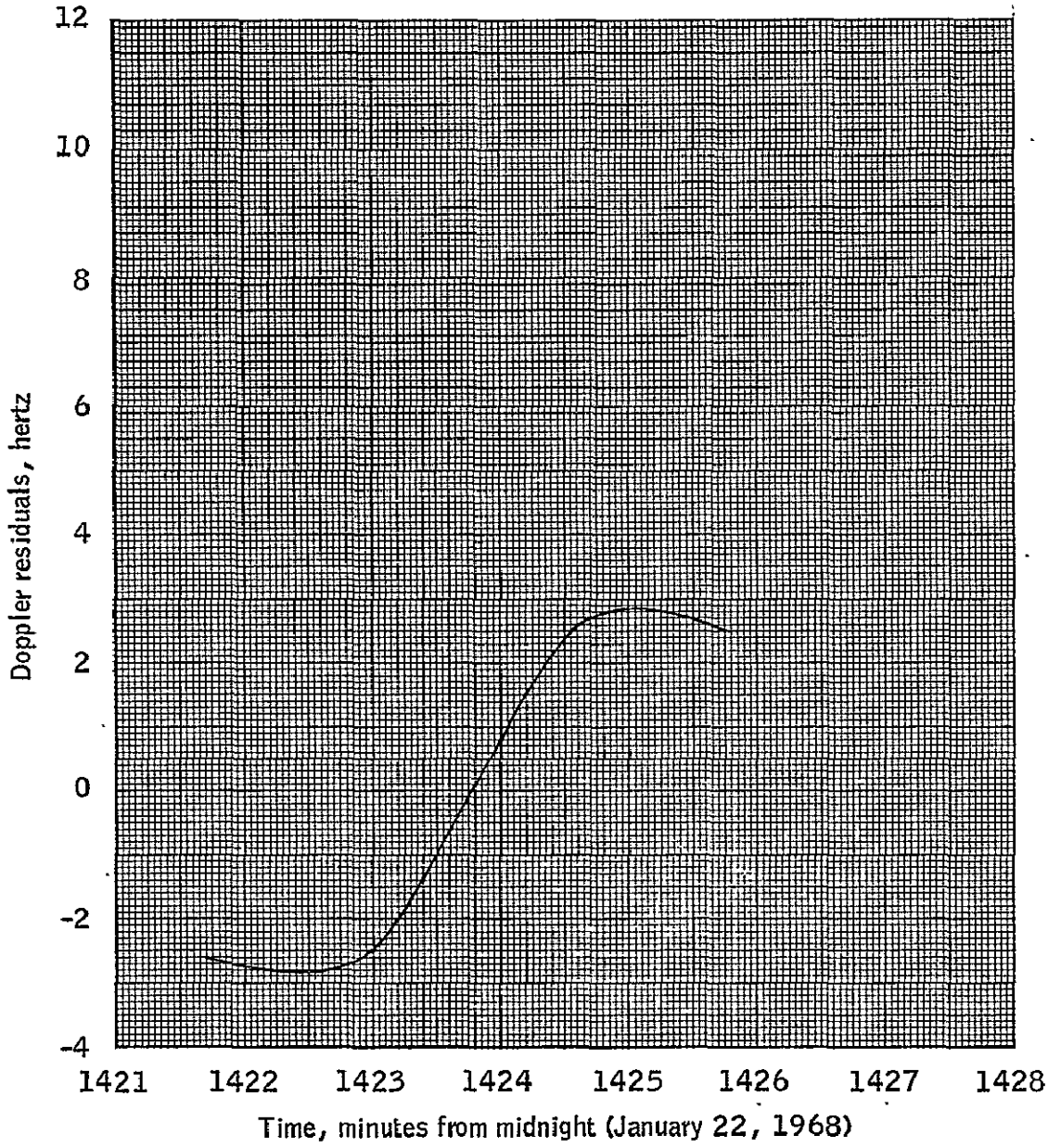
(f) Y_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 2.-Continued.



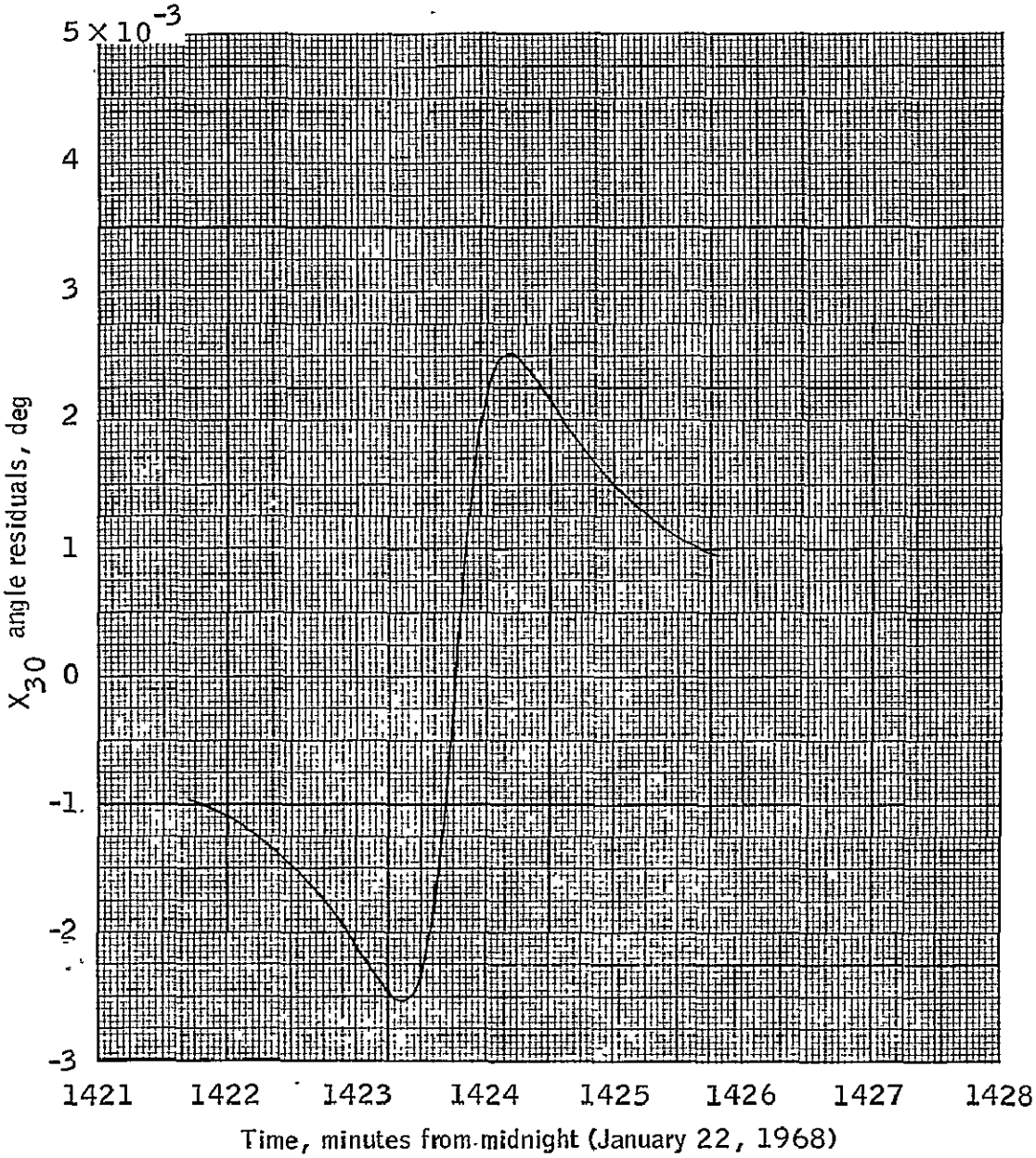
(g) Range residuals for -.0005-degree perturbation of latitude.

Figure 2.- Continued.



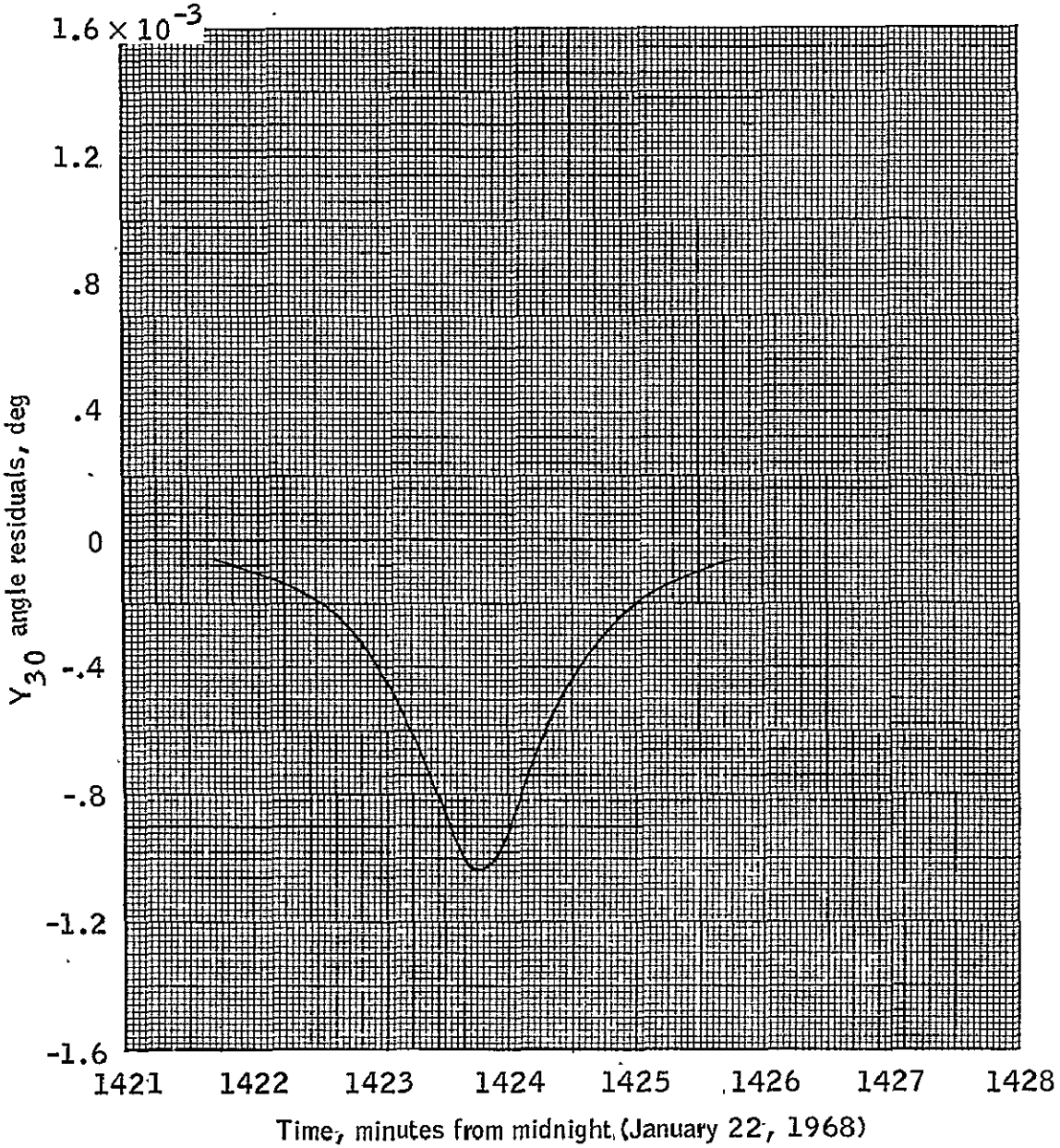
(h) Doppler residuals for -.0005-degree perturbation of latitude.

Figure 2.- Continued.



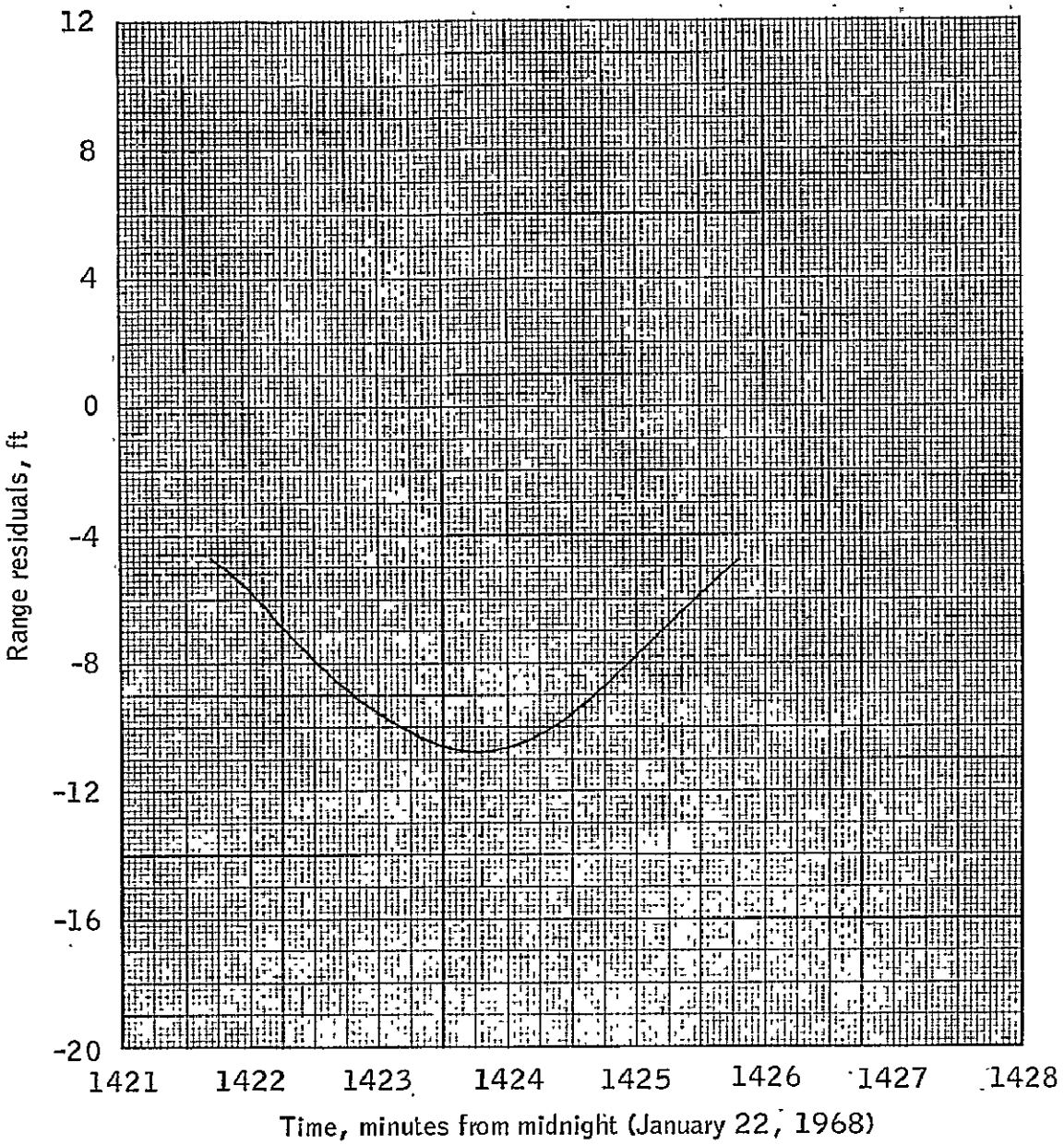
(i) X_{30} angle residuals for -50-foot perturbation of altitude.

Figure 2.- Continued.



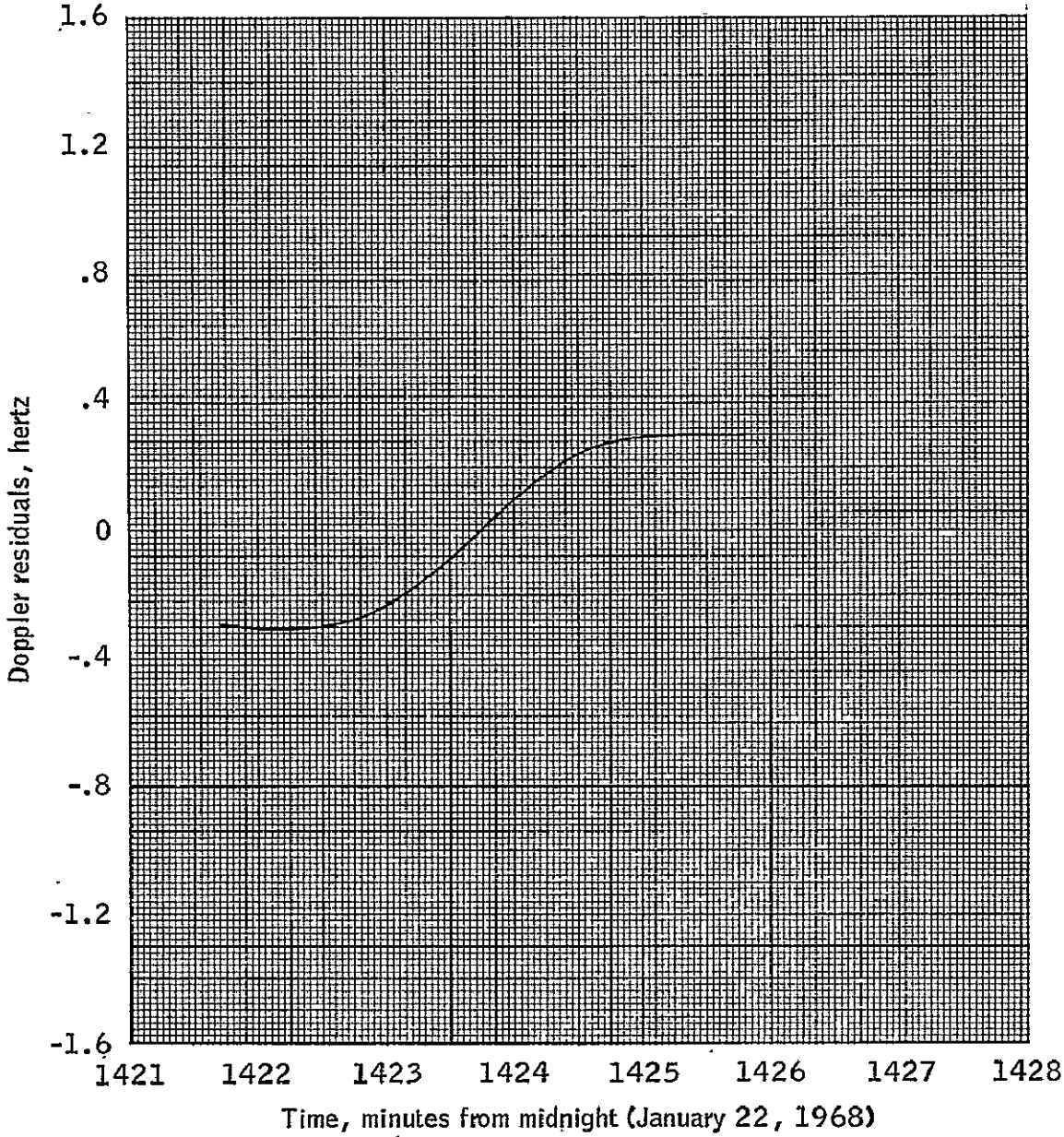
(j) Y_{30} angle residuals for -50-foot perturbation of altitude.

Figure 2.- Continued.



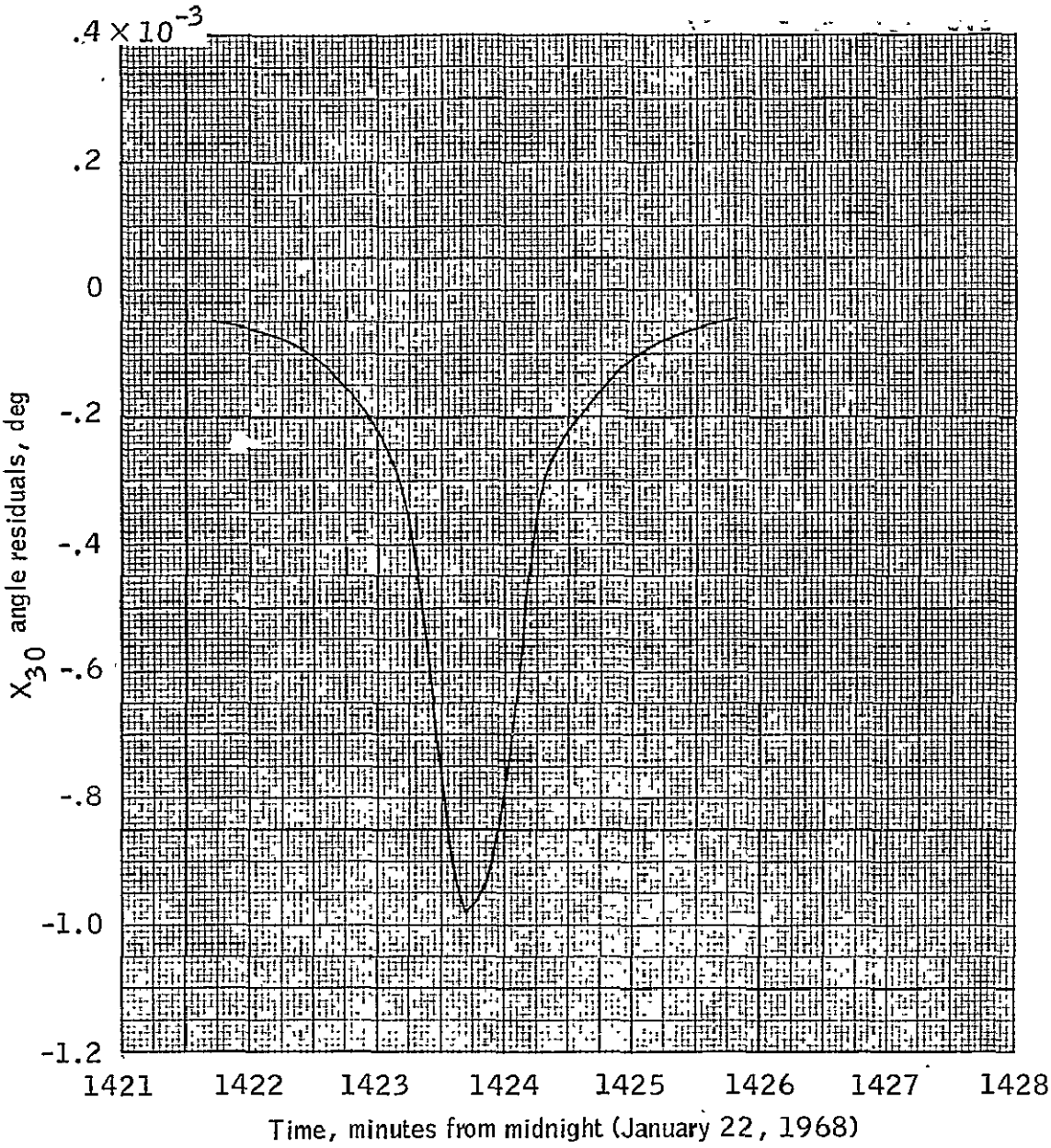
(k) Range residuals for -50-foot perturbation of altitude.

Figure 2.- Continued.



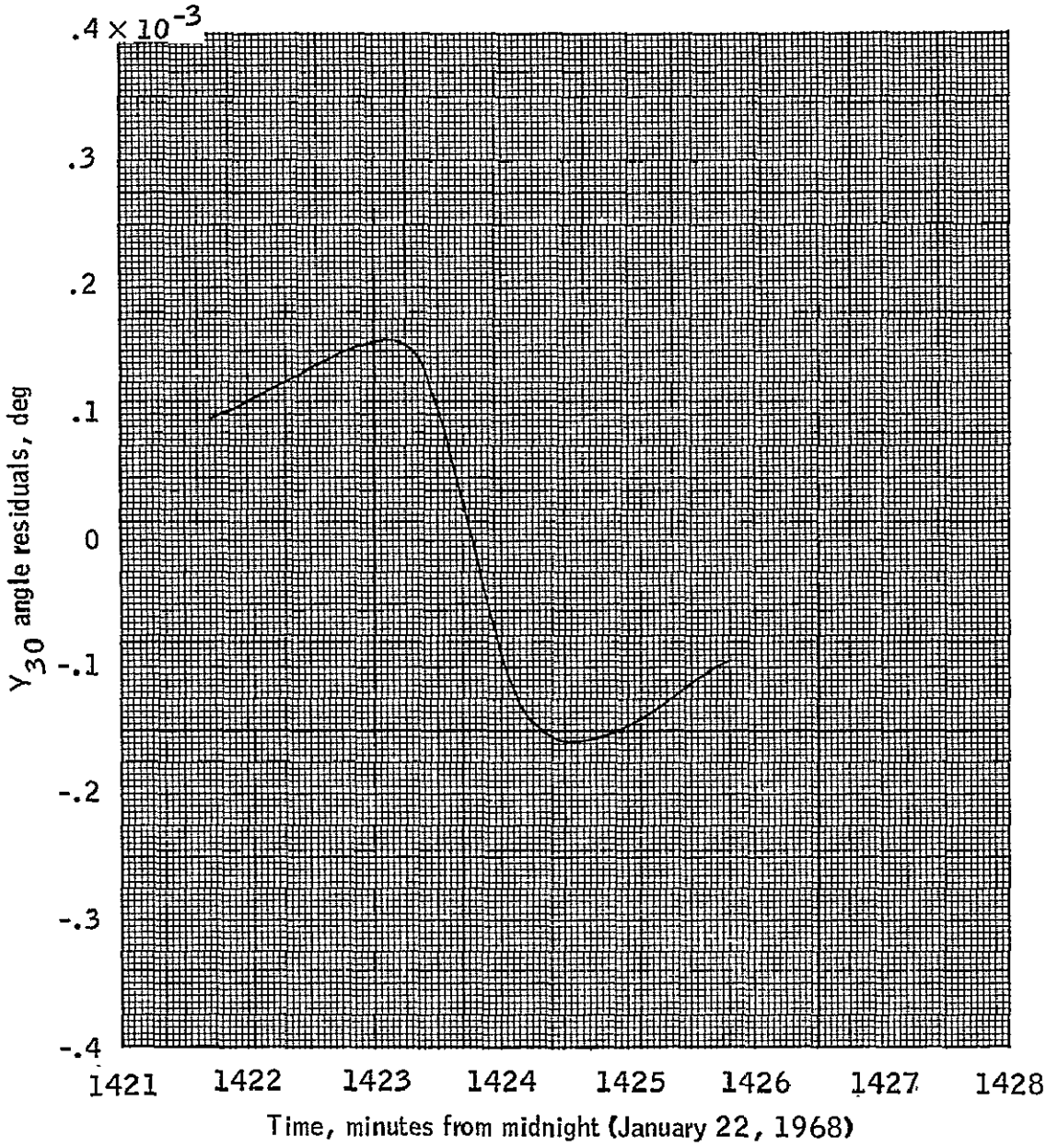
(l) Doppler residuals for -50-foot perturbation of altitude.

Figure 2.- Continued.



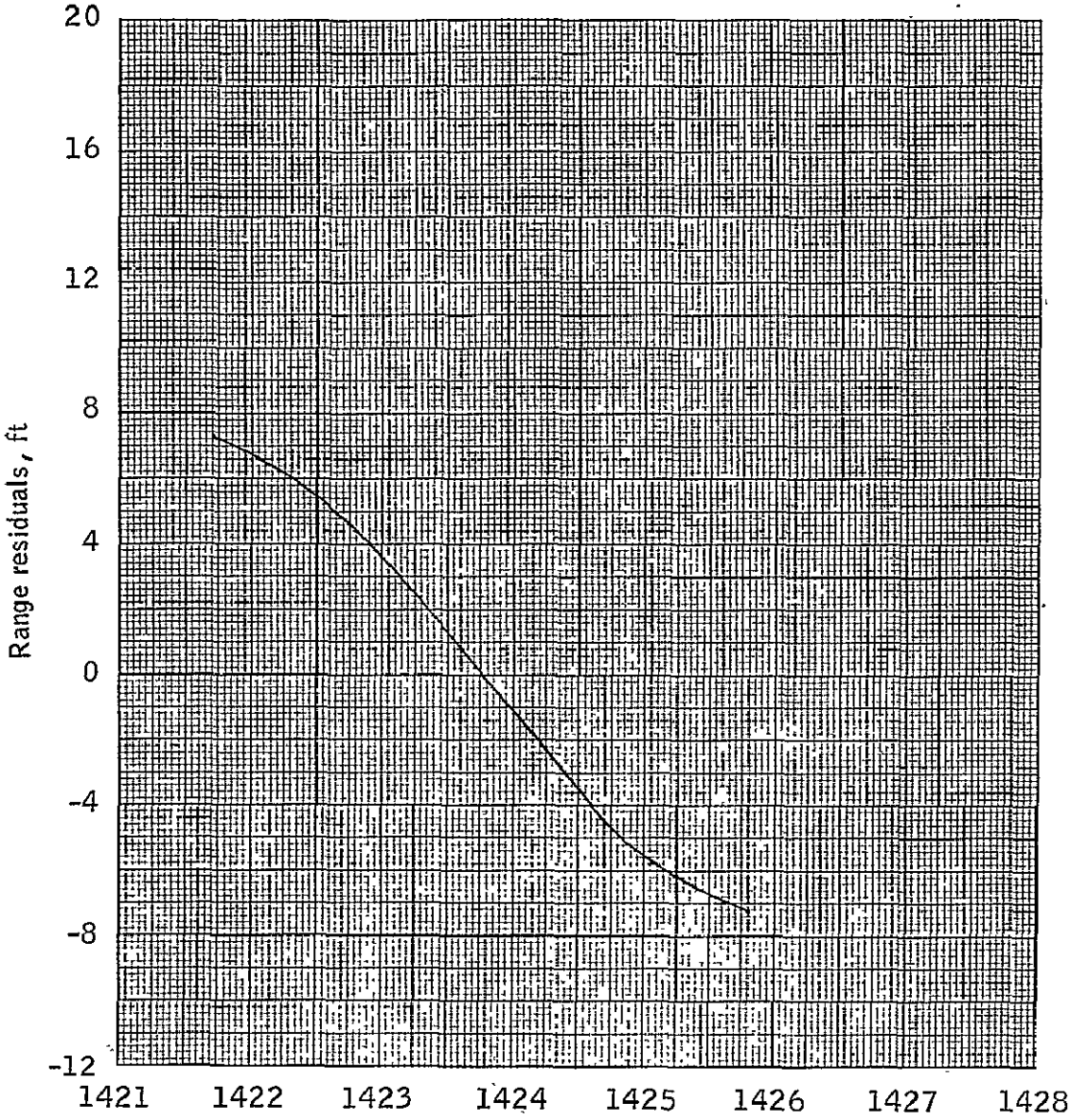
(m) X_{30} angle residuals for -.025-second perturbation of time.

Figure 2.- Continued.



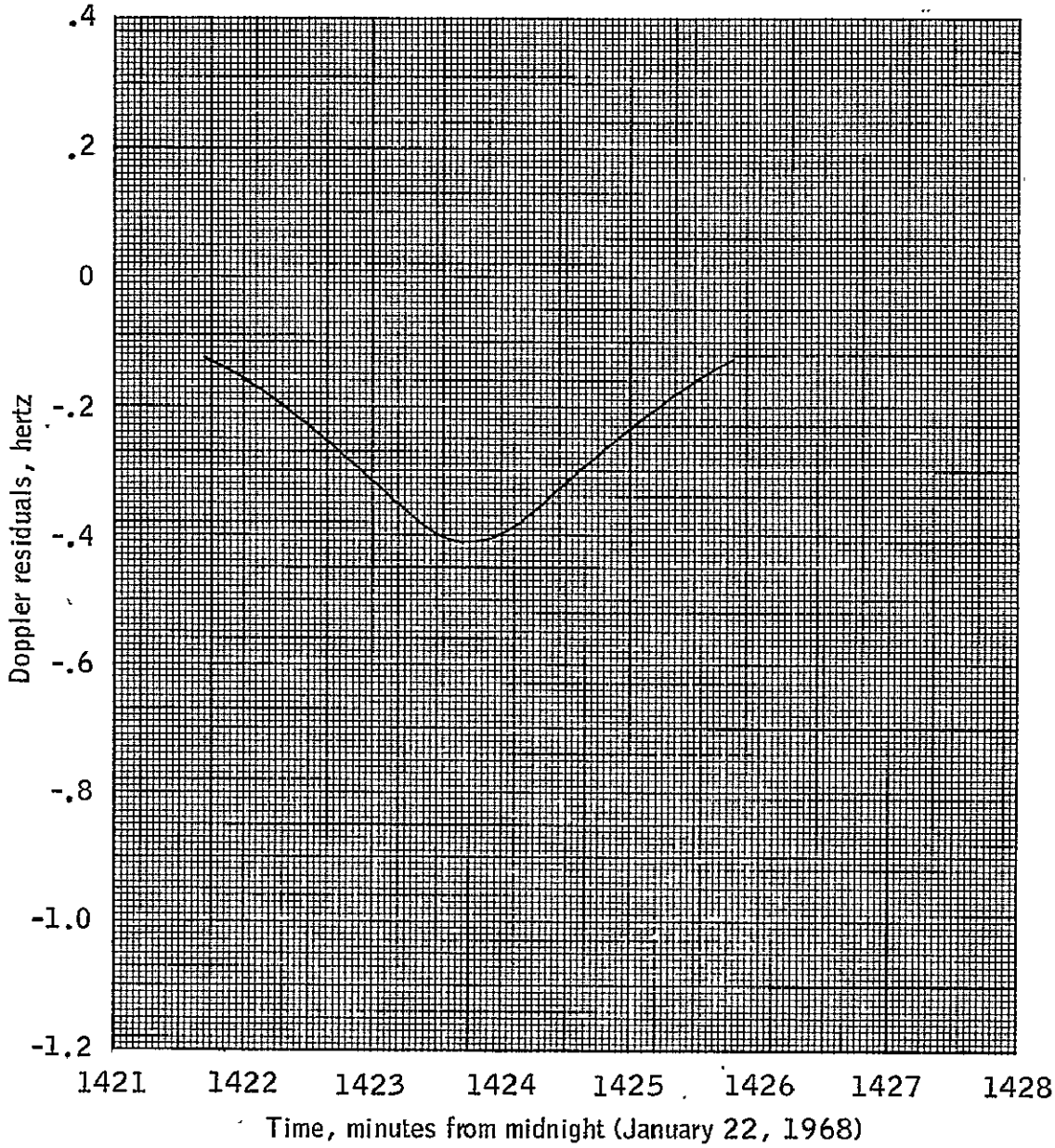
(n) Y_{30} angle residuals for -.025-second perturbation of time.

Figure 2.- Continued.



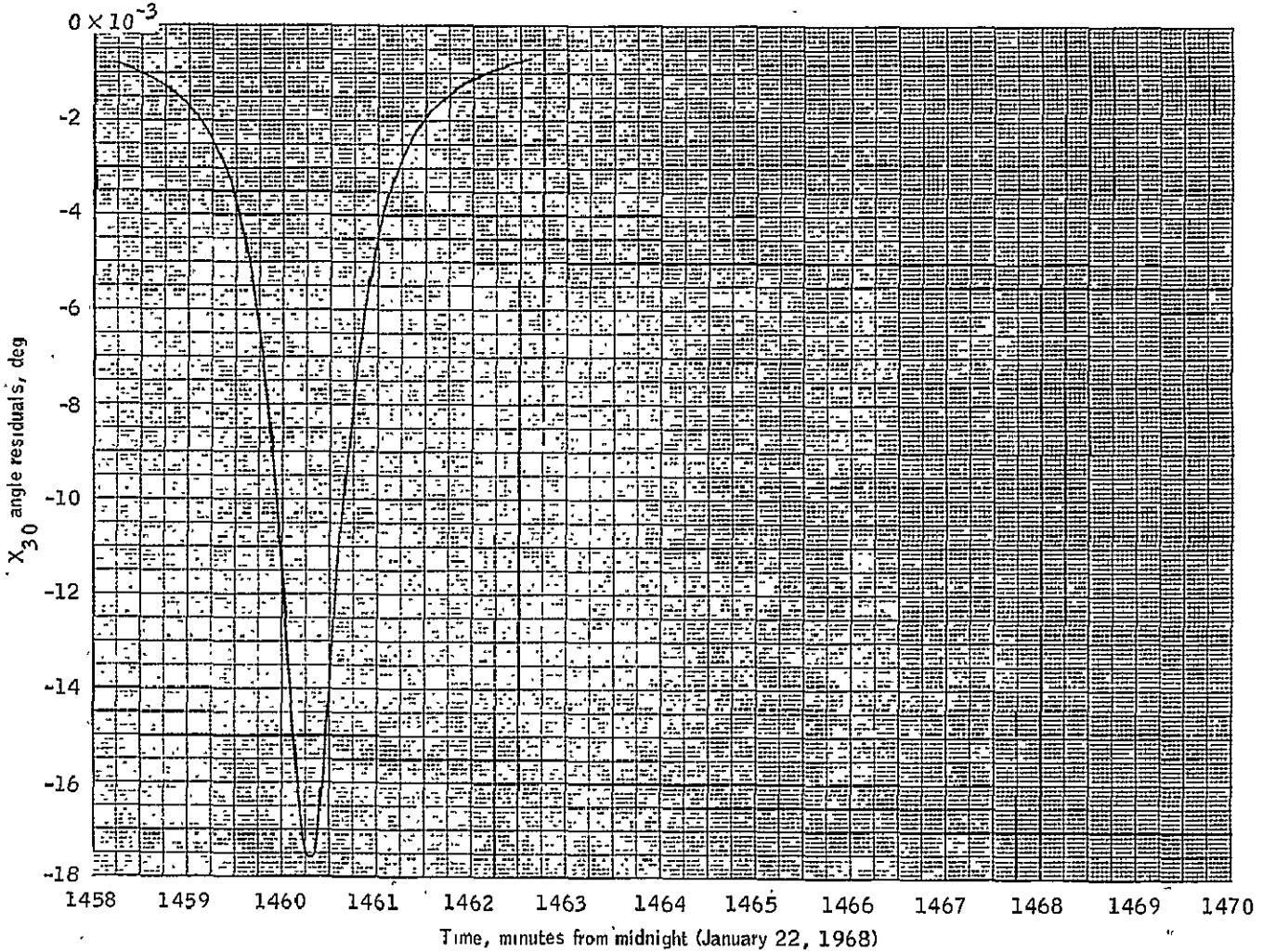
(o) Range residuals for -.025-second perturbation of time.

Figure 2.- Continued.



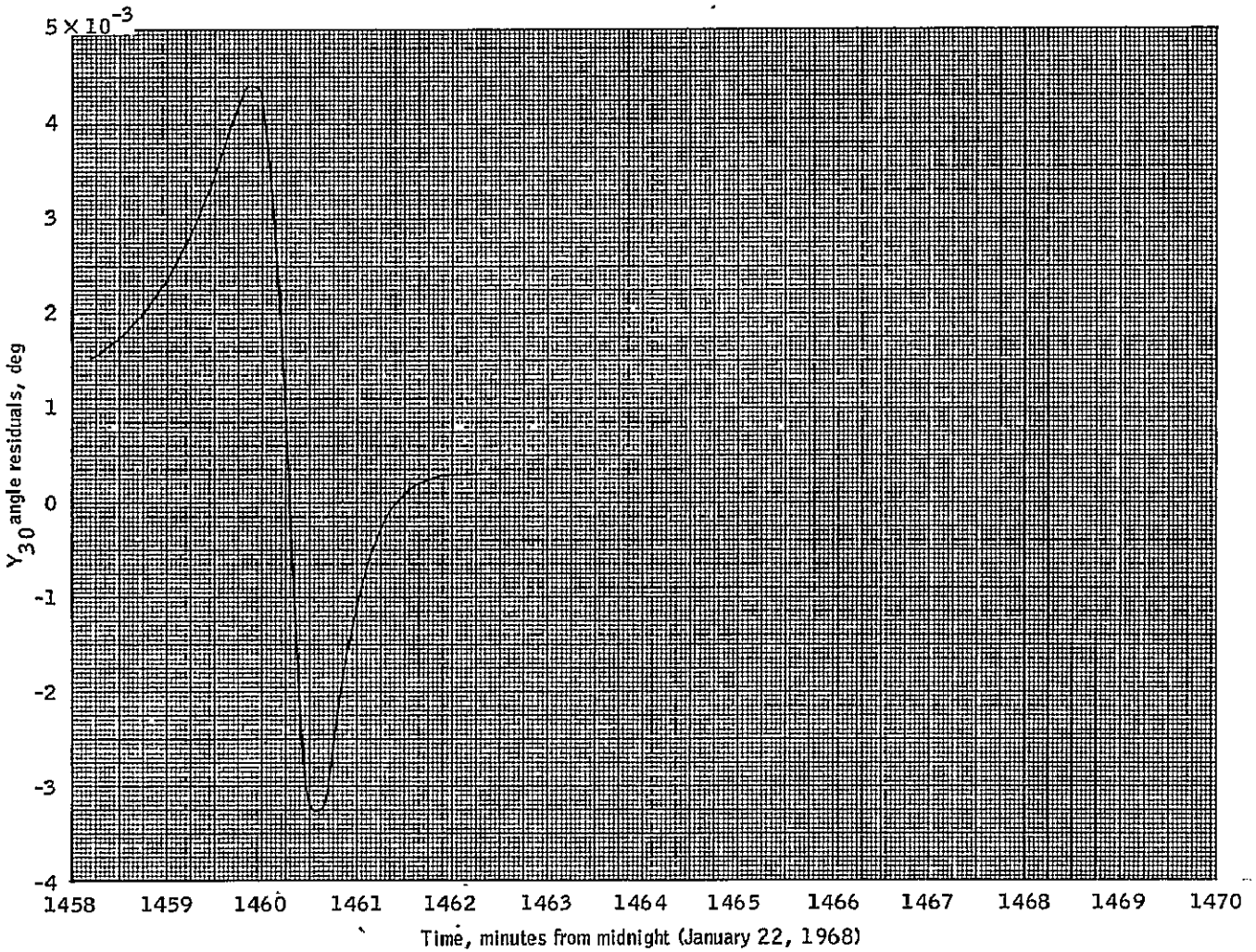
(p) Doppler residuals for -.025-second perturbation of time.

Figure 2.- Concluded.



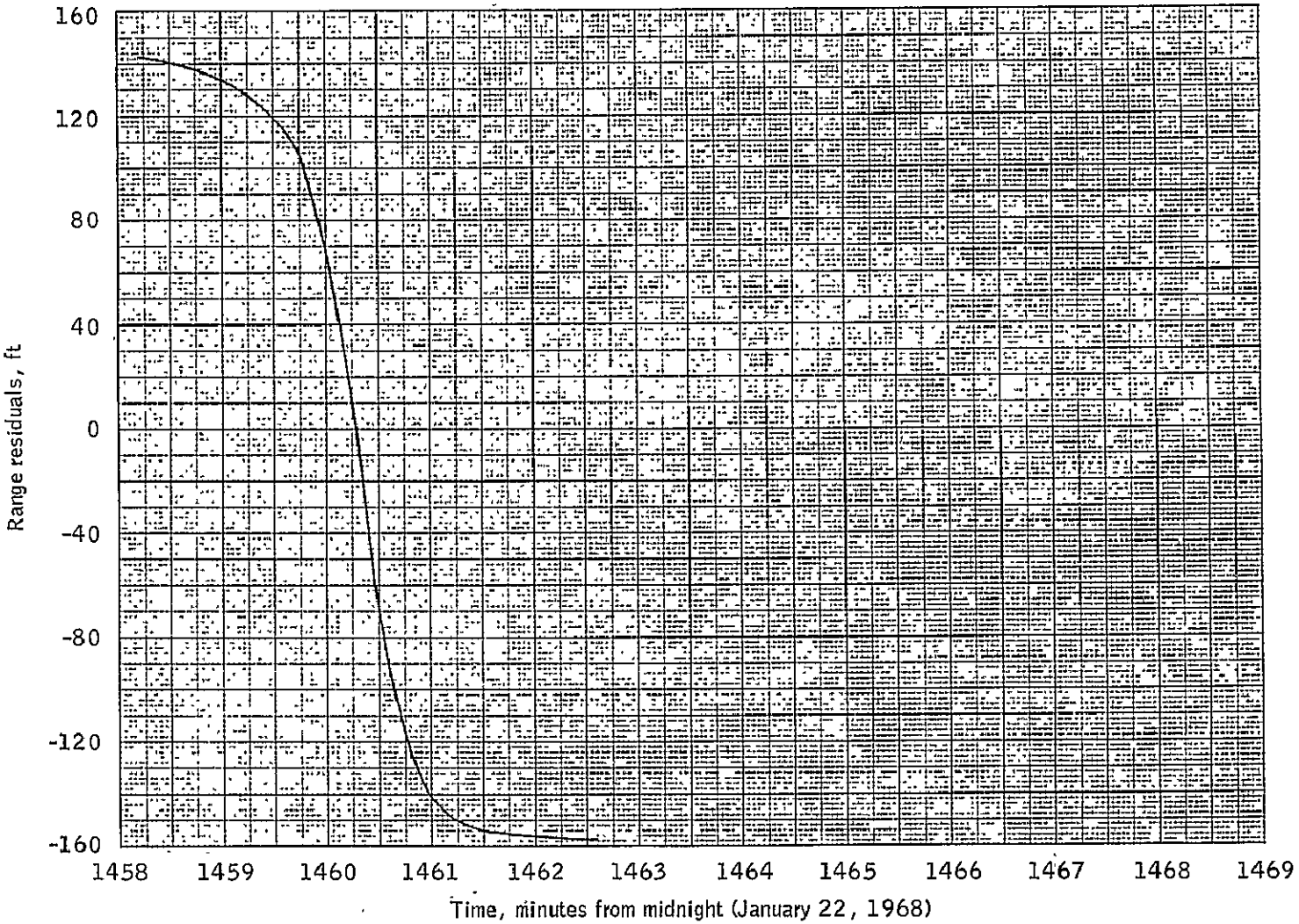
(a) X_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 3.- Residual patterns in USB data from the Guaymas tracking station.



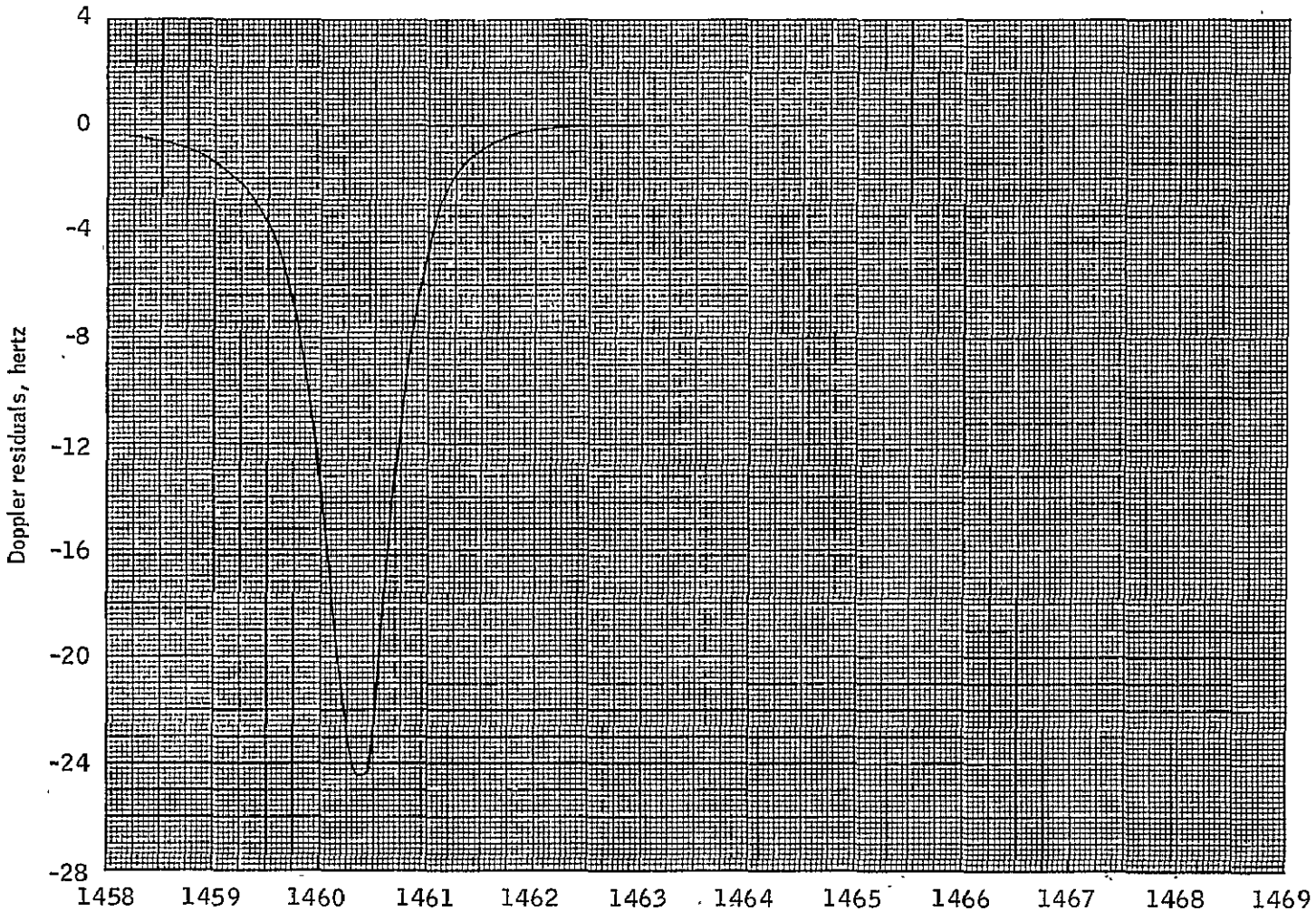
(b) Y_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 3.- Continued.



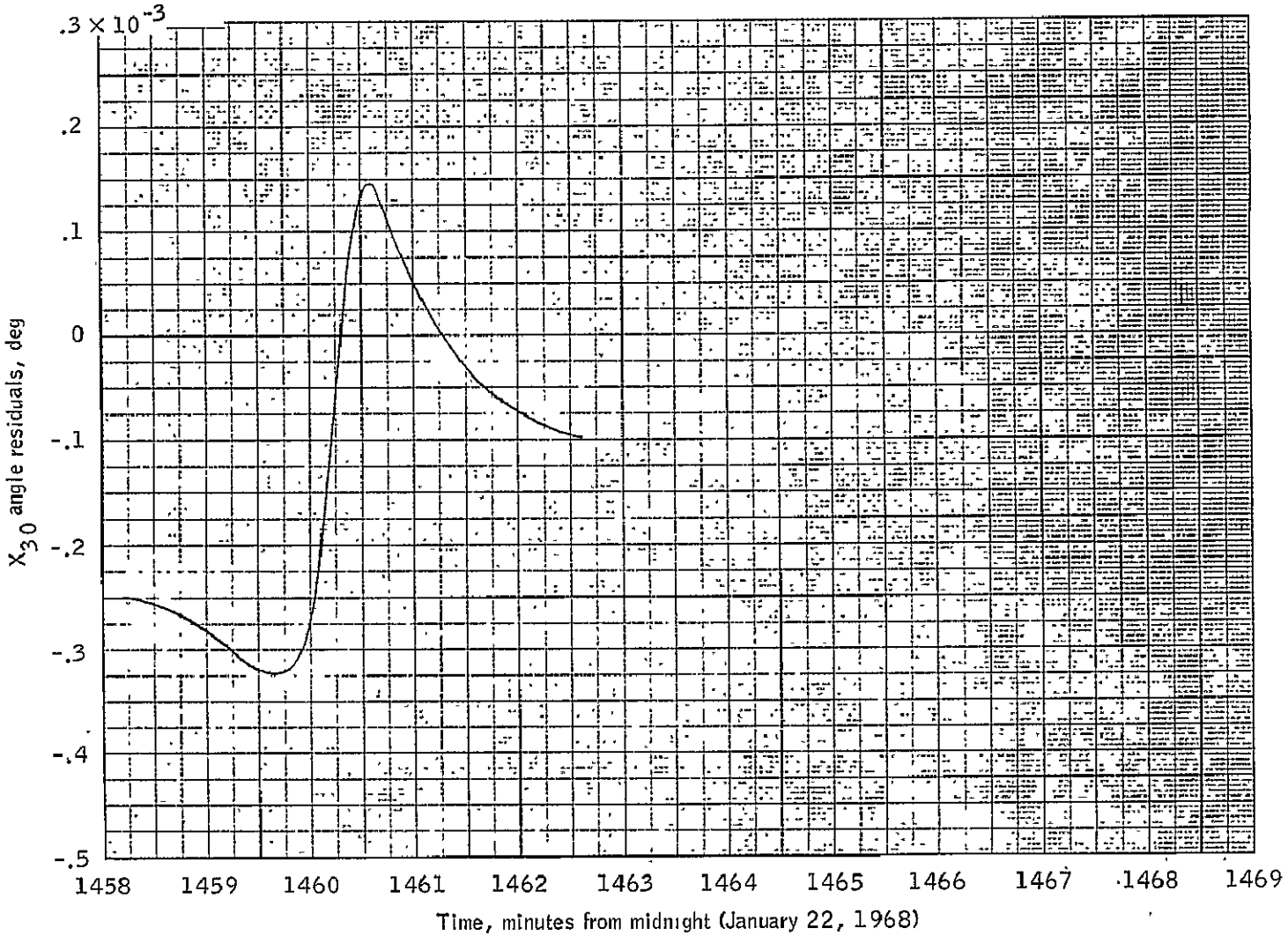
(c) Range residuals for -.0005-degree perturbation of longitude.

Figure 3.- Continued.



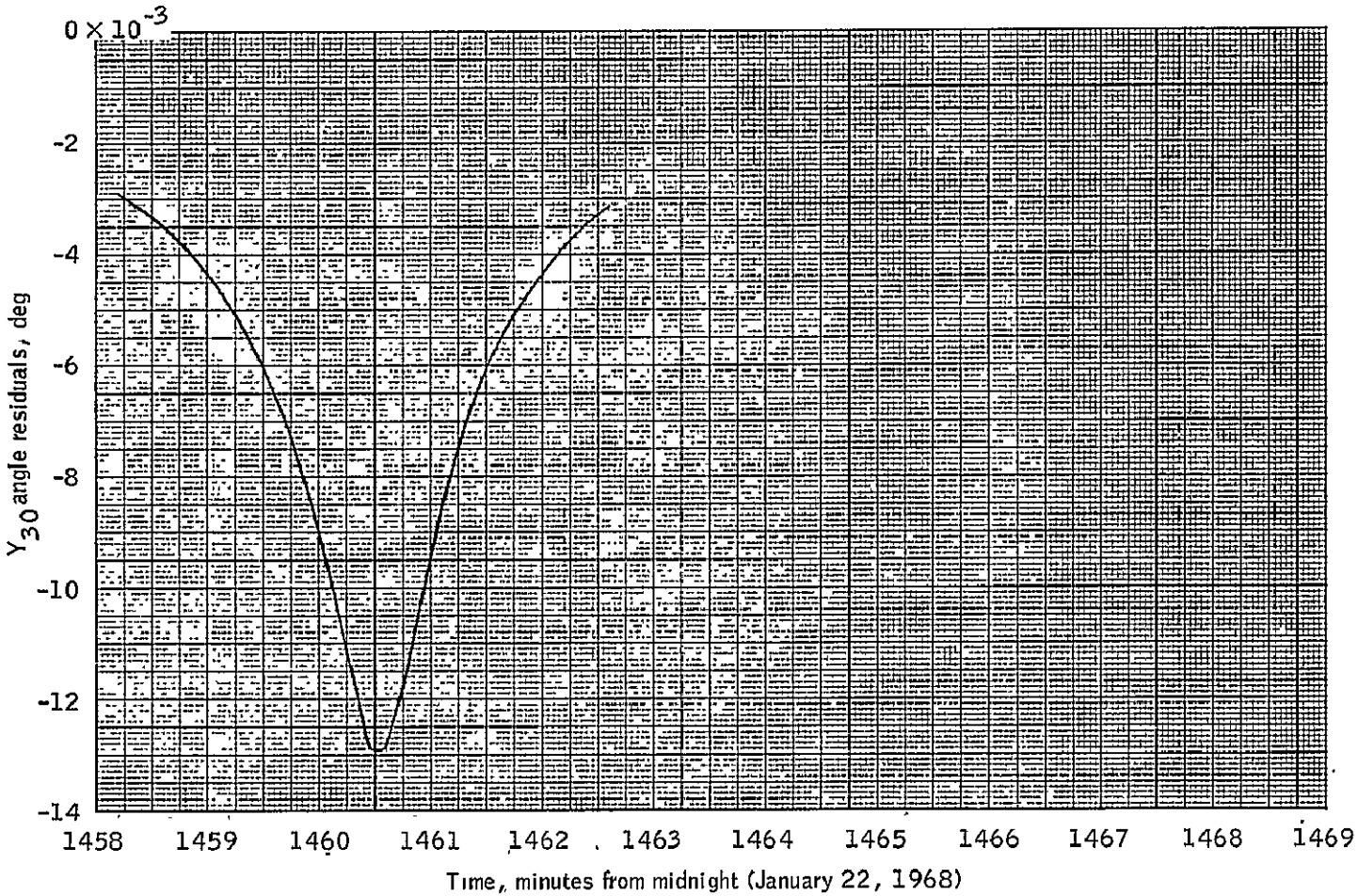
(d) Doppler residuals for -.0005-degree perturbation of longitude.

Figure 3.- Continued.



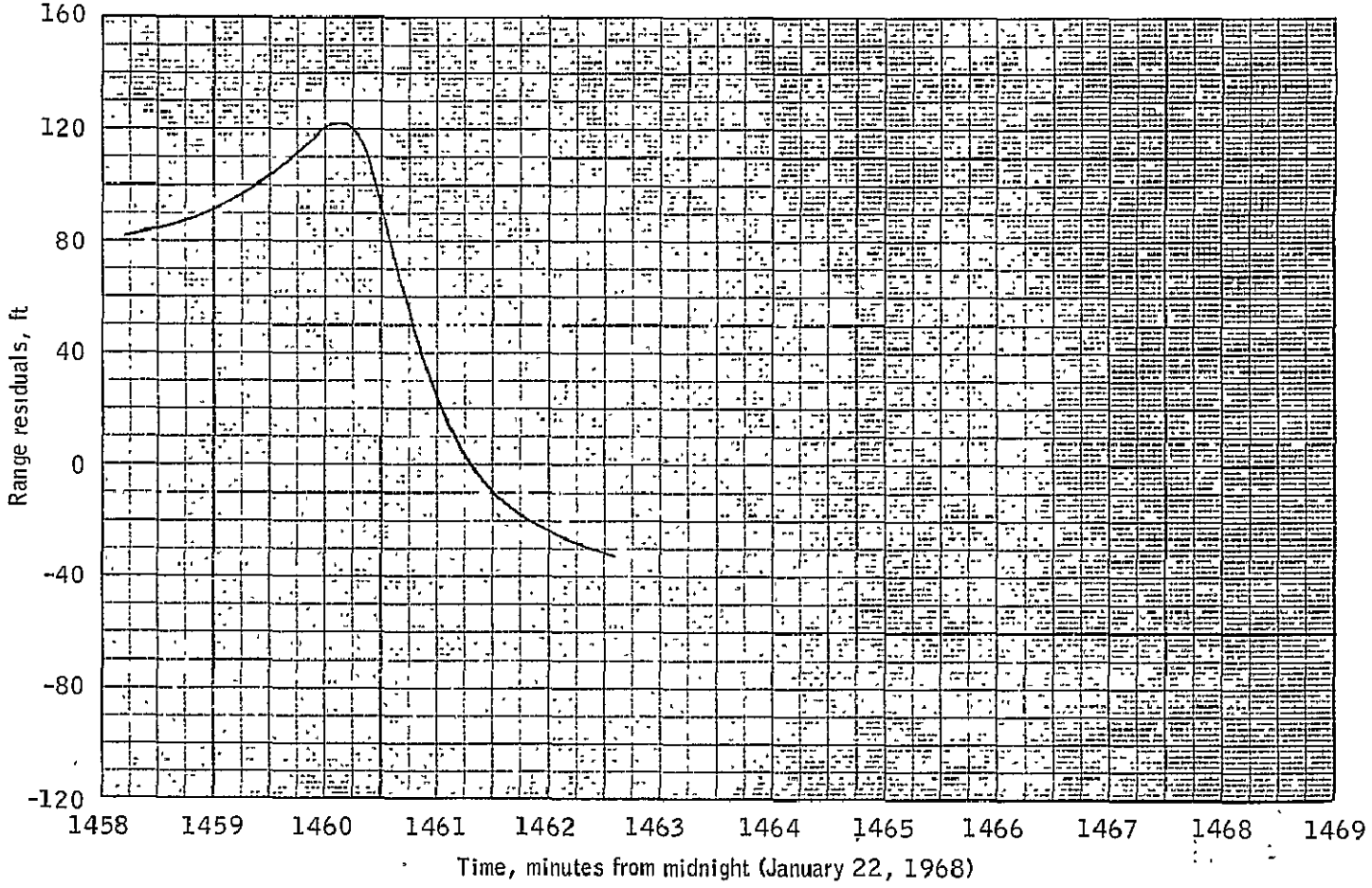
(e) X_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 3.- Continued.



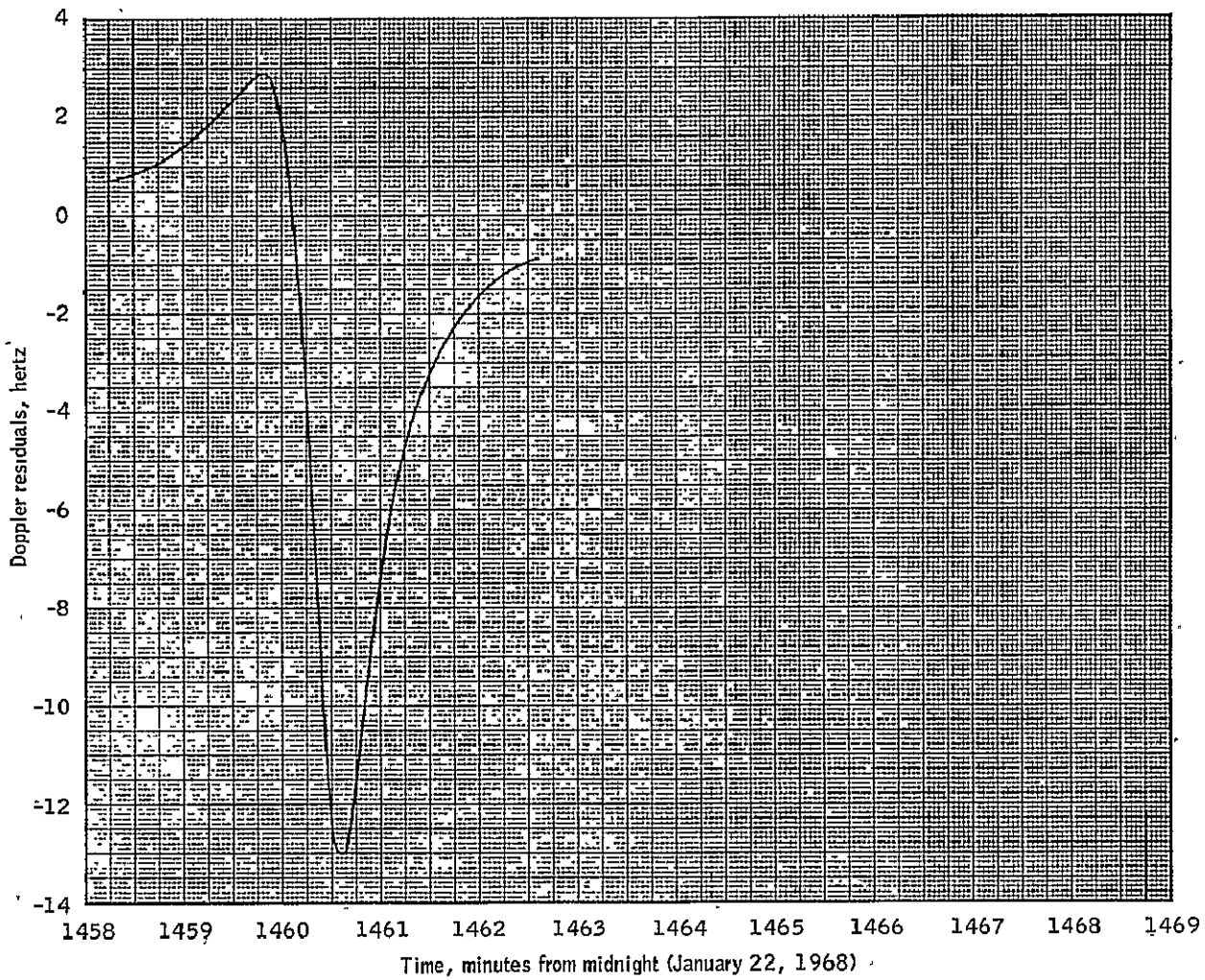
(f) Y_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 3.- Continued.



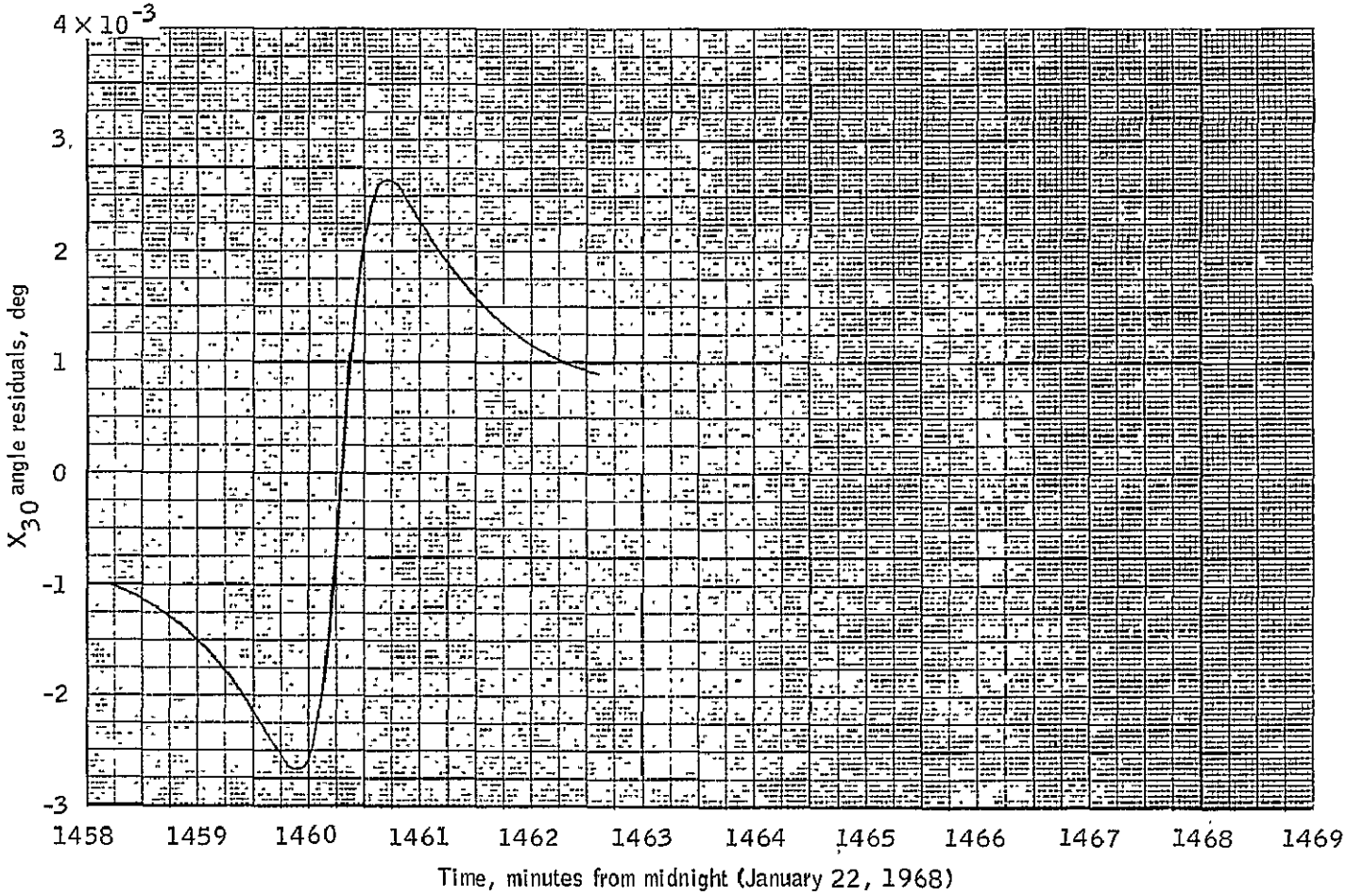
(g) Range residuals for -.0005-degree perturbation of latitude.

Figure 3.- Continued.



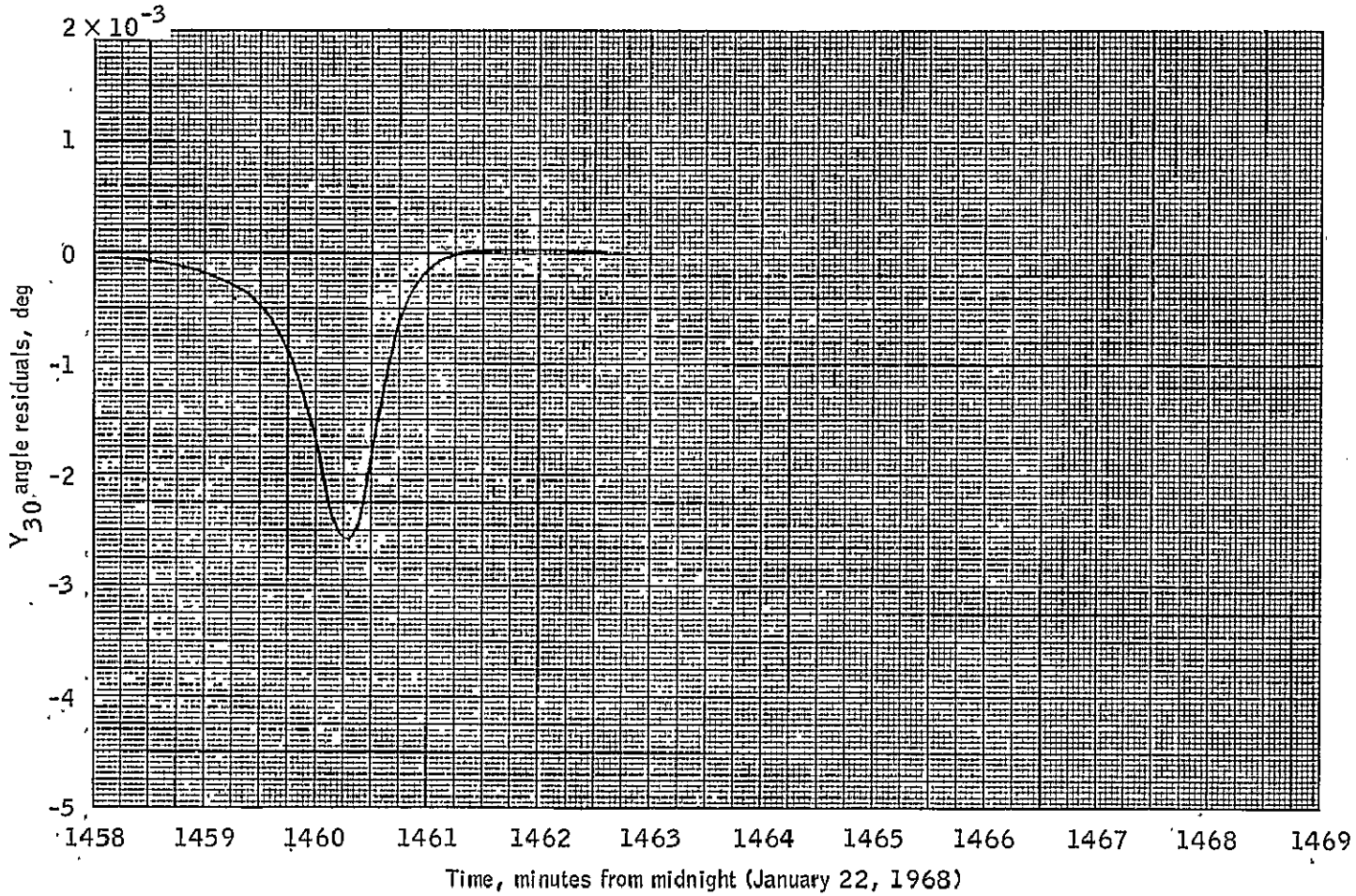
(h) Doppler residuals for -.0005-degree perturbation of latitude.

Figure 3.- Continued.



(i) X_{30} angle residuals for -50-foot perturbation of altitude.

Figure 3.- Continued.



(j) Y_{30} angle residuals for -50-foot perturbation of altitude.

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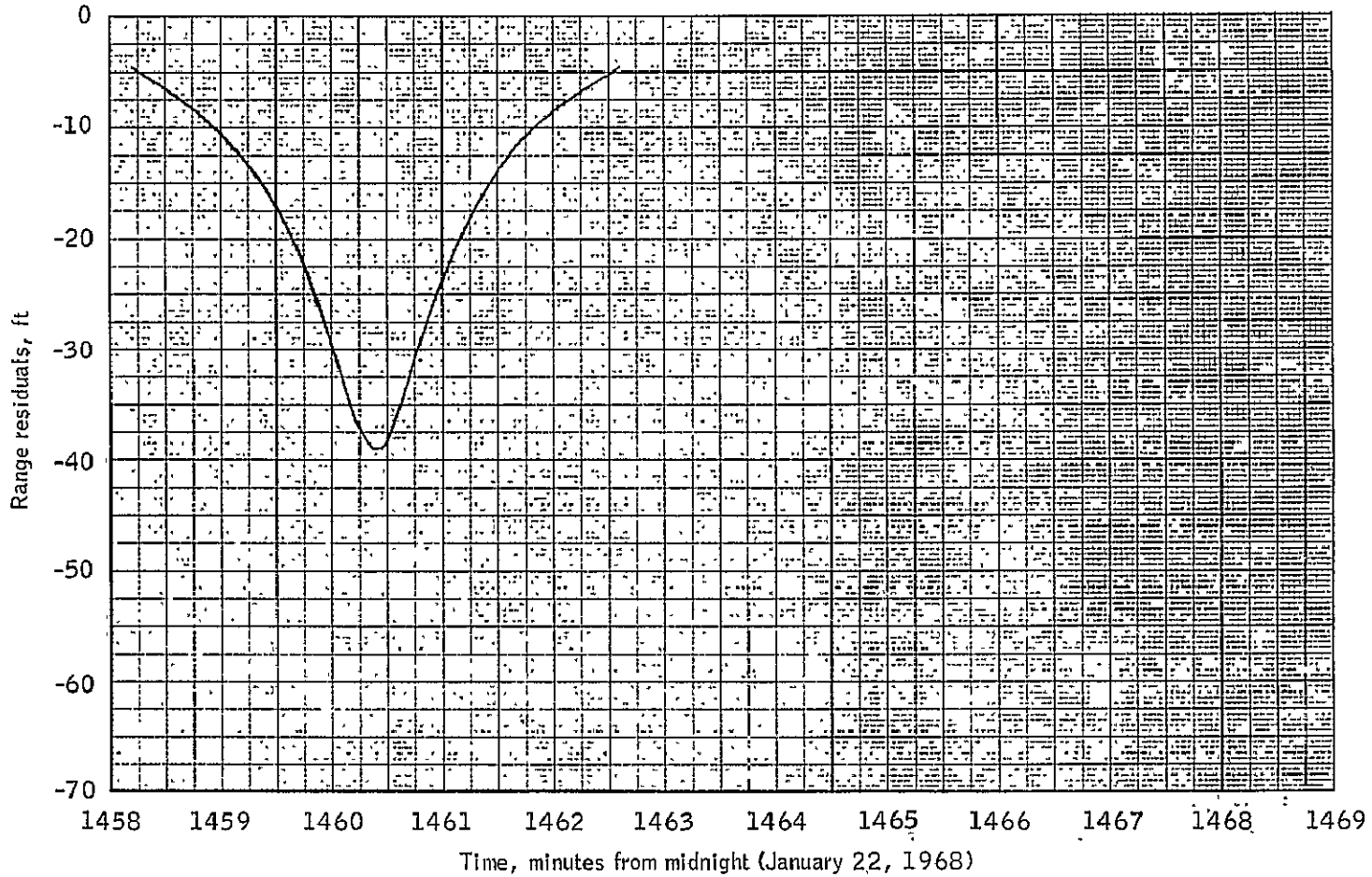
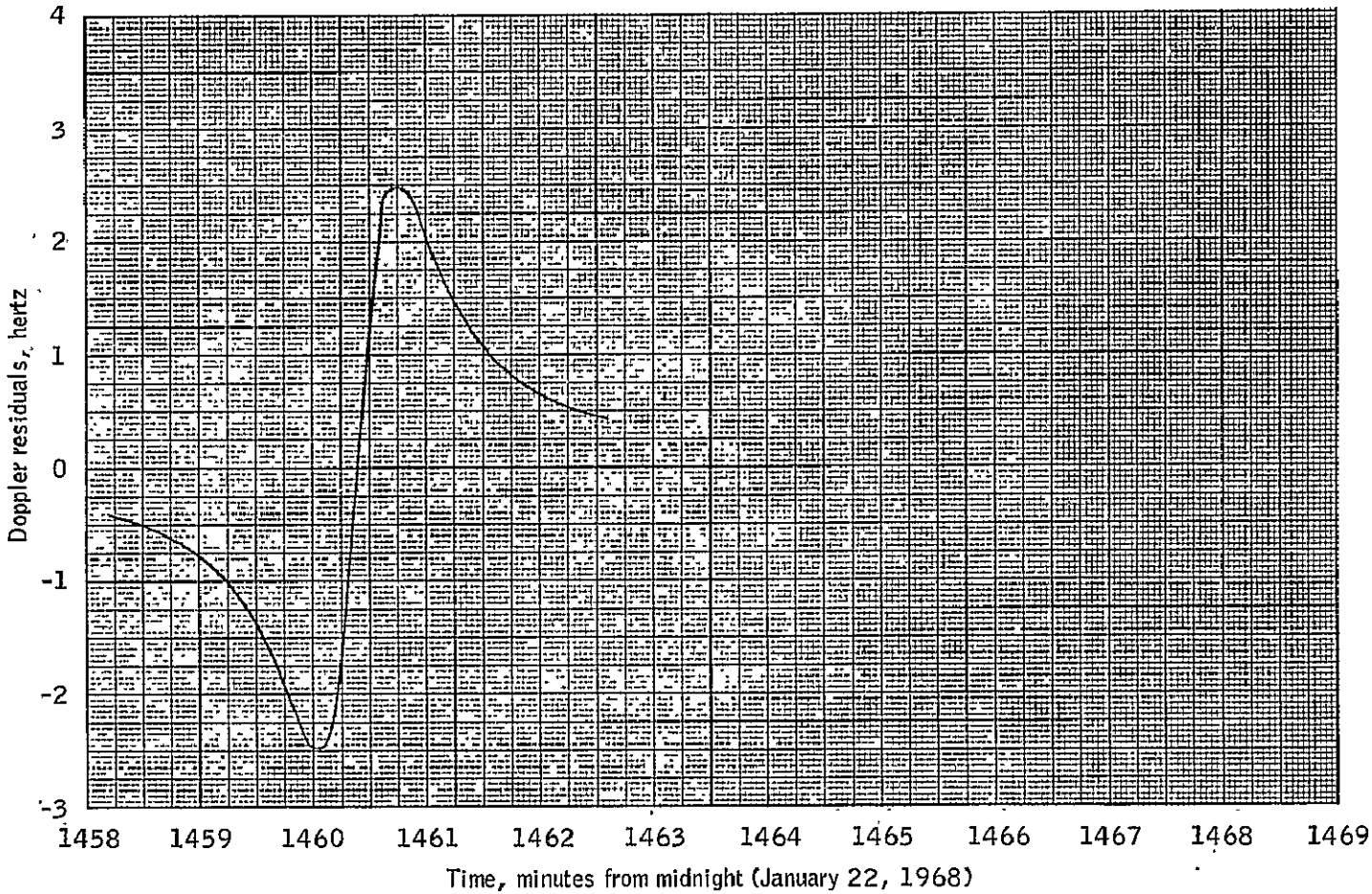


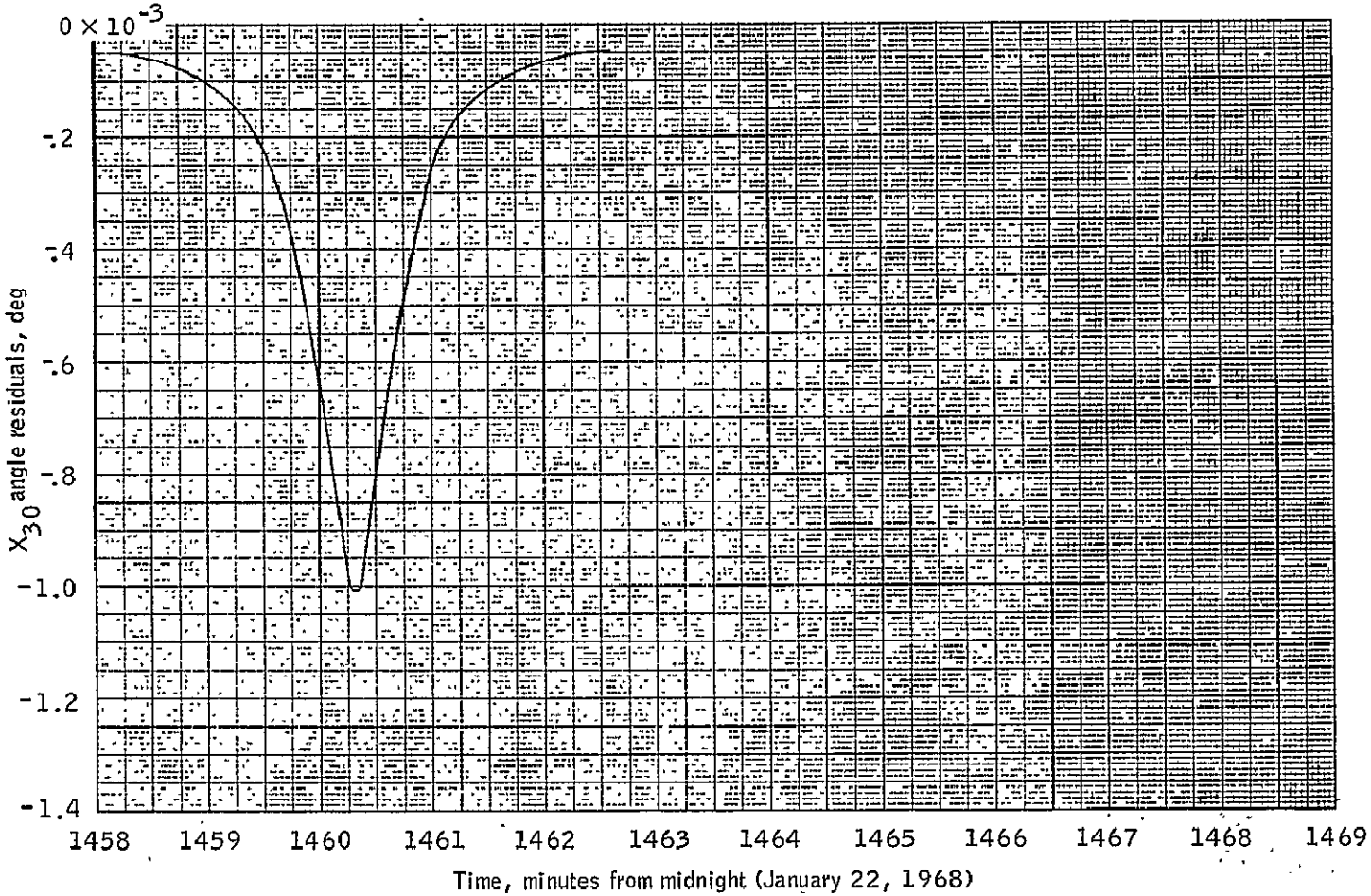
(k) Range residuals for -50-foot perturbation of altitude.

Figure 3.- Continued.



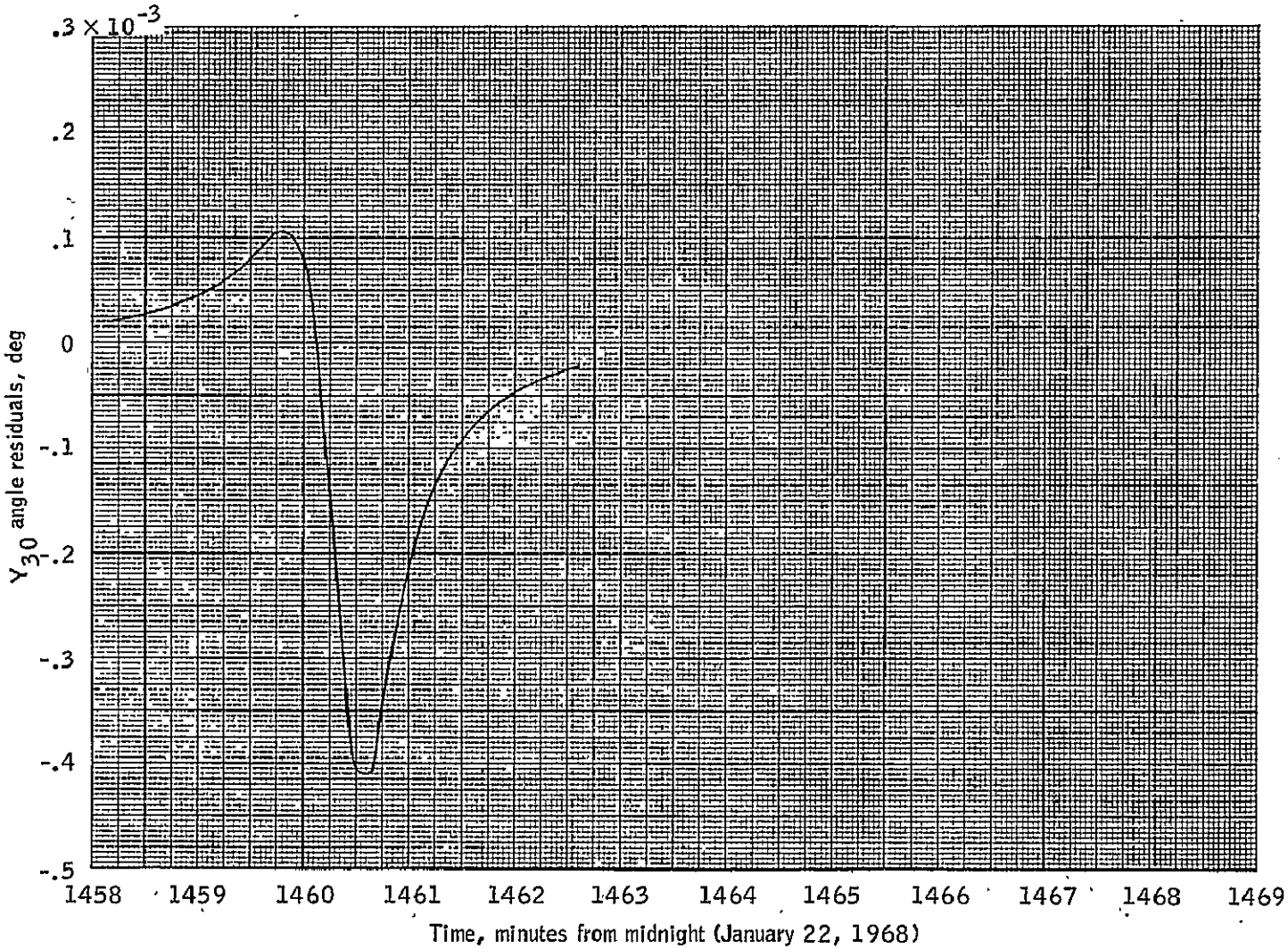
(l) Doppler residuals for -50-foot perturbation of altitude.

Figure 3.- Continued.



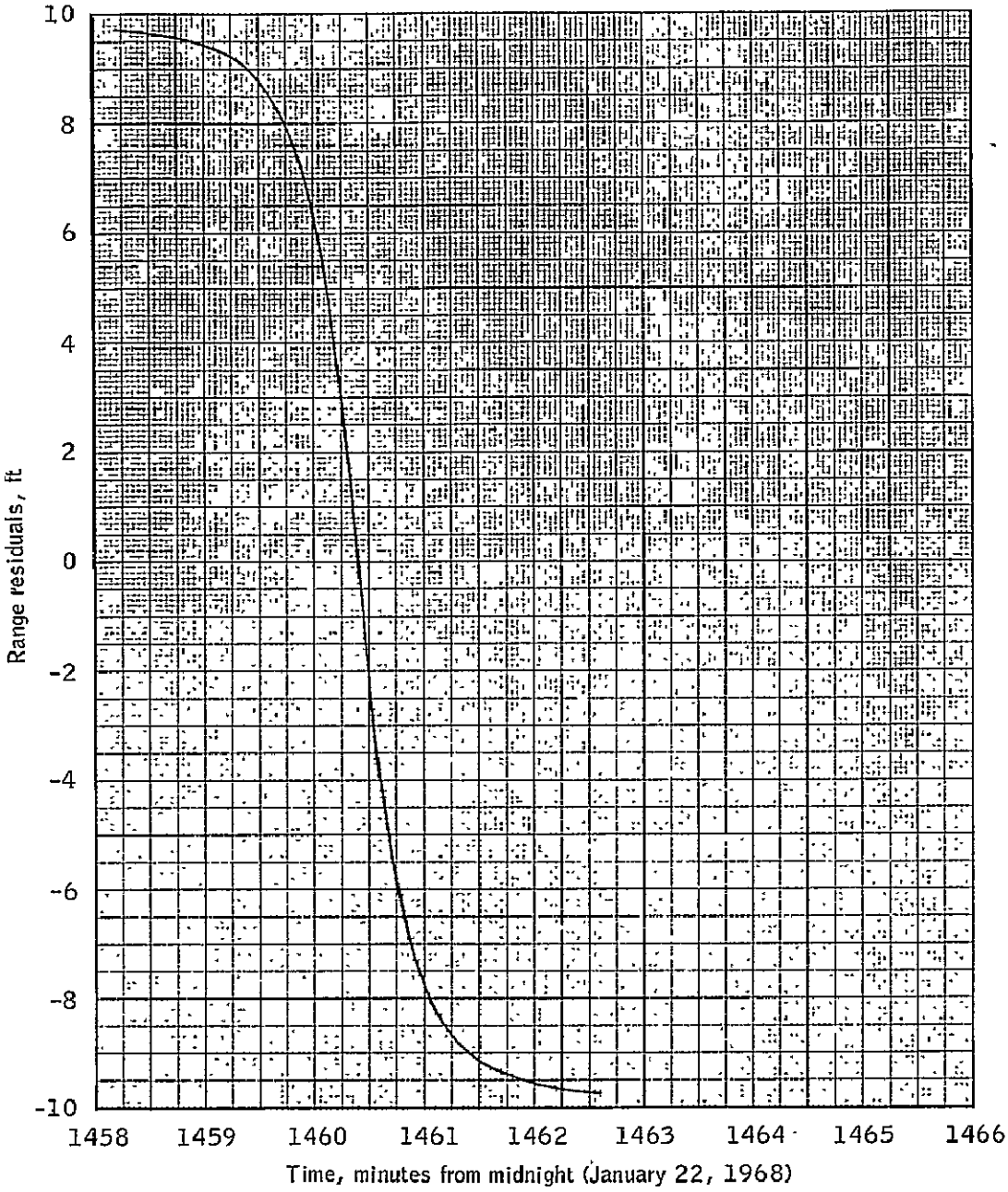
(m) X_{30} angle residuals for -.025-second perturbation of time.

Figure 3.- Continued.



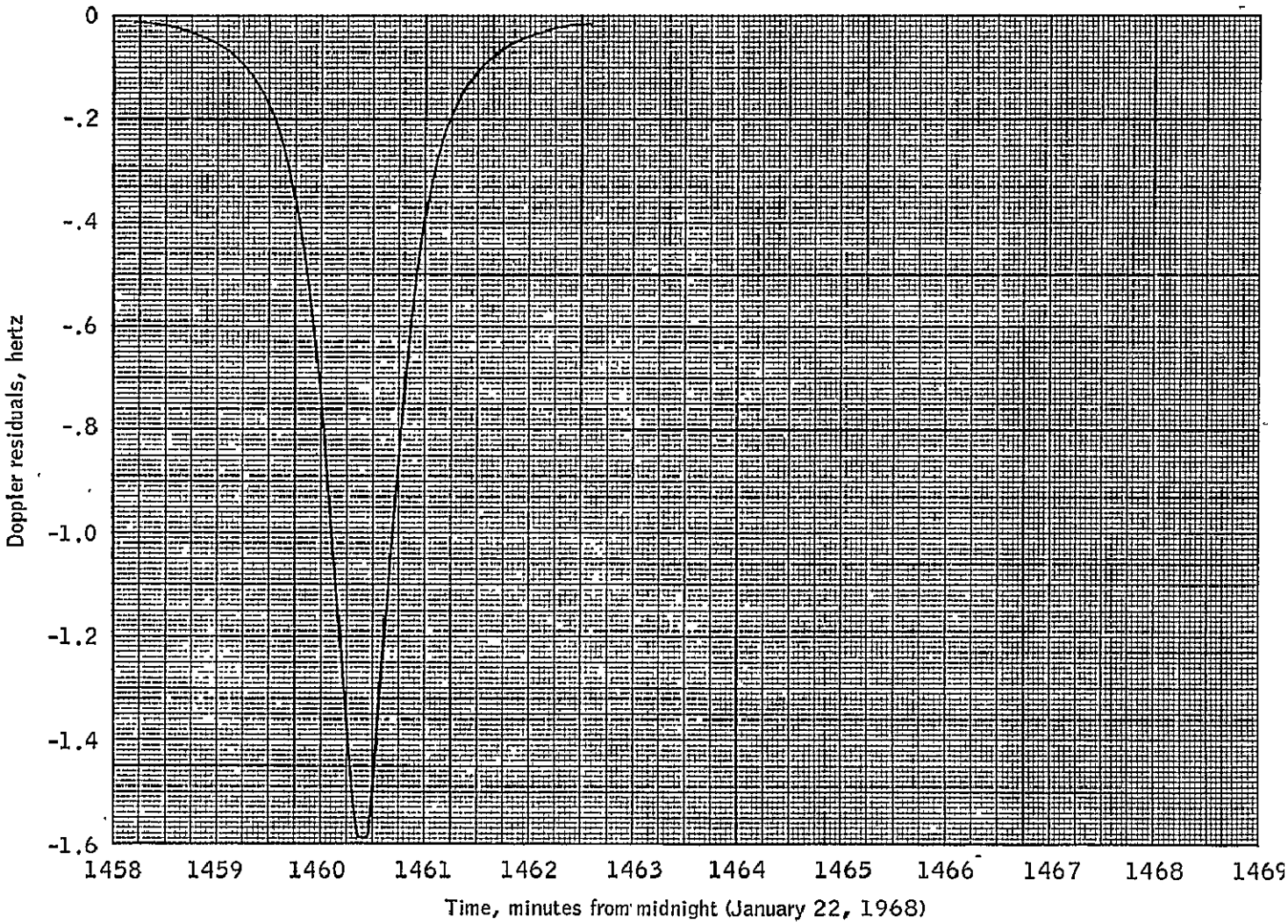
(n) Y_{30} angle residuals for -.025-second perturbation of time.

Figure 3.- Continued.



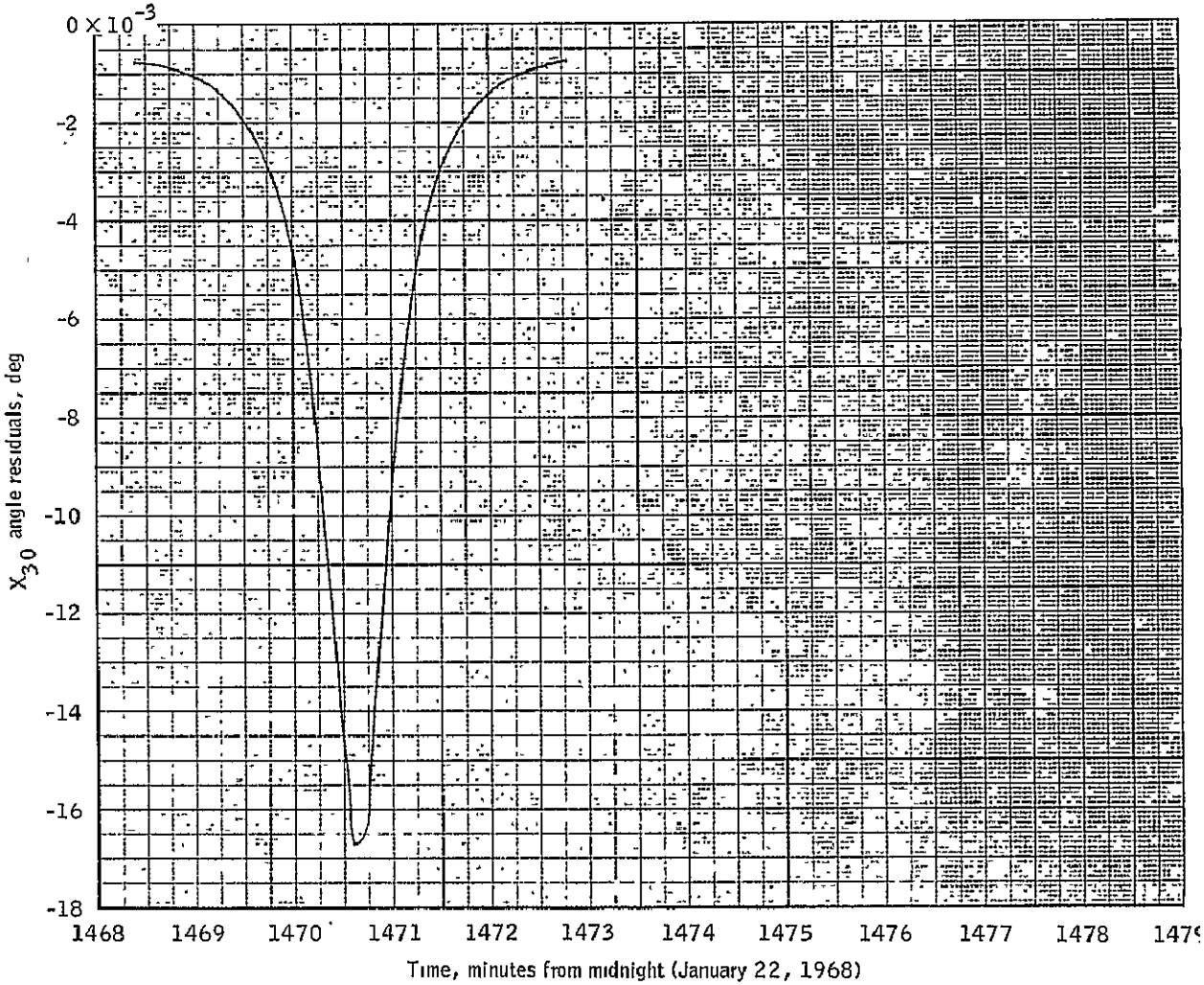
(o) Range residuals for -.025-second perturbation of time.

Figure 3.- Continued.



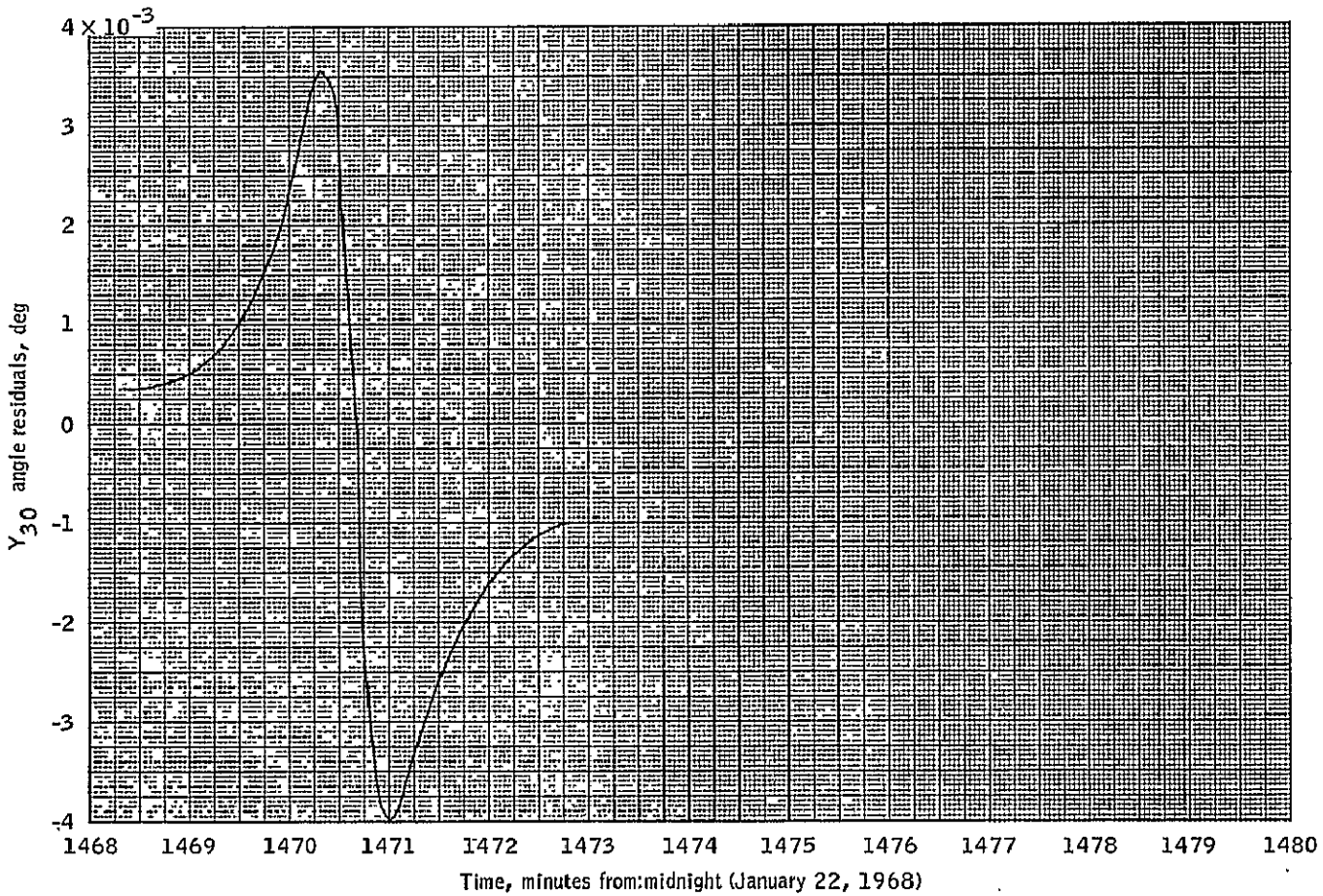
(p) Doppler residuals for -.025-second perturbation of time.

Figure 3.- Concluded.



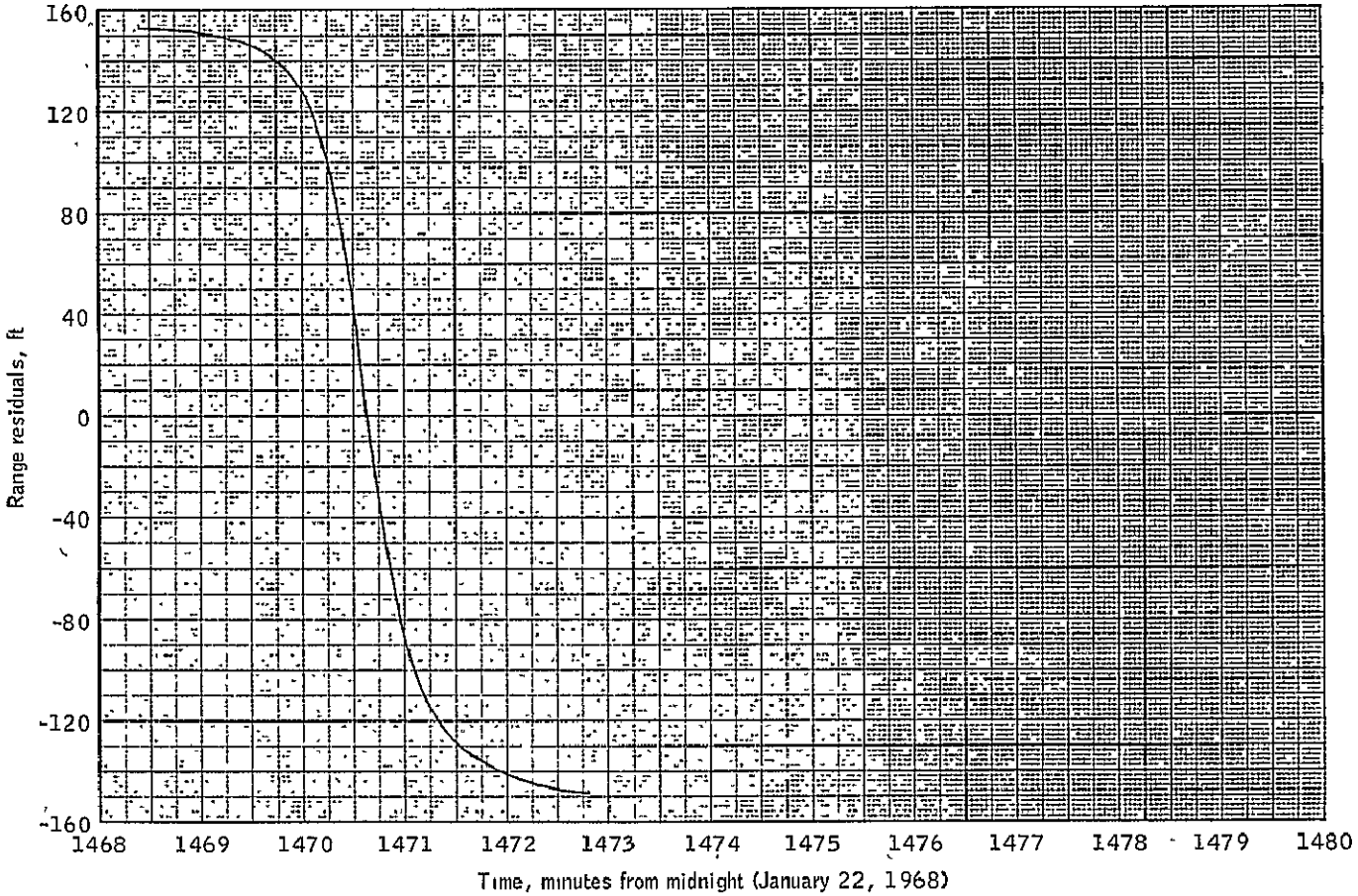
(a) X_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 4.- Residual patterns in USB data from the Bermuda tracking station.



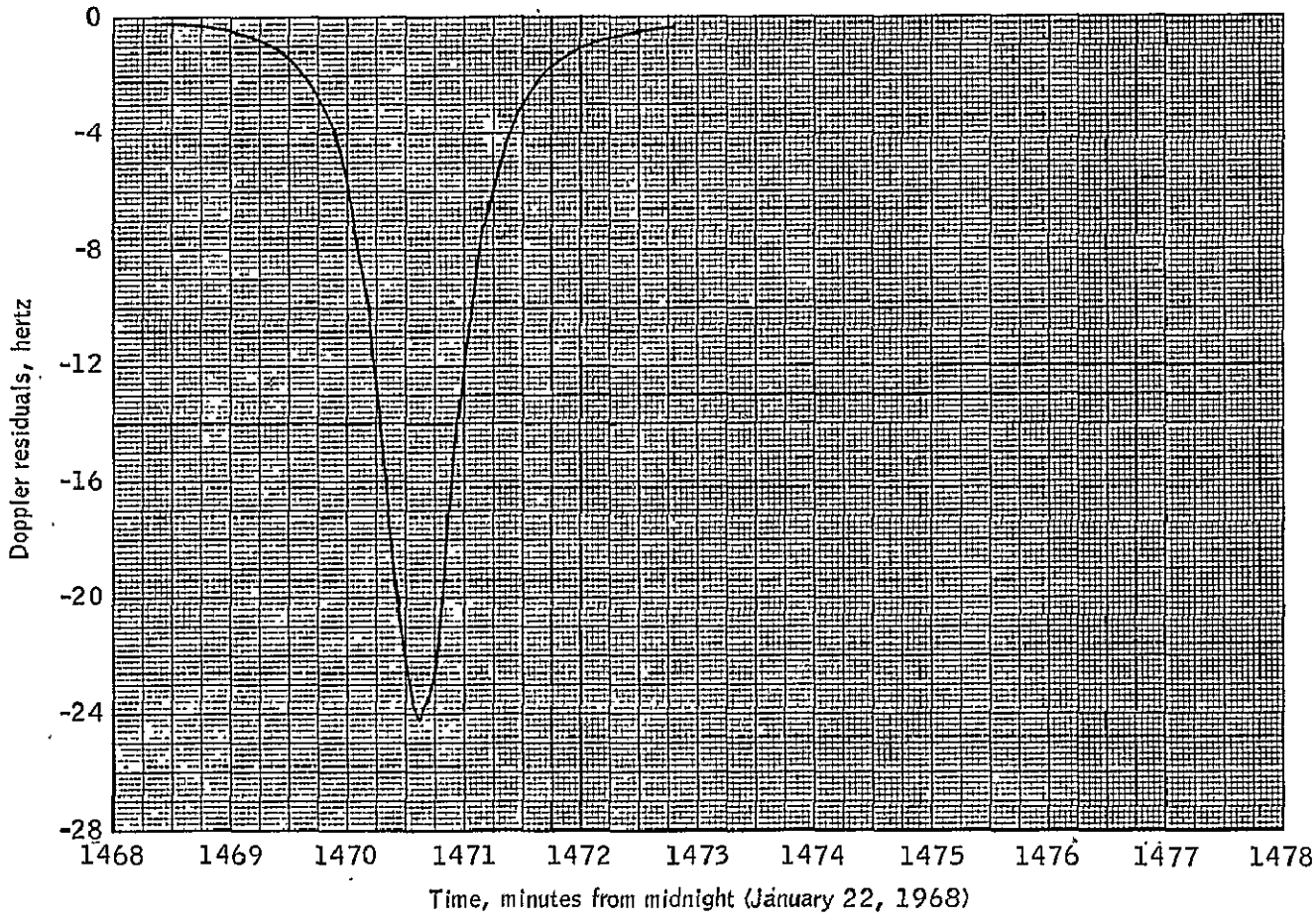
(b) Y_{30} angle residuals for −.0005-degree perturbation of longitude.

Figure 4.- Continued.



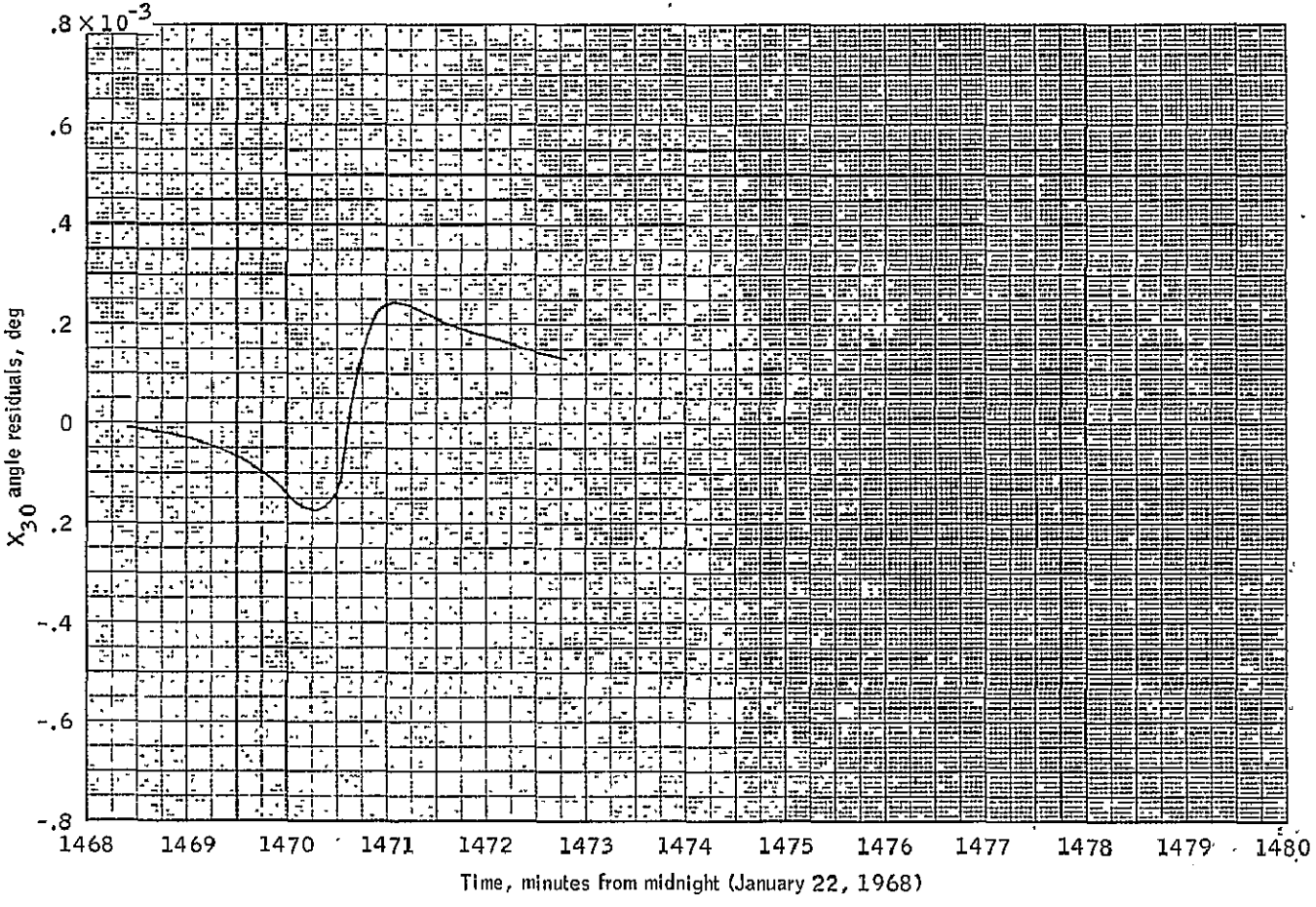
(c) Range residuals for -.0005-degree perturbation of longitude.

Figure 4.- Continued.



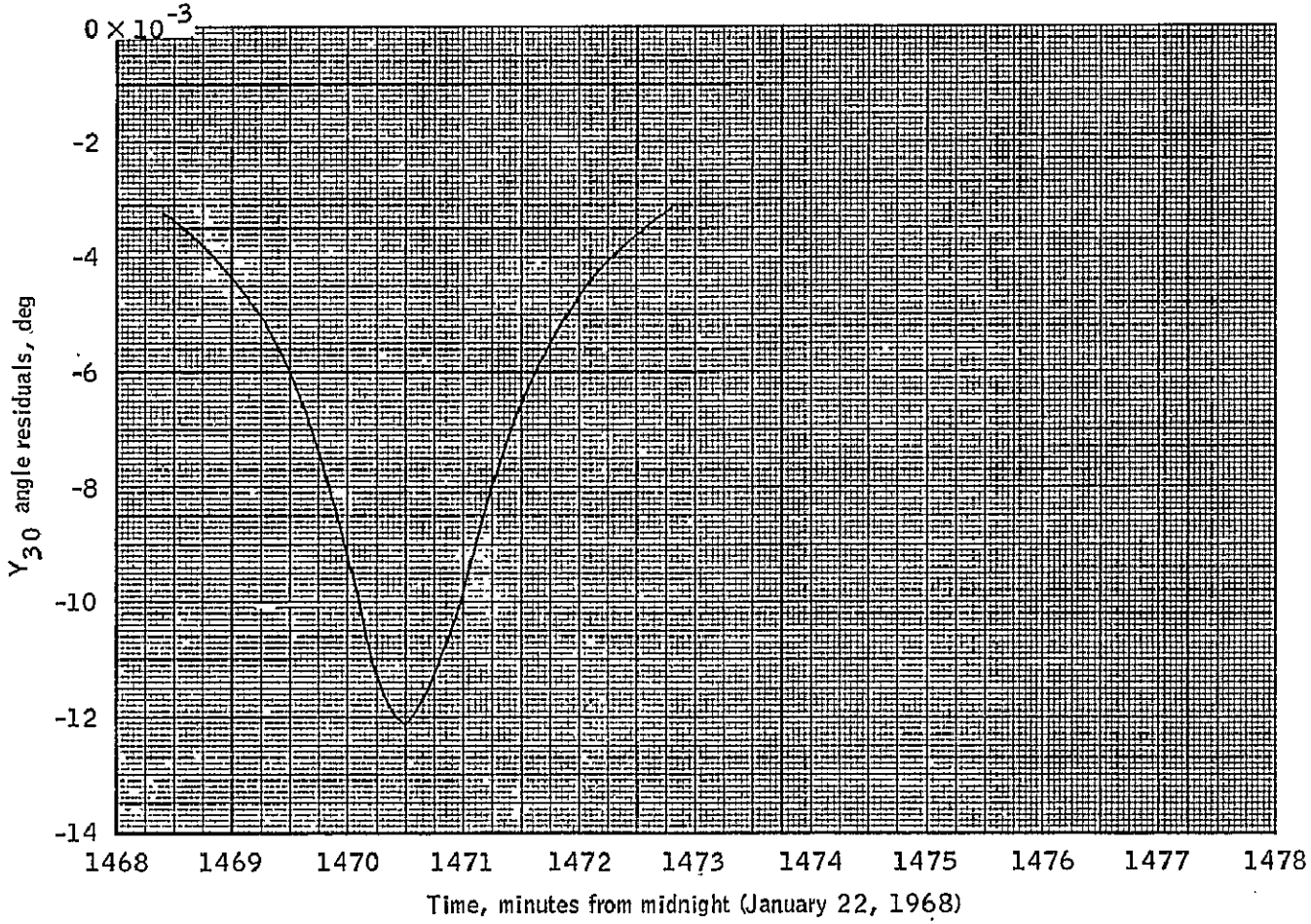
(d) Doppler residuals for -.0005-degree perturbation of longitude.

Figure 4.- Continued.



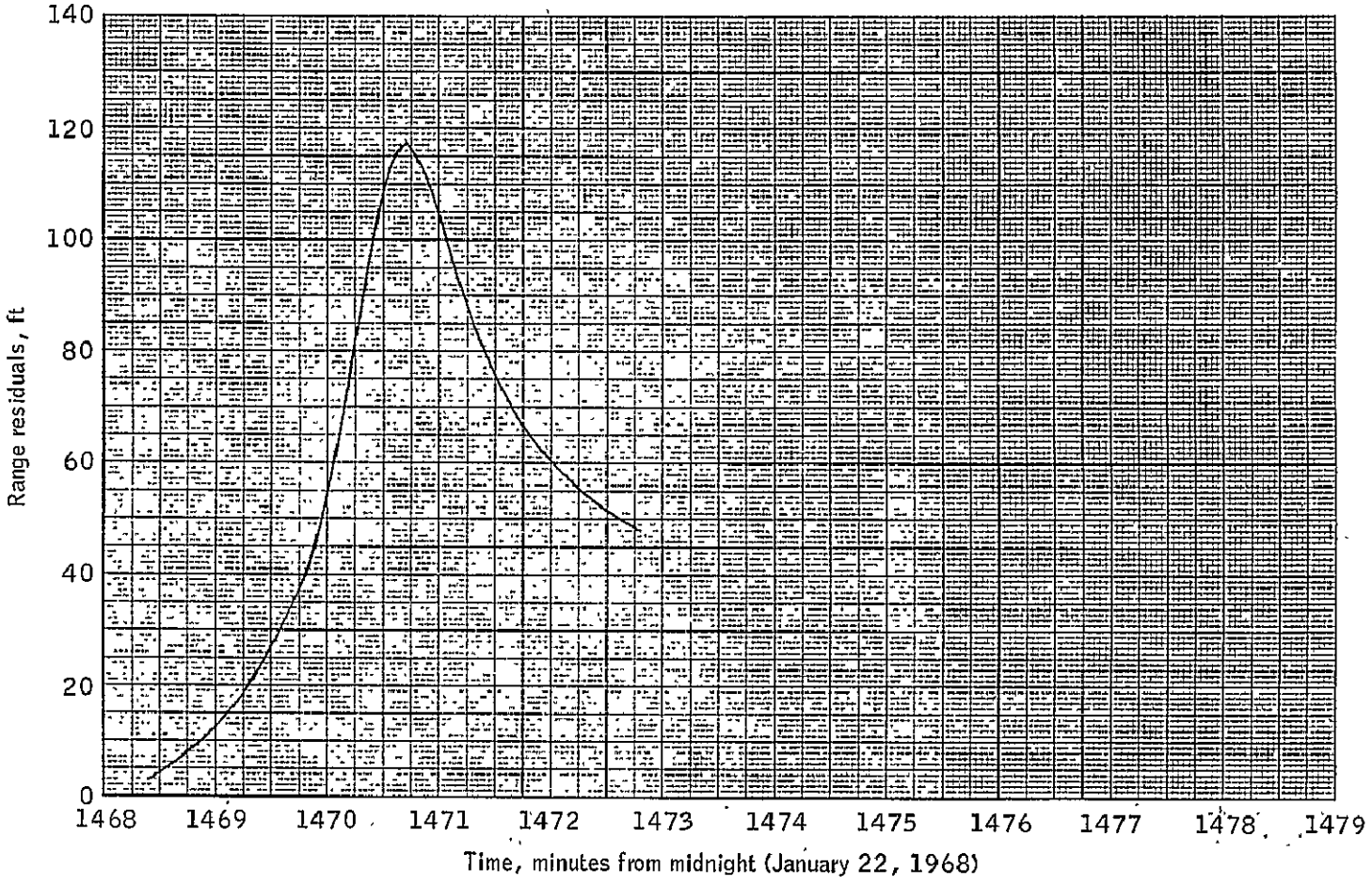
(e) X_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 4.- Continued.



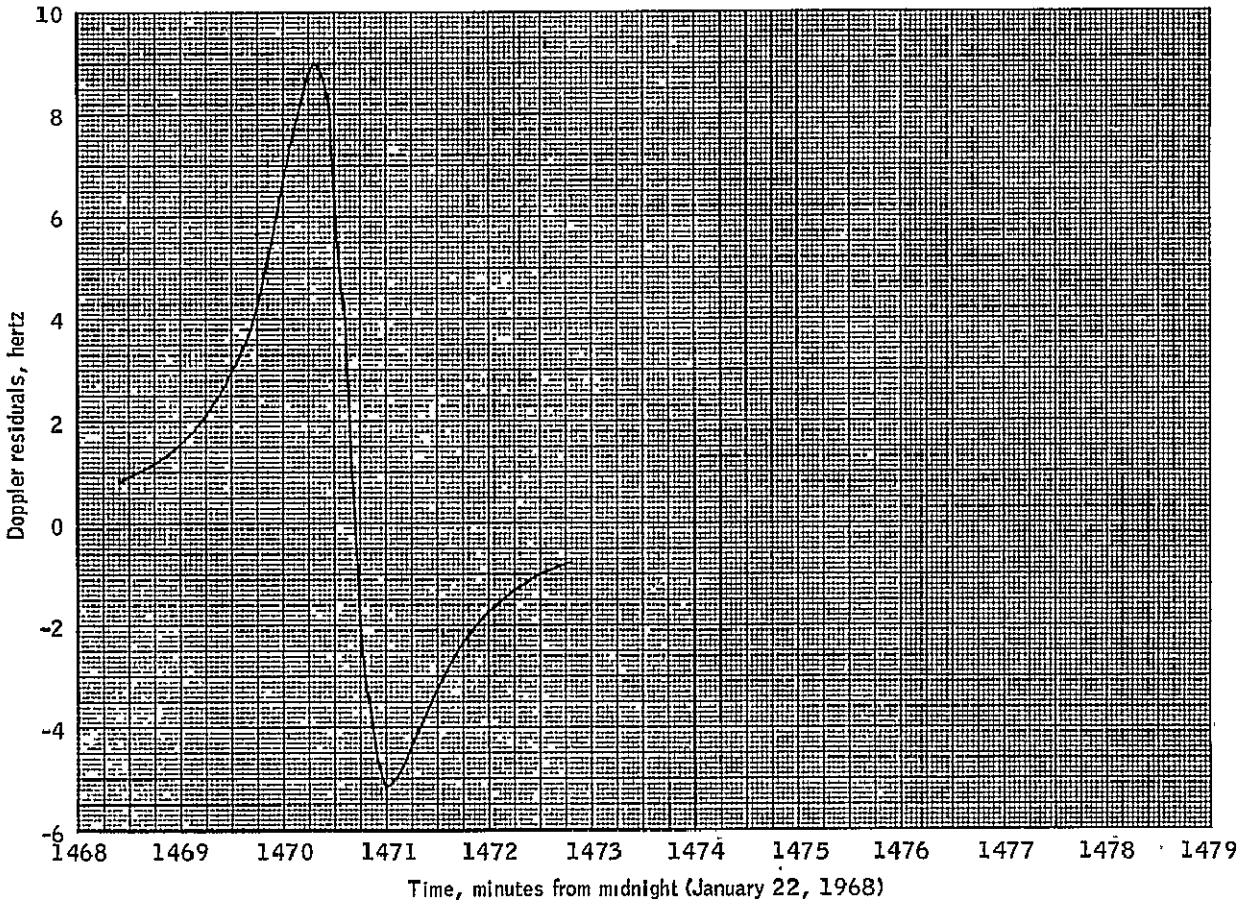
(f) Y_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 4.- Continued.



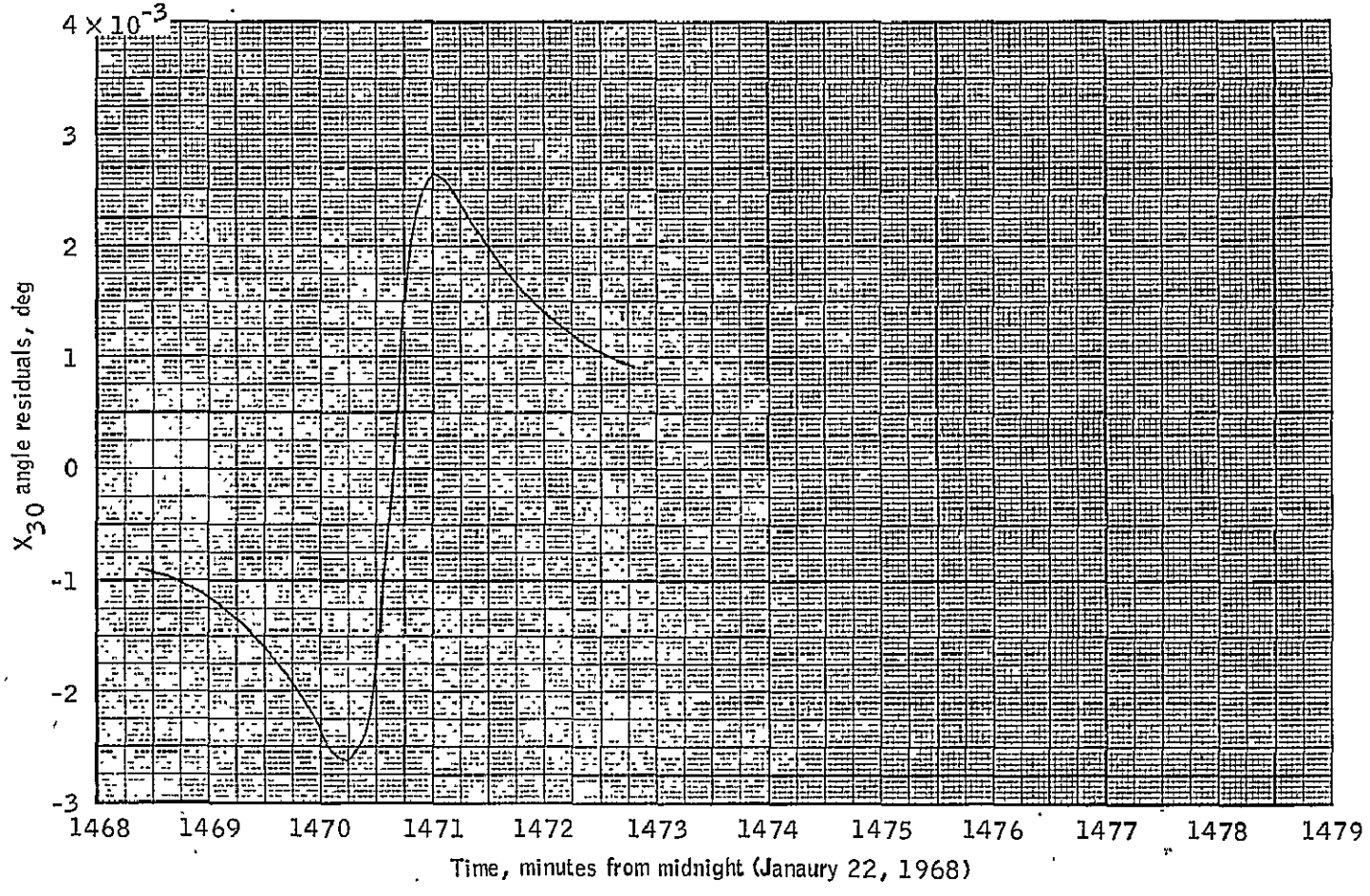
(g) Range residuals for -.0005-degree perturbation of latitude.

Figure 4.- Continued.



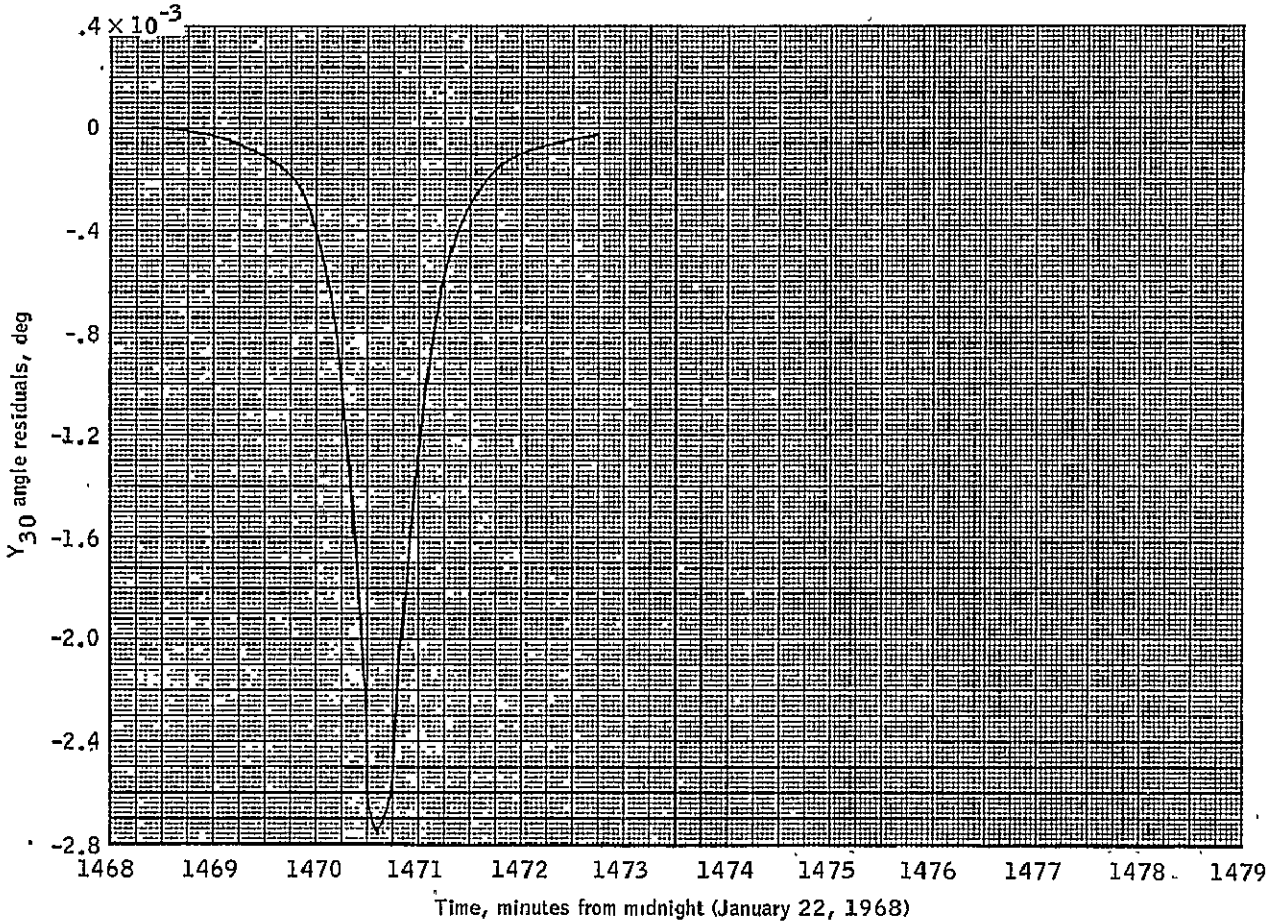
(h) Doppler residuals for -.0005-degree perturbation of latitude.

Figure 4.- Continued.



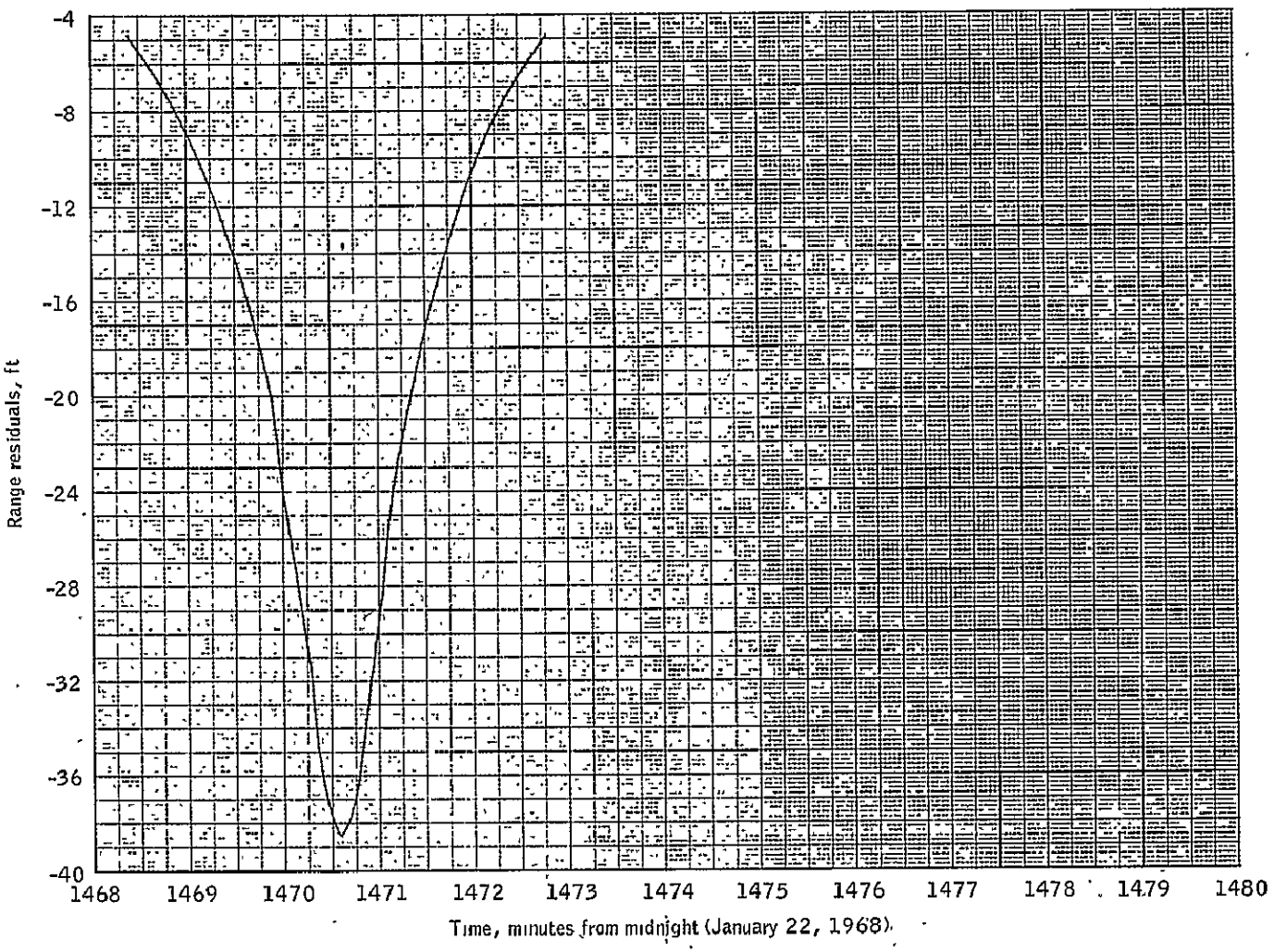
(i) X_{30} angle residuals for -50-foot perturbation of altitude.

Figure 4.- Continued.



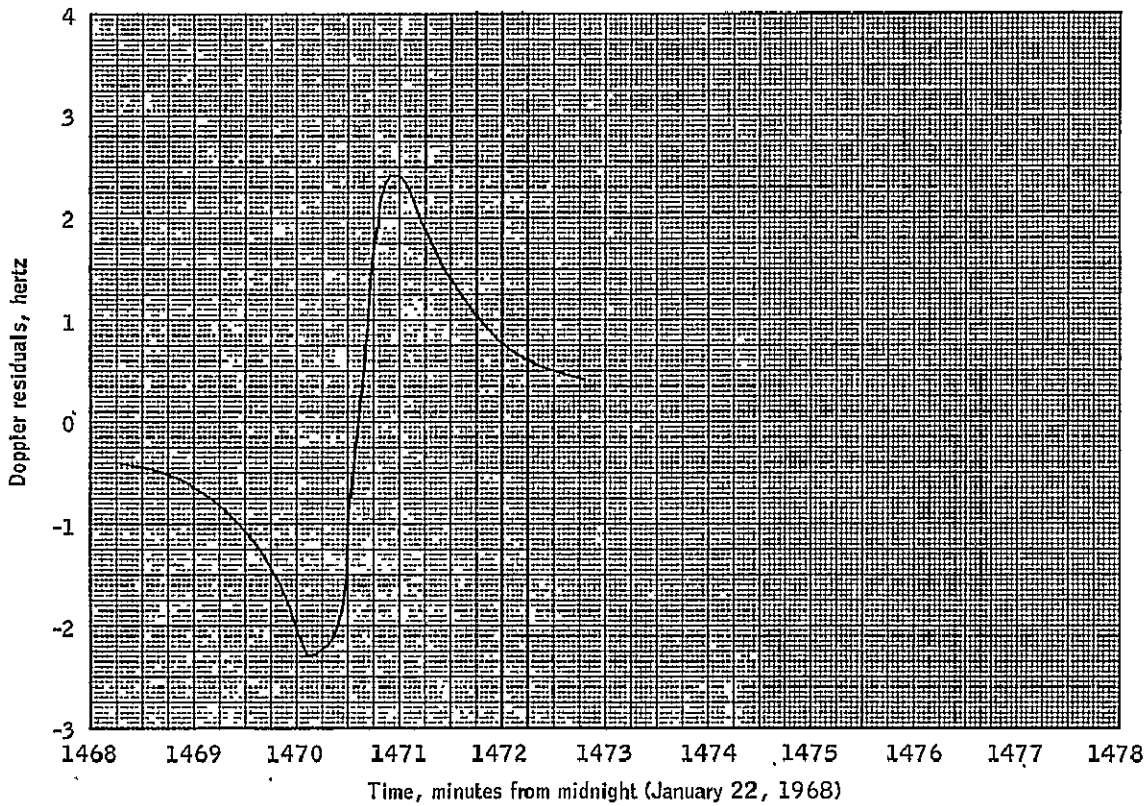
(j) Y_{30} angle residuals for -50-foot perturbation of altitude.

Figure 4.- Continued.



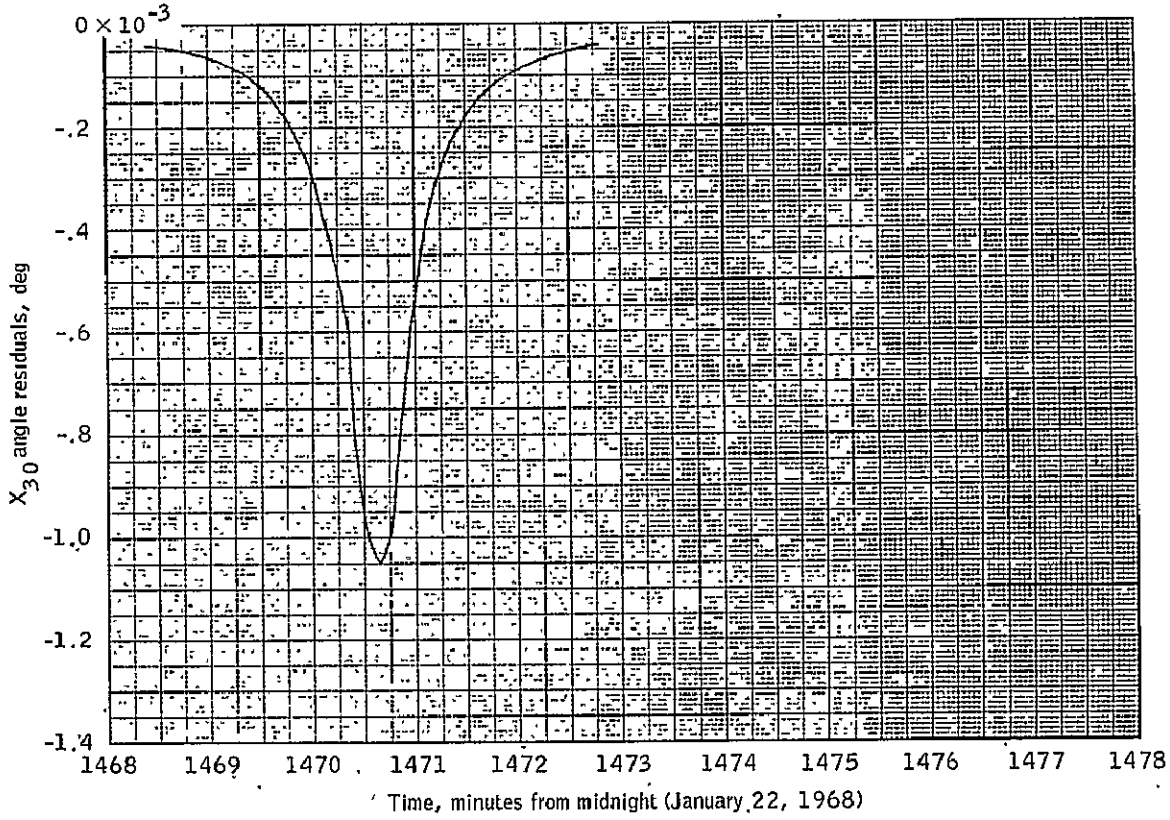
(k) Range residuals for -50-foot perturbation of altitude.

Figure 4.- Continued.



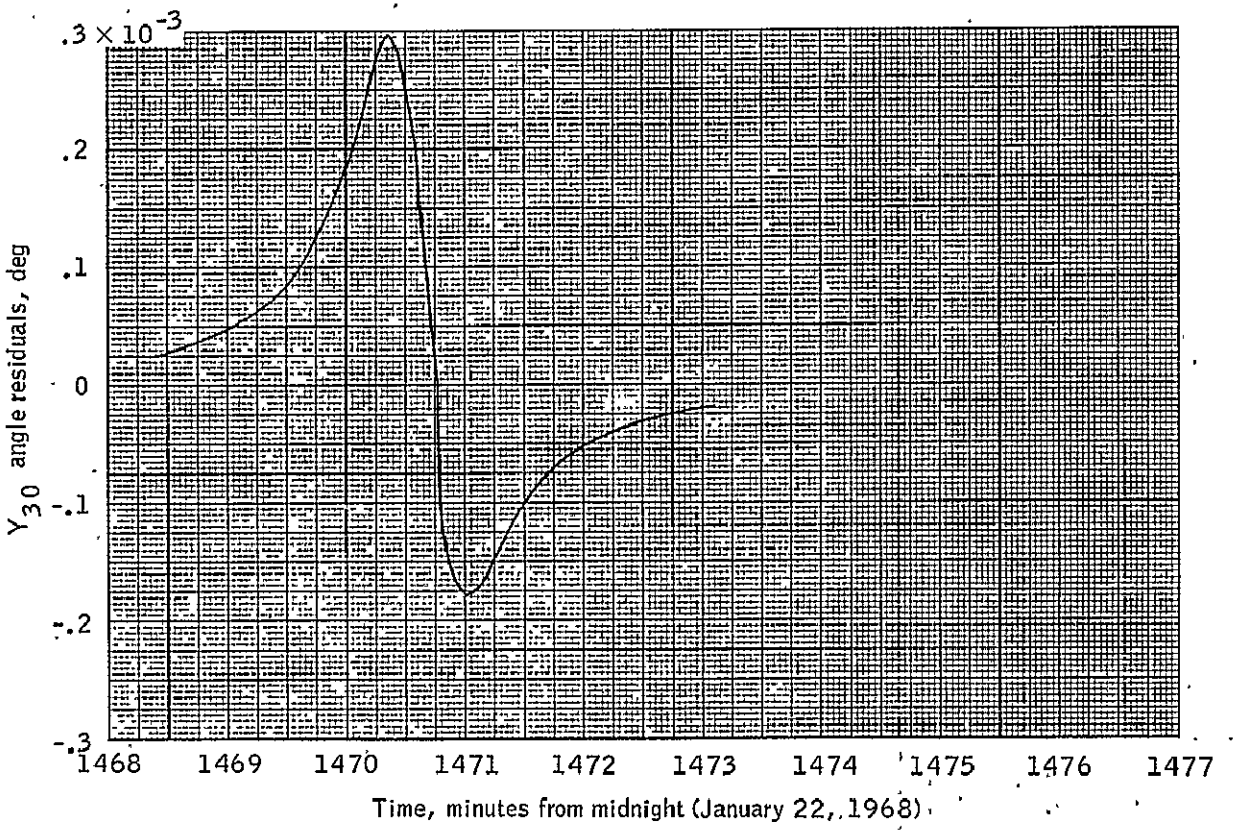
(l) Doppler residuals for -50-foot perturbation of altitude.

Figure 4.- Continued.



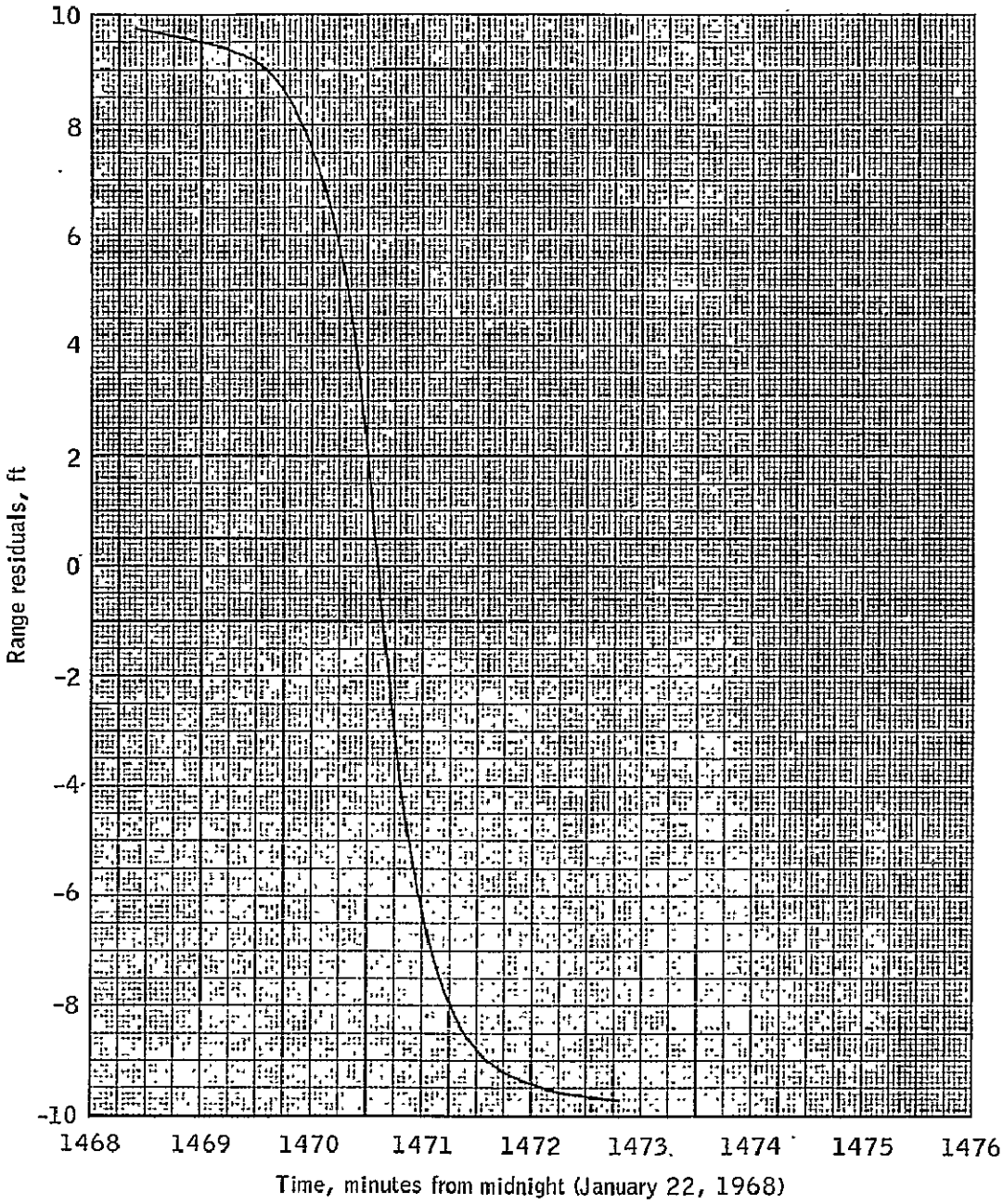
(m) X_{30} angle residuals for -.025-second perturbation of time.

Figure 4.- Continued.



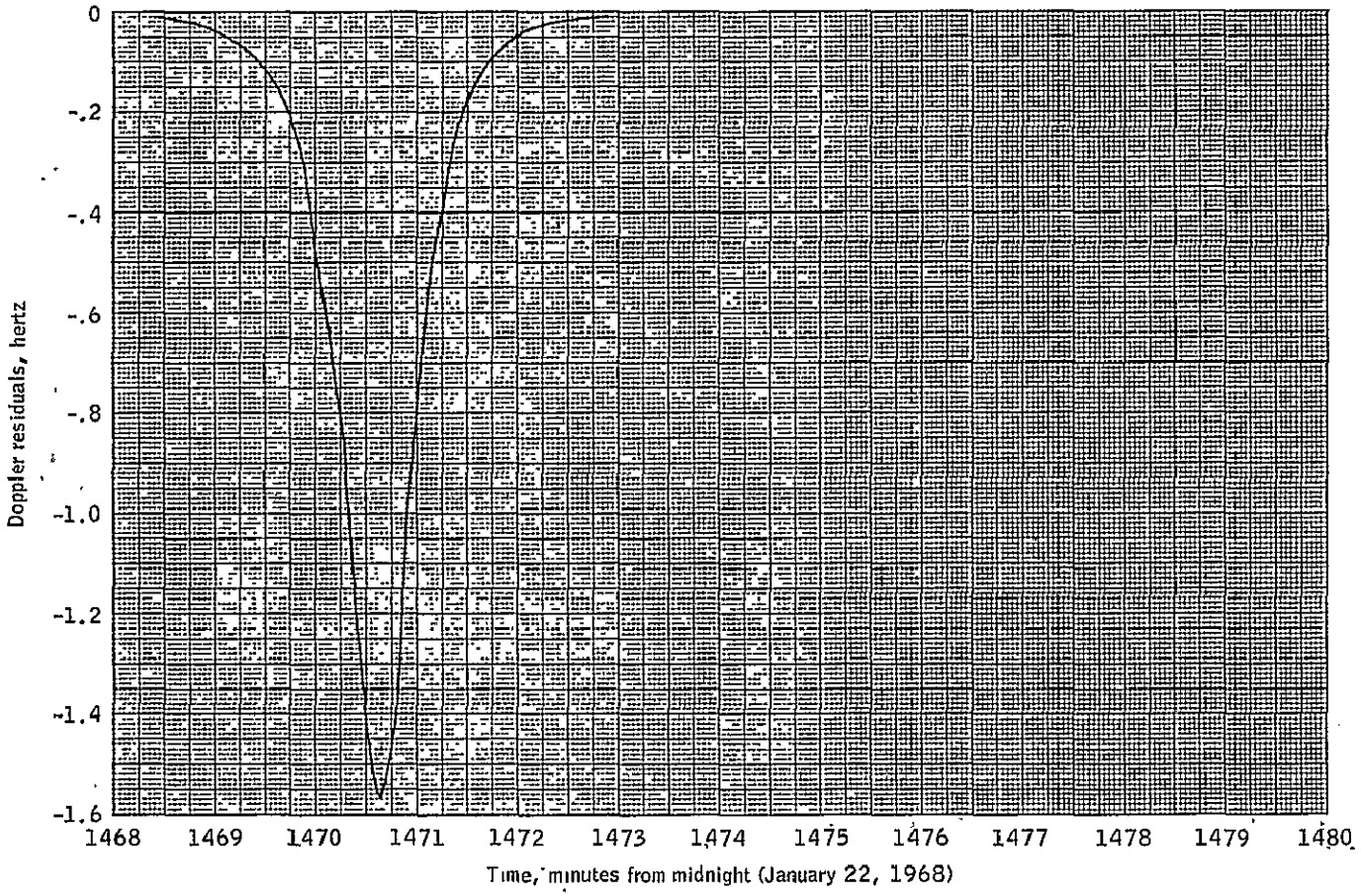
(n) Y_{30} angle residuals for -.025-second perturbation of time.

Figure 4.- Continued.



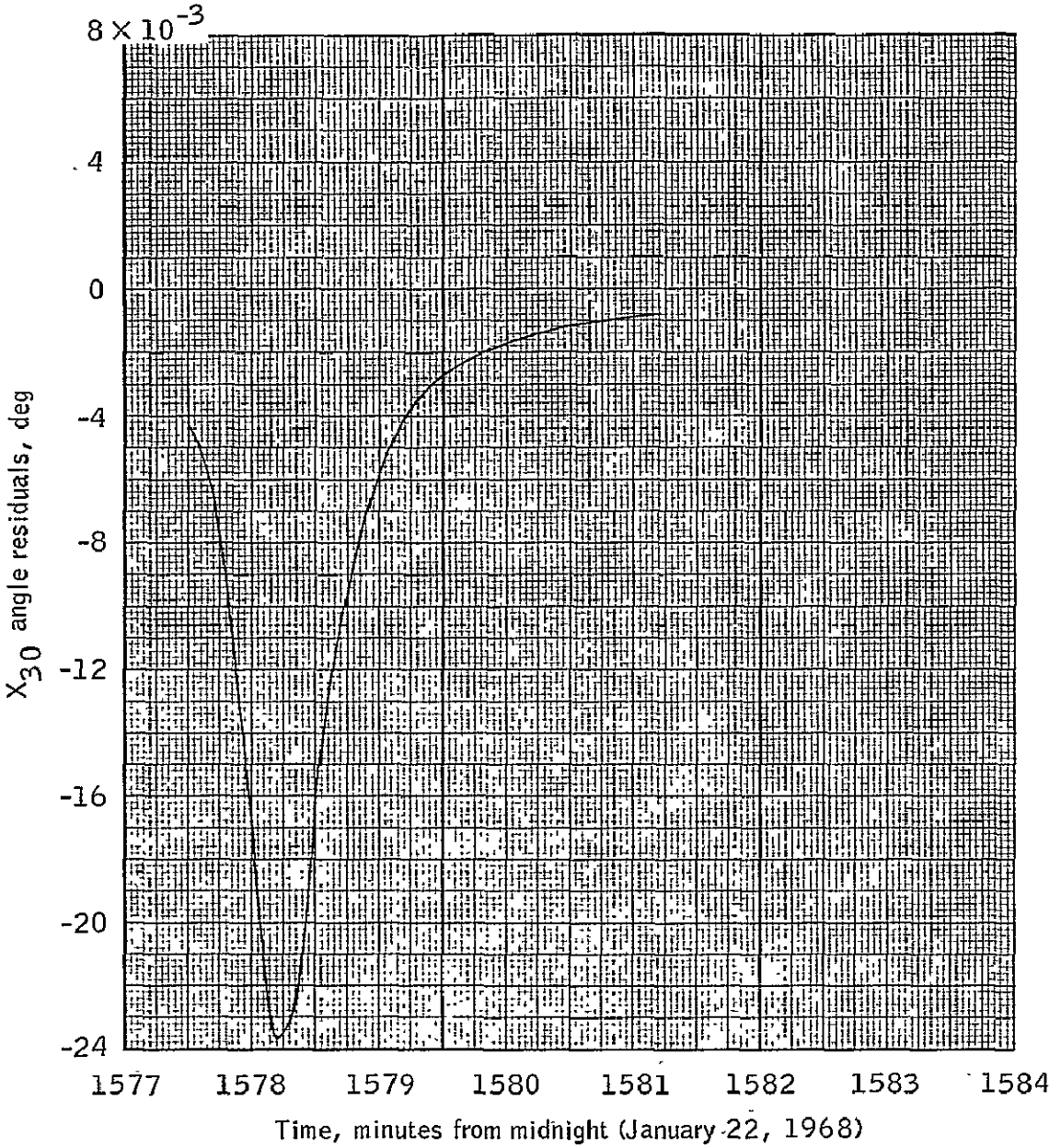
(o) Range residuals for -.025-second perturbation of time.

Figure 4.- Continued.



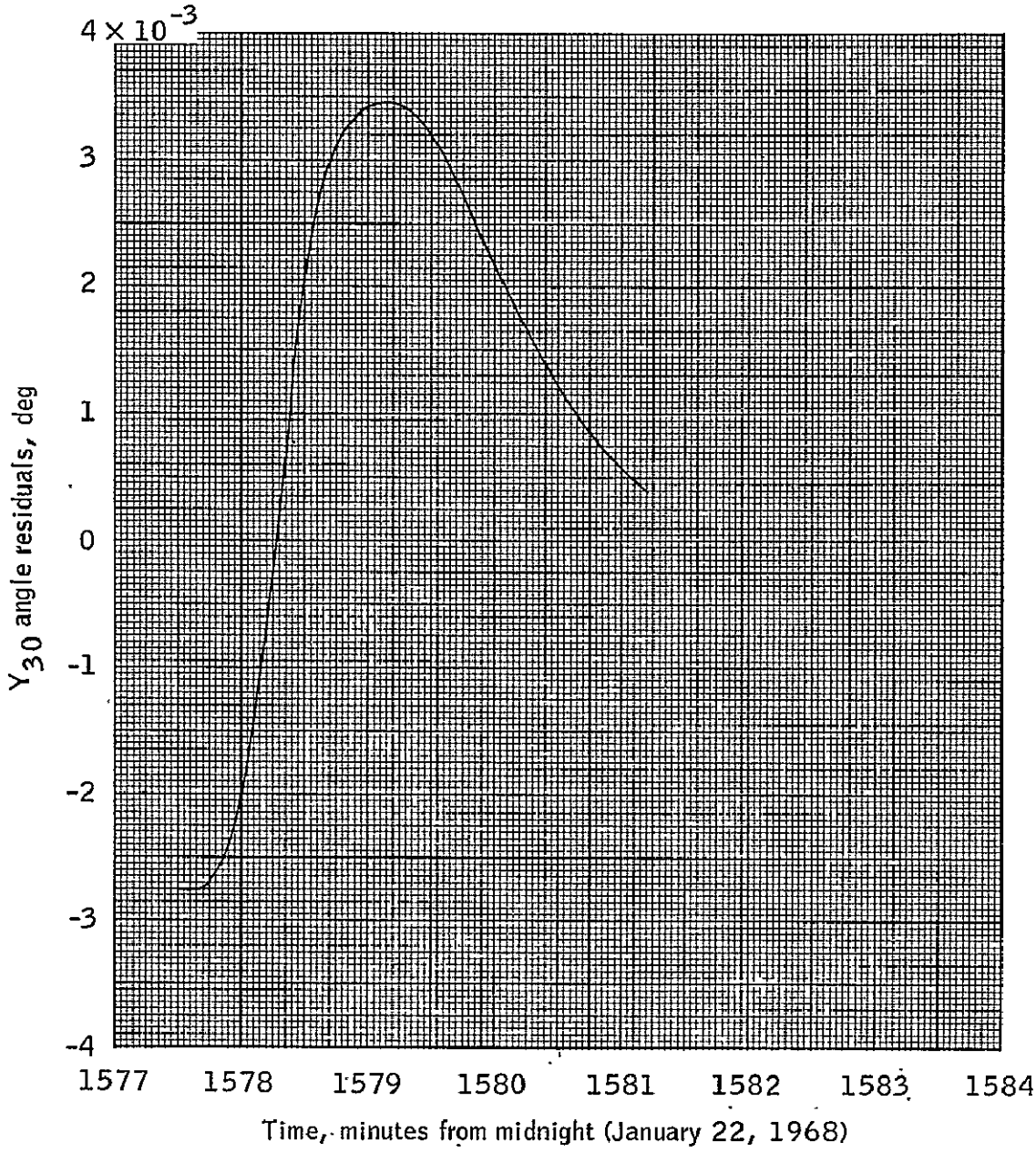
(p) *Doppler residuals for -.025-second perturbation of time.*

Figure 4.- Concluded.



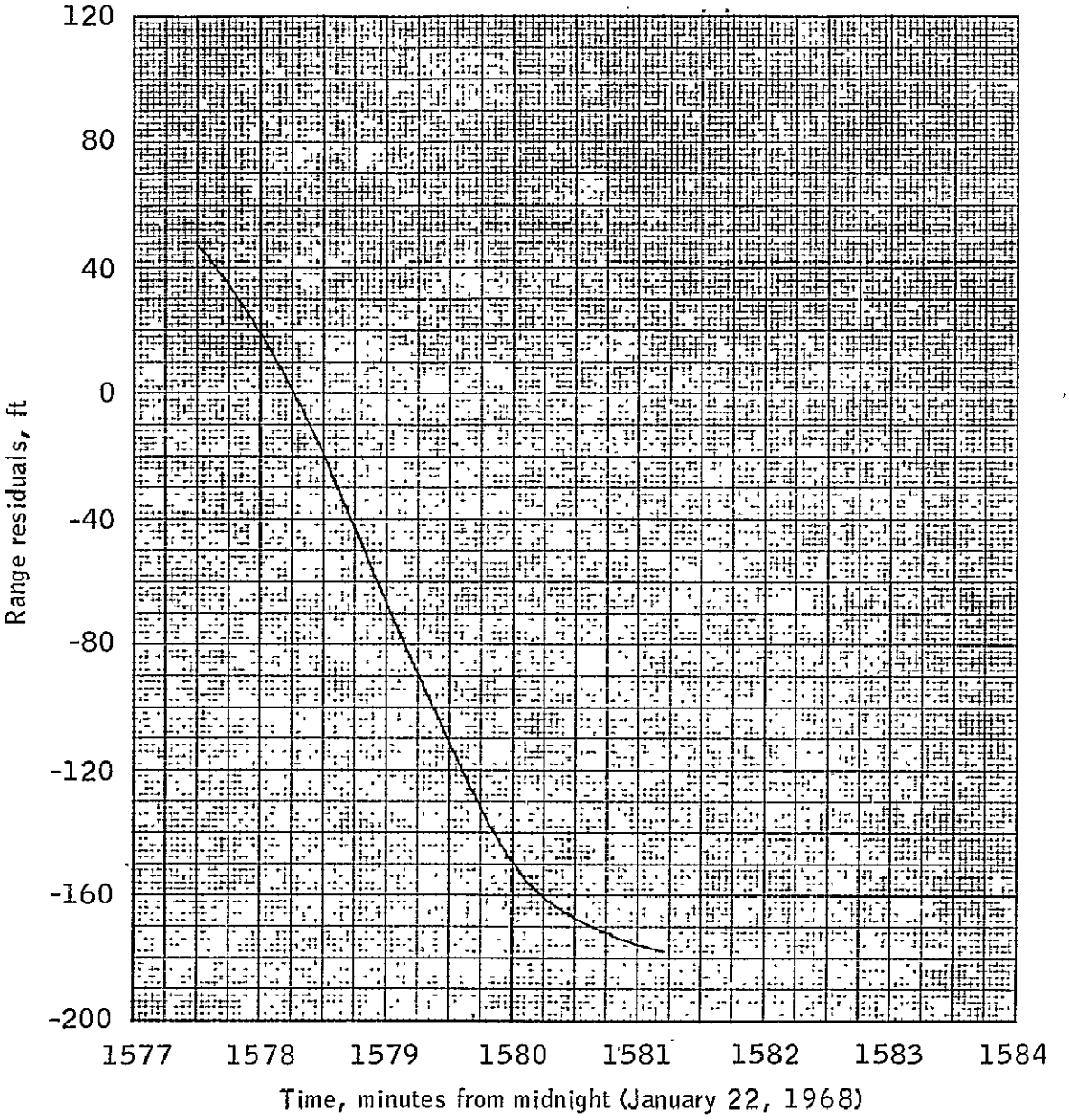
(a) X_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 5.- Residual patterns in USB data from the Ascension tracking station.



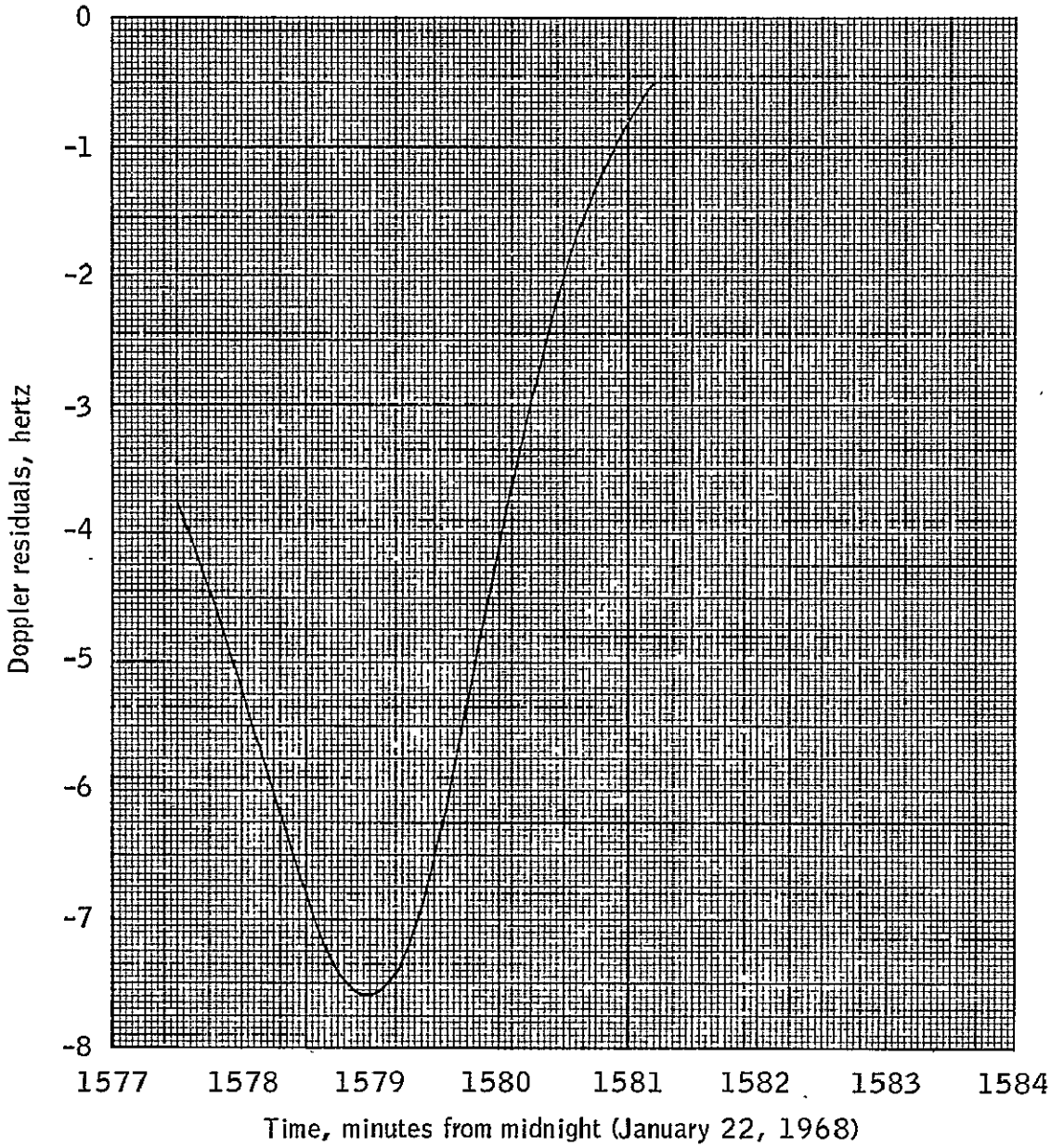
(b) Y_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 5.- Continued.



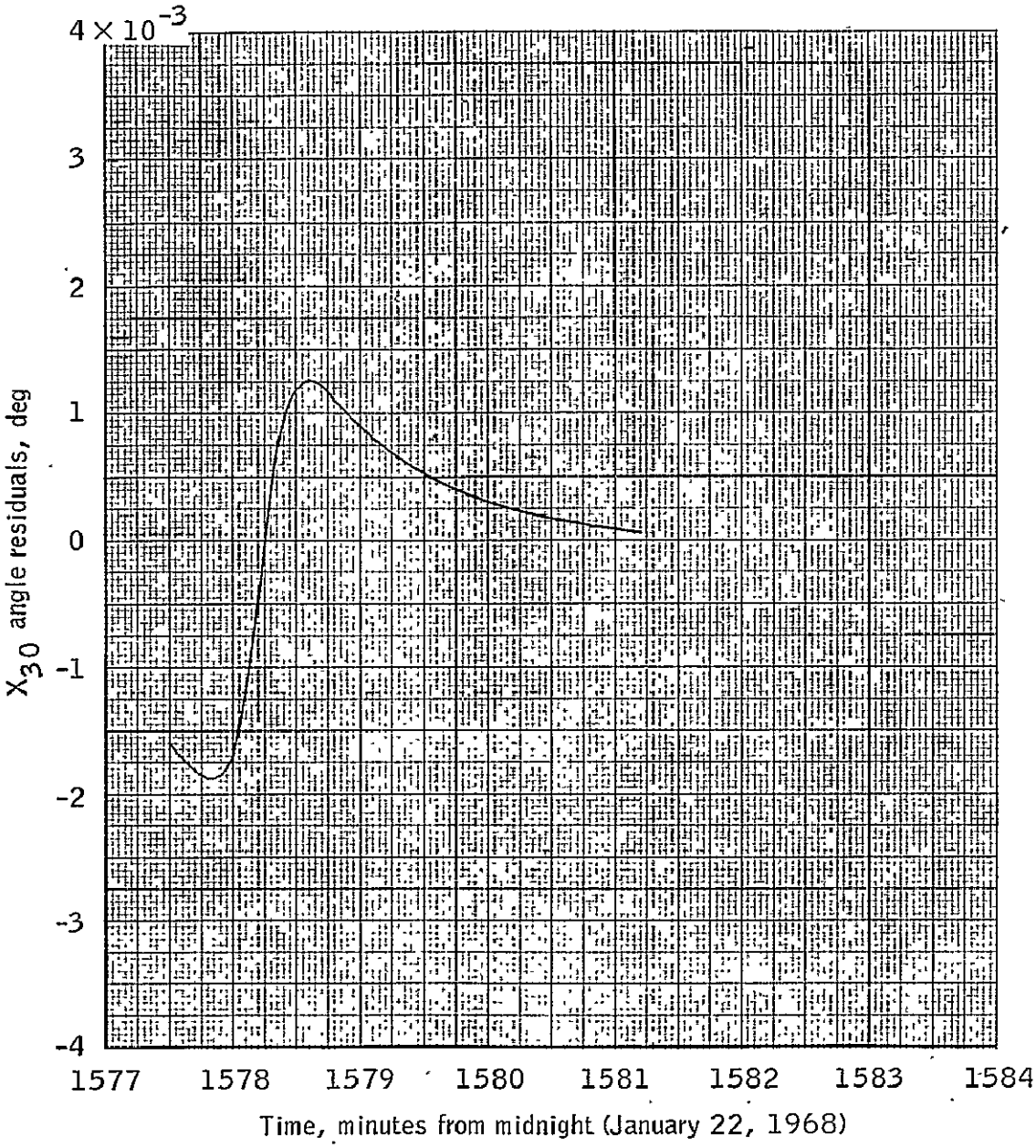
(c) Range residuals for -.0005-degree perturbation of longitude.

Figure 5.- Continued.



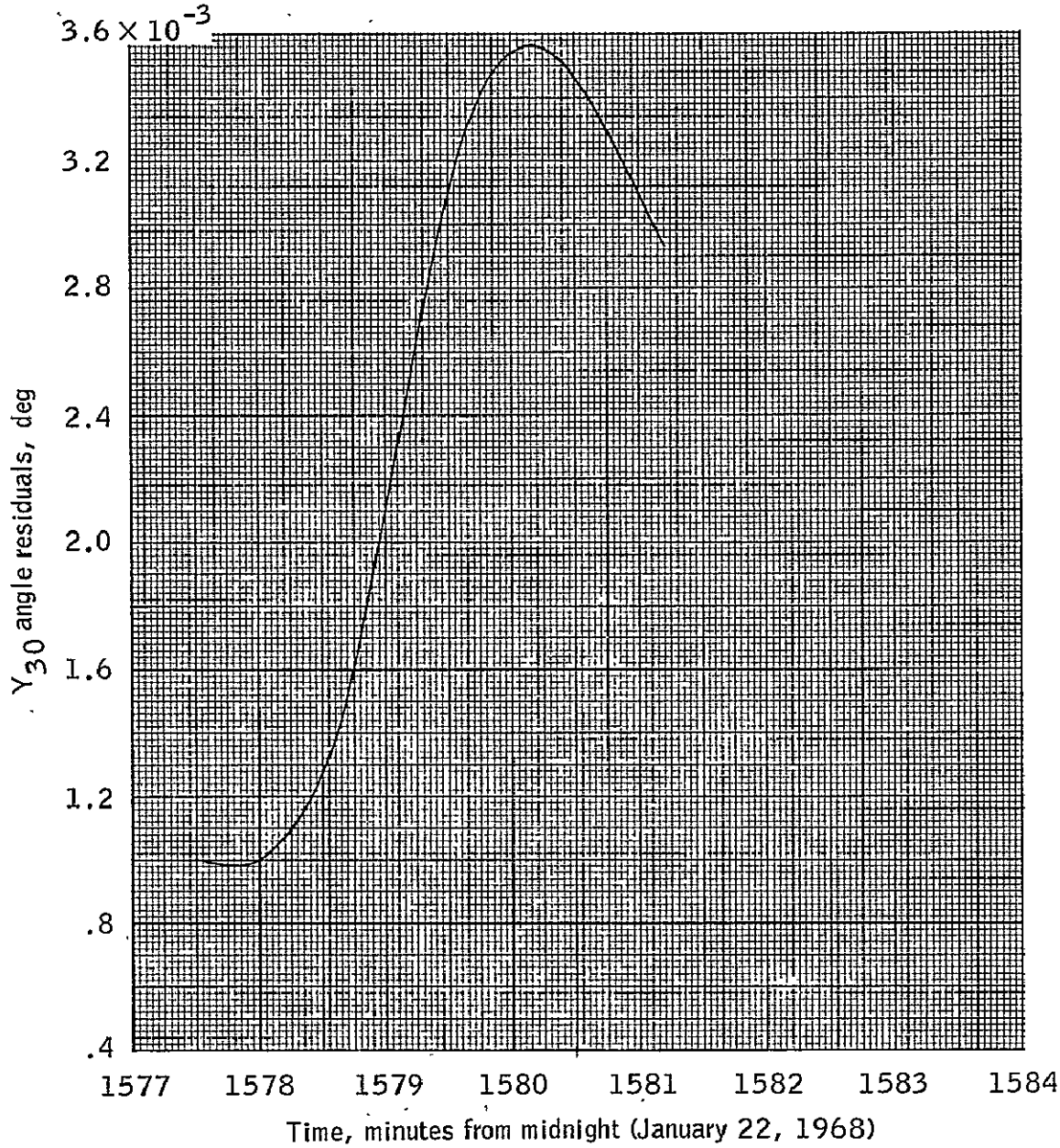
(d) Doppler residuals for -.0005-degree perturbation of longitude.

Figure 5.- Continued.



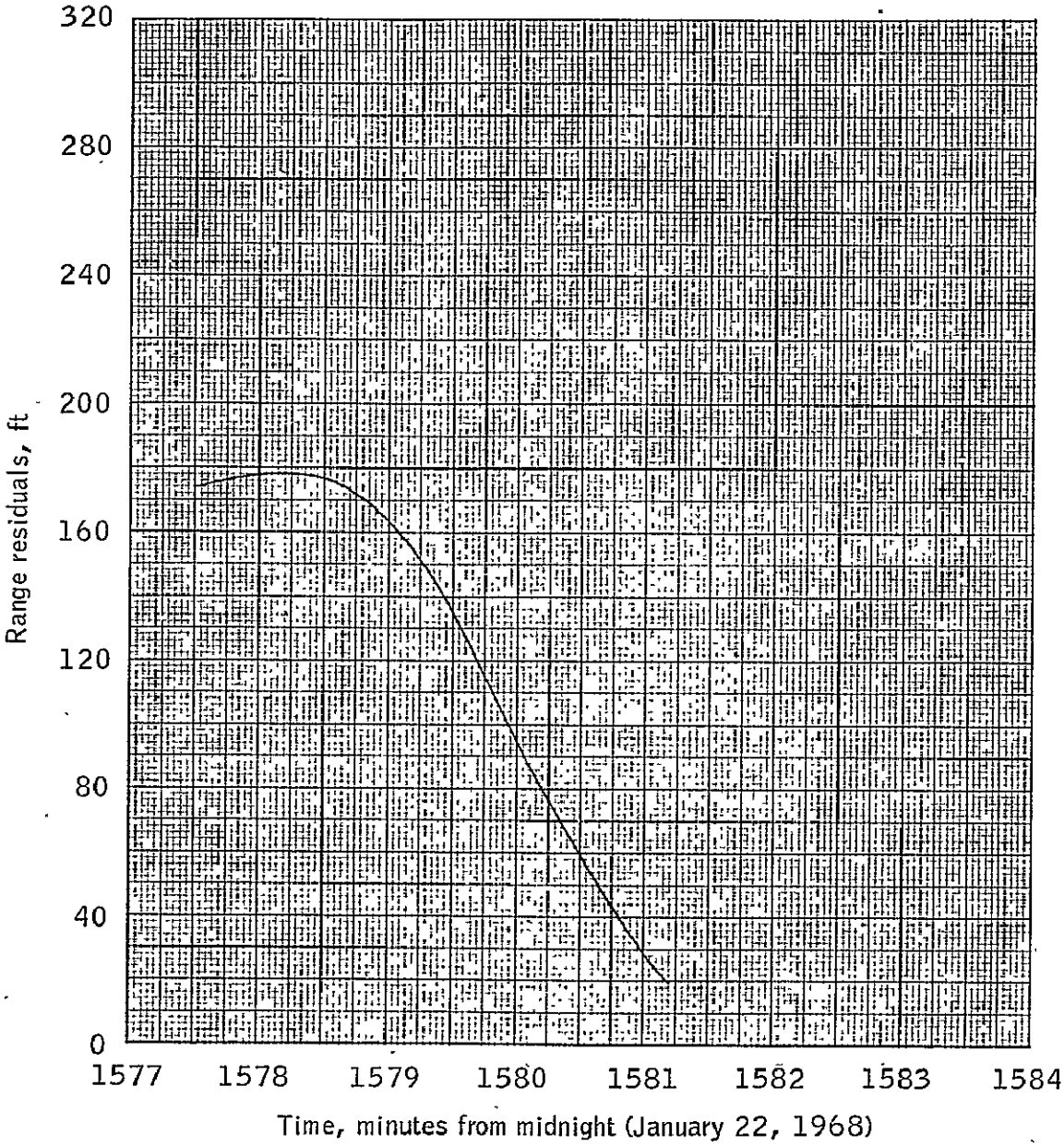
(e) X_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 5.- Continued.



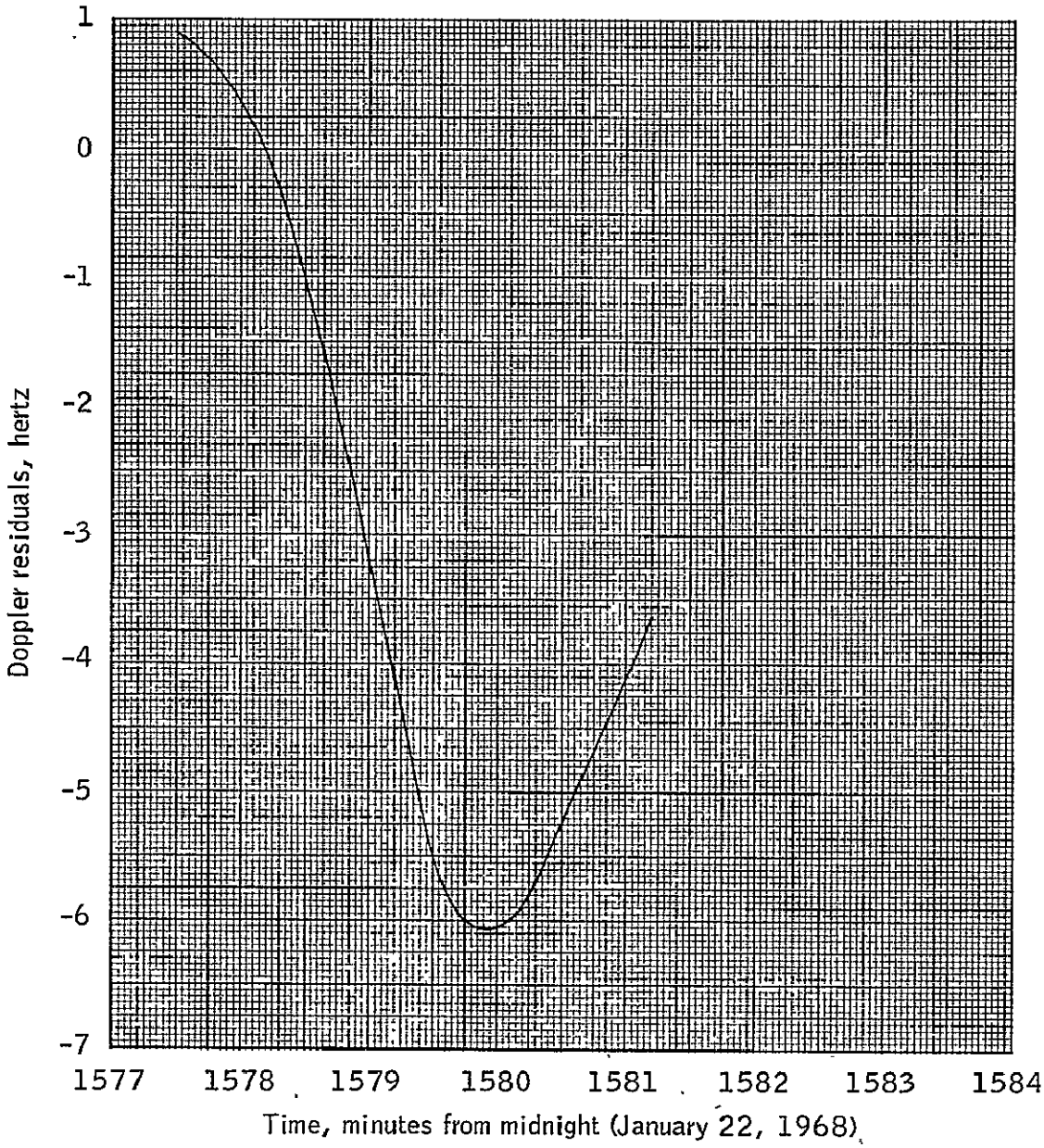
(f) Y_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 5.- Continued.



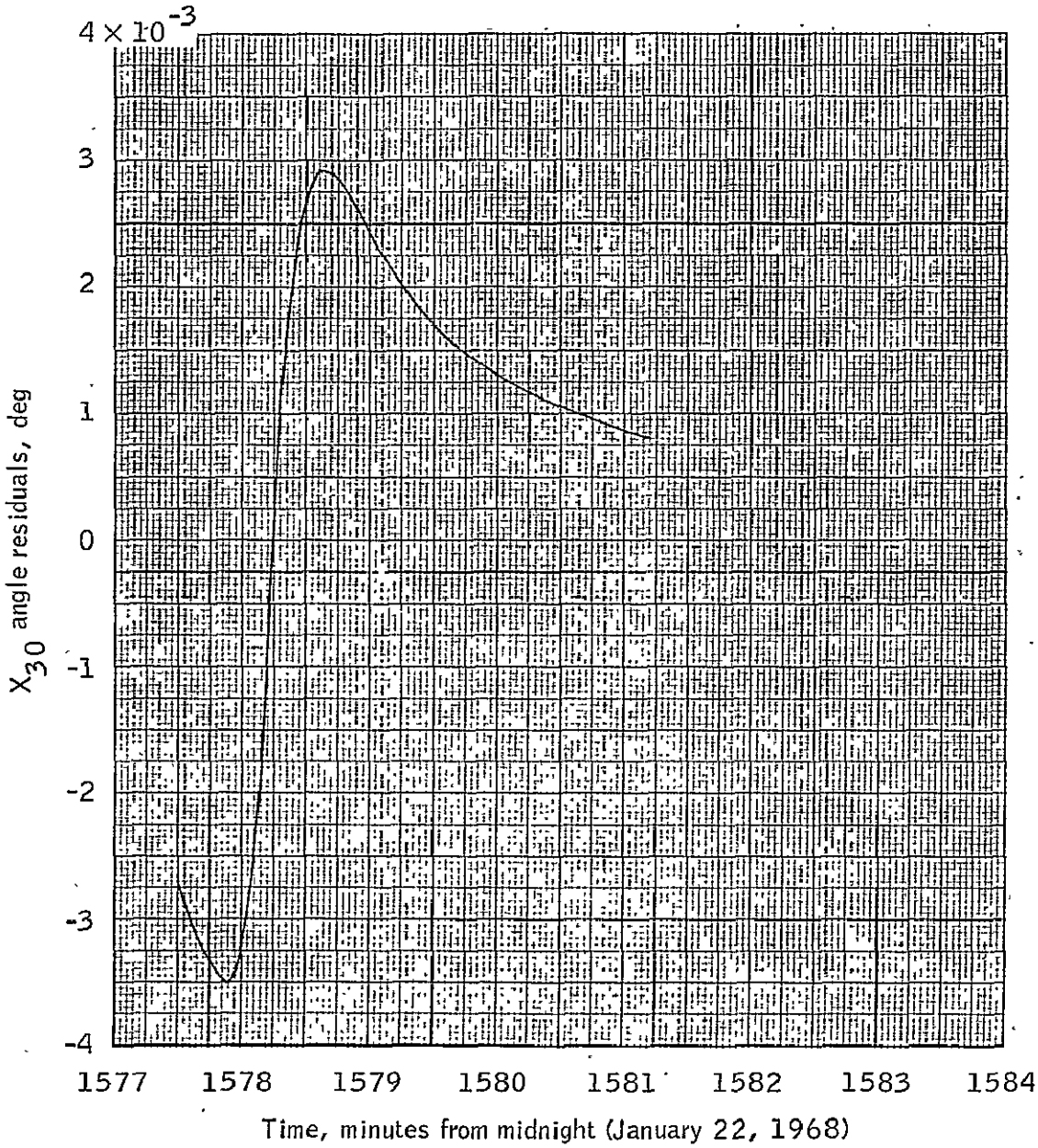
(g) Range residuals for -.0005-degree perturbation of latitude.

Figure 5.- Continued.



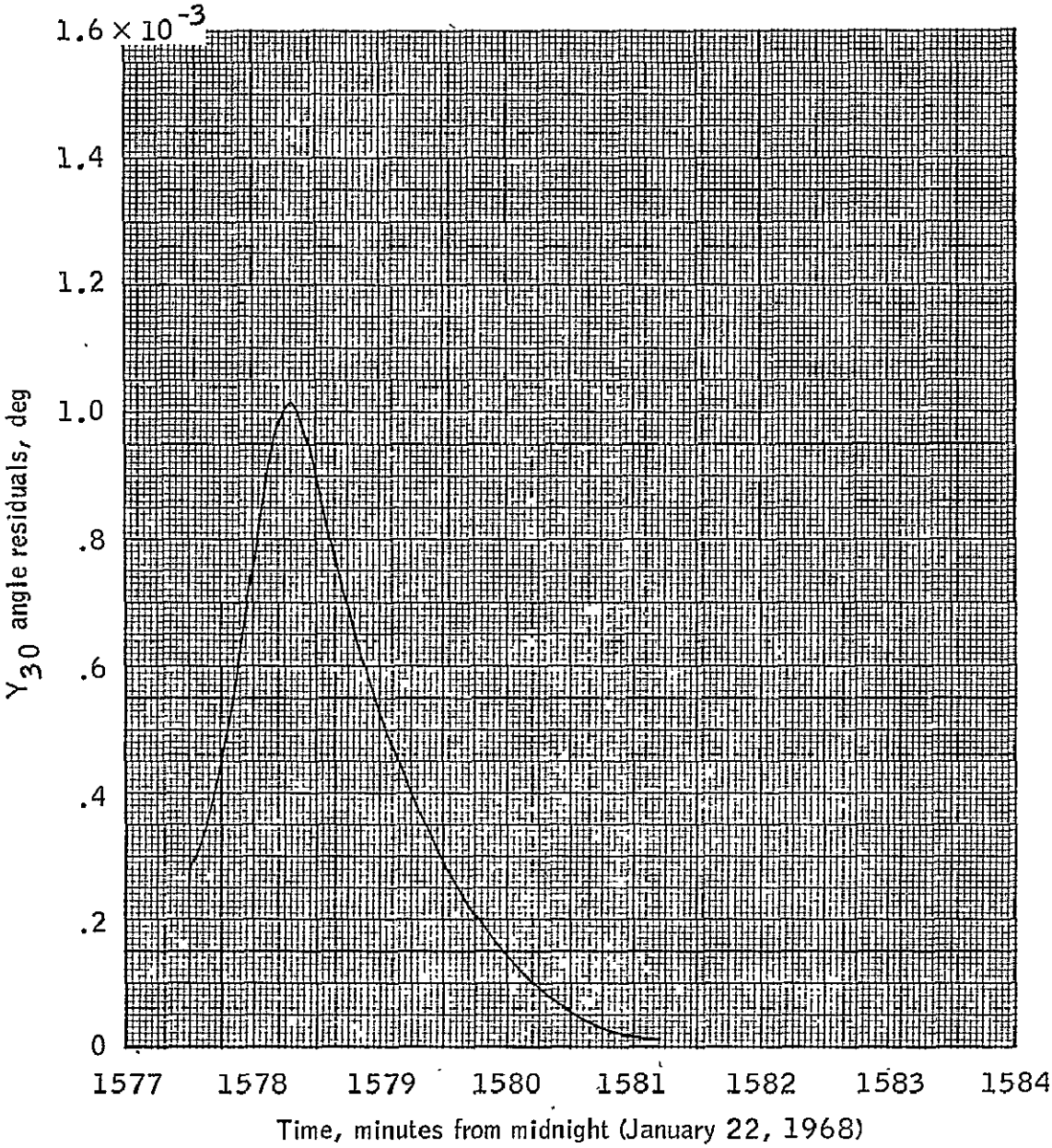
(h) Doppler residuals for -.0005-degree perturbation of latitude.

Figure 5.- Continued.



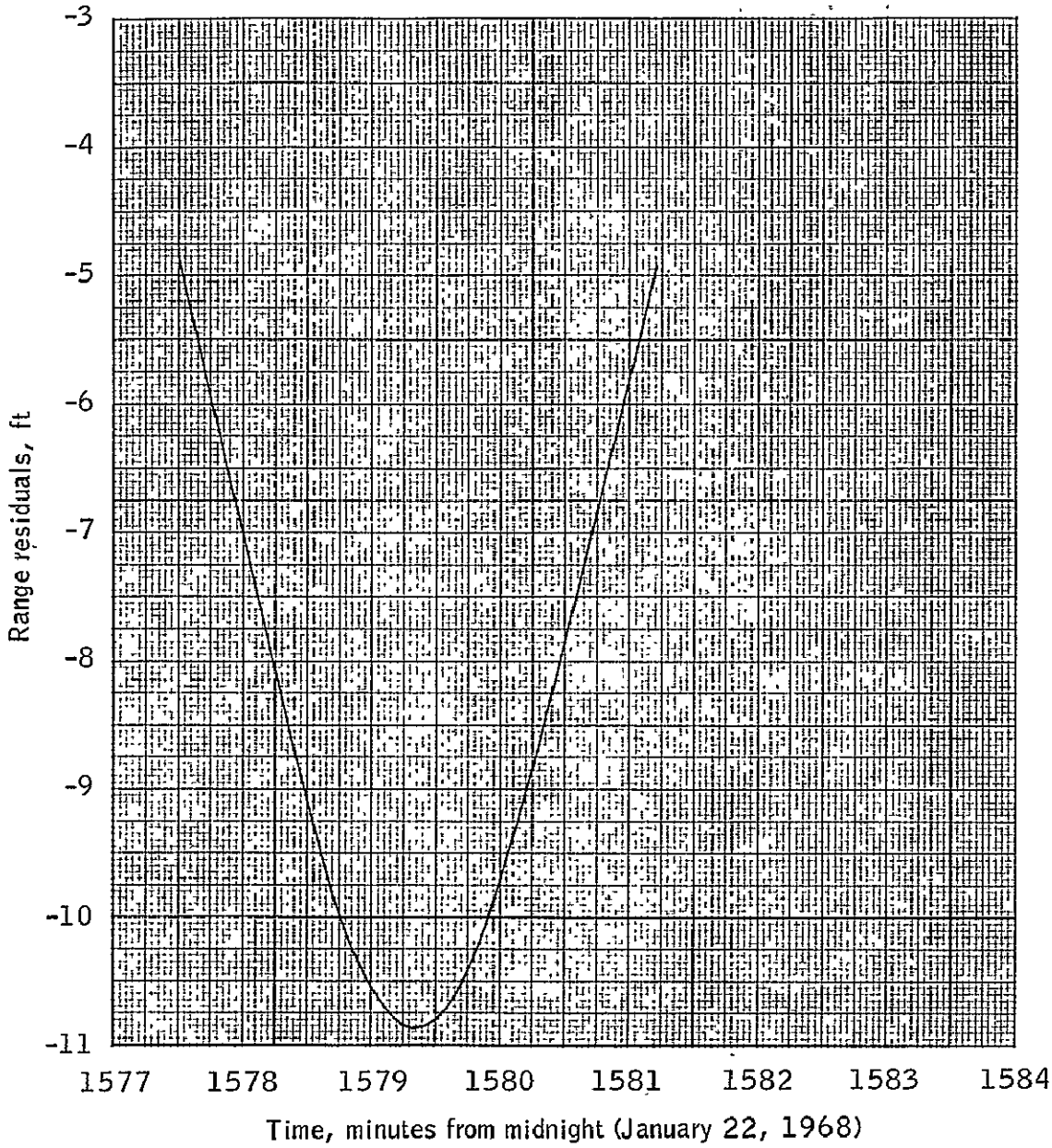
(i) X_{30} angle residuals for -50-foot perturbation of altitude.

Figure 5.- Continued.



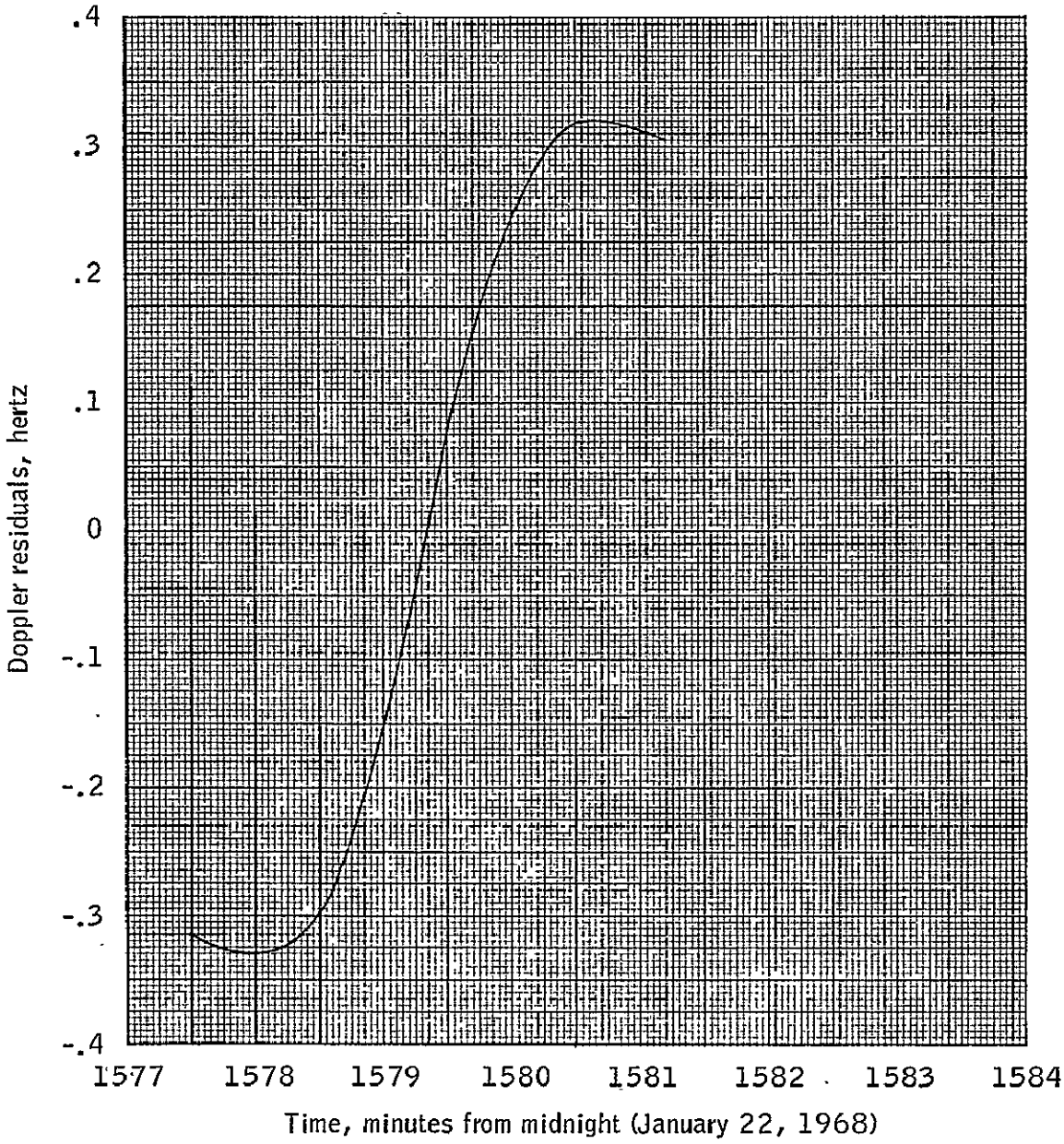
(j) Y_{30} angle residuals for -50-foot perturbation of altitude.

Figure 5.- Continued.



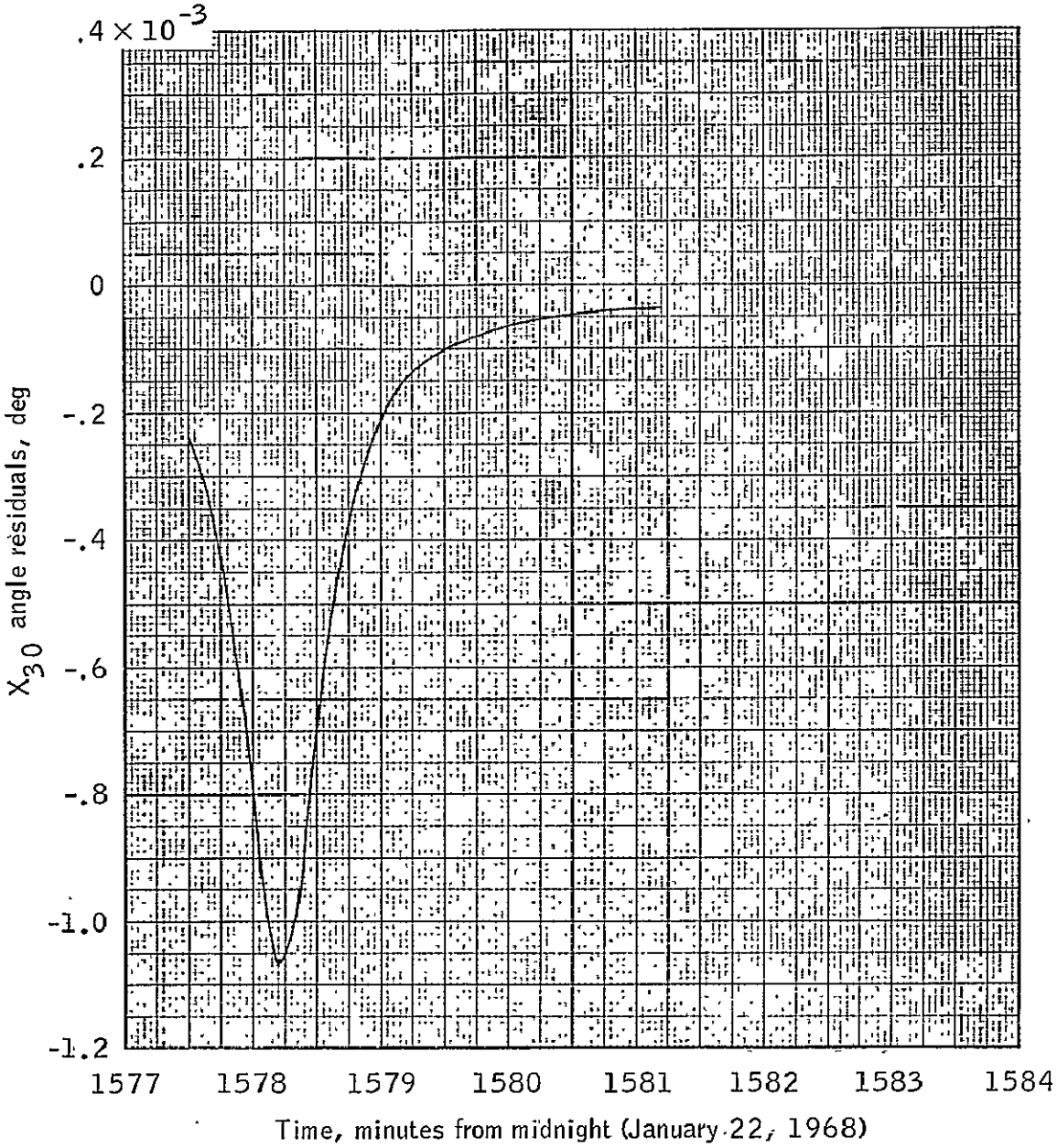
(k) Range residuals for -50-foot perturbation of altitude.

Figure 5.- Continued.



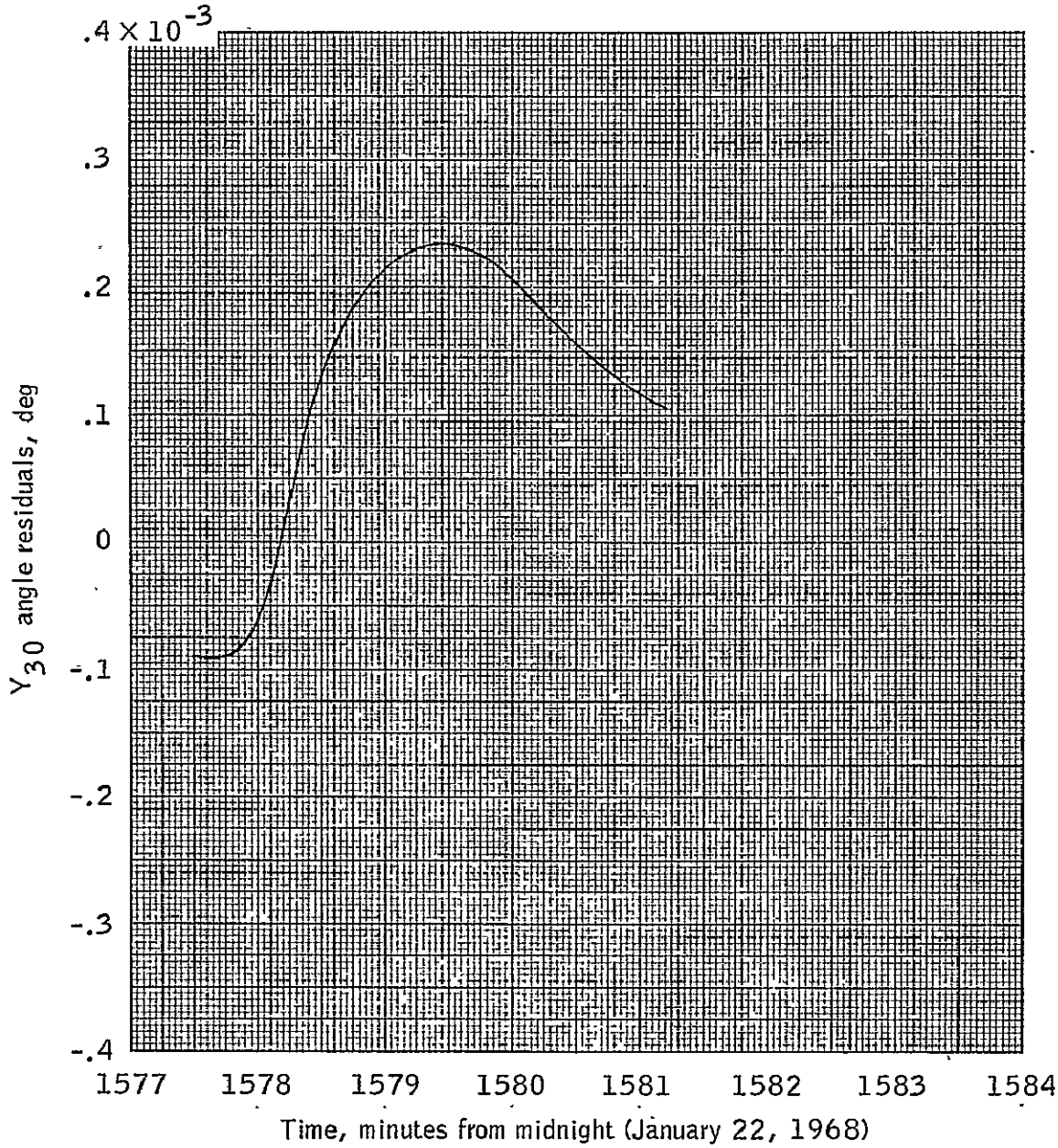
(l) Doppler residuals for -50-foot perturbation of altitude.

Figure 5.- Continued.



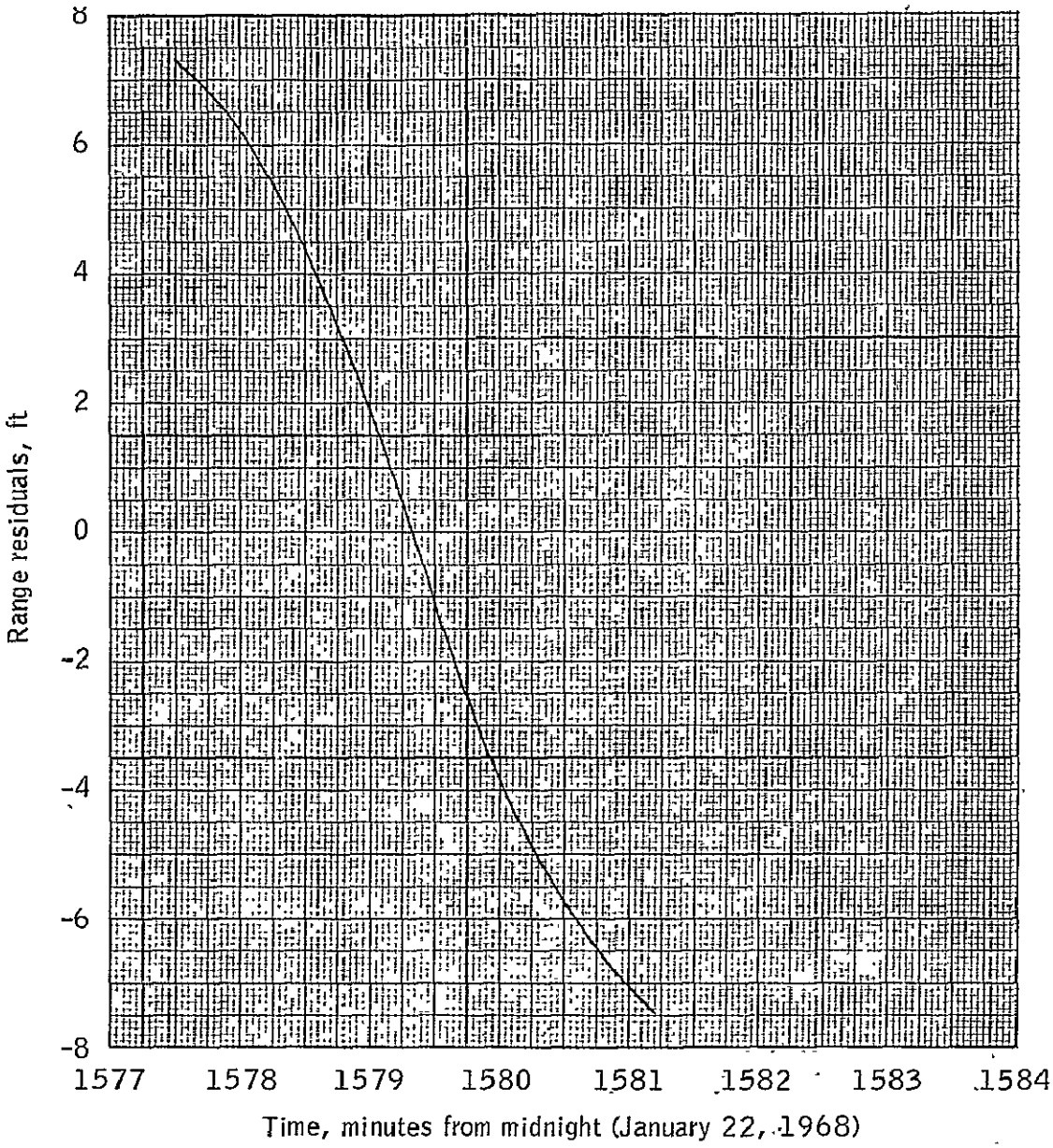
(m) X_{30} angle residuals for -.025-second perturbation of time.

Figure 5.- Continued.



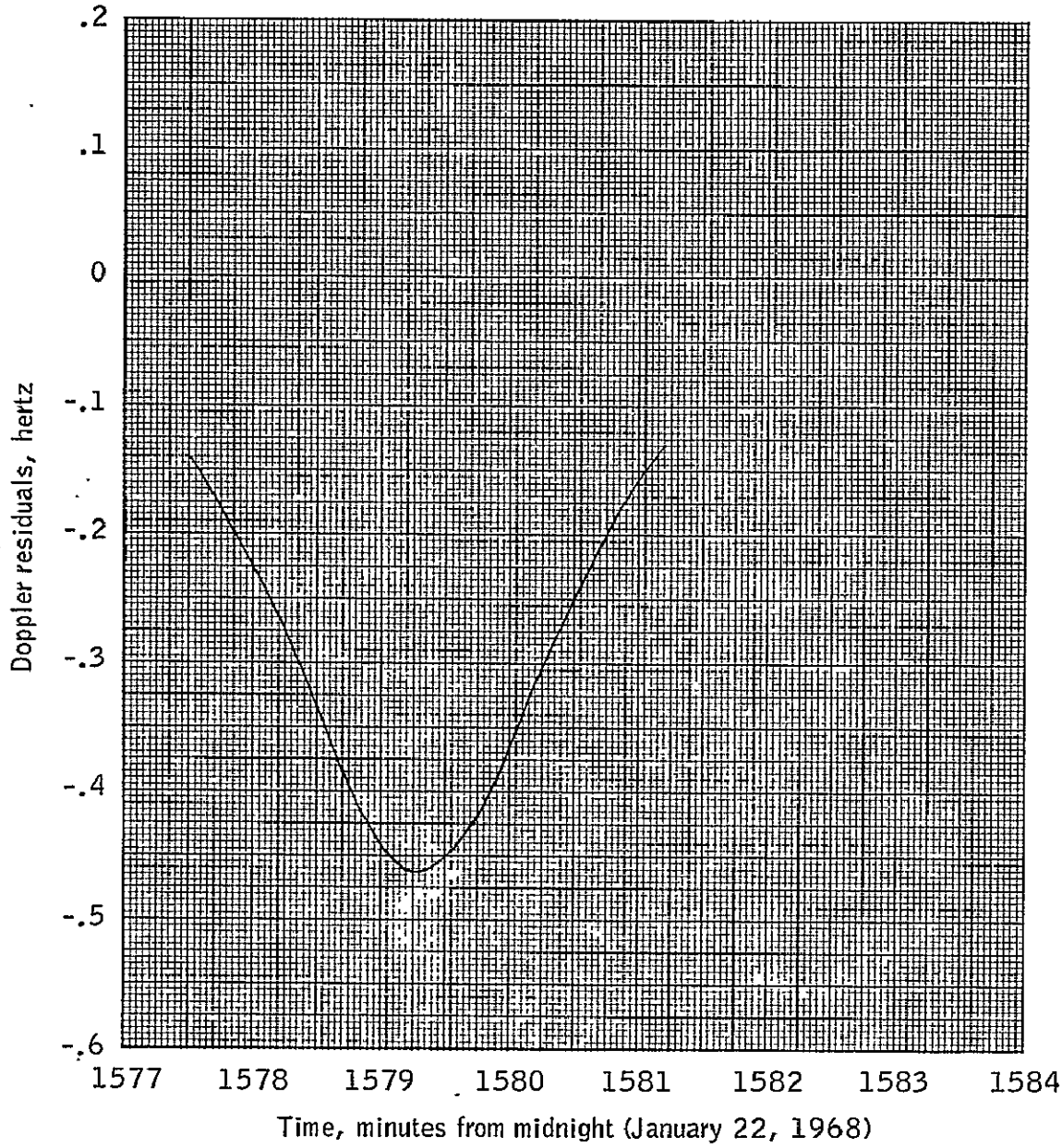
(n) Y_{30} angle residuals for -.025-second perturbation of time.

Figure 5.- Continued.



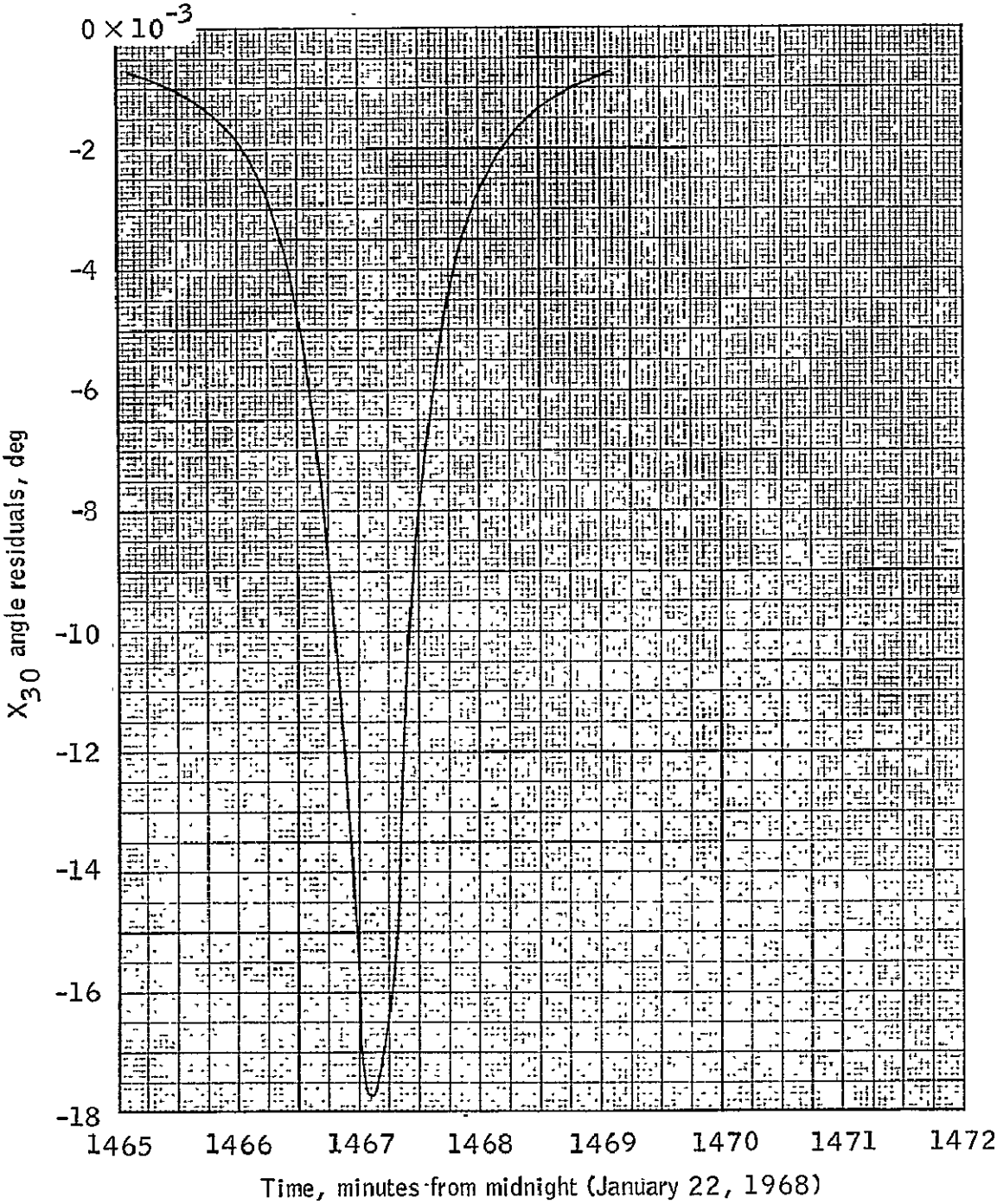
(o) Range residuals for -.025-second perturbation of time.

Figure 5.- Continued.



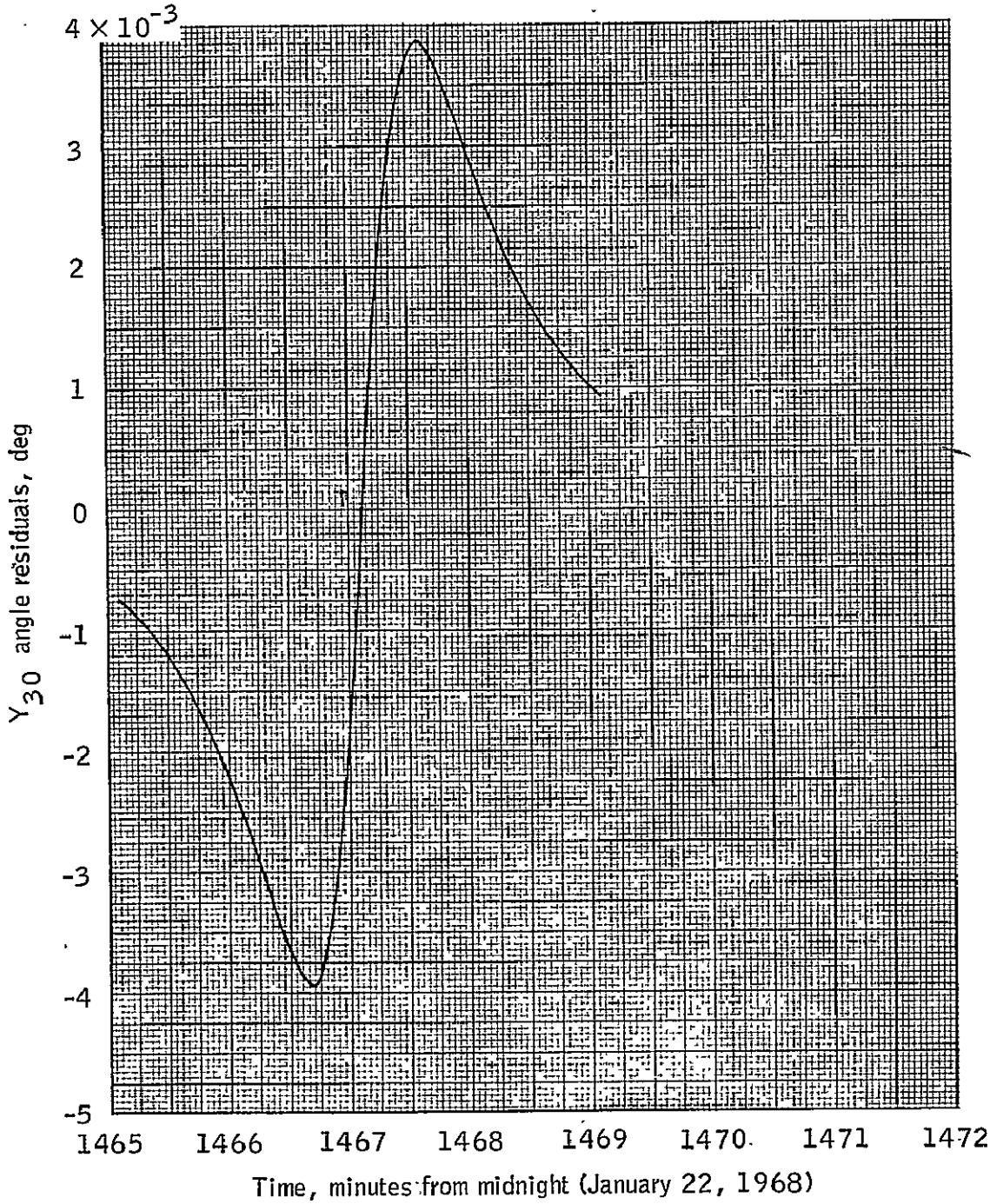
(p) Doppler residuals for -.025-second perturbation of time.

Figure 5.- Concluded.



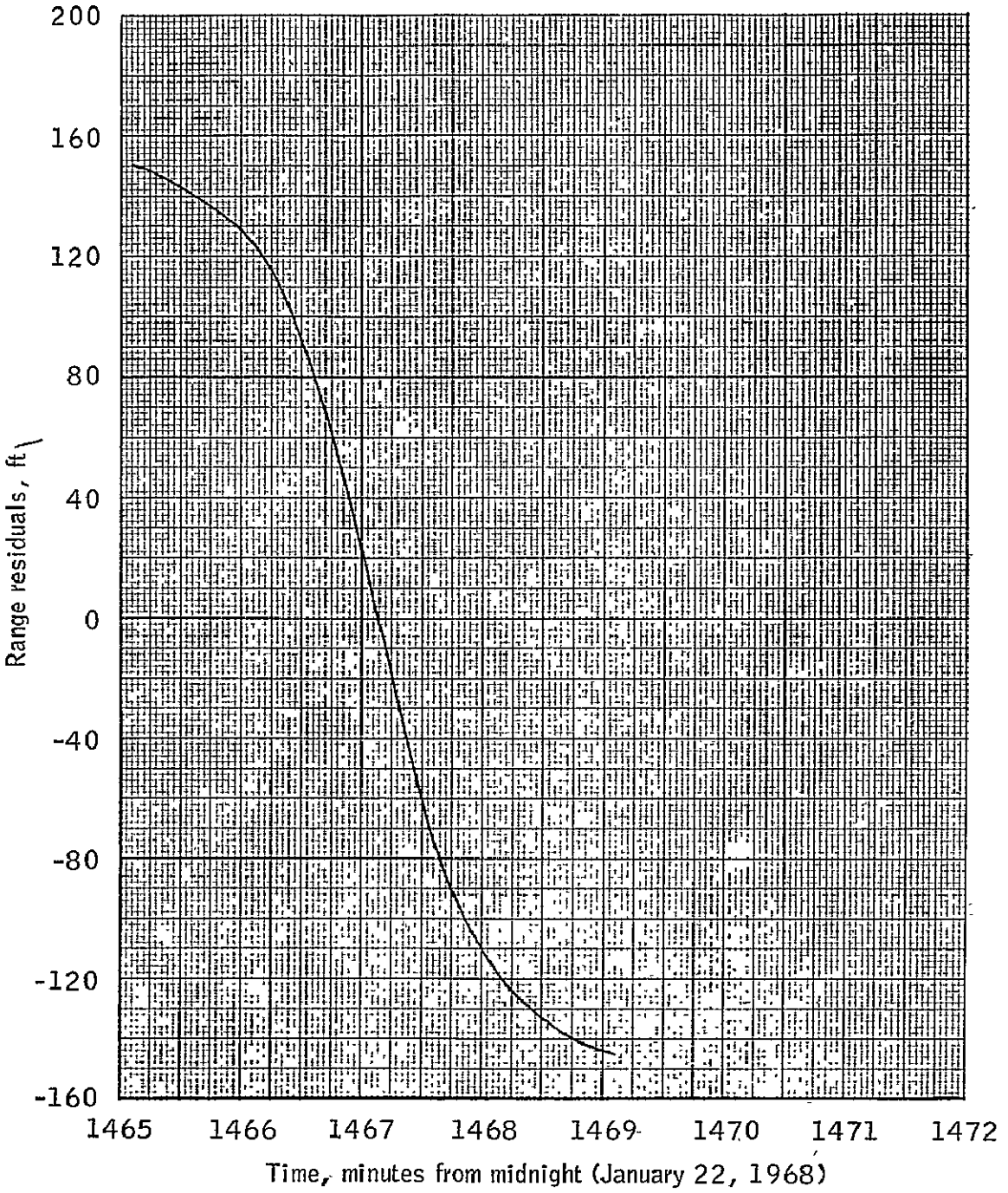
(a) X_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 6.- Residual patterns in USB data from the Merritt Island tracking station.



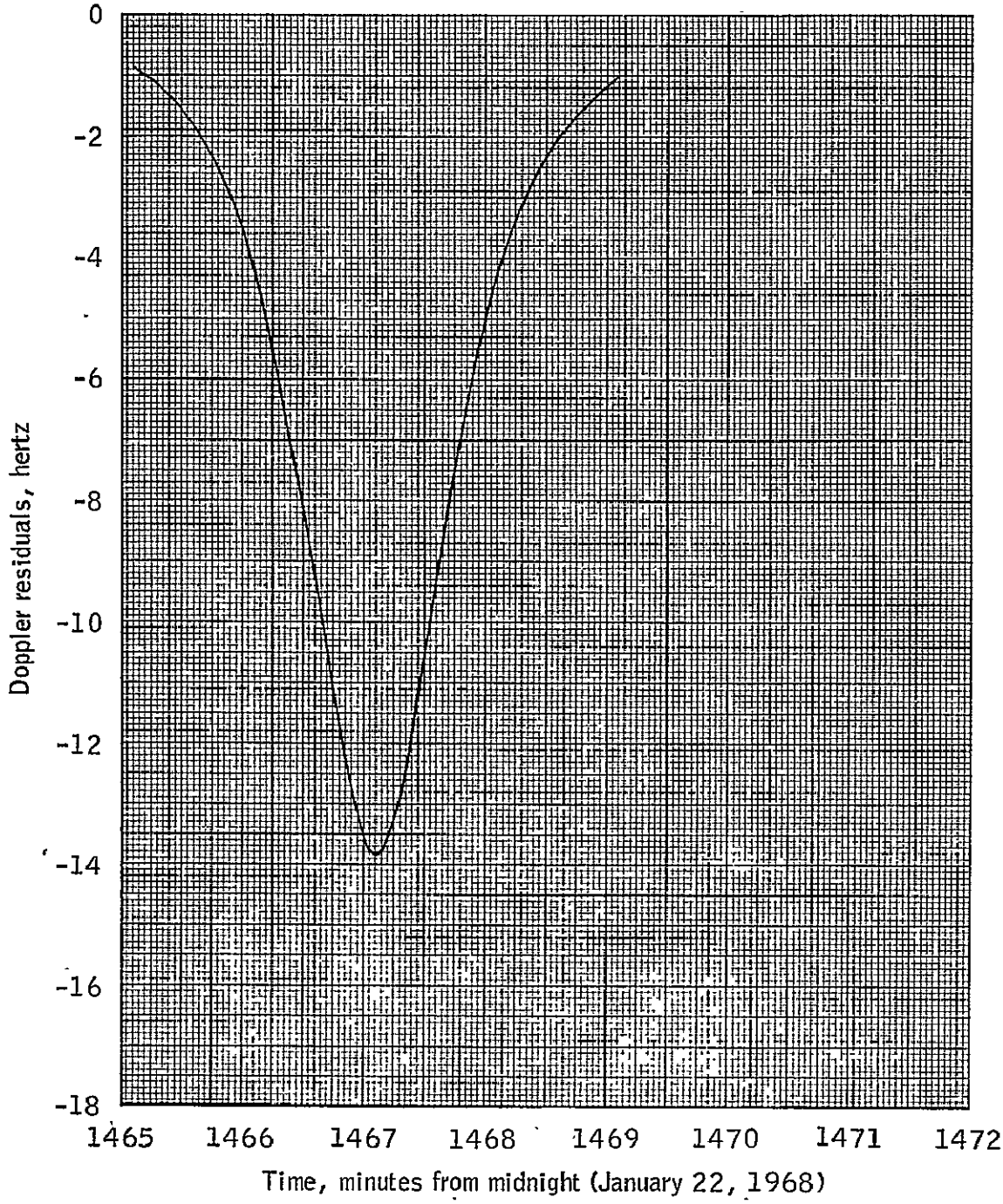
(b) Y_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 6.- Continued.



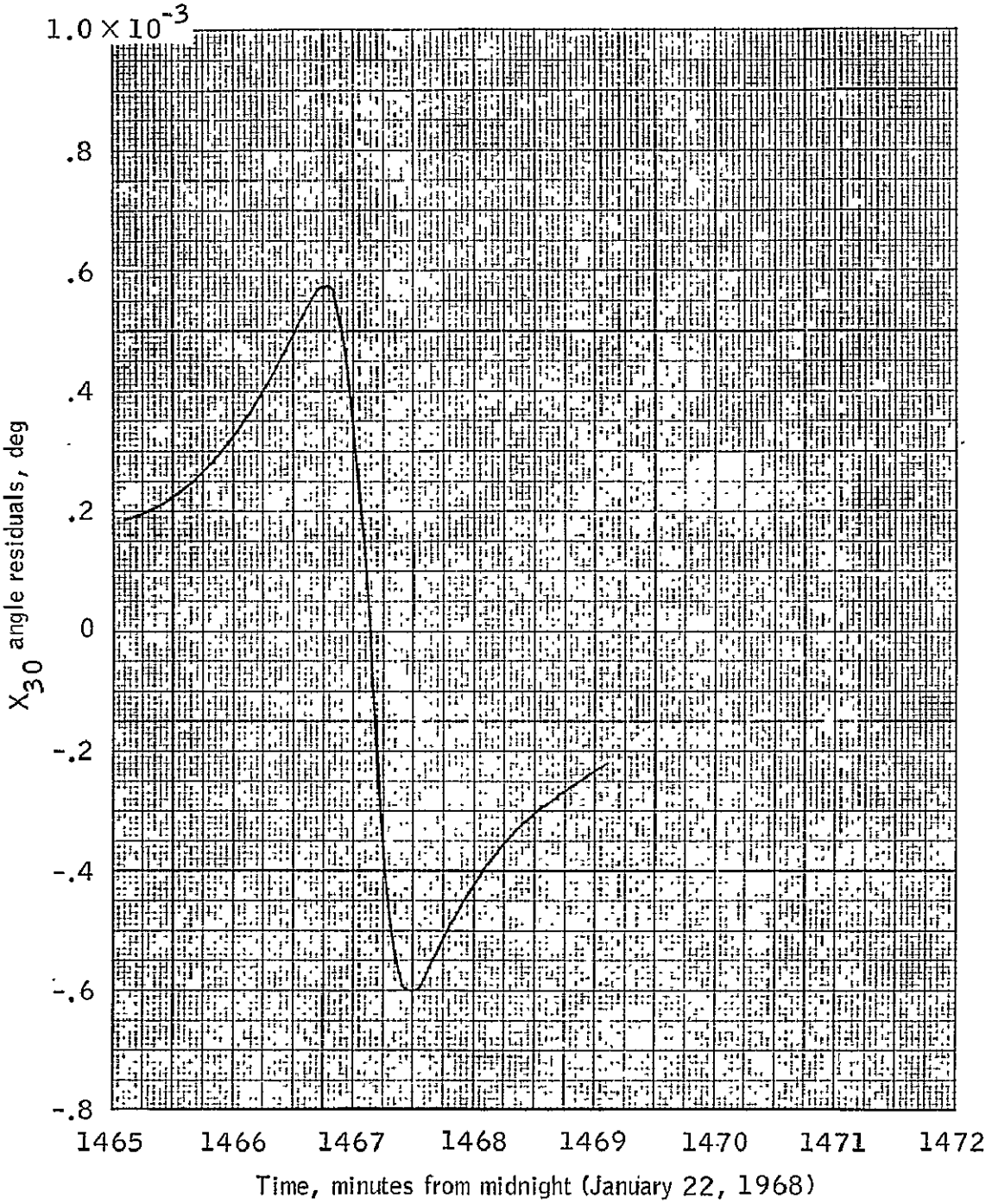
(c) Range residuals for -.0005-degree perturbation of longitude.

Figure 6.- Continued.



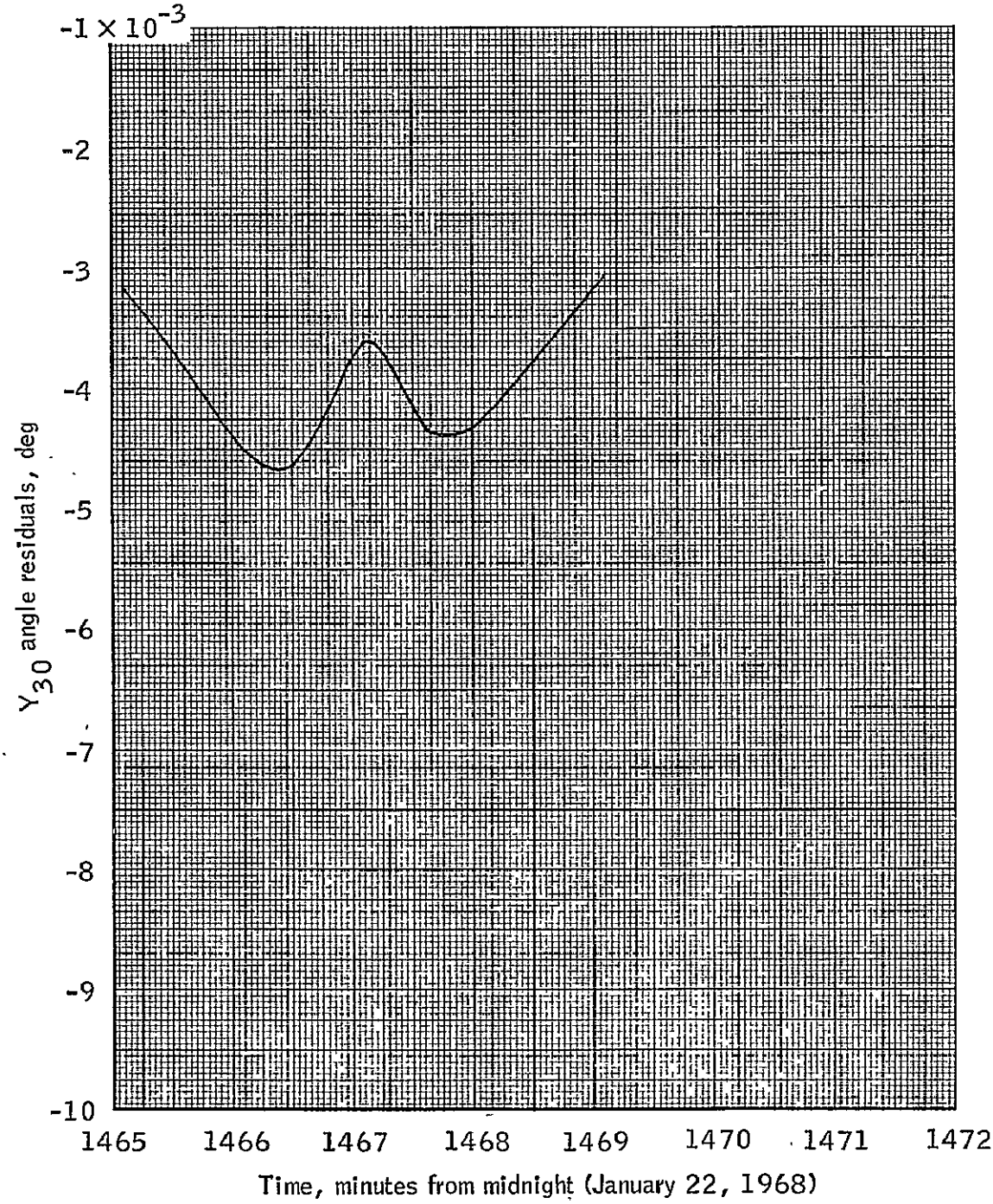
(d) Doppler residuals for -.0005-degree perturbation of longitude.

Figure 6.- Continued.



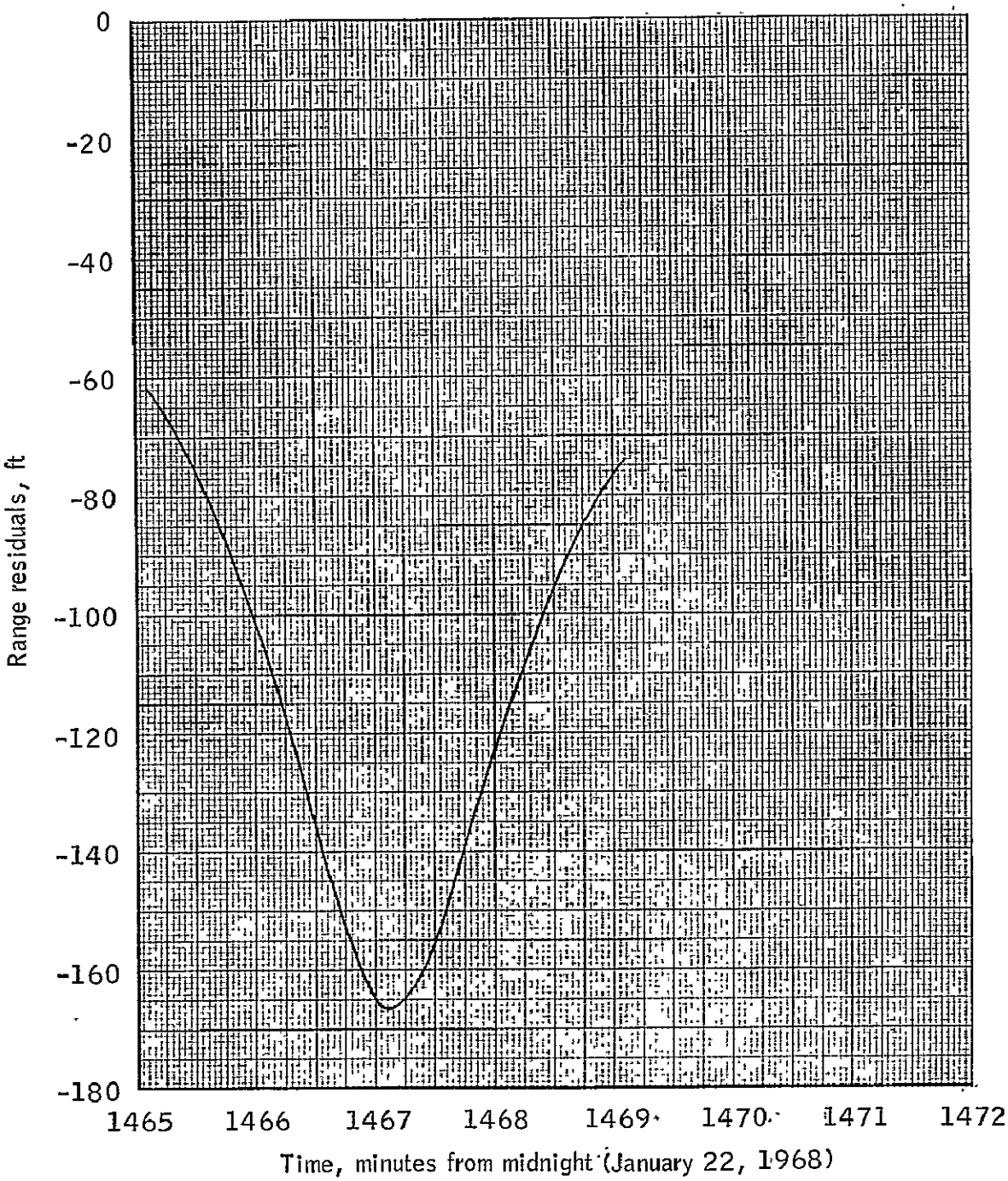
(e) X_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 6.- Continued.



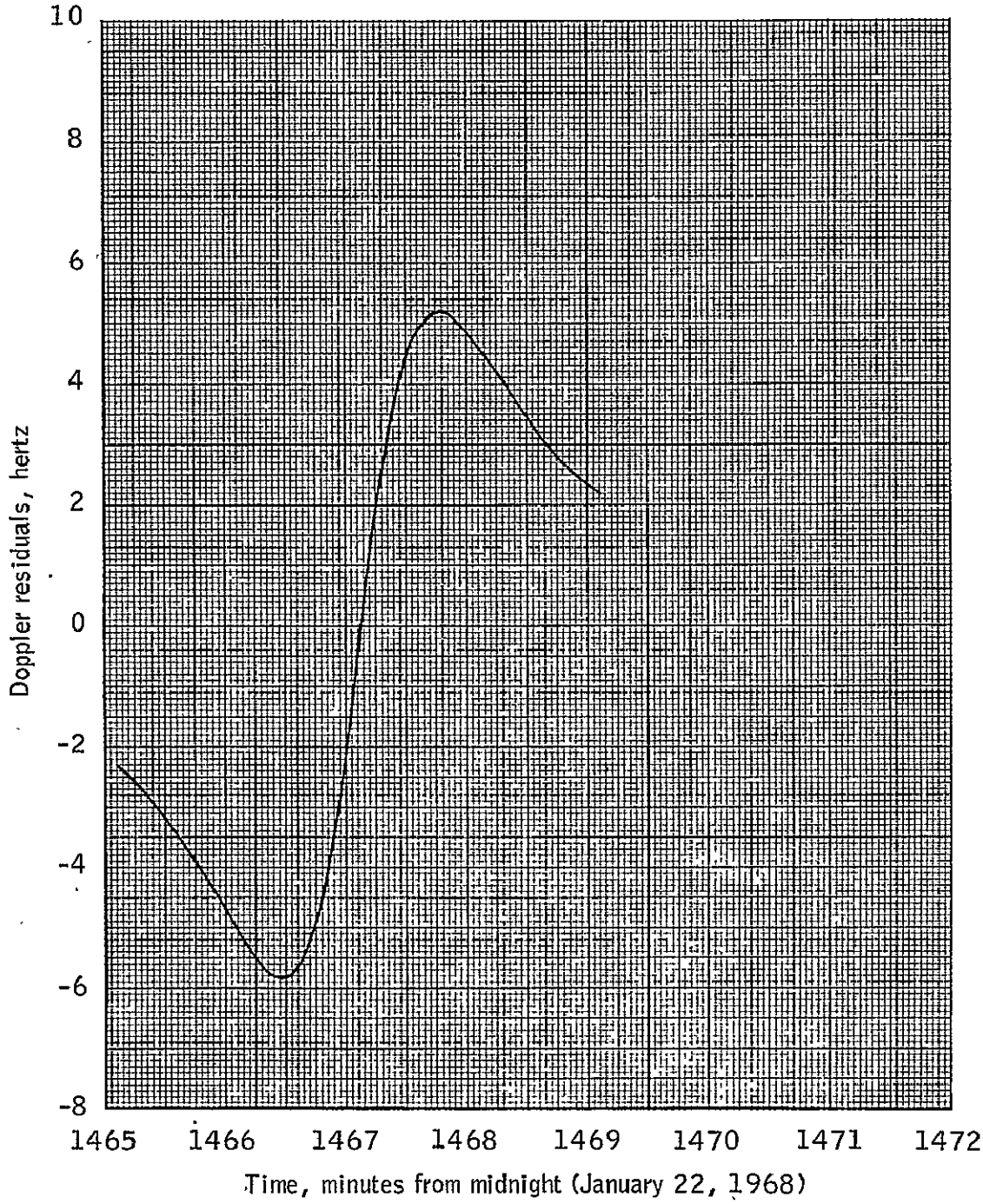
(f) Y_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 6.- Continued.



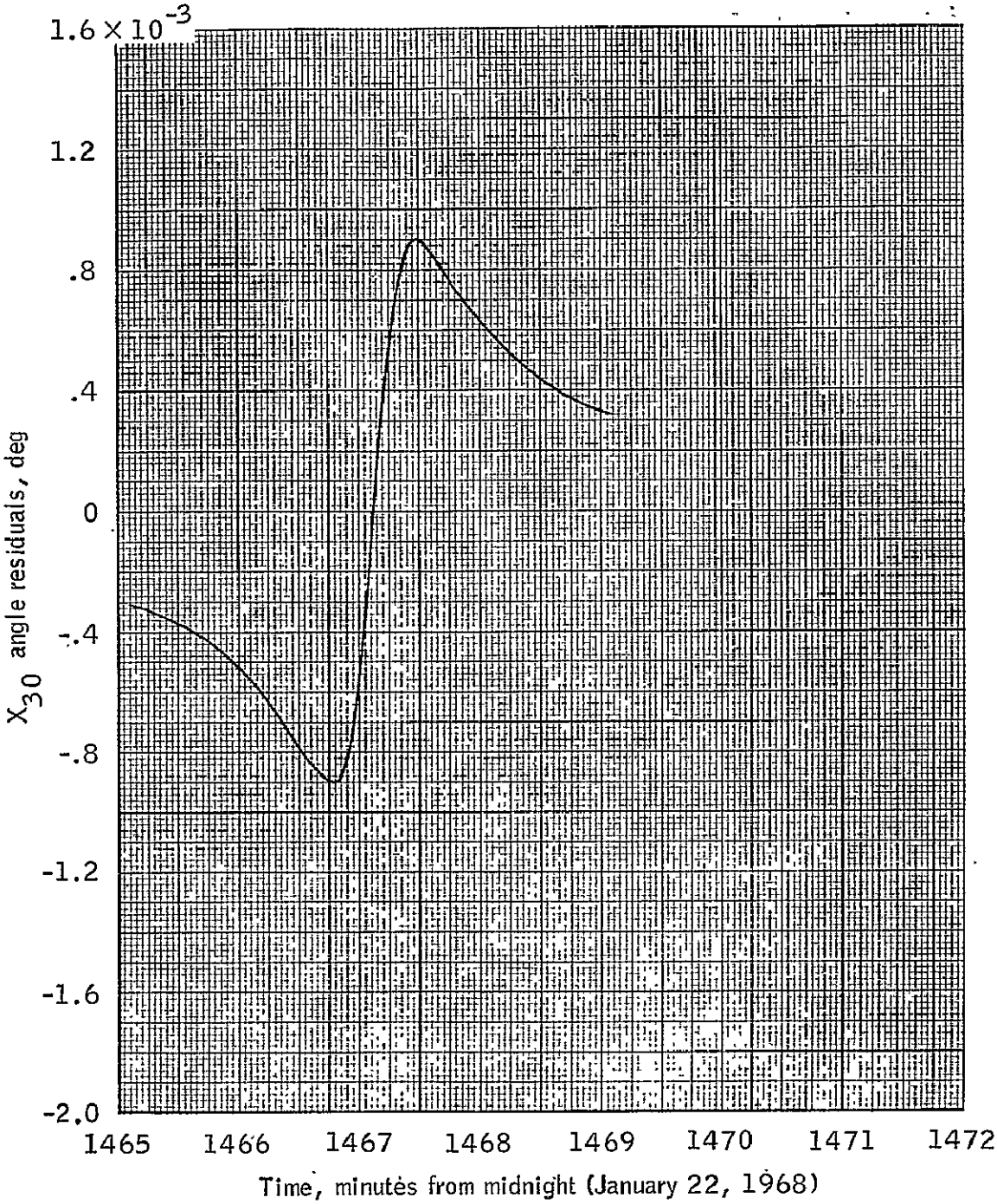
(g) Range residuals for −.0005-degree perturbation of latitude.

Figure 6:- Continued.



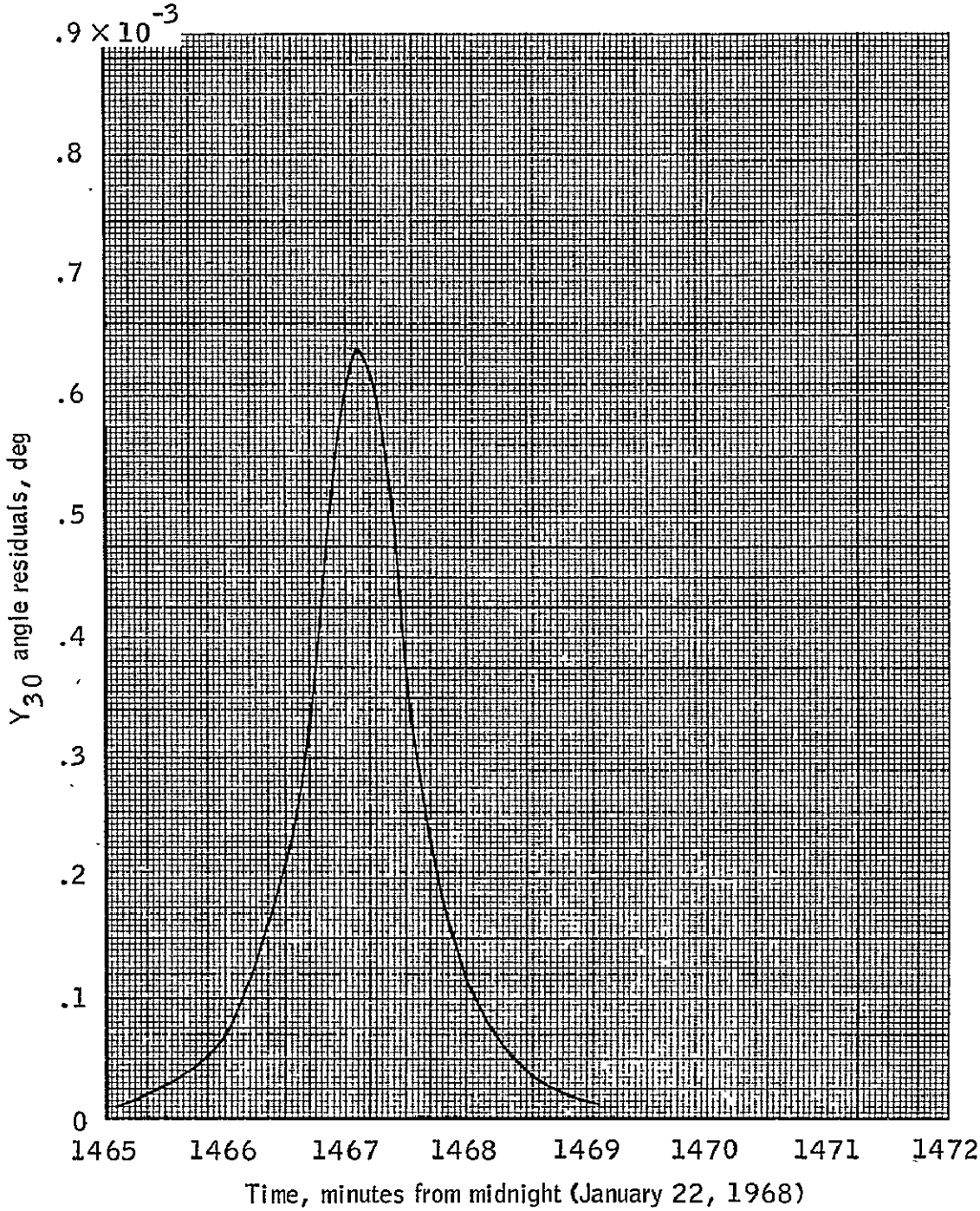
(h) Doppler residuals for -.0005-degree perturbation of latitude.

Figure 6.- Continued.



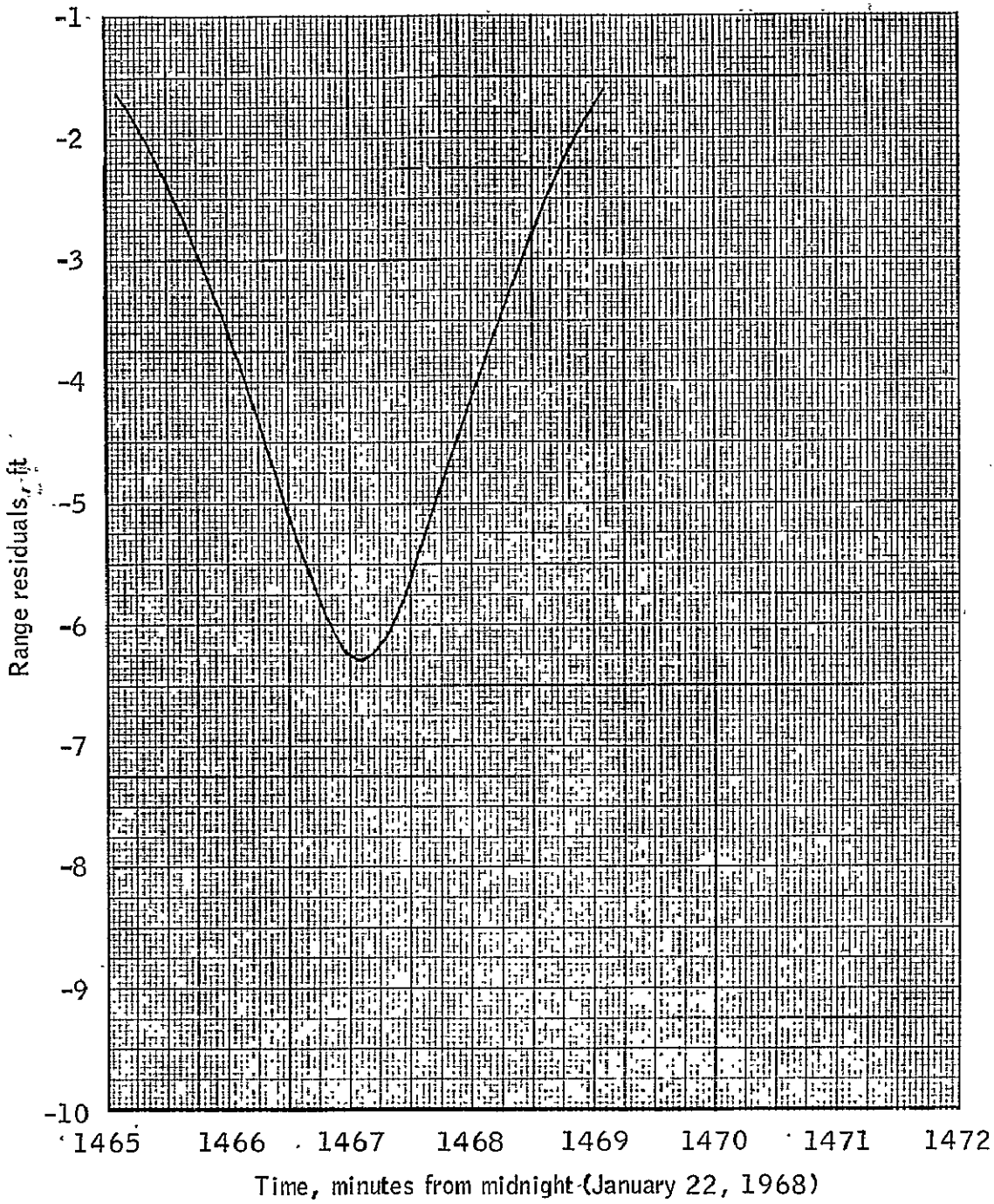
(i) X_{30} angle residuals for -50-foot perturbation of altitude.

Figure 6.- Continued.



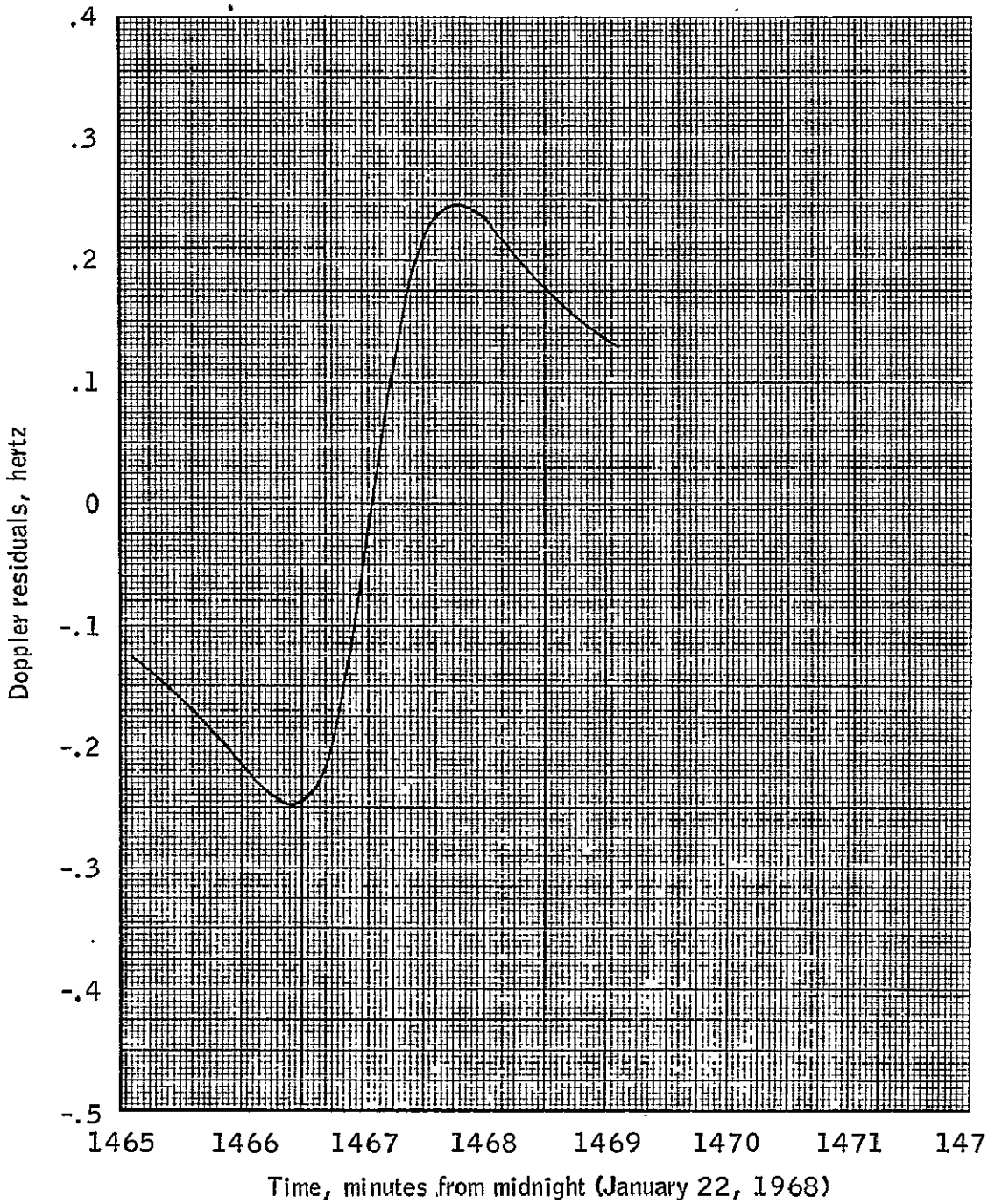
(j) Y_{30} angle residuals for -50-foot perturbation of altitude.

Figure 6.- Continued.



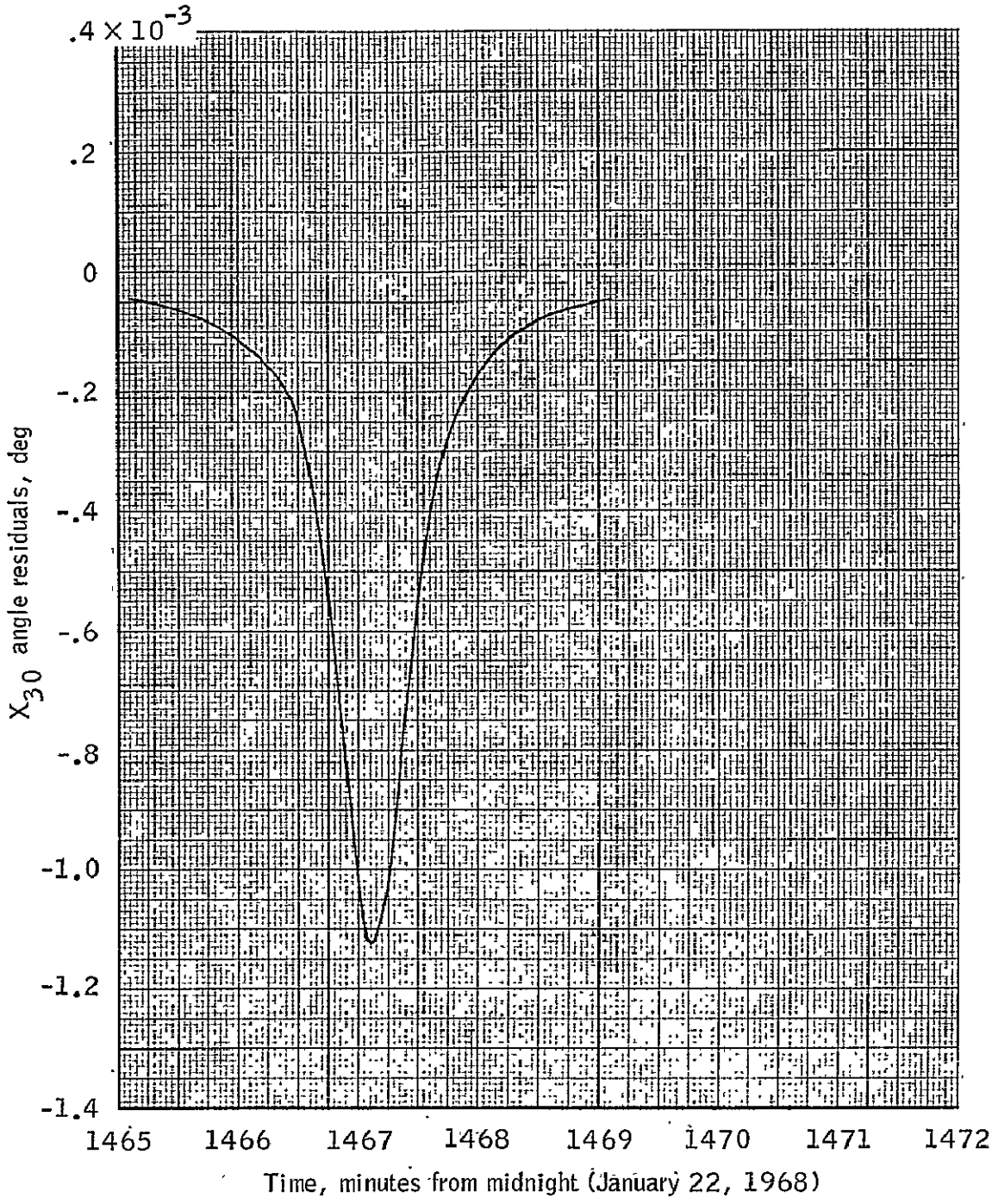
(k) Range residuals for -50-foot perturbation of altitude.

Figure 6.- Continued.



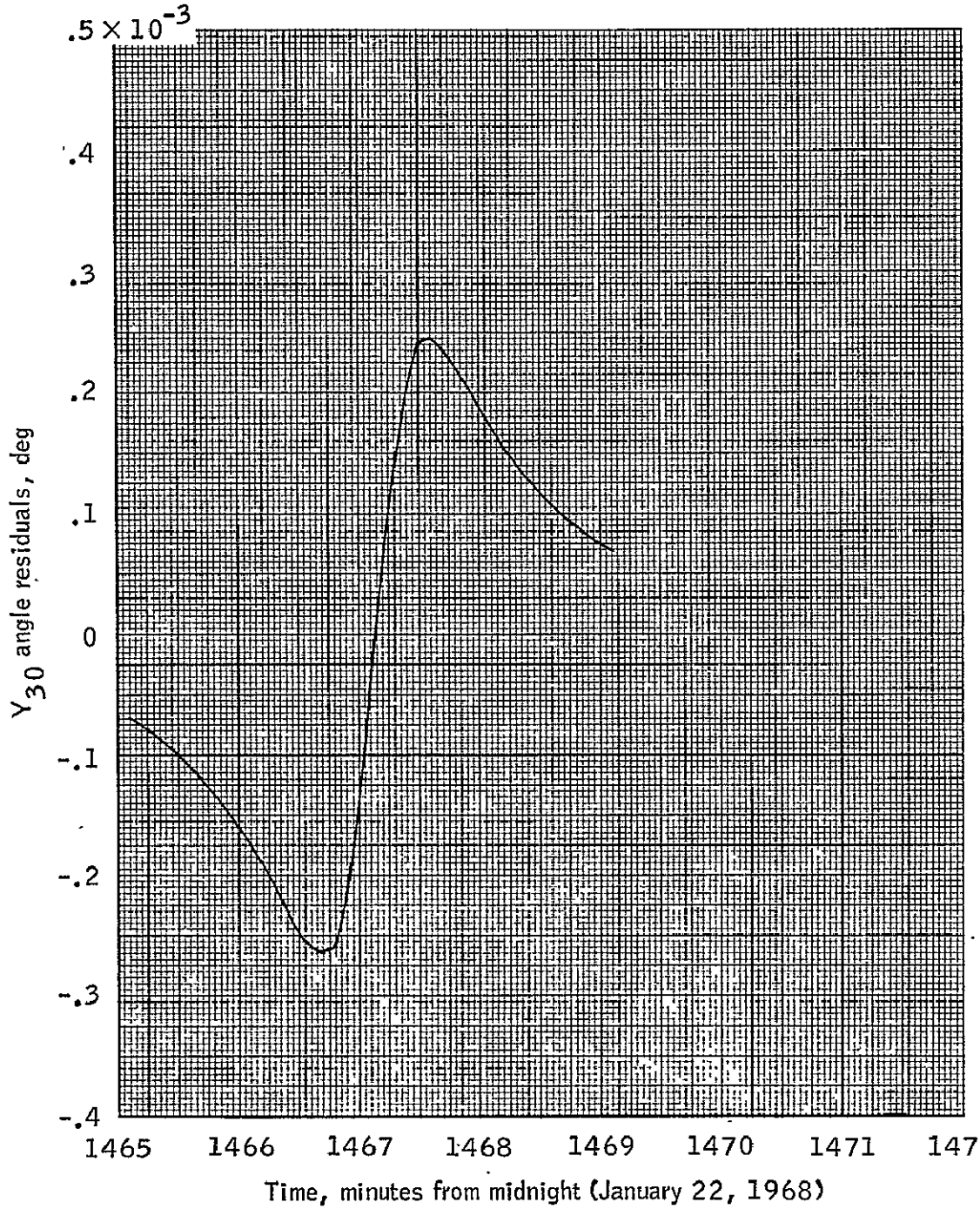
(l) Doppler residuals for -50-foot perturbation of altitude.

Figure 6.- Continued.



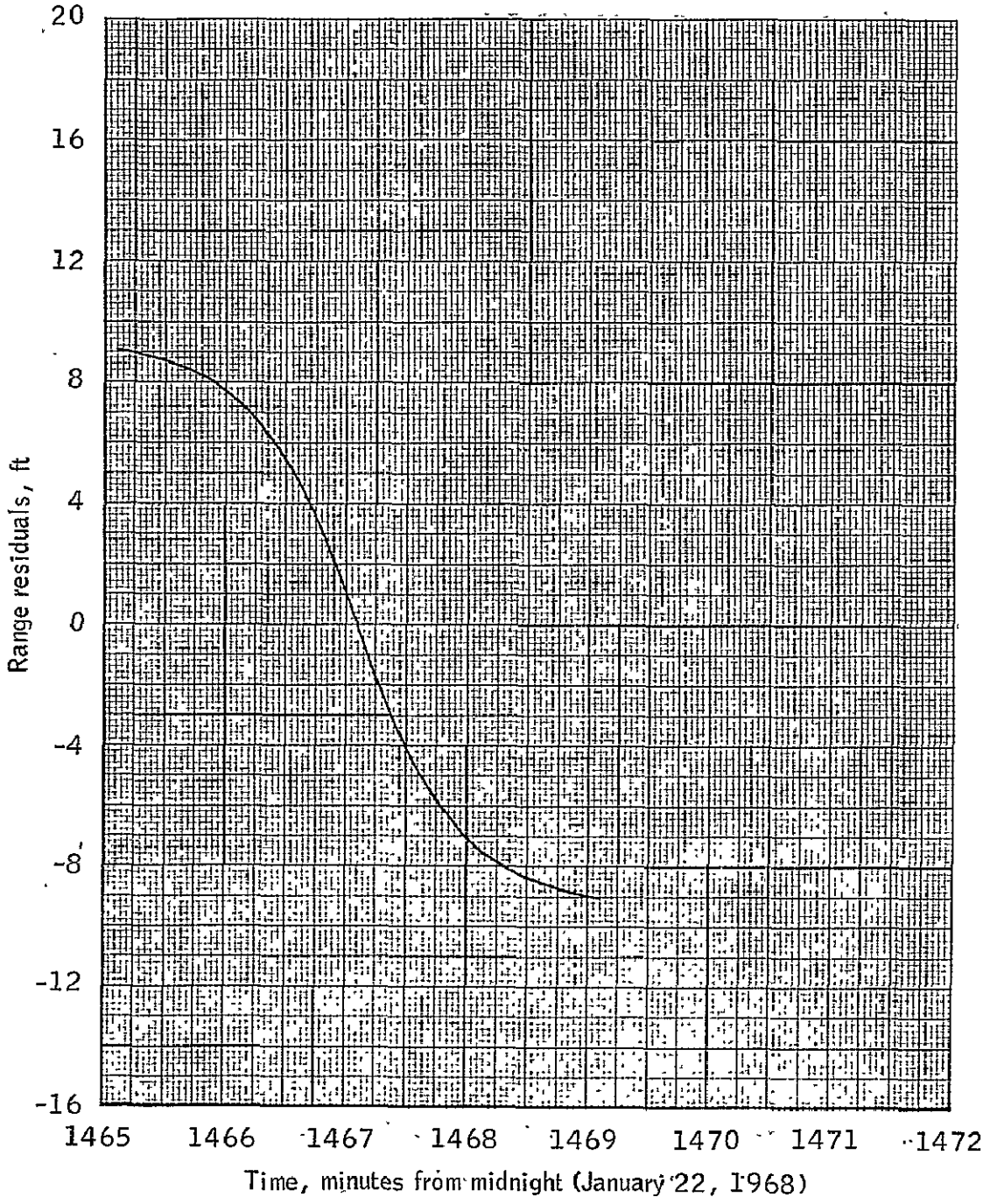
(m) X_{30} angle residuals for -.025-second perturbation of time.

Figure 6.- Continued.



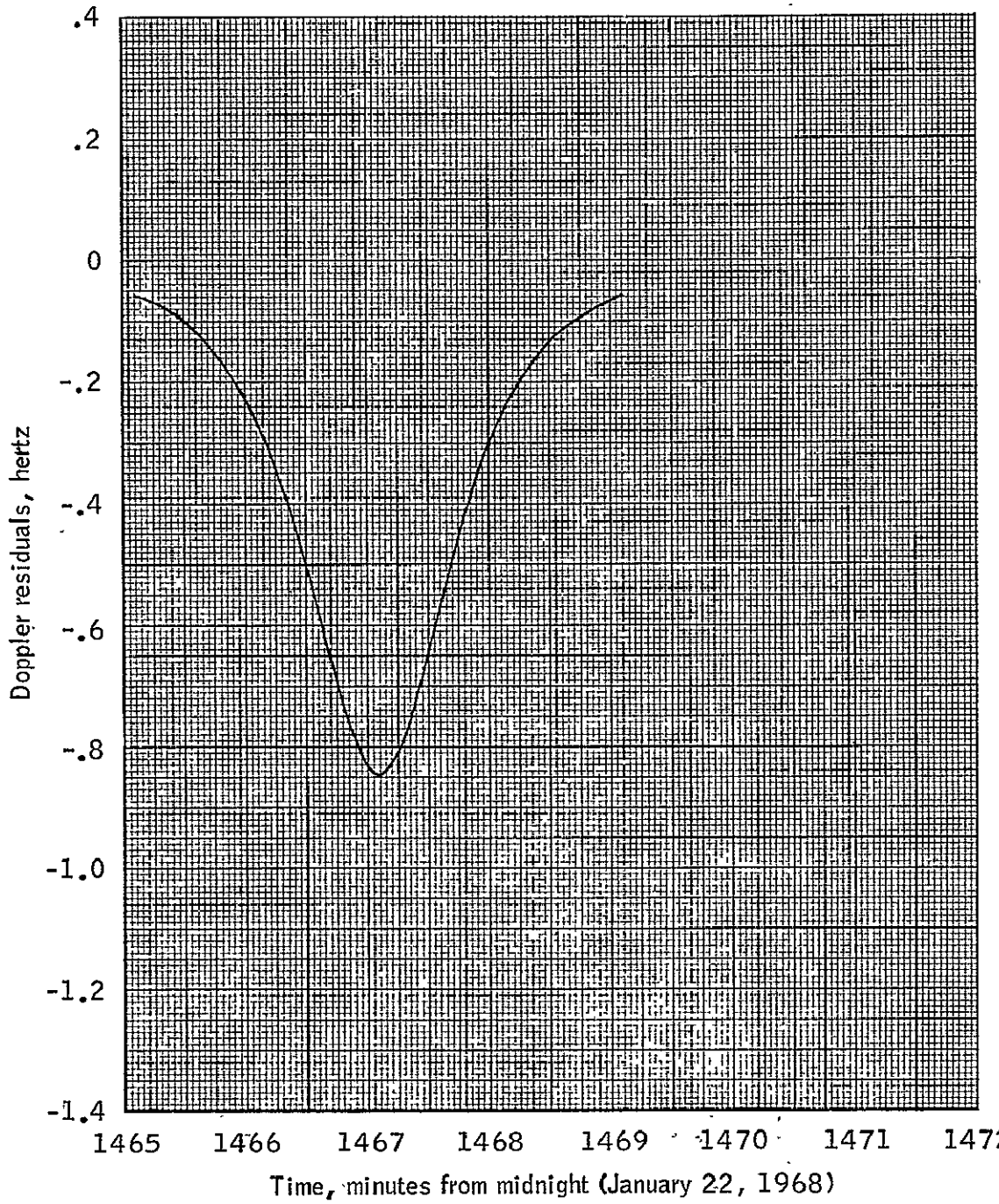
(n) Y_{30} angle residuals for -.025-second perturbation of time.

Figure 6.- Continued.



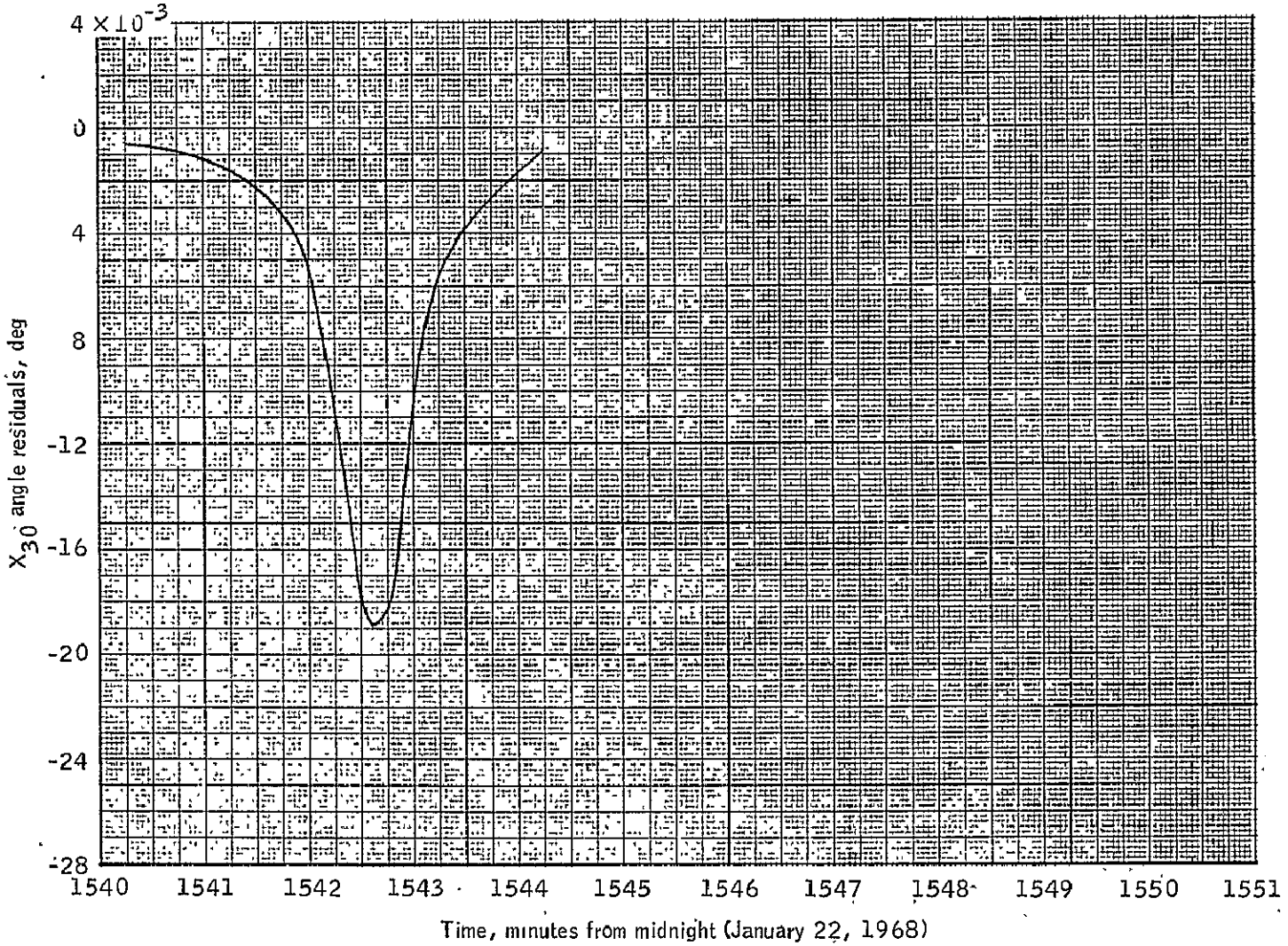
(o) Range residuals for -.025-second perturbation of time.

Figure 6.- Continued.



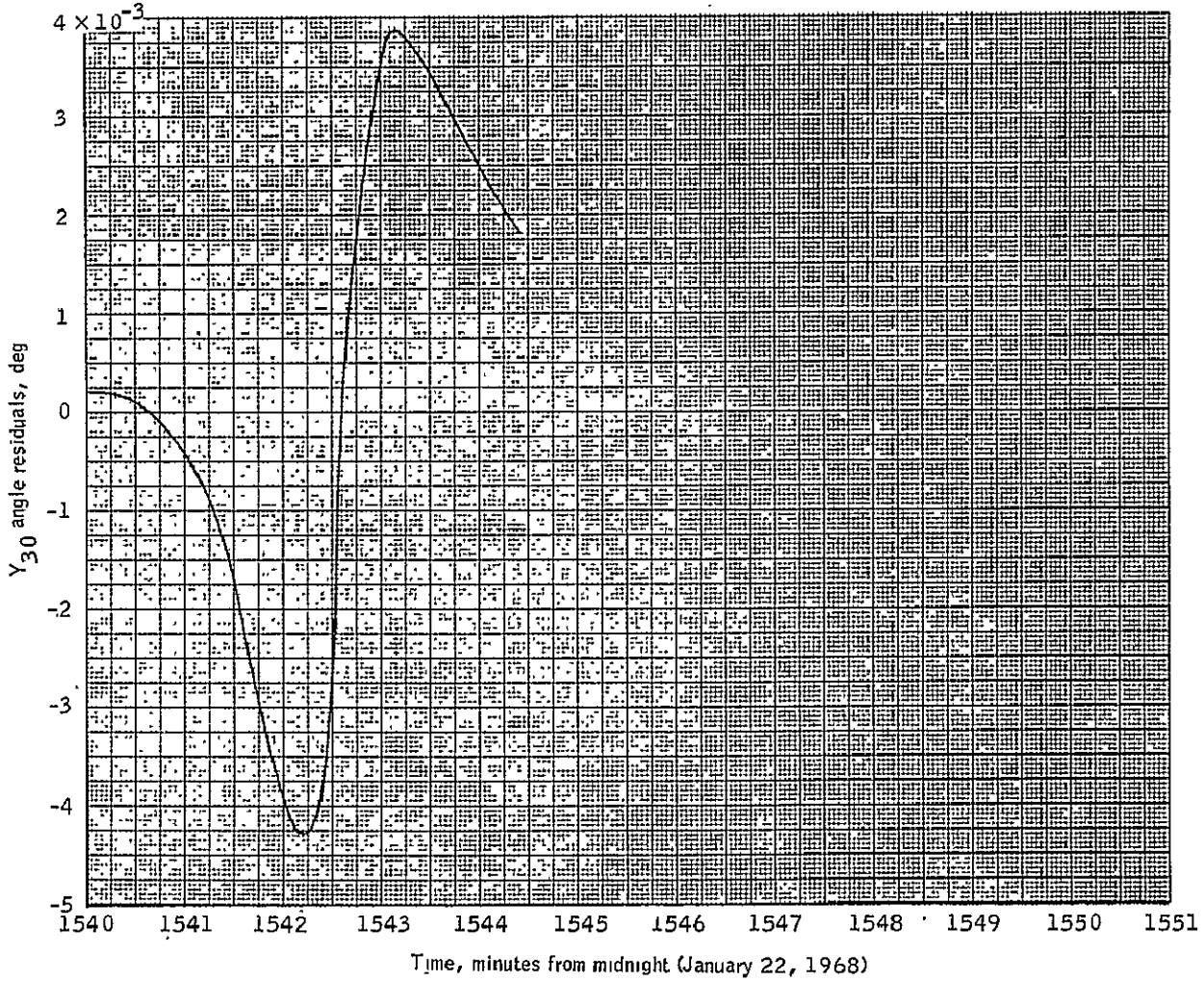
(p) Doppler residuals for -.025-second perturbation of time.

Figure 6.- Concluded.



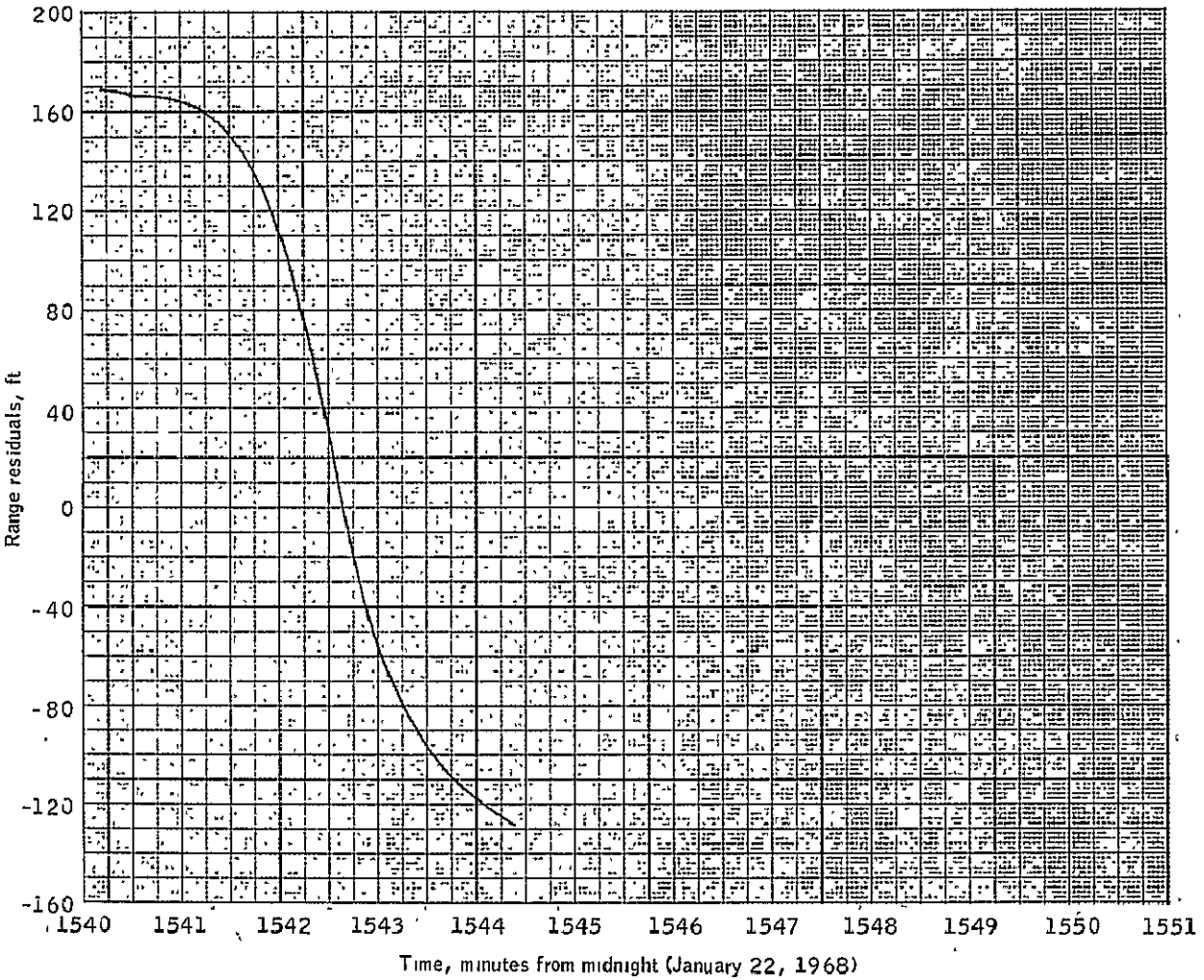
(a) X_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 7.- Residual patterns in USB data from the Hawaii tracking station.



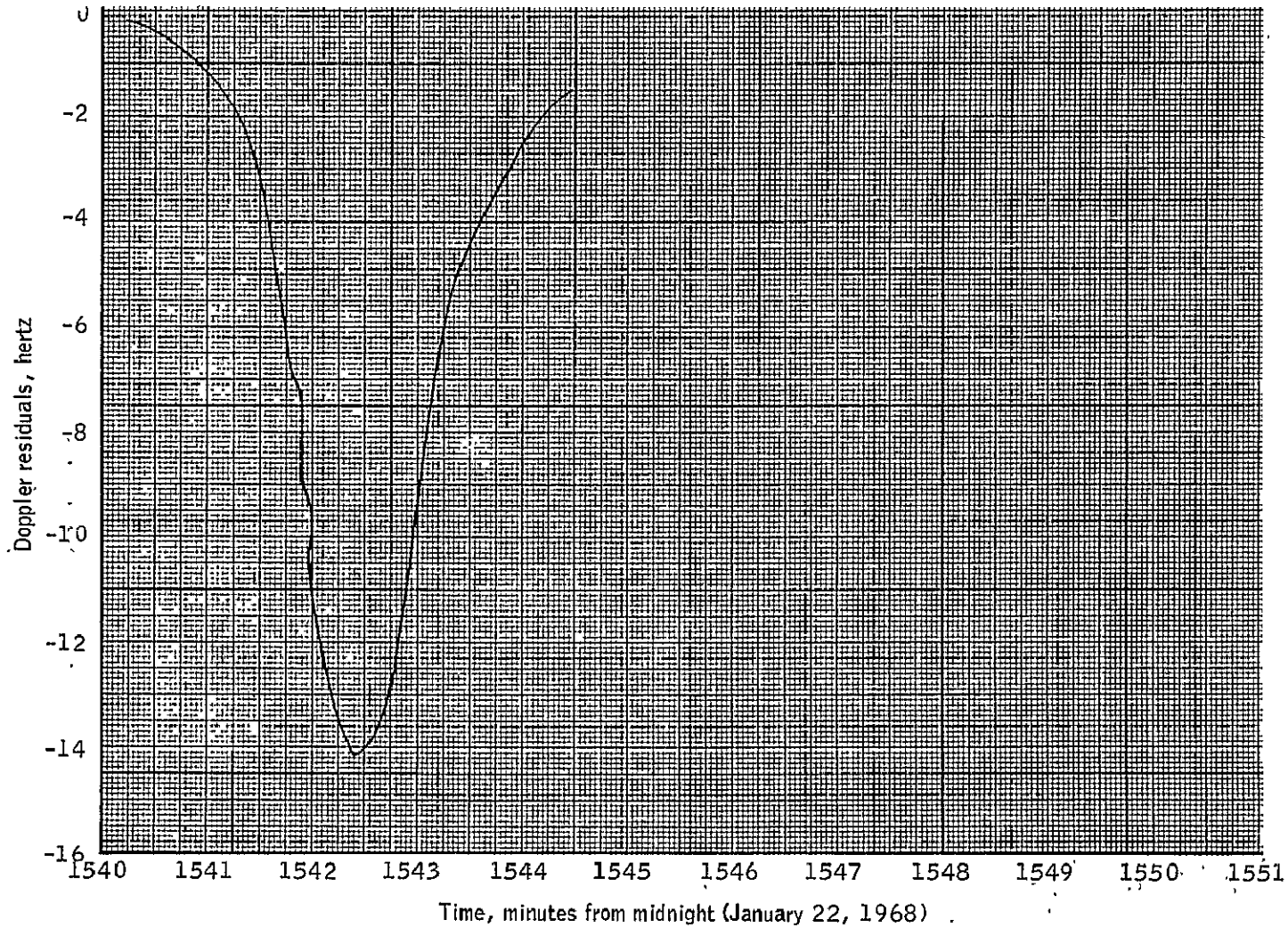
(b) Y_{30} angle residuals for -.0005-degree pertubation of longitude.

Figure 7.- Continued.



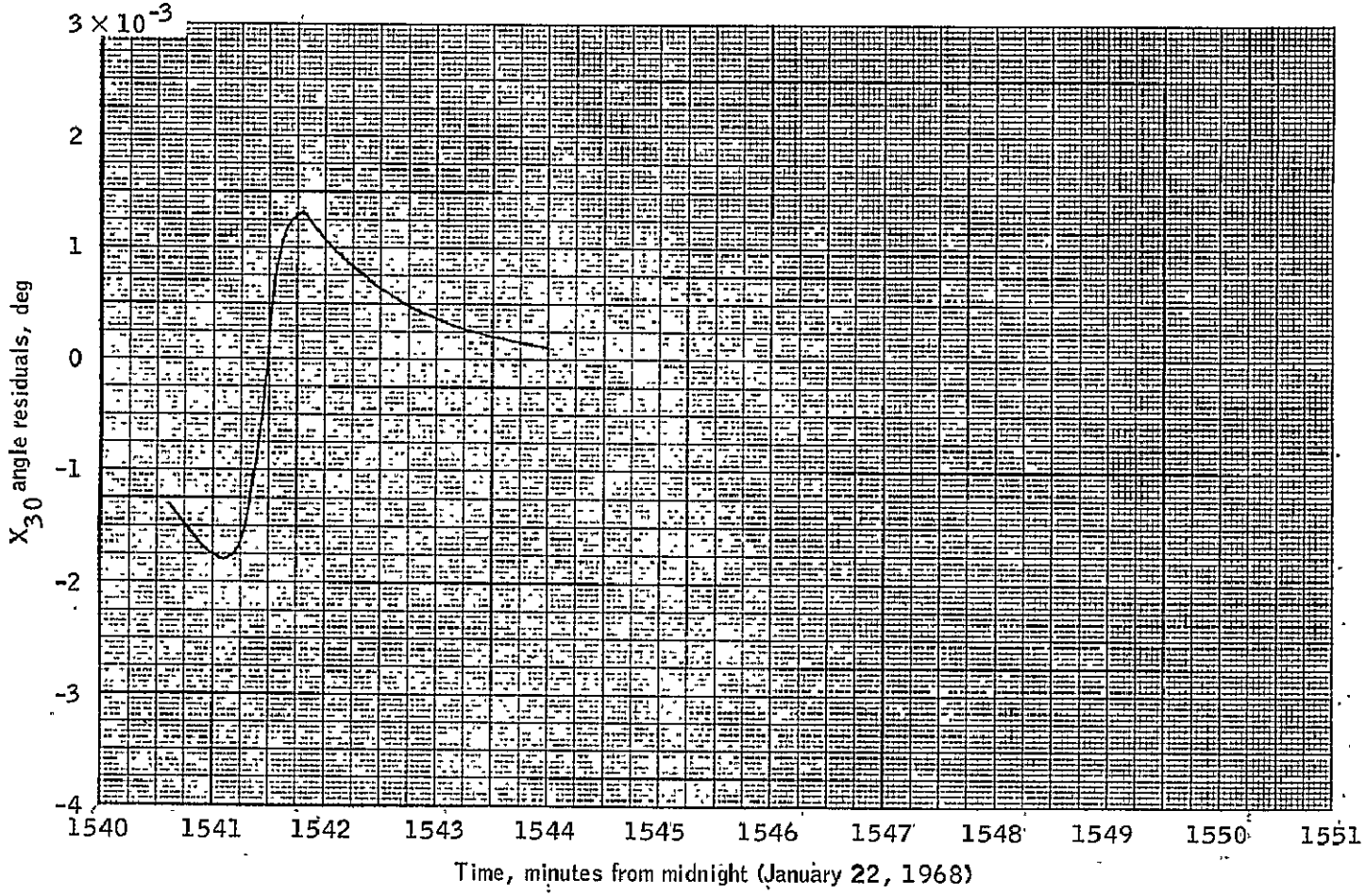
(c) Range residual for -.0005-degree pertubation of longitude.

Figure 7.- Continued.



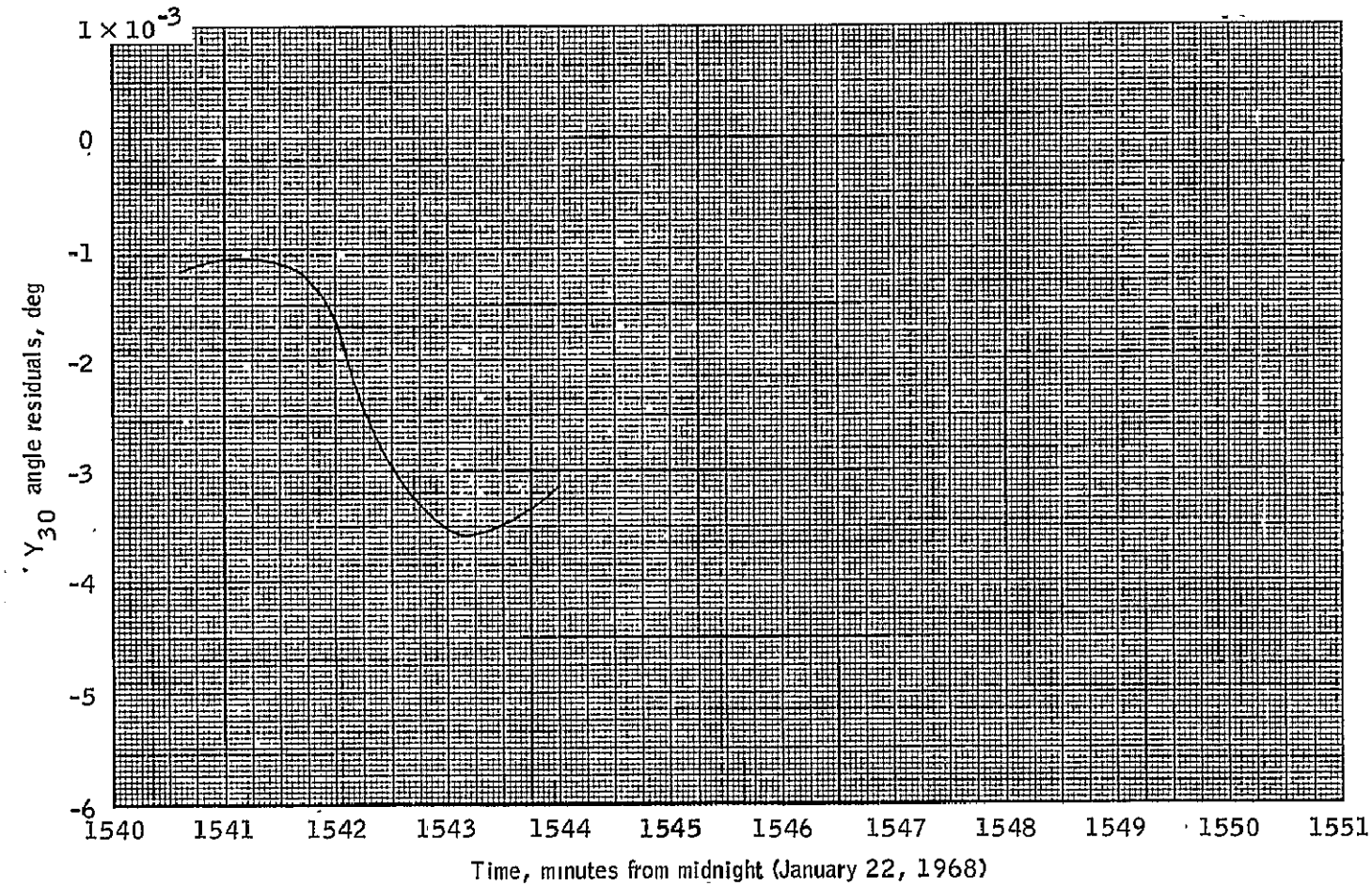
(d) Doppler residual for -.0005-degree pertubation of longitude.

Figure 7.- Continued.-



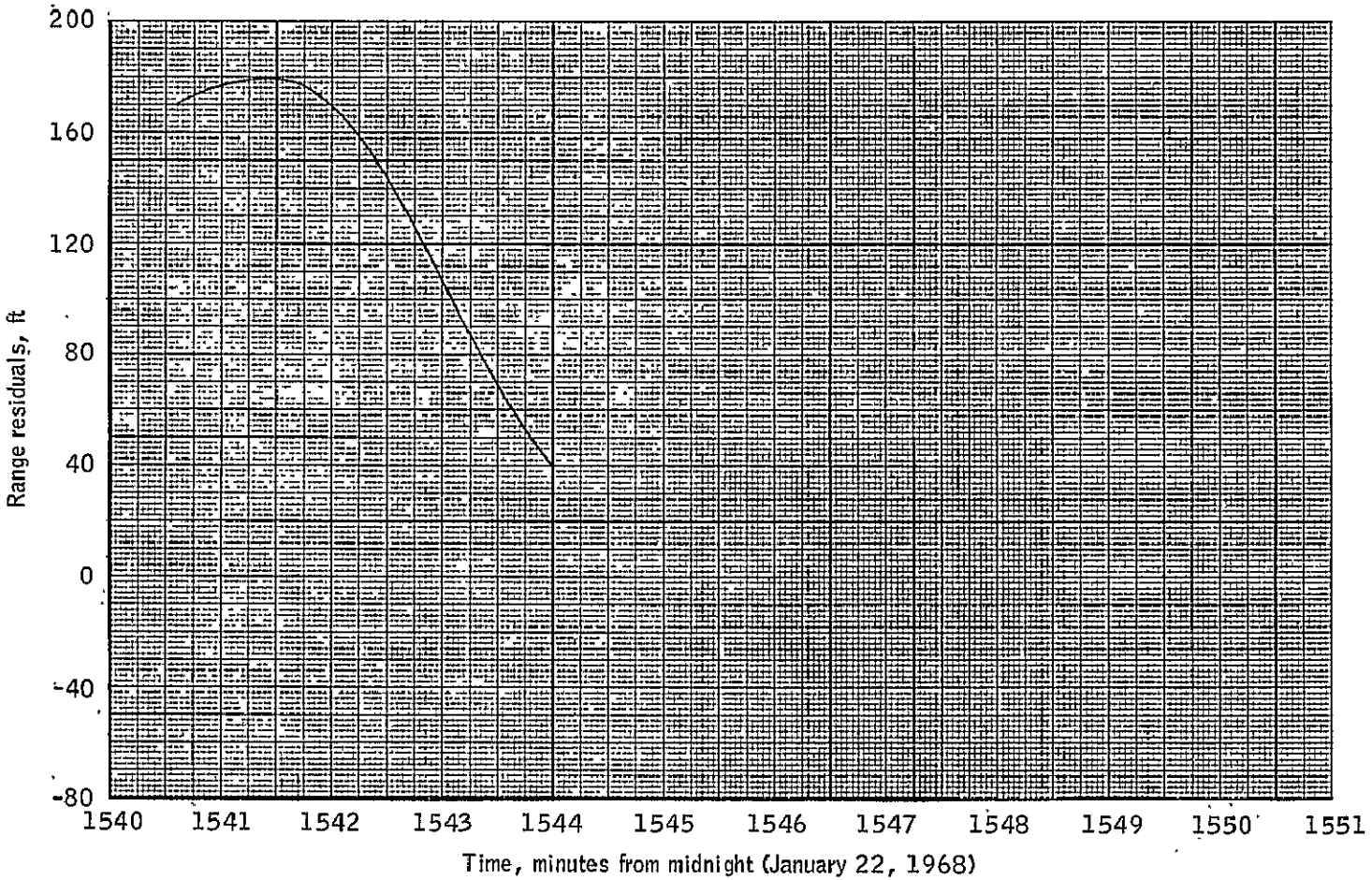
(e) X_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 7.- Continued.



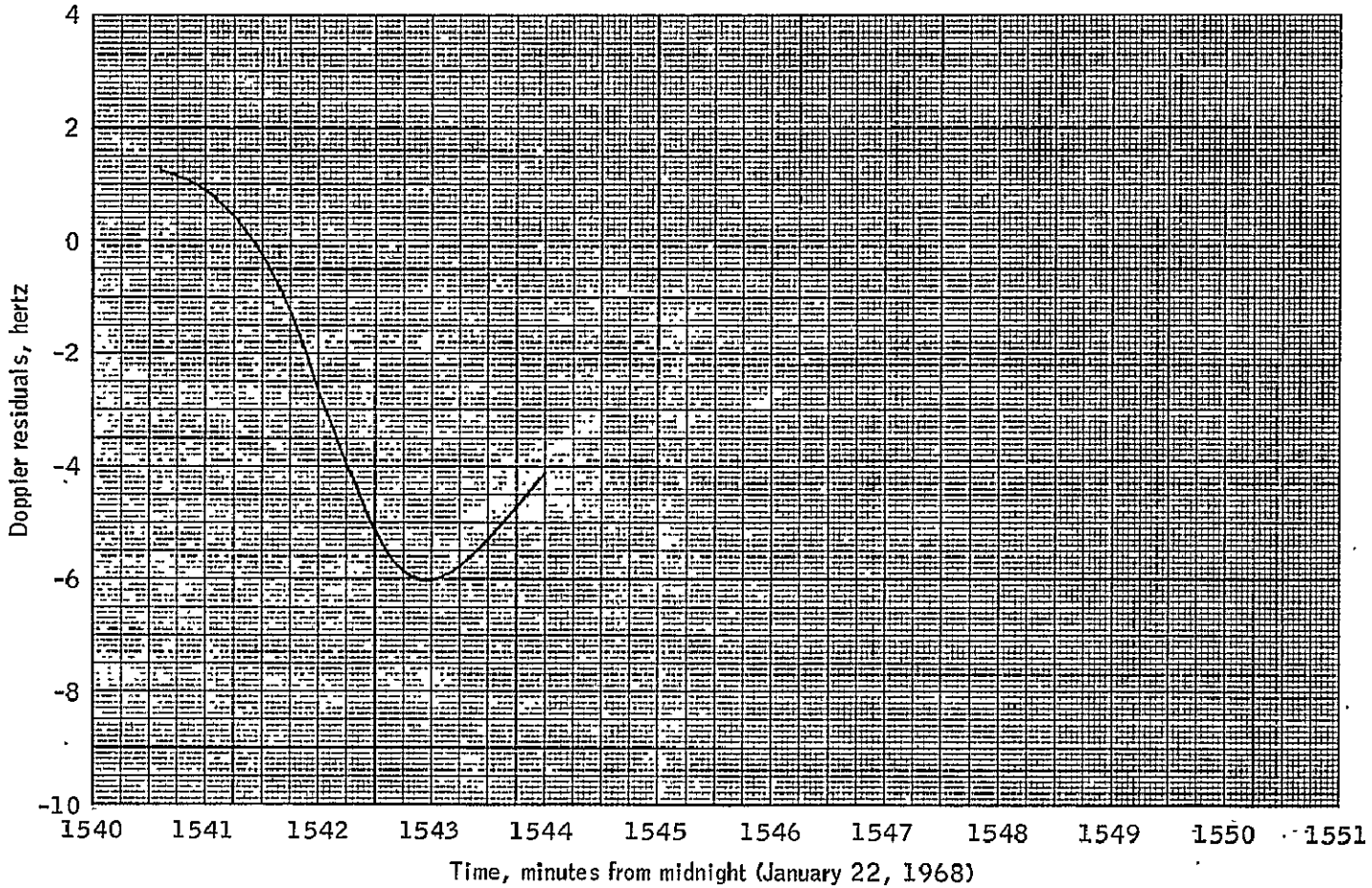
(f) Y_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 7.- Continued.



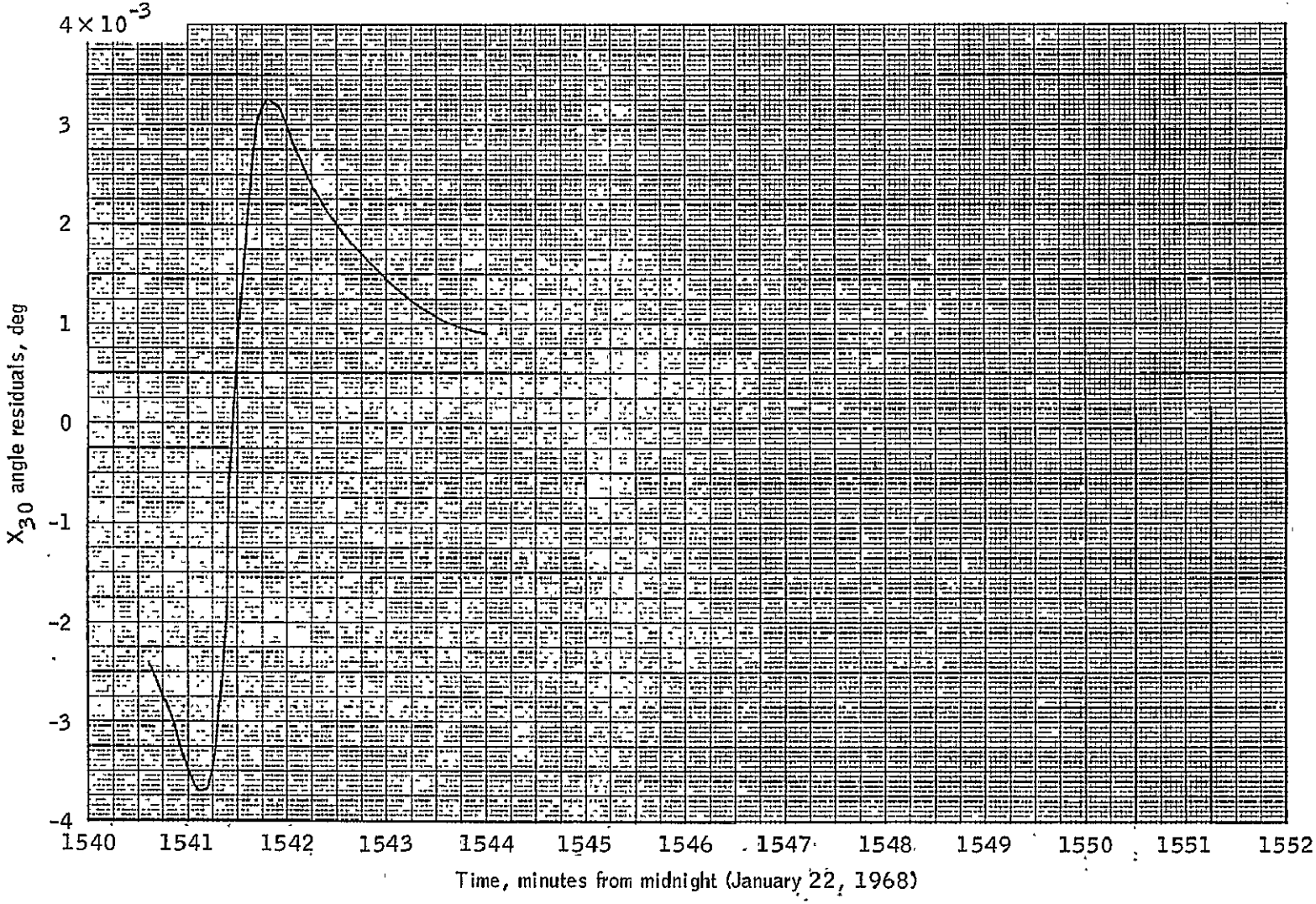
(g) Range residuals for -.0005-degree perturbation of latitude.

Figure 7.- Continued.



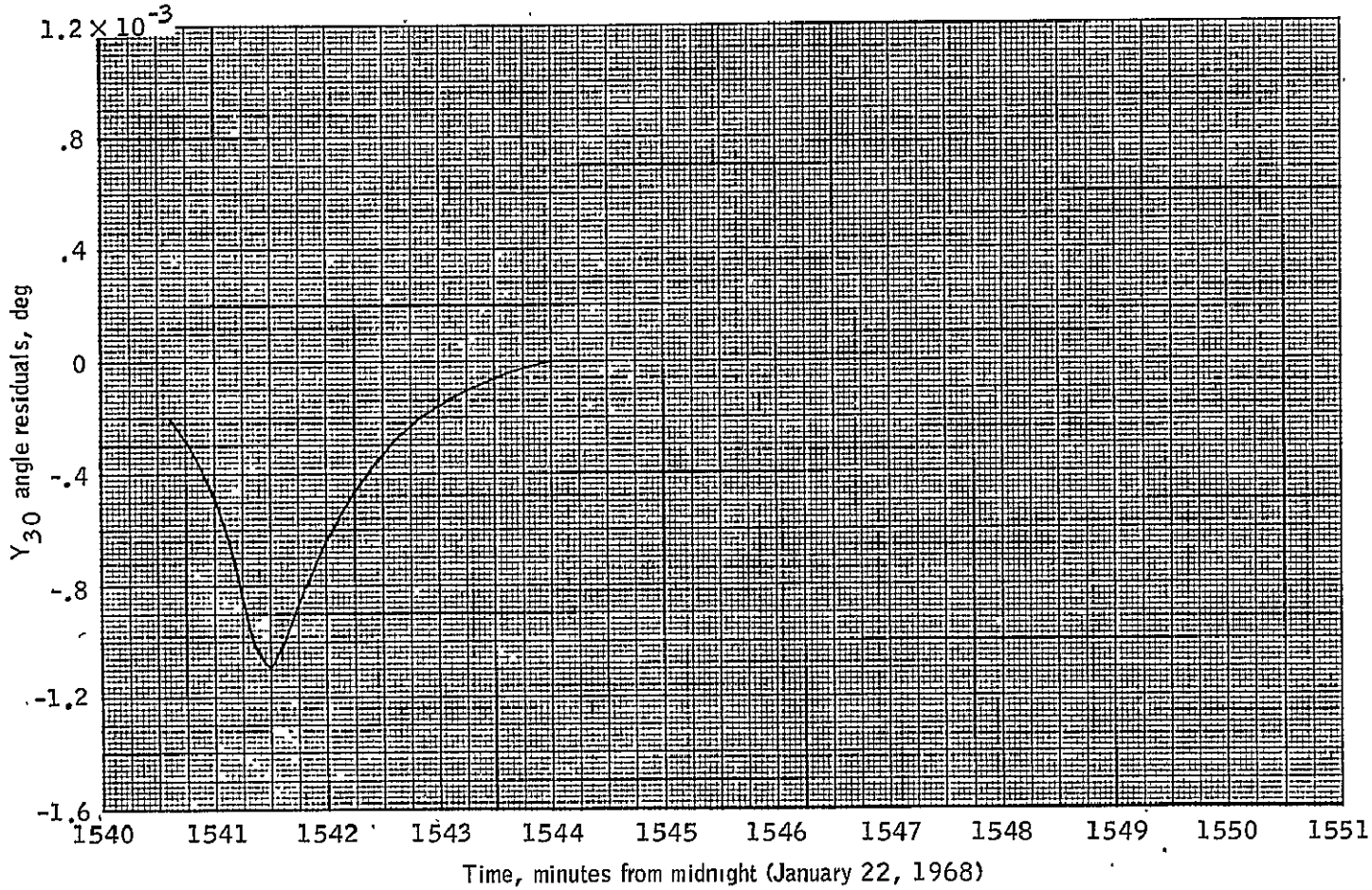
(h) Doppler residuals for -.0005-degree perturbation of latitude.

Figure 7.- Continued.



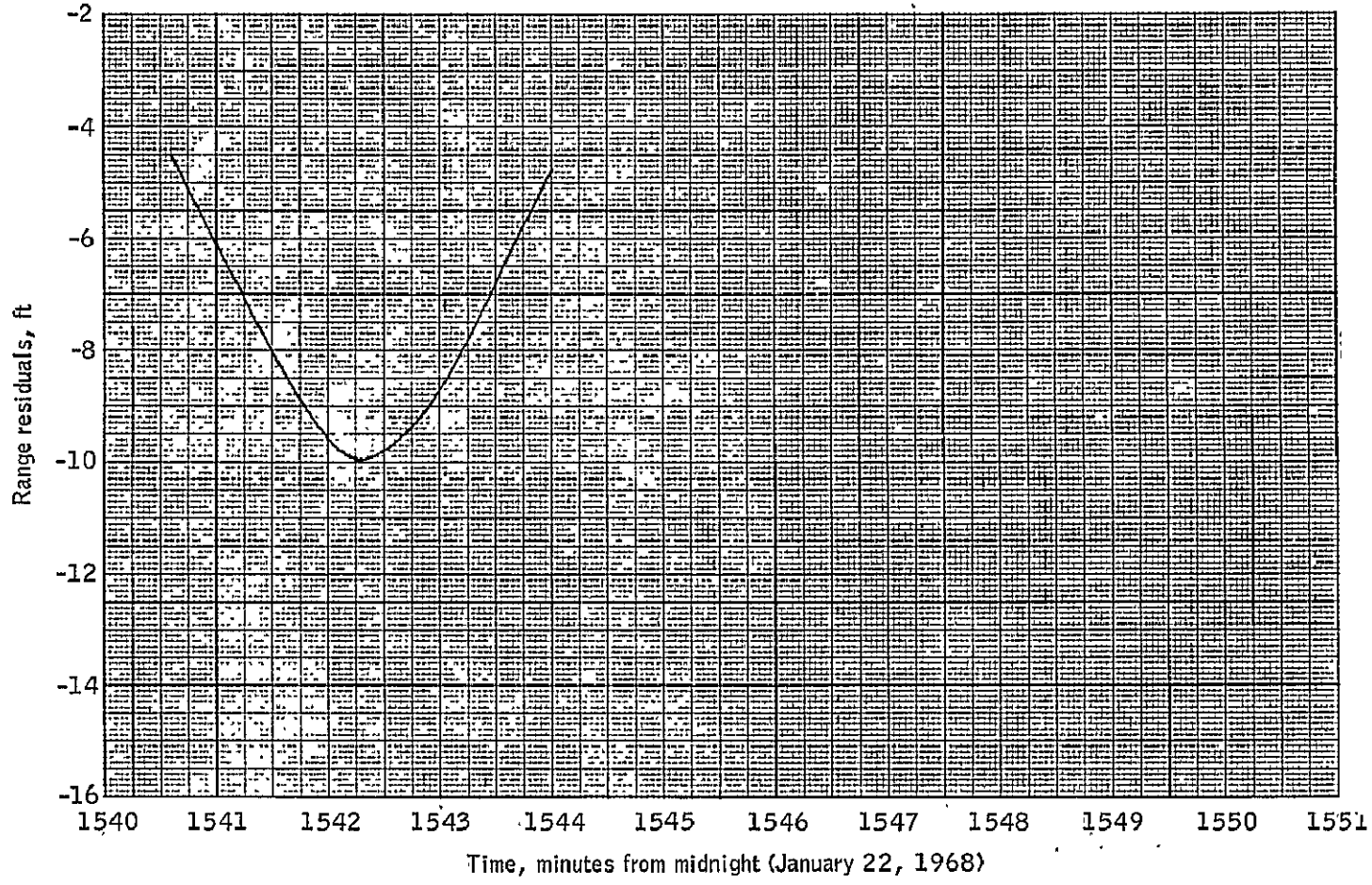
(i) X_{30} angle residuals for -50-foot perturbation of altitude.

Figure7.- Continued.



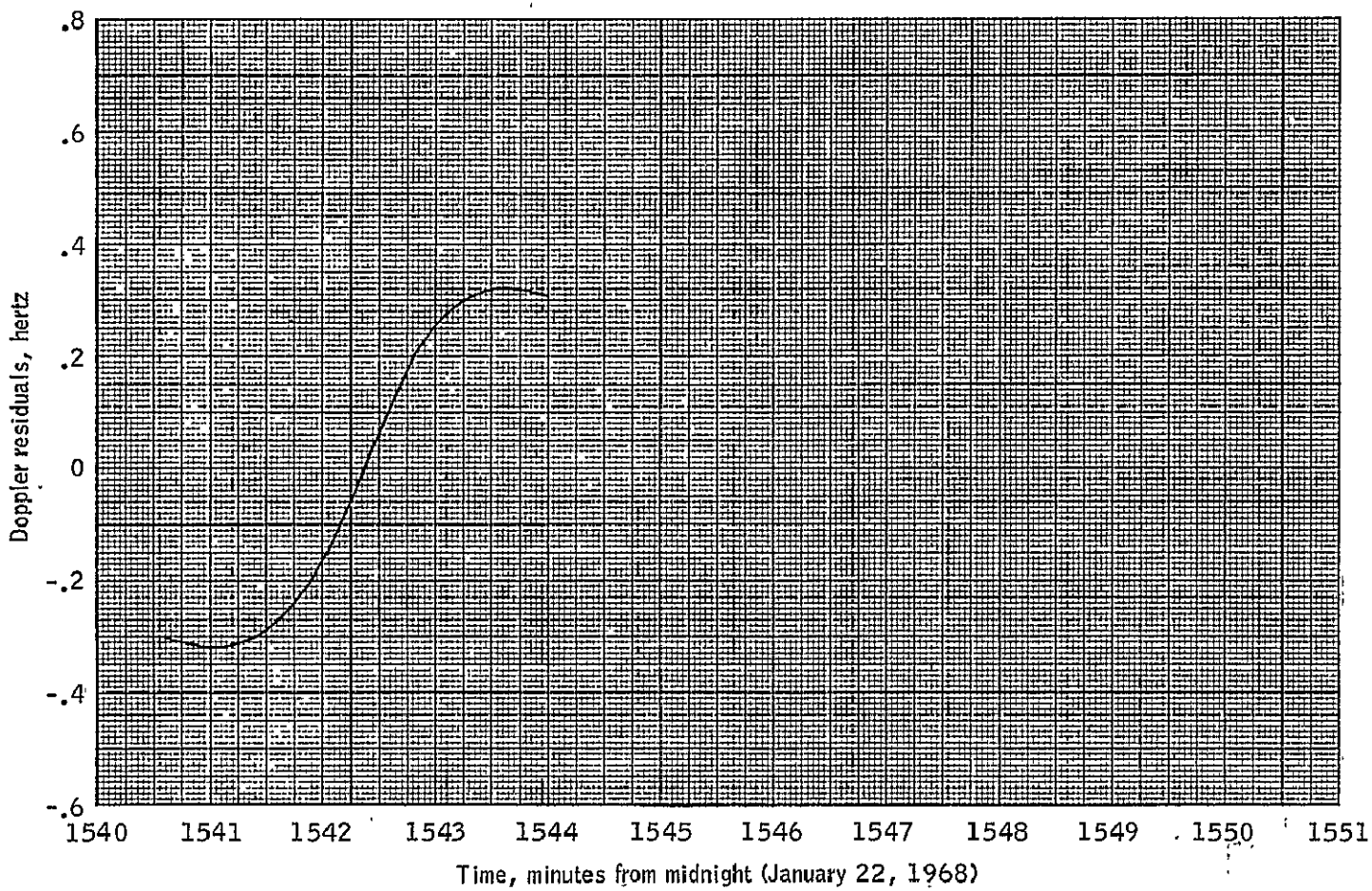
(j) Y_{30} angle residuals for -50-foot perturbation of altitude.

Figure 7.- Continued.



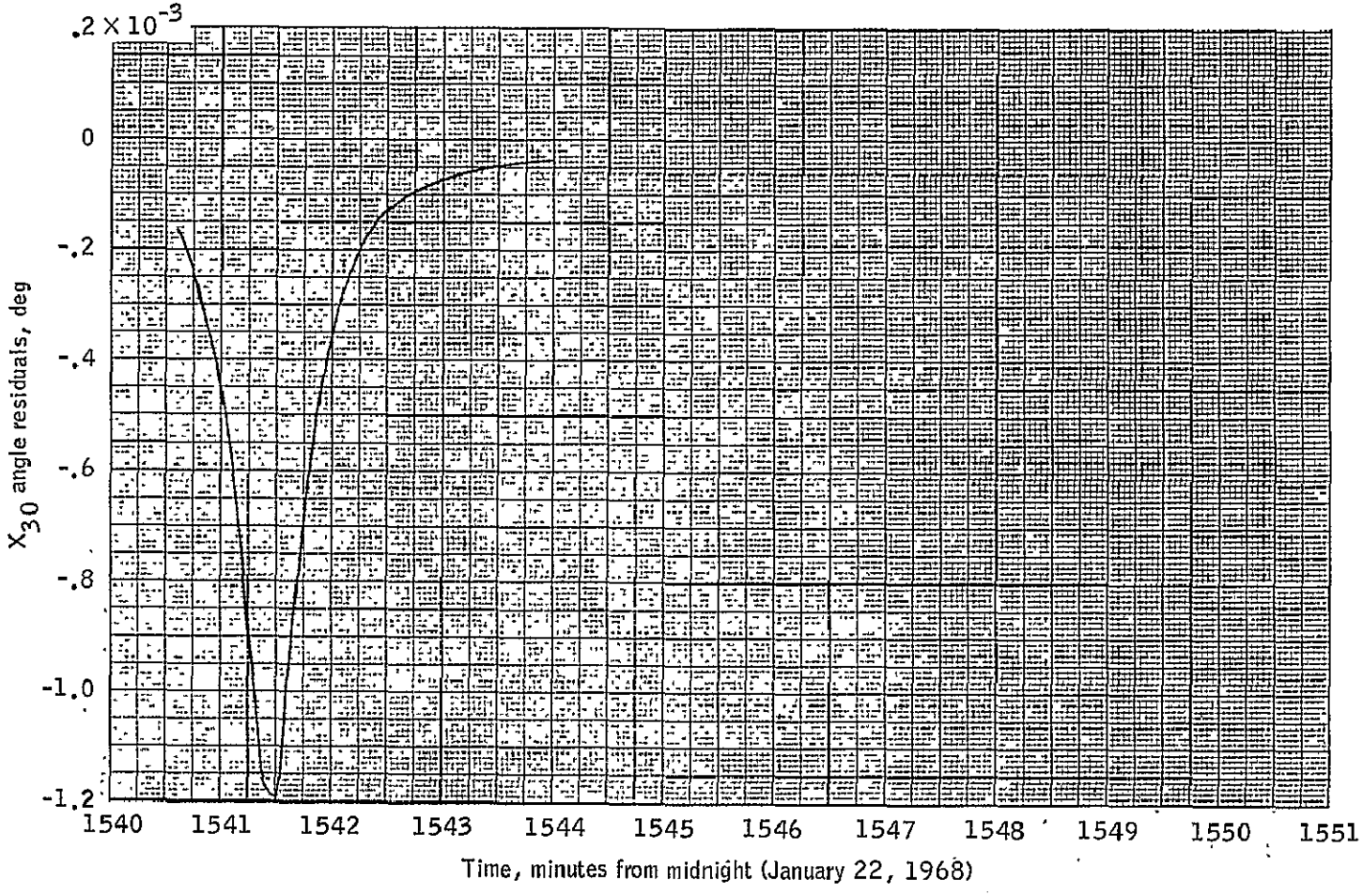
(k) Range residuals for -50-foot perturbation of altitude.

Figure 7.- Continued.



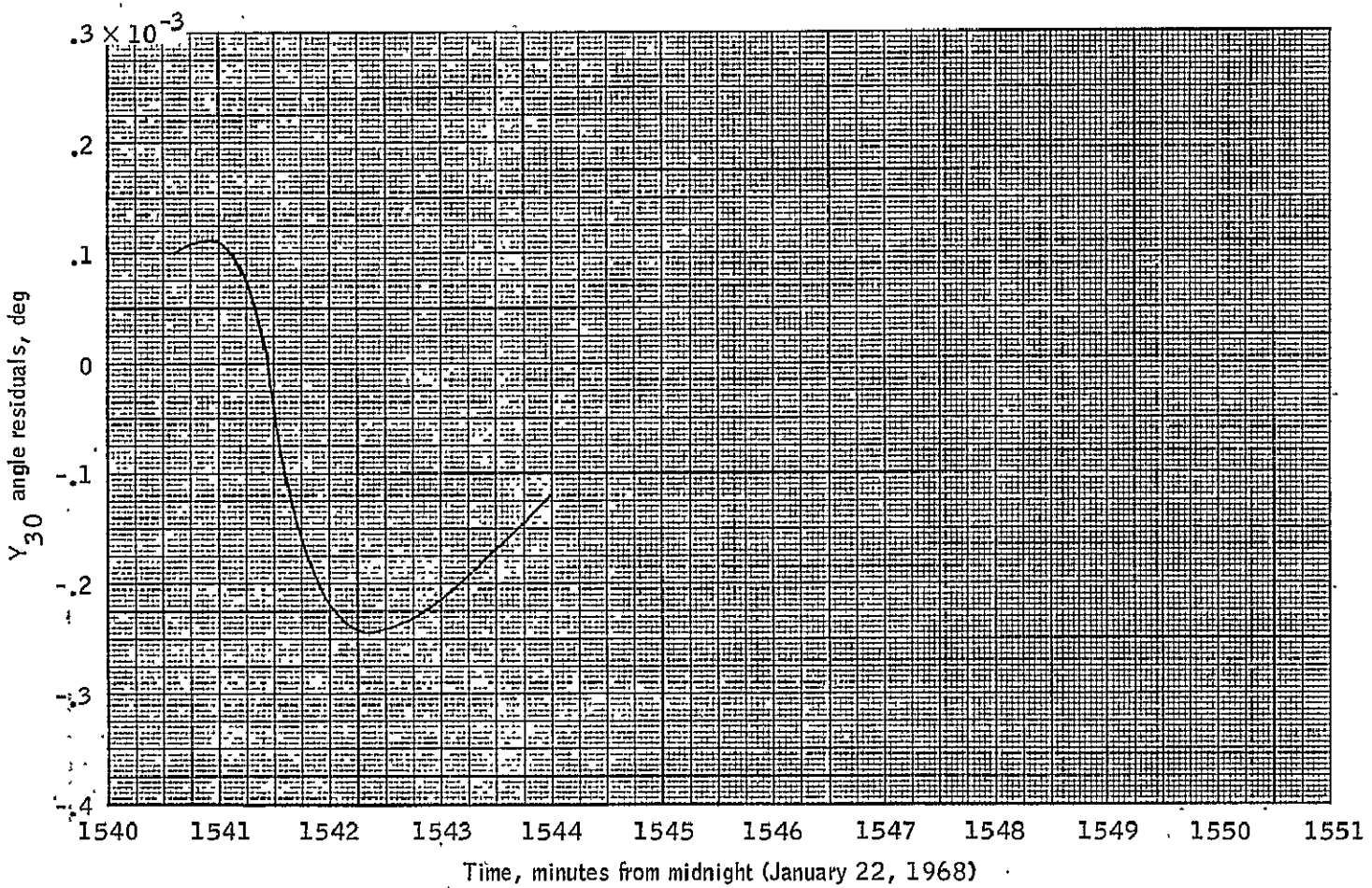
(l) Doppler residuals for -50-foot perturbation of altitude.

Figure 7.- Continued.



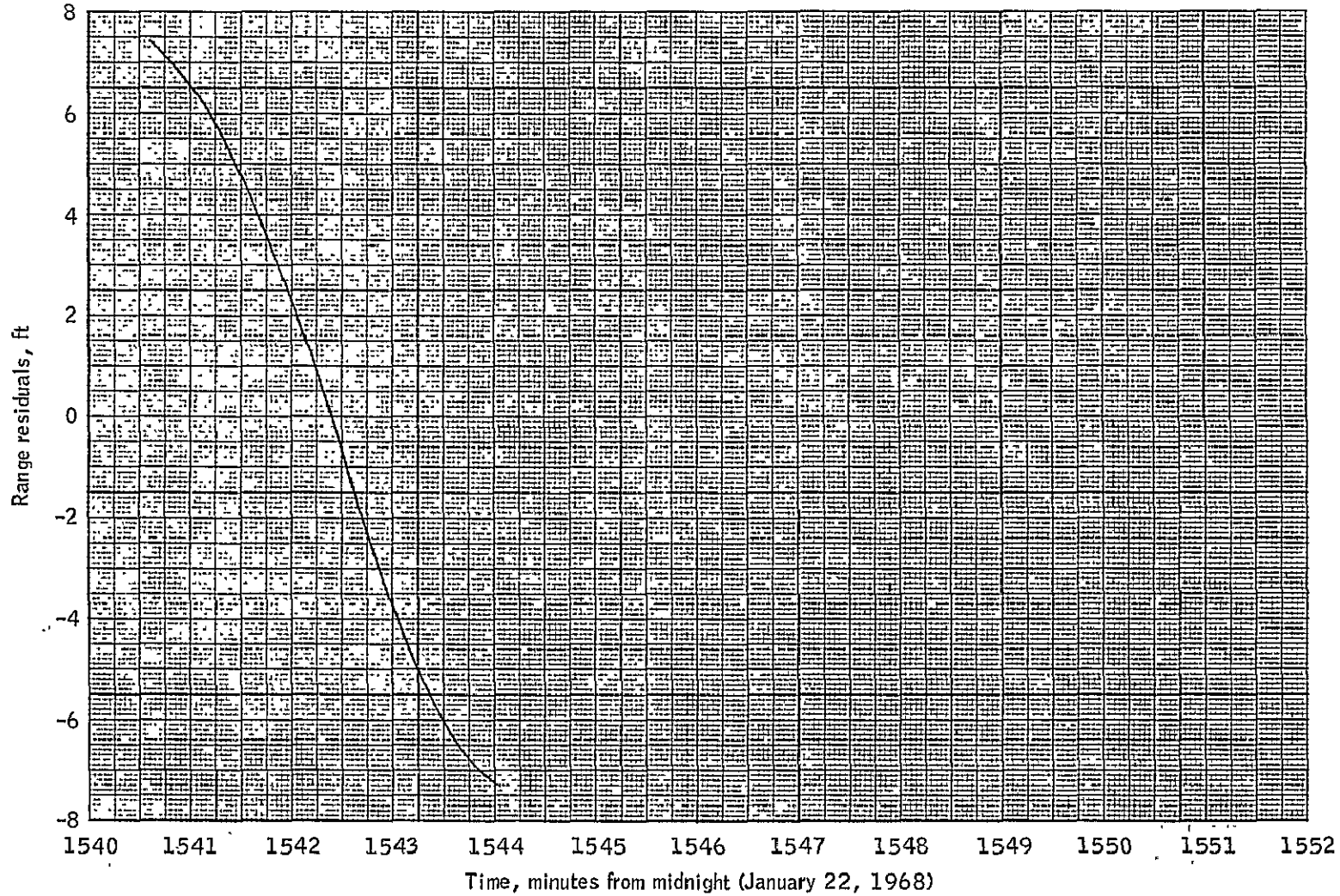
(m) X_{30} angle residuals for -.025-second perturbation of time.

Figure 7.- Continued.



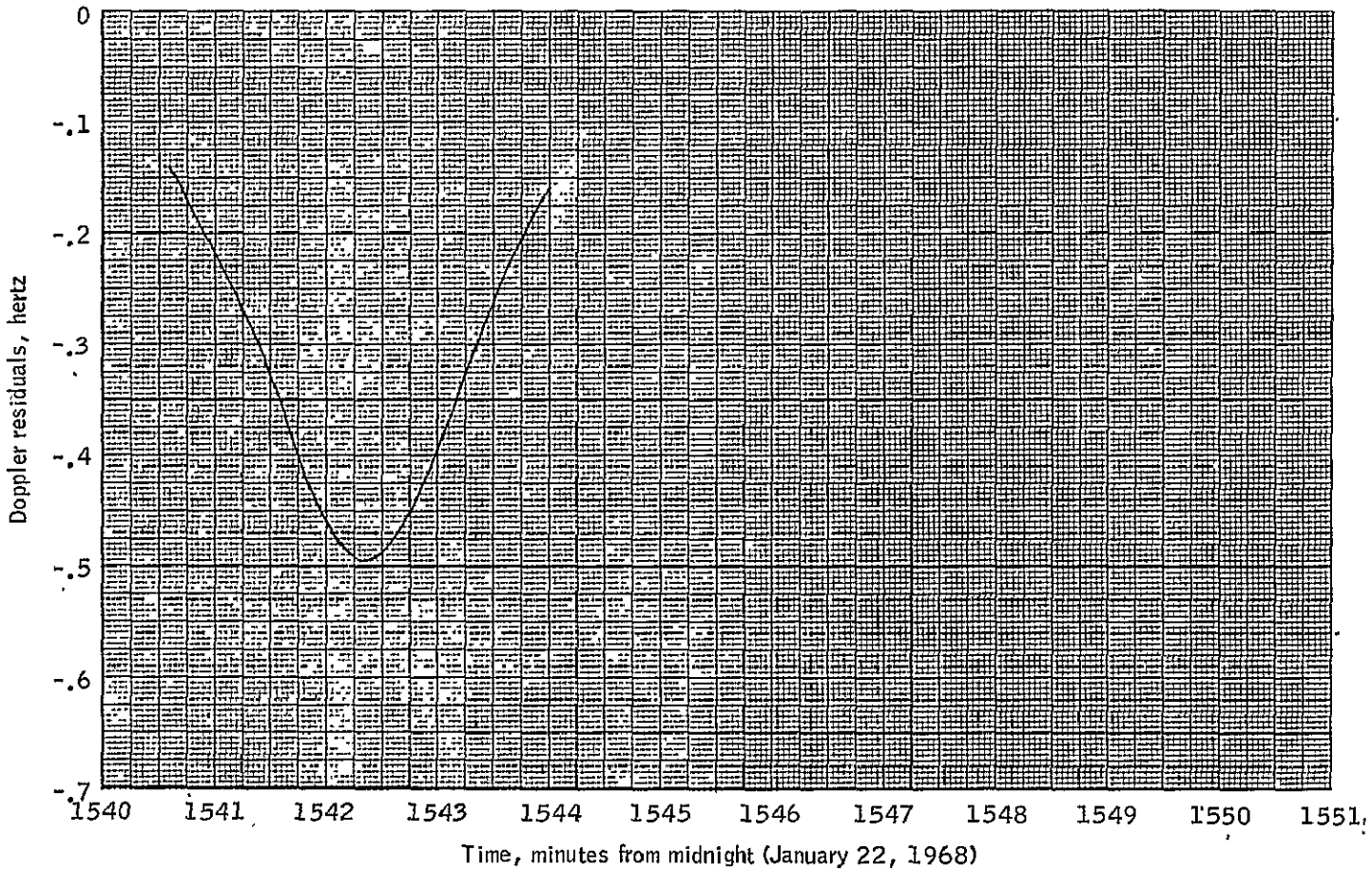
(n) Y_{30} angle residuals for -.025-second perturbation of time.

Figure 7.- Continued.



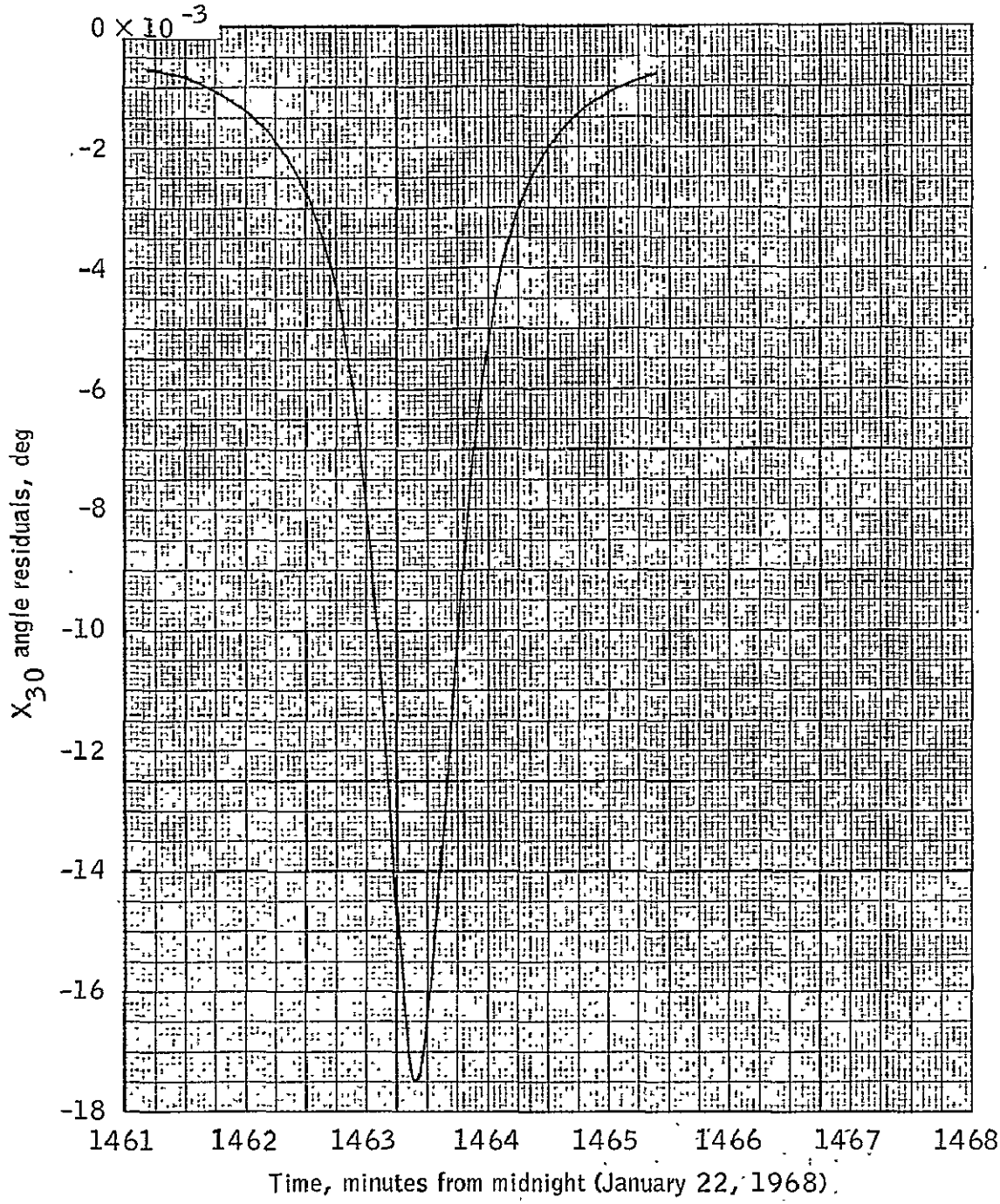
(o) Range residuals for -.025-second perturbation of time.

Figure 7.- Continued.



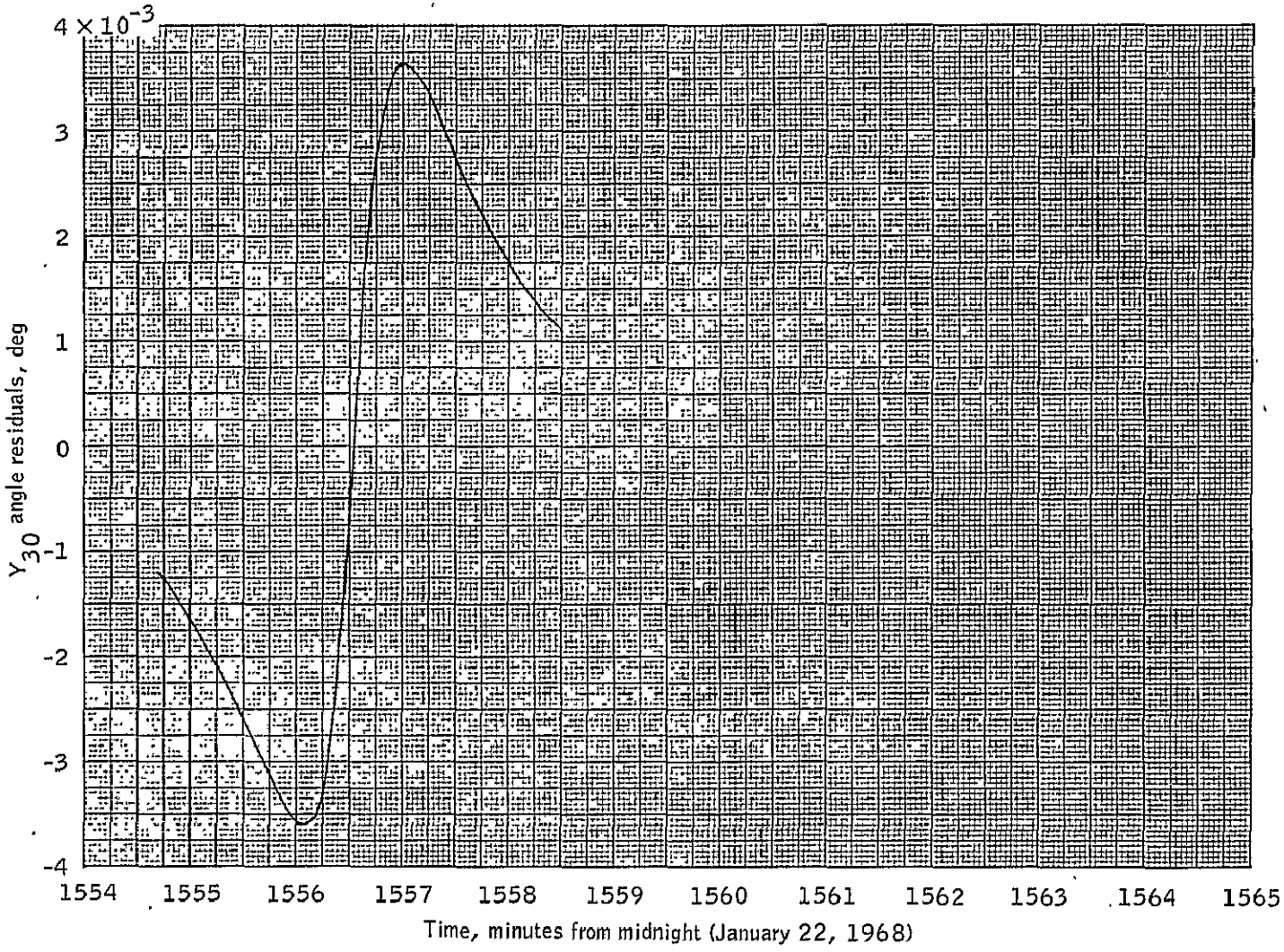
(p) Doppler residuals for -.025-second perturbation of time.

Figure 7.- Concluded.



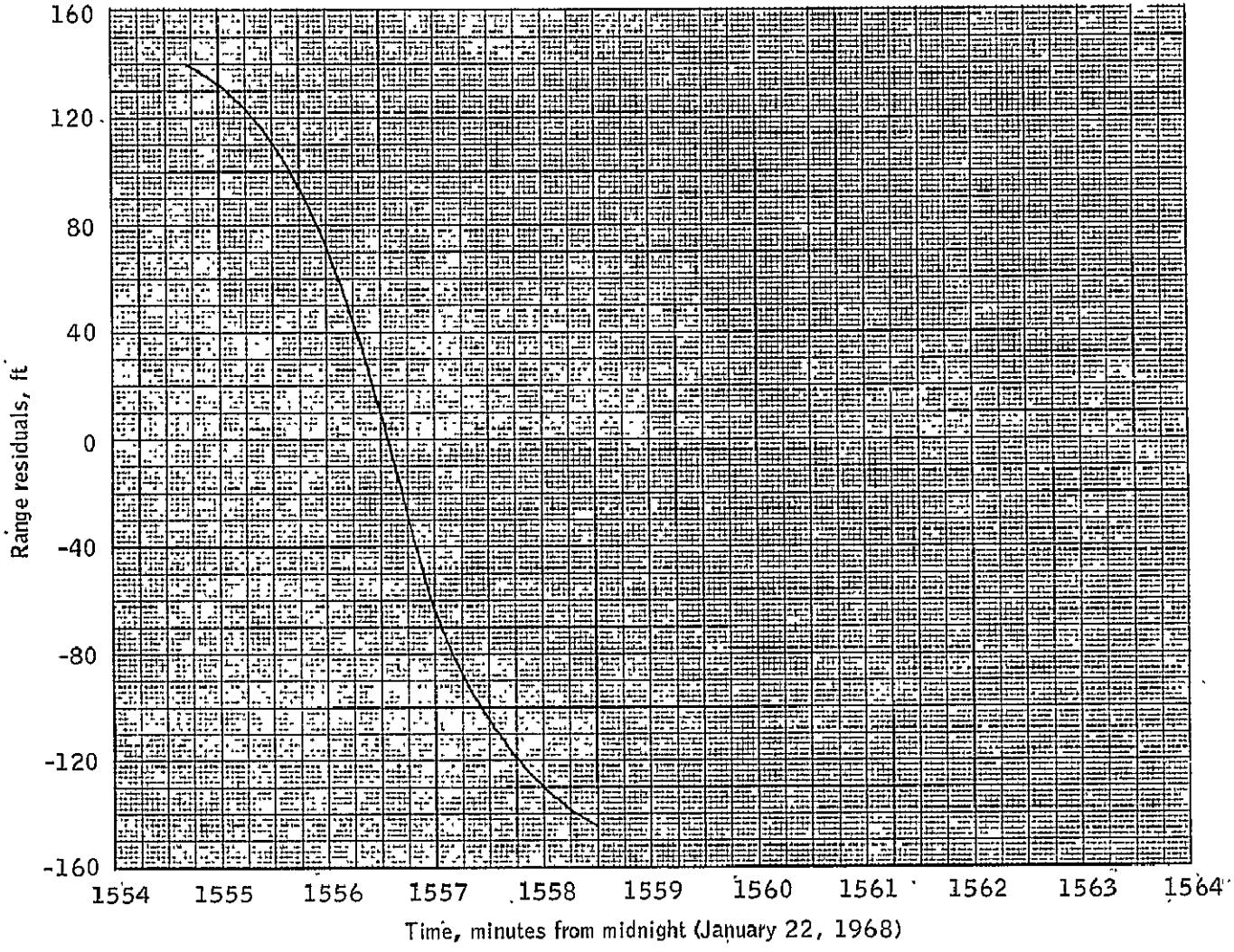
(a) X_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 8.- Residual patterns in USB data from the Texas tracking station.



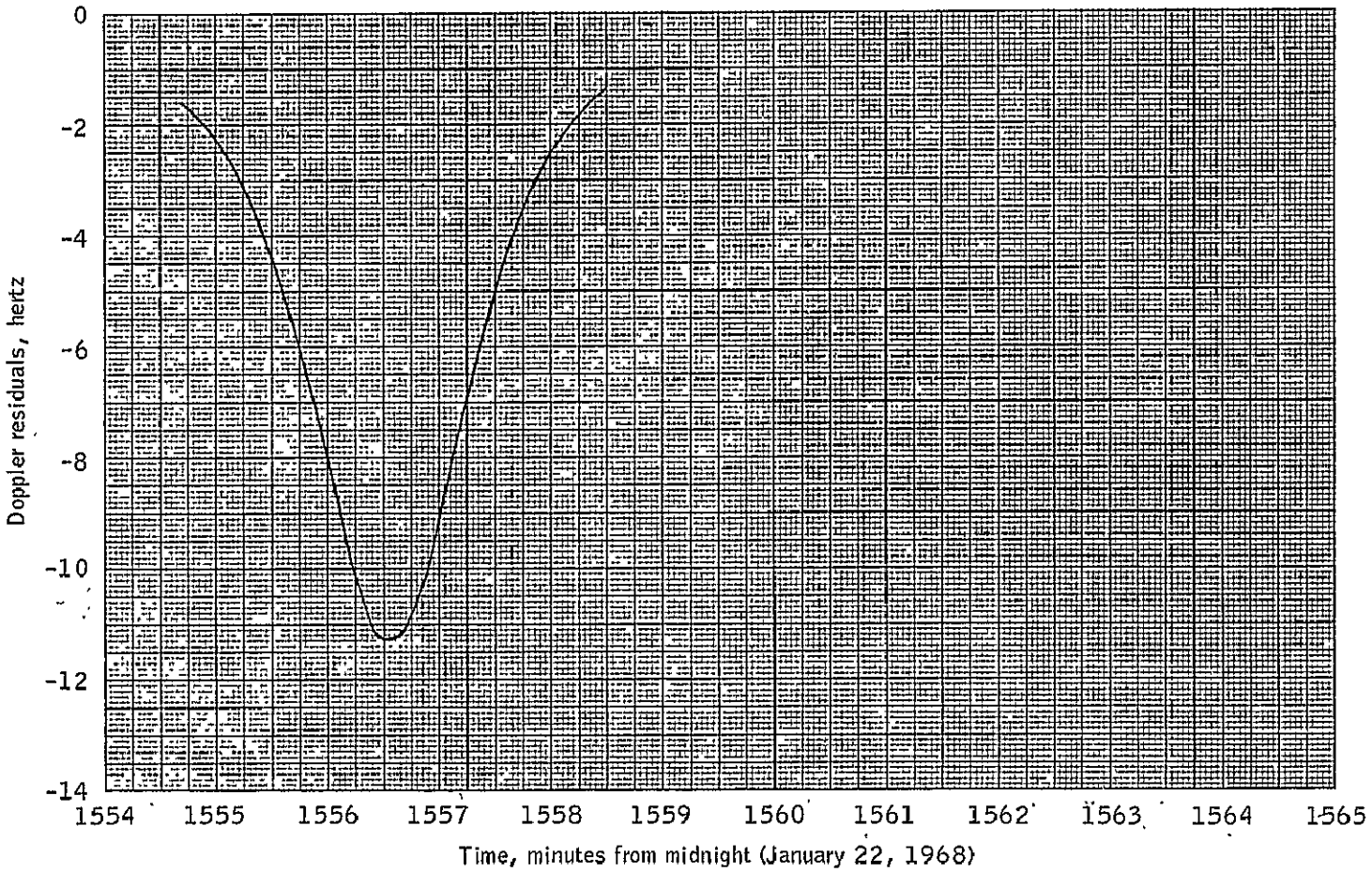
(b) Y_{30} angle residuals for -.0005-degree perturbation of longitude.

Figure 8.- Continued.



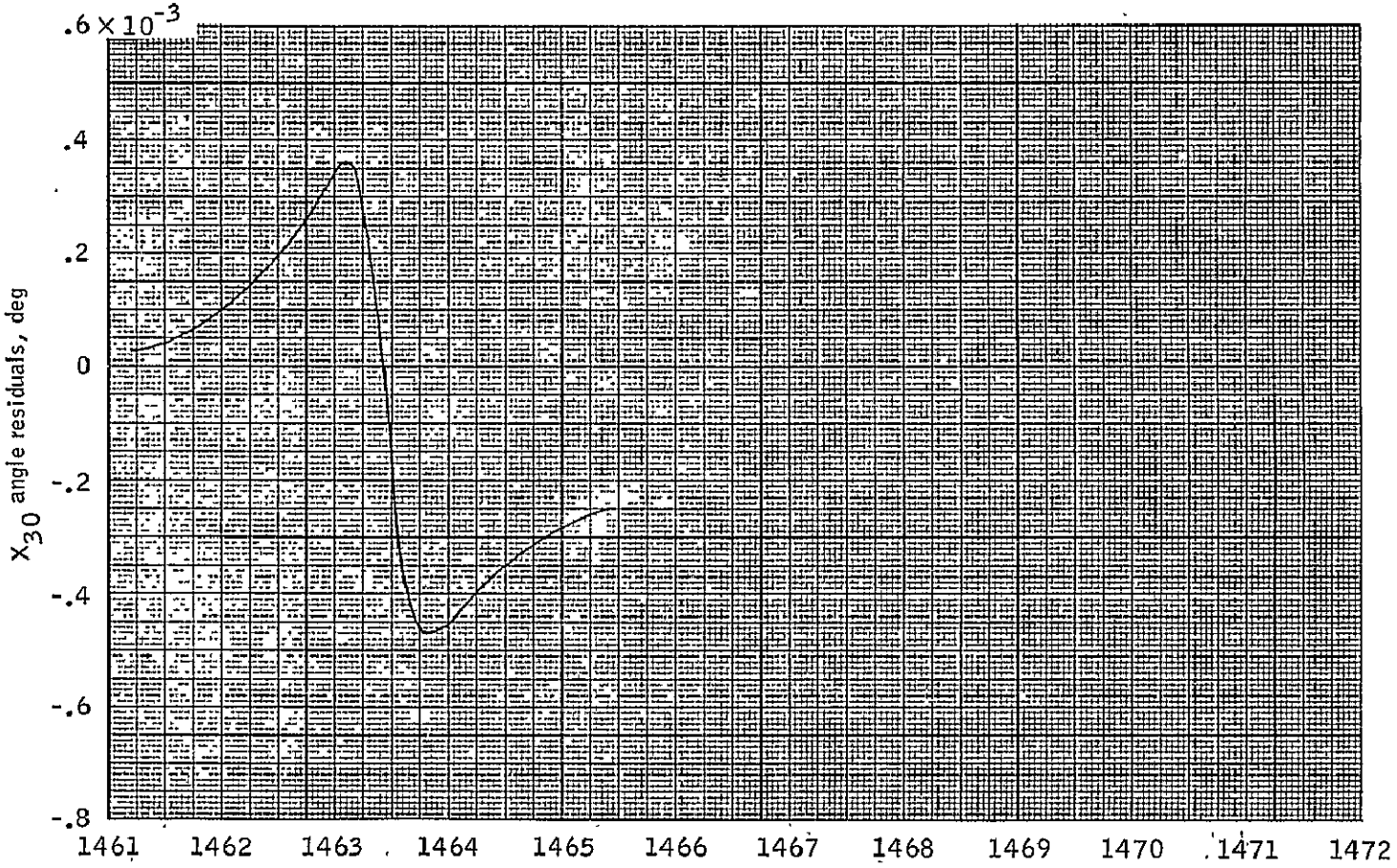
(c) Range residuals for -.0005-degree perturbation of longitude.

Figure 8.- Continued.



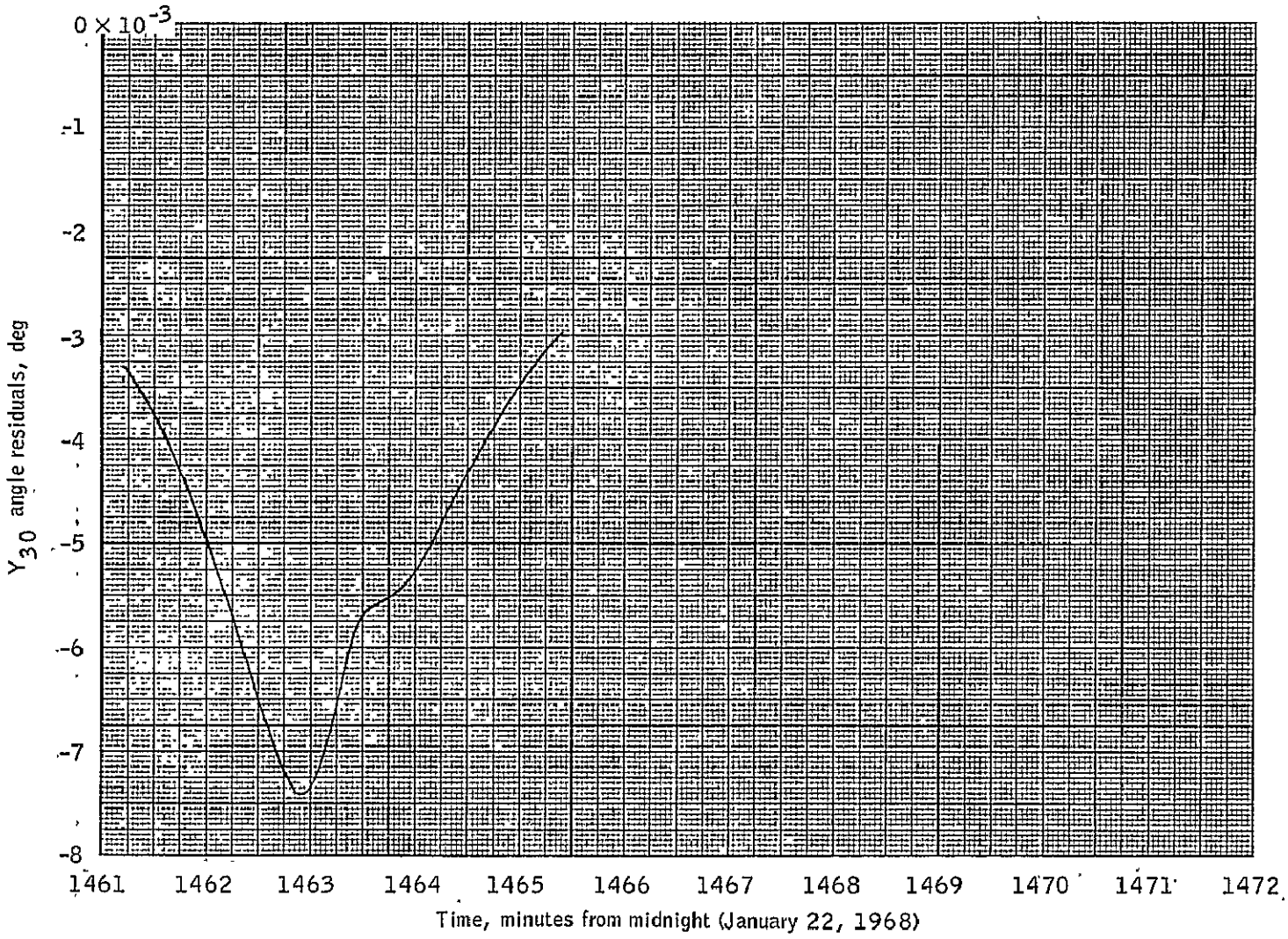
(d) Doppler residuals for -.0005-degree perturbation of longitude.

Figure 8.- Continued.



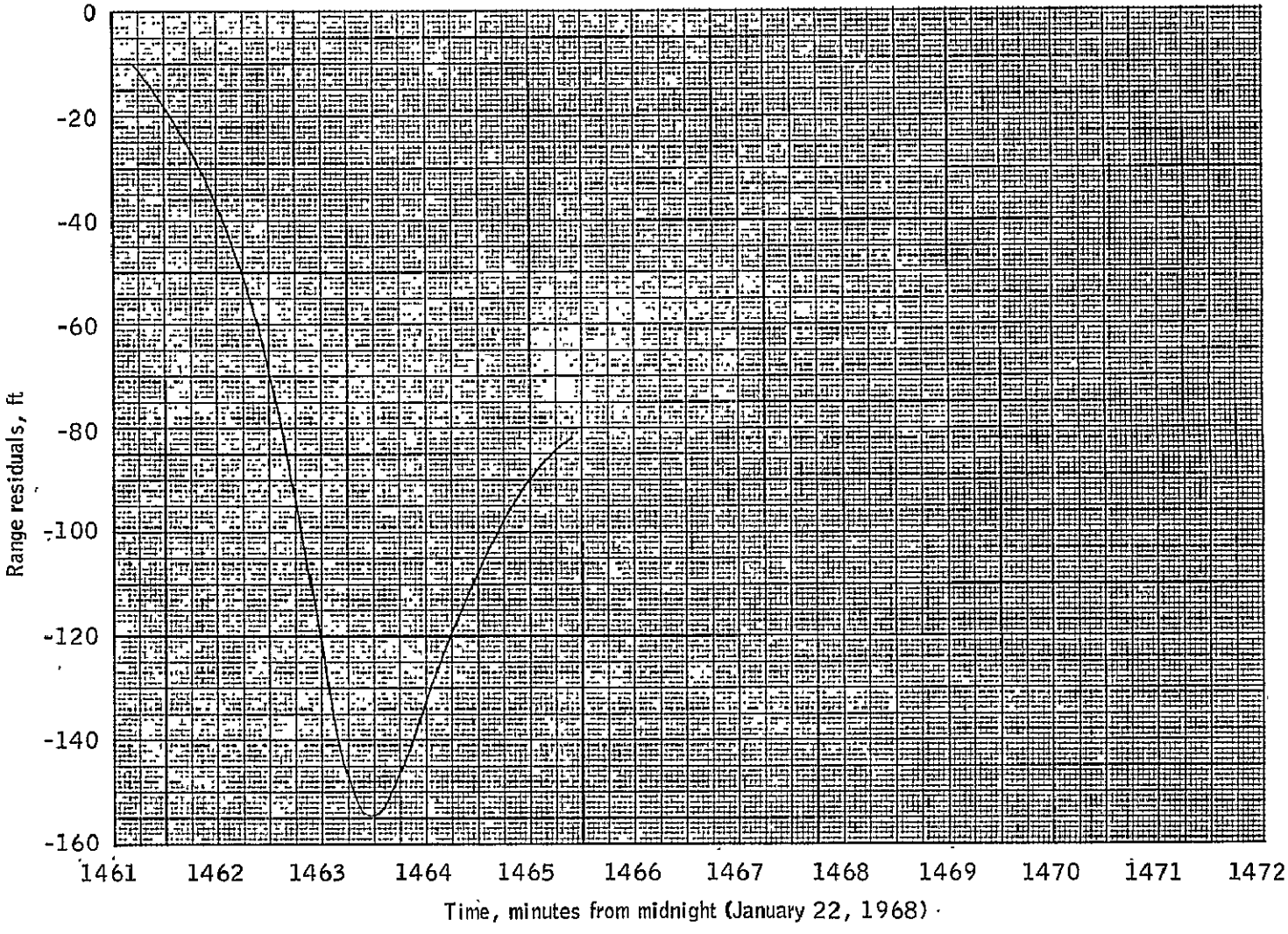
(e) X_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 8.- Continued.



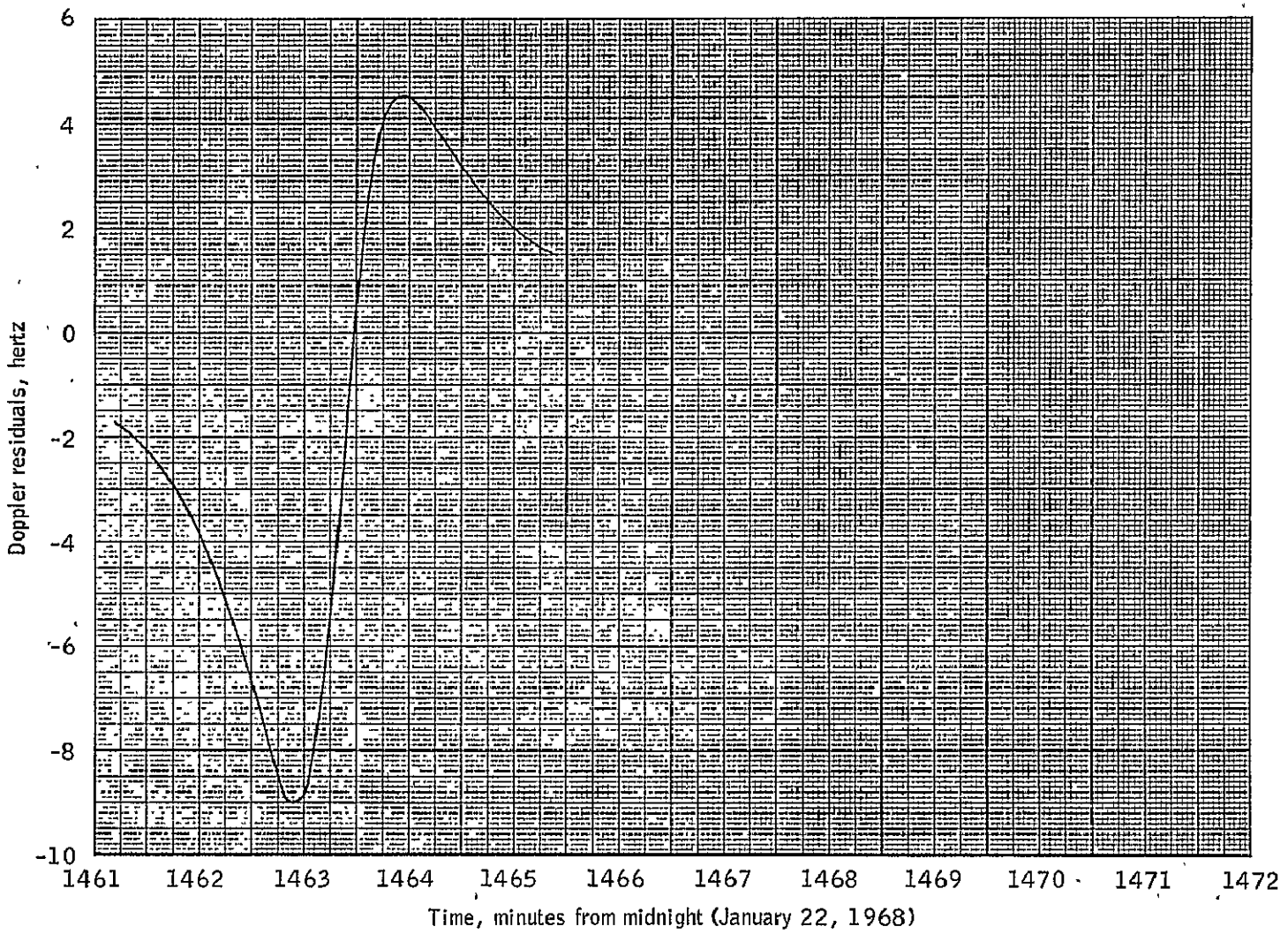
(f) Y_{30} angle residuals for -.0005-degree perturbation of latitude.

Figure 8.- Continued.



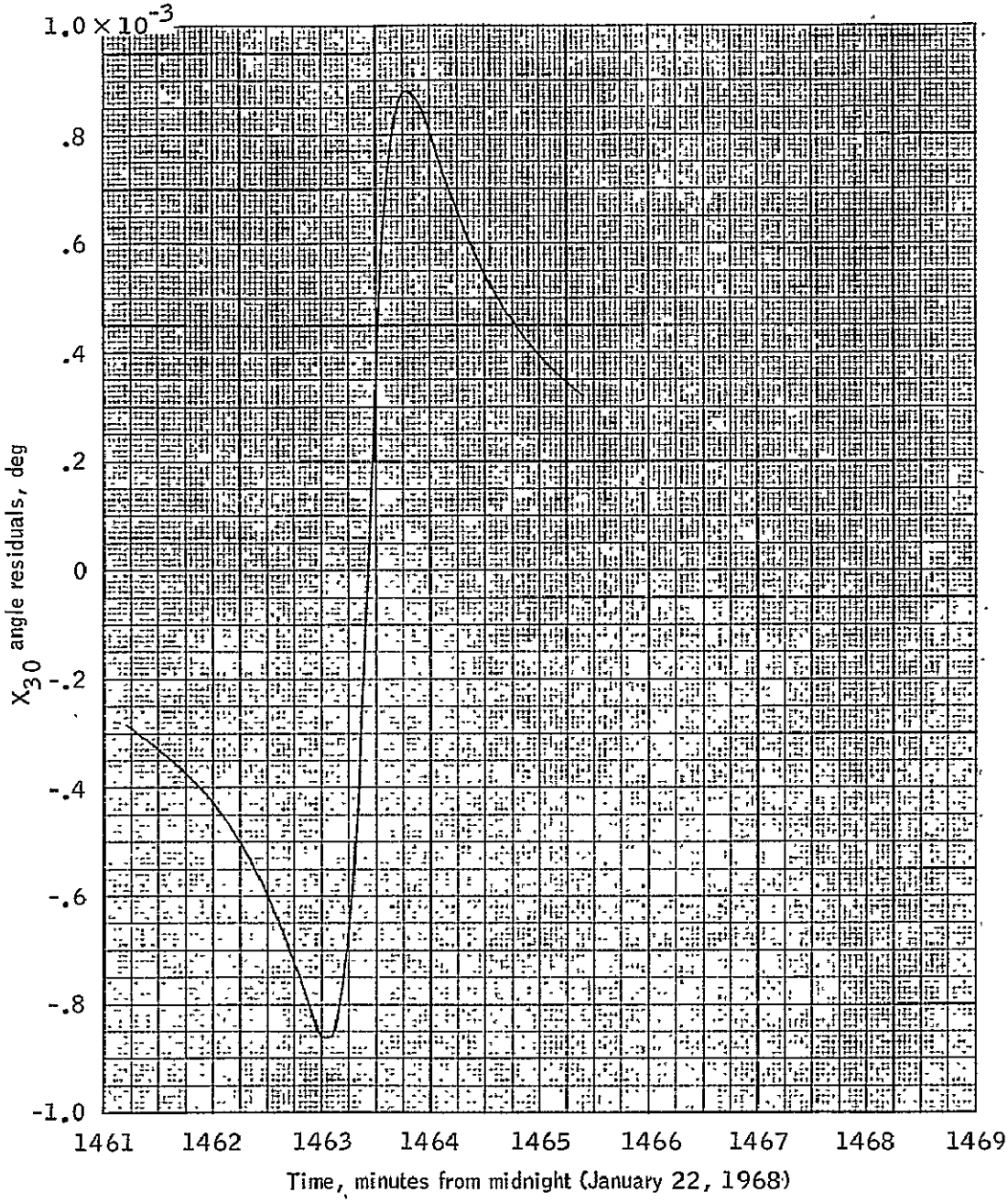
(g) Range residuals for -.0005-degree perturbation of latitude.

Figure 8.- Continued.



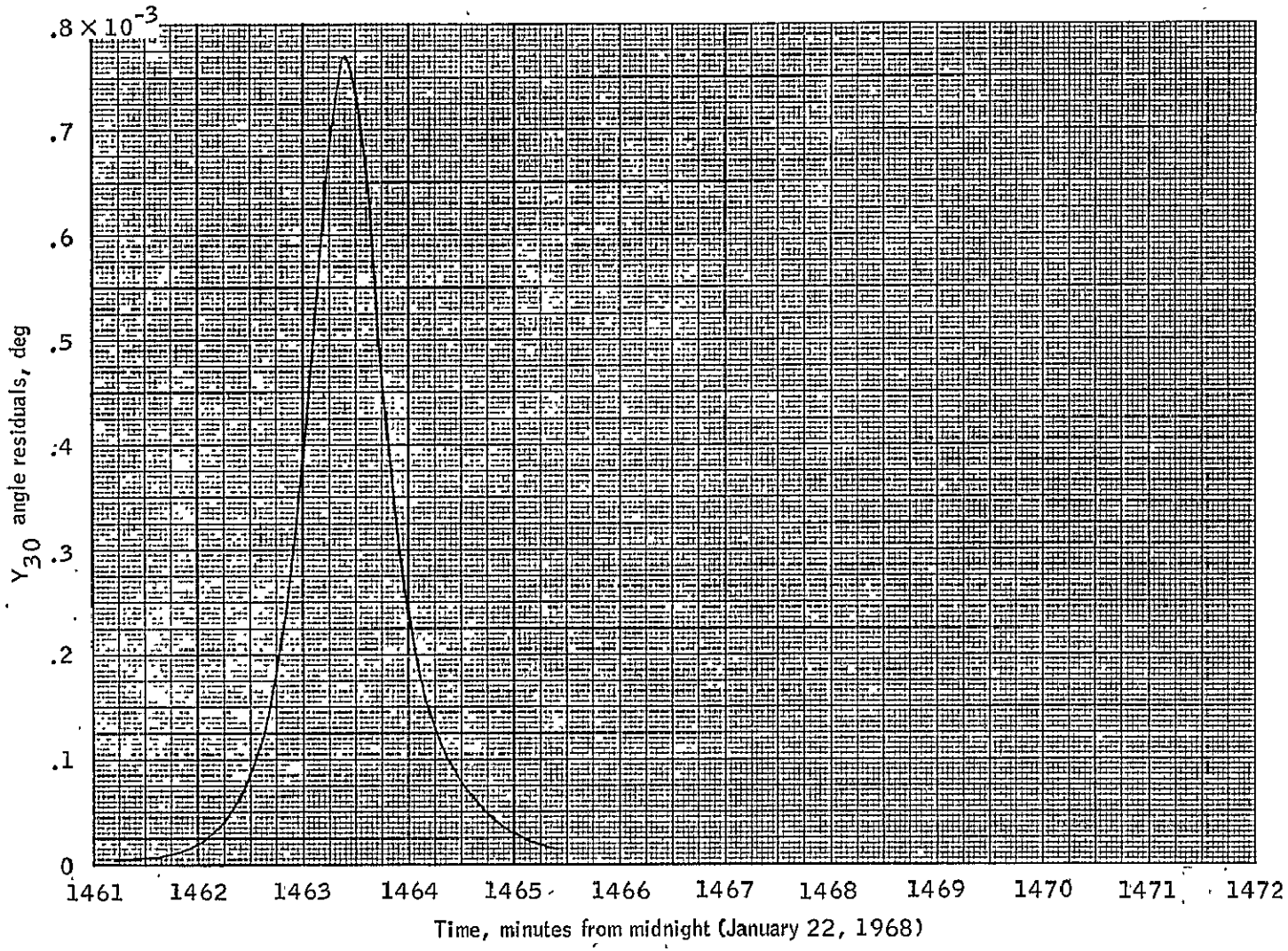
(h) Doppler residuals for -.0005-degree perturbation of latitude.

Figure 8.- Continued.



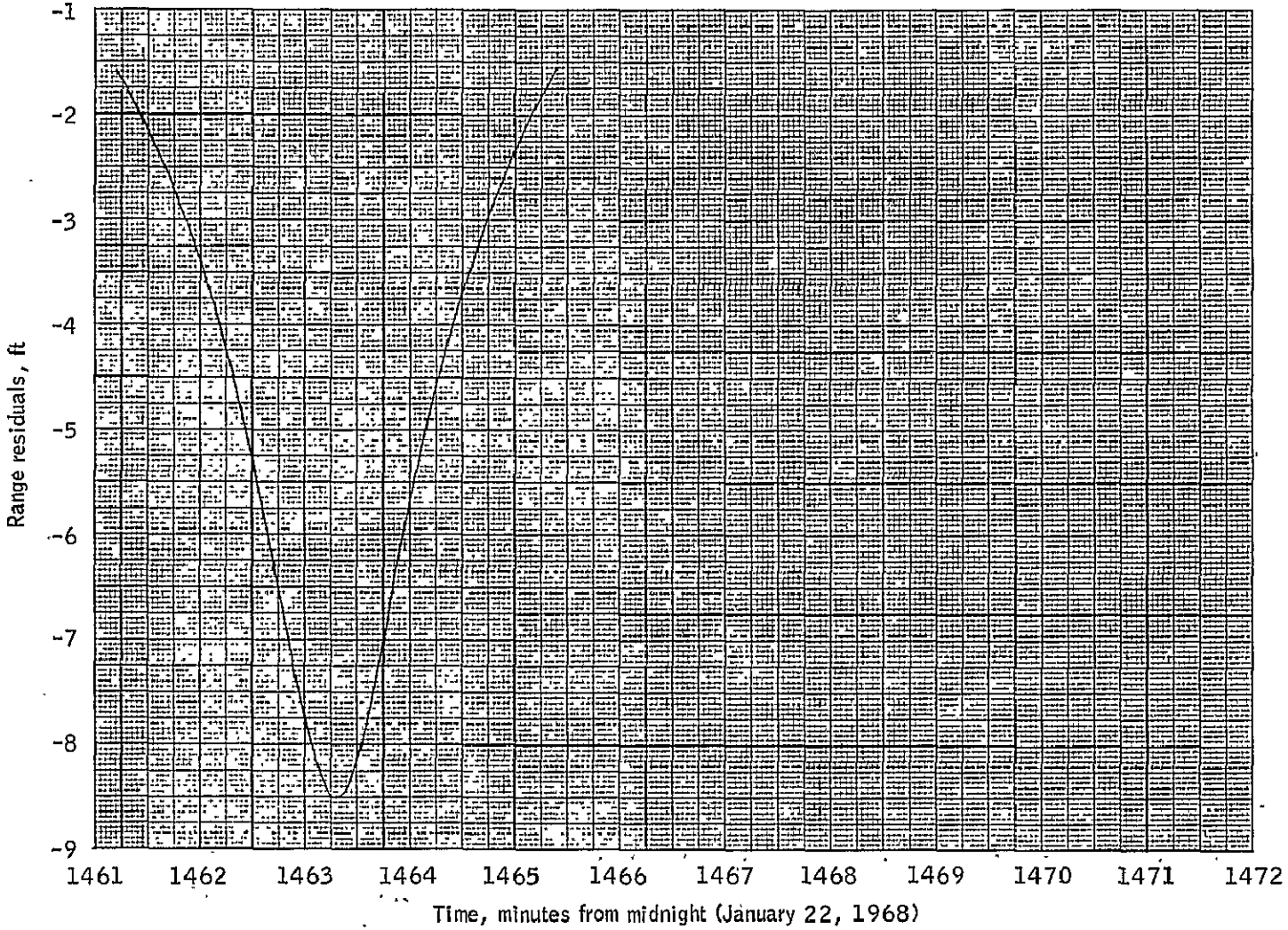
(i) X_{30} angle residuals for −50-foot perturbation of altitude.

Figure 8.- Continued.



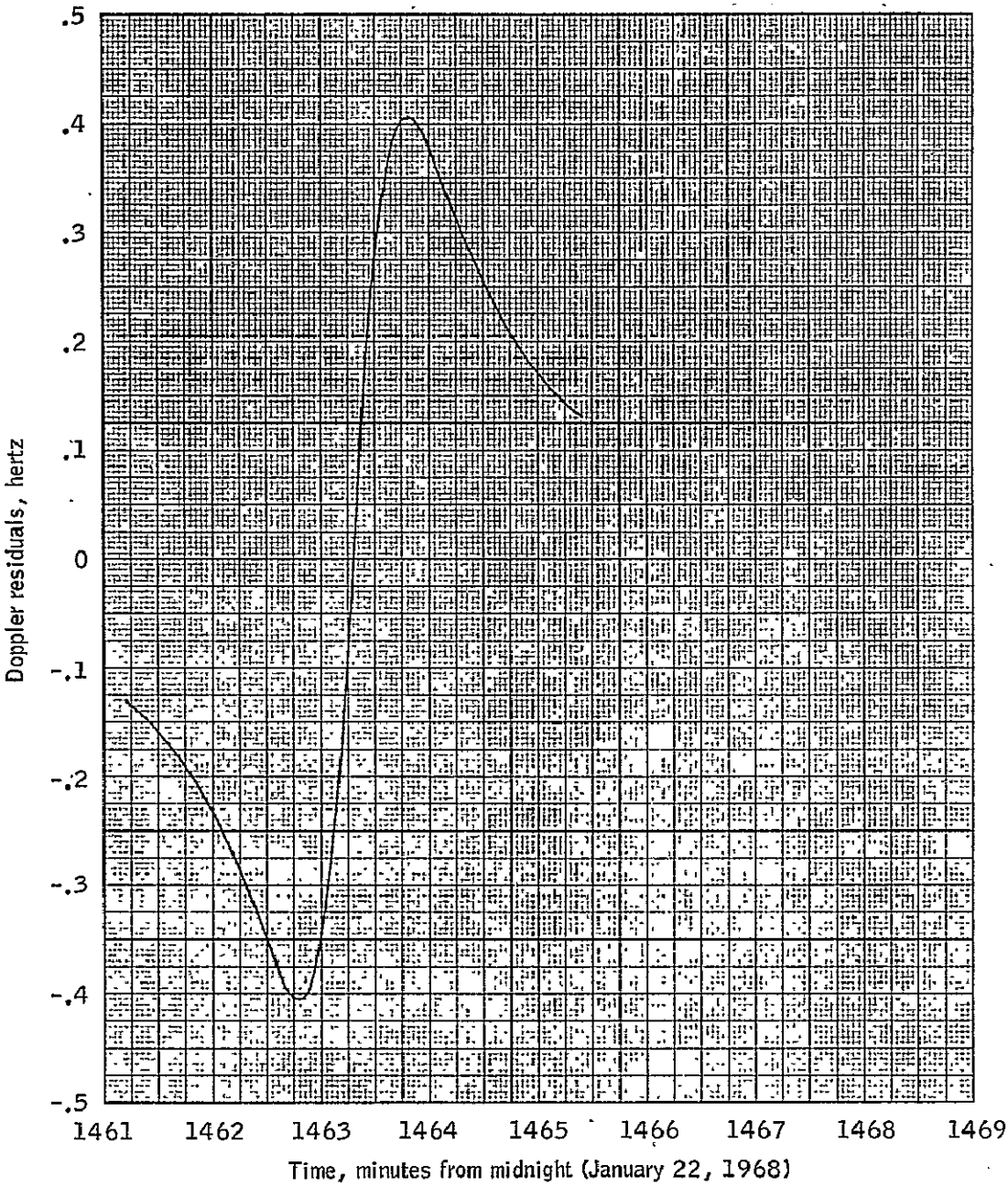
(j) Y_{30} angle residuals for -50-foot perturbation of altitude.

Figure 8.- Continued.



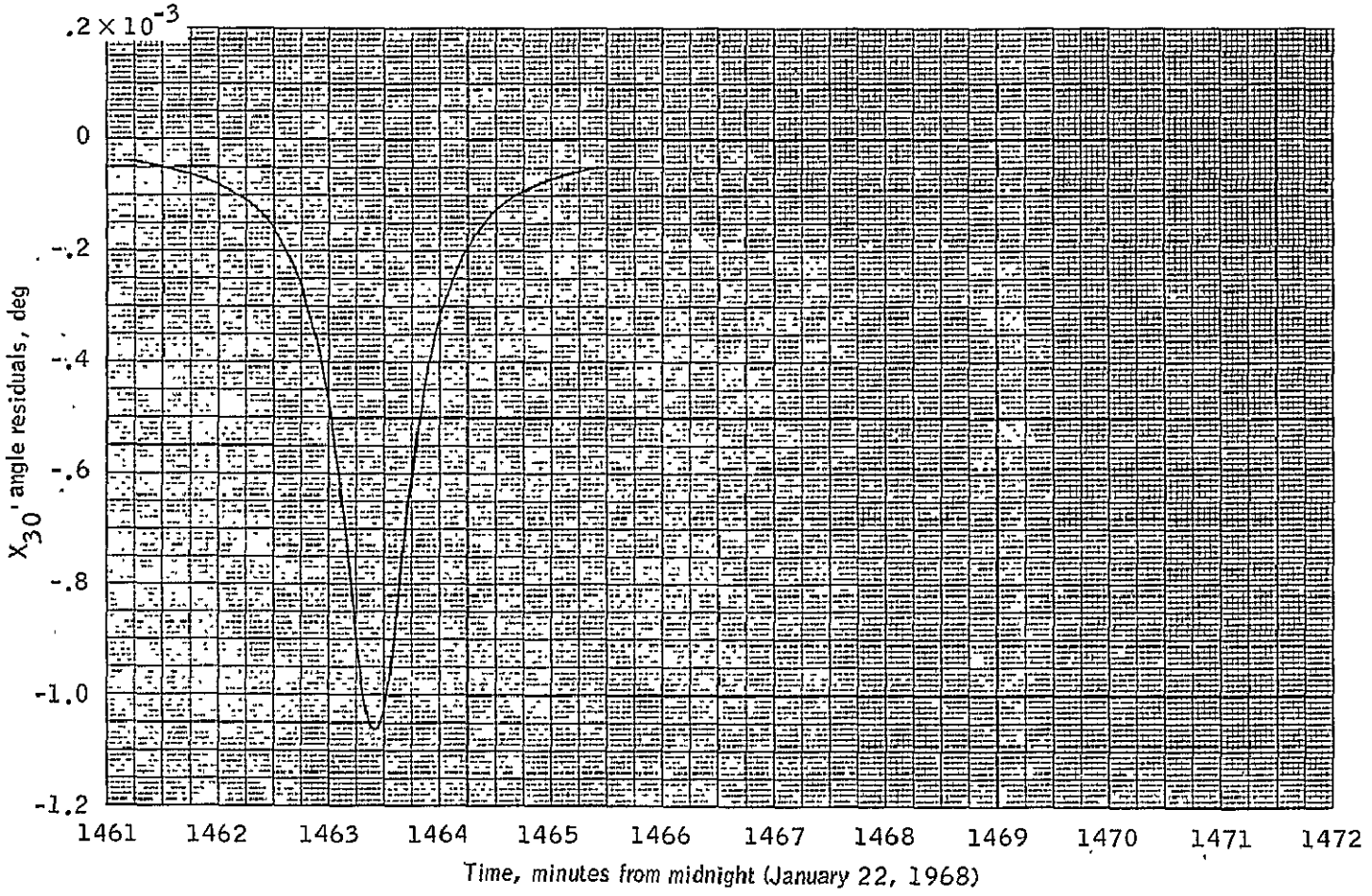
(k) Range residuals for -50-foot perturbation of altitude.

Figure 8.- Continued.



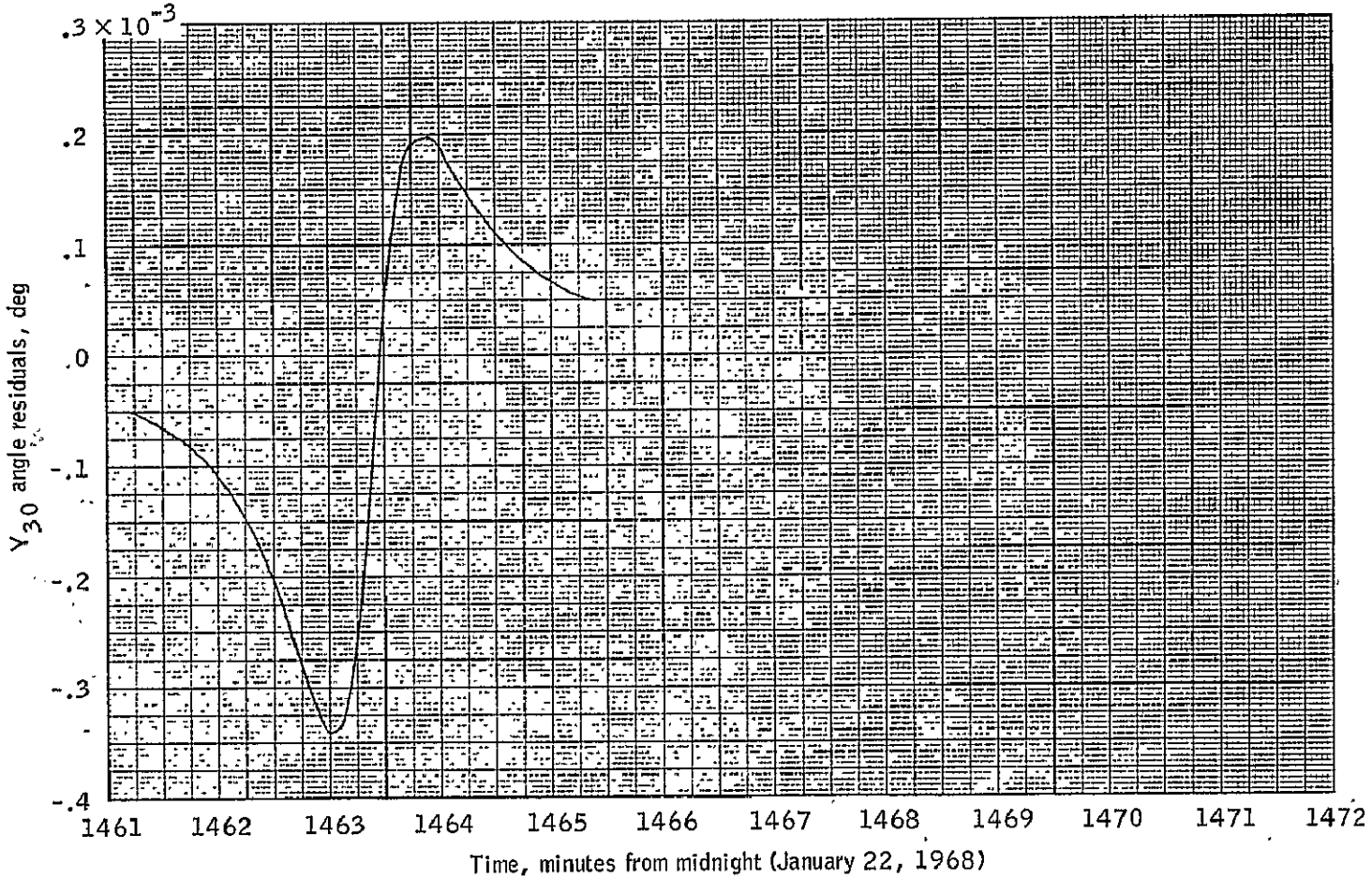
(l) Doppler residuals for -50-foot perturbation of altitude.

Figure 8.- Continued.



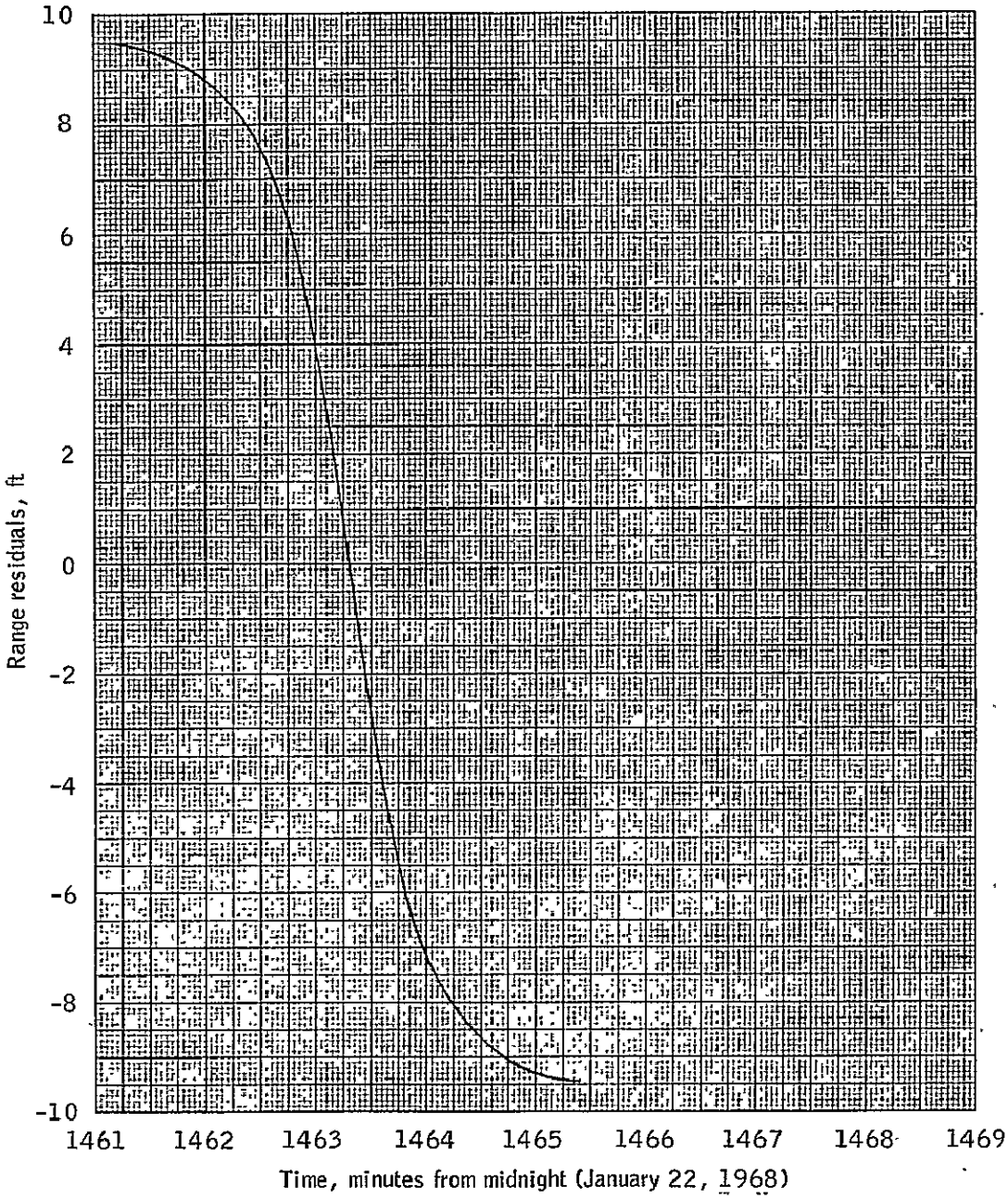
(m) X_{30} angle residuals for -.025-second perturbation of time.

Figure 8.- Continued.



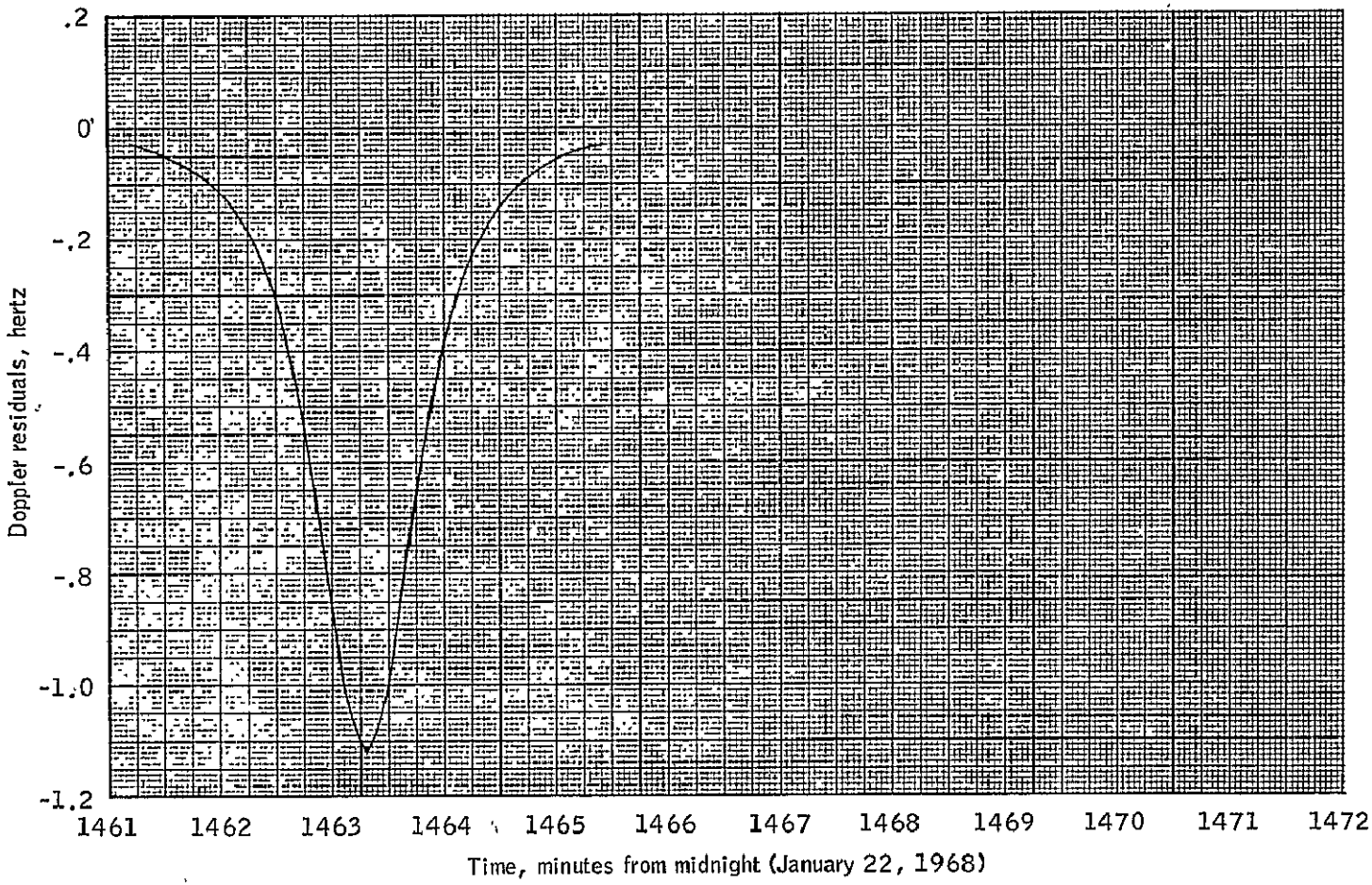
(n) Y_{30} angle residuals for -.025-second perturbation of time.

Figure 8.- Continued.



(o) Range residuals for -.025-second perturbation of time.

Figure 8.- Continued.



(p) Doppler residuals for -.025-second perturbation of time.

Figure 8.- Concluded.