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TIME SERIES ANALYSIS OF GUNNER
TRACKING ERROR

Nancy R. Rich, et al

Army Missile Command
Redstone Arsenal, Alabama

3 October 1973

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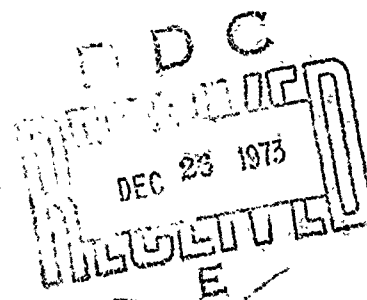
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TIME SERIES ANALYSIS OF GUNNER TRACKING ERROR

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U.S. ARMY MISSILE COMMAND

Redstone Arsenal, Alabama

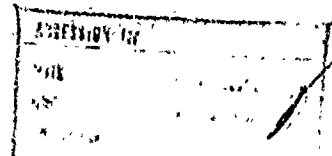
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1. Introduction

Successful prediction of the amount of error incurred in gunner tracking of a moving target has become an important phase in the development of weapon systems. A great deal of data in engineering, economics, and the natural sciences occurs in the form of time series where observations are dependent and where the nature of this dependence is of utmost importance.

The purpose of this report is to present an evaluation of the gunner error data described in Section 2, thereby defining a time series model. This model and its parameters can be used to simulate data for future problems of a similar nature or may be used as a subroutine to missile flight simulation.

2. Data Description

Tests to determine the gunner tracking error characteristics were conducted at Redstone Arsenal during the period 13 through 18 July 1972. The King Air, a twin engine Beechcraft, was the target utilized for these tests.

A 16mm film camera was attached to the monocular output of the tracker unit. This output presents the same view to the film camera as the binocular output presents to the gunner.

There were four gunners who participated in the tests. They were instructed to track the centroid to the target aircraft when details were not resolvable. When resolvable they were to track the intersection at the wing and fuselage. The amount of error was shown to be independent of individual gunner, that is, there was no statistical significance.

3. Model Building

This section discusses the time series model building for the gunners' error data. After examining all the data available, we conclude that the data forms a stationary time series except at the beginning where a transient occurs during acquisition, and at the end where a transient is introduced by the simulated missile in flight signal. Runs with too few data were eliminated. The total number of runs was then 143. A few nonstationary data can also be seen. They occupy 13.29 percent of the total.

When the data are recorded with equally spaced time intervals, we generally use a linear time series model to fit the data. A commonly used model for univariate time series can be written as

$$Y_t - \mu = \phi_1(Y_{t-1} - \mu) + \phi_2(Y_{t-2} - \mu) + \dots + \phi_p(Y_{t-p} - \mu) + a_t - \theta_1 a_{t-1} - \dots - \theta_q a_{t-q} \quad (1.1)$$

where

subscript t = time

Y_t = the value of the time series at time t

μ = the expected value of Y_t

a_t = a white noise process, i.e., a_t is independent, identically distributed $N(0, \sigma_a^2)$

p, q = two parameters depending on the properties of a particular time series.

Model (1.1) is called a mixed model with autoregressive and moving average components. It has been widely used in practice with fruitful results (see e.g., Box and Jenkins [1], Fuller and Tsokos [2], Cleveland [3, 4], and Box et al [5]). The intuitive idea behind the model (1.1) is the assumption that the present value Y_t depends on the values of Y_t in the near past, i.e., $Y_{t-1}, Y_{t-2}, \dots, Y_{t-p}$. This is the autoregressive component

$$(Y_t - \mu) = \phi_1(Y_{t-1} - \mu) + \phi_2(Y_{t-2} - \mu) + \dots + \phi_p(Y_{t-p} - \mu)$$

The moving average component $a_t - \theta_1 a_{t-1} - \dots - \theta_q a_{t-q}$ indicates that the present value Y_t depends not only on the present noise a_t , but also the previous noise $a_{t-1}, \dots, a_{t-q}$. This is reasonable since the noise will not diminish very rapidly in real situations. The noise prolongs its influence on Y_t for a certain period.

In practice when time series data are given, a model of the form (1.1) can generally be built. The detailed procedure has been given in Box and Jenkins [1]. There are four main steps.

a. Model Identification

In this first step, autocorrelation coefficients, partial autocorrelation coefficients, and inverse correlation coefficients (e.g., Cleveland [3]) are used to determine the values of p and q in

model (1.1). The value p is called the order of the autoregressive component and the value q is called the order of the moving average component in a mixed model (1.1).

b. Parameter Estimation

After the values of p and q have been determined, there are $p + q + 2$ parameters: $\mu, \phi_1, \phi_2, \dots, \phi_p, \theta_1, \dots, \theta_q$ and the variance σ_a^2 of a_t to be determined. The method used to estimate ϕ 's and θ 's has been described in Box and Jenkins (Chapter 7, [1]), Clevenston [6], and Parzen [7]. The main technique is the maximum likelihood estimation. Generally, the calculation needs the help of spectral density estimation [7] or nonlinear least squares estimation [1].

c. Diagnostic Checking

The estimated values $\hat{\mu}, \hat{\phi}, \hat{\theta}$, and $\hat{\sigma}_a^2$ of the parameters μ, ϕ, θ , and σ_a^2 , respectively, are not generally equal to the real value of these parameters. The model with estimated parameters

$$\begin{aligned} (Y_t - \hat{\mu}) &= \hat{\phi}_1 (Y_{t-1} - \hat{\mu}) + \dots + \hat{\phi}_p (Y_{t-p} - \hat{\mu}) + a_t - \hat{\theta}_1 a_{t-1} \\ &\quad - \dots - \hat{\theta}_q a_{t-q} \end{aligned} \quad (1.2)$$

may not fit the original data well. Diagnostic checking determines whether our estimated model fits the data well. The residual process $\{\hat{a}_t\}$ is examined. If the $\{\hat{a}_t\}$ is close to a white noise process, the model is considered to be adequate and the whole model building procedure is over. Otherwise, we go to the next step.

d. Modification of the Model

If the model we built is found inadequate through the diagnostic checking, we will try to fit the data by a new modified model. Generally, the residual process $\{\hat{a}_t\}$ will reveal some information on how the model should be rebuilt. In most cases, a pair of new values of p and q will be obtained. Using these new values of p and q , we undergo steps b., c., and d. for this new model building.

All the four steps have been carefully followed for building the gunners' error data model. For the (apparently) stationary time series, with azimuth and elevation both counted, the total number of realizations

was 248. Each time series of azimuth and elevation is run separately (Tables 1 and 2). Sixty-two percent of the stationary series can be fitted well by a third order autoregressive process [$p = 3$, $q = 0$ in model (1.1)], i.e.,

$$Y_t - \mu = \phi_1(Y_{t-1} - \mu) + \phi_2(Y_{t-2} - \mu) + \phi_3(Y_{t-3} - \mu) + a_t \quad (1.3)$$

A few data can not be fitted well by (1.3); they are fitted by a more complicated model. These models and their percentages of the total data are given in Table 1. Due to the biological and psychological differences among gunners, there are variations in these parameters. The means and variances of these parameters are also given in Table 1.

TABLE 1. GUNNER'S ERROR MODEL FOR AZIMUTH

General model (3rd order autoregressive process) (62.90%)					
	μ	ϕ_1	ϕ_2	ϕ_3	σ_a^2
Mean	0.0393	0.4489	0.2362	0.1245	0.0128
Variance	0.0108	0.0170	0.0066	0.0087	0.0001
Special Model					
			Mean	Variance	
1) $\phi_4 \neq 0$	(17.74%)		0.1490	0.0050	
2) $\phi_5 \neq 0$	(4.84%)		0.0962	0.0076	
3) $\phi_6 \neq 0$	(5.65%)		0.0485	0.0189	
4) $\phi_7 \neq 0$	(3.22%)		0.1218	0.0060	
5) $\phi_8 \neq 0$	(0.81%)		0.1844	0.0000	
6) $\phi_9 \neq 0$	(2.42%)		0.0196	0.0142	
7) $\phi_{10} \neq 0$	(1.61%)		0.0568	0.0145	
8) $\phi_{11} \neq 0$	(0.81%)		0.0970	0	

TABLE 2. GUNNER'S ERROR MODEL FOR ELEVATION

General model (3rd order autoregressive process) (60.48%)					
	μ	ϕ_1	ϕ_2	ϕ_3	σ_a^2
Mean	-0.0515	0.3692	0.2165	0.1448	0.0045
Variance	0.0124	0.0188	0.0051	0.0057	0.0001
Special Model					
			Mean	Variance	
1) $\phi_4 \neq 0$	(15.32%)		0.1535	0.0014	
2) $\phi_5 \neq 0$	(8.87%)		0.1255	0.0088	
3) $\phi_6 \neq 0$	(7.25%)		0.1125	0.0039	
4) $\phi_7 \neq 0$	(4.84%)		0.1221	0.0087	
5) $\phi_8 \neq 0$	(0.81%)		0.1497	0	
6) $\phi_9 \neq 0$	(0.81%)		0.1204	0	
7) $\phi_{10} \neq 0$	(0.81%)		0.1178	0	
8) $\phi_{11} \neq 0$	(0.81%)		0.0573	0	

A question arises whether the azimuth error and elevation error are dependent on each other during a gunner's aiming. The data show that we can consider the azimuth error and elevation error to be two independent processes. The following procedure is followed.

A general model describing the relation between two time series is a linear transfer function model. Let X_t be the time series of azimuth and Y_t be the time series of elevation. A linear transfer function model can be written as

$$\begin{aligned}
 (Y_t - \mu_y) = & \alpha_1(Y_{t-1} - \mu_y) + \dots + \alpha_m(Y_{t-m} - \mu_y) \\
 & + \beta_1(X_{t-1} - \mu_x) + \dots + \beta_n(X_{t-n} - \mu_x) + N_t
 \end{aligned}
 \tag{1.4}$$

where

$$\mu_y = E(Y_t)$$

$$\mu_x = E(X_t)$$

$$N_t = \text{a noise process}$$

m, n = the numbers of past values of X_t and Y_t on which the present Y_t depends.

Intuitively, model (1.4) indicates that the present azimuth value Y_t may depend on the previous values of both azimuth and elevation. This model has been used in many practical situations and gives good results (see e.g., Box and Jenkins [1]). Since we have already found a good model for Y_t in the previous model buildings, we may combine the Y model and (1.4) and have

$$a_t = \beta_1(X_{t-1} - \mu_x) + \dots + \beta_n(X_{t-n} - \mu_x) + N_t \quad (1.5)$$

where a_t is the noise process from the model of Y_t . Since a_t is a white noise process, the values β 's can be easily estimated (Box and Jenkins [1] p. 380).

An attempt has been made to fit all the corresponding pairs of azimuth error data and elevation error data by model (1.4). Except for a few exceptions (1 percent of the total), the β values are very small (less than 0.05 for all $\beta_1, \beta_2, \dots, \beta_{25}$). Hence, we consider that the error in elevation has no significant influence on that in azimuth. A similar model fitting by replacing X by Y and Y by X in (1.4) has also been run for all pairs of data. An independence relation is also obtained here. Hence, we conclude that there is no significant dependence between azimuth error and elevation error.

4. Simulation Procedure

In order to simulate the total performance of a guided missile system with a man in the loop, we may use the gunner's model described in the previous section. Considering the nonrepeatability of man's reactions, it must be realized that for any single simulation the error model will not give the same results as given by man. However, man's behavior on the average should agree with that of the error mode.

Simulation of a gunner's behavior may be performed as follows:

a). Choose 2 random numbers γ_1 and γ_2 in $[0, 1]$. γ_1 is used to construct azimuth error, if

$\gamma_1 \in [0, 0.6290]$, a third order autoregressive model will be used,

$\gamma_1 \in [0.6291, 0.8064]$, a fourth order autoregressive model with $\phi_4 \neq 0$ will be used,

$\gamma_1 \in [0.8065, 0.8548]$, a fifth order autoregressive model with $\phi_5 \neq 0$ will be used,

$\gamma_1 \in [0.8549, 0.9113]$, a sixth order autoregressive model with $\phi_6 \neq 0$ will be used,

$\gamma_1 \in [0.9114, 0.9435]$, a seventh order autoregressive model with $\phi_7 \neq 0$ will be used,

$\gamma_1 \in [0.9436, 0.9516]$, an eighth order autoregressive model with $\phi_8 \neq 0$ will be used,

$\gamma_1 \in [0.9517, 0.9758]$, a ninth order autoregressive model with $\phi_9 \neq 0$ will be used,

$\gamma_1 \in [0.9759, 0.9919]$, a tenth order autoregressive model with $\phi_{10} \neq 0$ will be used,

$\gamma_1 \in [0.9920, 1.00]$, an eleventh order autoregressive model with $\phi_{11} \neq 0$ will be used.

Thus, we have chosen a model for azimuth error process. γ_2 is used to construct elevation error, if

$\gamma_2 \in [0, 0.6048]$, a third order autoregressive model will be used,

$\gamma_2 \in [0.6049, 0.7580]$, a fourth order autoregressive model with $\phi_4 \neq 0$ will be used,

$\gamma_2 \in [0.7581, 0.8467]$, a fifth order autoregressive model with $\phi_5 \neq 0$ will be used,

$\gamma_2 \in [0.8468, 0.9192]$, a sixth order autoregressive model with $\phi_6 \neq 0$ will be used,

$\gamma_2 \in [0.9193, 0.9676]$, a seventh order autoregressive model with $\phi_7 \neq 0$ will be used,

$\gamma_2 \in [0.9677, 0.9757]$, an eighth order autoregressive model with $\phi_8 \neq 0$ will be used,

$\gamma_2 \in [0.9758, 0.9838]$, a ninth order autoregressive model with $\phi_9 \neq 0$ will be used,

$\gamma_2 \in [0.9839, 0.9919]$, a tenth order autoregressive model with $\phi_{10} \neq 0$ will be used,

$\gamma_2 \in [0.9920, 1.0]$, an eleventh order autoregressive model with $\phi_{11} \neq 0$ will be used.

b) Use normal random number generator to generate the required parameters μ , ϕ 's, and σ_a^2 .

c) Using a polynomial root solver, check the roots of $X^p - \phi_1 X^{p-1} - \dots - \phi_p = 0$. If any of the roots is greater than or equal to 1, discard this set of ϕ 's and select another group of parameters.

d) Let X_t denote the azimuth error process and Y_t denote the elevation error process. Then according to the models and parameters chosen by steps a) and b), we can simulate X_t and Y_t consecutively by generating normal random deviates a_t from $N(0, \sigma_a^2)$.

e) If the perfect aim of a gunner at time t is (A_t, E_t) , then our simulated coordinate of a gunner at time t is $(A_t + Y_t, E_t + Y_t)$. A simulation example:

INITIALLY SELECTED VALUES

MEAN-AVAR PH12-PH13-JUMP-PH1(JUMP)
 AZIMUTH 2200 0113 0205 0012 0216
 ELEVATION 0000 0127 0219 0248 0232

TIME	AZIMUTH	ELEVATION	TIME	AZIMUTH	ELEVATION	TIME	AZIMUTH	ELEVATION	TIME	AZIMUTH	ELEVATION
1	0105	0132	50	0113	0010	110	0013	0000	160	0037	0200
2	0137	0200	51	0256	0111	112	0074	0005	167	0133	0301
3	0303	0133	52	0145	0030	113	0290	0030	168	0000	0200
4	0503	0130	53	0363	0035	114	0030	0000	169	0033	0000
5	0551	0000	54	0365	0040	115	0052	0010	170	0142	0100
6	0813	0030	55	0431	0071	116	0019	0010	171	0096	0040
7	0920	0150	56	0212	0050	117	0000	0000	172	0154	0174
8	0111	0777	57	0367	0094	118	0023	0000	173	0249	0319
9	0109	0113	58	0415	0030	119	0035	0000	174	0290	0330
10	0762	0236	59	0250	0055	120	0262	0020	175	0040	0210
11	0115	0266	60	0300	0050	121	0000	0000	176	0060	0290
12	0100	0773	61	0481	0075	122	0172	0000	177	0121	0219
13	0357	0263	62	0493	0000	123	0000	0000	178	0030	0319
14	0275	0381	63	0340	0051	124	0003	0000	179	0033	0022
15	0107	0100	64	0210	0000	125	0000	0000	180	0000	0200
16	0201	0217	65	0357	0030	126	0270	0000	181	0050	0031
17	0135	0137	66	0312	0000	127	0000	0000	182	0040	0200
18	0230	0370	67	0432	0000	128	0077	0000	183	0152	0211
19	0211	0200	68	0300	0000	129	0000	0000	184	0000	0100
20	0200	0300	69	0351	0000	130	0173	0000	185	0139	0300
21	0172	0000	70	0200	0000	131	0000	0000	186	0000	0200
22	0300	0133	71	0201	0000	132	0075	0000	187	0120	0300
23	0307	0130	72	0300	0000	133	0000	0000	188	0000	0000
24	0252	0272	73	0177	0000	134	0073	0000	189	0070	0420
25	0200	0300	74	0100	0000	135	0000	0000	190	0000	0500
26	0135	0300	75	0473	0000	136	0000	0000	191	0000	0500
27	0130	0270	76	0500	0000	137	0000	0000	192	0000	0500
28	0272	0200	77	0421	0000	138	0212	0000	193	0000	0500
29	0200	0400	78	0440	0000	139	0100	0000	194	0000	0500
30	0100	0000	79	0500	0000	140	0200	0000	195	0000	0500
31	0200	0700	80	0500	0000	141	0000	0000	196	0000	0500
32	0230	0920	81	0700	0000	142	0000	0000	197	0000	0500
33	0300	0500	82	0600	0000	143	0000	0000	198	0000	0500
34	0307	0275	83	0350	0000	144	0100	0000	199	0000	0500
35	0300	0000	84	0000	0000	145	0000	0000	200	0000	0500
36	0330	0130	85	0430	0000	146	0000	0000	201	0000	0500
37	0200	0200	86	0500	0000	147	0000	0000	202	0000	0500
38	0300	0370	87	0300	0000	148	0000	0000	203	0000	0500
39	0300	0300	88	0000	0000	149	0000	0000	204	0000	0500
40	0310	0210	89	0200	0000	150	0000	0000	205	0000	0500
41	0300	0200	90	0200	0000	151	0000	0000	206	0000	0500
42	0300	0100	91	0320	0000	152	0000	0000	207	0000	0500
43	0300	0100	92	0100	0000	153	0000	0000	208	0000	0500
44	0300	0250	93	0030	0000	154	0000	0000	209	0000	0500
45	0300	0320	94	0000	0000	155	0000	0000	210	0000	0500
46	0300	0300	95	0000	0000	156	0000	0000	211	0000	0500
47	0300	0100	96	0000	0000	157	0000	0000	212	0000	0500
48	0300	0200	97	0000	0000	158	0000	0000	213	0000	0500
49	0300	0300	98	0000	0000	159	0000	0000	214	0000	0500
50	0300	0100	99	0000	0000	160	0000	0000	215	0000	0500
51	0310	0200	100	0000	0000	161	0000	0000	216	0000	0500
52	0300	0200	101	0000	0000	162	0000	0000	217	0000	0500
53	0300	0200	102	0000	0000	163	0000	0000	218	0000	0500
54	0300	0250	103	0000	0000	164	0000	0000	219	0000	0500
55	0300	0200	104	0000	0000	165	0000	0000	220	0000	0500



5. Data Listing

IC	C	GO	END	N	S42	MEAN	PHI(1)	PHI(2)	PHI(3)	PHI(4)	J	PHI(1)
71	A	200	1871	1672	.0113	.0144	.4264	.2255	.0507	.1050		
71	F	200	1871	1672	.0137	-.0635	.3749	.1885	.1763			
72	A	200	1846	1647	.0140	.0609	.3738	.2084	.1884	.1840		
72	F	200	1846	1647	.0112	-.0425	.3455	.2078	.1023			
73	A	200	1900	1701	.0060	.4496	.5839	.2665	.1235			
73	F	200	1900	1701	.0155	.0033	.2696	.3010	.1601	.1792		
74	A	200	1840	1641	.0078	.3525	.4525	.3704	.1410			
74	F	200	1840	1641	.0126	-.0575	.3259	.2309	.1909			
75	A	200	1969	1770	.0148	.1717	.4411	.2000	.0206	.3001		
75	F	200	1969	1770	.0064	.0034	.3297	.2425	.1903	.1618		
76	A	100	700	601	.0150	.2694	.6508	.2501	.0576			
76	F	100	700	601	.0086	-.0303	.3532	.2434	.1018		6	.1093
77	A	1	1000	1000	.0095	.0770	.4021	.1700	.2710			
77	F	1	1000	1000	.0080	-.1069	.1017	.1749	.1405	.1283		
NONSTATIONARY ERRORS												
80	A	1	800	800	.0058	.0254	.3702	.1945	.1168			
80	F	1	800	800	.0030	-.0002	.2284	.1367	.1403	.1397		
NONSTATIONARY ERRORS												
83	A	50	600	551	.0170	-.010	.4304	.1611	.0806	.1514		
83	F	50	600	551	.0382	-.1897	.4015	.2132	.0896			
84	A	300	700	401	.0221	.3117	.5664	.1914	.0938			
84	F	300	700	401	.0201	.0780	.4187	.2114	.0510			
85	A	1	600	600	.0119	.0418	.2852	.2704	.2035		7	.1578
85	F	1	600	600	.0255	-.1488	.2901	.2907	.2063			
87	A	100	969	870	.0207	.1607	.5782	.3003	.0406			
87	F	100	969	870	.0461	-.2600	.2633	.2518	.2301			
88	A	100	650	551	.0104	.0275	.5184	.1914	.1963			
88	F	100	650	551	.0222	-.1410	.3069	.1102	.1520			
90	A	160	420	261	.0073	.0641	.5248	.2078	.1811		7	.0072
90	F	160	420	261	.0052	-.1017	.4402	.0700	.2247		5	.0685
91	A	50	619	570	.0383	-.0144	.5027	.3148	.0588			
91	F	50	619	570	.0361	-.1740	.3097	.2124	.1009			
NONSTATIONARY ERRORS												
93	A	50	635	586	.0036	.0498	.6677	.3037	-.0786			
93	F	50	635	586	.0104	-.0817	.2702	.2114	.1912			
94	A	100	462	363	.0164	-.0925	.3303	.1600	.1134		5	.1606
94	F	100	462	363	.0092	-.0466	.3146	-.0297	.2530			
95	A	100	400	301	.0043	.0473	.4300	.3193	.1472			
95	F	100	400	301	.0224	-.1197	.0611	.1491	.1363		6	.1471
96	A	50	478	420	.0035	.0710	.7877	.1634	-.0884			
96	F	50	478	420	.0000	-.0271	.5178	.2314	.0756			
98	A	100	691	592	.0073	-.0097	.6505	.1674	.0870			
98	F	100	691	592	.0160	.0890	.3740	.1887	.1036	.1409		
99	A	80	446	367	.0134	-.0858	.2680	.1778	.3652			
99	F	80	446	367	.0055	-.0370	.3508	.2133	.2557			
100	A	40	380	341	.0025	.0161	.7123	.1640	.0142			
100	F	40	380	341	.0130	-.0327	.2340	.3581	.1681			
101	A	50	280	231	.0202	-.1301	.2144	.3572	.2270			
101	F	50	280	231	.0040	.0462	.6545	.2046	-.0224			
102	A	50	500	451	.0244	-.1771	.4110	.1364	-.0135	.2169		
102	F	50	533	451	.0074	.0138	.5838	.0365	.2737			
104	A	100	557	458	.0063	.0048	.4172	.3274	.0798			
104	F	100	557	458	.0261	-.1957	.1087	.1763	.0714	.1667		
105	A	100	1000	901	.0064	-.0411	.4528	.3484	.0640			
105	F	100	1000	901	.0067	.0000	.4630	.3561	.0322			

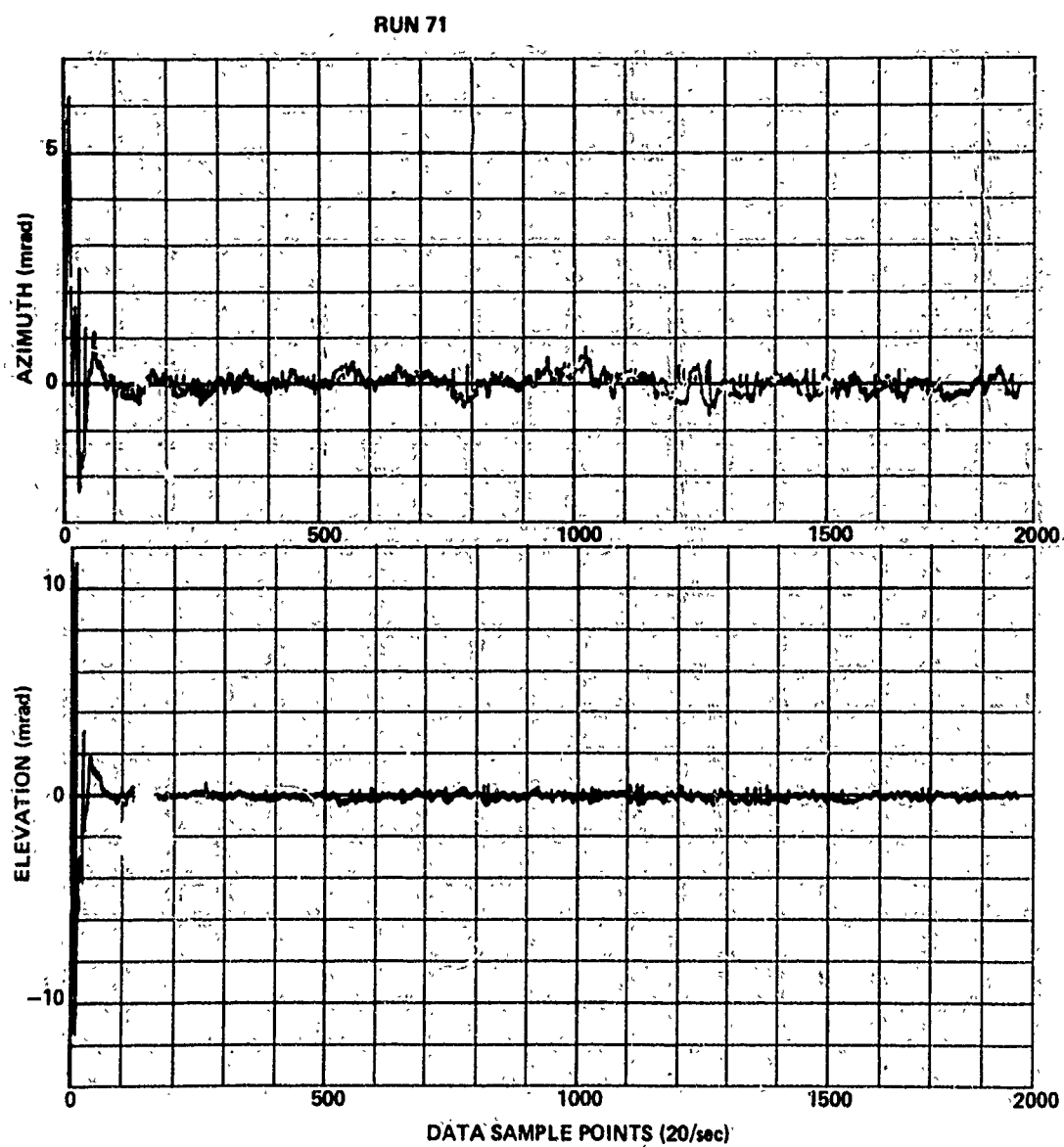
106 A	100	500	401	.0050	-.0160	.3821	.2255	.1596		5	.0604
106 F	100	500	401	.0352	-.2446	.0917	.2914	.1532		6	.1982
107 A	100	639	540	.0250	-.1320	.3561	.1739	.2001			
107 F	100	639	540	.0216	-.0874	.3435	.2668	.1681		6	.0882
108 A	50	547	498	.0023	-.0715	.4978	.3109	.1839		9	-.1140
108 F	50	547	498	.0254	-.2015	.2893	.1421	.2106			
NONSTATIONARY ERRORS											
110 A	100	400	301	.0121	-.0040	.3860	.1864	.2853			
110 F	100	400	301	.0148	-.1021	.1354	.1328	.0164		5	.2499
111 A	100	1390	1291	.0350	-.0277	.2706	.1624	.1802	.1679	5	.1407
111 F	100	1390	1291	.0274	-.1155	.1800	.2694	.2173			
112 A	100	1500	1401	.0117	-.0216	.3628	.2952	.0593	.1779		
112 F	100	1500	1401	.0142	-.0667	.2767	.1841	.0926	.1803		
113 A	100	1865	1766	.0059	.1911	.4192	.2913	.2474			
113 F	100	1865	1766	.0158	-.0590	.2720	.2171	.2246		7	.1522
NONSTATIONARY ERRORS											
115 A	100	1801	1702	.0069	.0693	.4333	.2710	.2077			
115 F	100	1801	1702	.0176	-.1512	.2379	.1540	.1671		5	.1657
118 A	200	1400	1201	.0217	-.0544	.4501	.1877	.0830		6	.1722
118 F	200	1400	1201	.0136	-.1277	.4769	.2734	.1630			
NONSTATIONARY ERRORS											
120 A	100	1842	1743	.0693	-.1709	.2288	.2019	.2573	.2196		
120 F	100	1842	1743	.0067	-.0300	.4493	.3072	.1324			
121 A	200	1895	1696	.0214	-.0311	.5367	.2136	.1149			
121 F	200	1895	1696	.0131	-.0900	.3927	.2076	.0901			
122 A	100	1900	1801	.0369	-.1522	.4019	.2378	.1770			
122 F	100	1900	1801	.0094	-.0312	.4926	.1900	.1290			
123 A	200	1887	1688	.0219	-.0336	.3915	.2248	.1775	.1351		
123 F	200	1887	1688	.0132	-.0708	.3962	.2564	.2039			
124 A	200	1600	1401	.0245	-.1123	.4691	.1291	.1340		10	.1772
124 F	200	1600	1401	.0132	-.0114	.4846	.3025	.0705			
125 A	1	1300	1300	.0025	-.1239	.5558	.2671	.0349			
125 F	1	1300	1300	.0169	-.1089	.2814	.3412	.1815			
127 A	1000	1800	801	.0421	-.1025	.2014	.2487	.2784	.1782		
127 F	1000	1800	801	.0105	-.1590	.3954	.2123	.1482	.0598		
128 A	1000	1582	583	.0092	-.0356	.5331	.2694	.0936			
128 F	1000	1582	583	.0129	-.0579	.4365	.2104	.1609			
129 A	200	1400	1201	.0519	-.2150	.3659	.2150	.2142			
129 F	200	1400	1201	.0106	-.0479	.3628	.2668	.1580			
130 A	200	1794	1595	.0106	.1361	.4584	.2714	.2202			
130 F	200	1794	1595	.0064	.0160	.4880	.2494	.1796			
132 A	200	1400	1201	.0213	-.0930	.3973	.3067	.1221			
132 F	200	1400	1201	.0134	-.0602	.5328	.1996	.1414			
133 A	200	1785	1586	.0271	-.1965	.3816	.2473	.1585		11	.0970
133 F	200	1785	1586	.0167	-.0701	.3527	.3065	.1737			
TOO FEW DATA											
TOO FEW DATA											
134 A	700	1000	301	.0170	-.0444	.4163	.2690	.1633			
134 F	700	1000	301	.0068	.0061	.7834	.1805	-.1006			
138 A	1	600	600	.0067	.0068	.2308	.2758	.1924	.1070		
138 F	1	600	600	.0075	-.0514	.3373	.3601	.1412			
139 A	1	600	600	.0012	.0558	.6436	.2495	.0025			
139 F	1	600	600	.0037	-.0429	.3054	.2288	.1893		8	.1497
NONSTATIONARY ERRORS											
141 A	50	450	401	.0064	-.0227	.5580	.2370	.0972			
141 F	50	450	401	.0070	-.0455	.5764	.2072	.1062			
142 A	50	600	551	.0038	-.0236	.4963	.2384	.0857			
142 F	50	600	551	.0061	-.0515	.4462	.2150	.1861			
144 A	20	700	681	.0076	.0261	.4710	.2212	.1200			
144 F	20	700	681	.0080	.0079	.4278	.2462	.2341			
145 A	50	500	451	.0036	.0239	.5016	.3745	-.0037			
145 F	50	500	451	.0064	.0015	.6275	.2415	.0011			
147 A	80	400	321	.0080	.0525	.3644	.0274	.0100			

147 F	80	400	321	.0062	-.0027	.2648	.1491	.1827	
148 A	100	600	501	.0066	-.0011	.5002	.2172	.1433	
148 F	100	600	501	.0100	-.0503	.2785	.2602	.1901	.1767
149	TOD FFW DATA								
170 A	1	530	530	.0059	.0896	.5664	.3237	.0554	
170 F	1	530	530	.0183	-.1240	.3994	.1519	.0976	
171 A	1	1898	1898	.0078	.0726	.6225	.2462	.0520	
171 F	1	1898	1898	.0060	.0254	.5518	.2918	.1547	5 -.1359
172	NONSTATIONARY ERRORS								
173 A	50	320	281	.0094	-.0226	.4094	.3765	.0724	6 -.0561
173 F	40	320	281	.0091	-.0857	.5412	.1802	.1704	
174 A	1	600	600	.0038	.0202	.4119	.2662	.2328	
174 F	1	600	600	.0055	-.0002	.4752	.2882	-.0027	.1531
175 A	100	500	401	.0213	-.1836	.2622	.2247	.1780	8 -.1844
175 F	100	500	401	.0029	.0870	.8338	.1773	-.0891	
176 A	200	500	301	.0028	.2021	.7383	.2501	.0406	10 -.0637
176 F	200	500	301	.0094	-.1054	.3549	.2206	.2185	10 -.1179
177 A	1	599	599	.0040	.3372	.6751	.2048	.0784	
177 F	1	599	599	.0103	-.0112	.3658	.2039	.1444	7 -.2212
178 A	1	1100	1100	.0056	.0037	.3939	.3117	.2187	
178 F	1	1100	1100	.0166	-.0087	.3066	.2574	.2502	
179 A	150	650	501	.0028	.1784	.6691	.1243	.1330	
179 F	150	650	501	.0043	-.0049	.3131	.2782	.1641	7 -.1468
180 A	50	250	201	.0018	.1214	.7568	.1150	.0506	
180 F	50	250	201	.0050	-.0504	.4701	.1844	.1257	.0561
182 A	1	800	800	.0061	.0529	.4165	.3013	.2035	
182 F	1	800	800	.0042	-.0026	.4478	.2820	.1653	
183 A	1	500	500	.0042	-.0280	.3210	.1871	.1928	
183 F	1	500	500	.0052	.0555	.4090	.1836	.2264	
184 A	1	872	872	.0057	-.0019	.3832	.2416	.2618	
184 F	1	872	872	.0082	-.0233	.3590	.2165	.1441	5 -.1844
185 A	1	600	600	.0100	-.0474	.4081	.2589	.1944	
185 F	1	600	600	.0069	.0093	.4598	.2339	.1938	
186 A	100	800	701	.0050	-.0059	.3649	.2877	.1429	
186 F	100	800	701	.0002	-.0521	.4041	.2303	.1892	
187 A	20	399	380	.0047	-.0101	.4461	.0950	.2233	
187 F	20	399	380	.0090	-.0368	.3012	.2523	.1924	
188 A	1	896	896	.0044	-.0049	.3811	.4132	.1418	
188 F	1	896	896	.0050	.0037	.3520	.2206	.1834	6 -.1722
189 A	1	800	800	.0020	.0240	.4465	.3601	.1594	
189 F	1	800	800	.0020	.0045	.3921	.2407	.1569	.1464
190 A	100	650	551	.0063	.1041	.4401	.2761	.0604	.1368
190 F	100	650	551	.0048	.0552	.4257	.2704	.2091	
191 A	150	450	301	.0050	-.0087	.2977	.2641	.2873	
191 F	150	450	301	.0054	-.0016	.2363	.2411	.1370	
192	TOD FFW DATA								
193 A	50	701	652	.0127	-.1395	.4149	.2855	.1194	
193 F	50	701	652	.0078	-.0699	.4067	.2023	.1470	5 -.1159
194 A	200	500	301	.0087	-.0276	.6454	.3026	-.0714	
194 F	200	500	301	.0058	-.0525	.6568	.1929	.2070	
197	NONSTATIONARY ERRORS								
198 A	1	1000	1000	.0061	.0631	.5435	.2500	.2351	8 -.1854
198 F	1	1000	1000	.0153	-.0664	.3462	.2204	.1650	
199 A	320	600	291	.0060	.0801	.6040	.2277	.0553	
199 F	320	600	291	.0065	.0516	.4207	.2985	.1740	
200 A	40	240	201	.0043	.1514	.5380	.2262	.1180	
200 F	40	240	201	.0433	-.1607	.3996	.2530	.0887	1625
202 A	100	516	417	.0120	.1549	.5757	.1840	.0630	.1144
202 F	100	516	417	.0040	-.0586	.3996	.1983	.2033	7 -.0592
203 A	100	1100	1001	.0093	-.0238	.2672	.1955	.1284	.2050

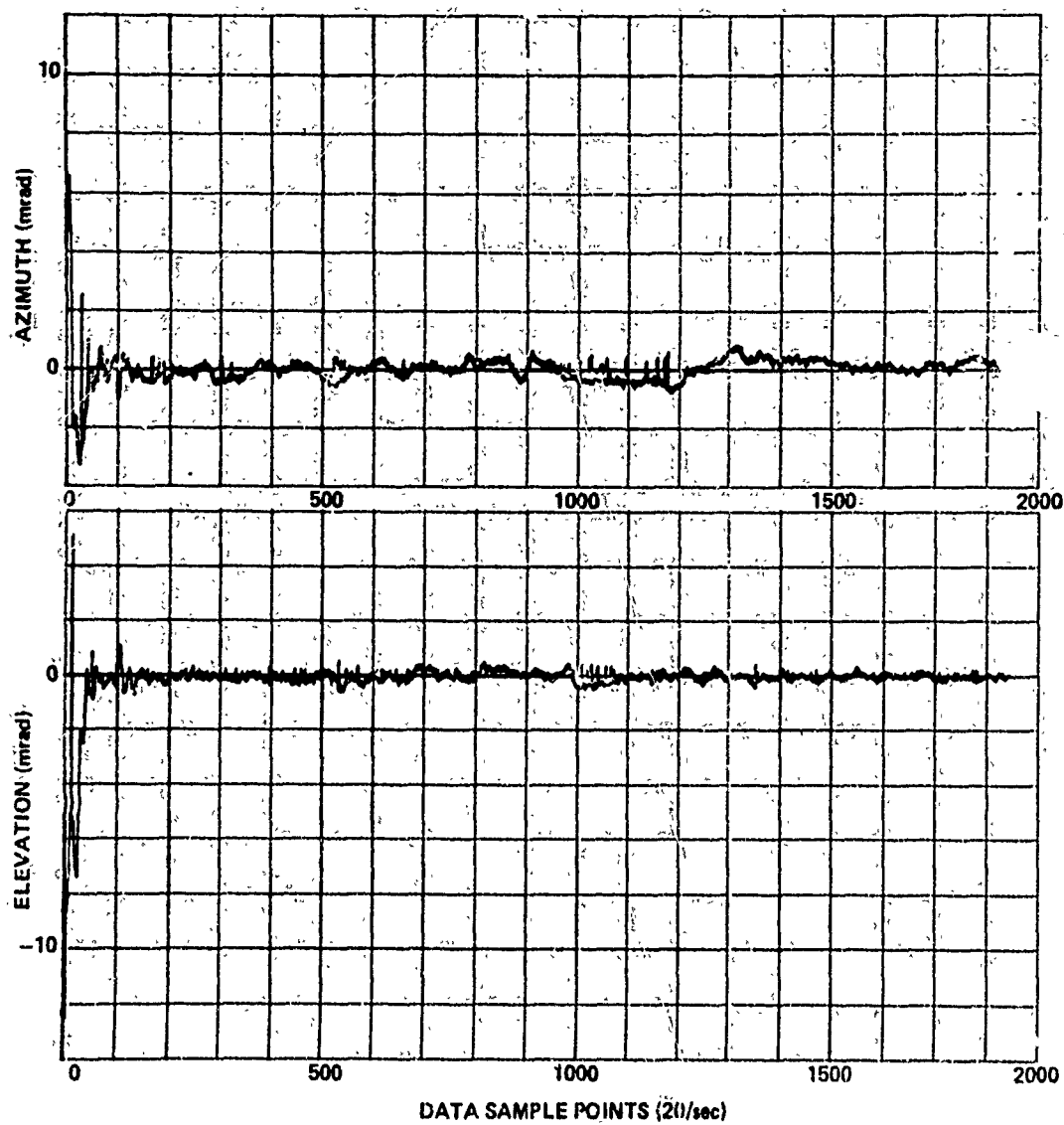
203 F	100	1100	1001	.0043	.0451	.4236	.1730	.1757	5	.1749
204 A	40	320	291	.0088	.2267	.7140	.1837	-.0267		
204 F	40	320	291	.0098	.1232	.8618	-.0751	-.1867	9	.1294
205 A	60	360	301	.0038	.3490	.6280	.1615	.1349		
205 F	60	360	301	.0069	-.0442	.4280	.1869	.1521		
NONSTATIONARY ERRORS										
206 A	80	377	298	.0208	-.0326	.3117	.1995	.0940		.1707
207 E	80	377	298	.0130	-.0493	.5376	.0182	.1343		
NONSTATIONARY ERRORS										
211 A	100	500	401	.0035	.0384	.5459	.2528	.1009	6	-.0538
215 F	100	500	401	.0122	-.0799	.2962	.2748	.1362		
217 A	50	500	451	.0309	.0854	.5270	.2847	.1073		
217 F	50	500	451	.0870	-.0727	.2136	.2674	.1211		.1844
219 A	50	503	454	.0239	.0331	.3507	.1866	.3642		-.0840
219 F	50	503	454	.0401	-.1041	.2235	.2509	.0483	5	.1242
219 A	100	604	505	.0025	.0171	.4249	.3383	.0871		
219 F	100	604	505	.0126	-.0736	.2455	.2266	.1811	7	.1964
TOO FEW DATA										
221 A	1	750	750	.0040	-.0178	.1926	.1114	.2643	5	.1657
221 F	1	750	750	.0061	-.0918	.2299	.3279	.2160		
TOO FEW DATA										
223 A	100	777	678	.0048	.0732	.6116	.2213	.0440		
223 F	100	777	678	.0080	-.1045	.2126	.2529	.1171		.1690
TOO FEW DATA										
230 A	50	400	351	.0042	-.0324	.3867	.2251	.1637		
230 F	50	400	351	.0080	-.0667	.2035	.1904	.0410		
NONSTATIONARY ERRORS										
235 A	80	400	321	.0040	-.0376	.3314	.1237	.1493		
235 F	80	400	321	.0078	-.0267	.4128	.1890	.3090		
236 A	100	550	451	.0038	.0511	.4529	.1303	.1537		
236 F	100	550	451	.0078	-.0354	.3676	.1773	.2951		
3 A	60	300	241	.0033	-.0405	.6078	.0985	-.0434		
3 F	60	300	241	.0020	-.0253	.3663	.1365	.0657		
TOO FEW DATA										
NONSTATIONARY ERRORS										
NONSTATIONARY ERRORS										
158 A	40	340	301	.0175	.0079	.6186	.1585	-.0210		
158 F	40	340	301	.0359	-.1151	.4167	.1200	.0878		
159 A	100	1400	1301	.0125	-.0328	.5253	.1515	.0565		.1141
159 F	100	1400	1301	.0078	-.0359	.4031	.2413	.0732		
160 A	100	1197	1098	.0088	.0946	.6450	.2358	-.0105		
160 F	100	1197	1098	.0101	-.0486	.4276	.2013	.1809		
161 A	50	500	451	.0173	.0192	.4155	.1222	.1264		
161 F	50	500	451	.0130	-.0387	.3884	.1832	.1884		
273 A	100	450	351	.0014	.0129	.3734	-.0775	.0787	5	-.0827
273 F	100	450	351	.0025	-.0451	.0717	.1303	.1040		
274 A	1	501	501	.0057	.0837	.4547	.2254	.0789		.1260
274 F	1	501	501	.0049	.0520	.3699	.1851	.2142	5	.1500
275 A	1	626	626	.0030	.0716	.4539	.2571	.1989		
275 F	1	626	626	.0035	-.0256	.4614	.2563	.1478		
276 A	100	500	401	.0057	.0253	.4056	.2924	.2036		
276 F	100	500	401	.0134	-.1145	.1148	.2019	.1265		.2013
278 A	100	500	401	.0074	.0122	.2891	.3323	.1620		
278 F	100	500	401	.0045	.0631	.2073	.3905	.2150		
279 A	150	526	377	.0061	.0435	.5675	.1297	-.1865		.2088
279 F	150	526	377	.0061	-.0214	.4449	.2482	.1485		
TOO FEW DATA										
294 A	60	675	616	.0210	.1433	.2292	.1483	.1447	6	.2310
294 F	60	675	616	.0330	-.1198	.2693	.1768	.0954		

295 A	70	550	491	.0081	.1784	.4123	.2479	.1096	.1209		
295 F	70	550	491	.0156	-.1160	.2491	-.0252	.1004	.1792		
296	NONSTATIONARY ERRORS										
297	TOO FEW DATA										
298 A	50	400	351	.0093	.0462	.3275	.1231	.1831		7	.2177
298 F	50	400	351	.0062	-.0090	.3776	.3094	.0112		7	.0753
300	NONSTATIONARY ERRORS										
301 A	100	426	327	.0095	.0415	.3086	.2236	.0752		9	.1755
301 F	100	426	327	.0075	-.1187	.3315	.1330	.1020		6	.1420
302 A	100	426	327	.0008	.1184	.2405	.2366	.2551			
302 F	100	426	327	.0008	.0457	.3506	.2688	.0878		6	.1021
303 A	1	450	450	.0079	.2411	.3908	.2531	.2373			
303 F	1	450	450	.0096	-.0578	.3478	.2466	.0861	.1792		
305	NONSTATIONARY ERRORS										
306	NONSTATIONARY ERRORS										
307 A	100	476	377	.0066	.3582	.3902	.1418	.2037		5	.1325
307 F	100	476	377	.0277	-.1769	.0900	.0809	.1051		5	.1182
308	TOO FEW DATA										
309 A	1	501	501	.0162	.1636	.2896	.1772	.1300		6	.1091
309 F	1	501	501	.0046	.0135	.4356	.1597	.1873		6	.0317
311 A	100	600	501	.0058	.1495	.2518	.2818	.2413			
311 F	100	600	501	.0055	-.0446	.3140	.1270	.1900			
312 A	100	1059	940	.0019	.0387	.3731	.4848	.0037	.0277		
312 F	100	1059	940	.0036	-.0025	.5615	.2175	.0540		11	.0573
313 A	50	1200	1151	.0027	.0614	.4023	.4314	.0958		9	.0026
313 F	50	1200	1151	.0095	-.0714	.3128	.1286	.1218		5	.1666
314 A	50	1166	1117	.0031	.0654	.5059	.3424	.0300			
314 F	50	1166	1117	.0063	-.0322	.4253	.2750	.1386			
315 A	120	1653	1534	.0032	.0366	.5541	.4116	-.0463			
315 F	120	1653	1534	.0076	-.0611	.3754	.2899	.0145			
316 A	200	1400	1201	.0044	.0035	.2834	.2784	.2146	.1485		
316 F	200	1400	1201	.0095	-.0897	.3209	.1710	.1300	.1795		
317 A	100	1500	1401	.0057	-.0298	.4104	.2352	.1493		7	.1046
317 F	100	1500	1401	.0118	-.0950	.3559	.2606	.2606			
318 A	150	700	551	.0037	.0084	.4065	.3131	.0978			
318 F	150	700	551	.0154	-.0663	.3288	.2745	.0809			
319 A	80	698	619	.0053	.0668	.4466	.2379	.1025		6	.1172
319 F	80	698	619	.0106	-.0494	.3130	.2534	.2079		6	.0851
320 A	50	1021	972	.0041	.0630	.3969	.2223	.1647	.1233		
320 F	50	1021	972	.0068	-.0660	.3730	.2447	.1992			

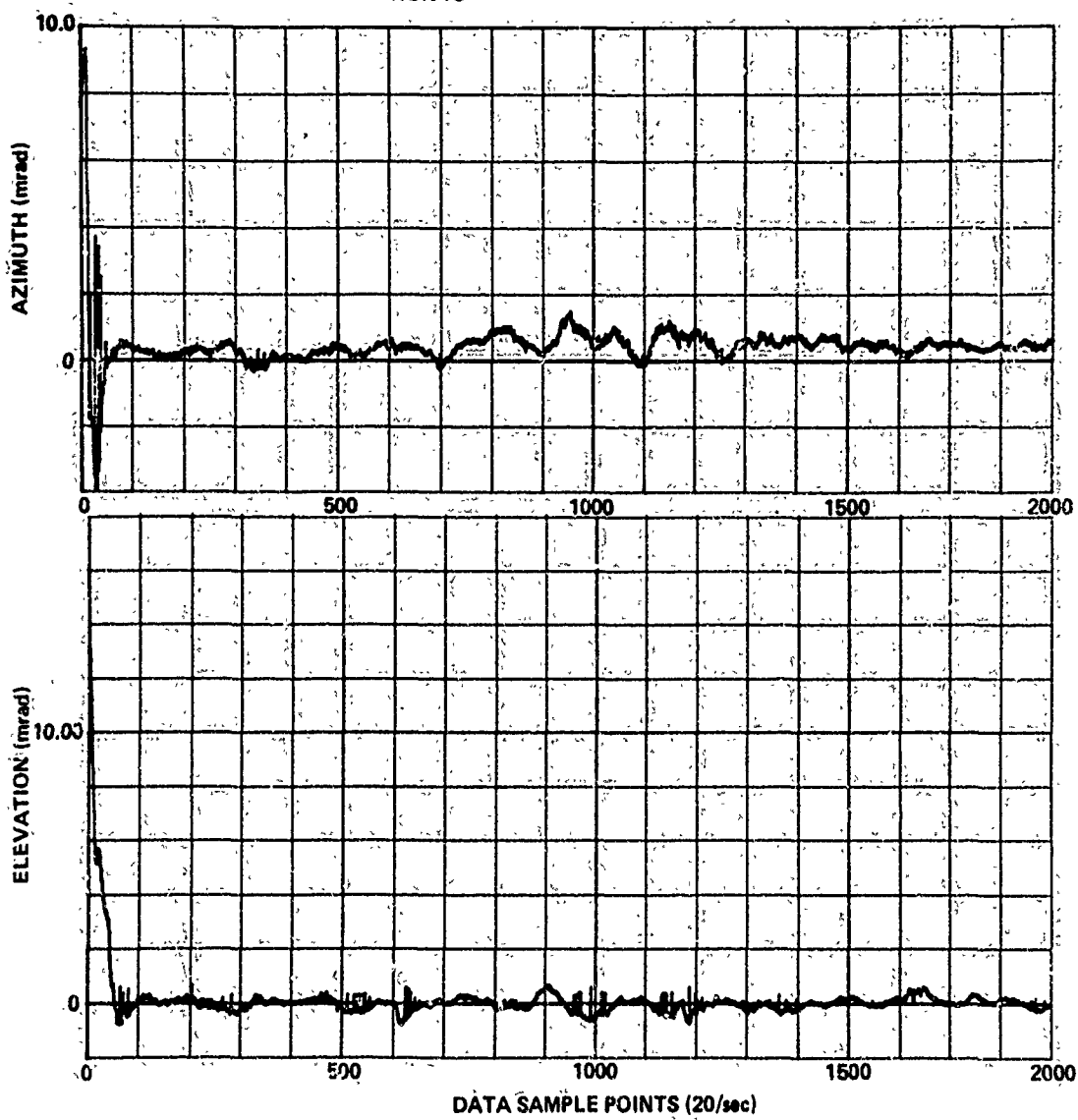
6. Data Plots



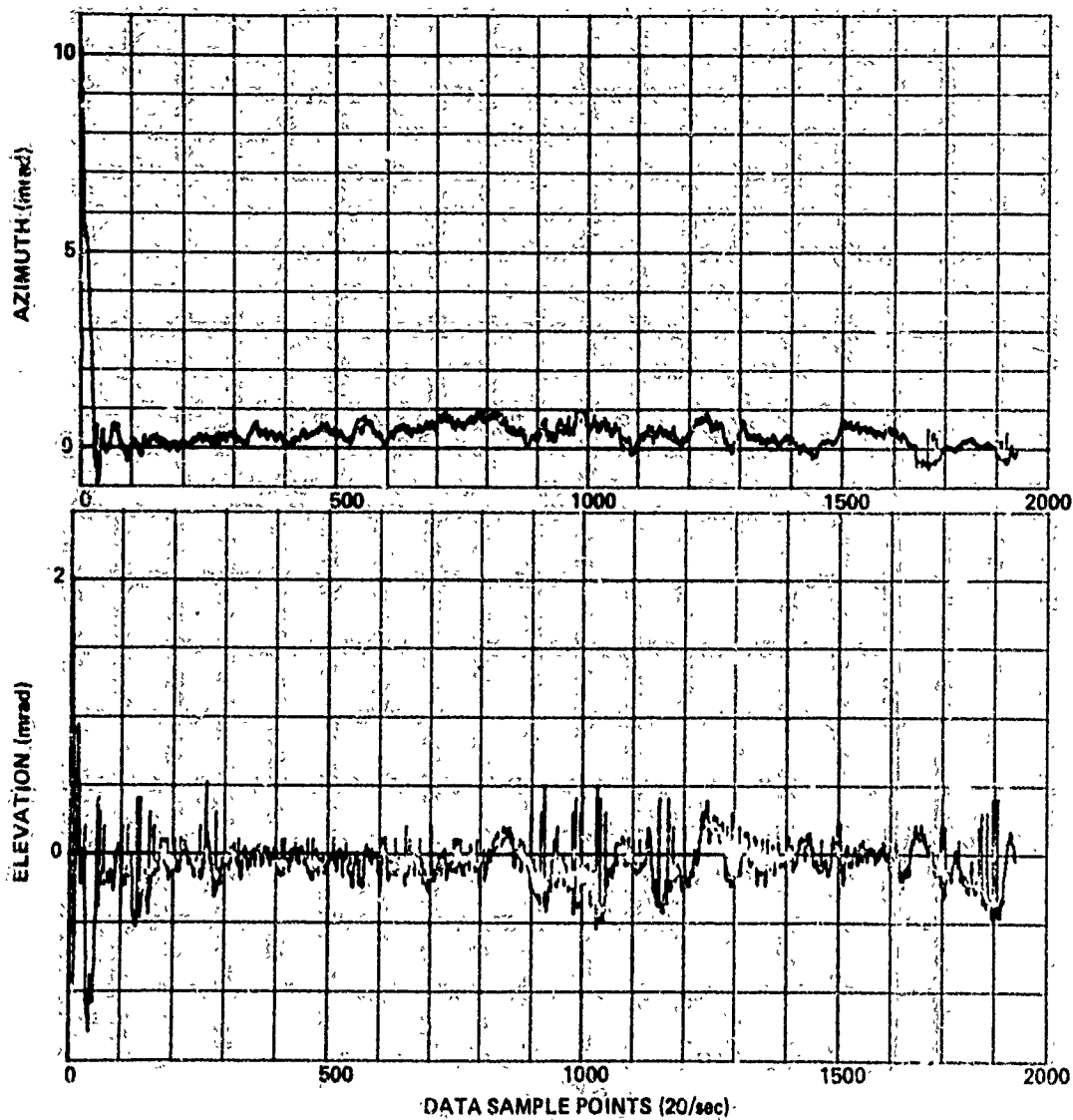
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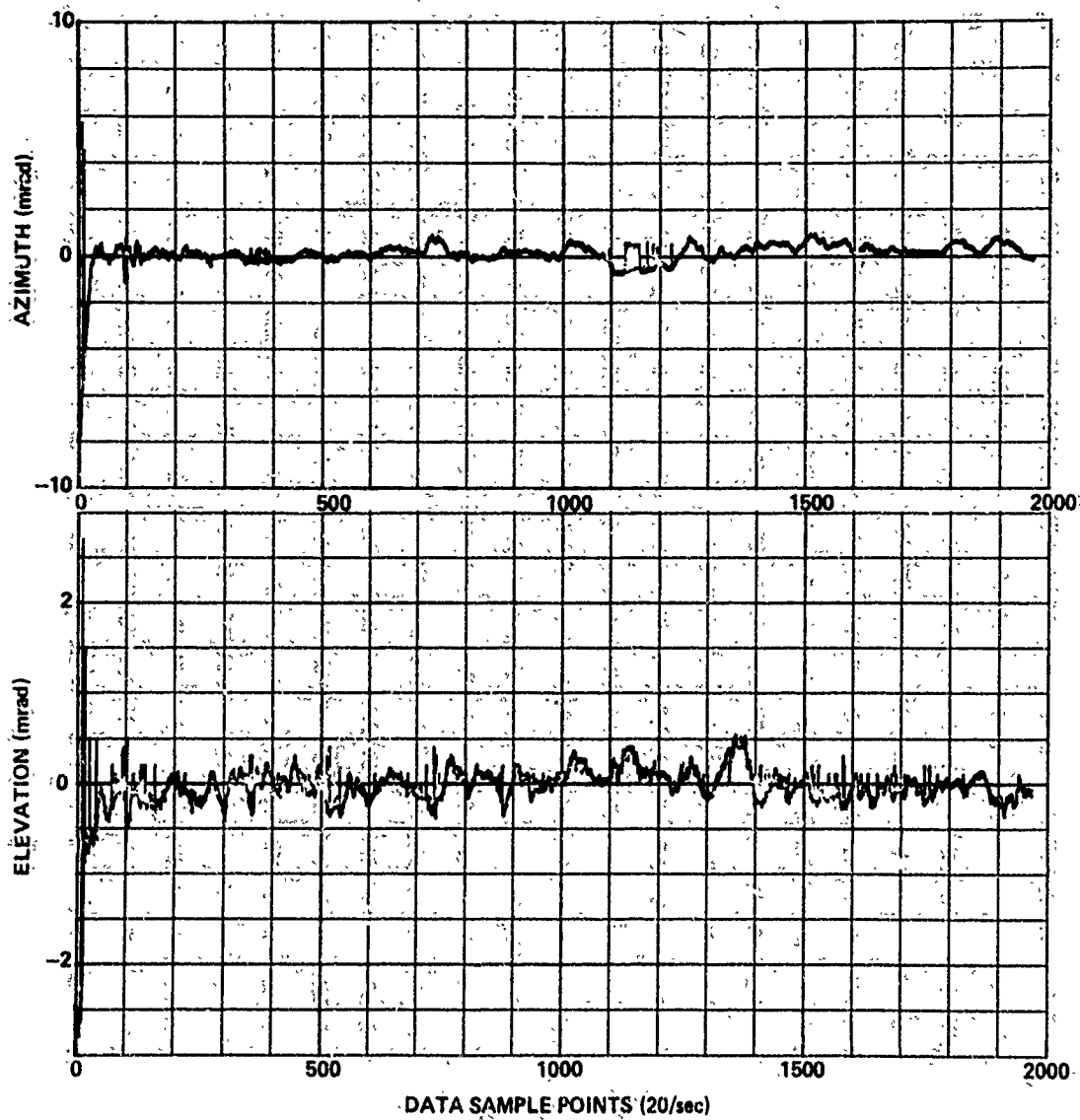
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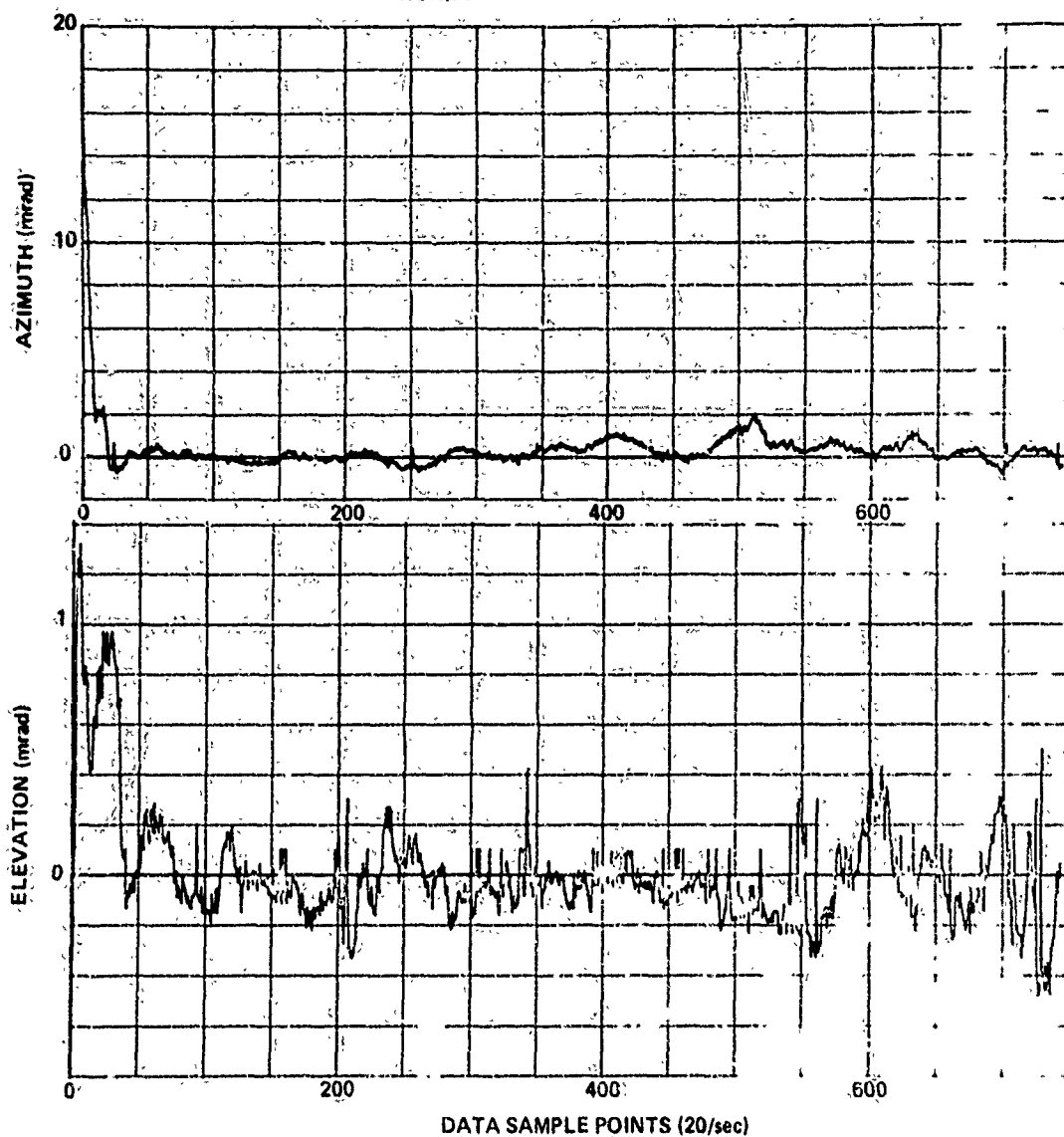
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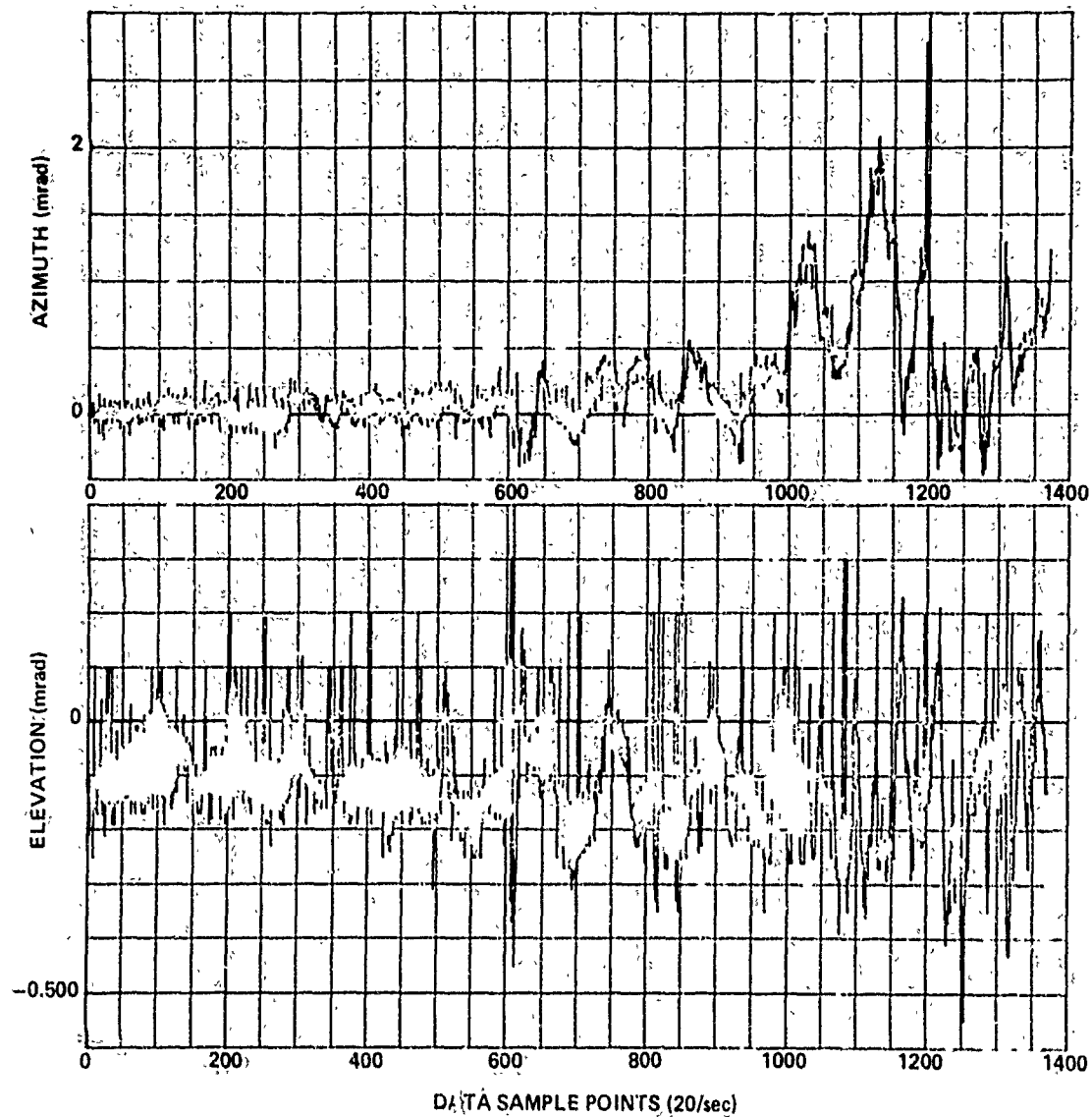
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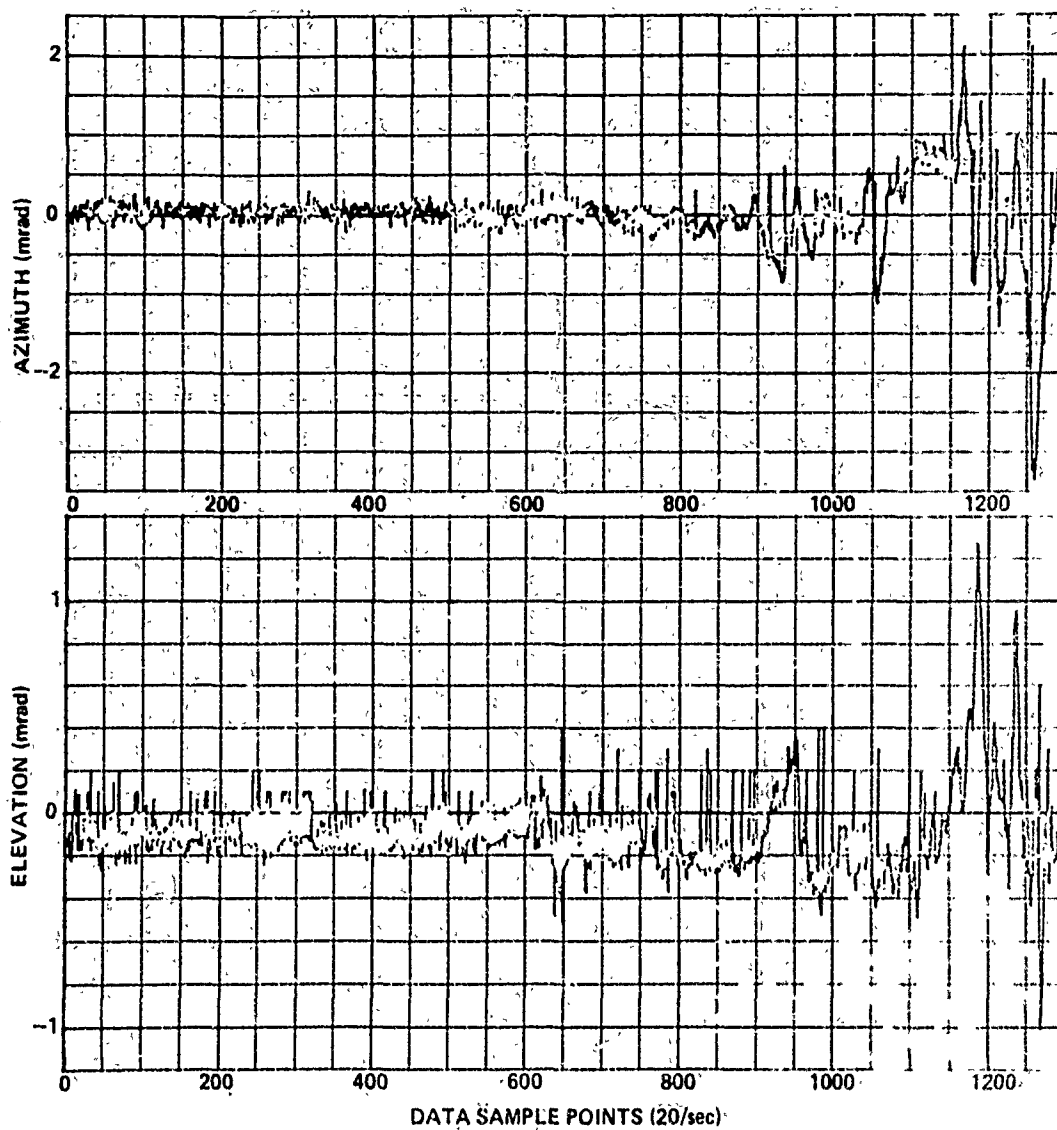
RUN 76



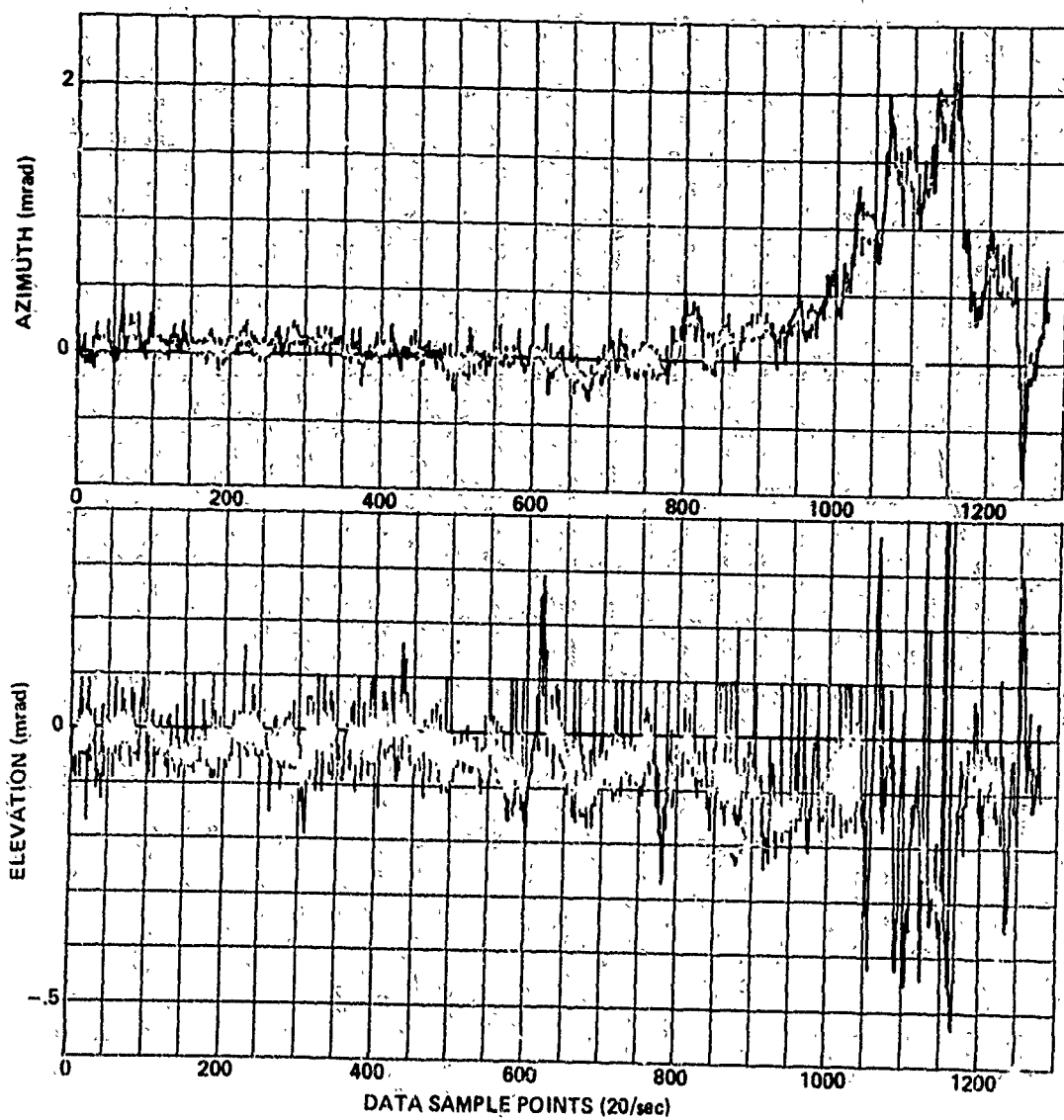
RUN 77



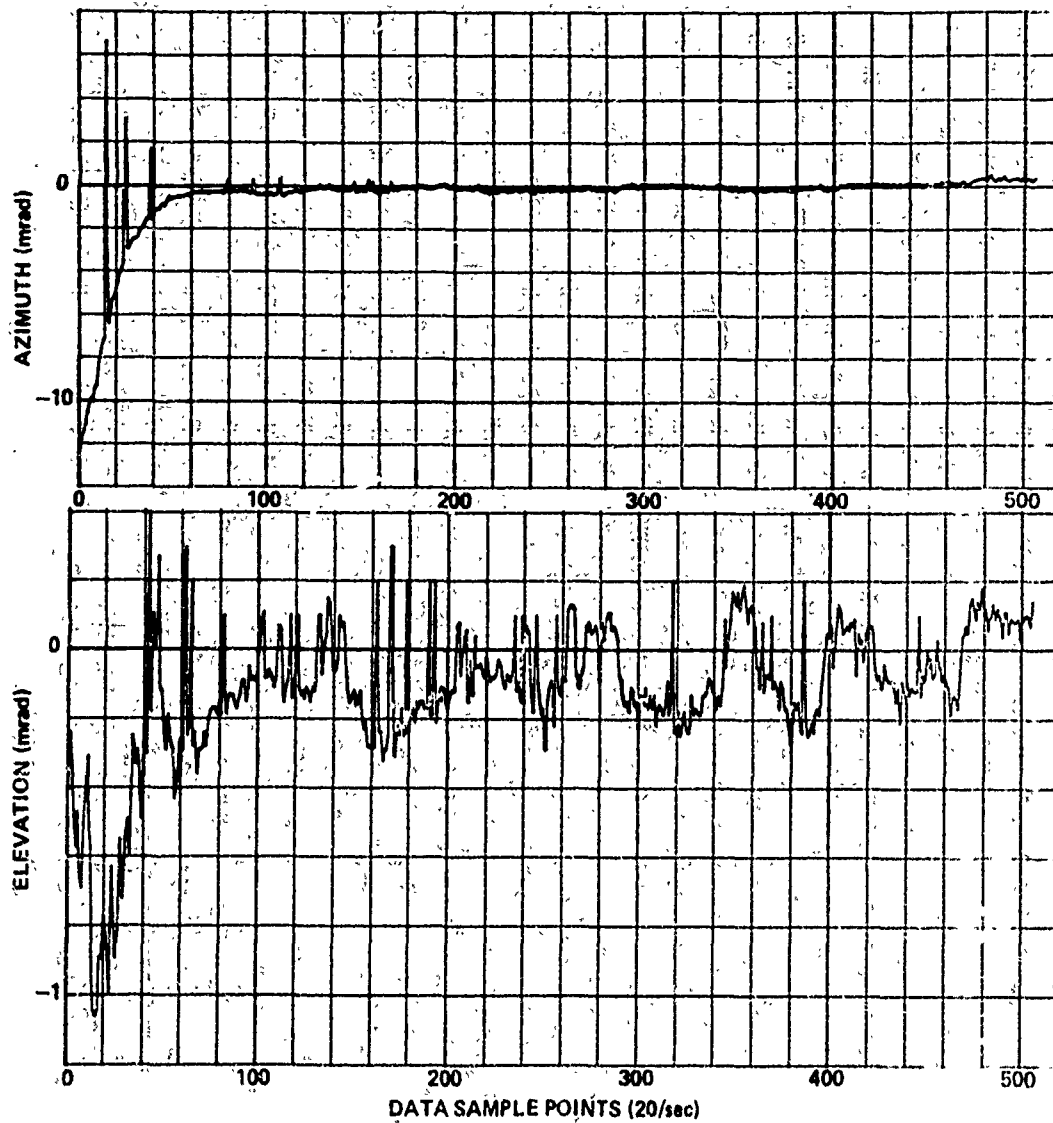
RUN 79



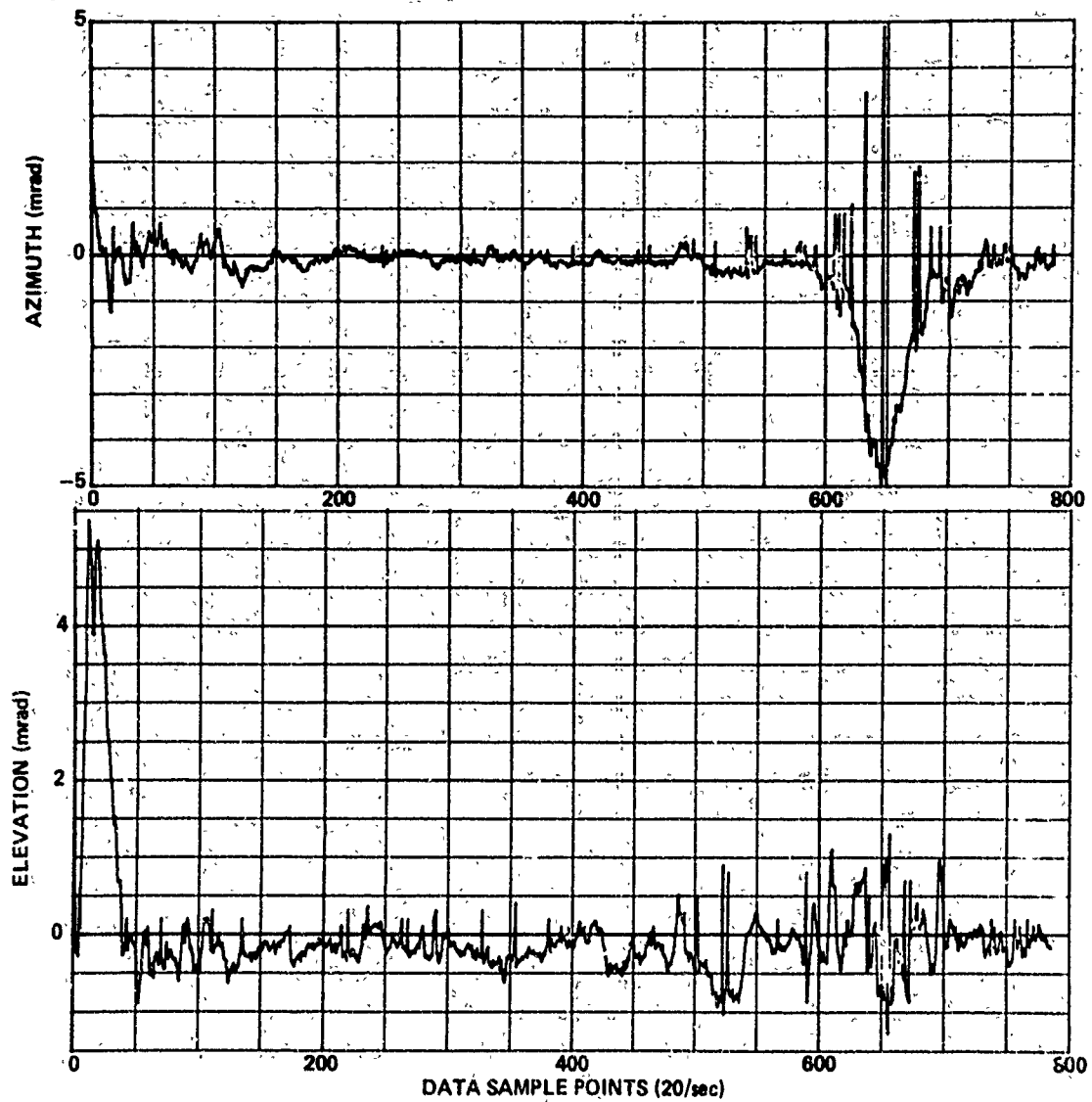
RUN 80



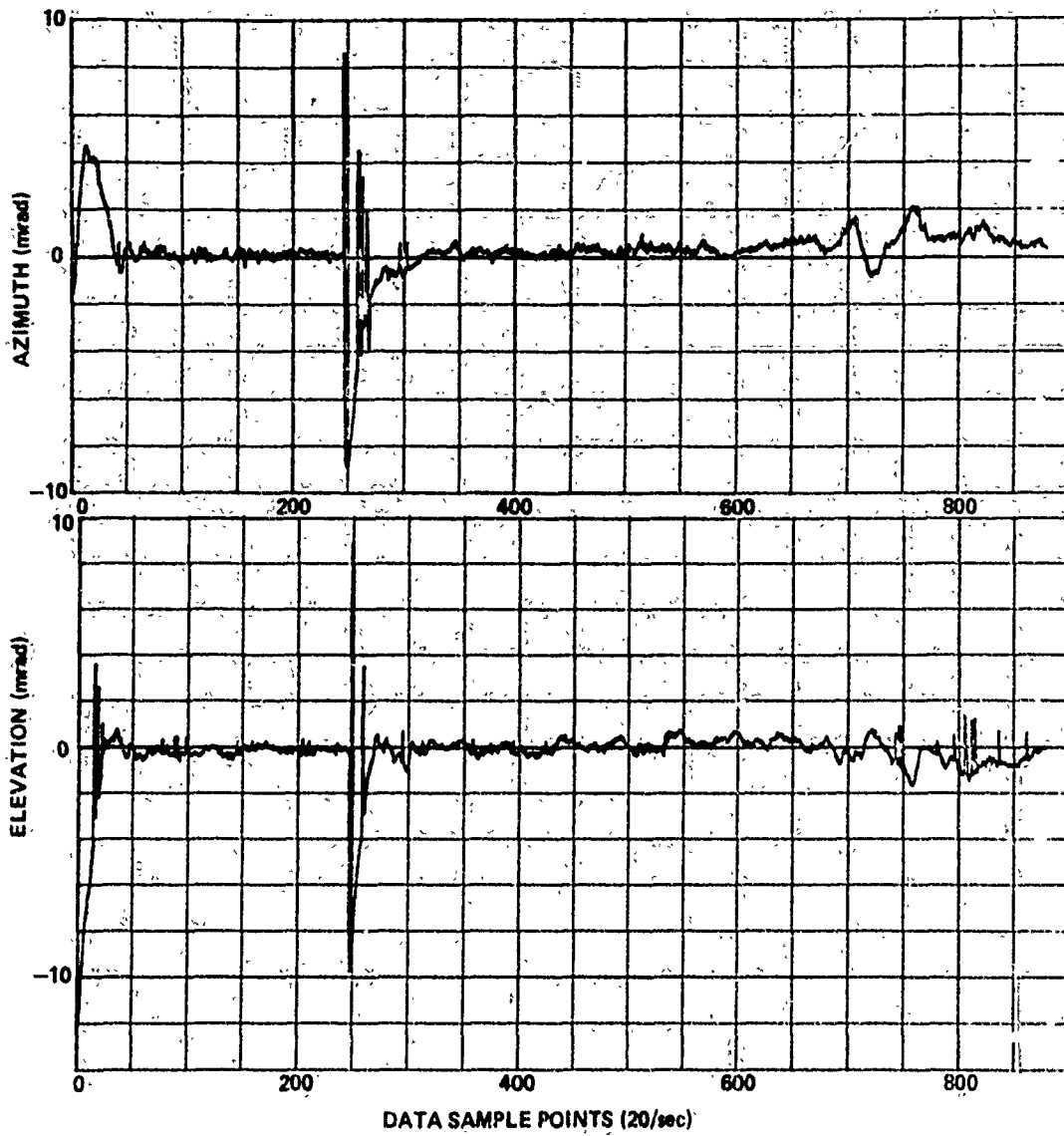
RUN 82



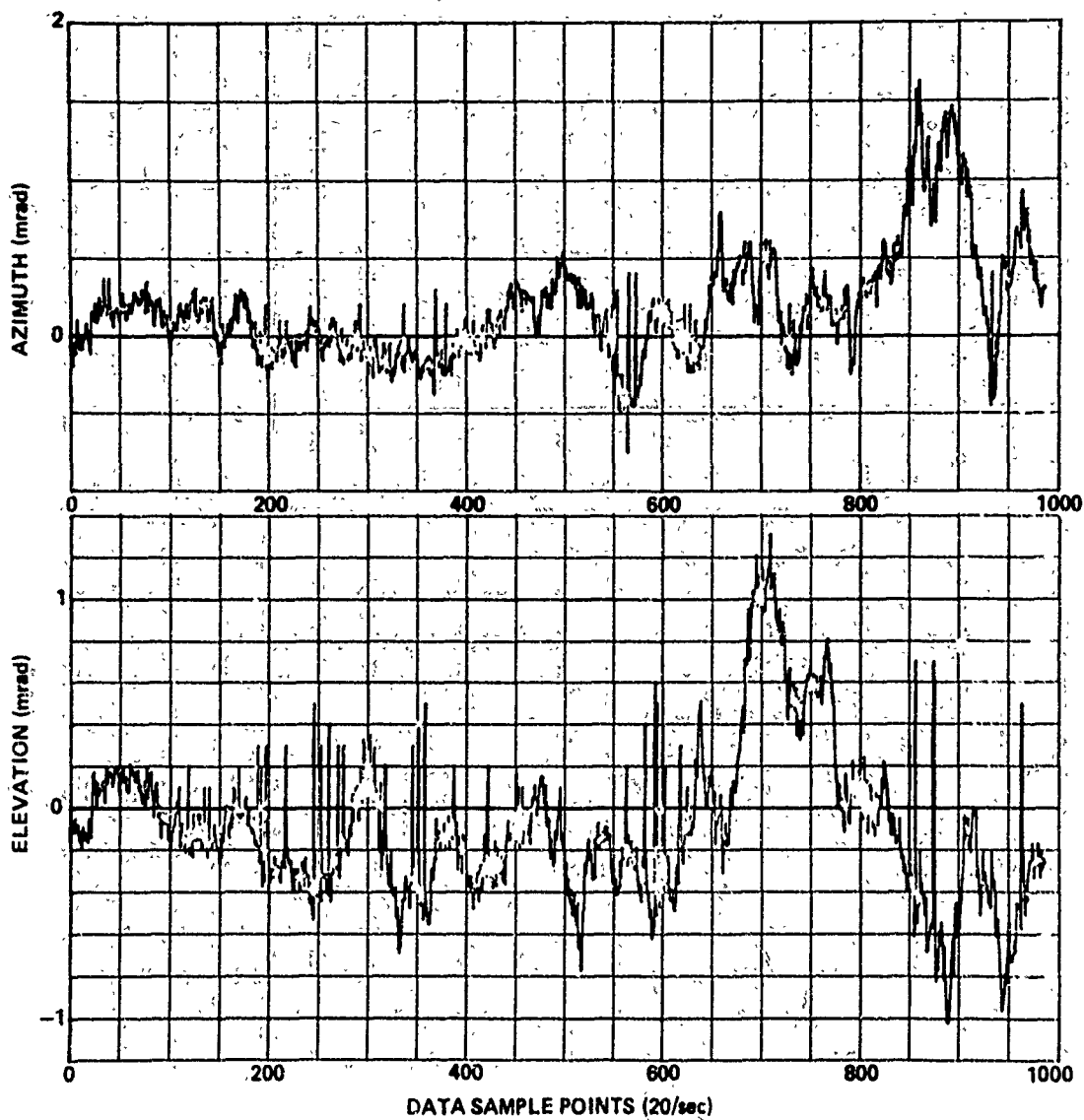
RUN 83



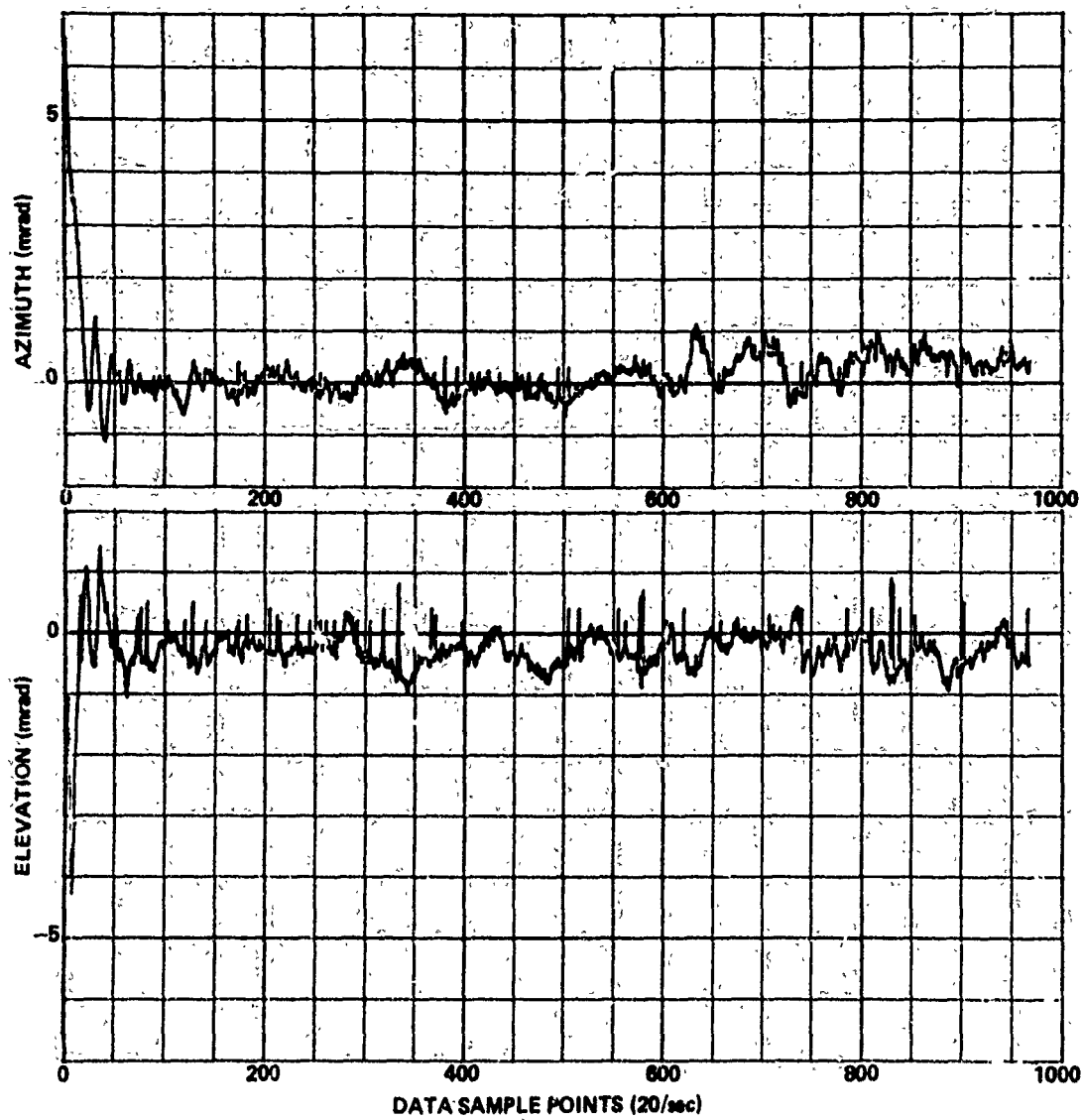
RUN 84



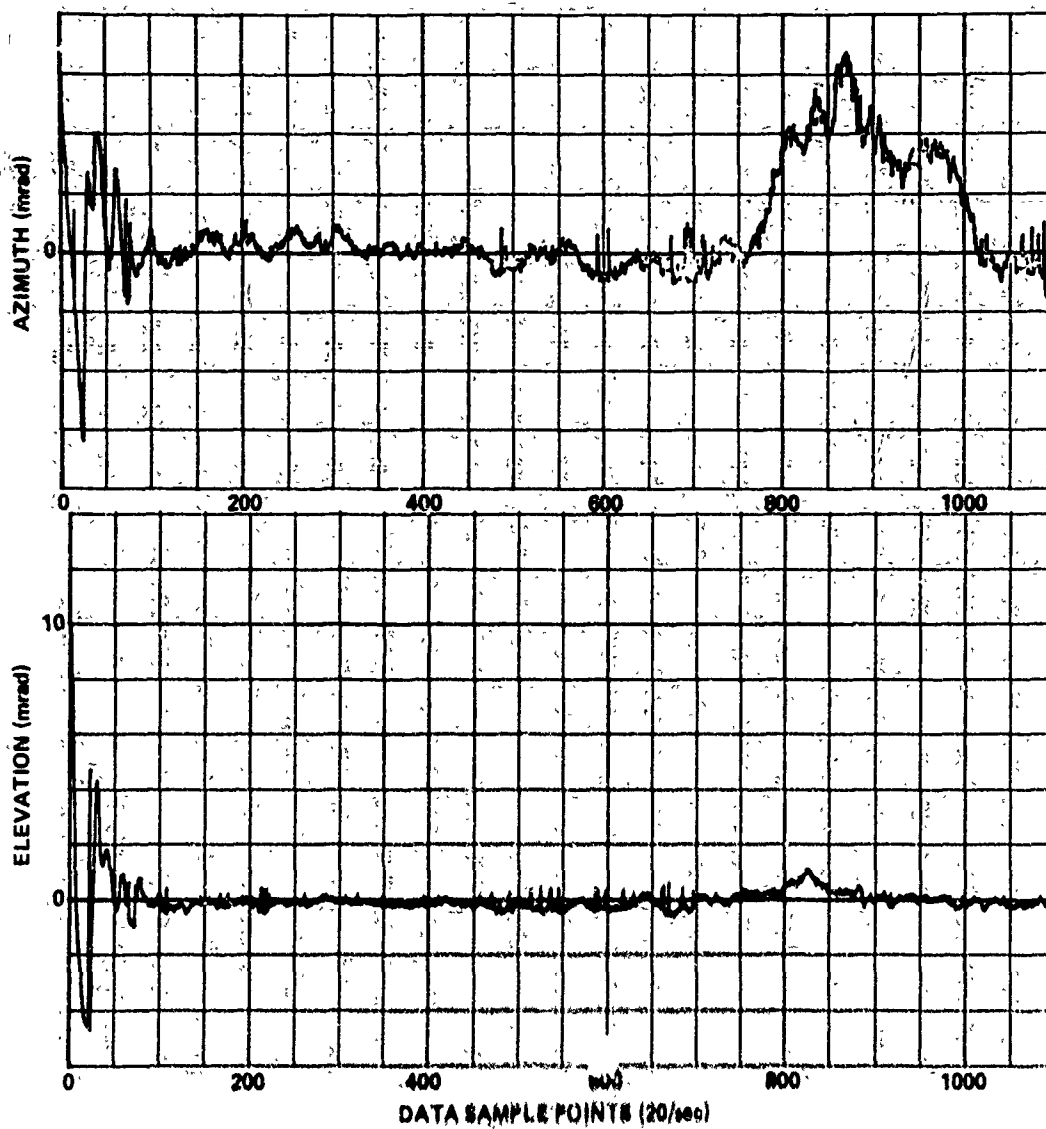
RUN 86



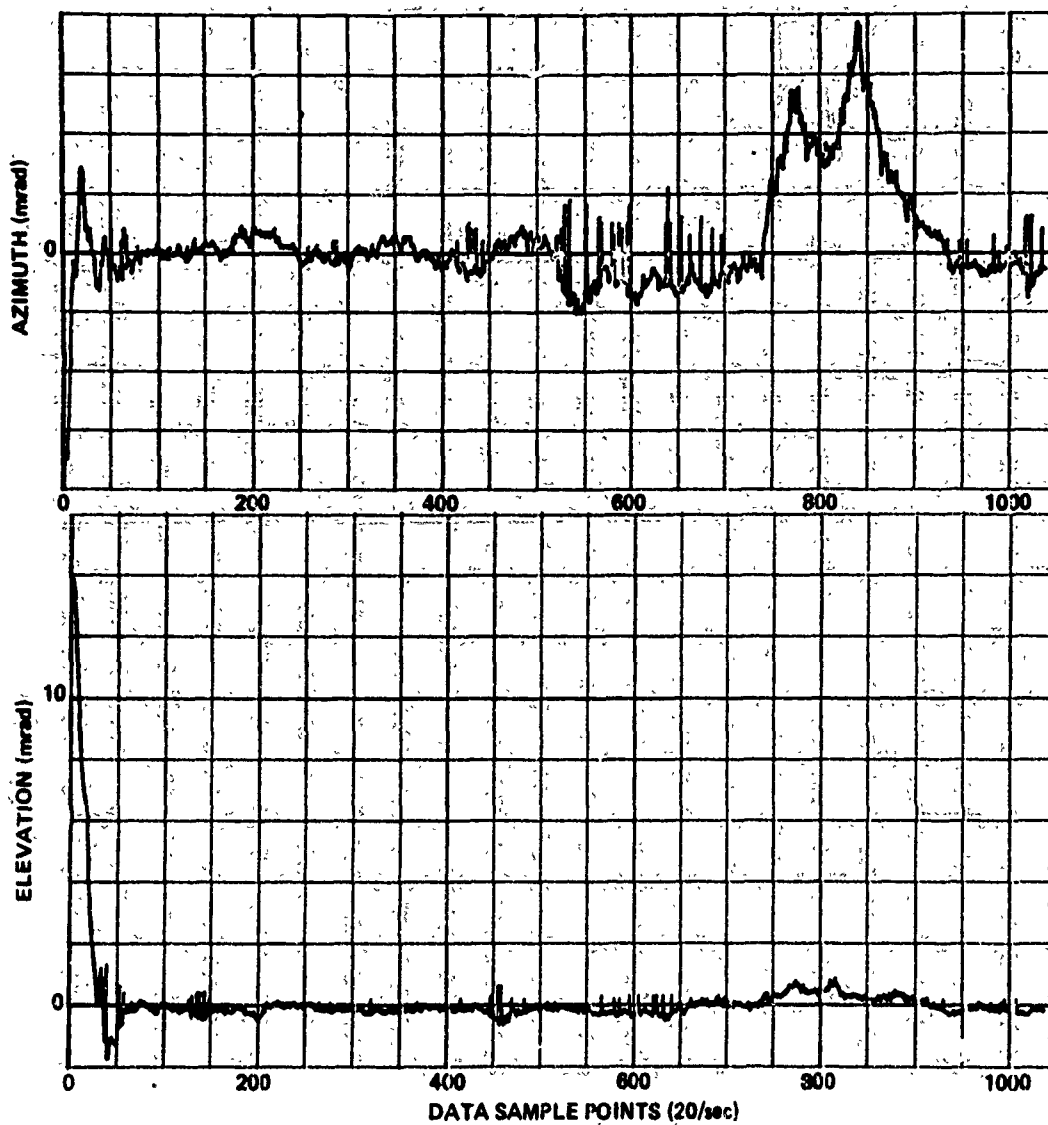
RUN 87



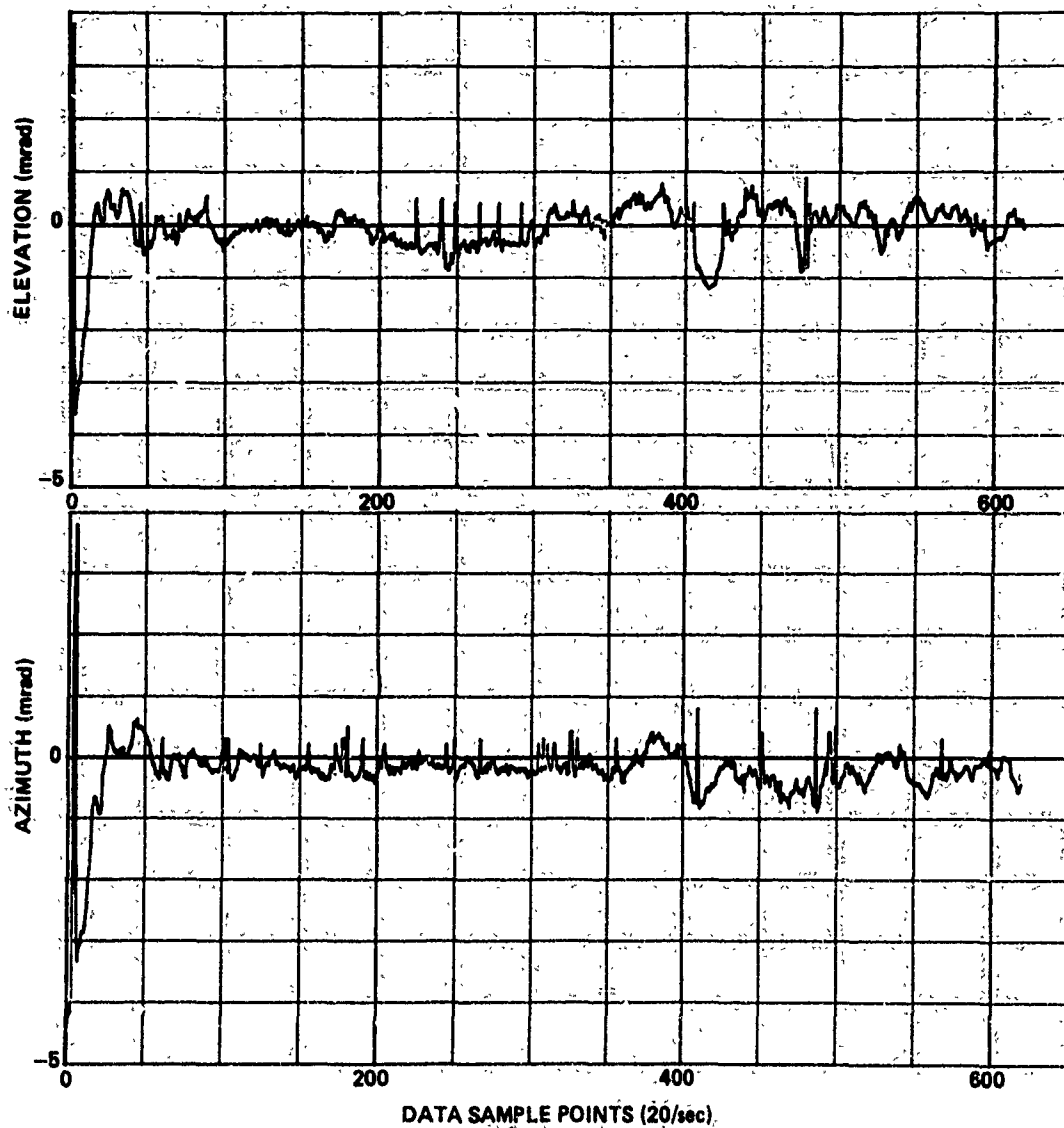
RUN 88



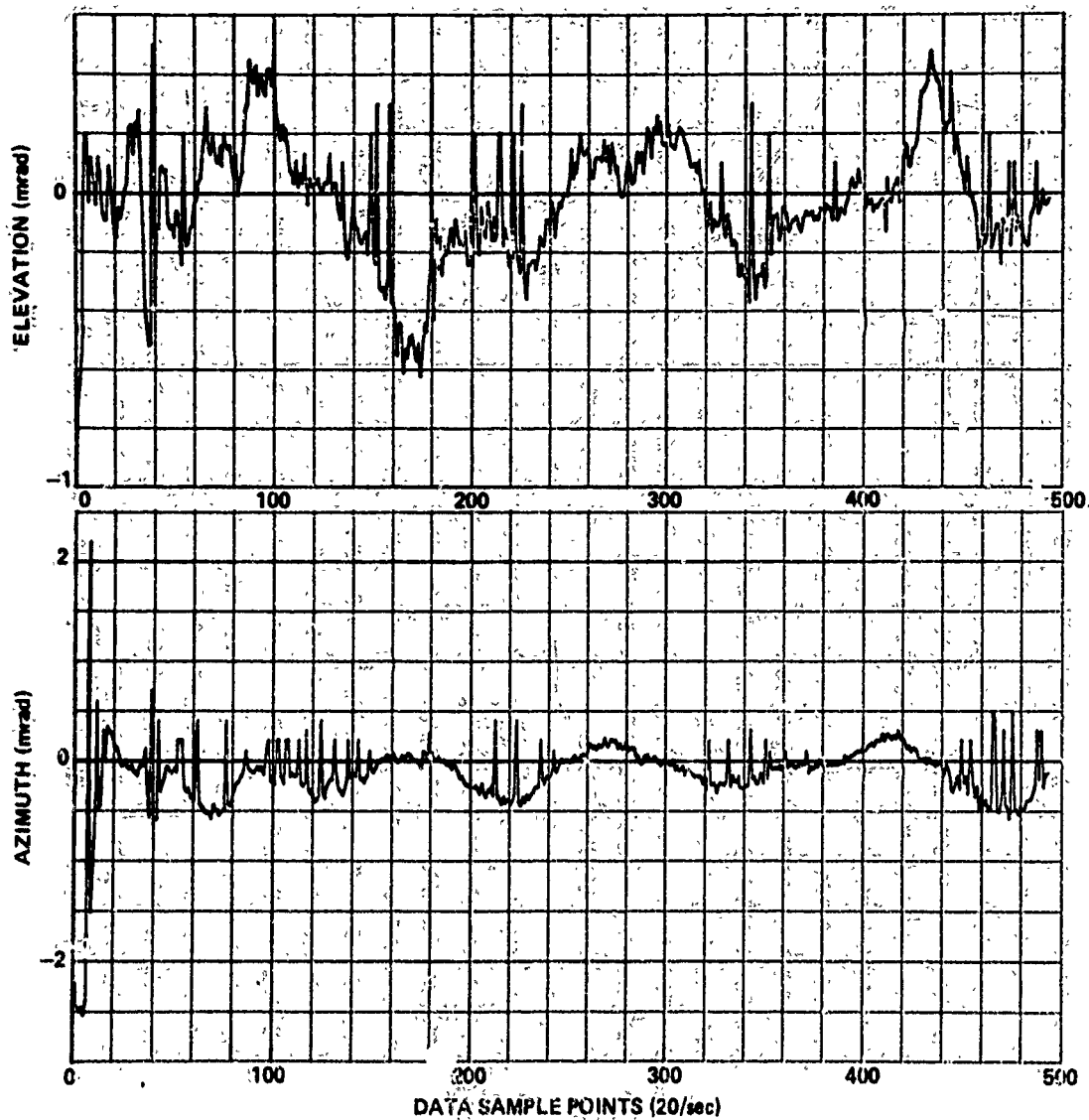
RUN 90



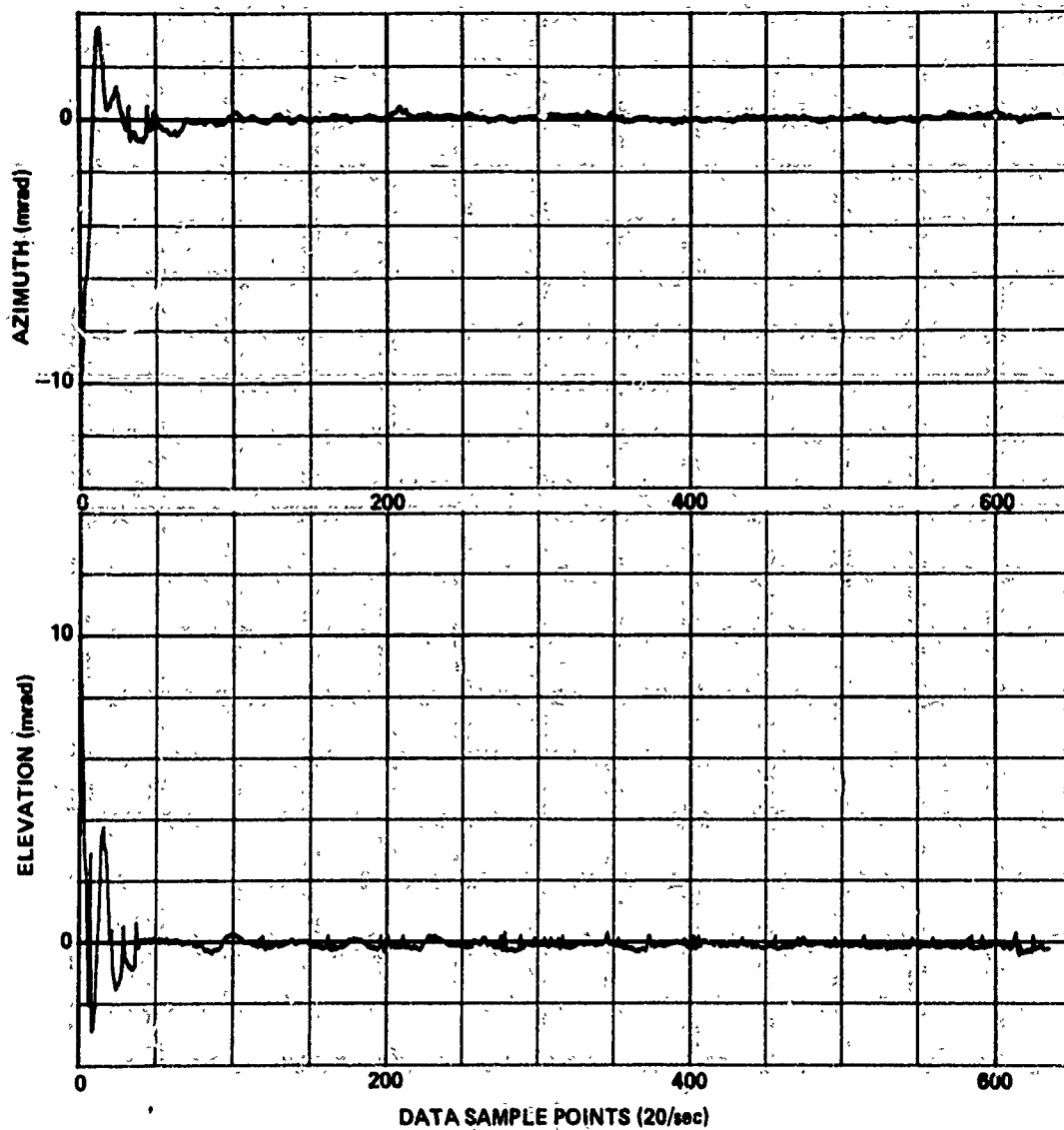
RUN 91



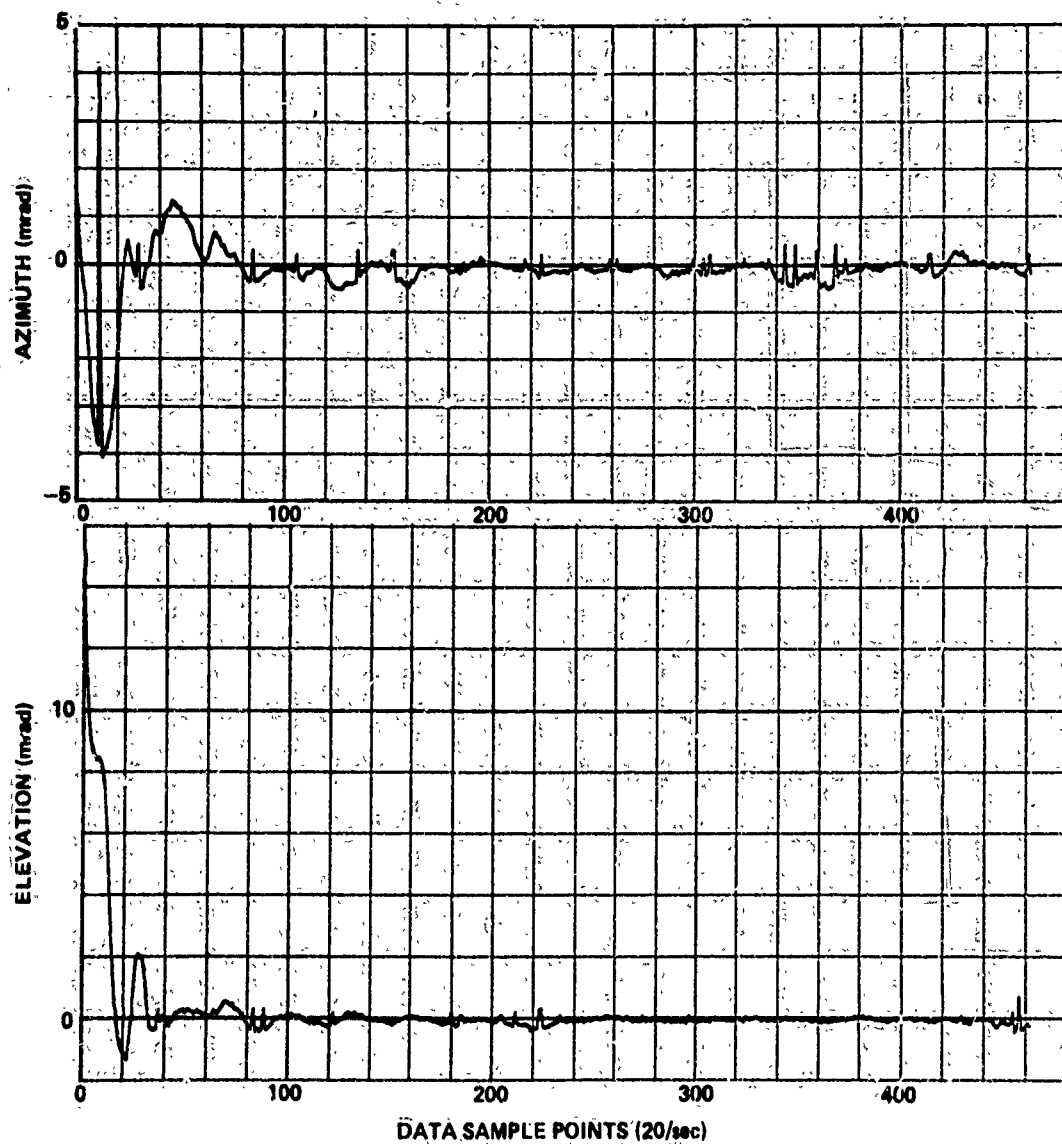
RUN 92



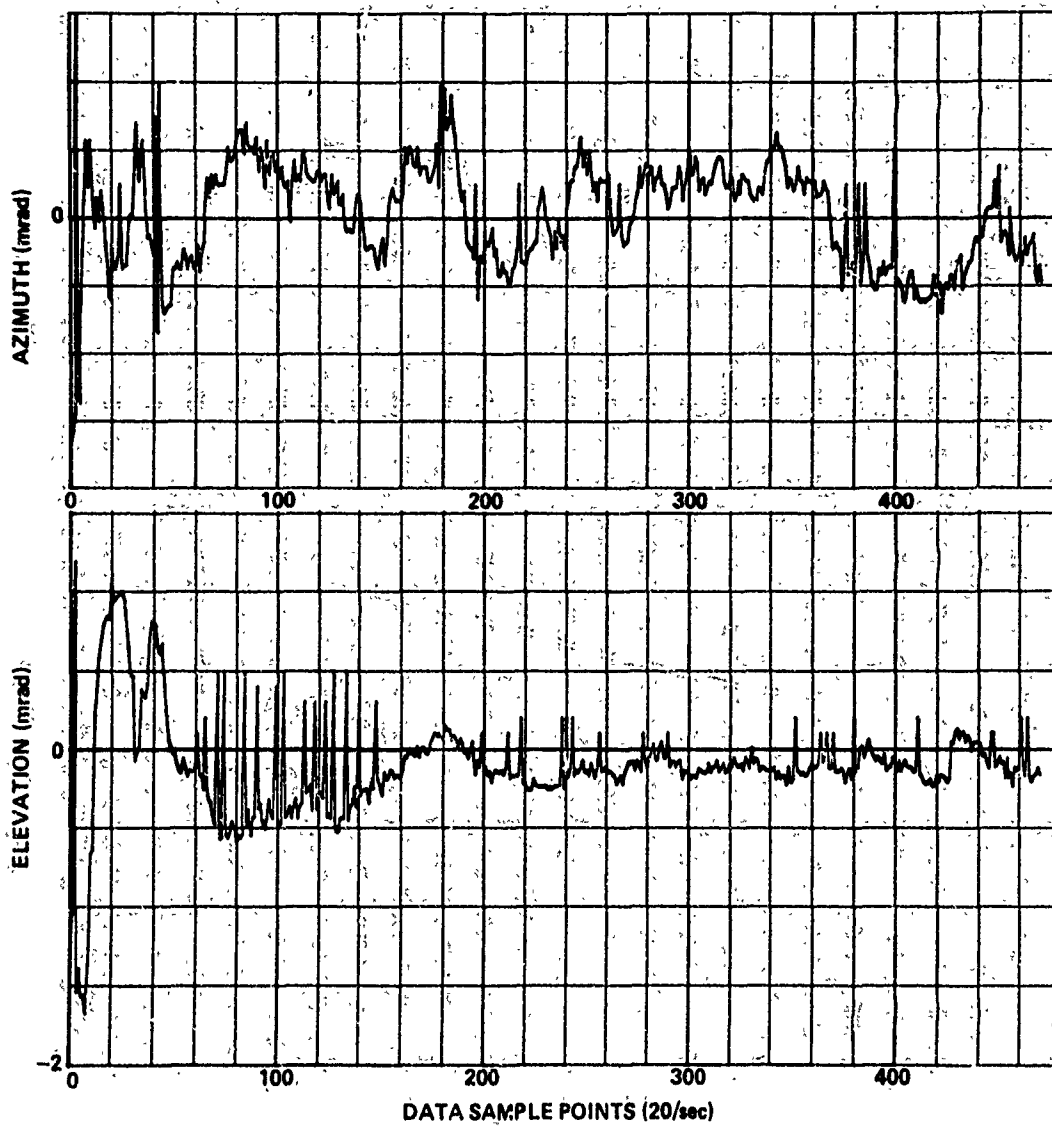
RUN 93



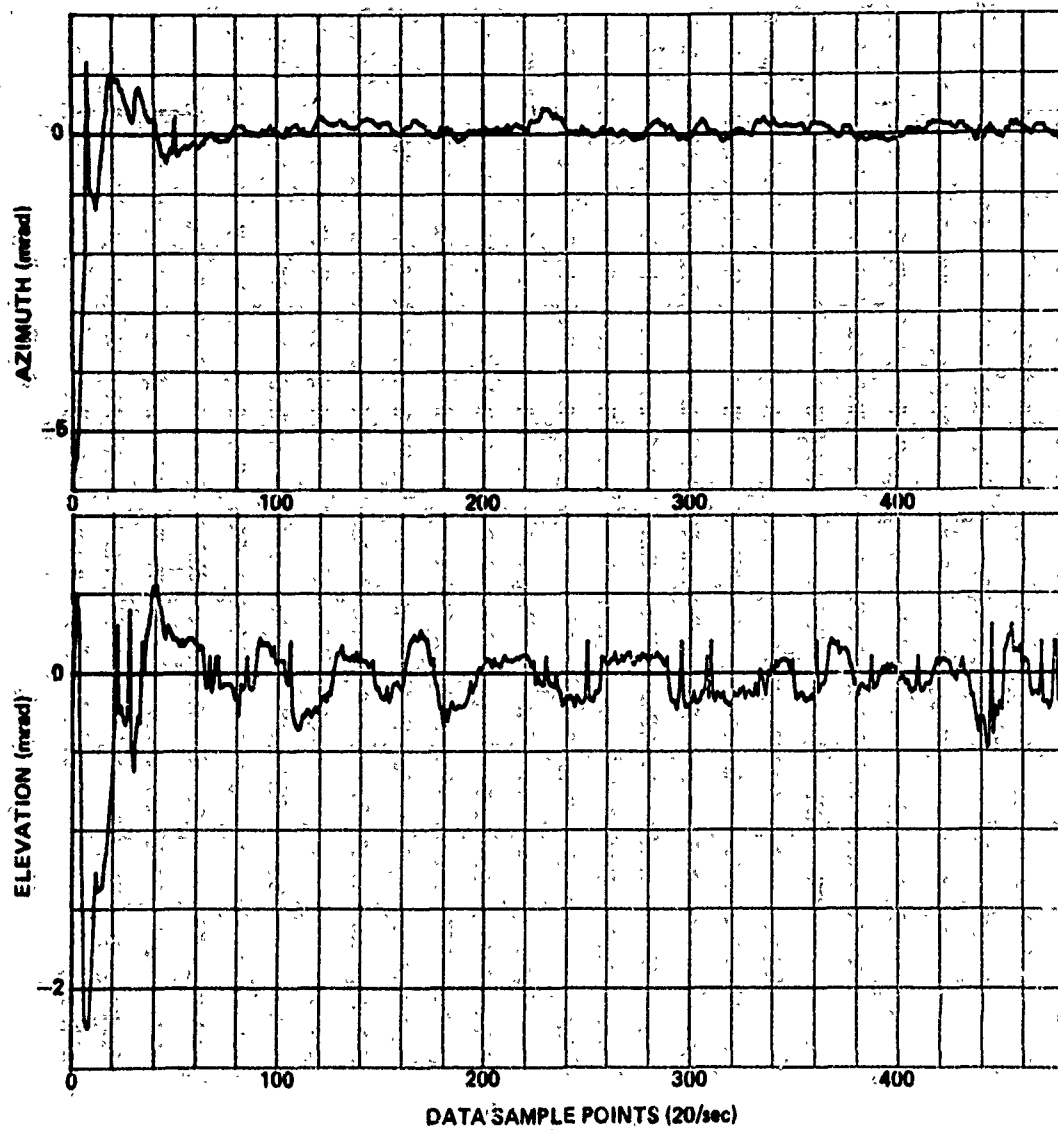
RUN 94



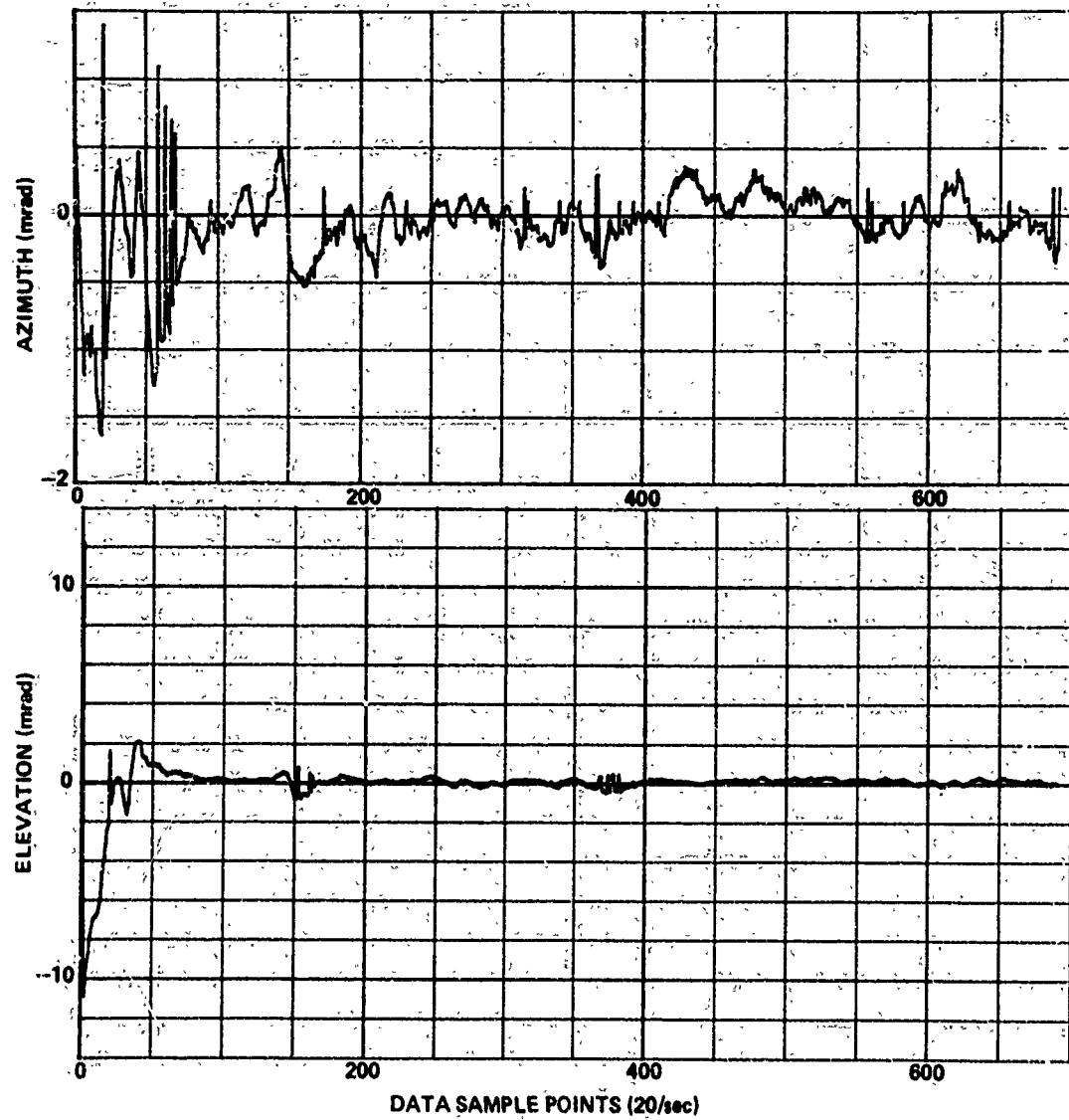
RUN 95



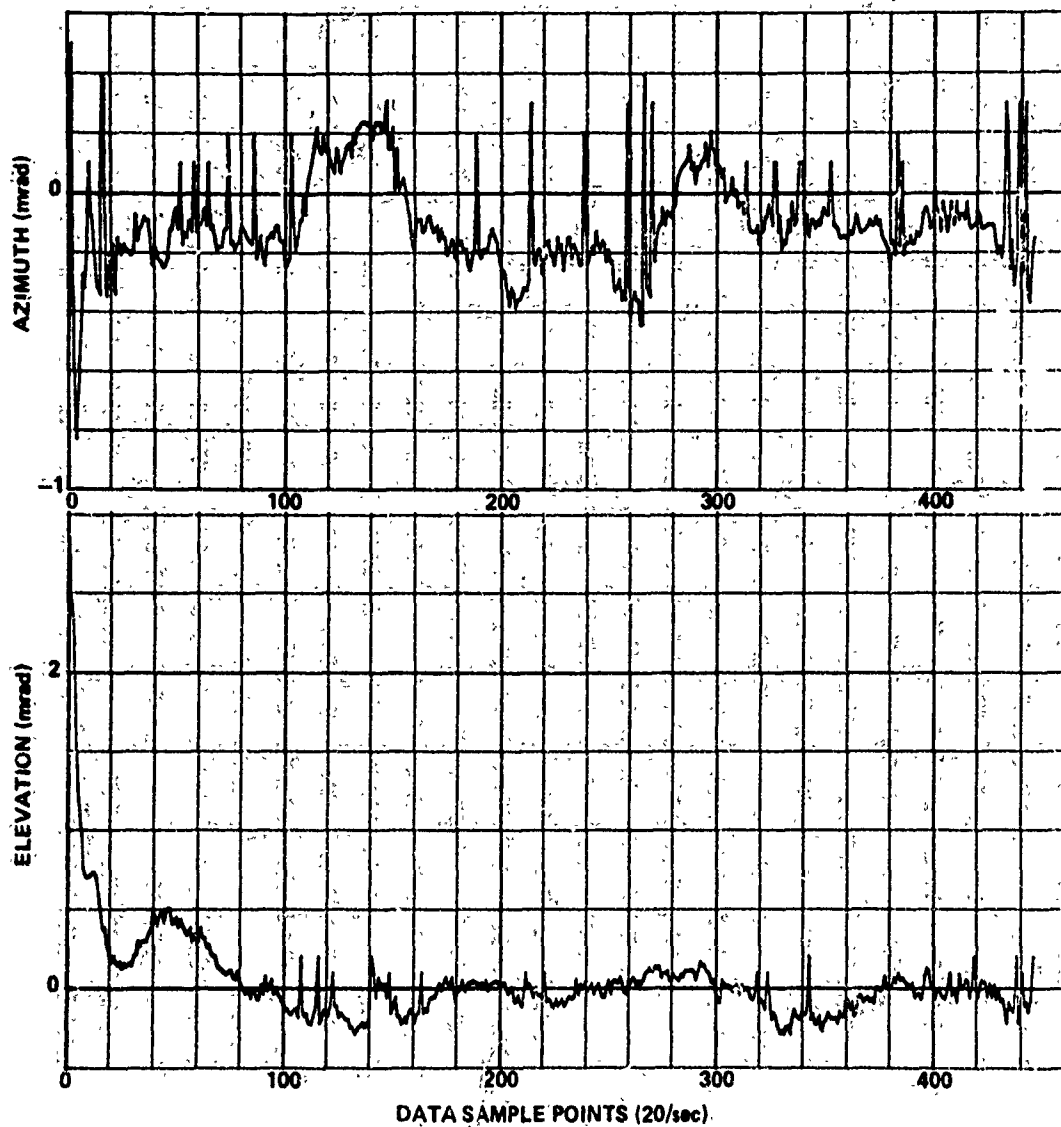
RUN 96



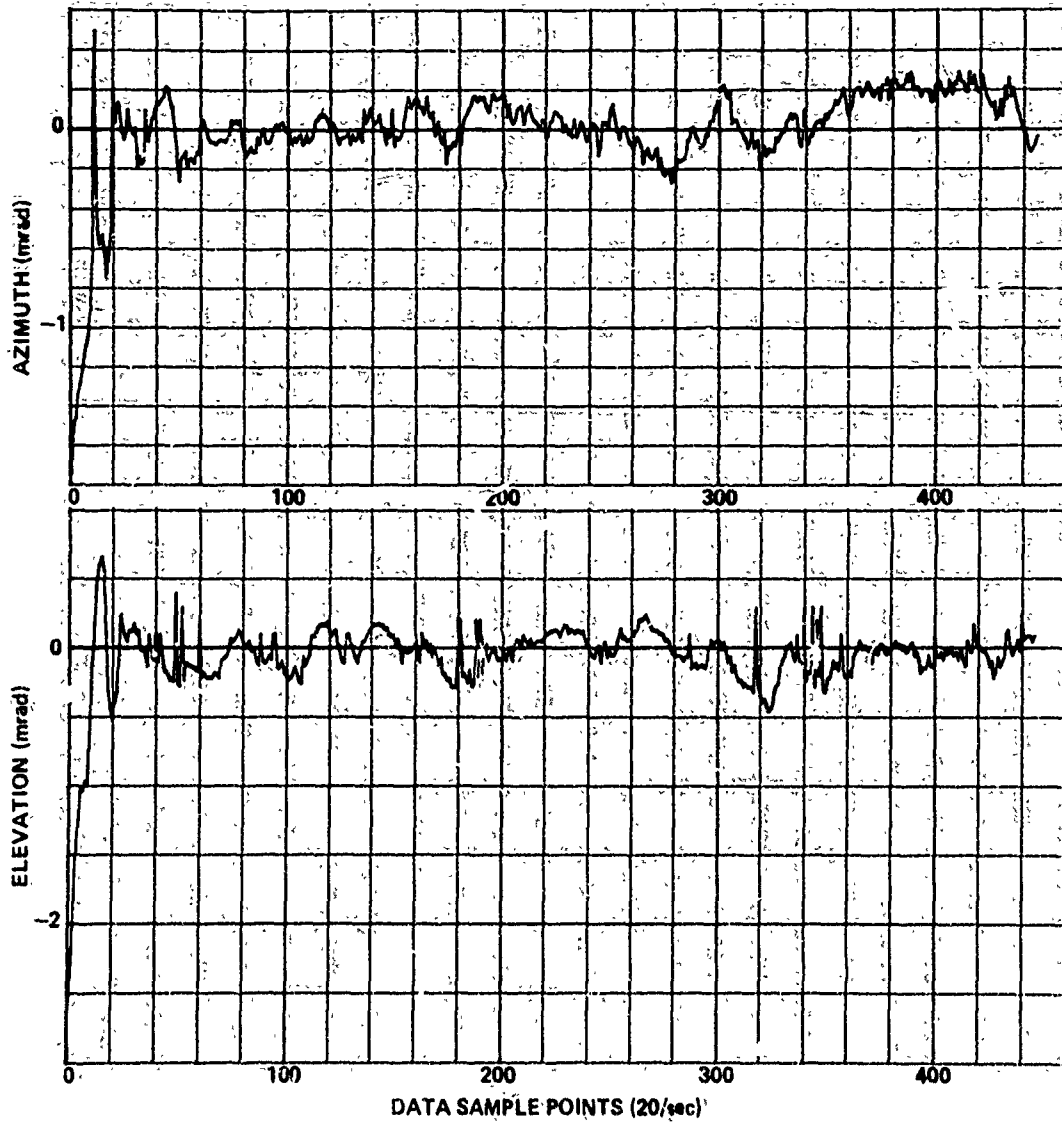
RUN 98

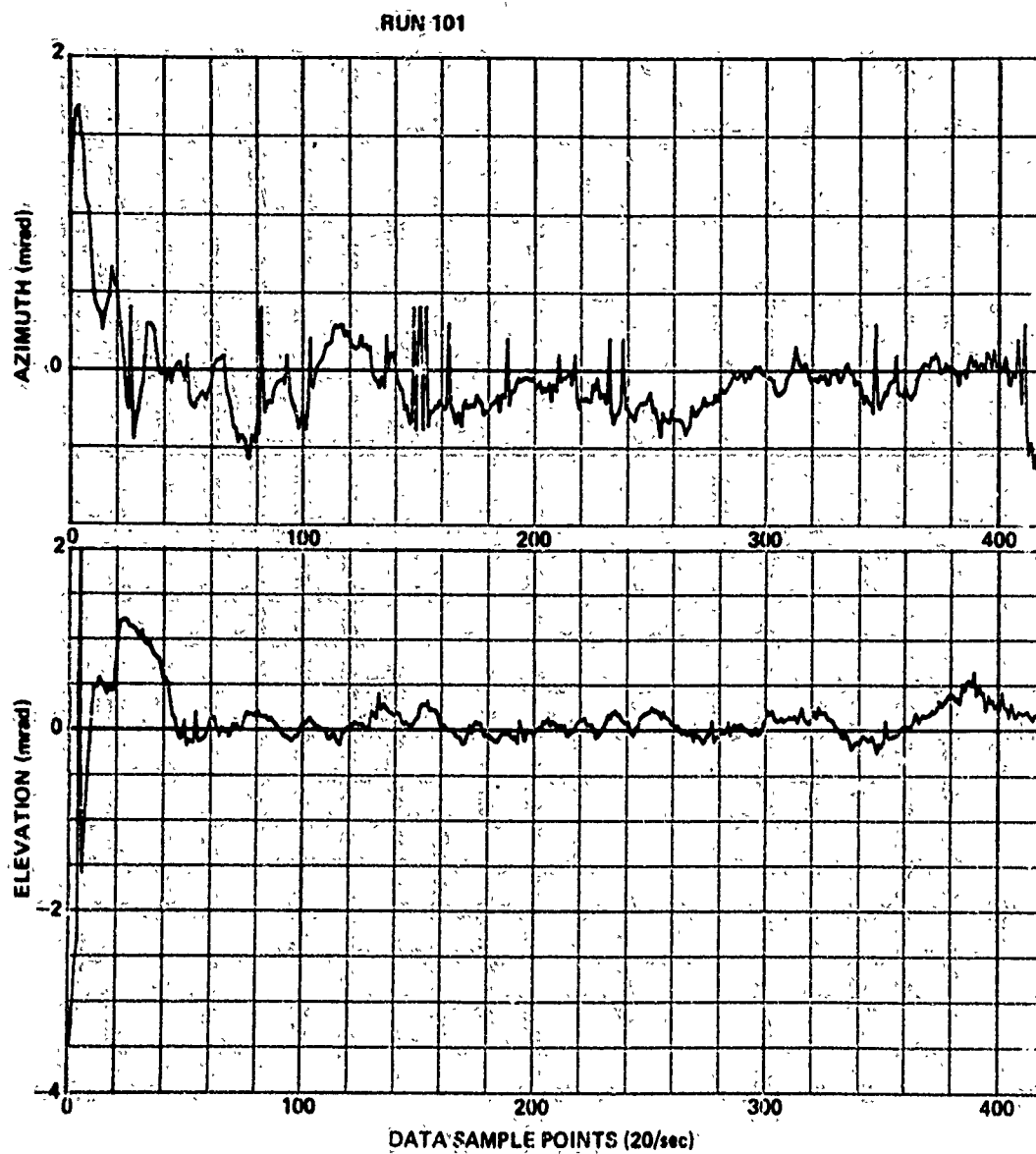


RUN 99

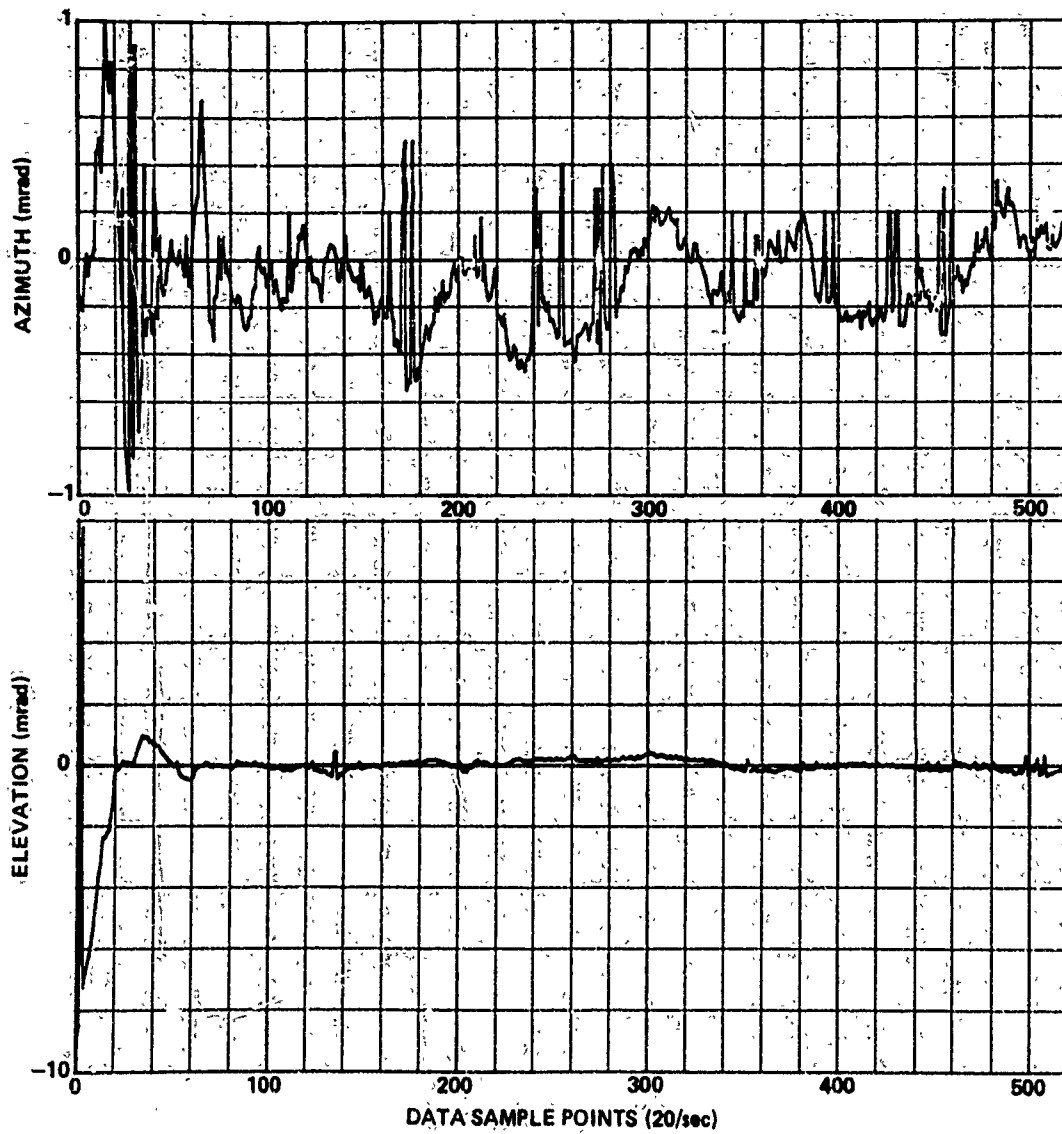


RUN 100

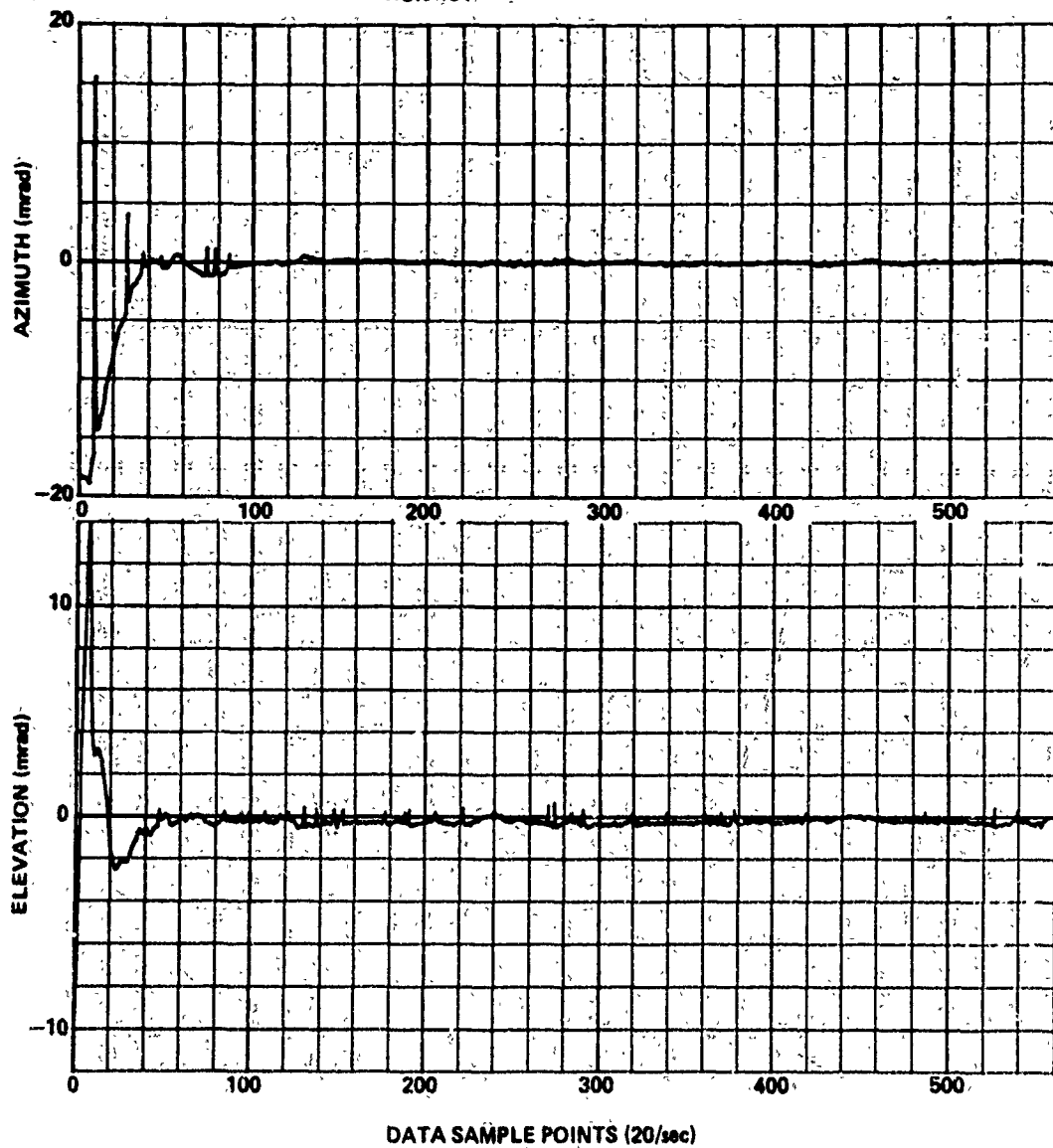




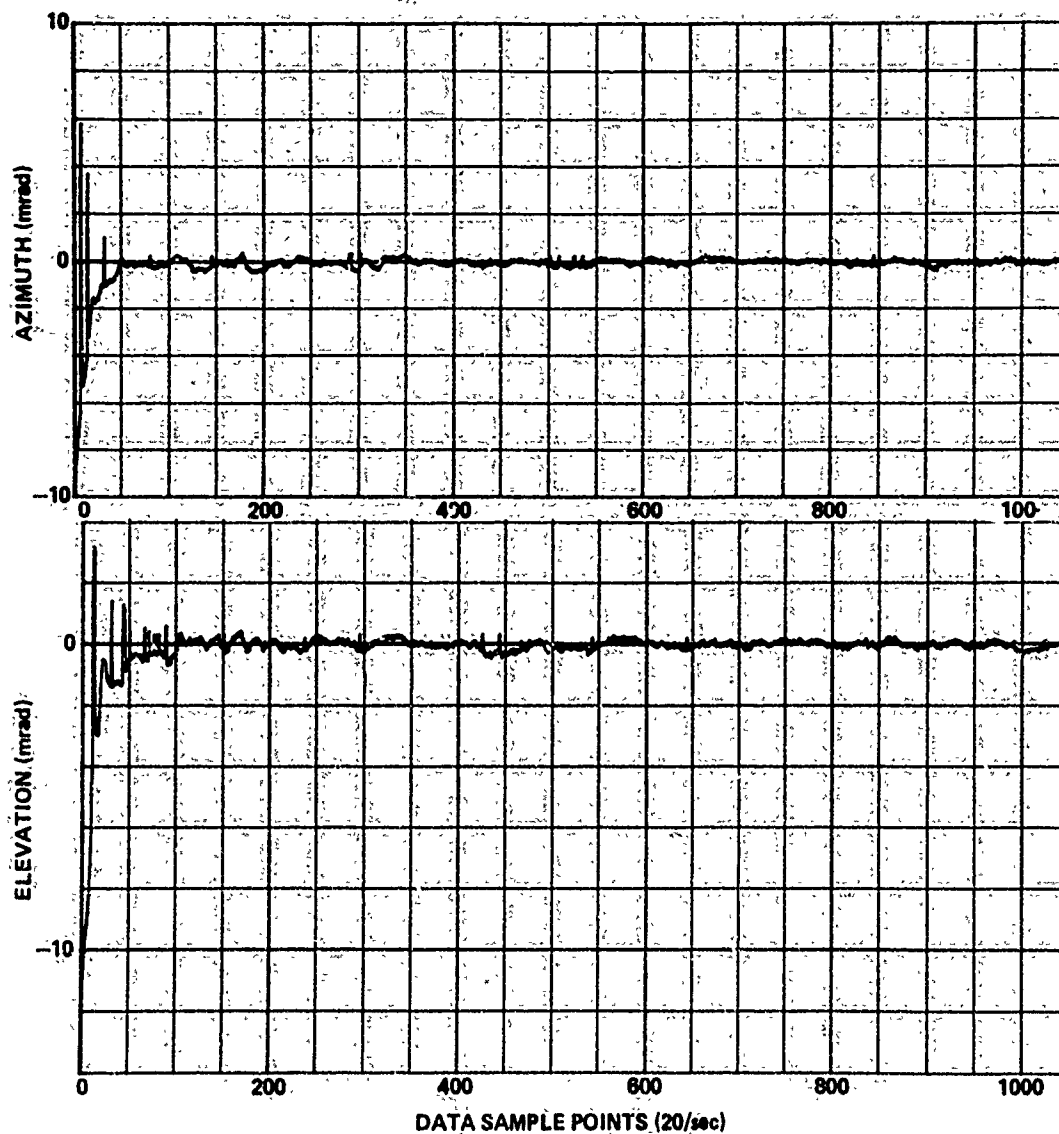
RUN 102



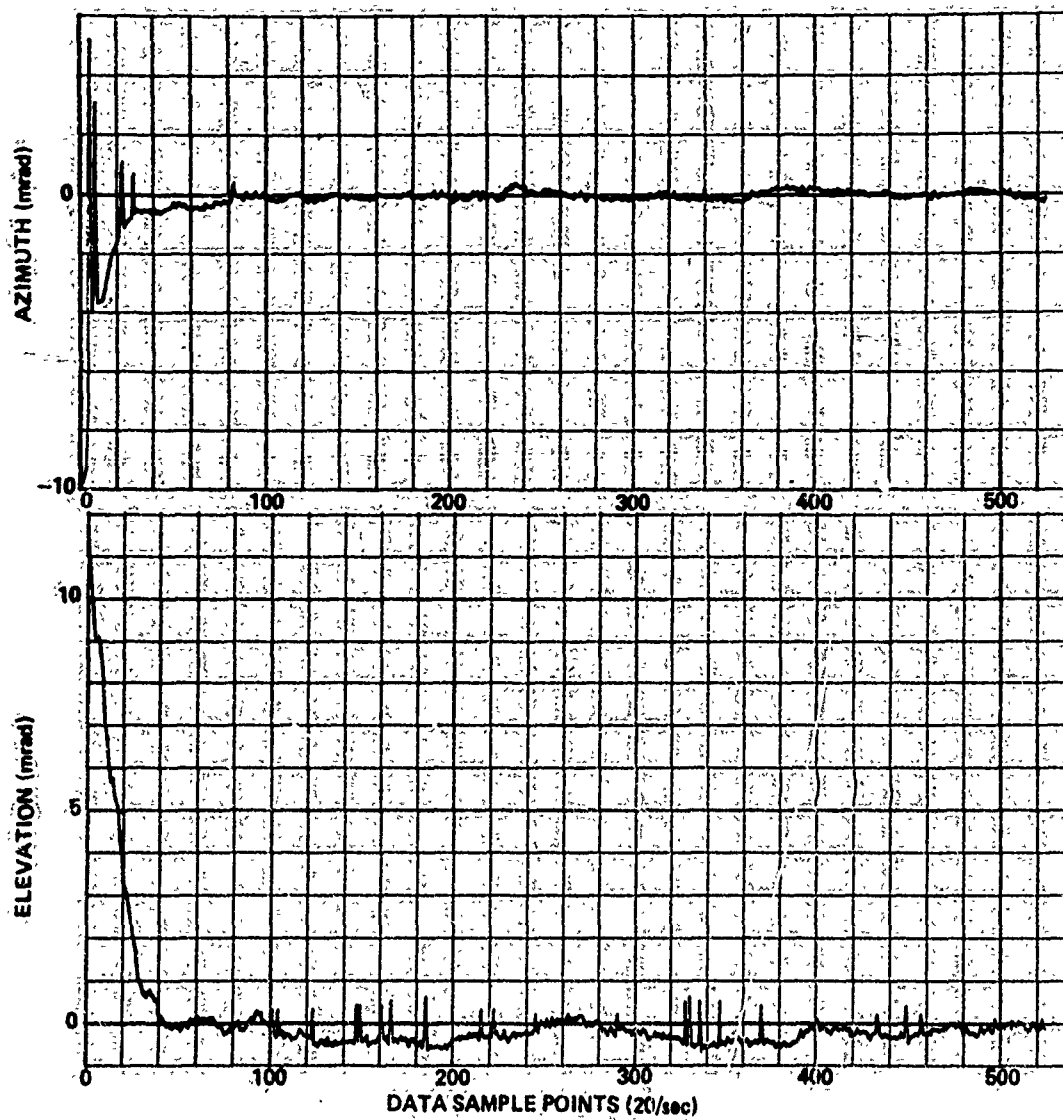
RUN 104



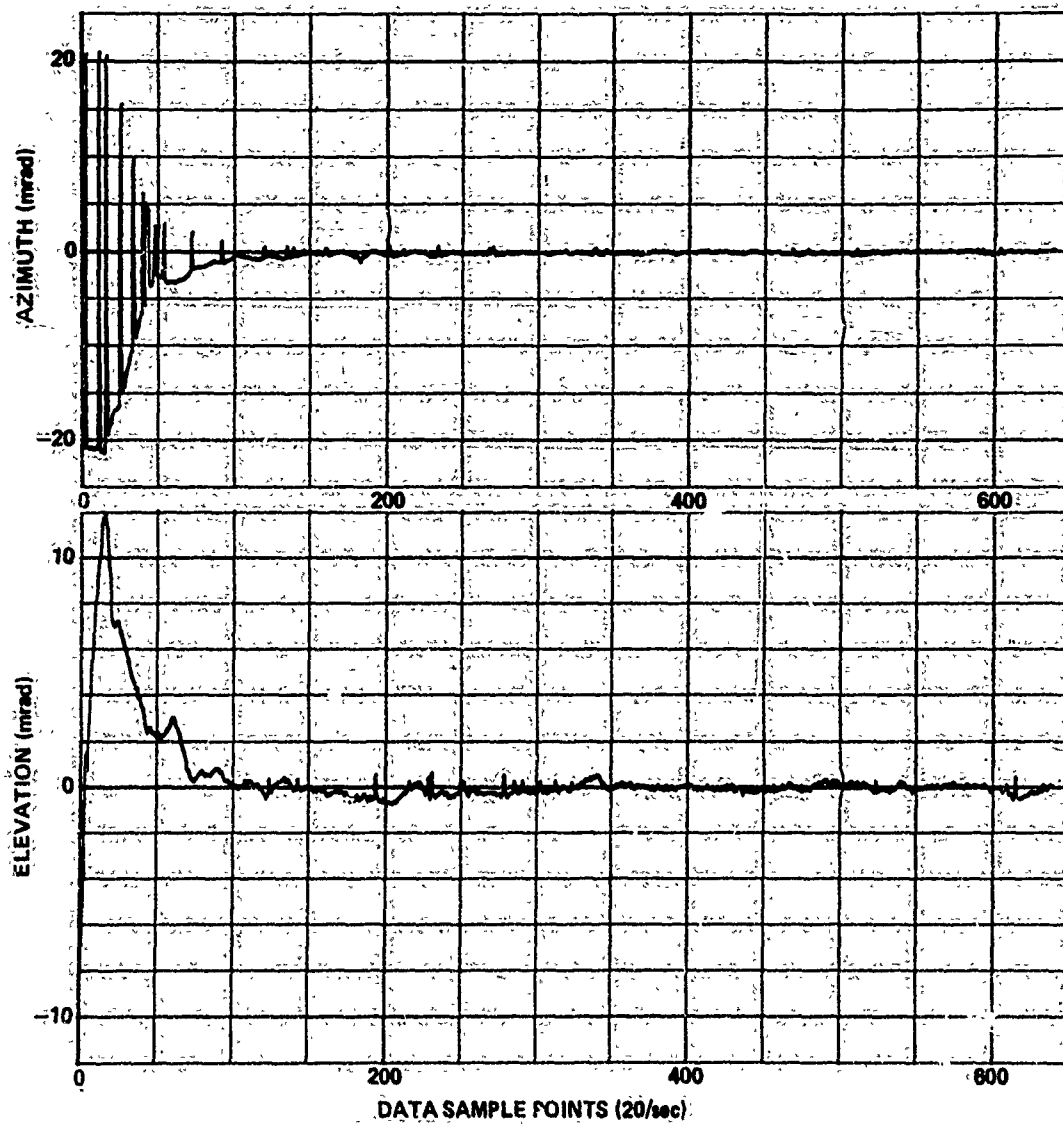
RUN 105



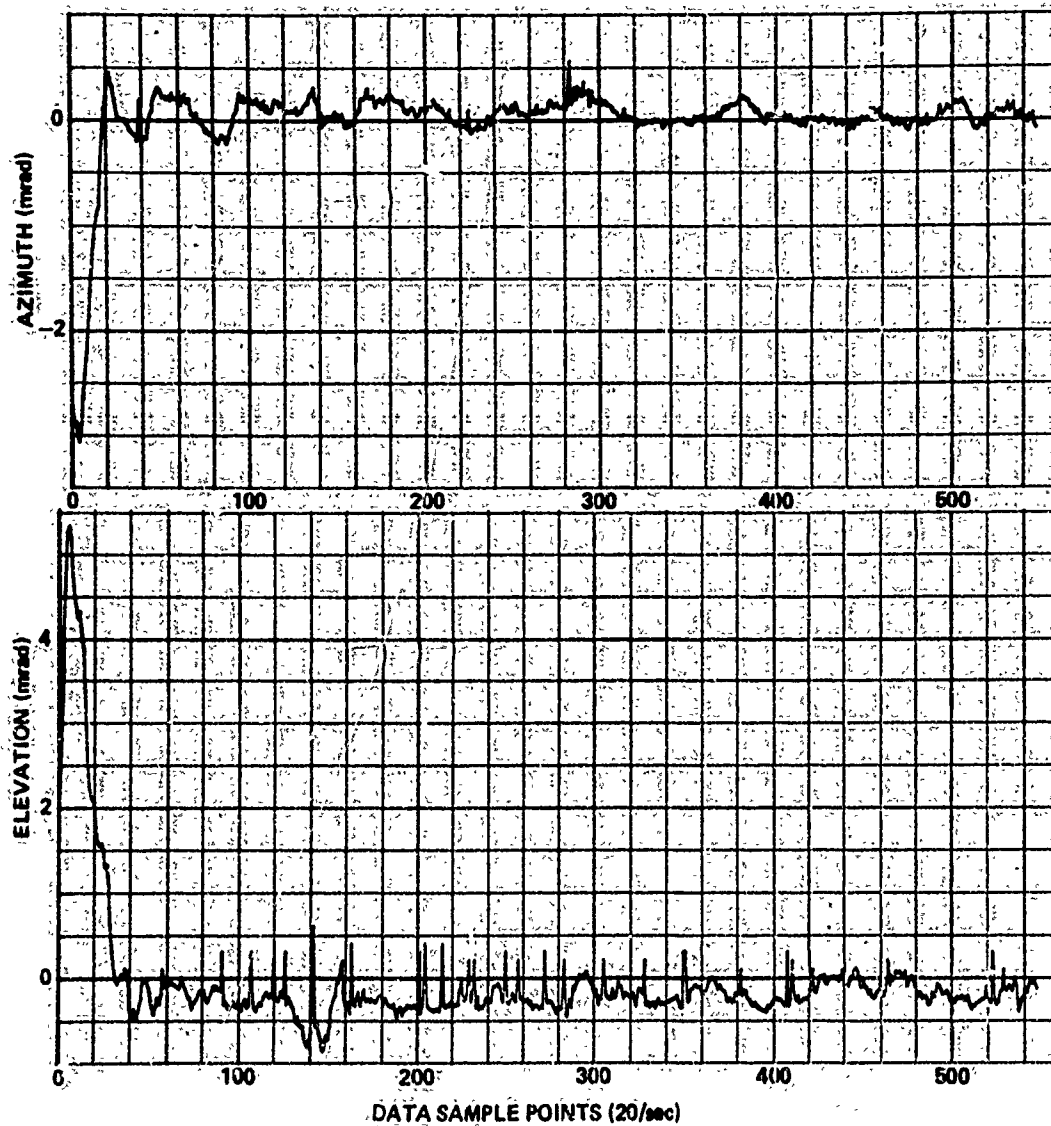
RUN 106



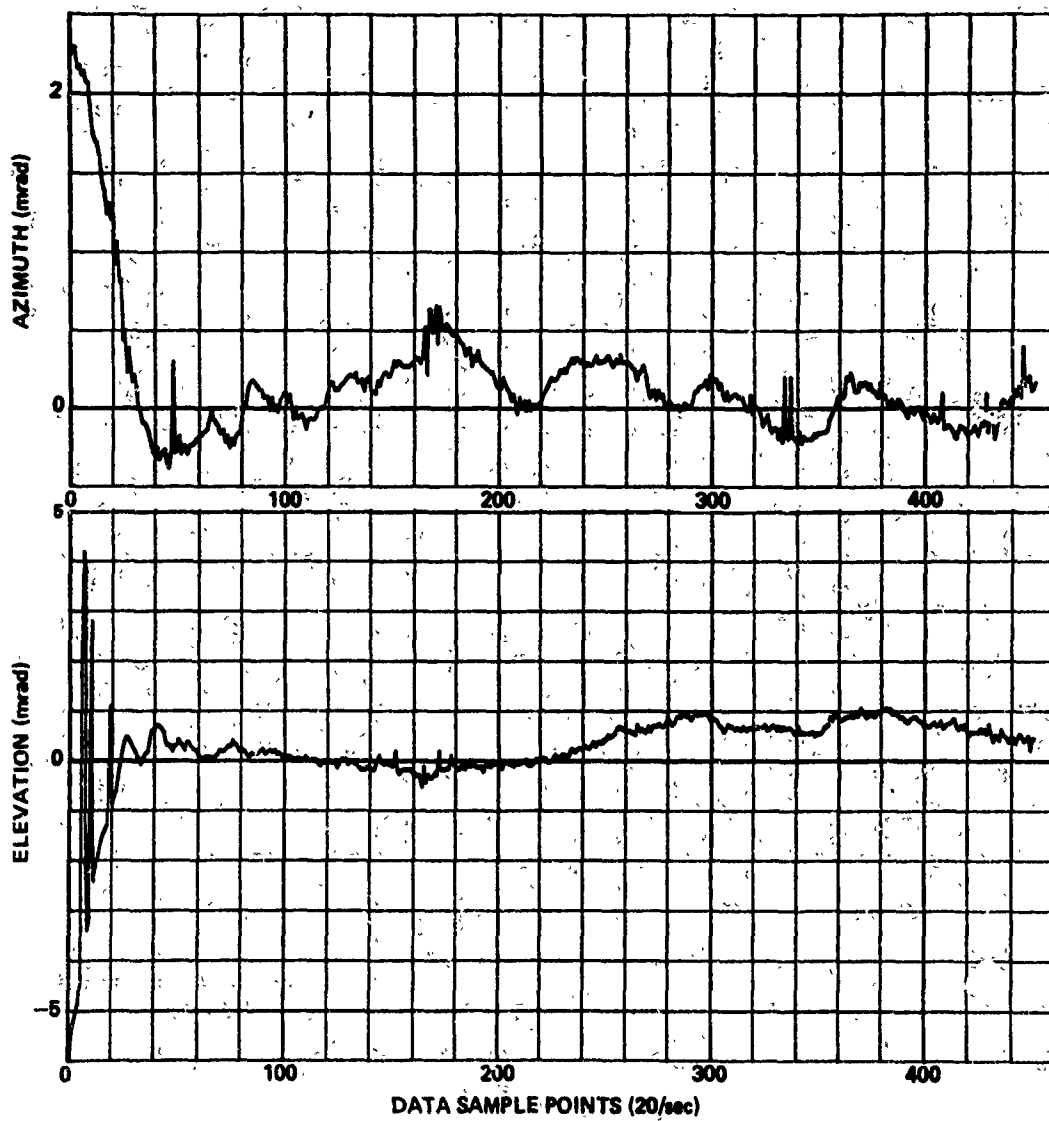
RUN 107



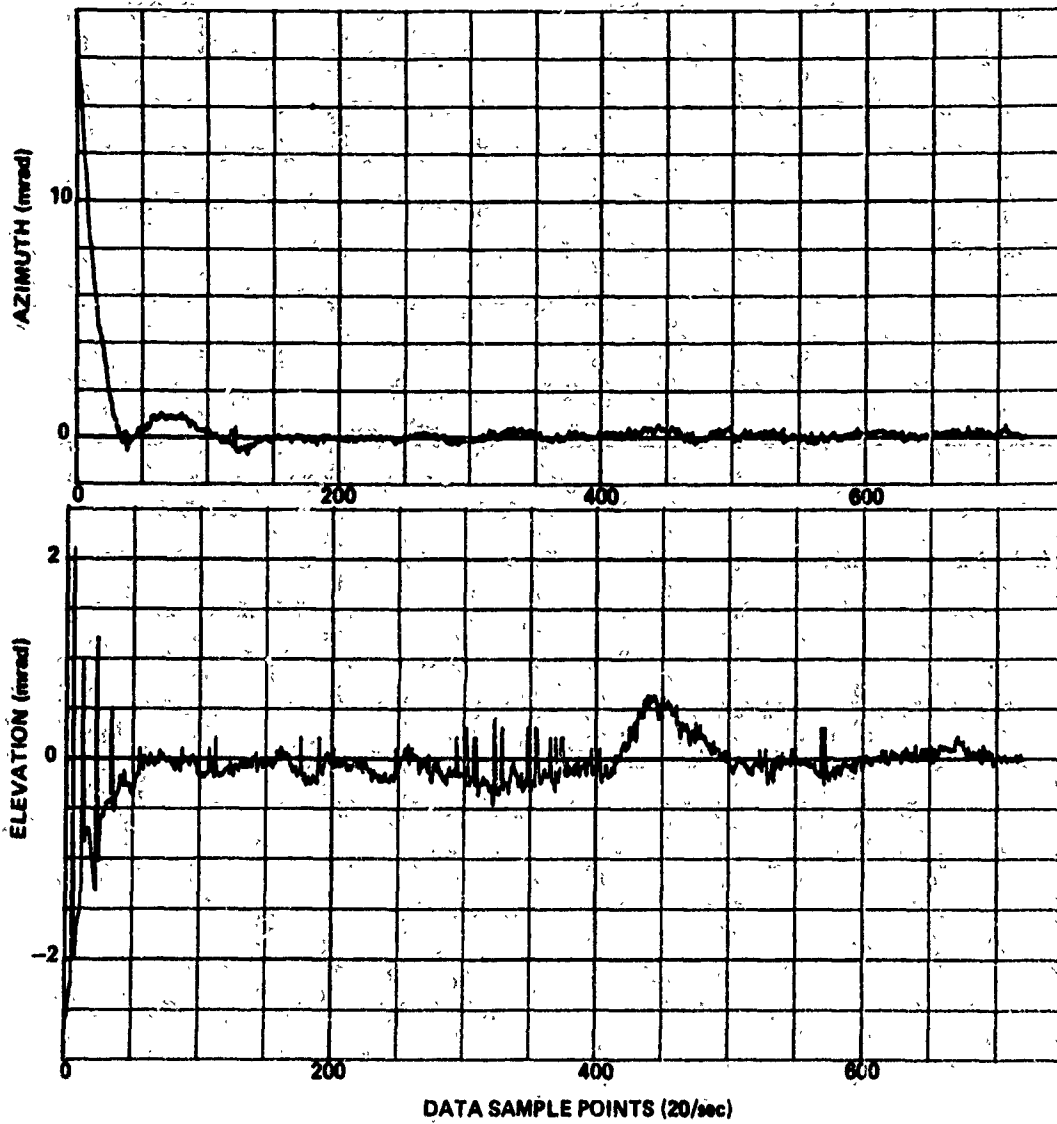
RUN 108



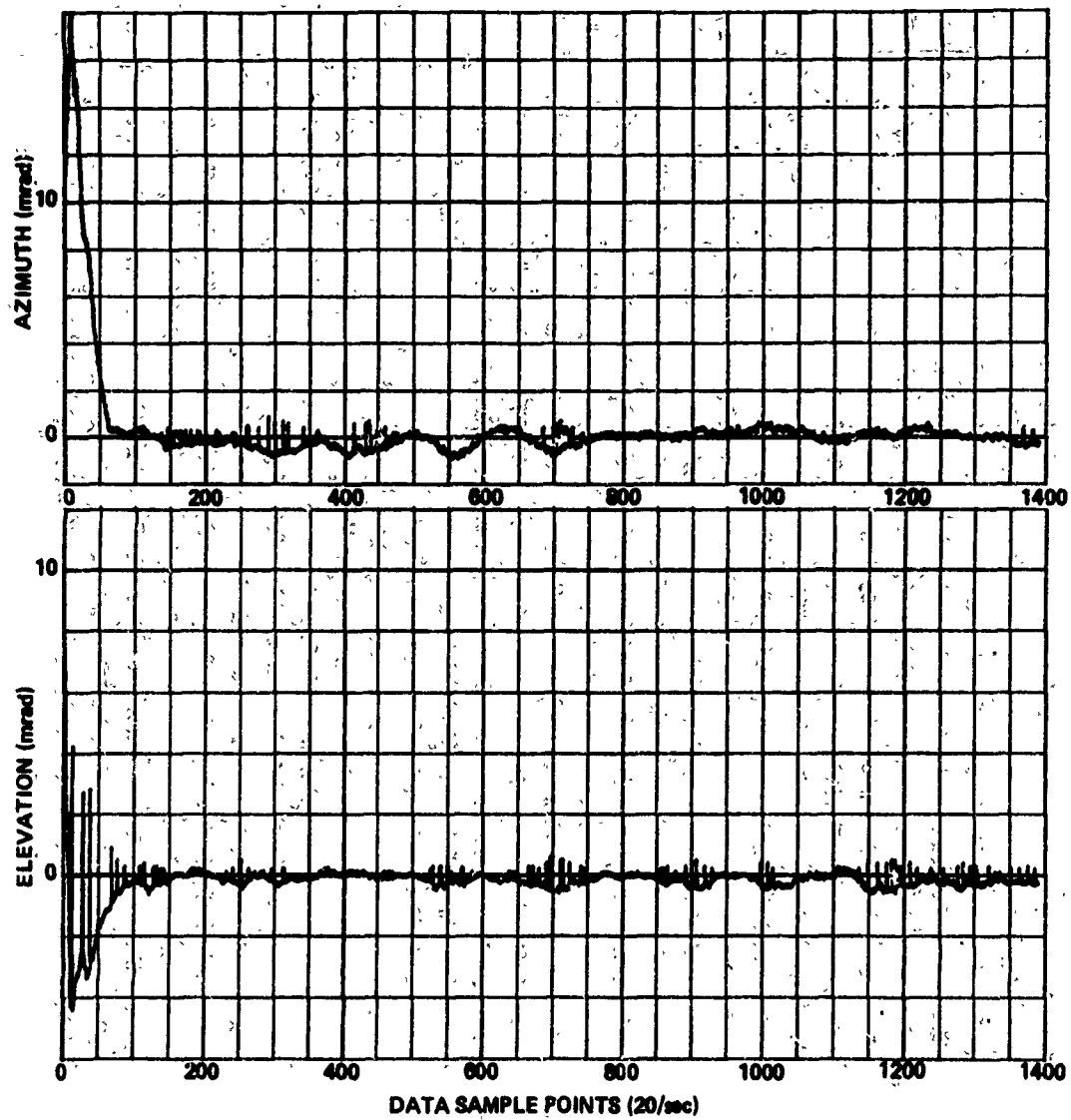
RUN 109



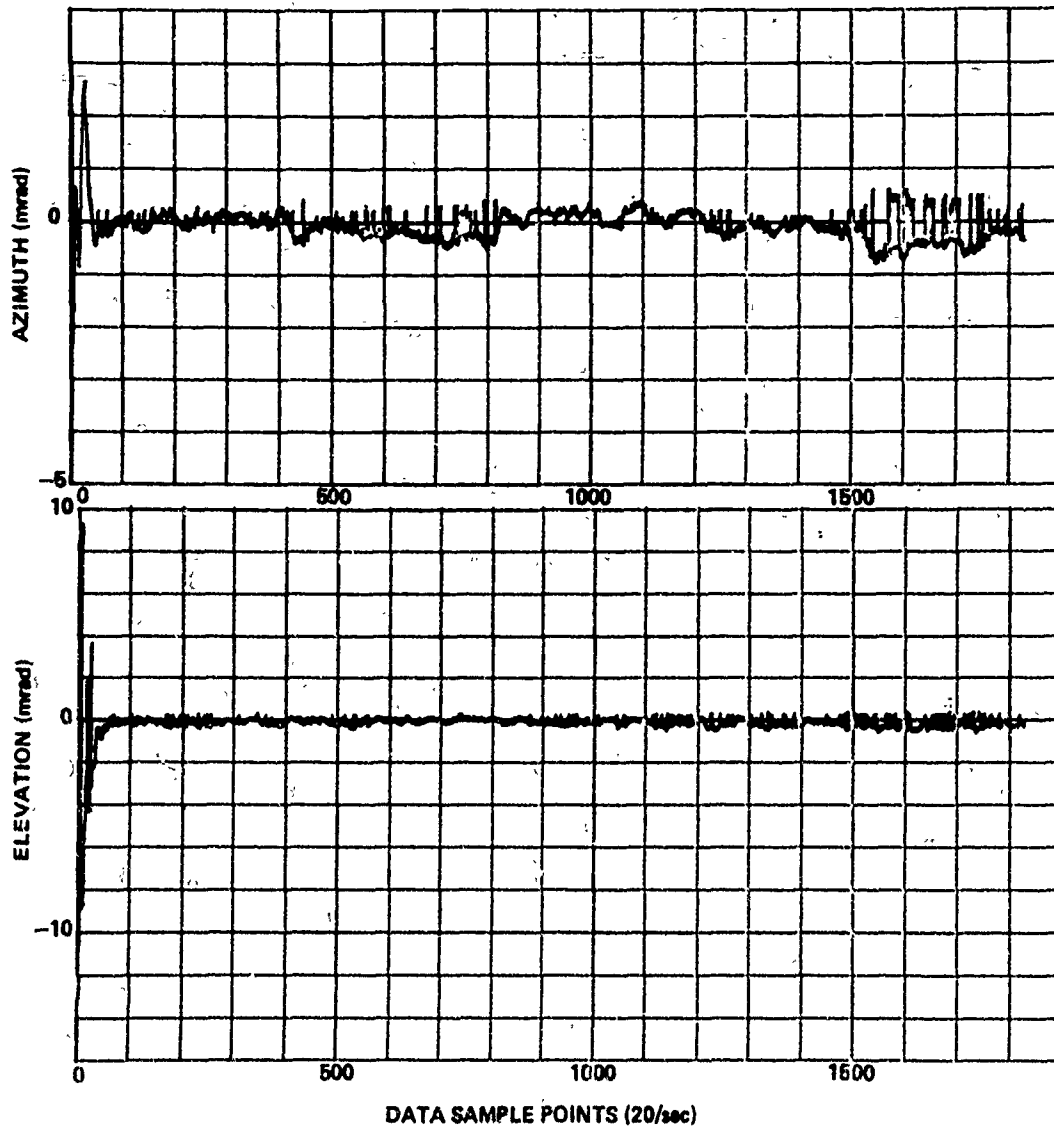
RUN 110



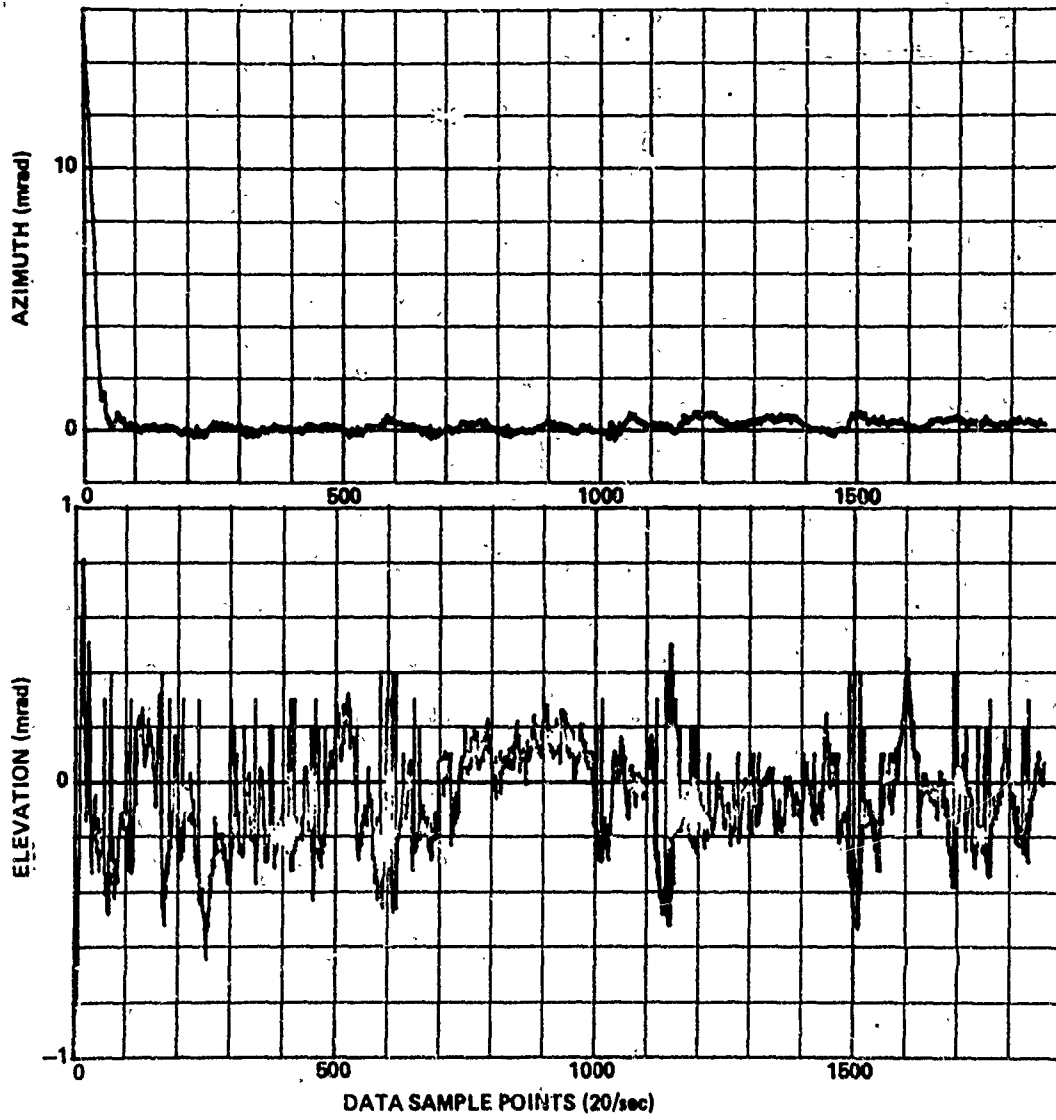
RUN 111



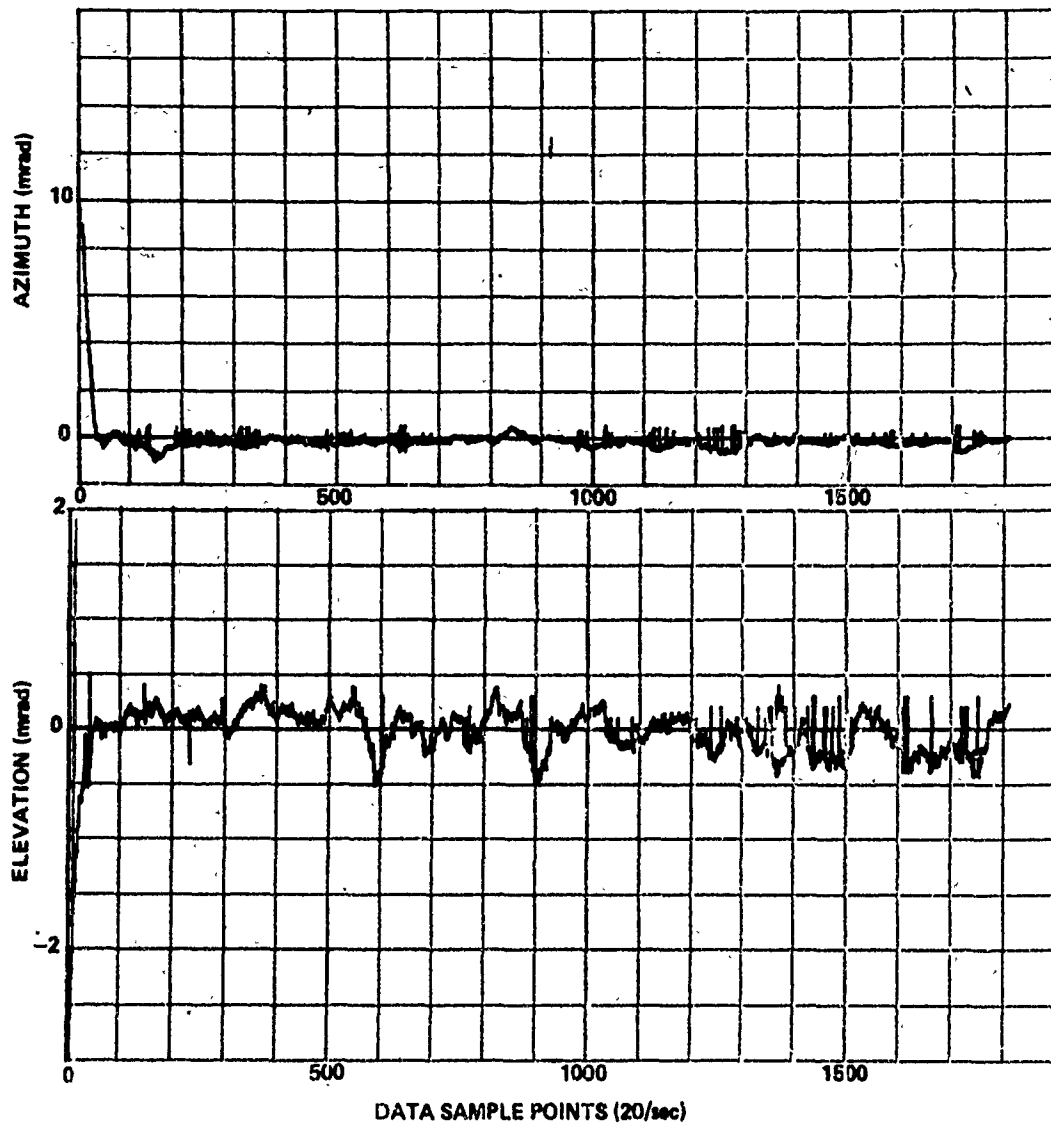
RUN 112



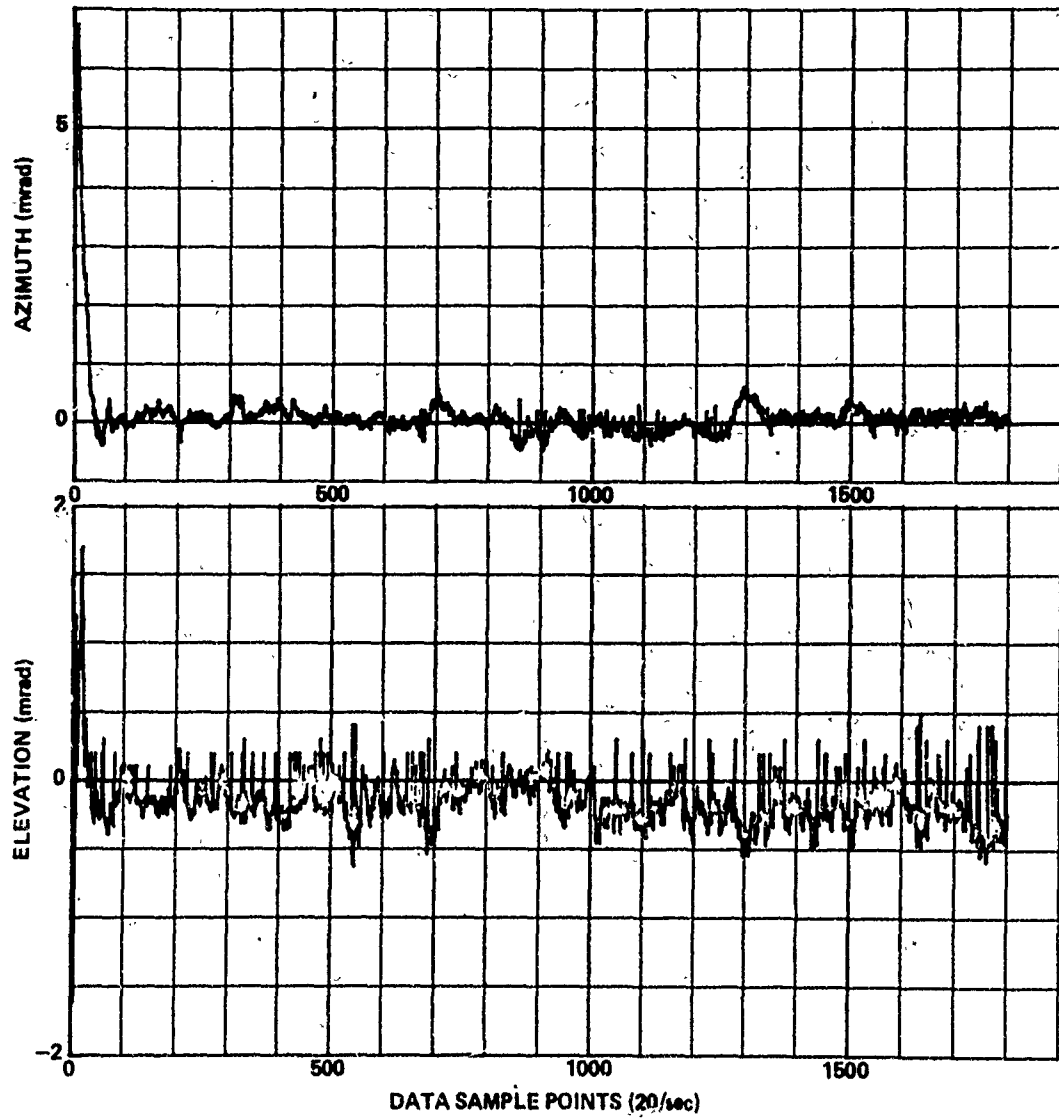
RUN 113



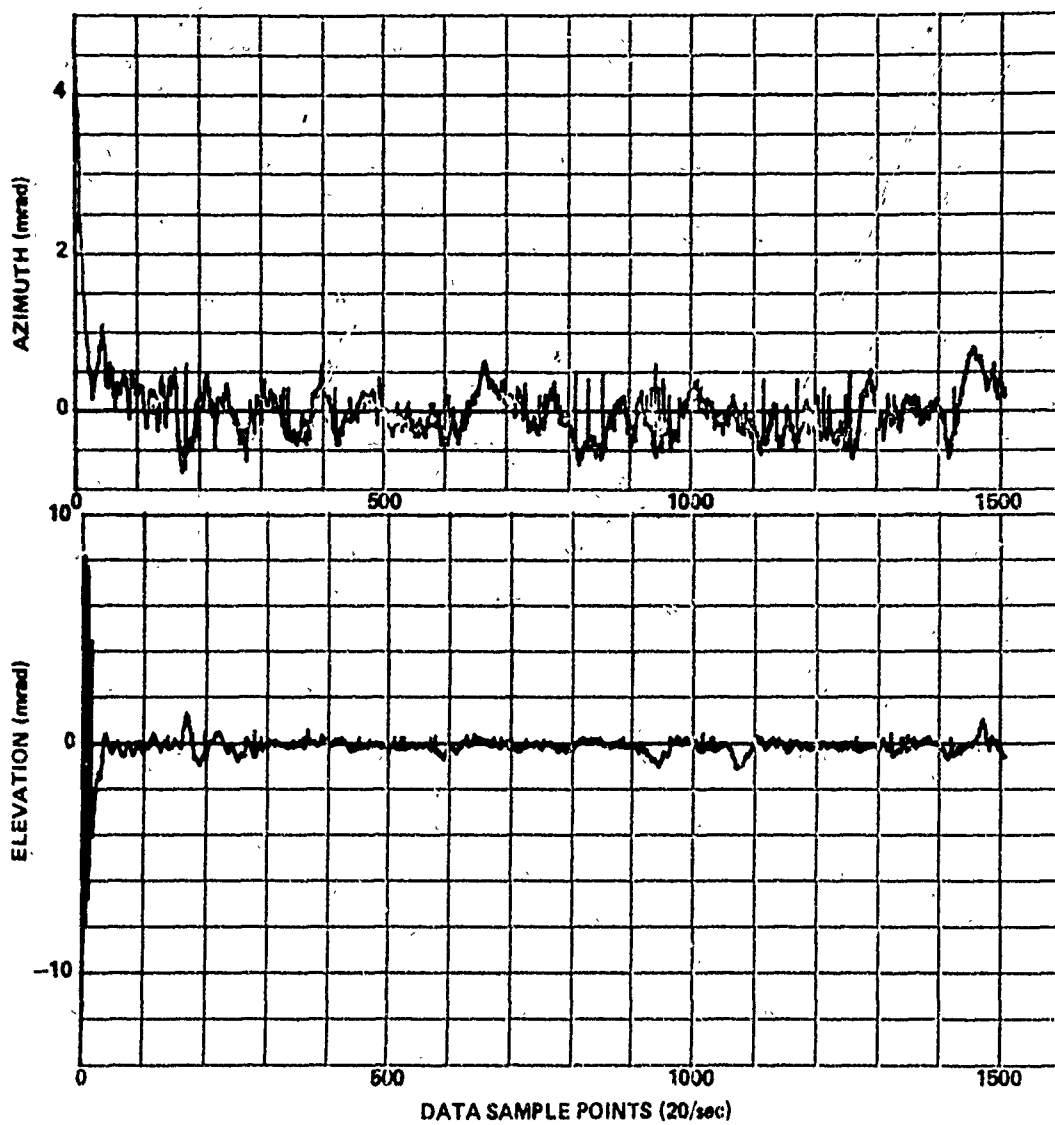
RUN 114



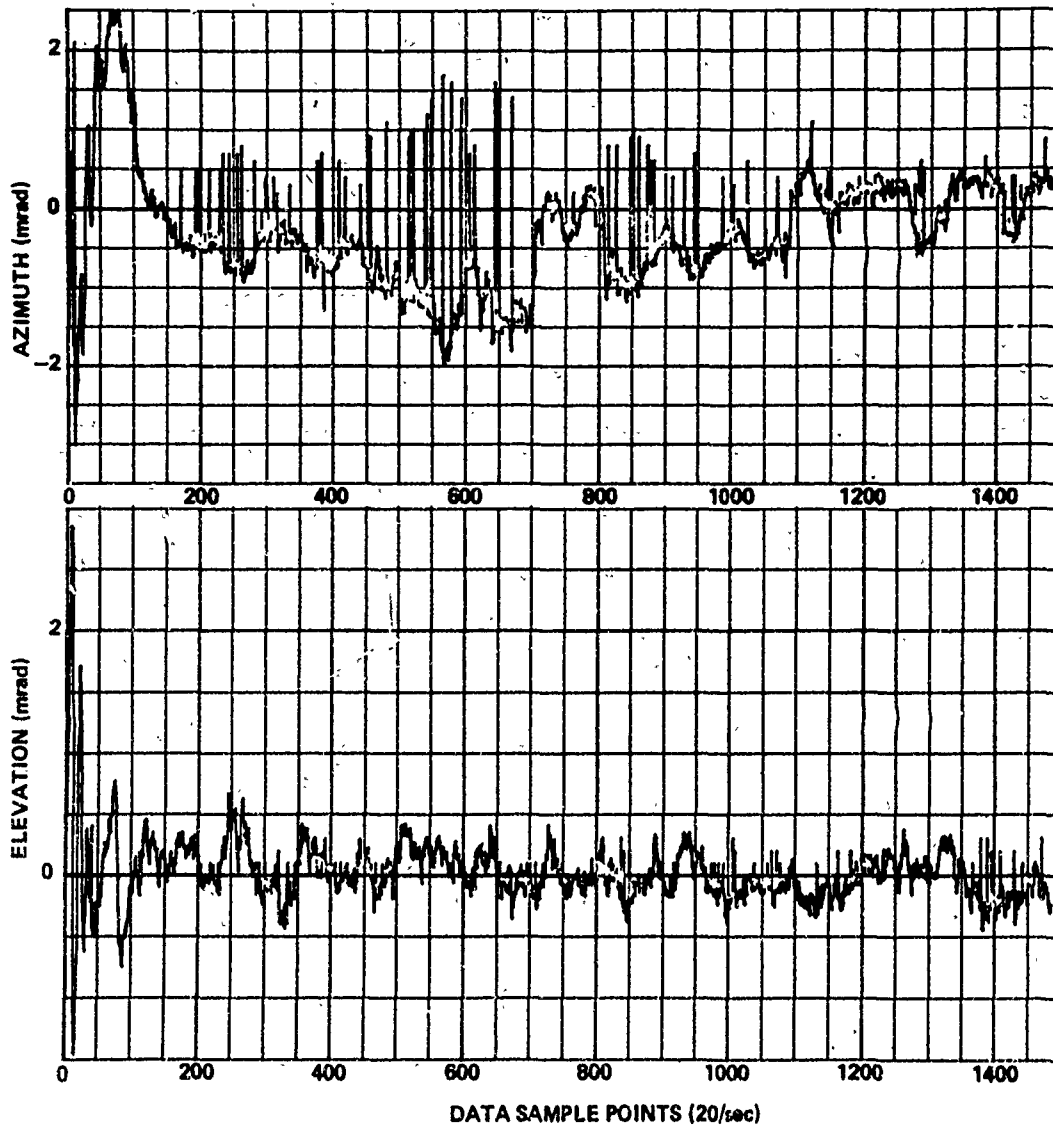
RUN 115



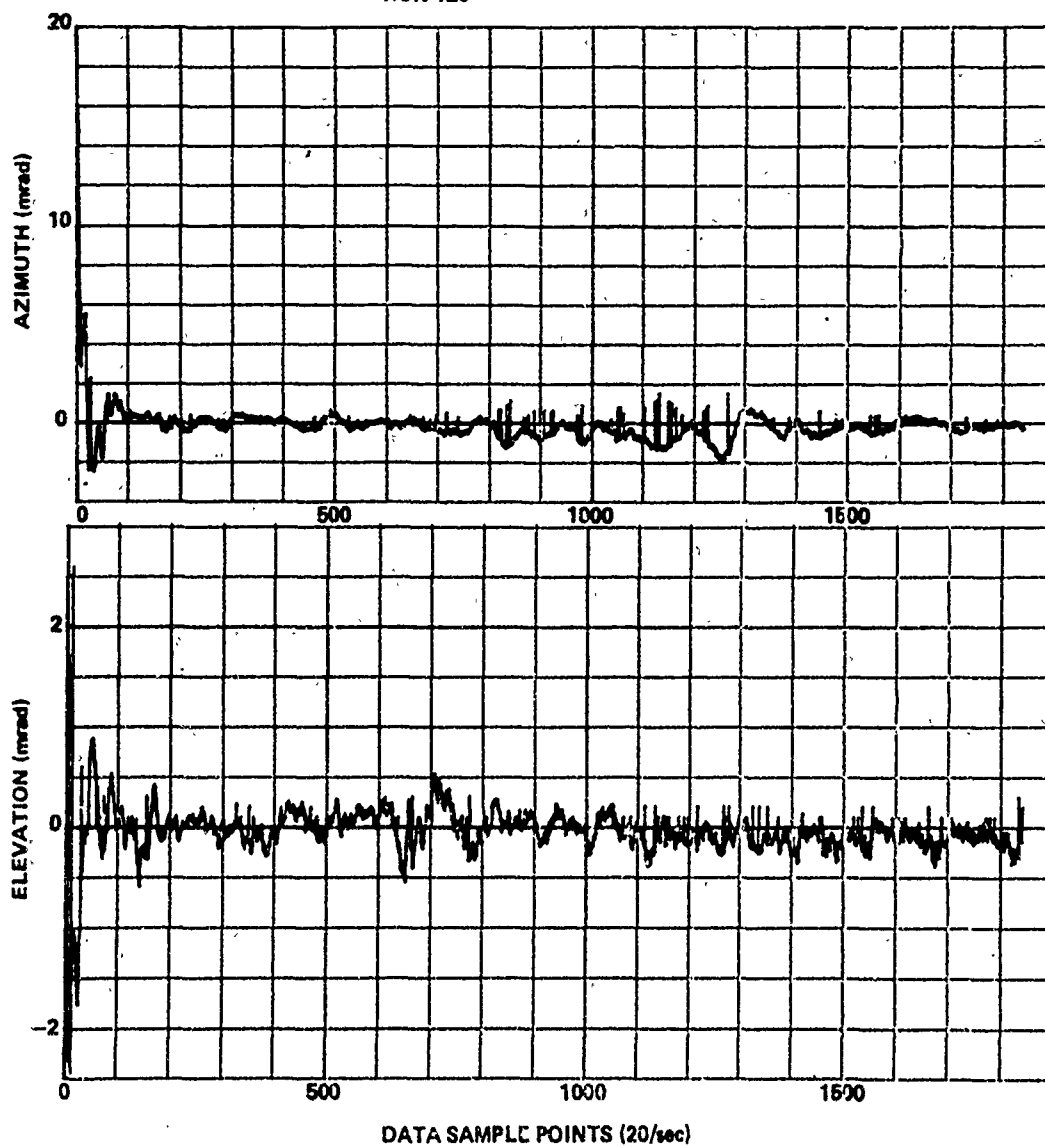
RUN 118



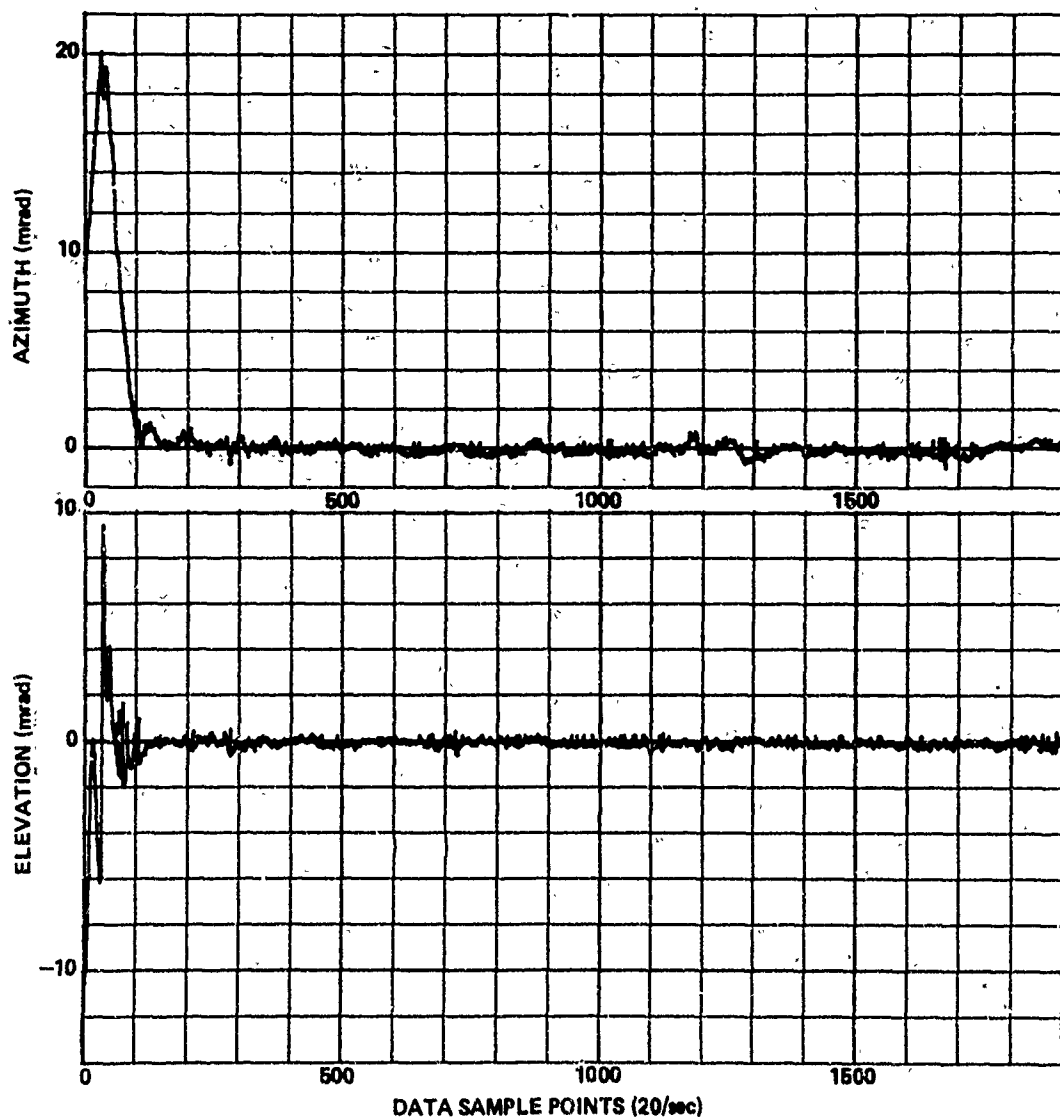
RUN 119



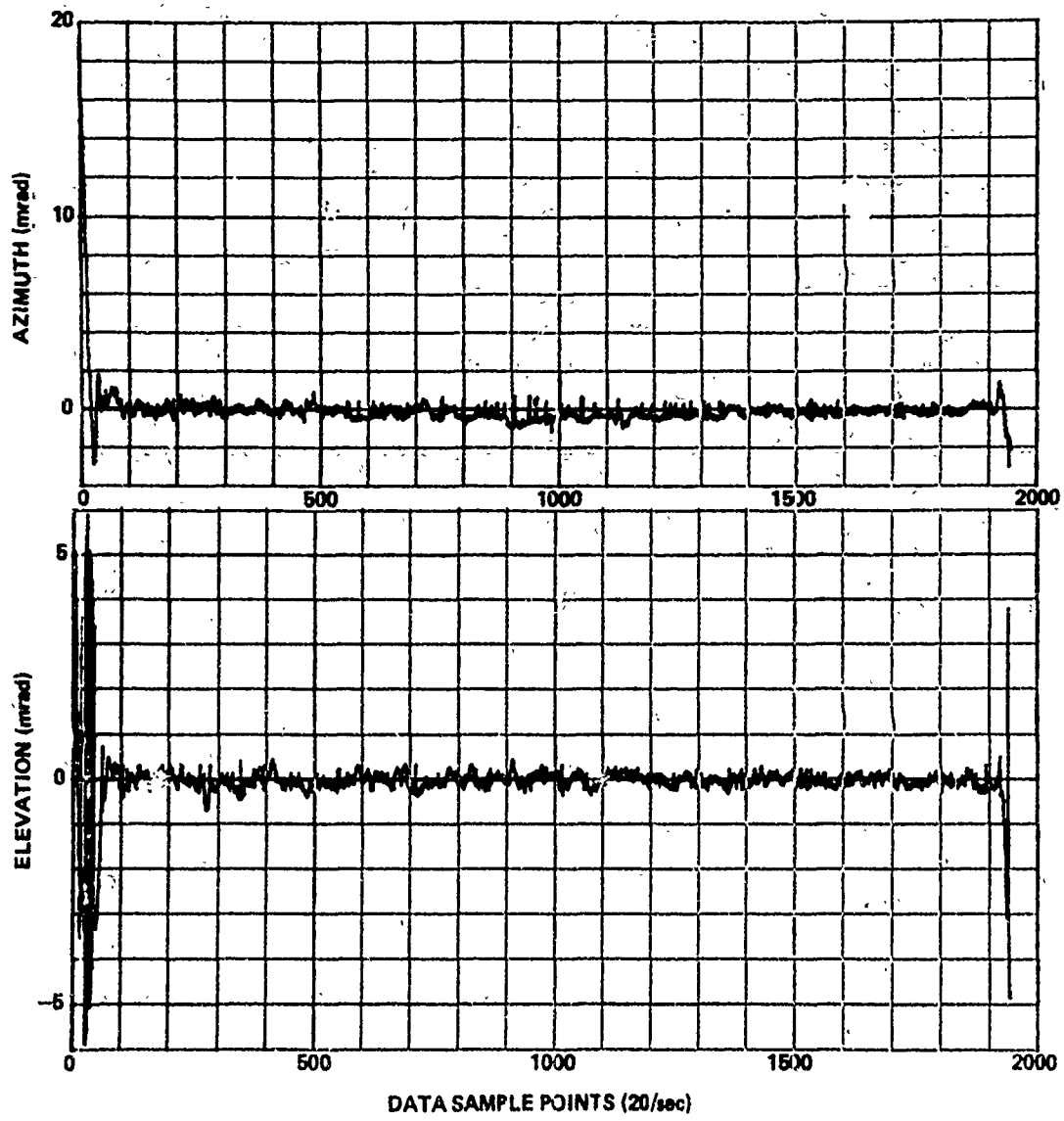
RUN 120



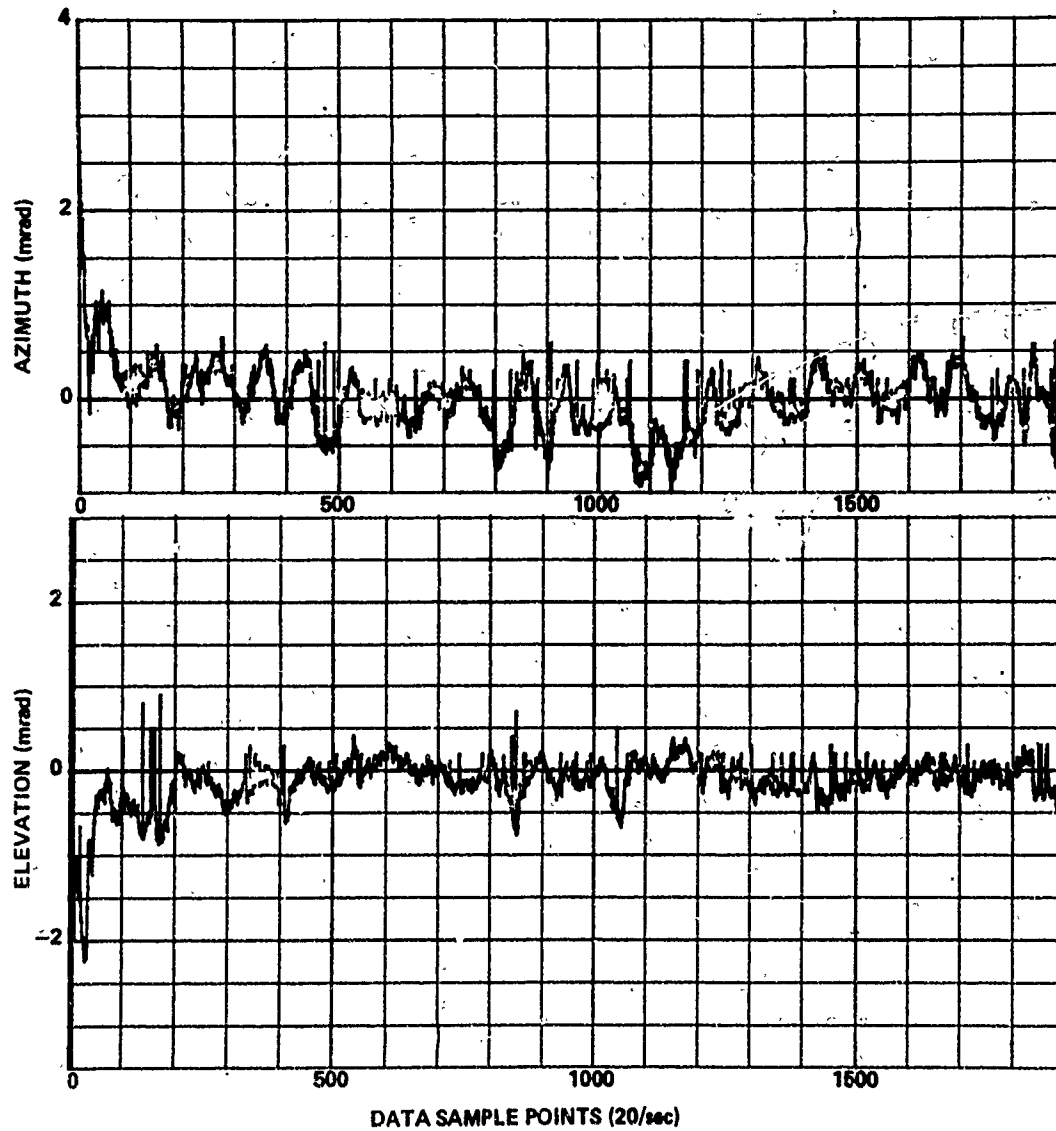
RUN 121



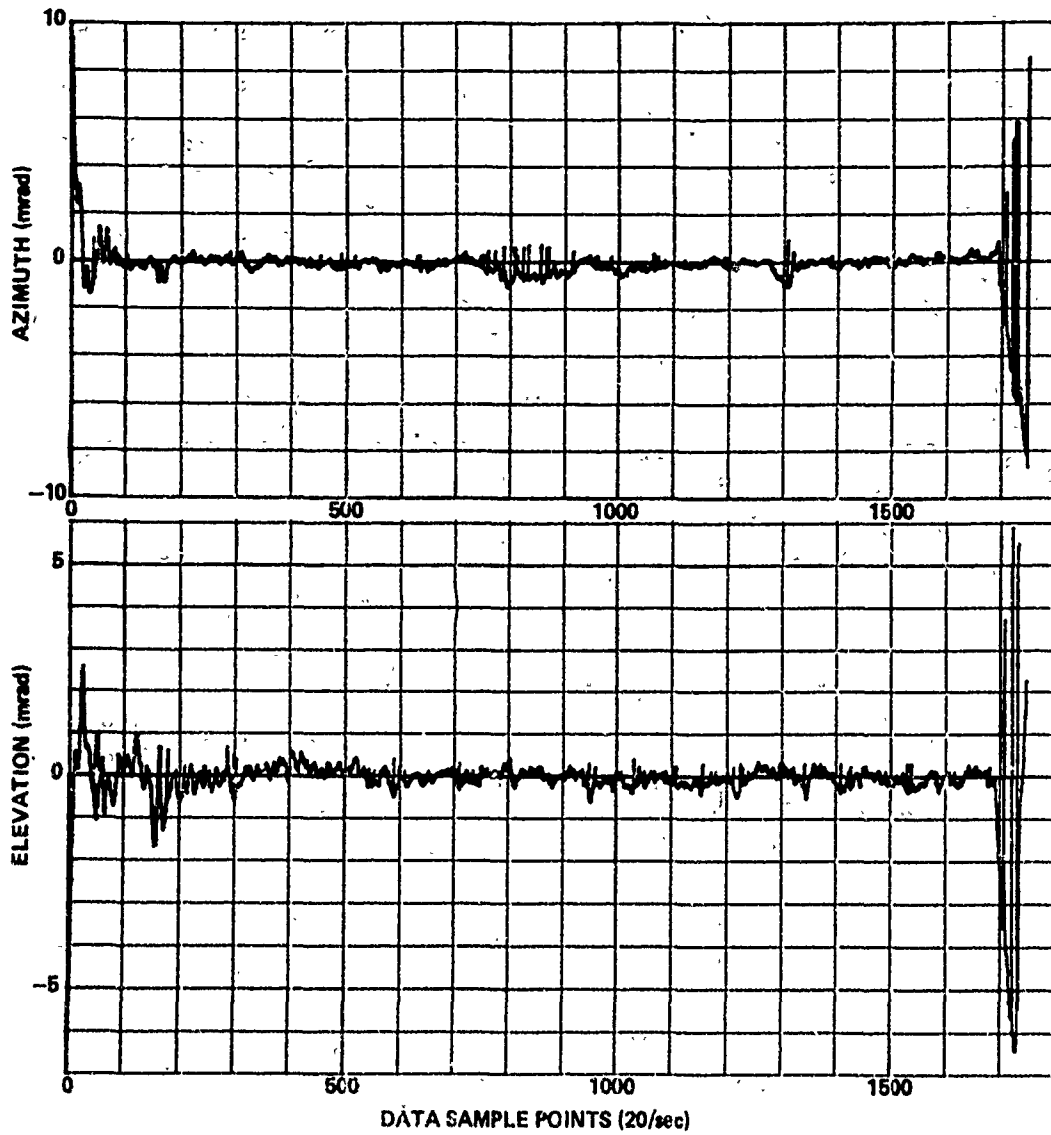
RUN 122



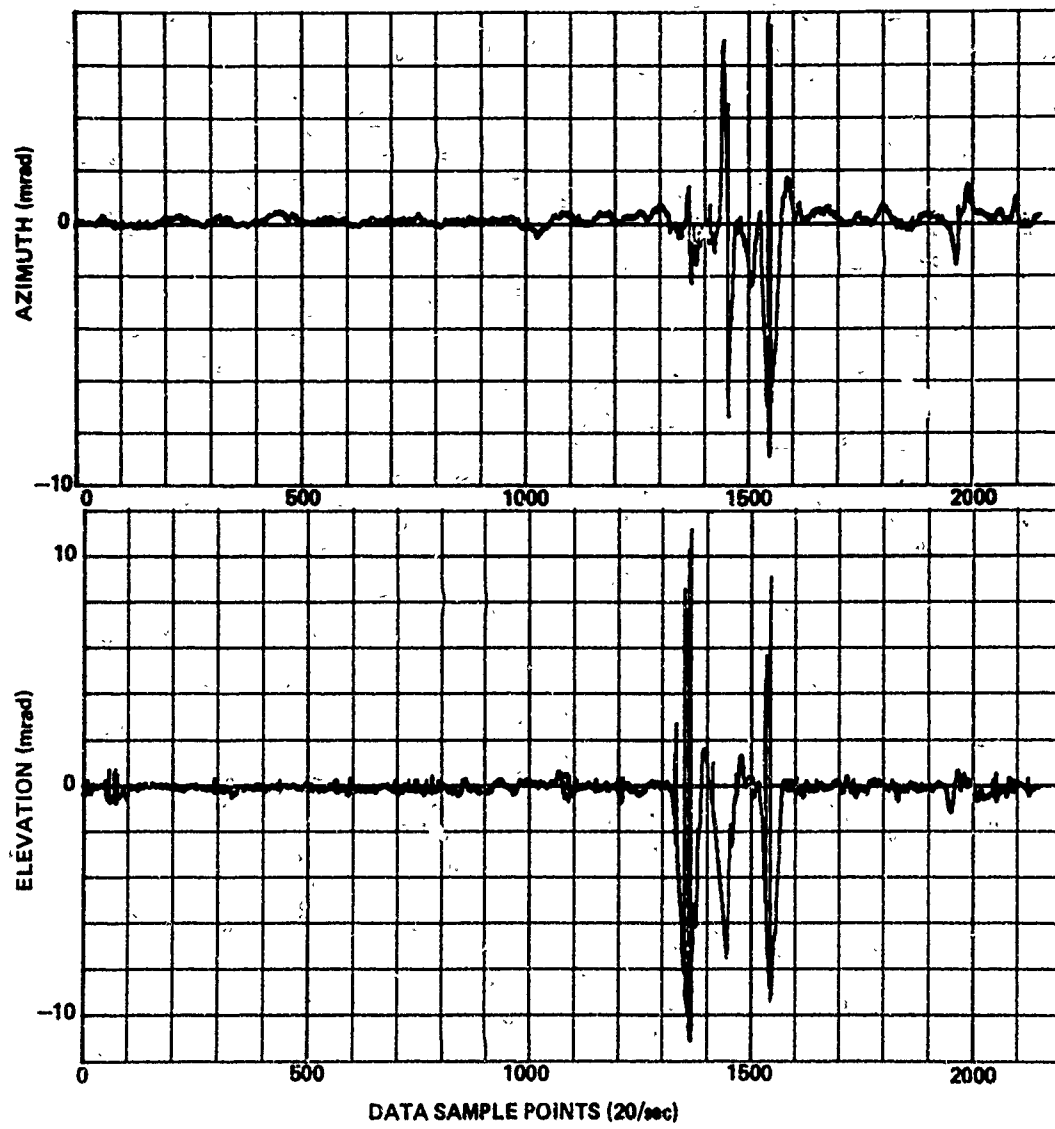
RUN 123



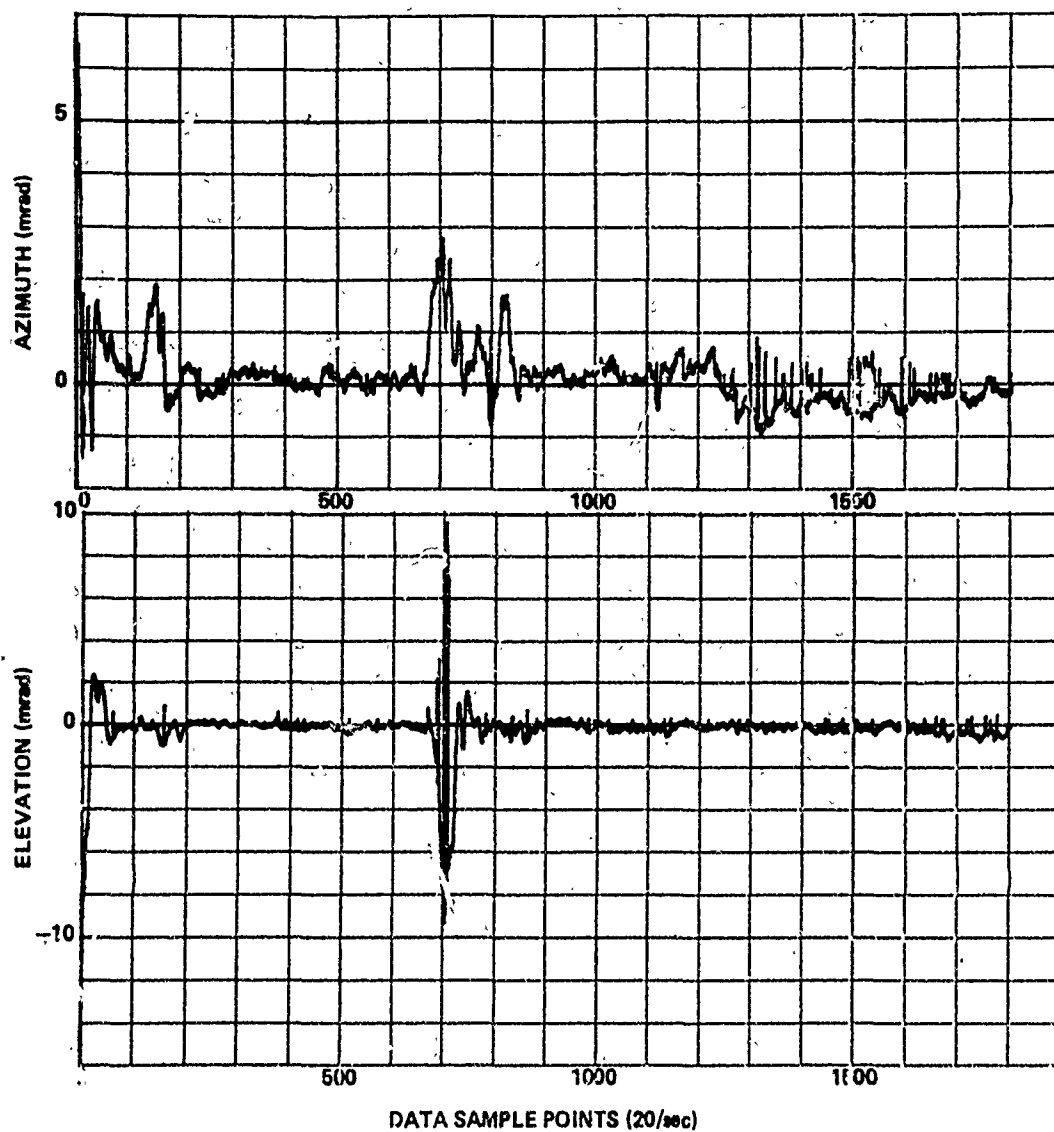
RUN 124



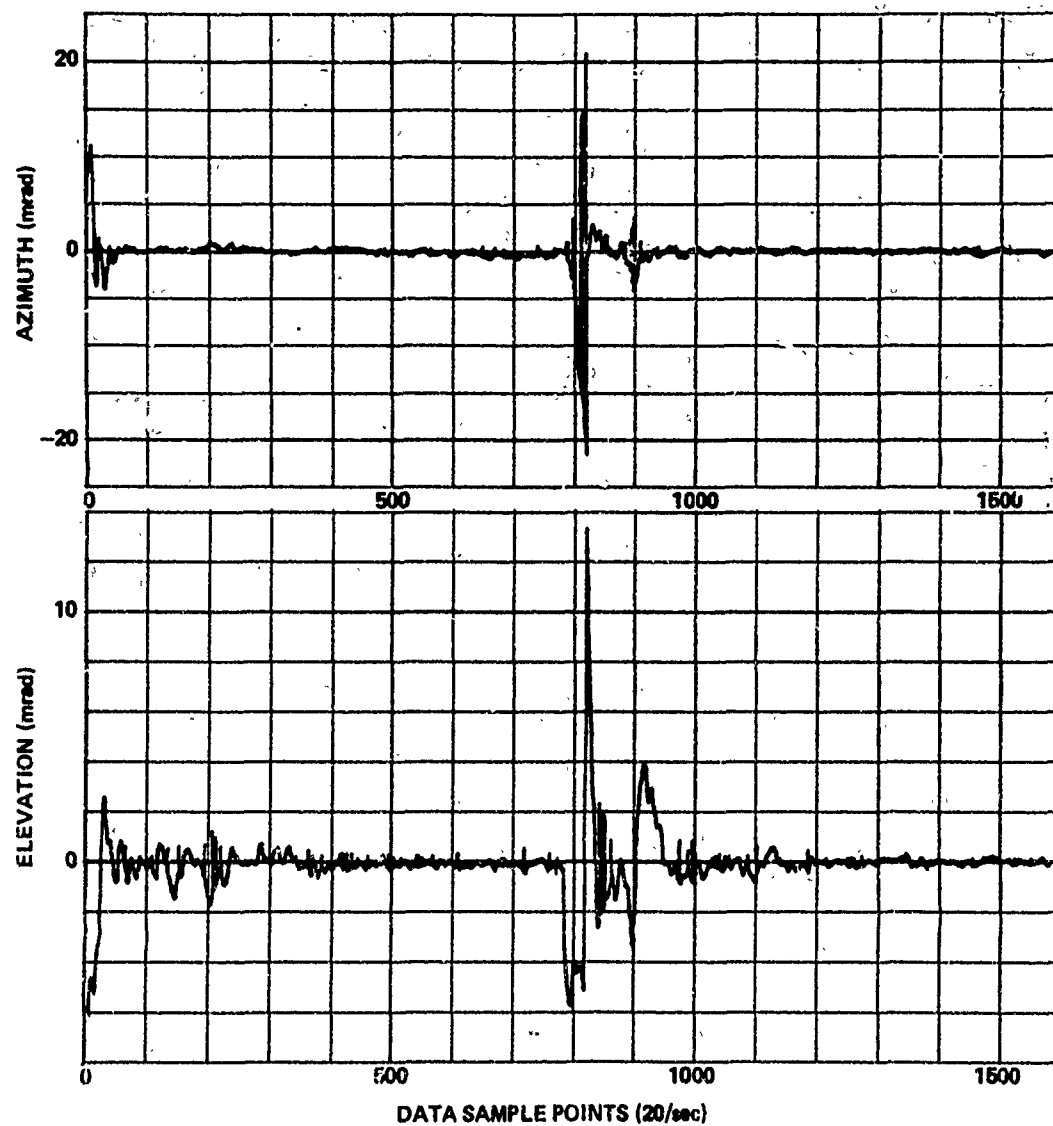
RUN 126



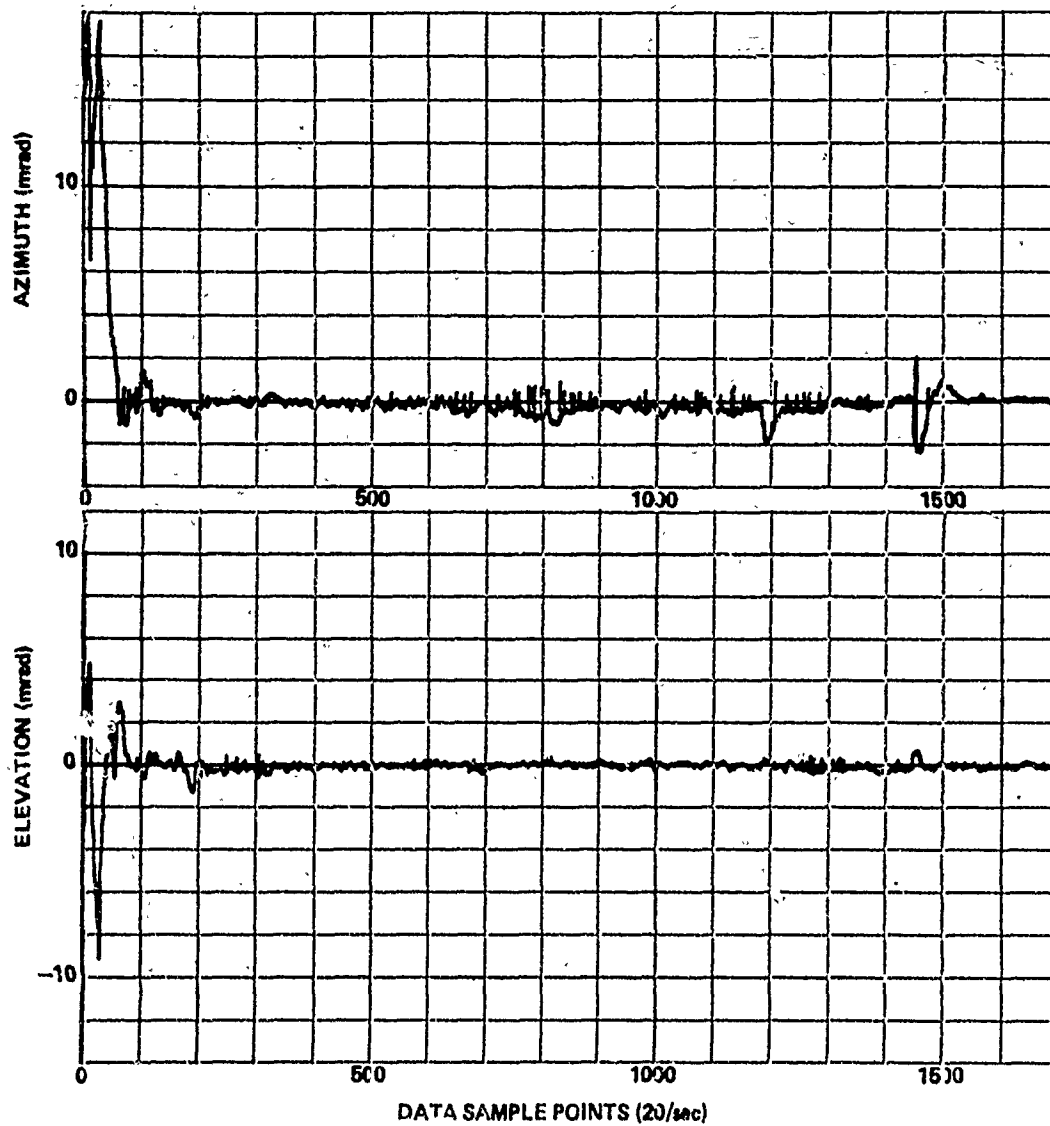
RUN 127



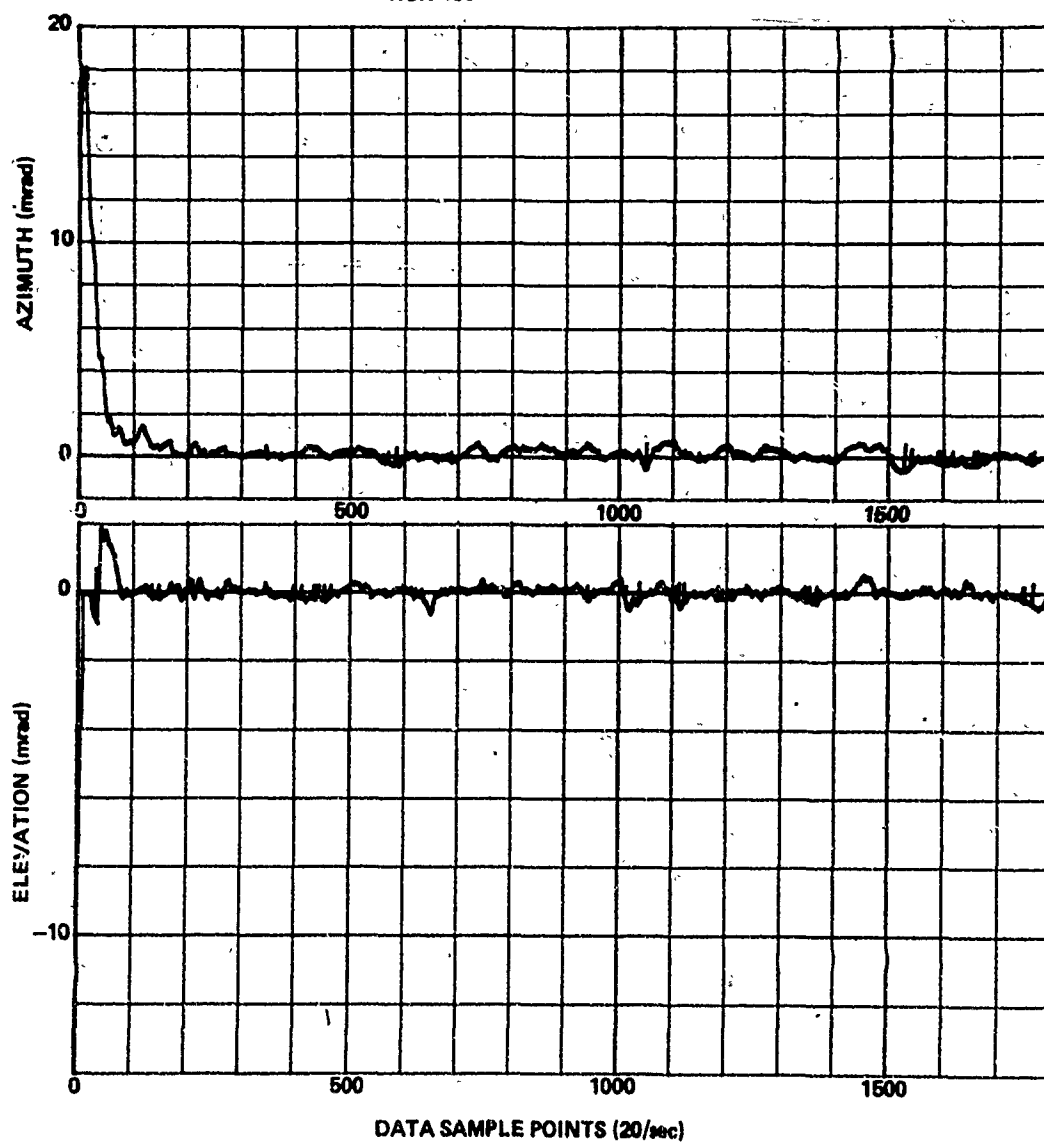
RUN 128



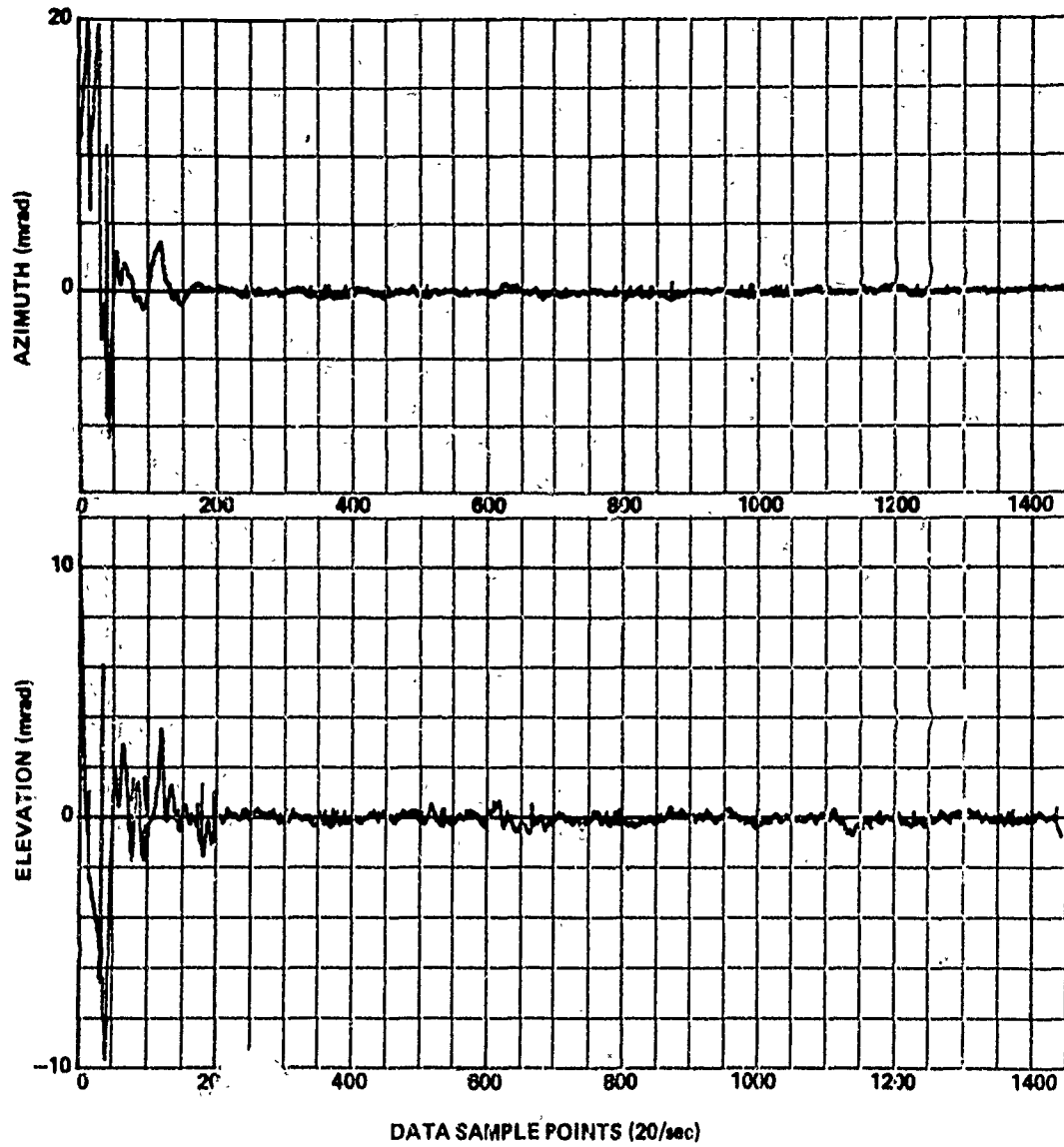
RUN 129



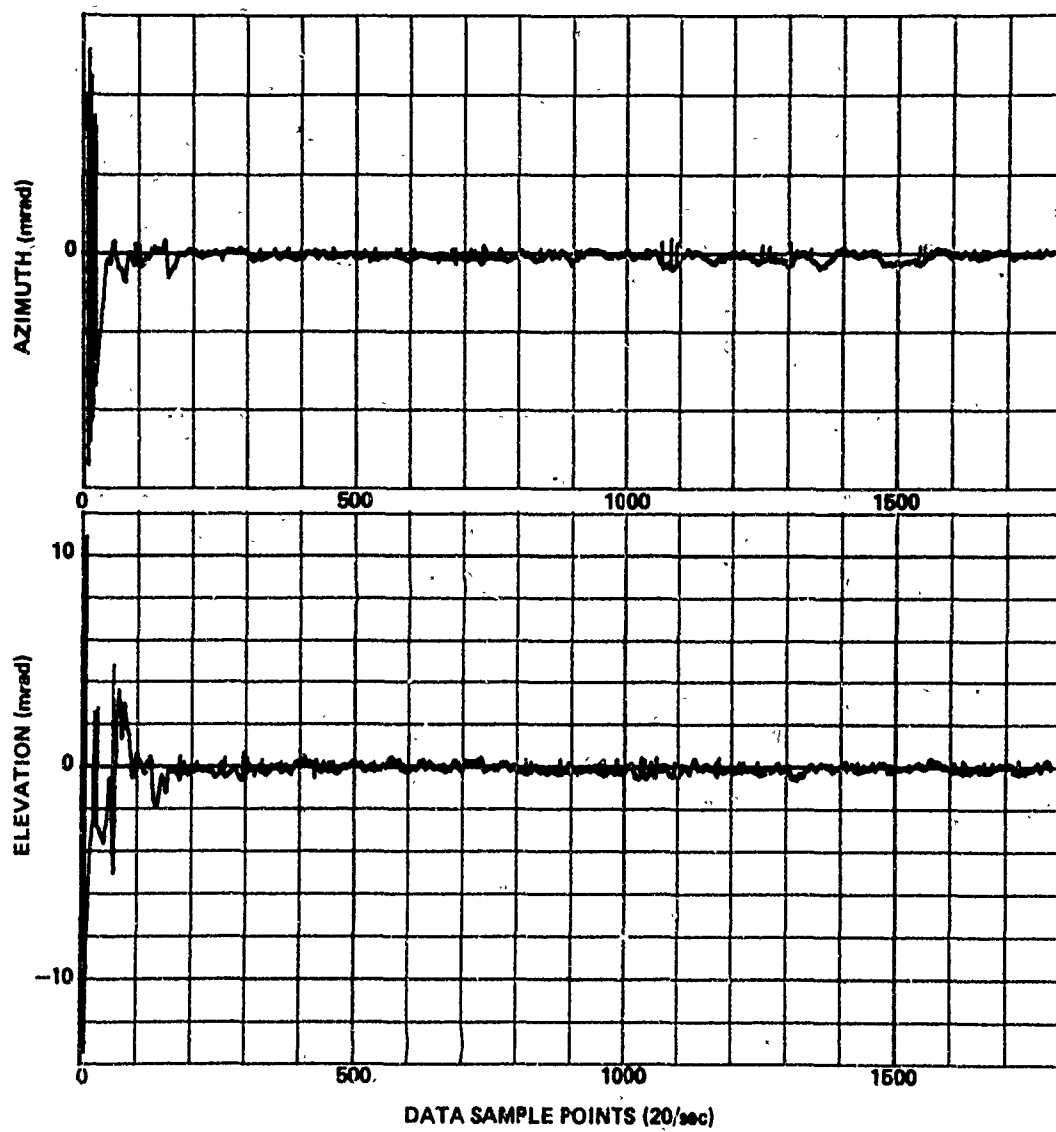
RUN 130



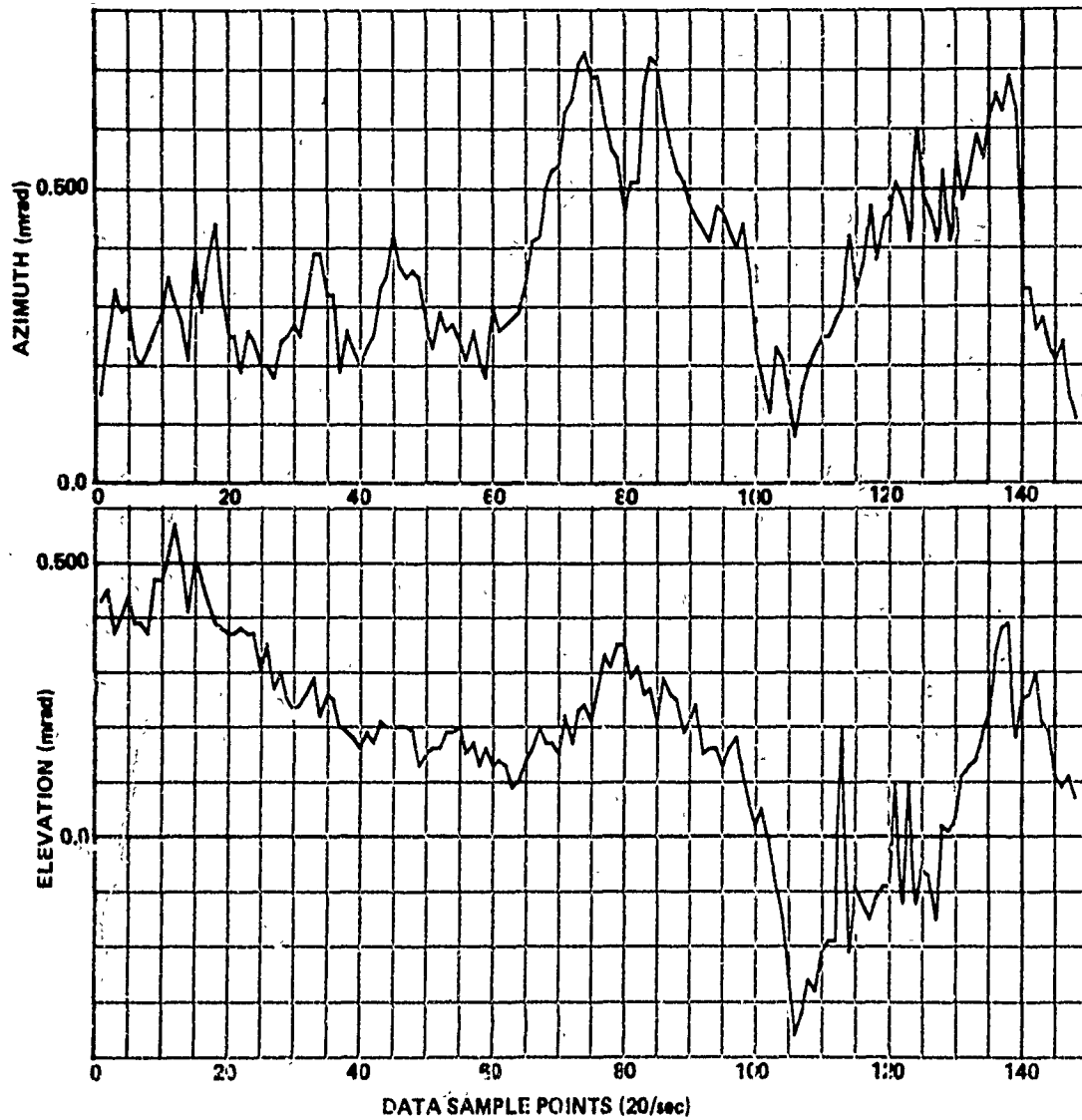
RUN 132



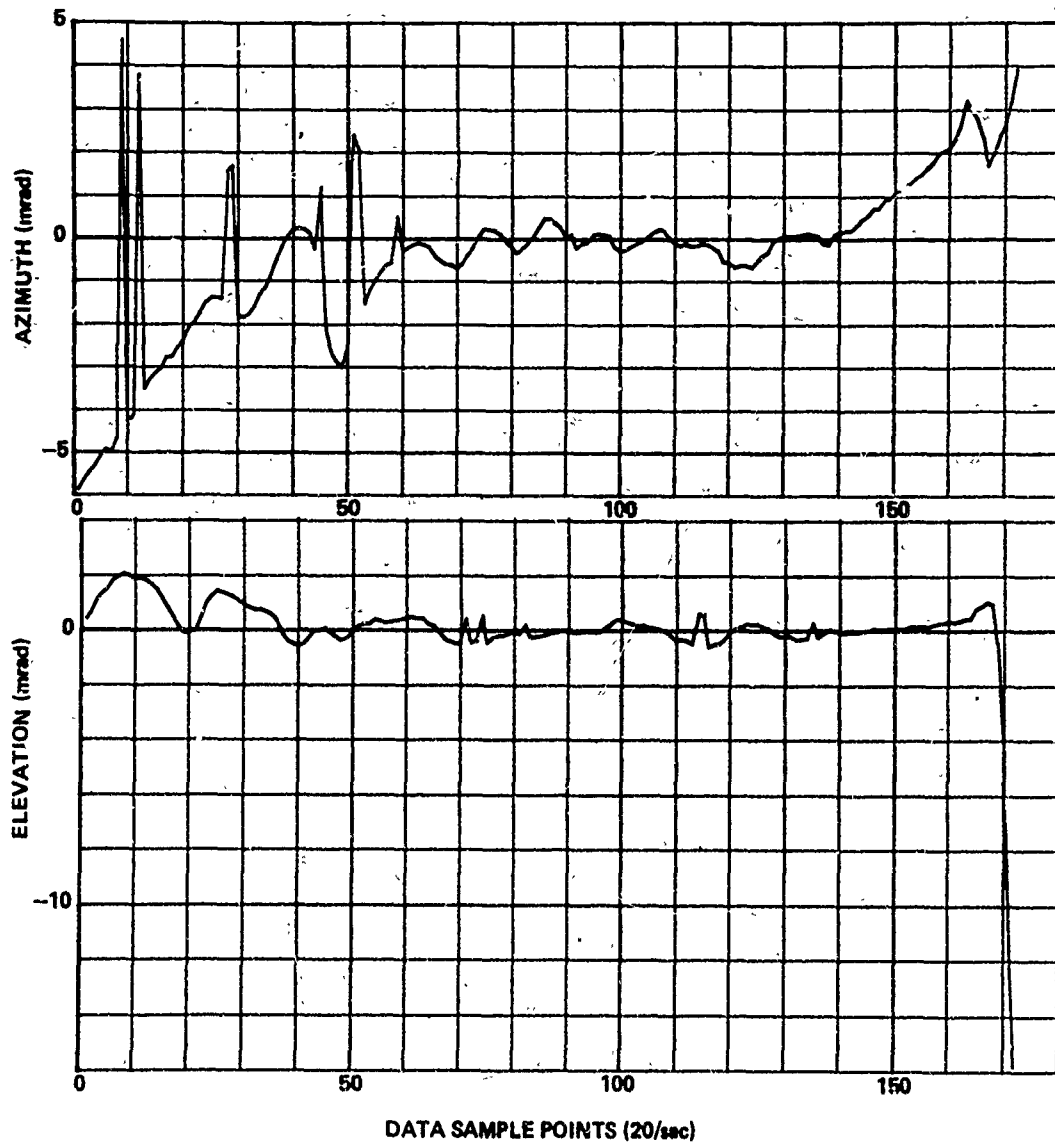
RUN 133



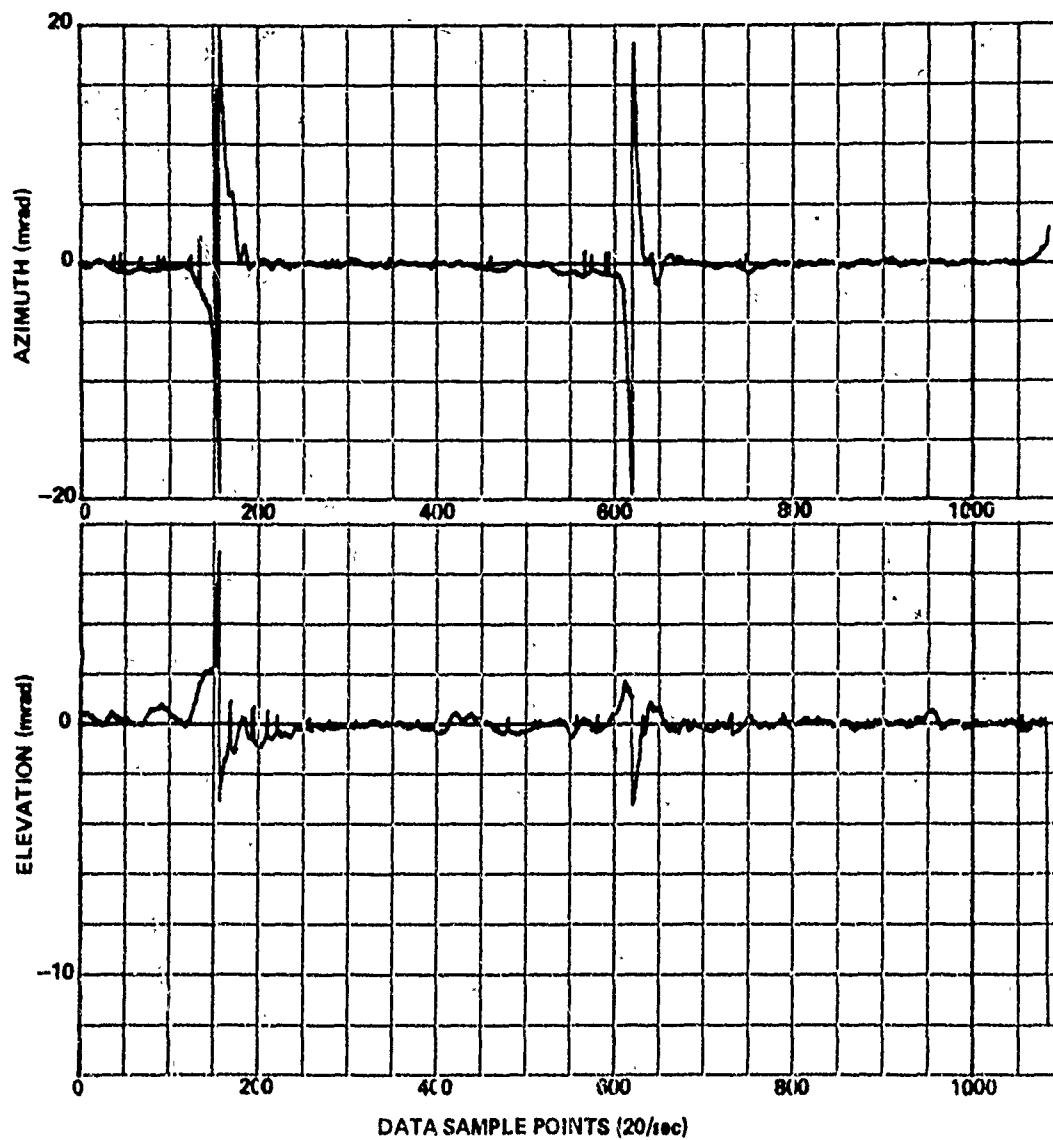
RUN 134



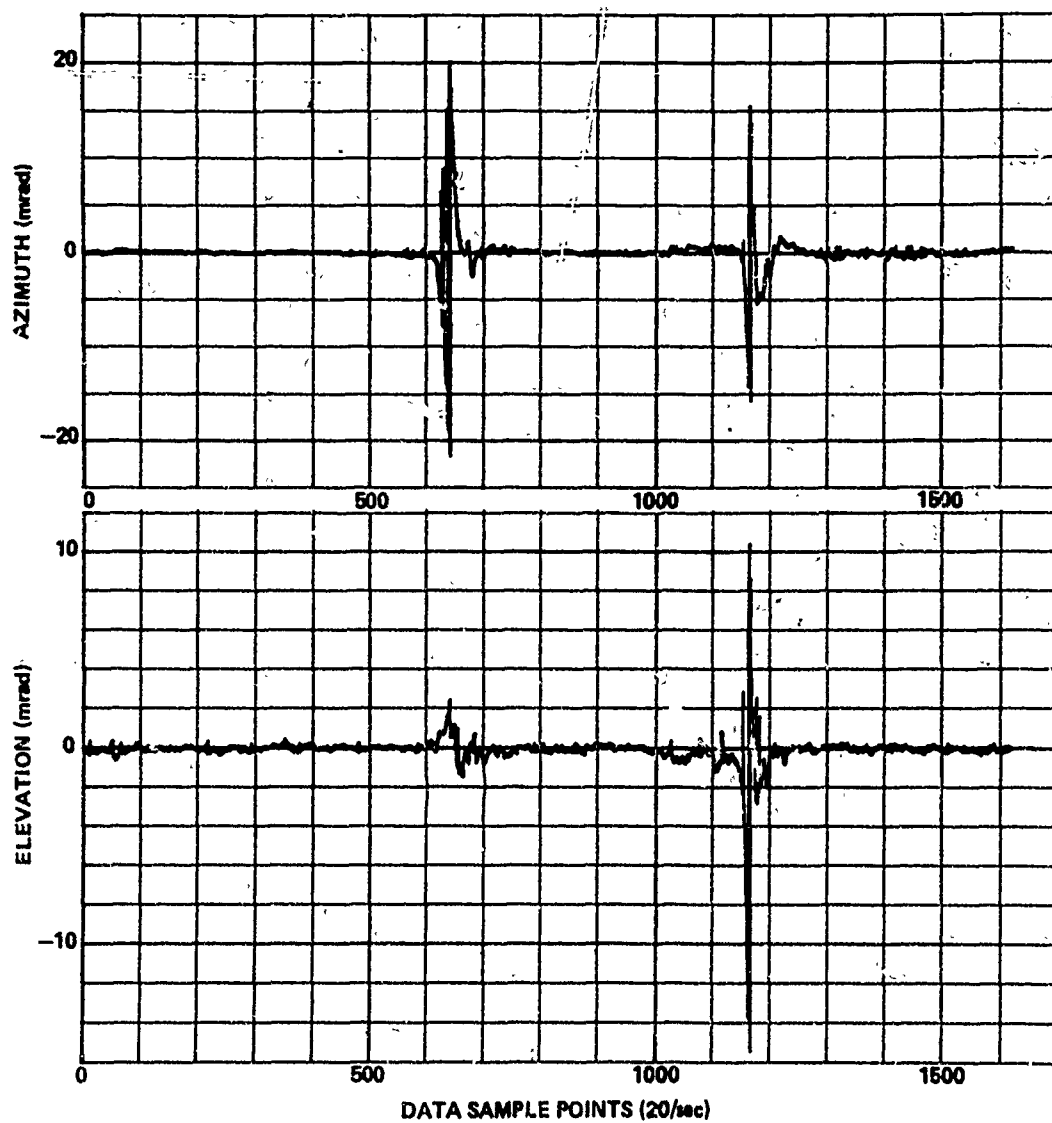
RUN 135



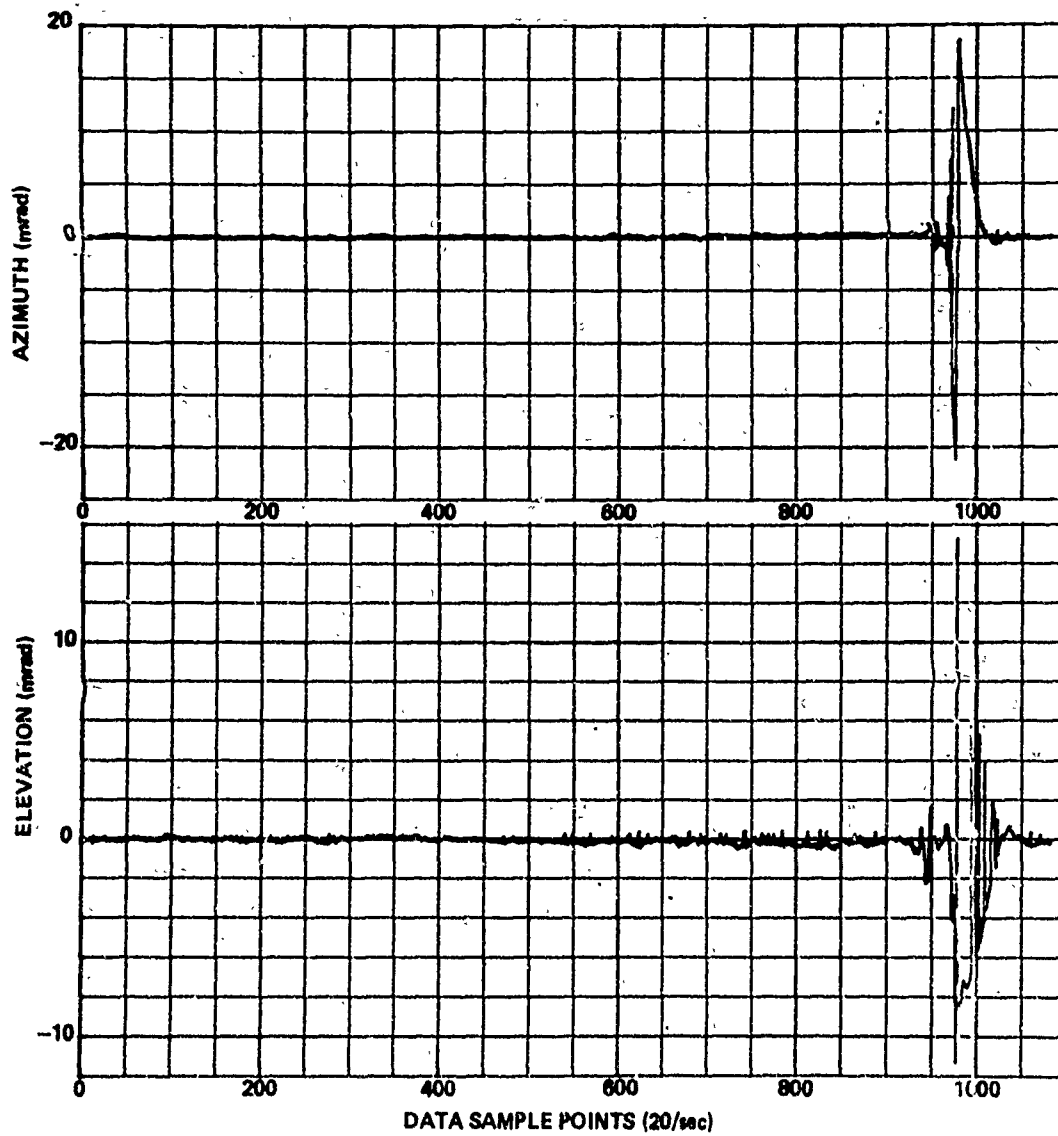
RUN 136



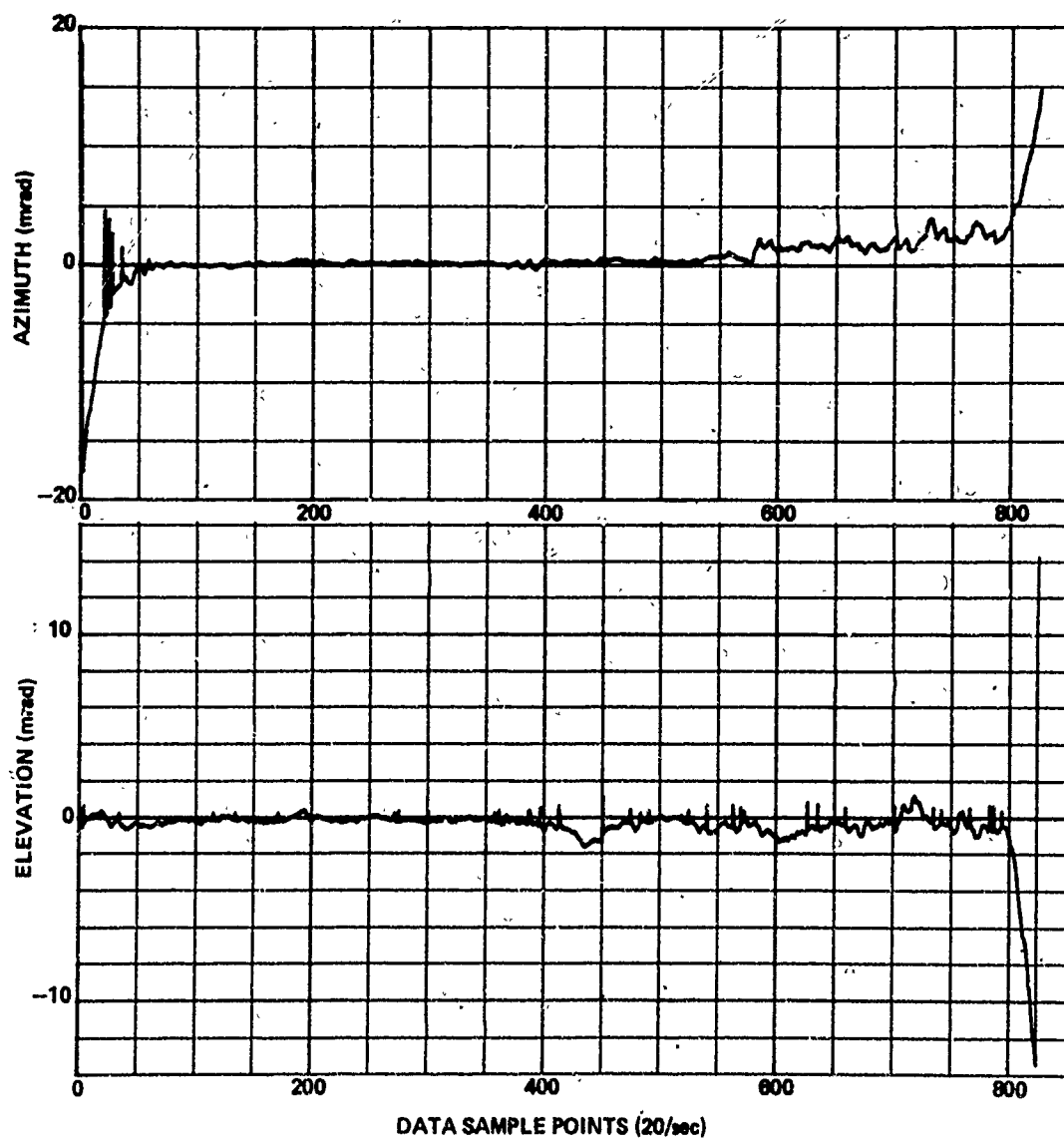
RUN 138



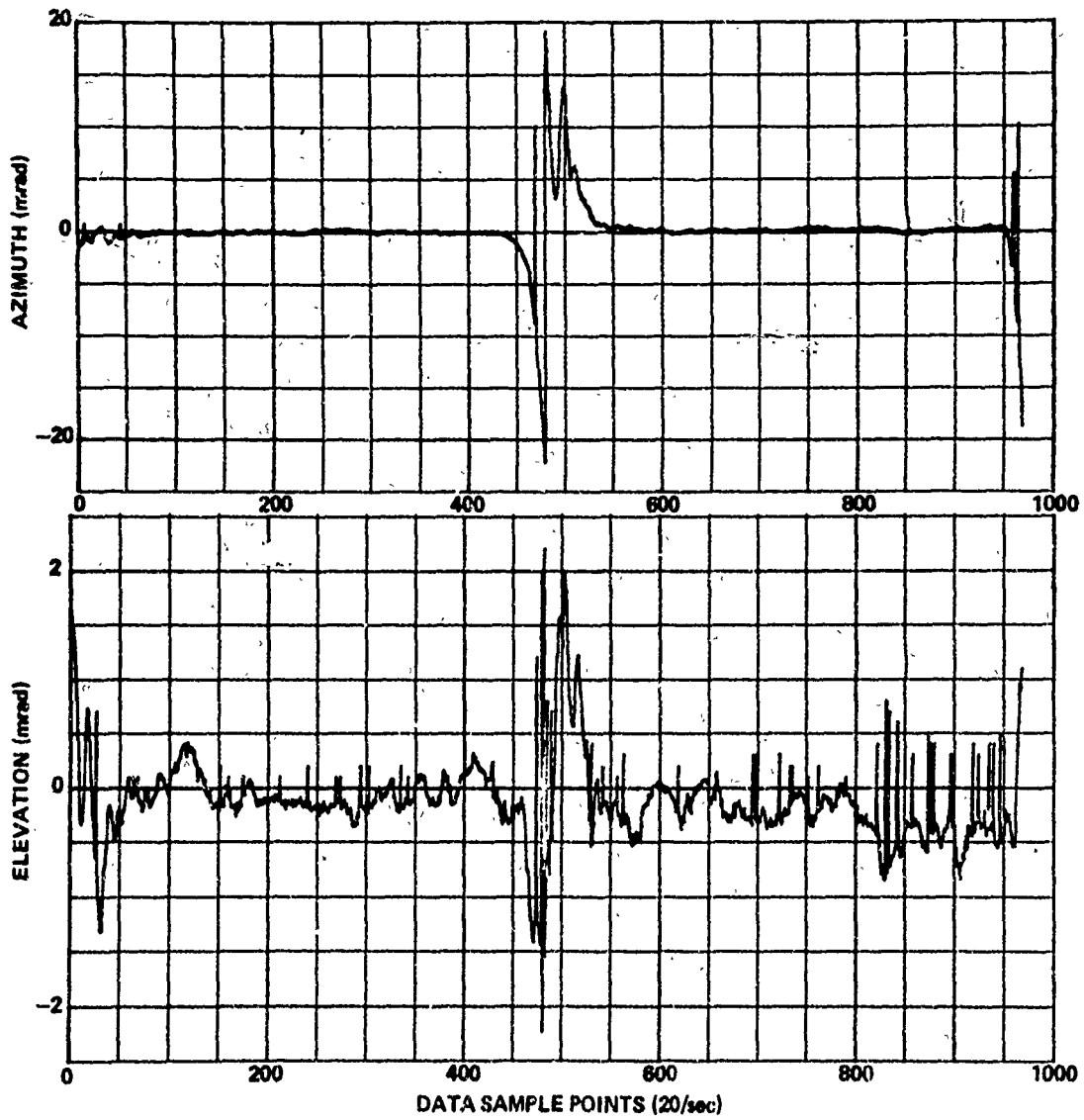
RUN 139



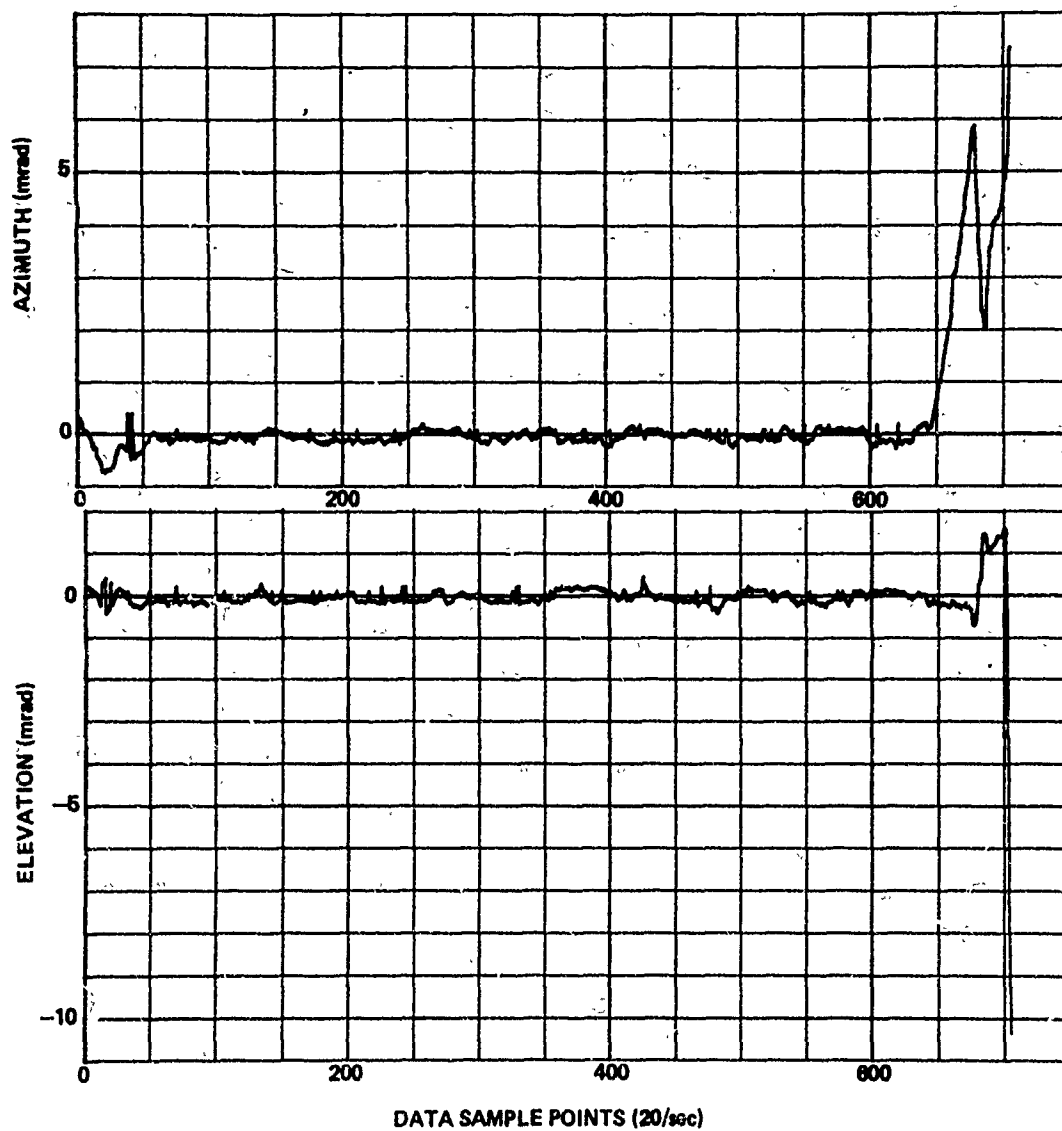
RUN 140



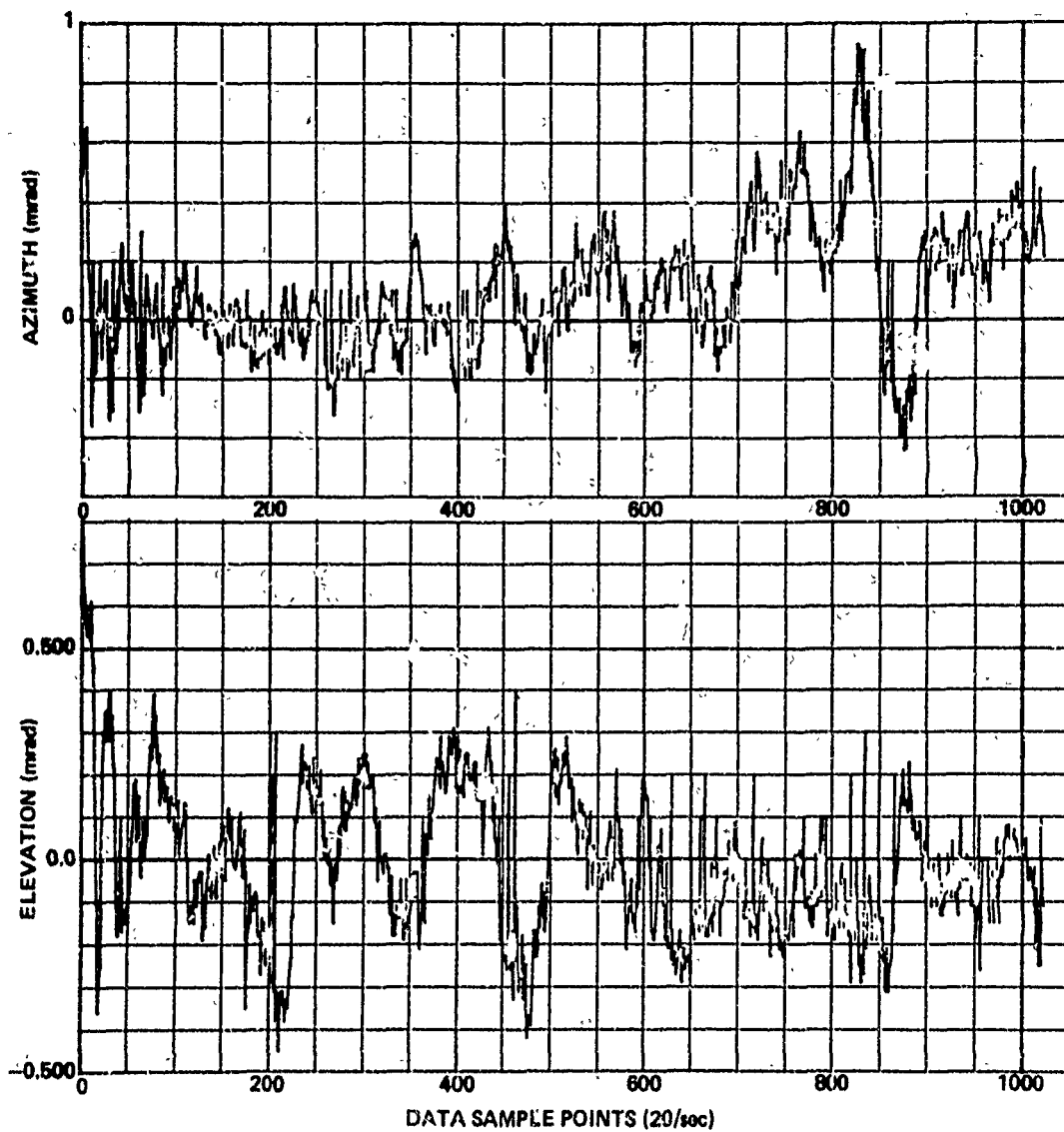
RUN 141



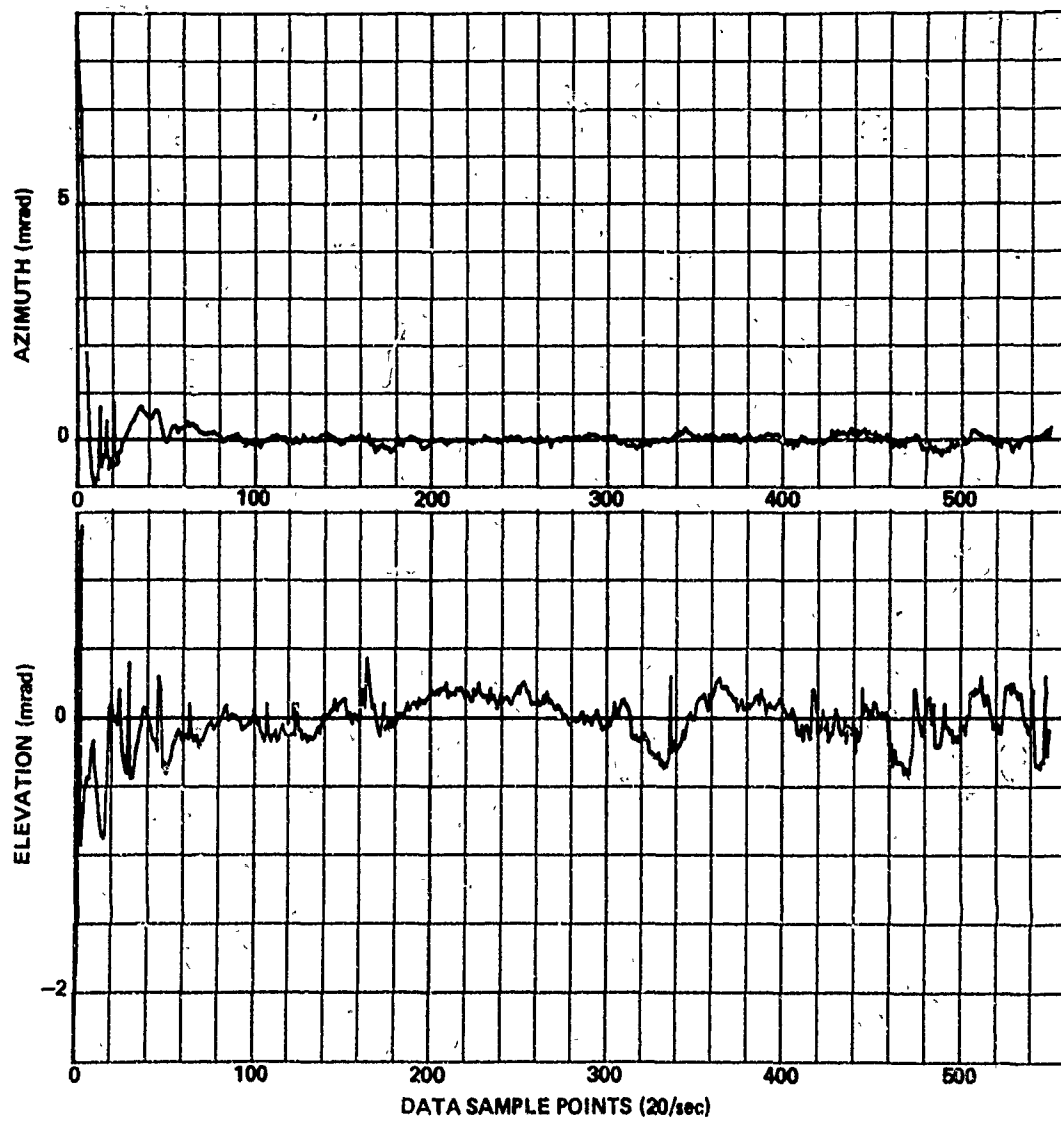
RUN 142



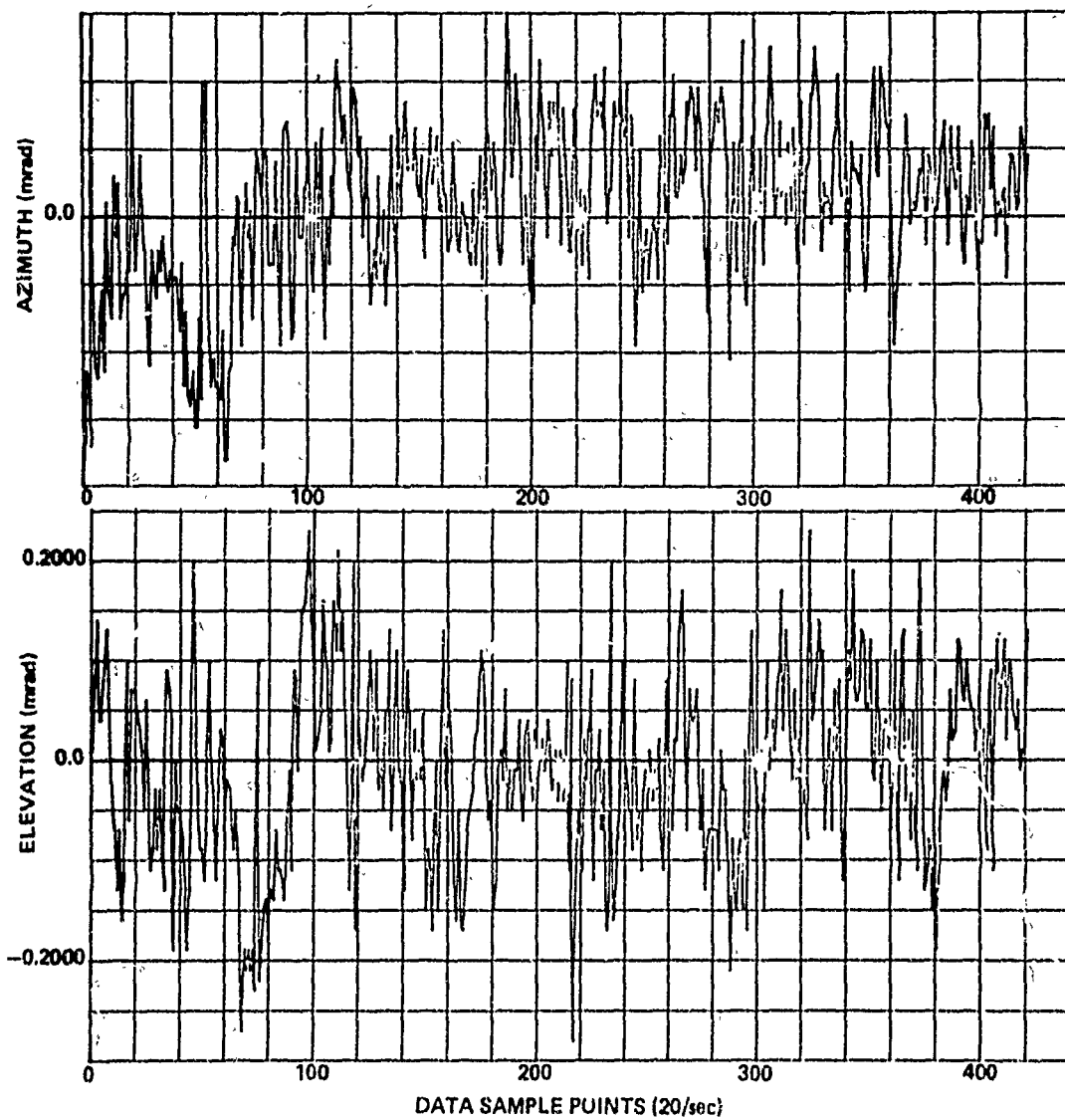
RUN 144



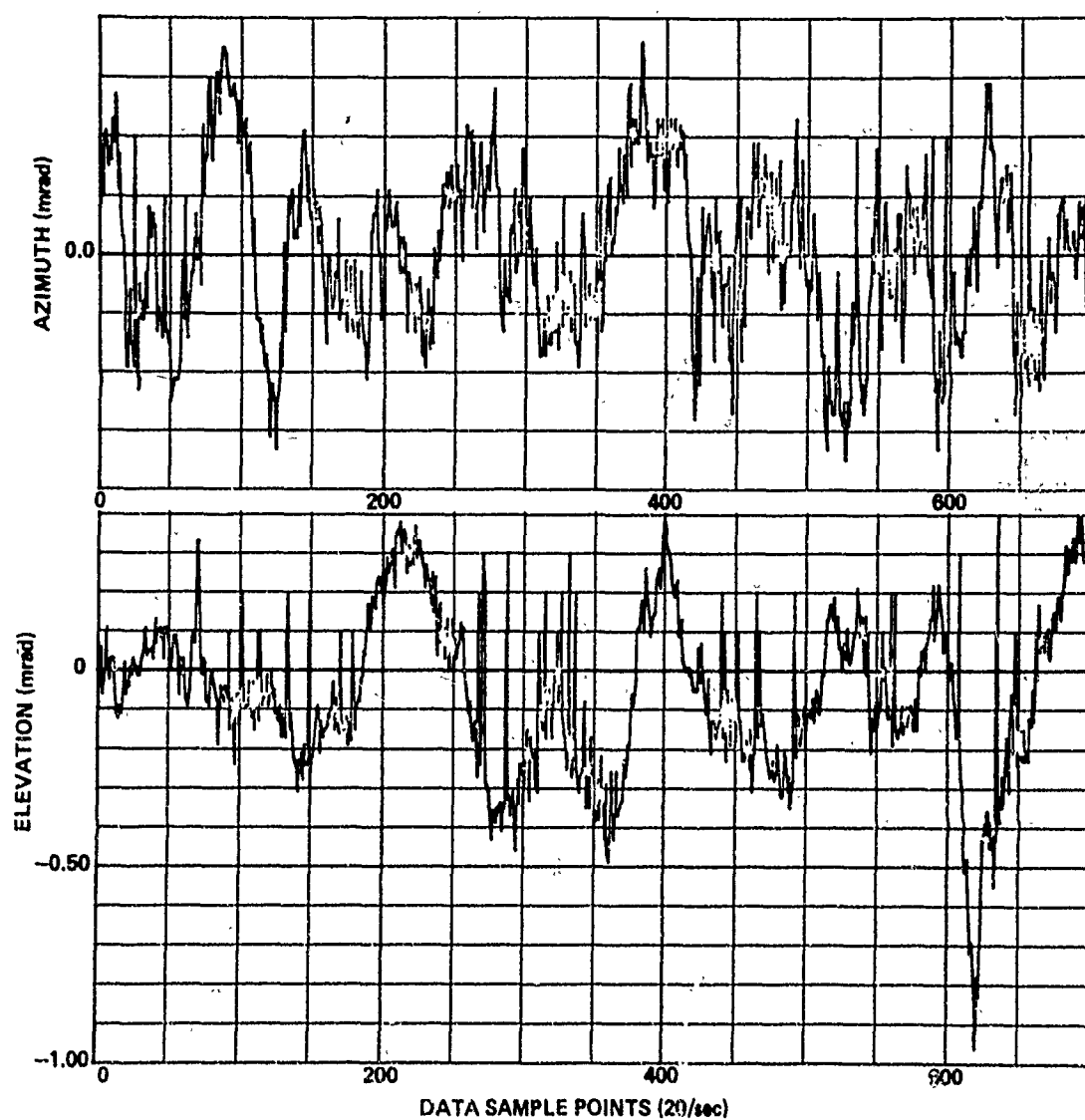
RUN 145



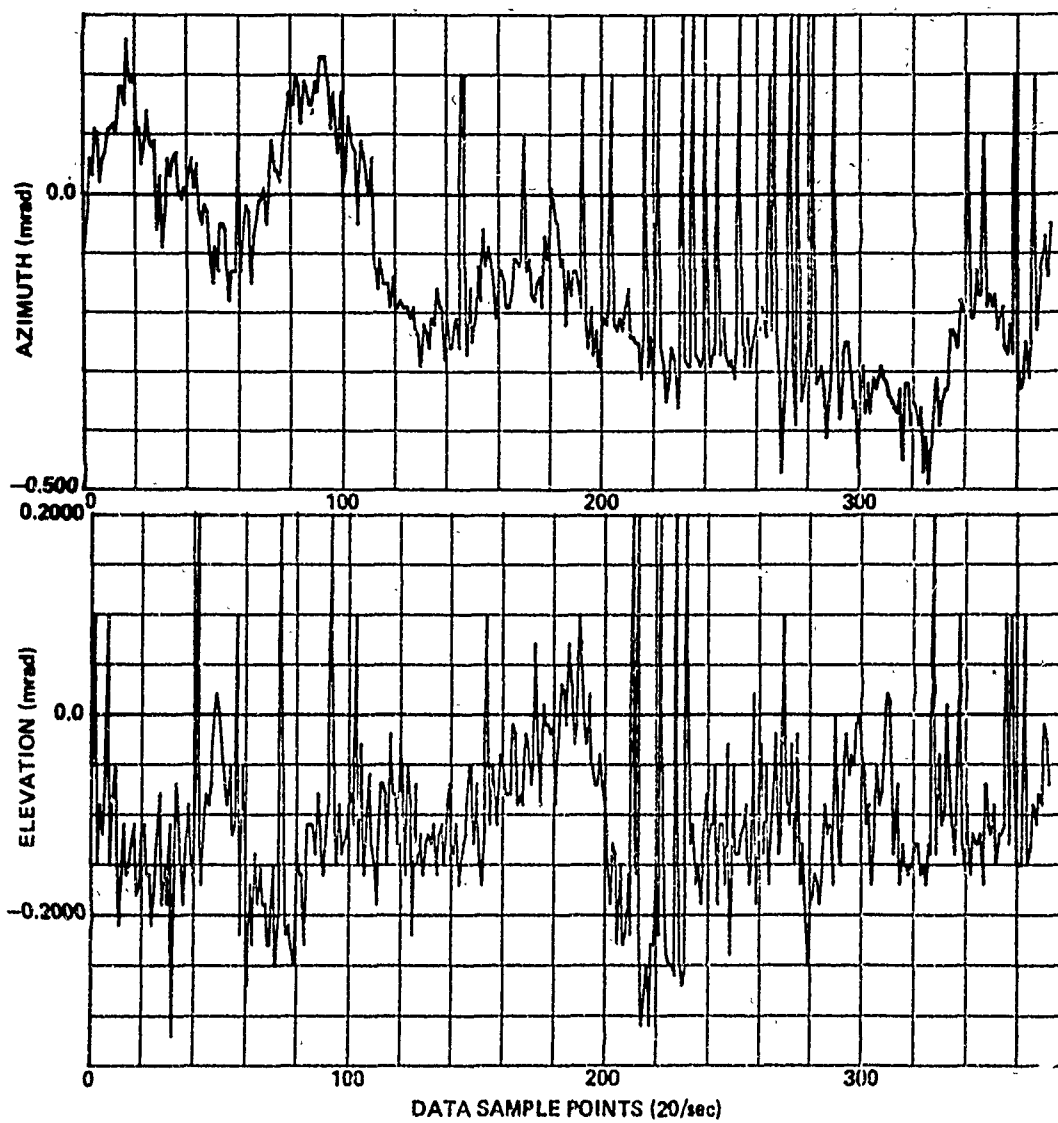
RUN 147



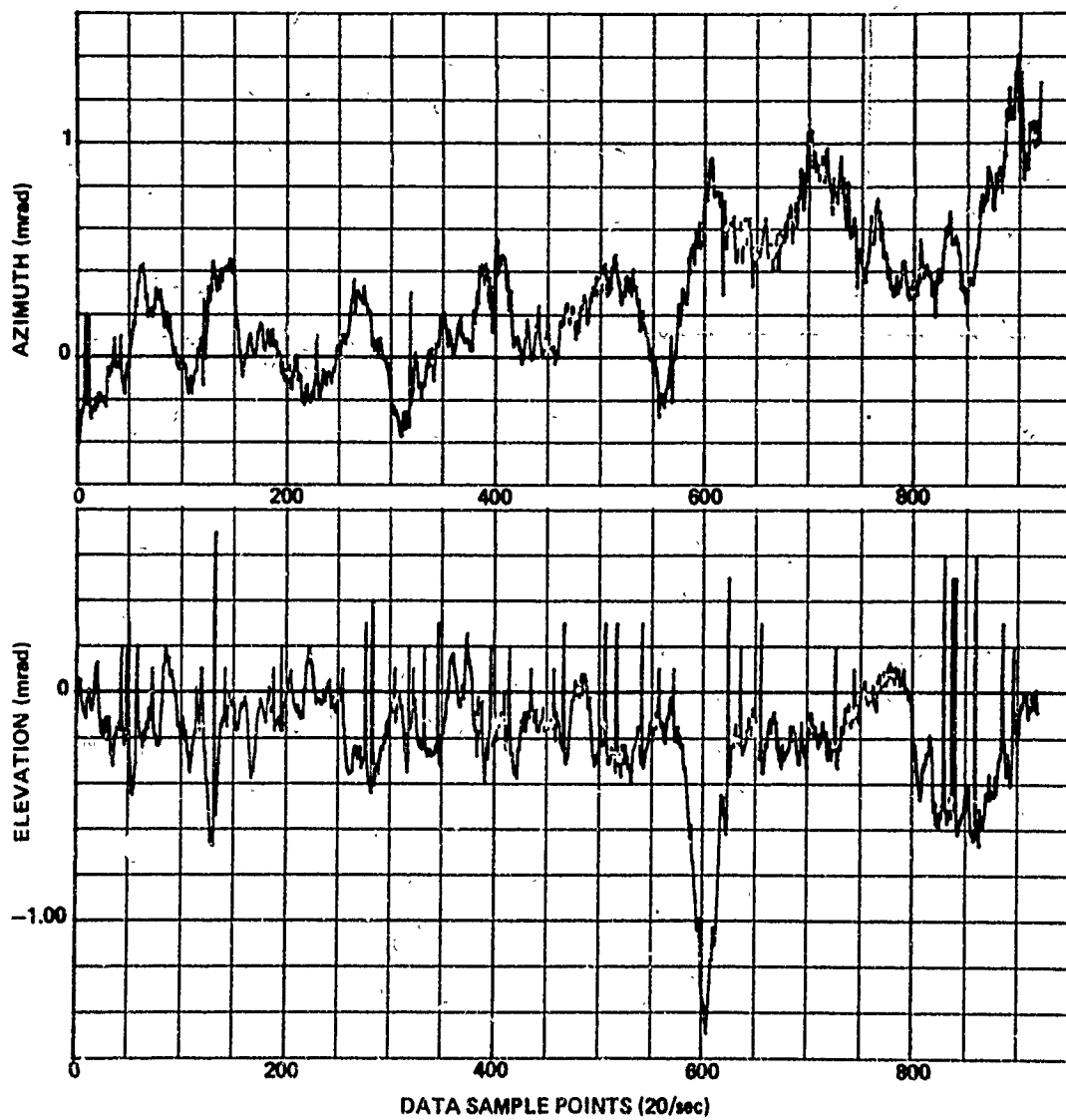
RUN 148



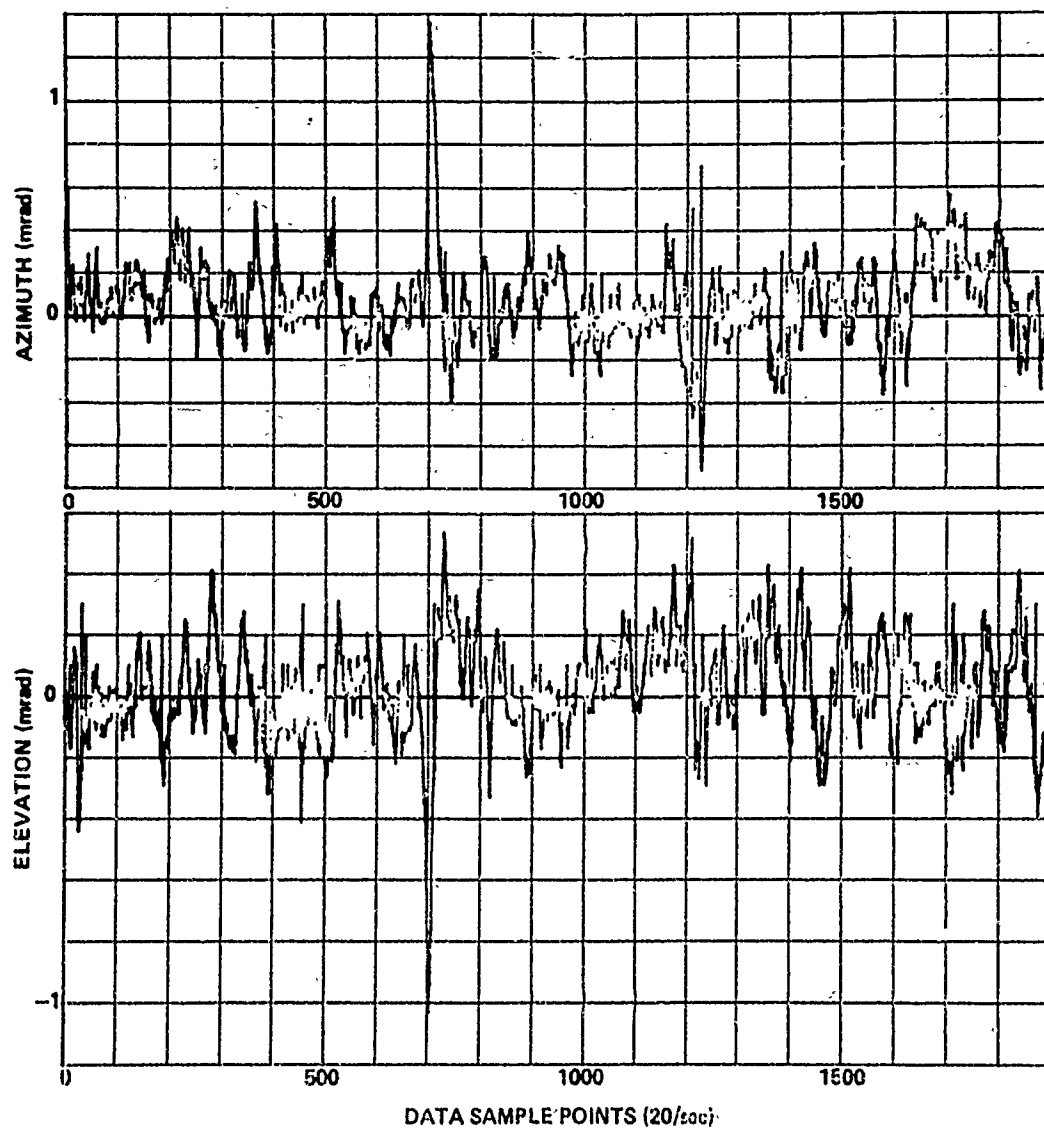
RUN 149



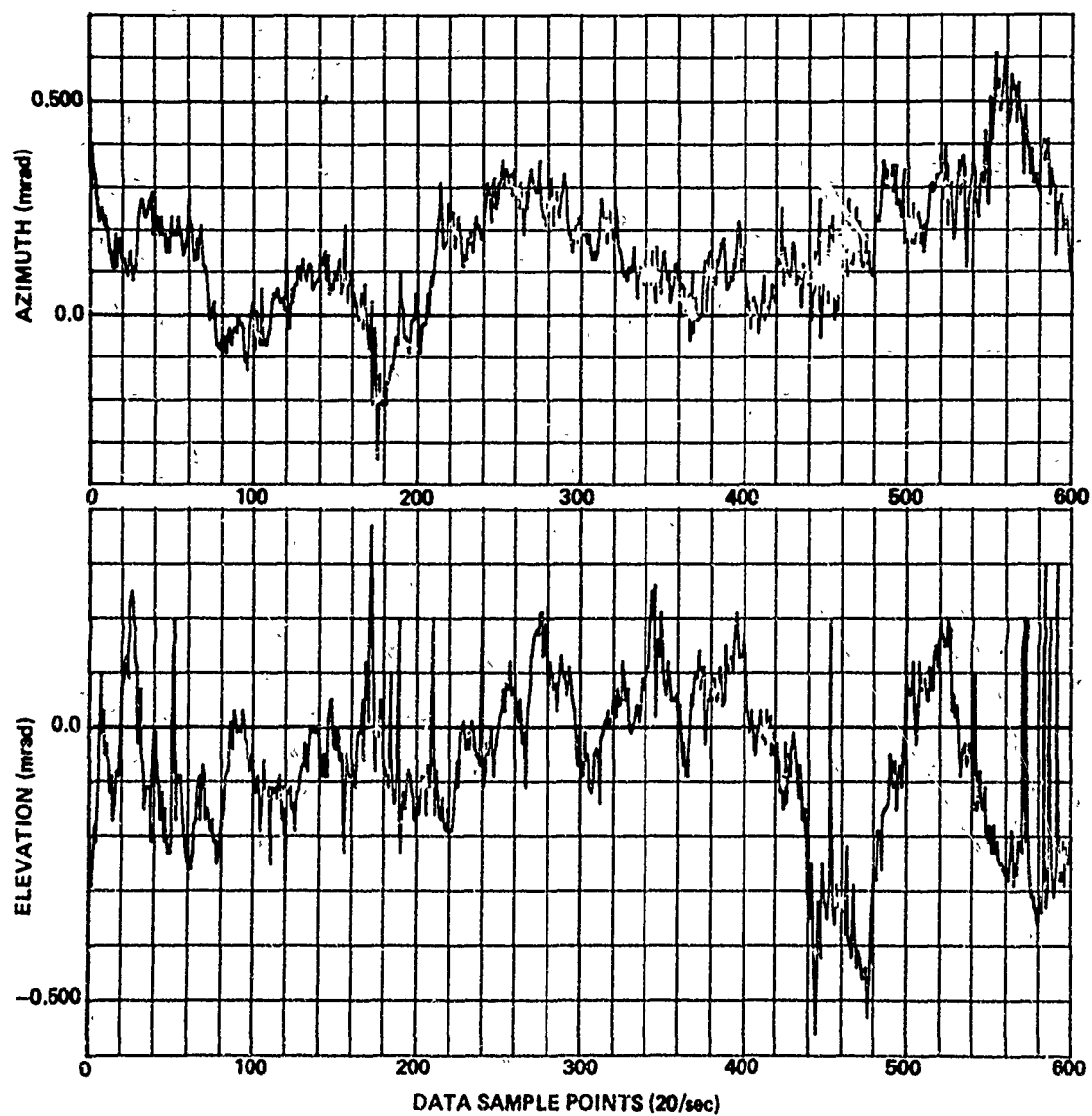
RUN 170



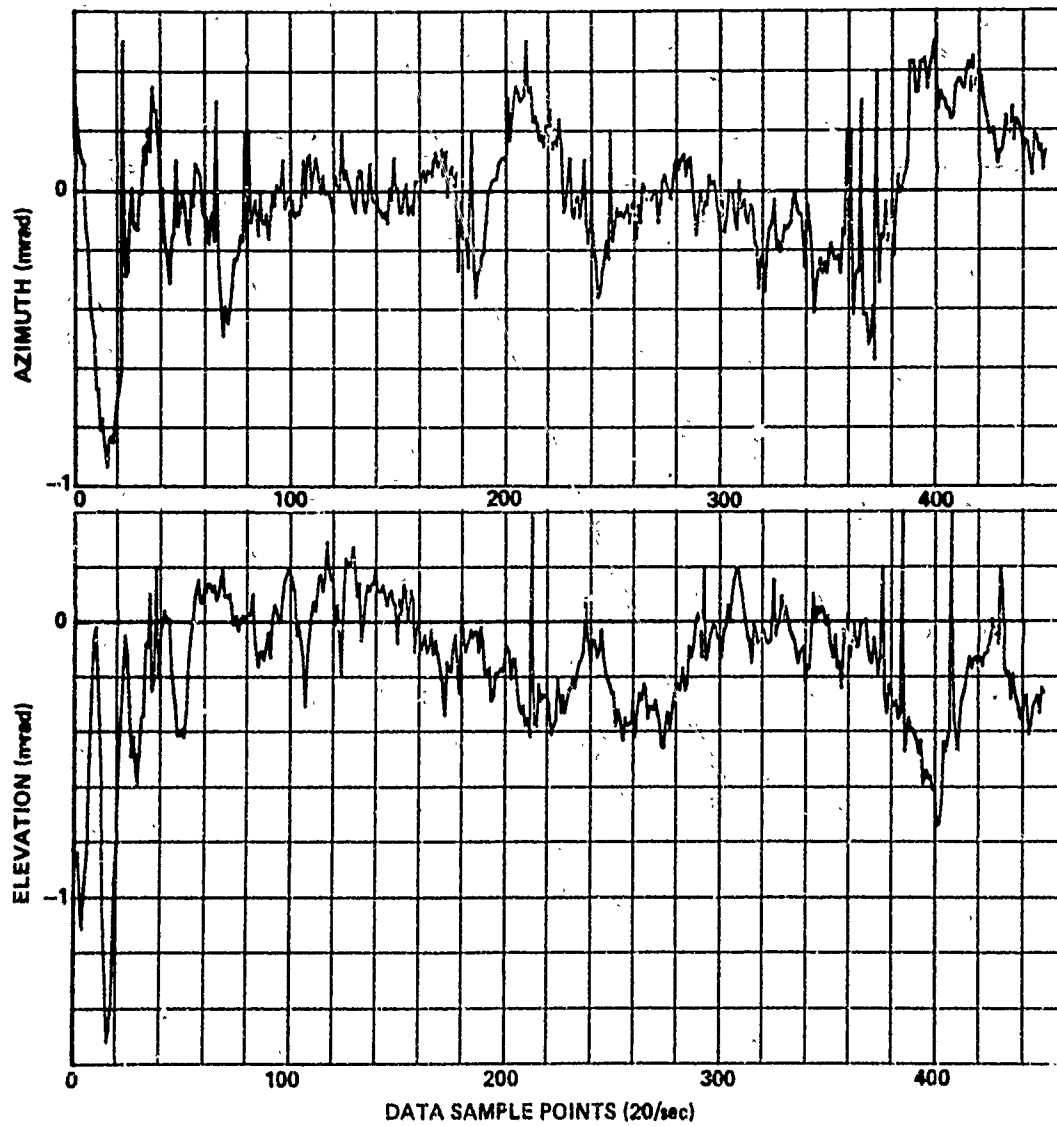
RUN 171



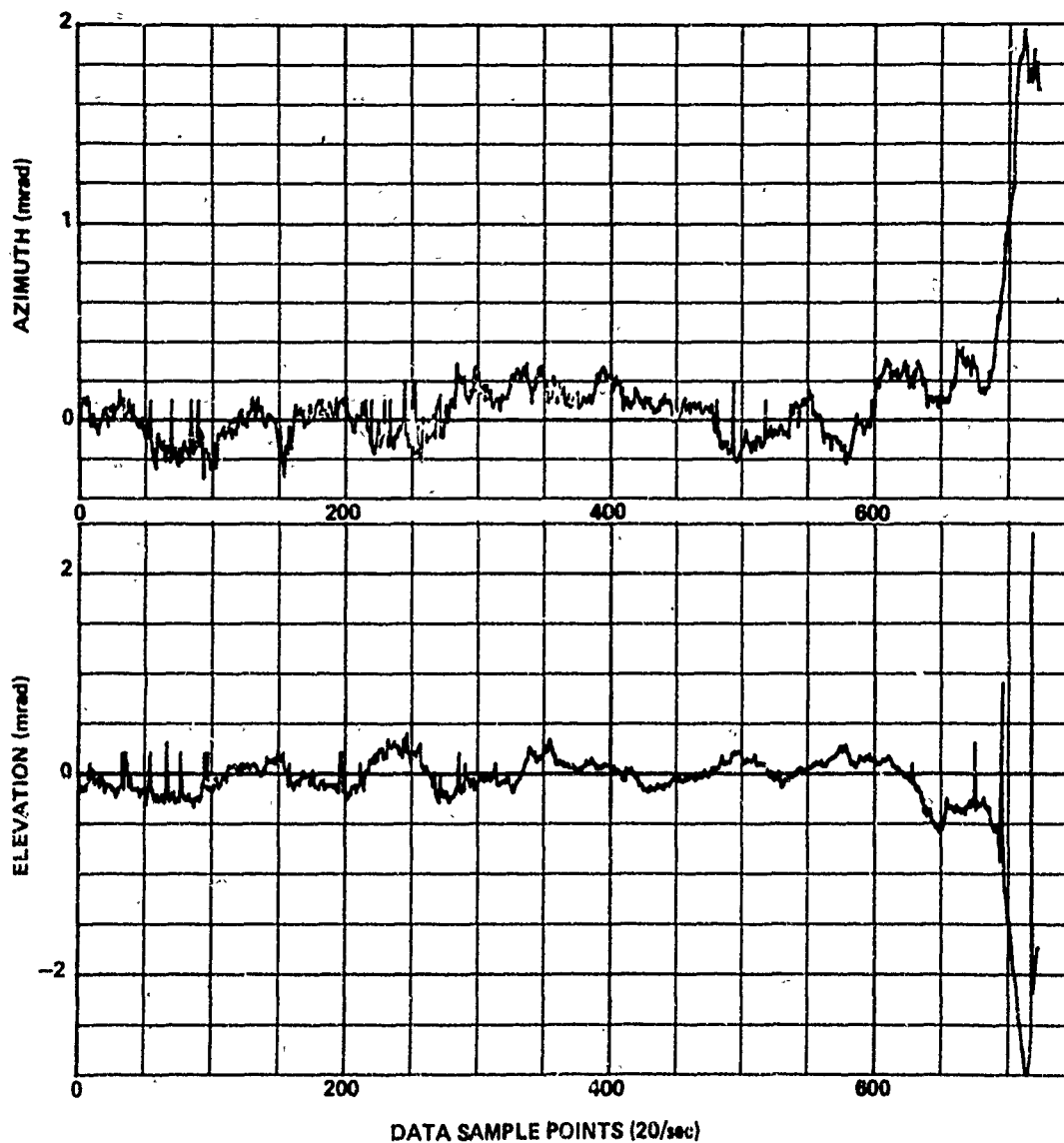
RUN 172



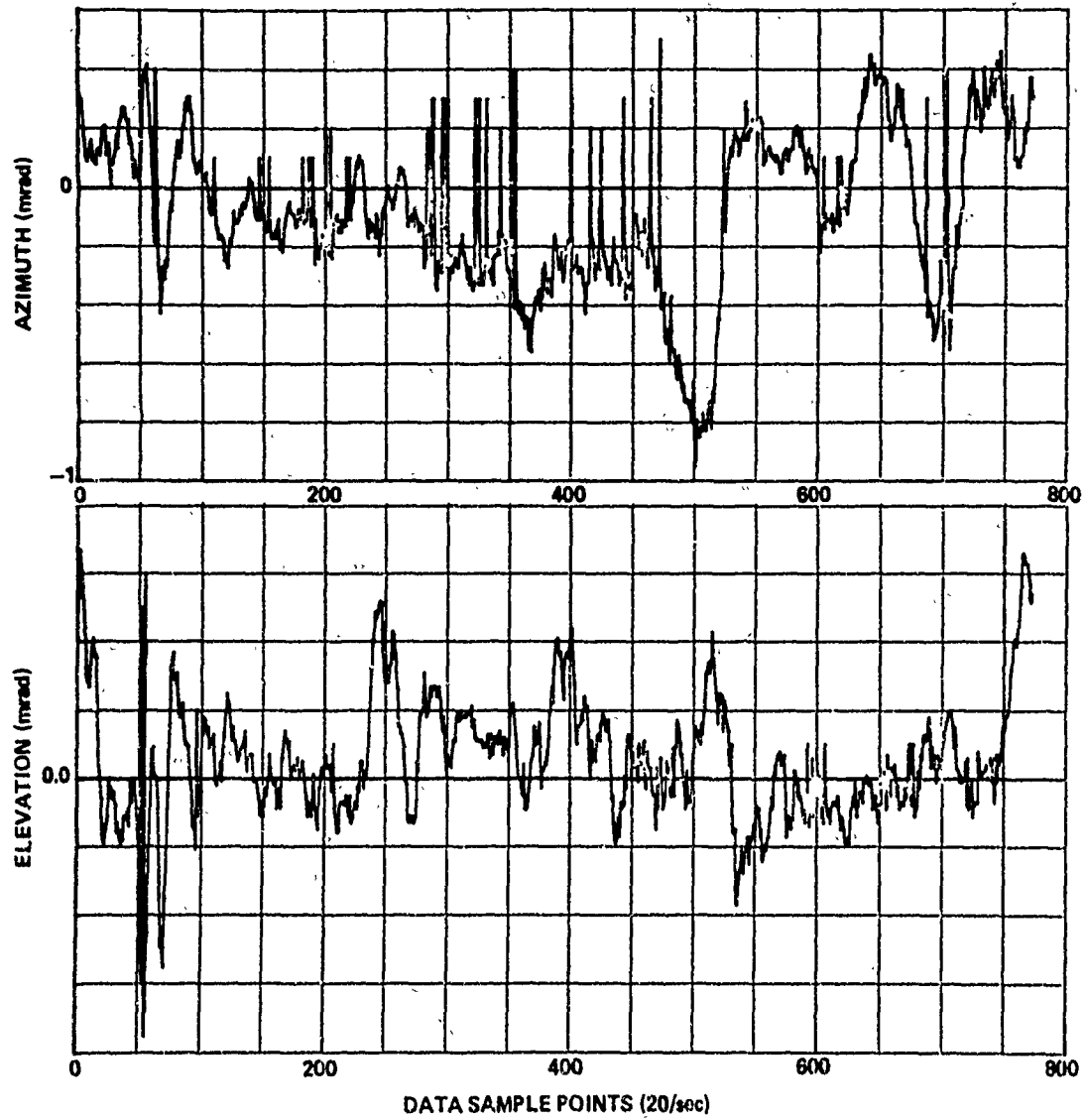
RUN 173



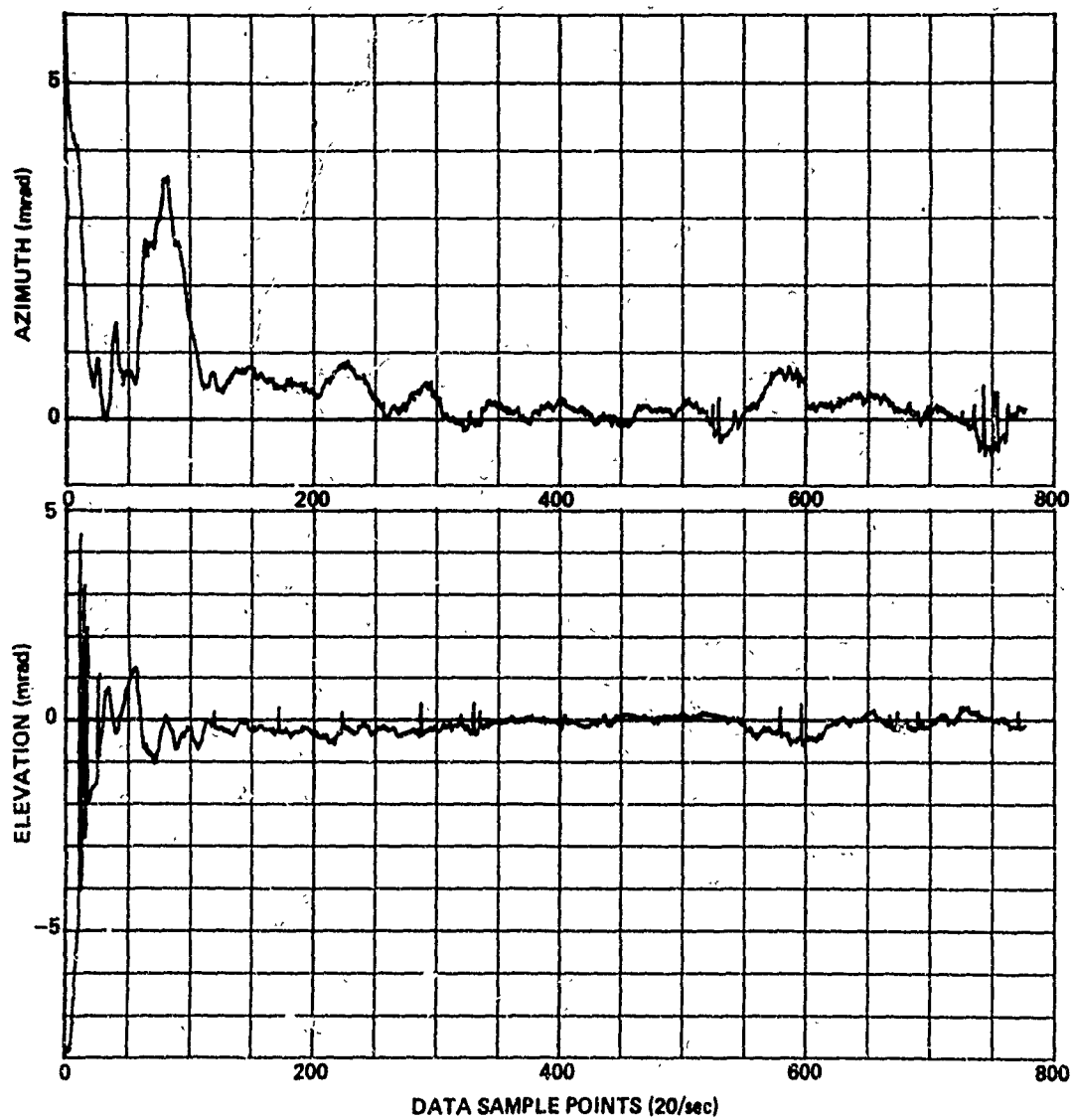
RUN 174



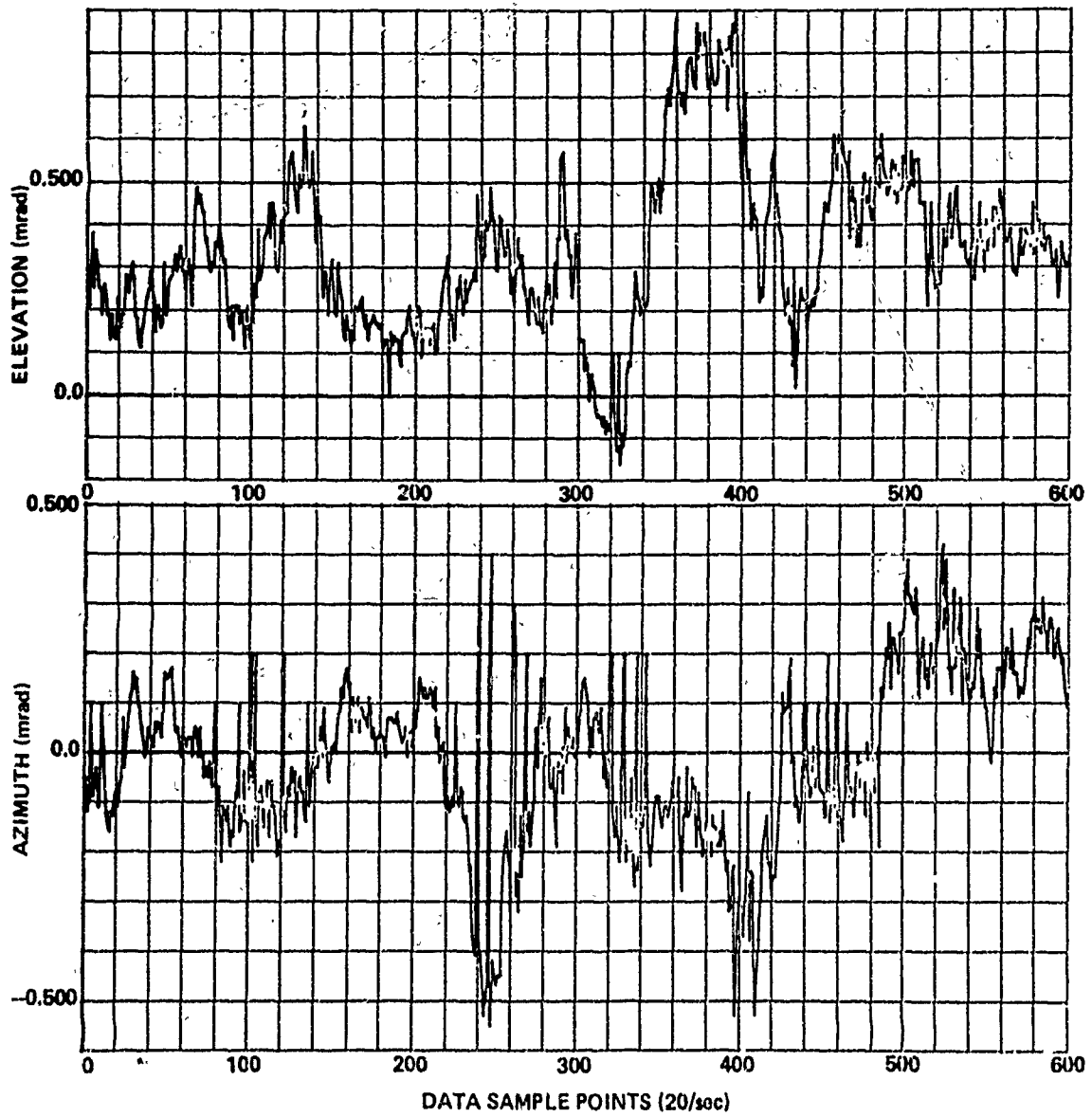
RUN 175



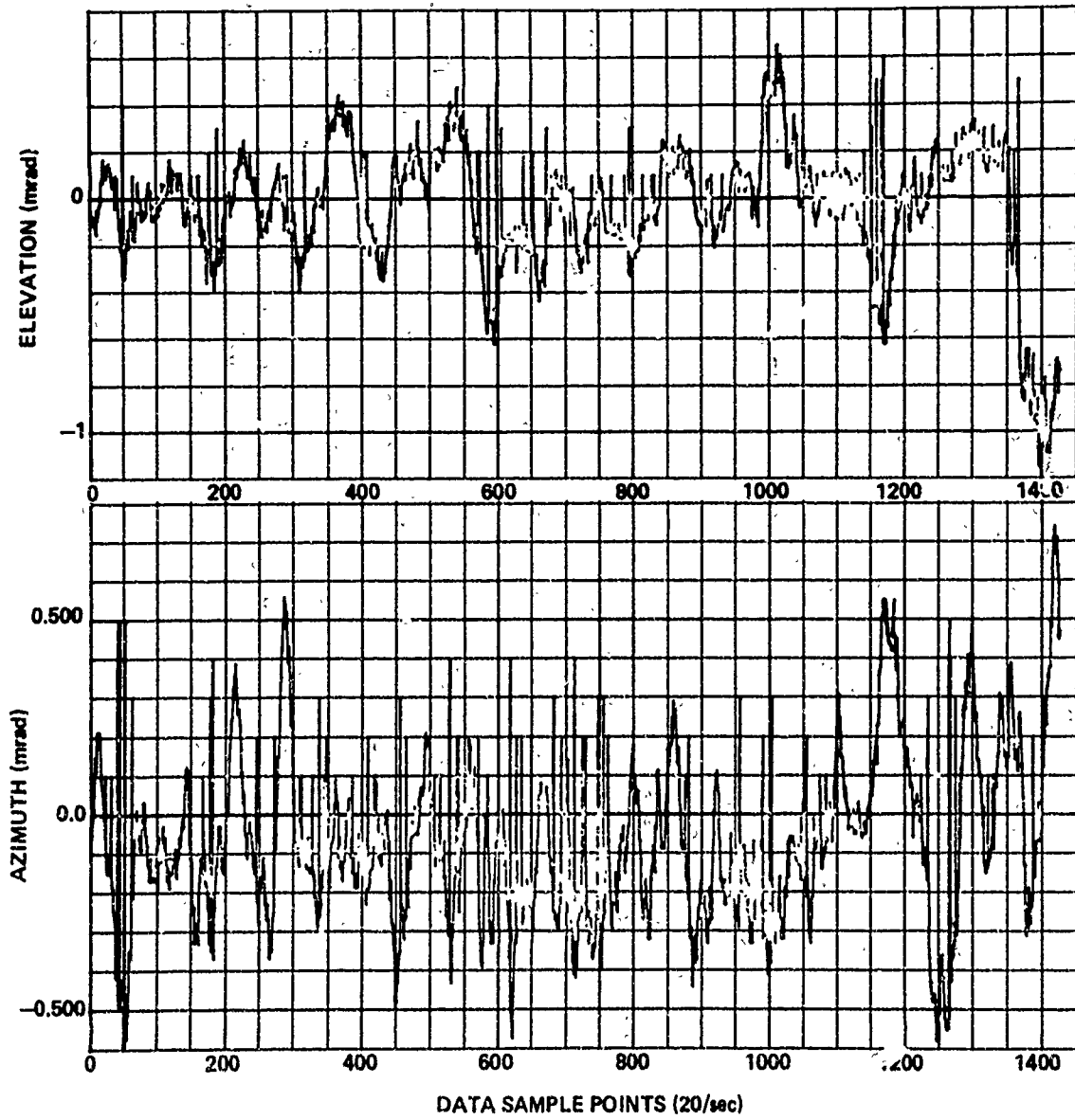
RUN 176



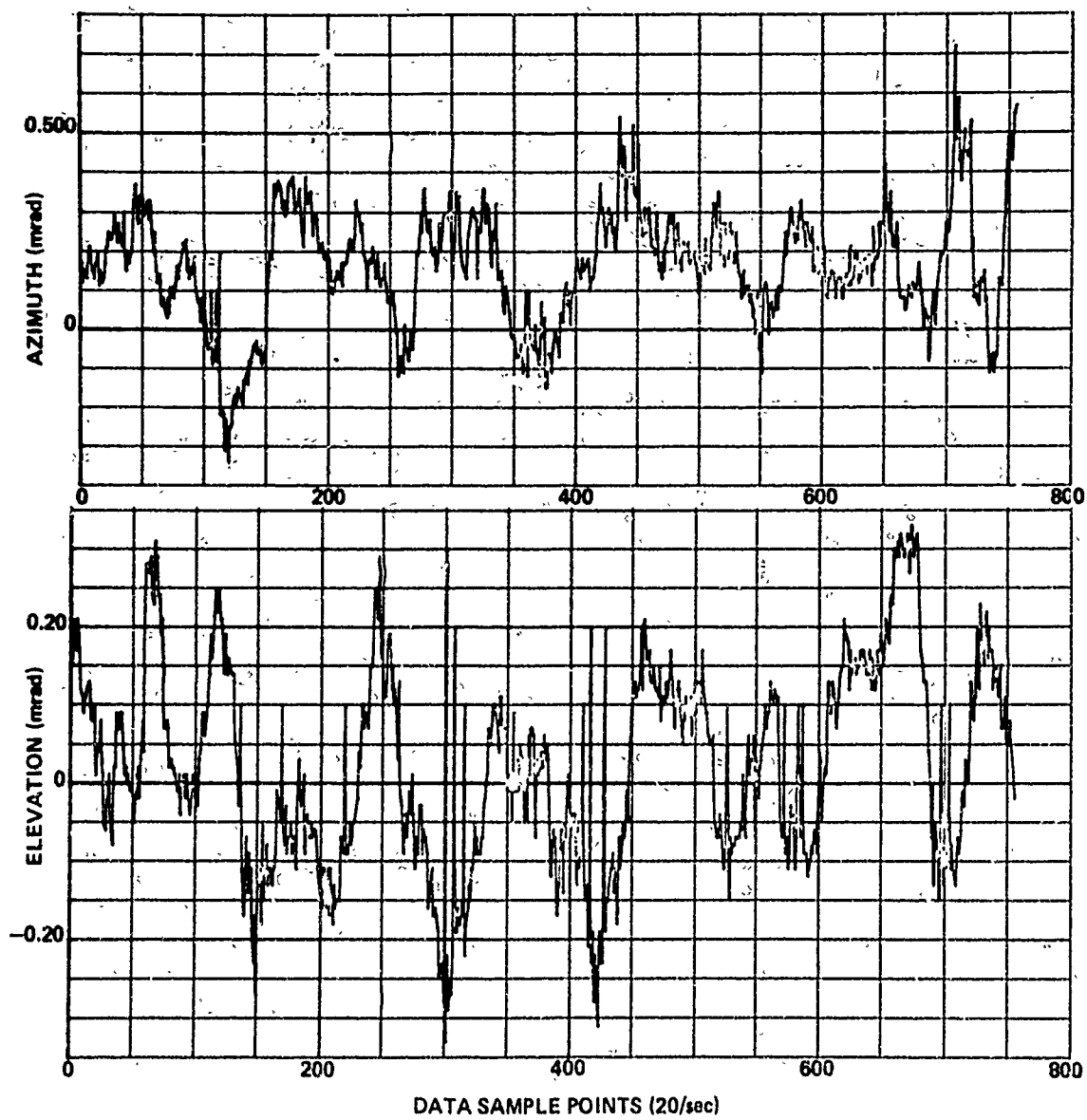
RUN 177



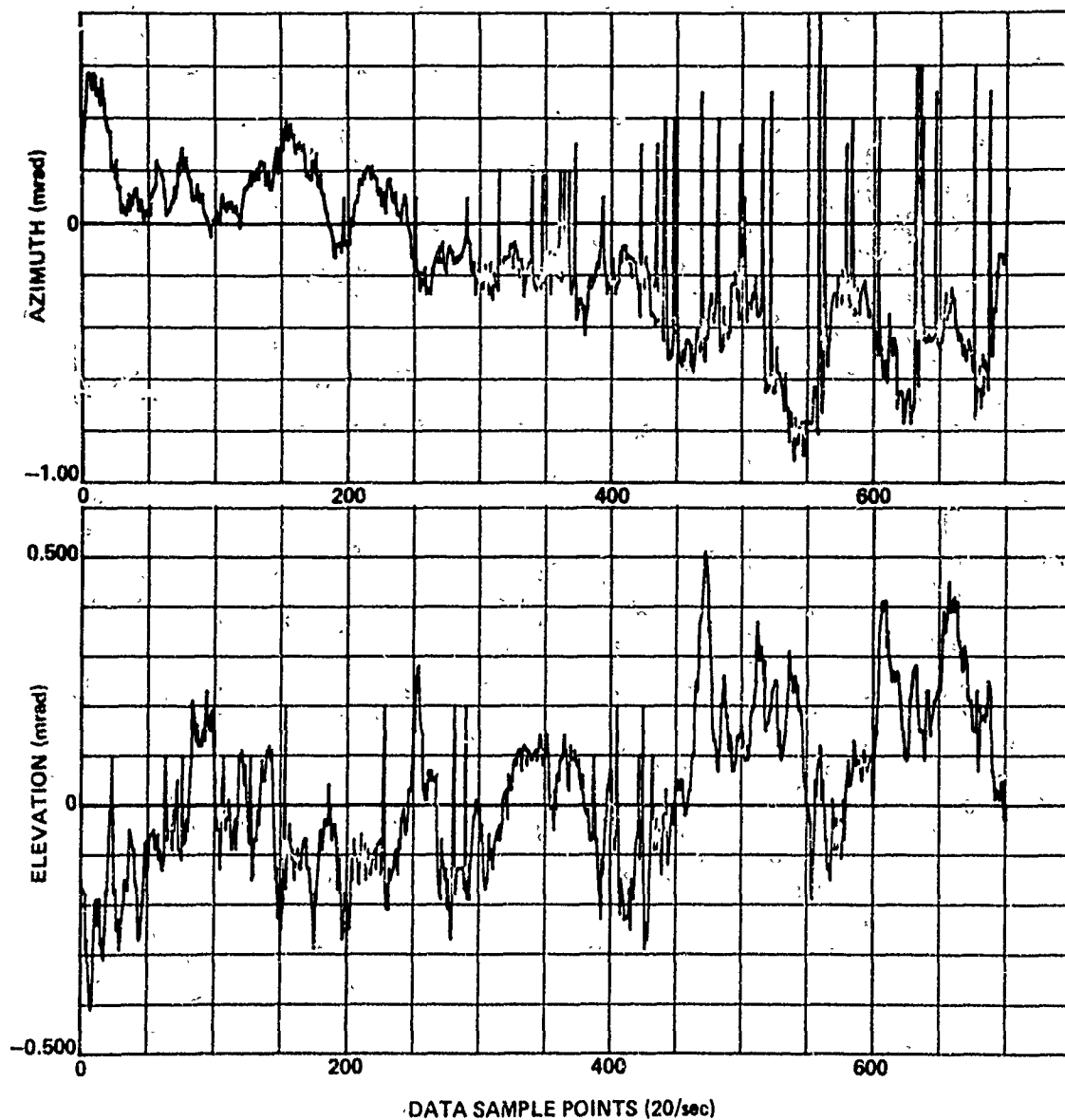
RUN 178



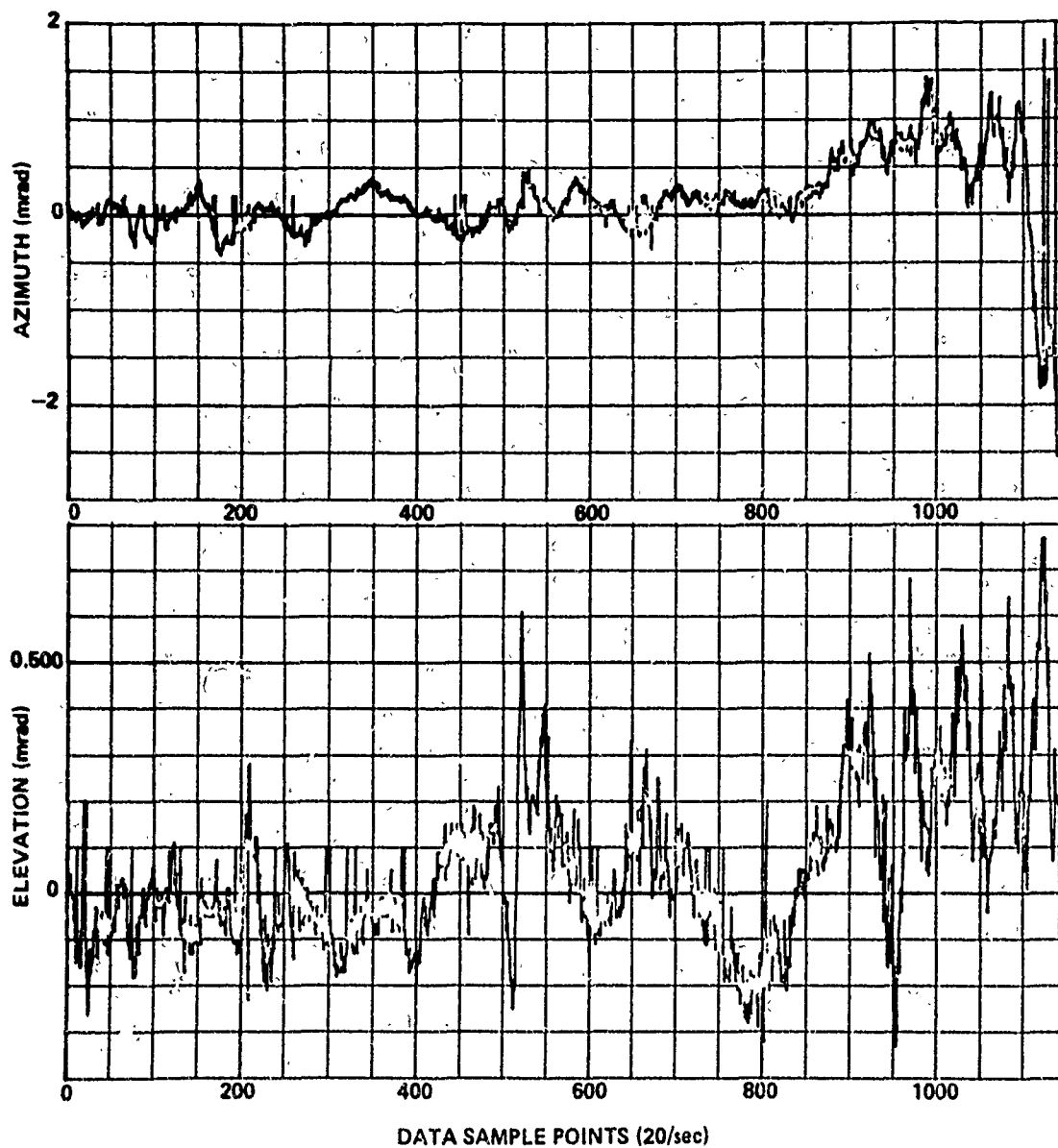
RUN 179



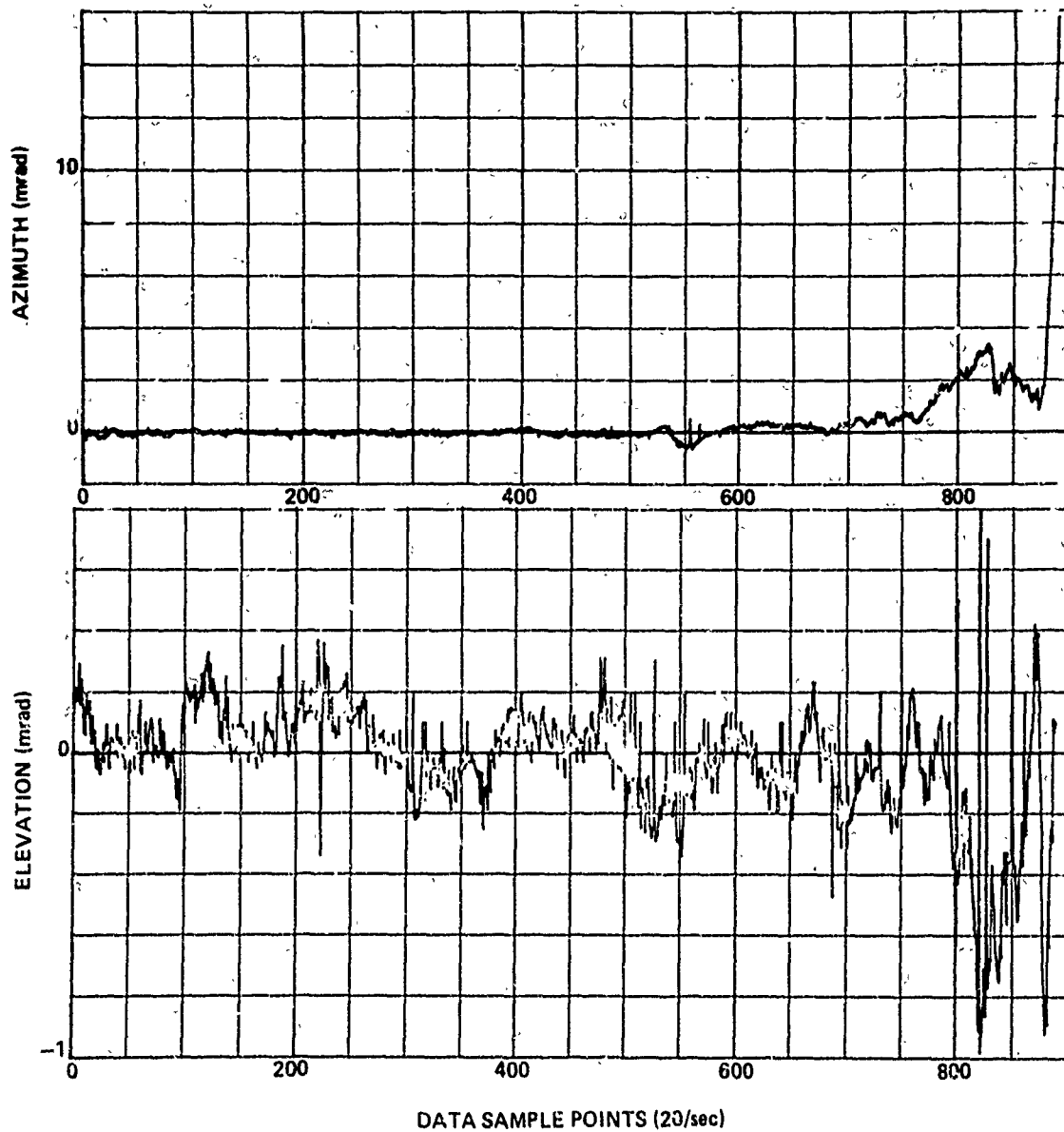
RUN 180



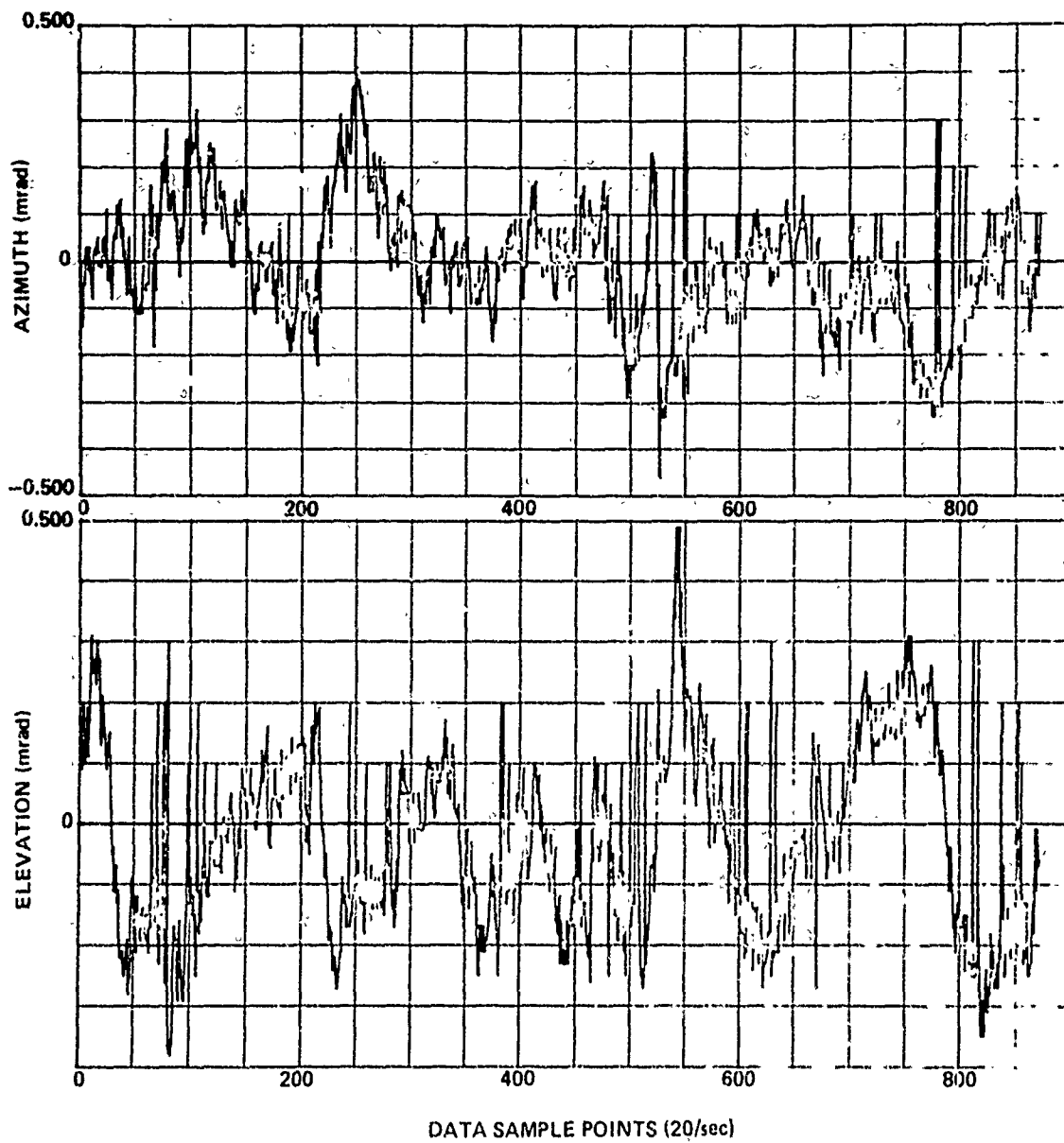
RUN 182



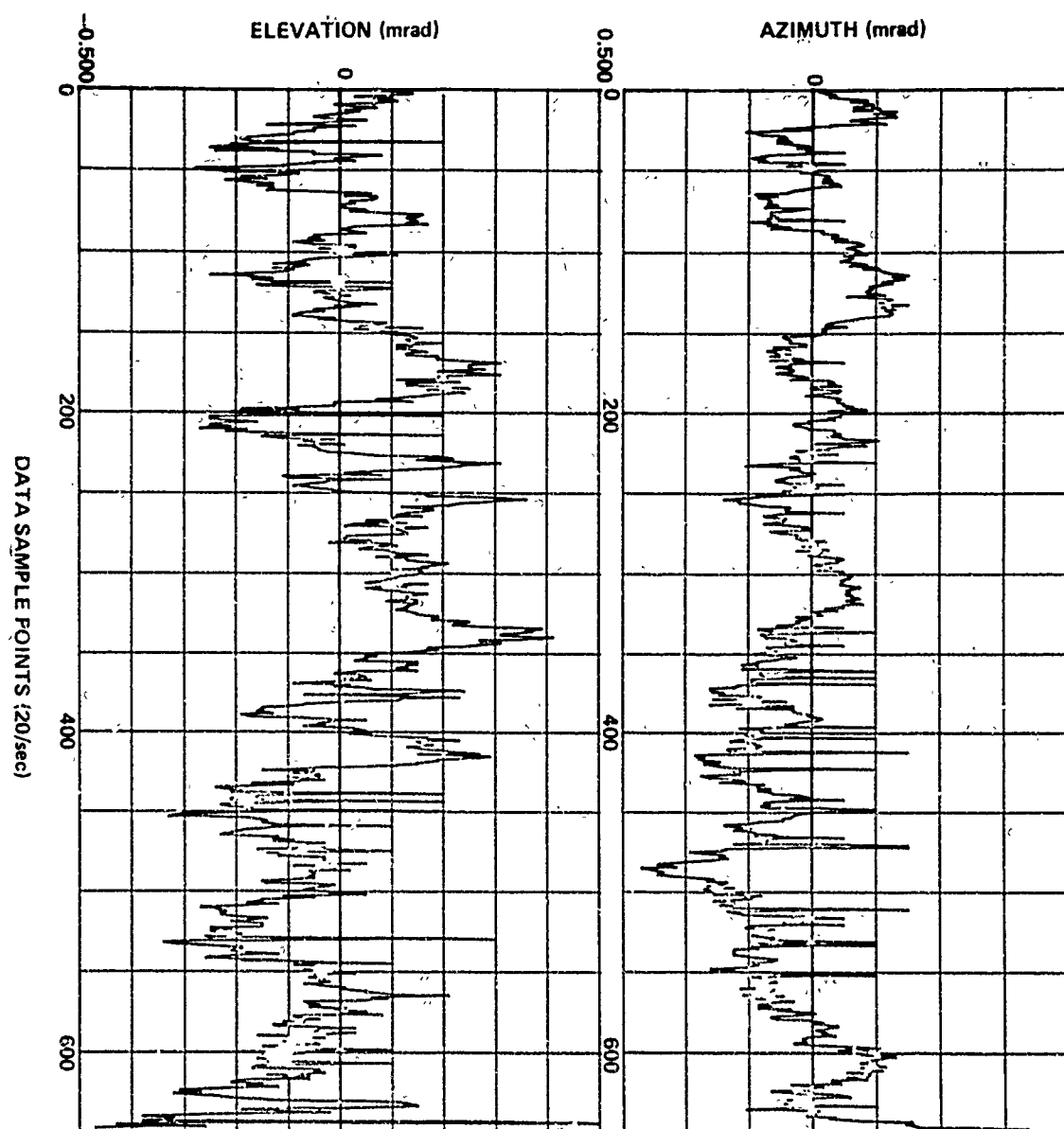
RUN 183



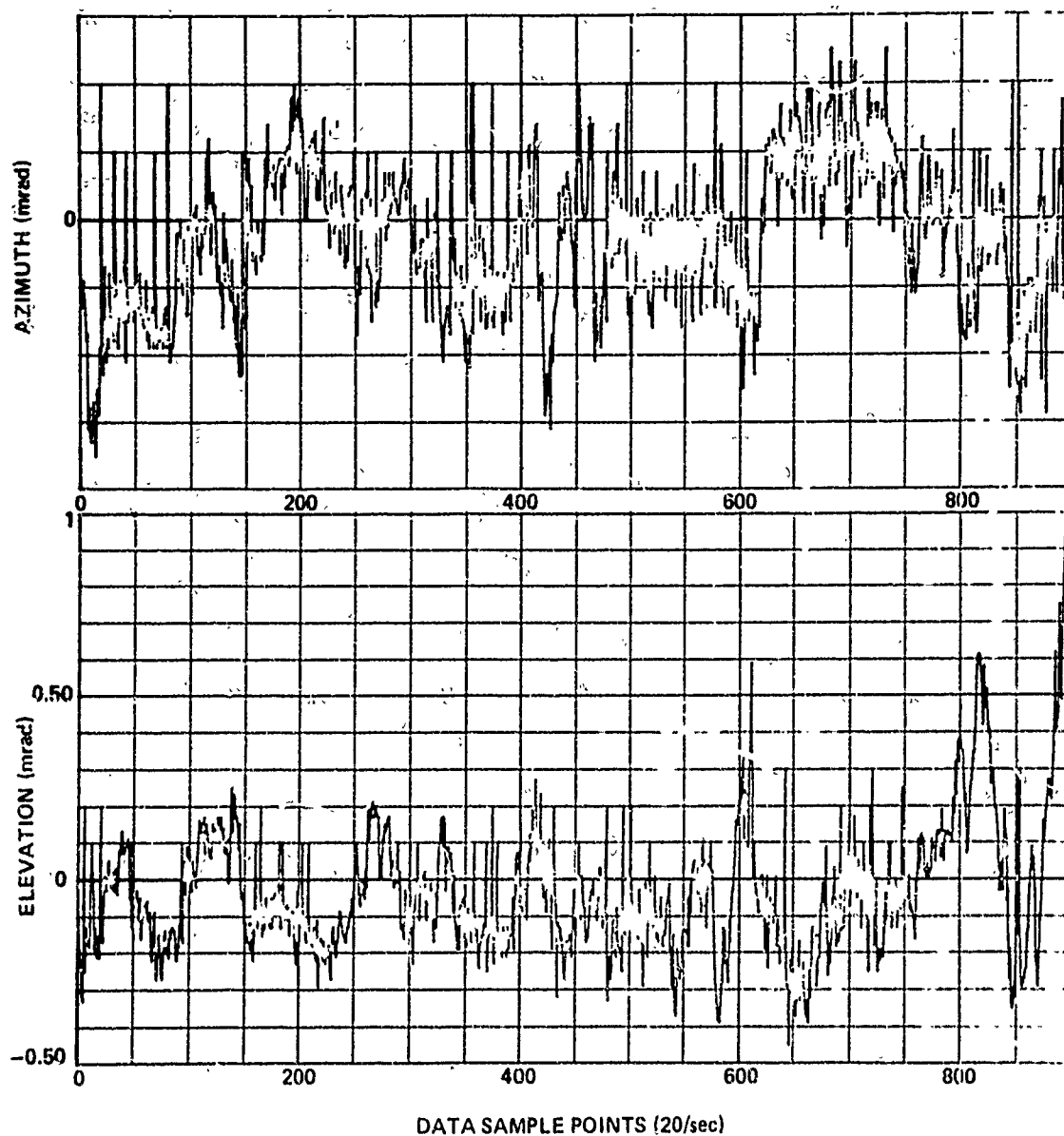
RUN 184



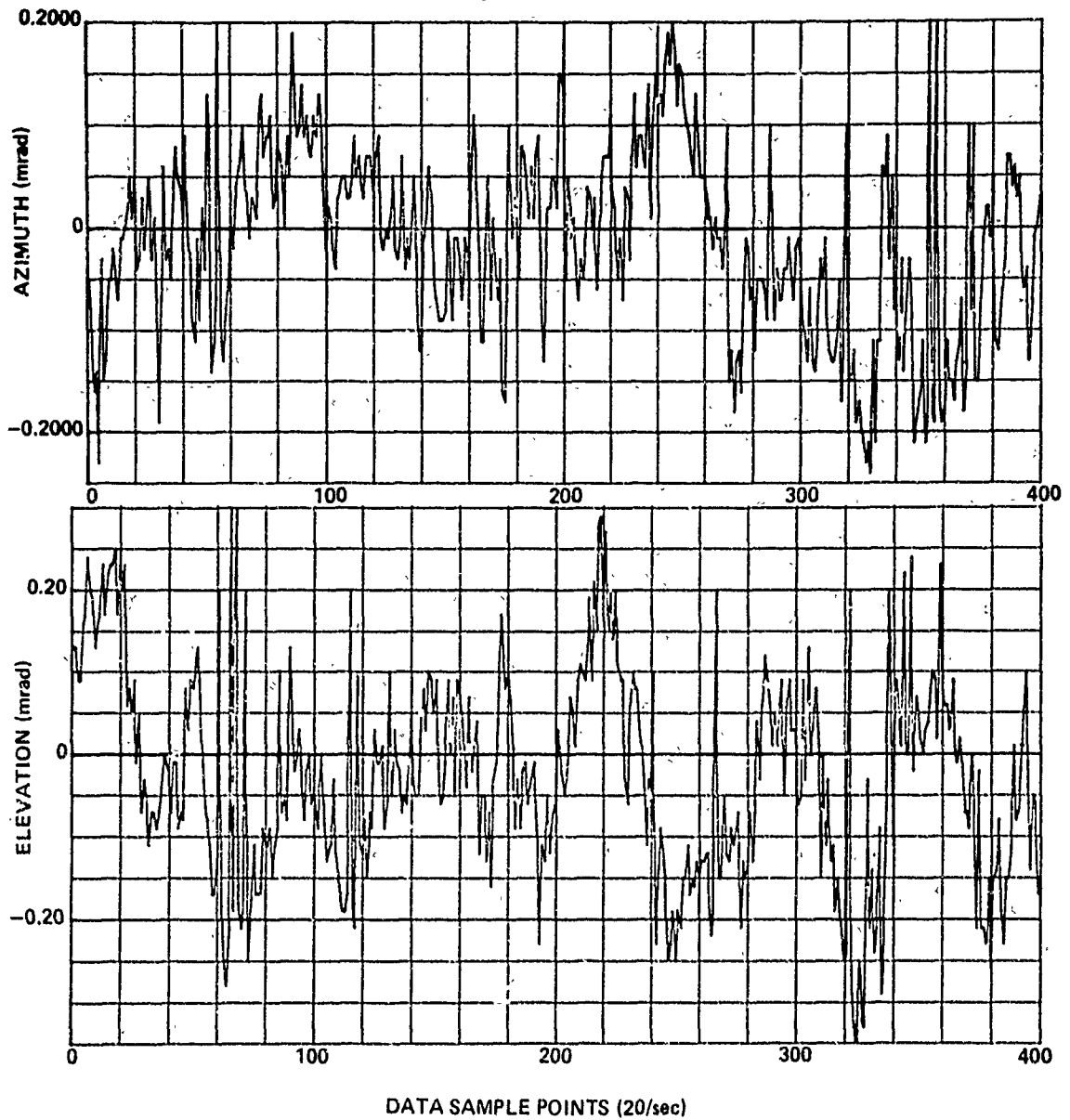
RUN 185



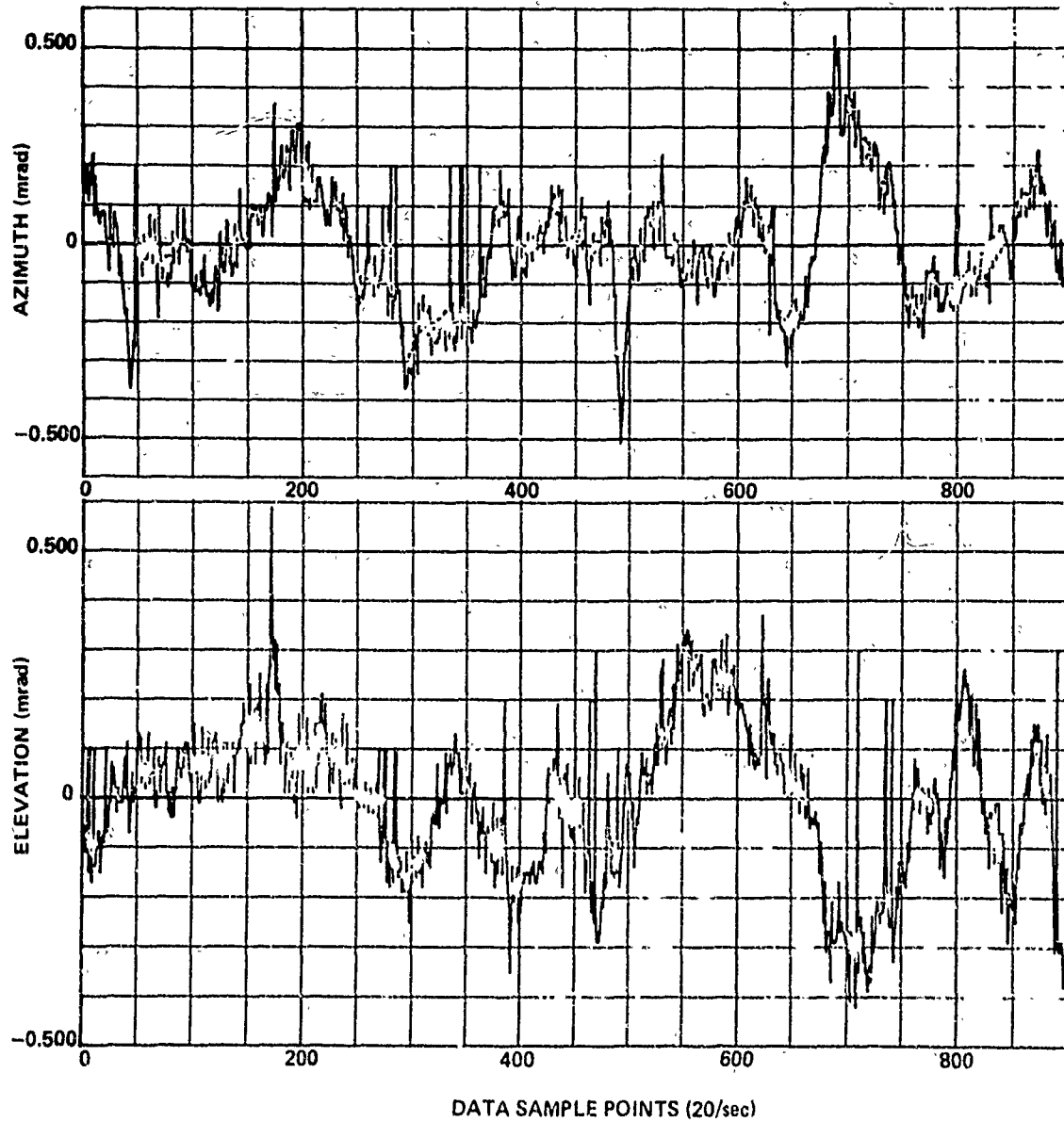
RUN 186



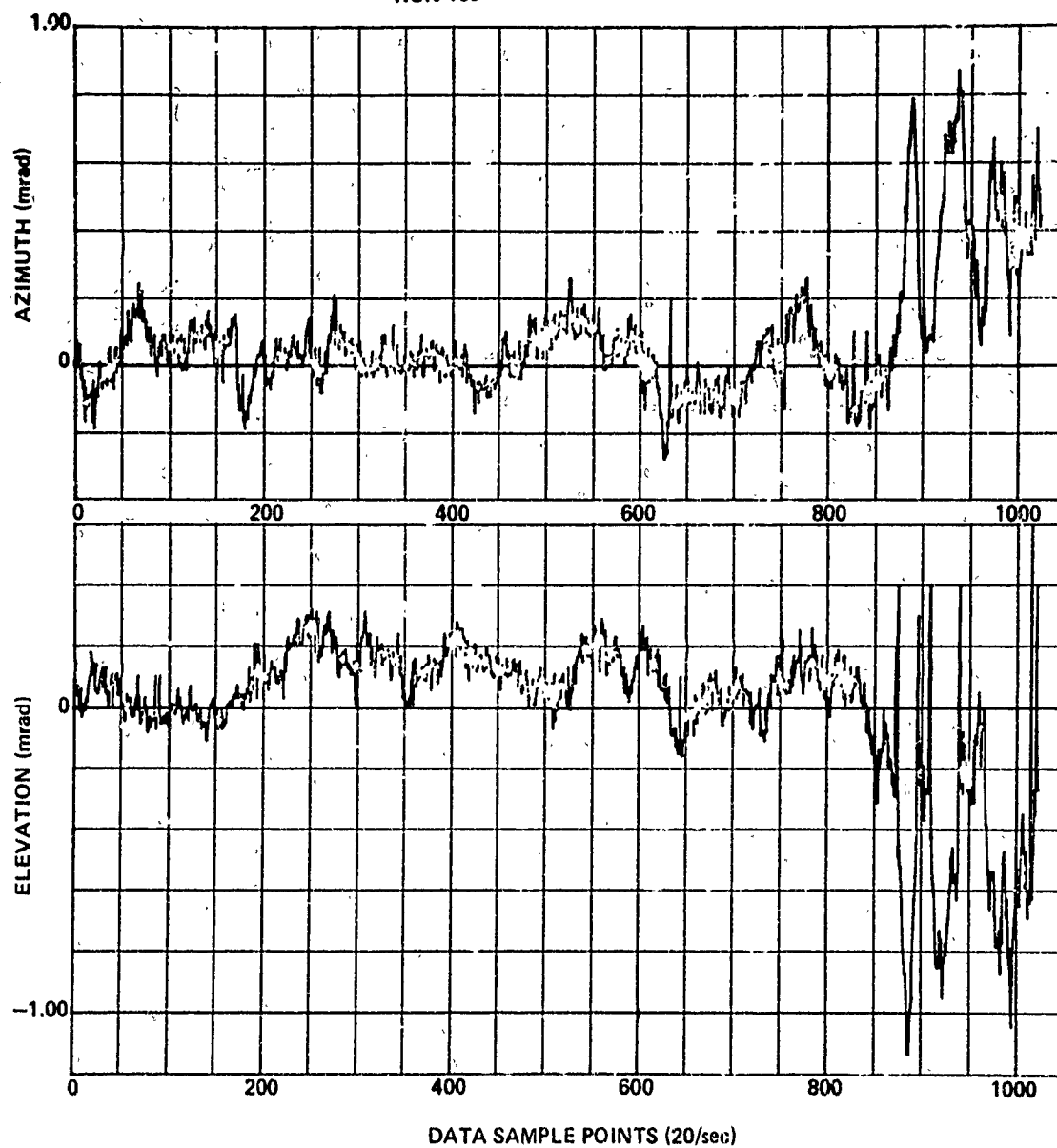
RUN 187



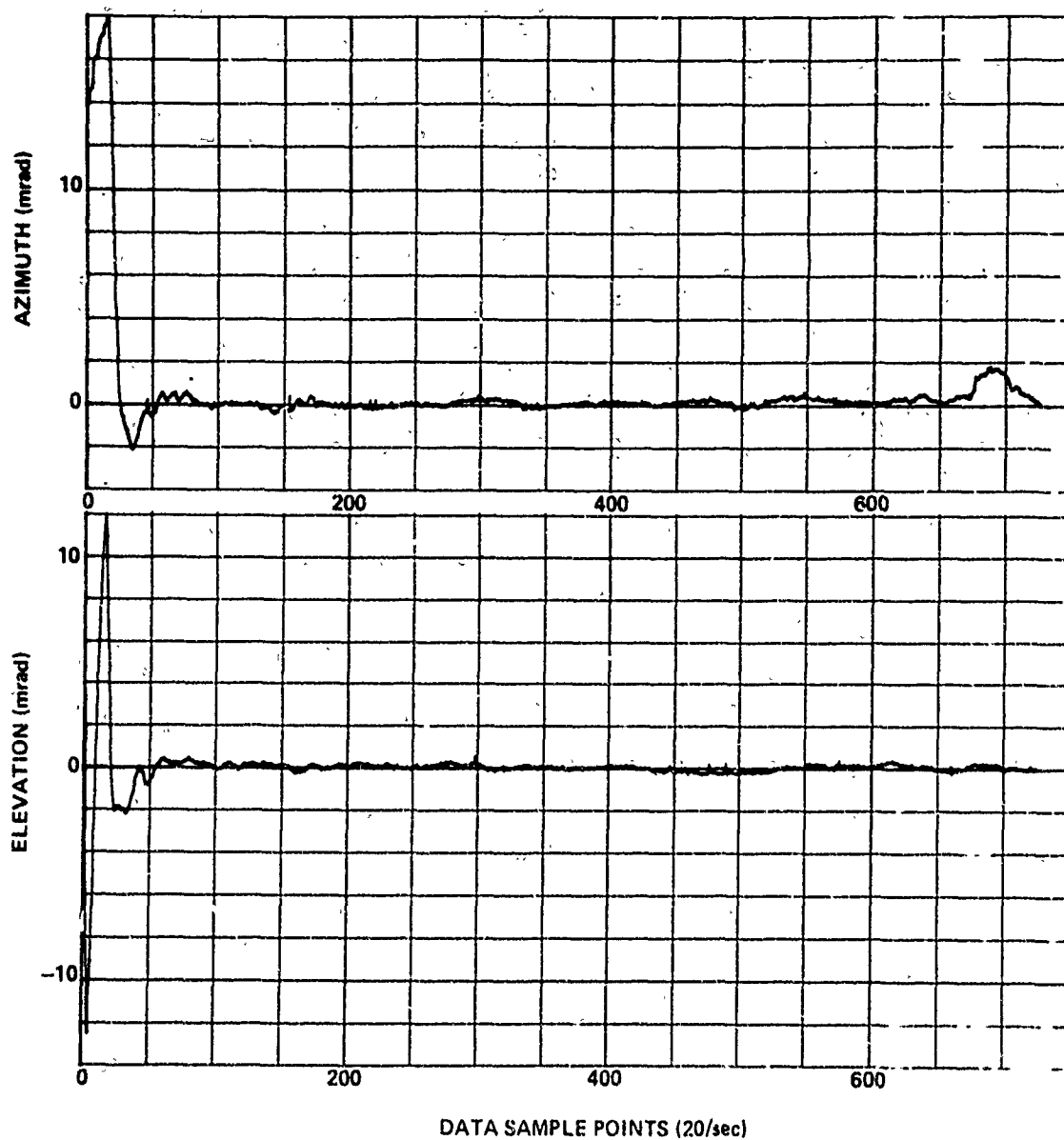
RUN 188



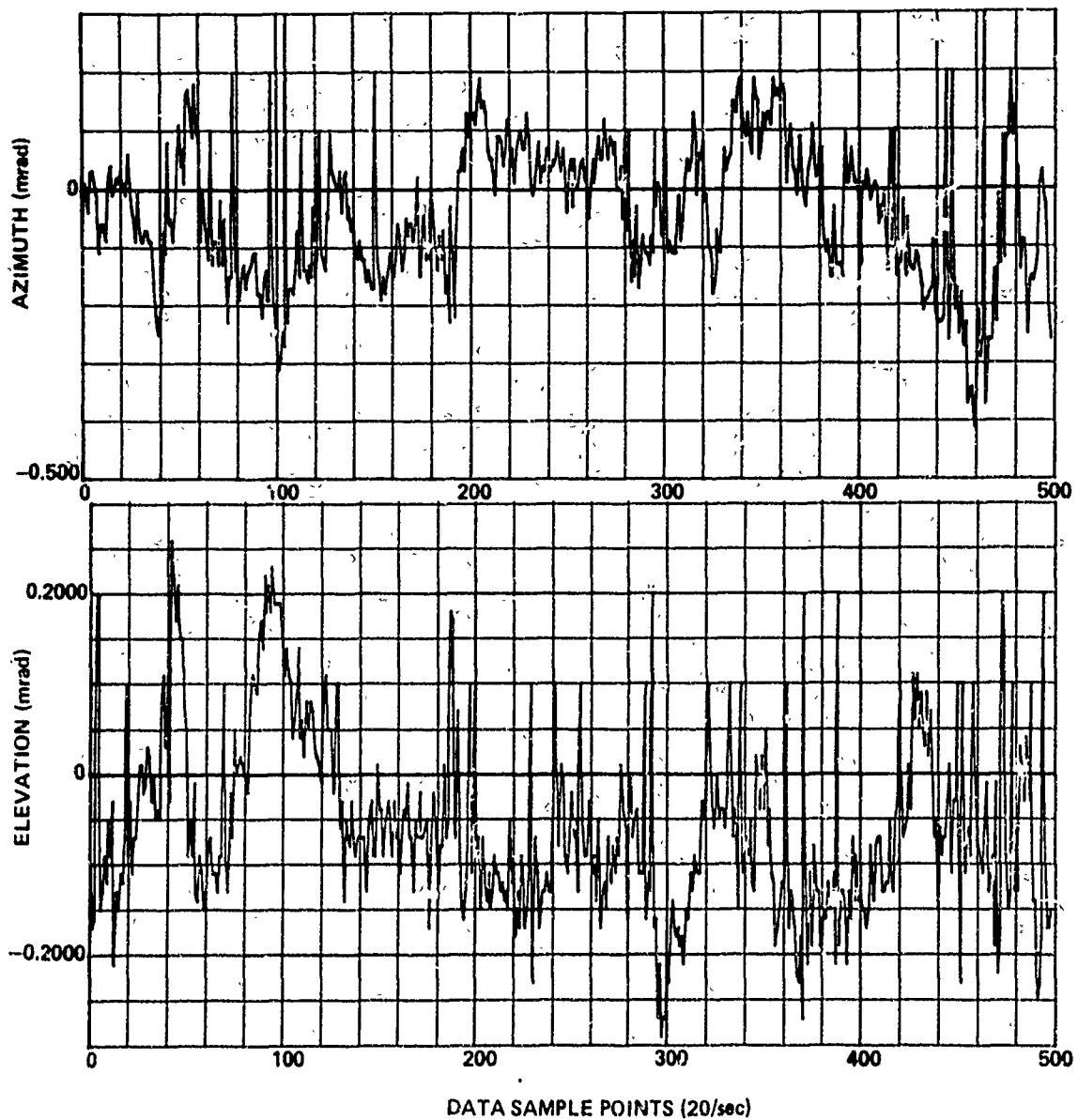
RUN 189



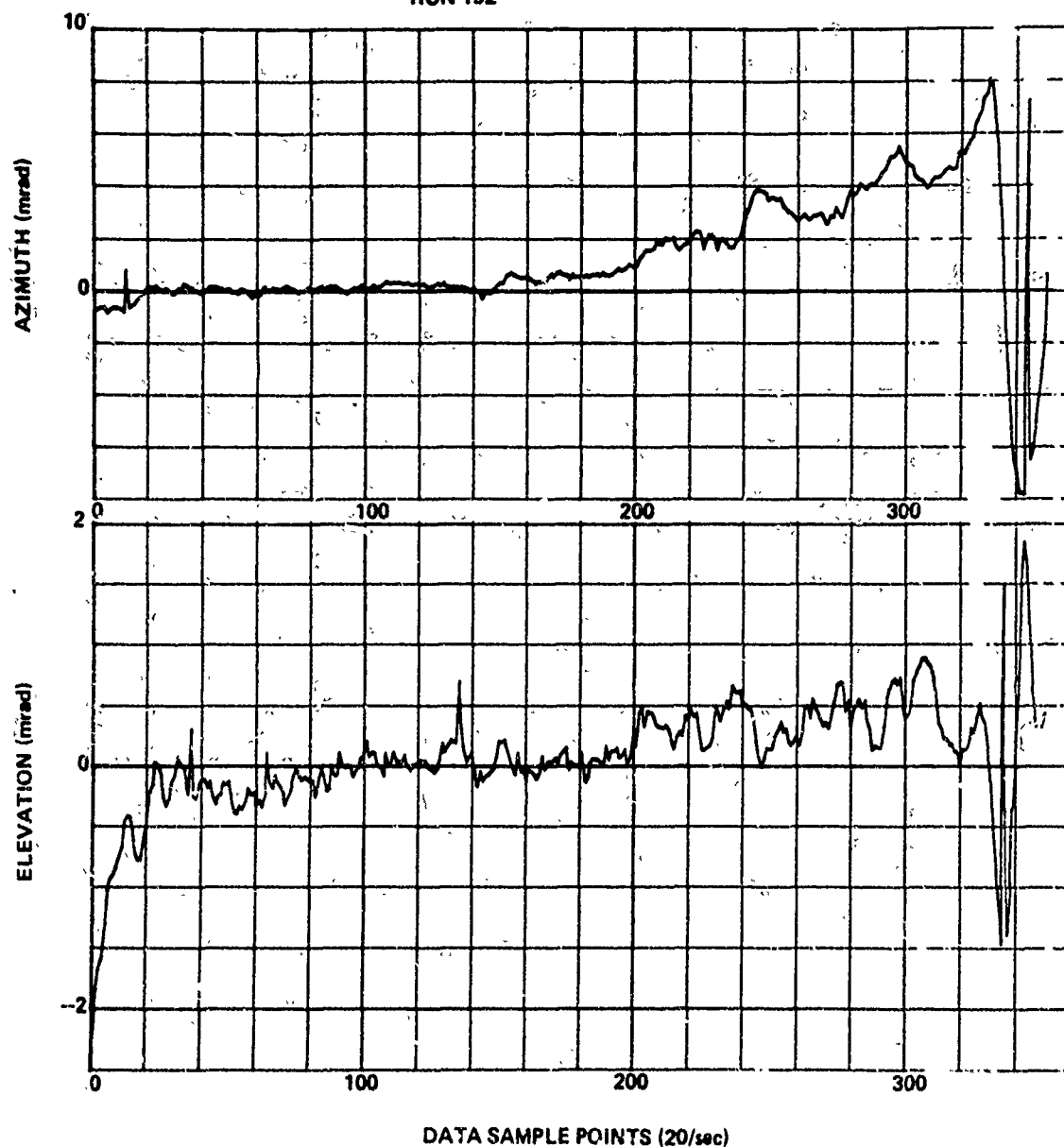
RUN 190



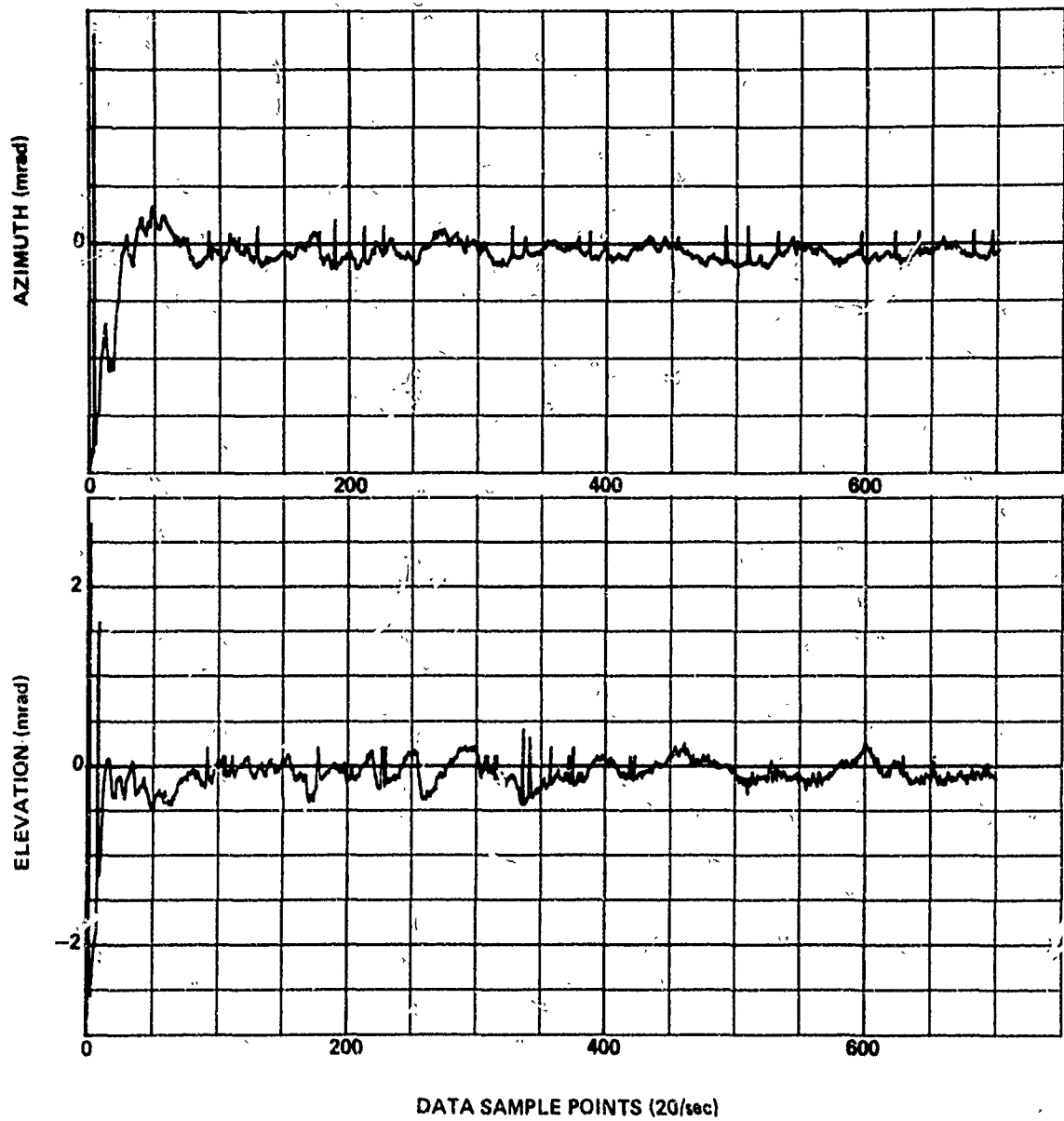
RUN 191



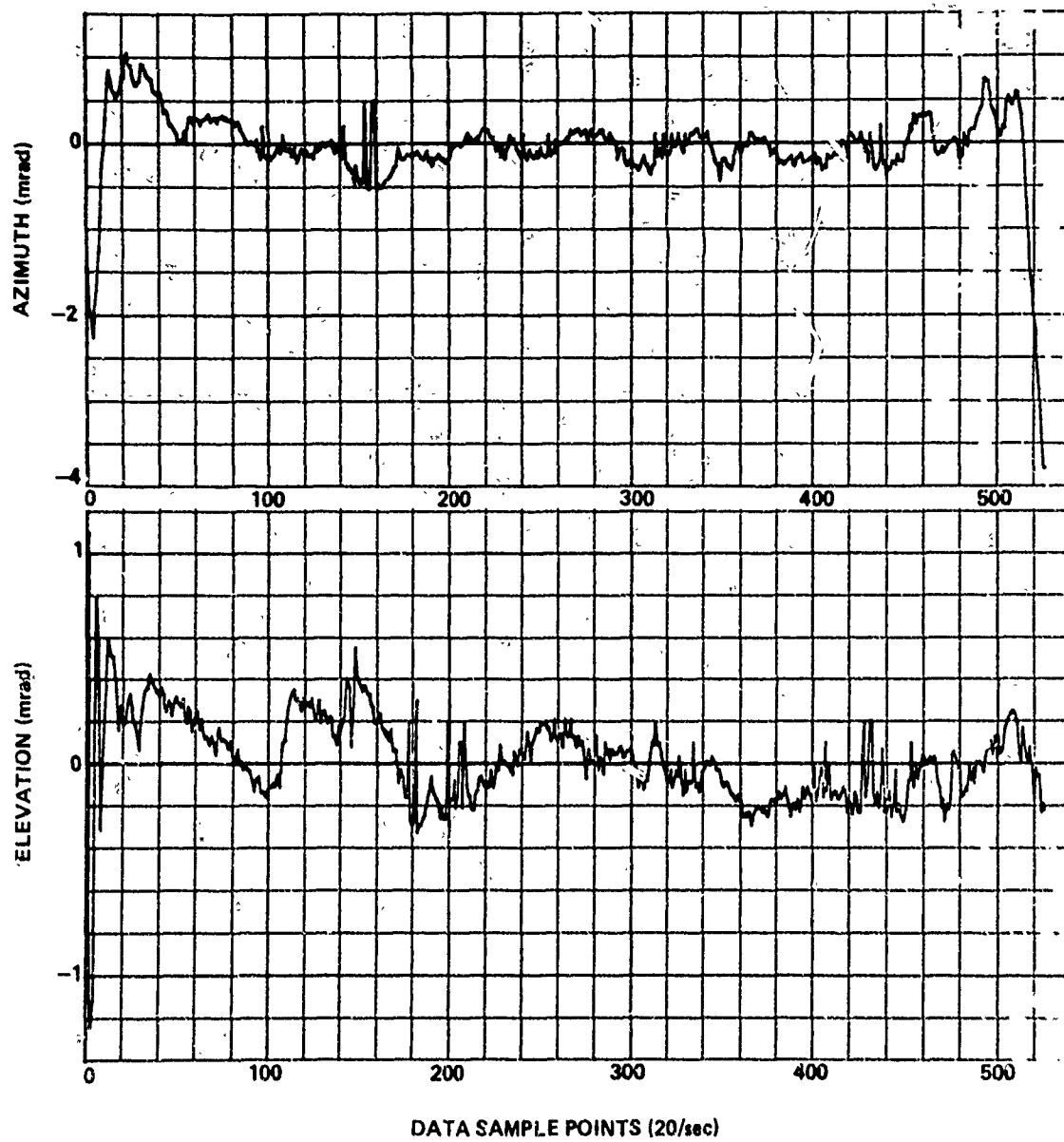
RUN 192



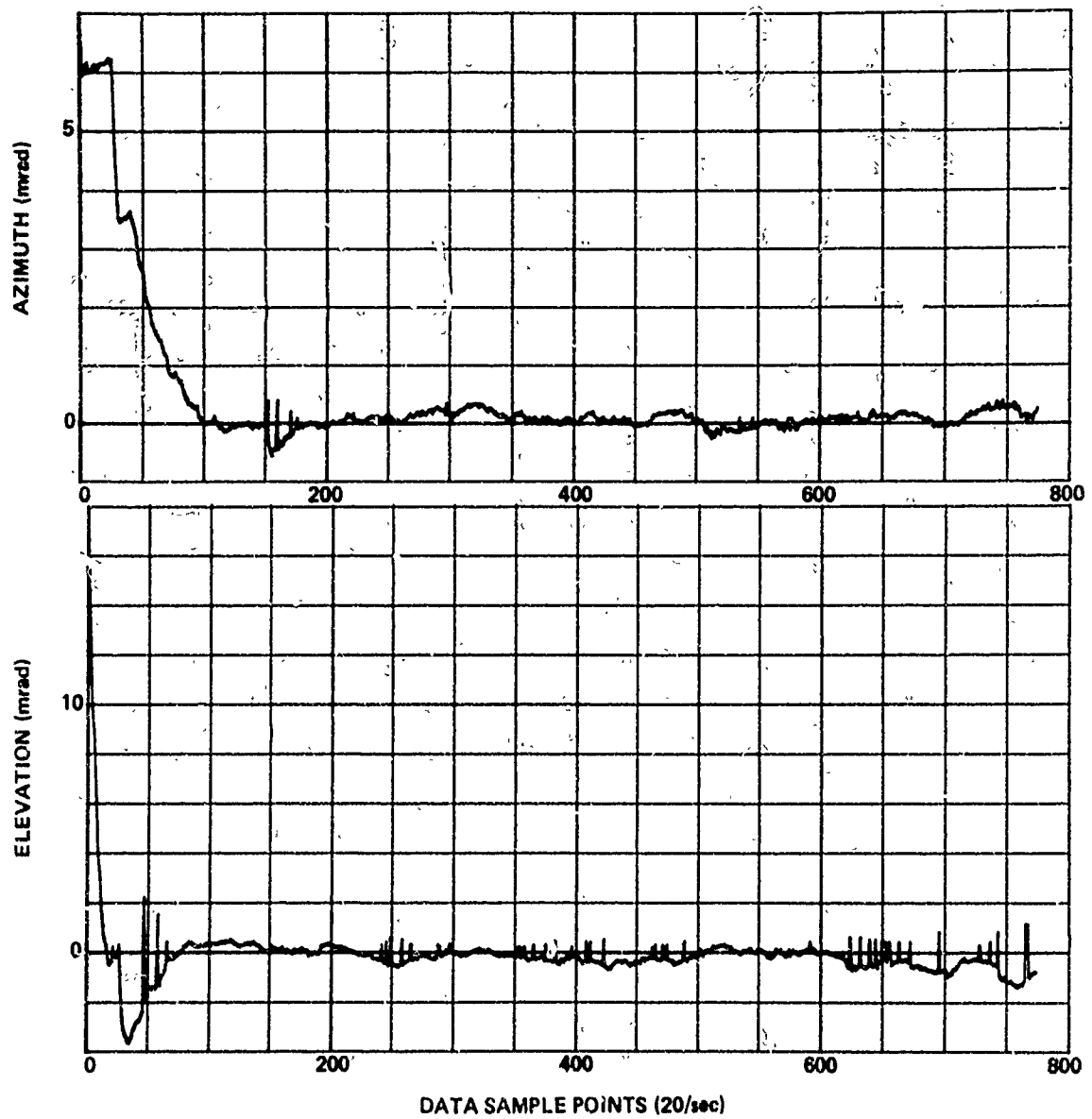
RUN 193

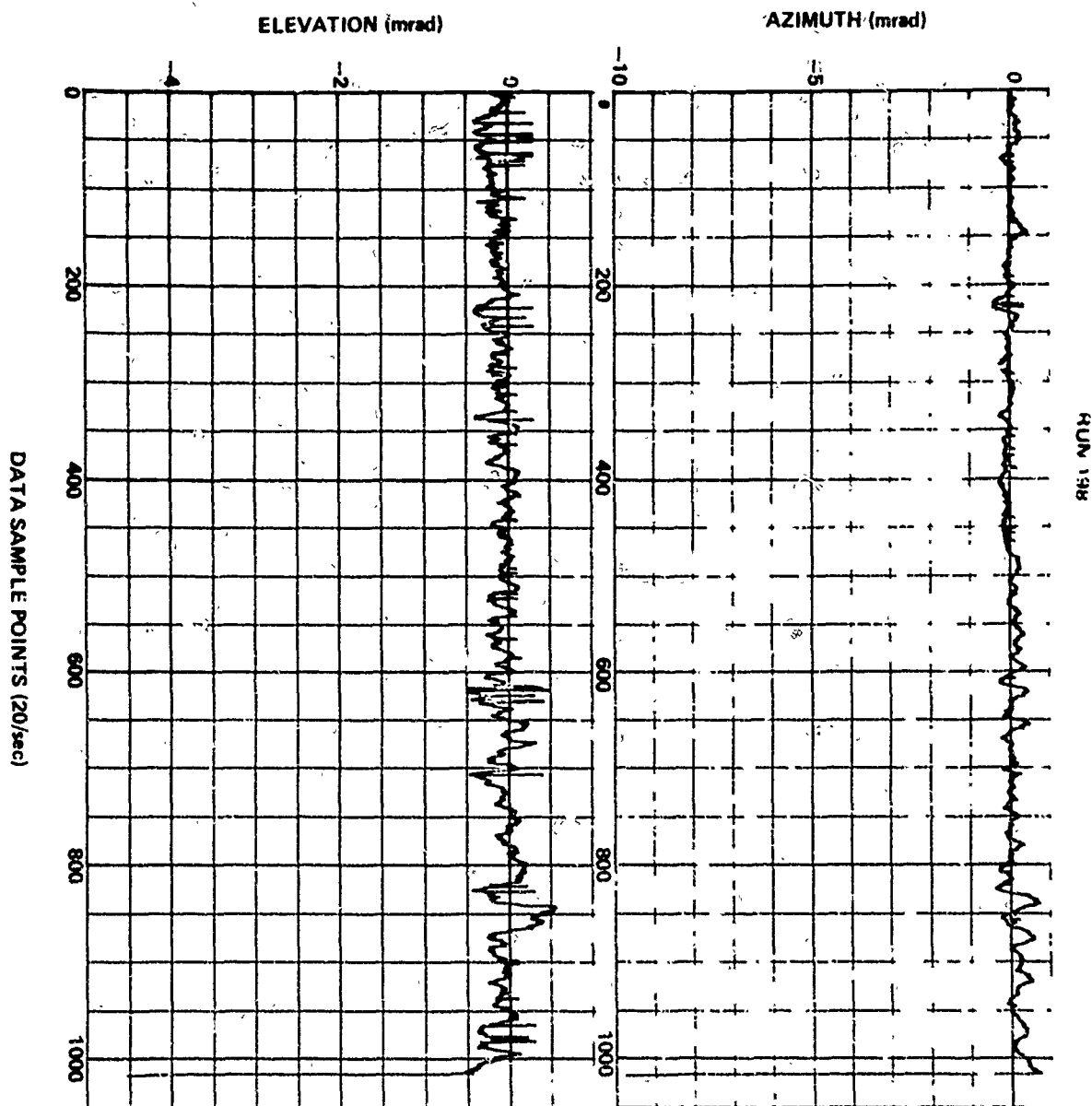


RUN 194

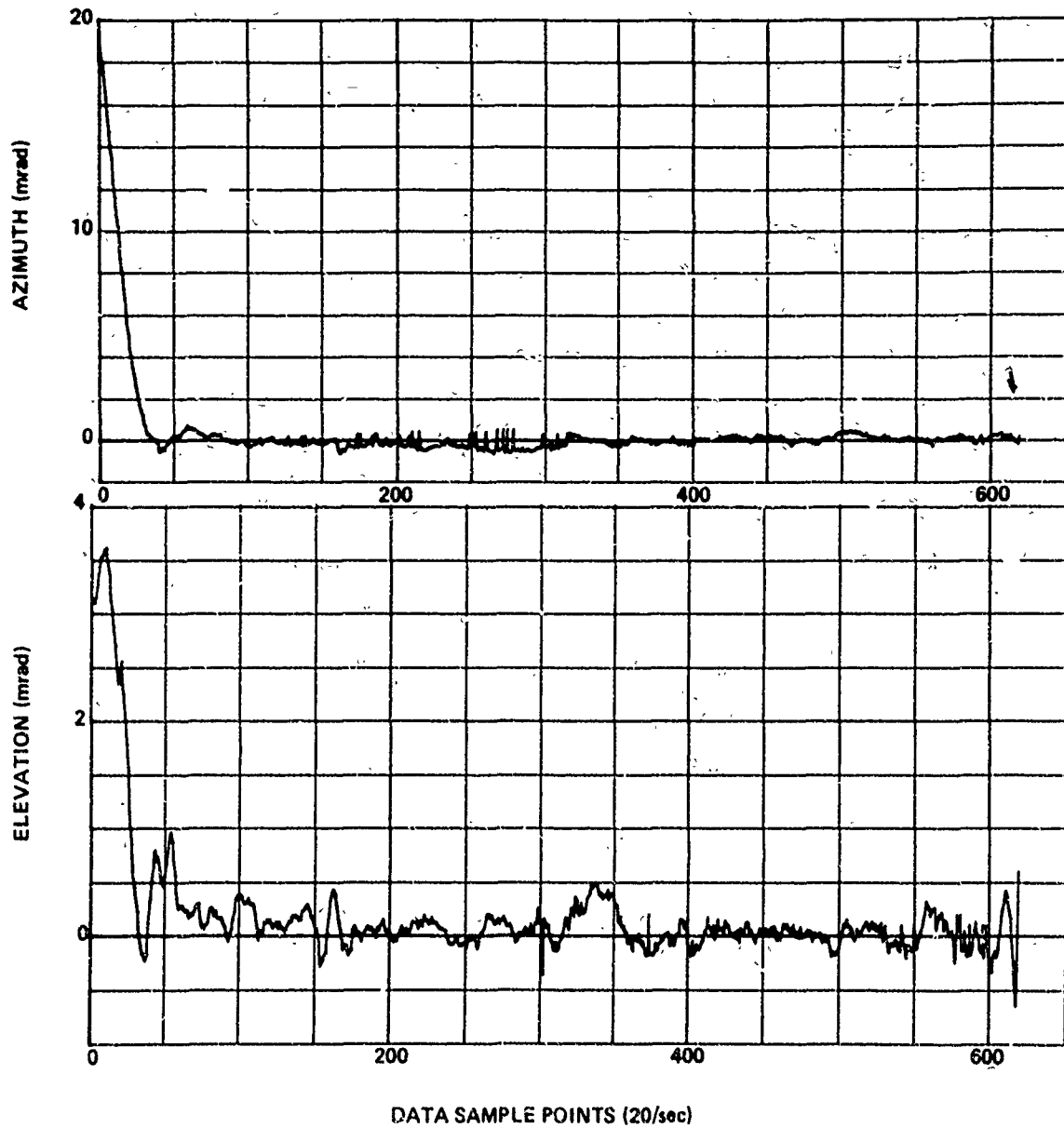


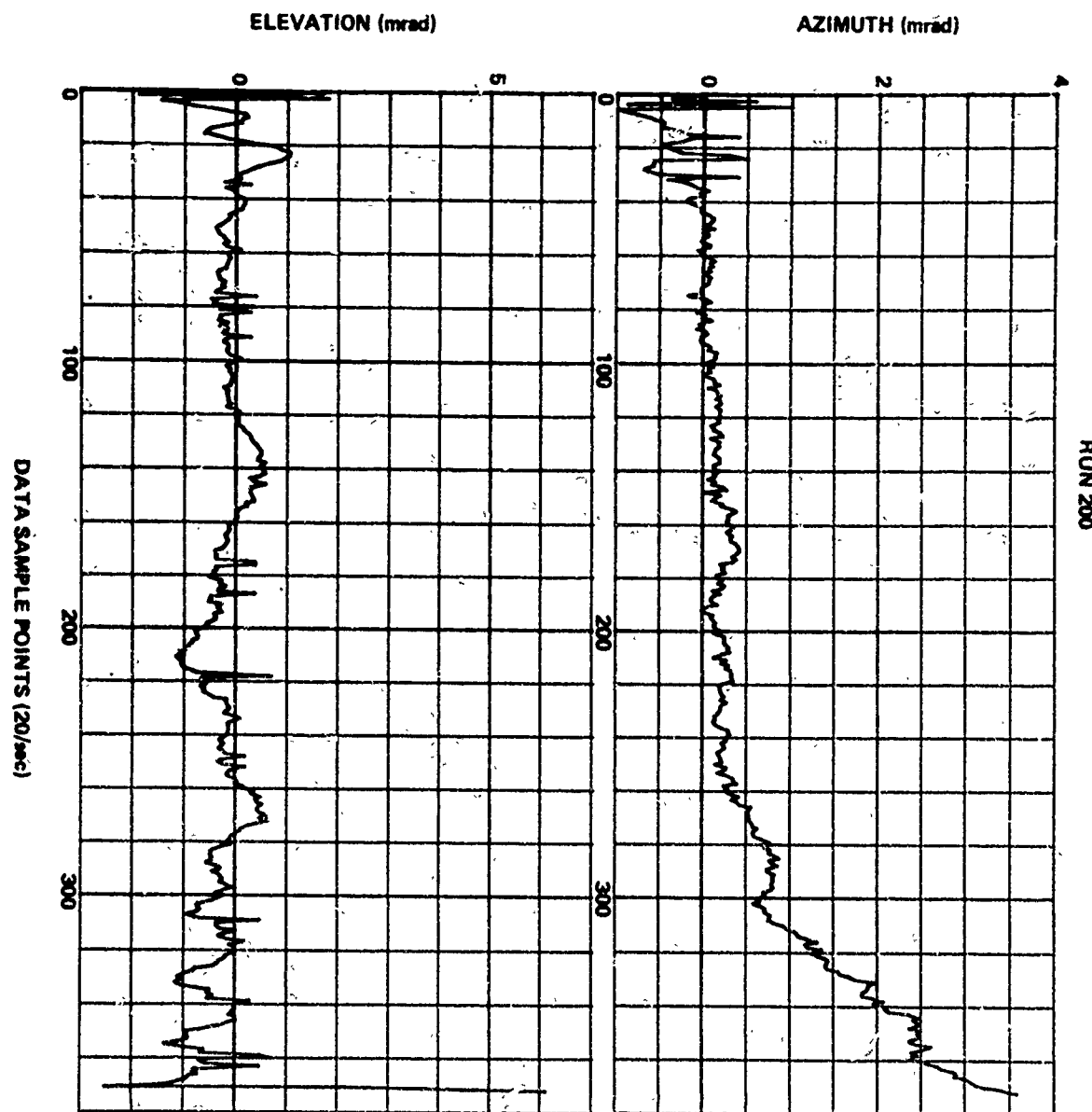
RUN 197.



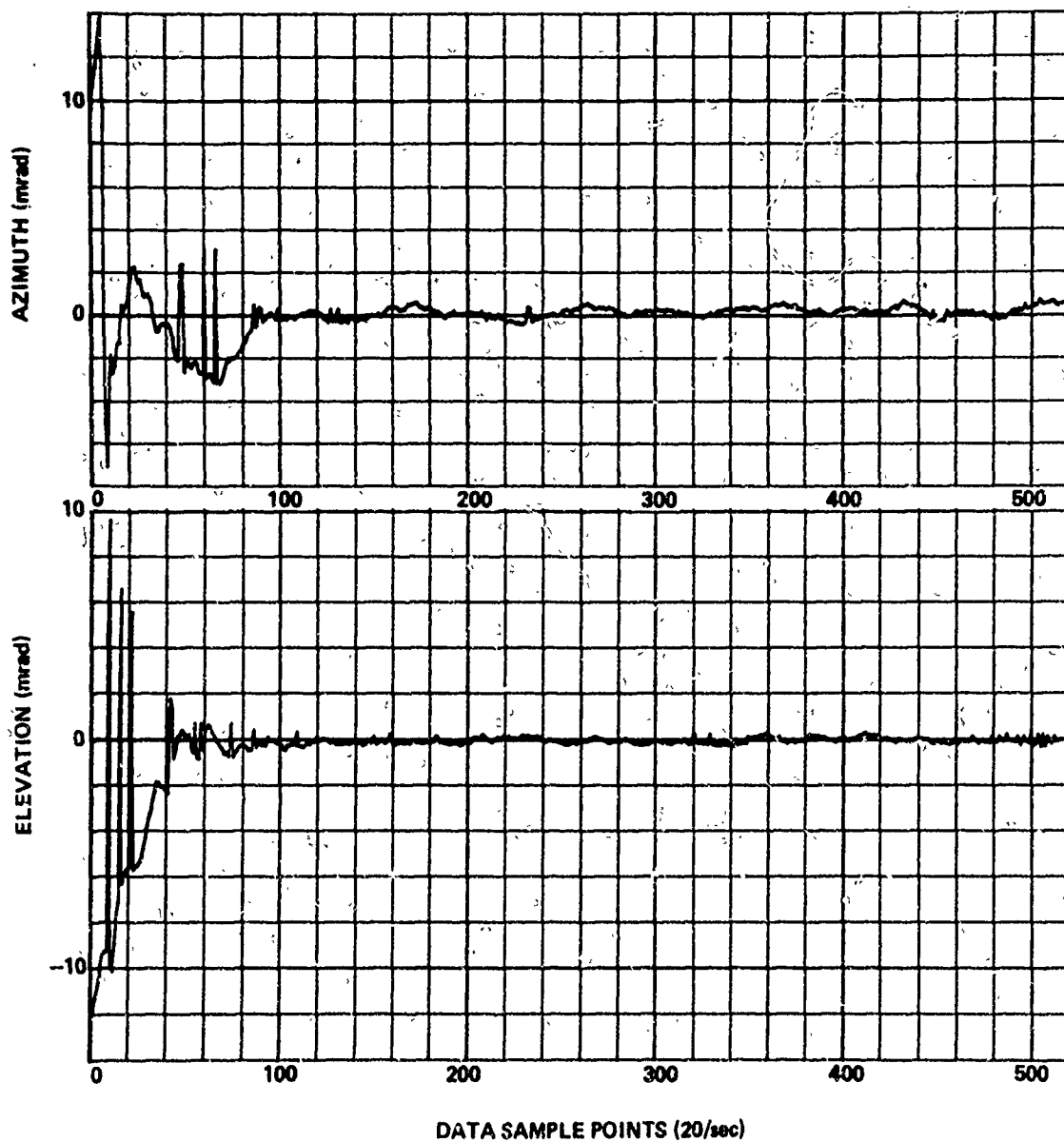


RUN 199

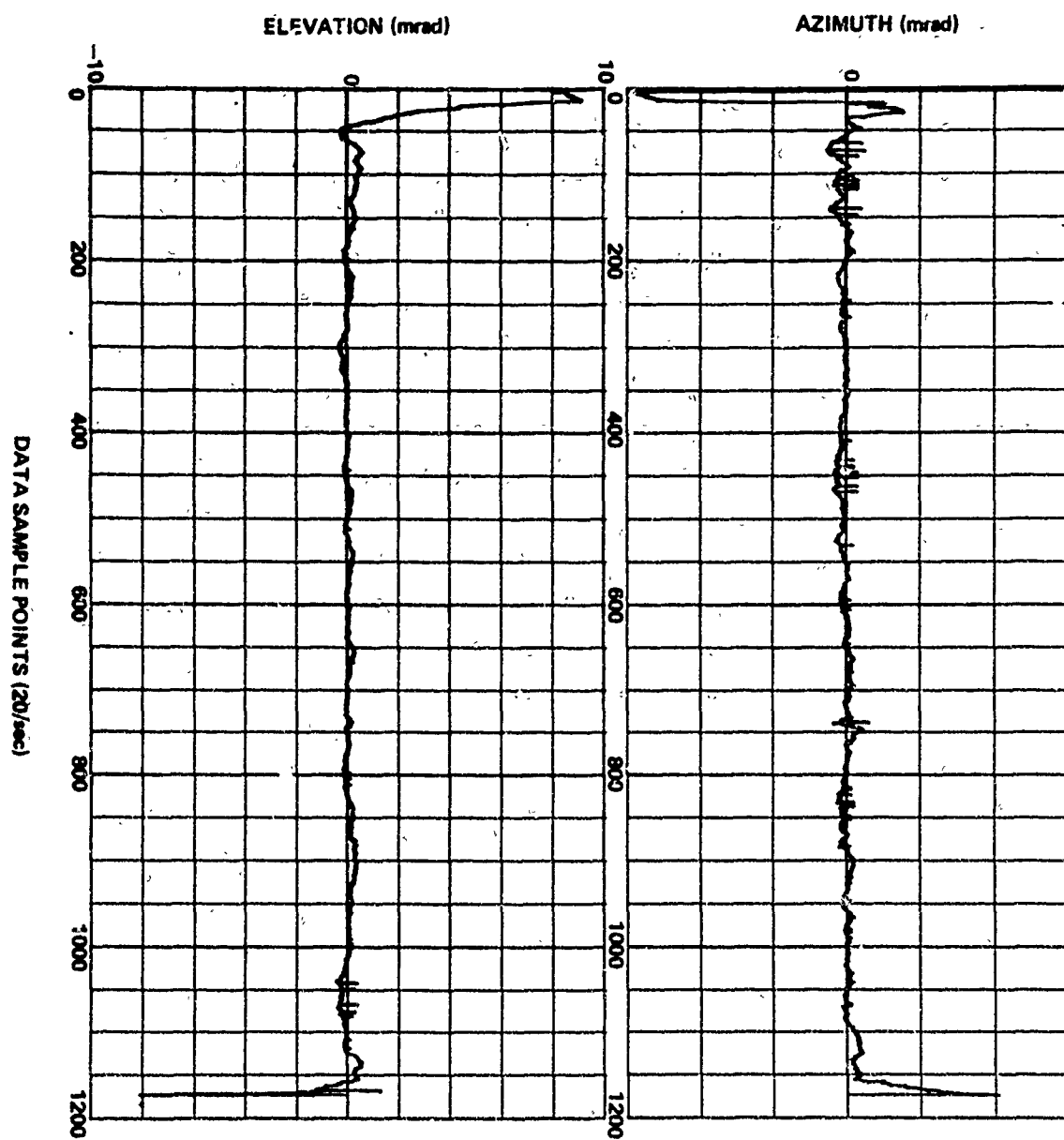


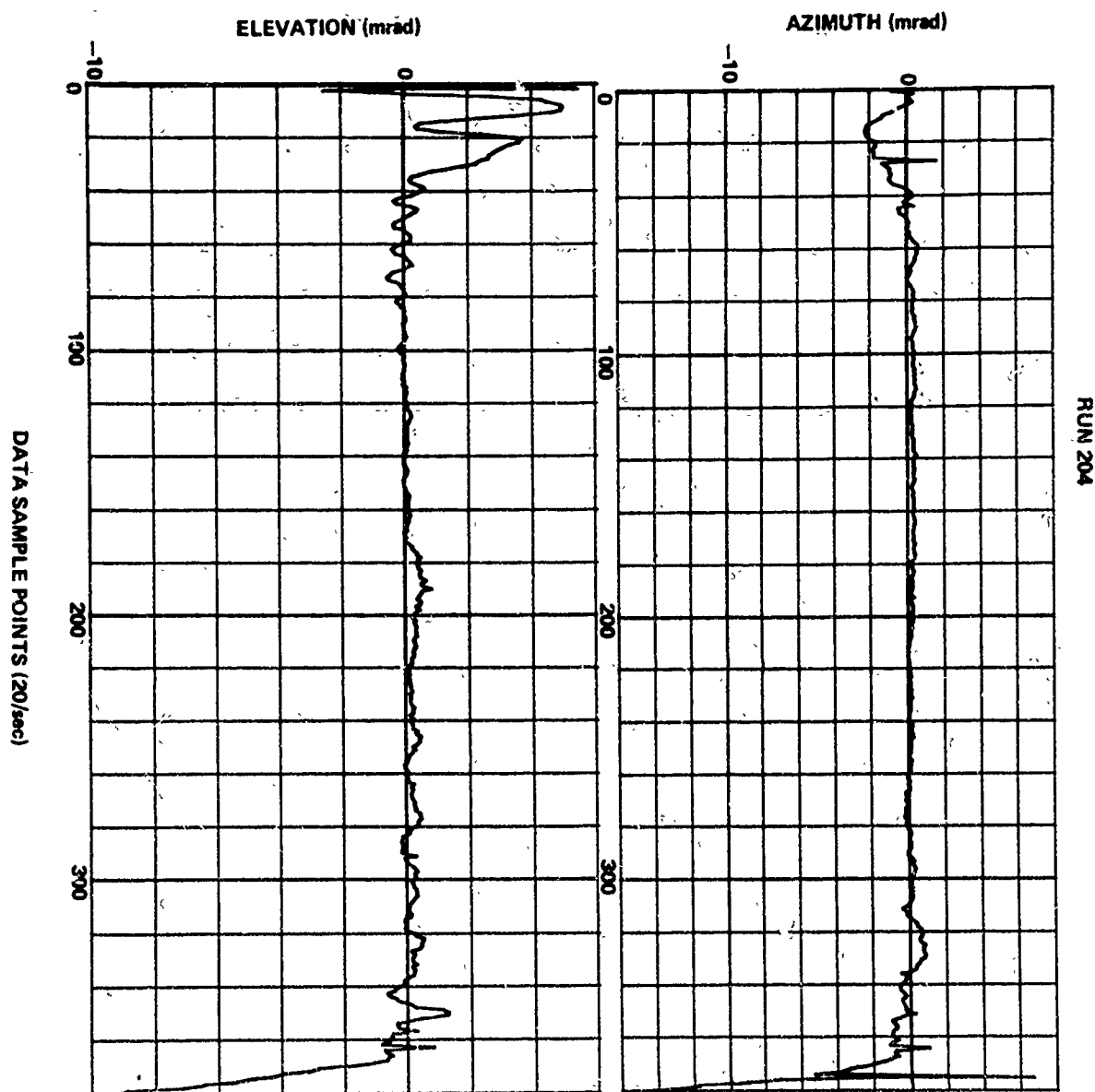


RUN 202

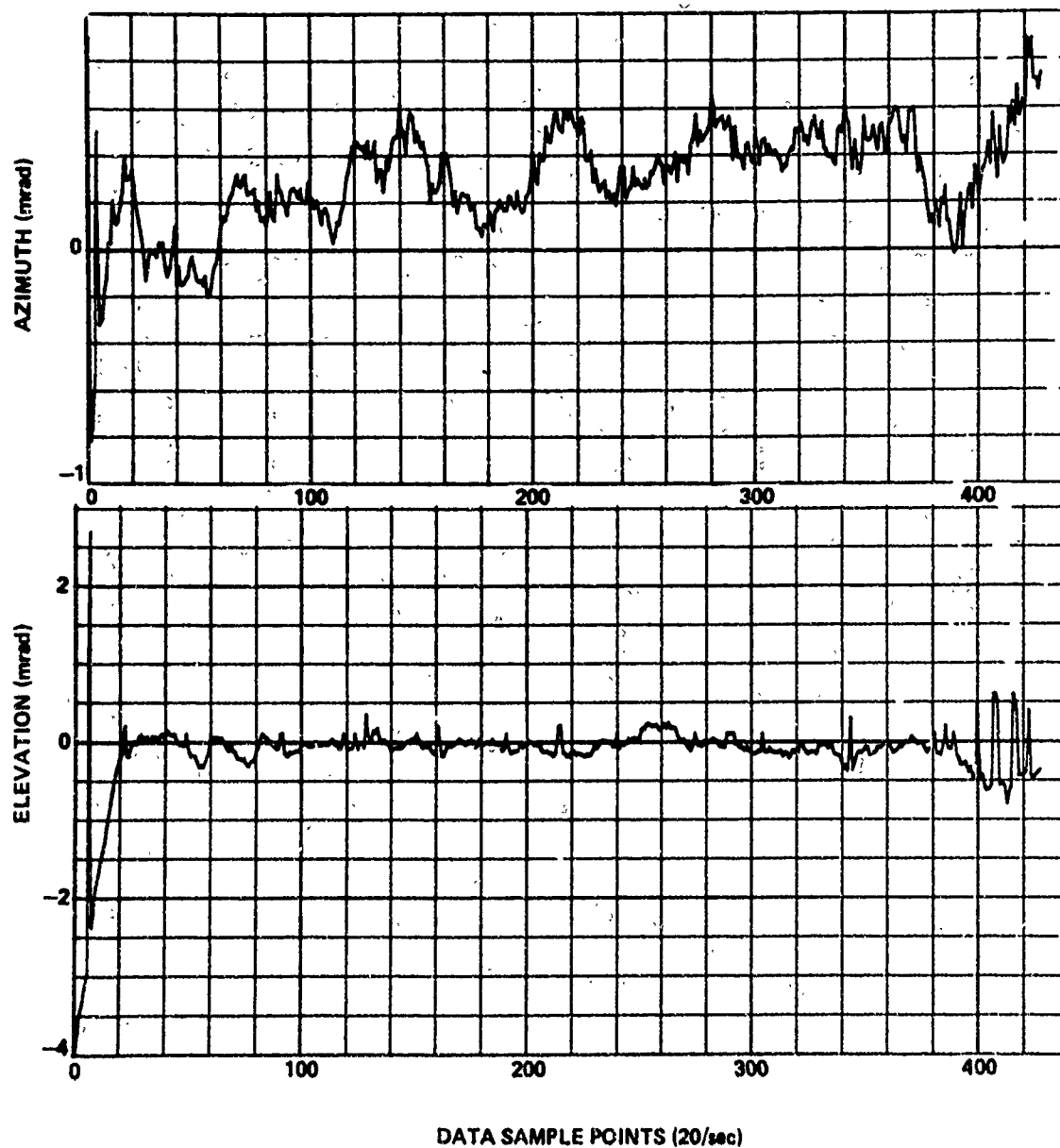


RUN 203

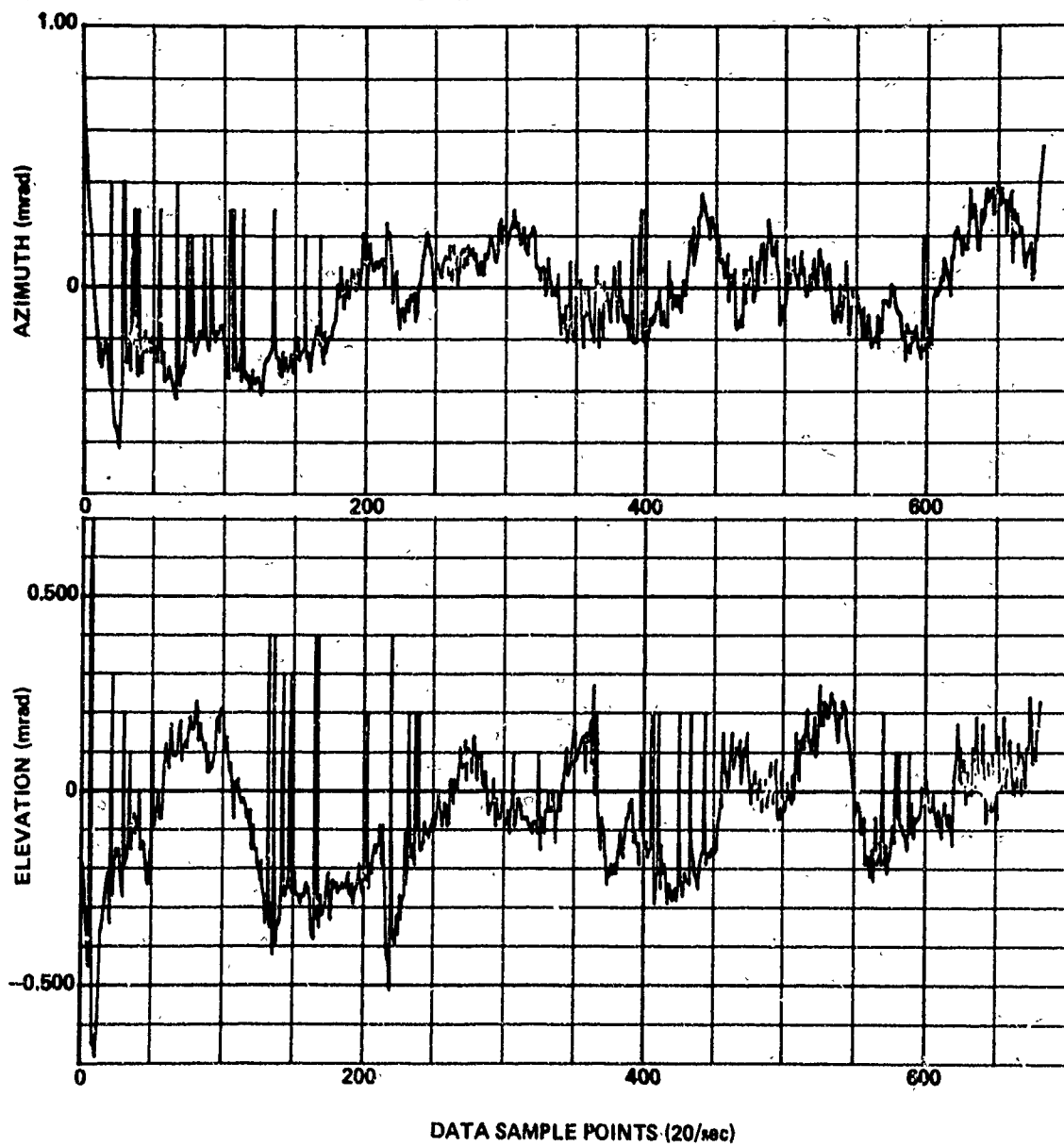




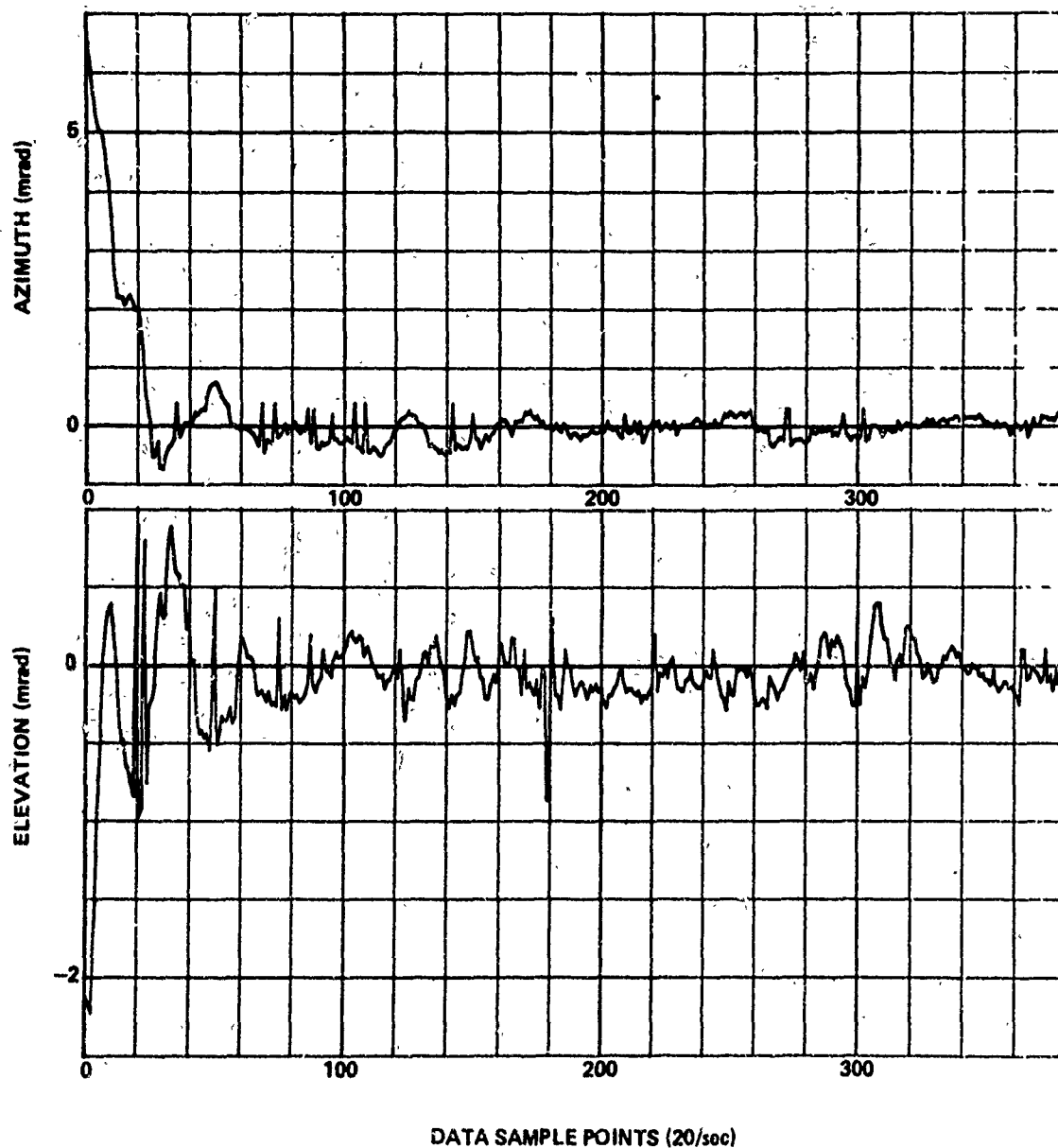
RUN 205



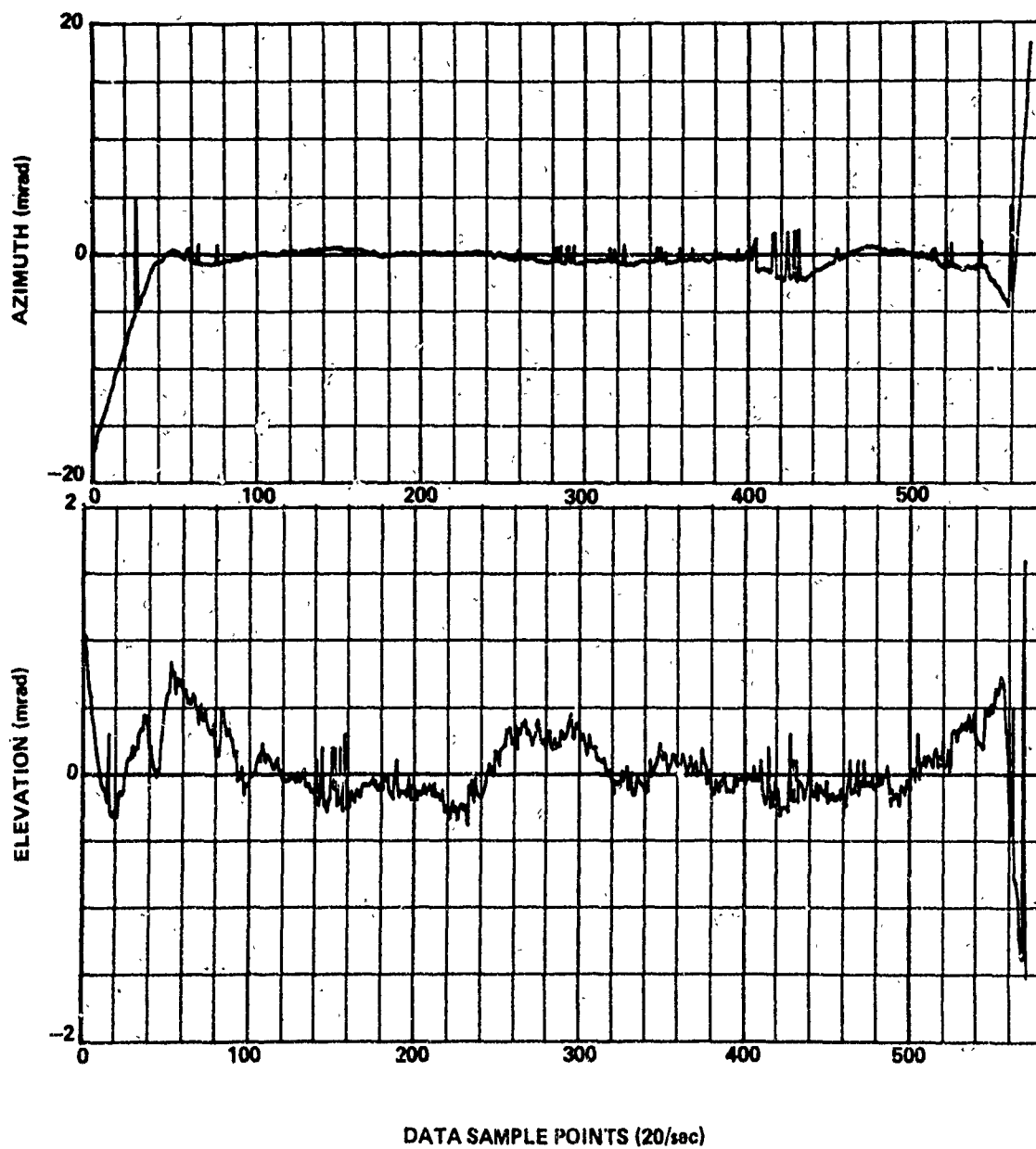
RUN 206



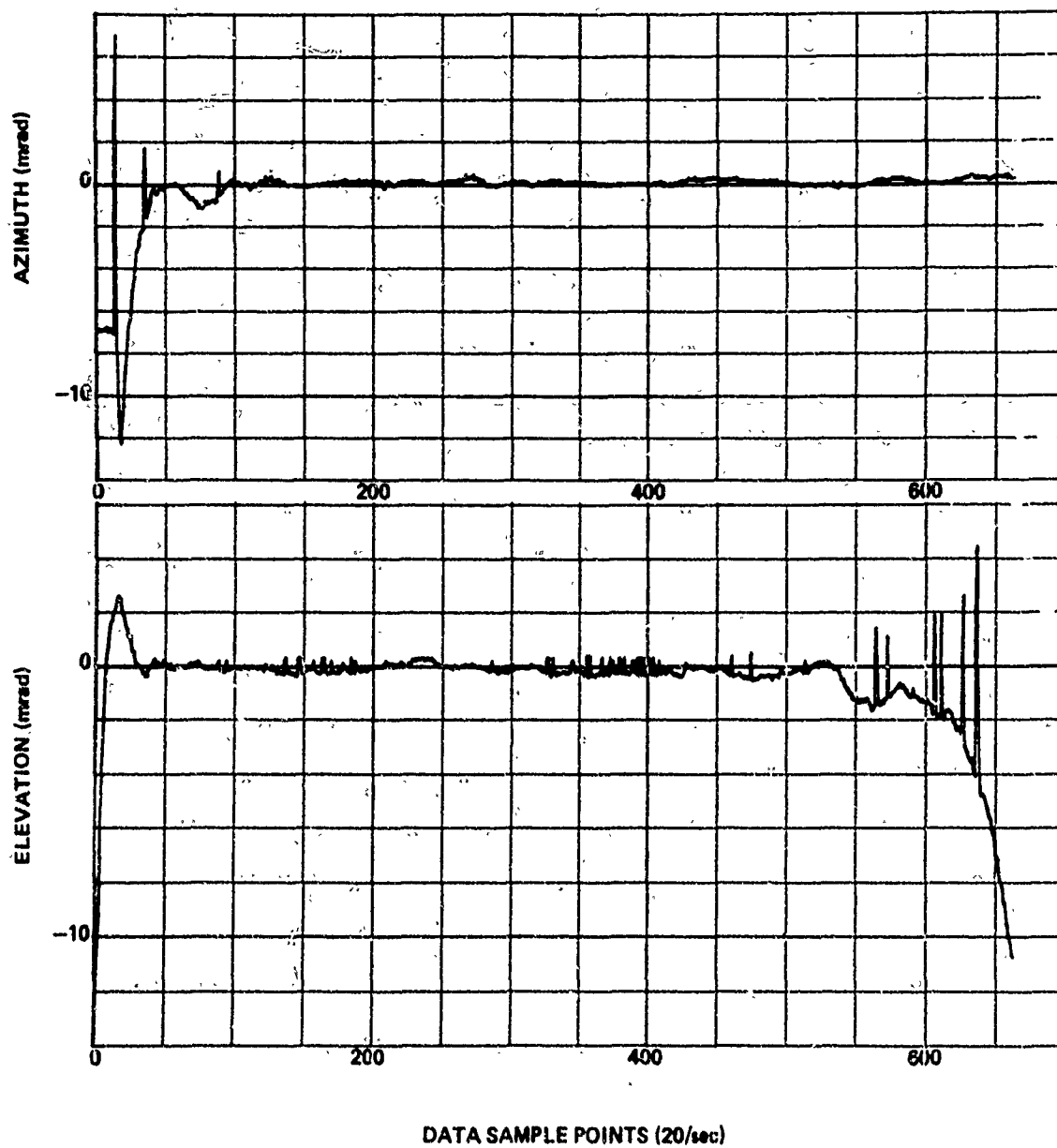
RUN 207

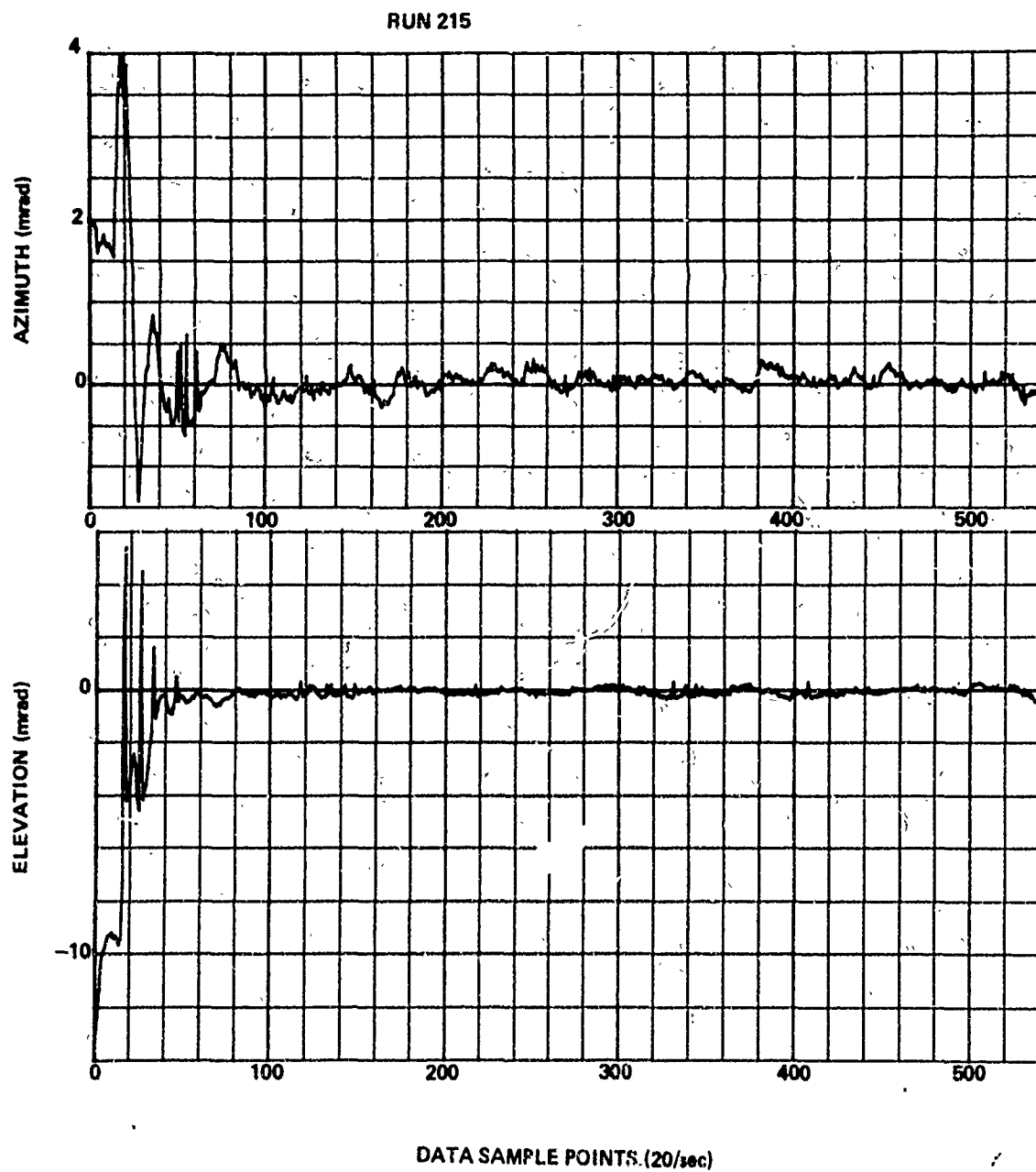


RUN 211

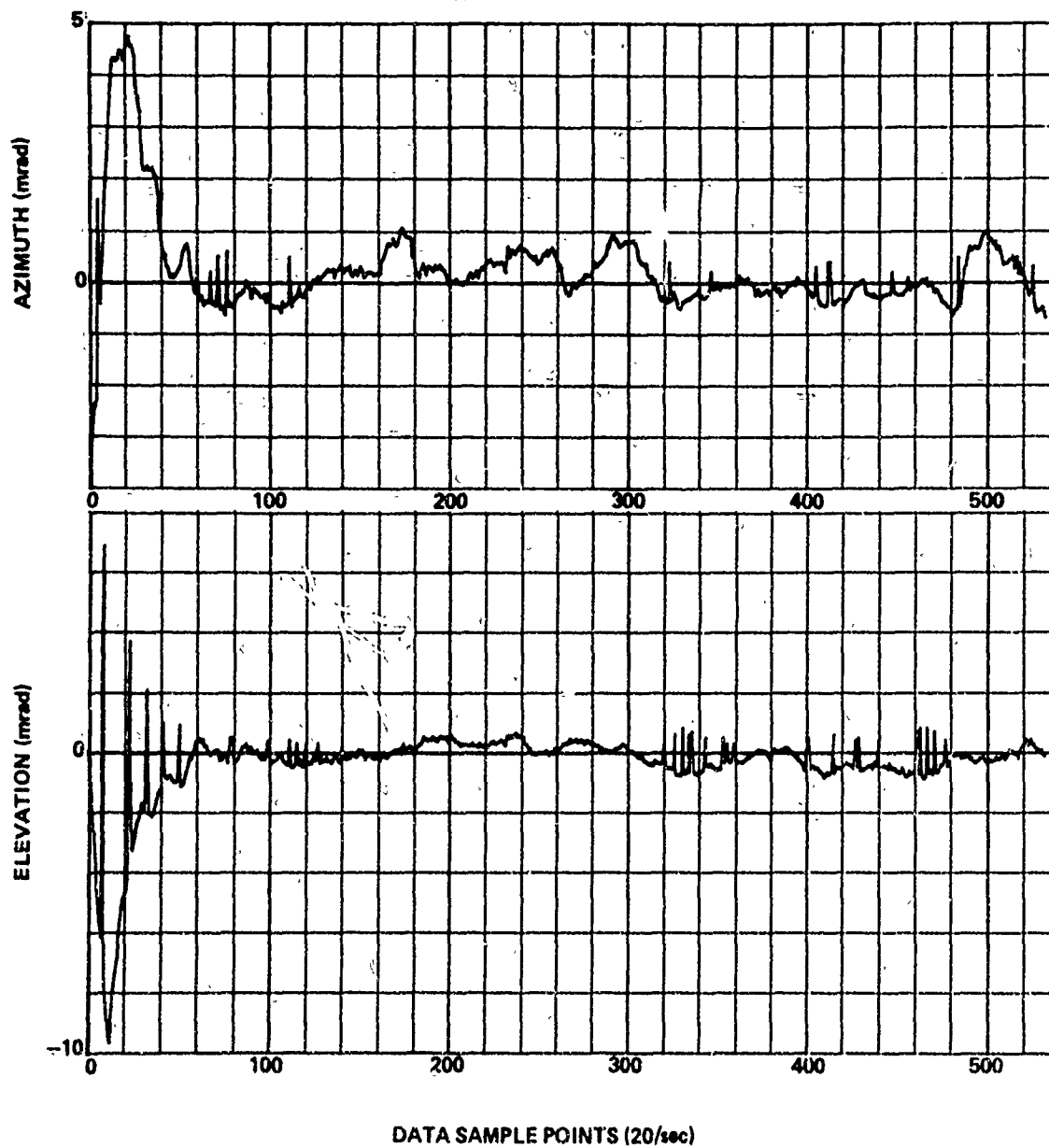


RUN 214

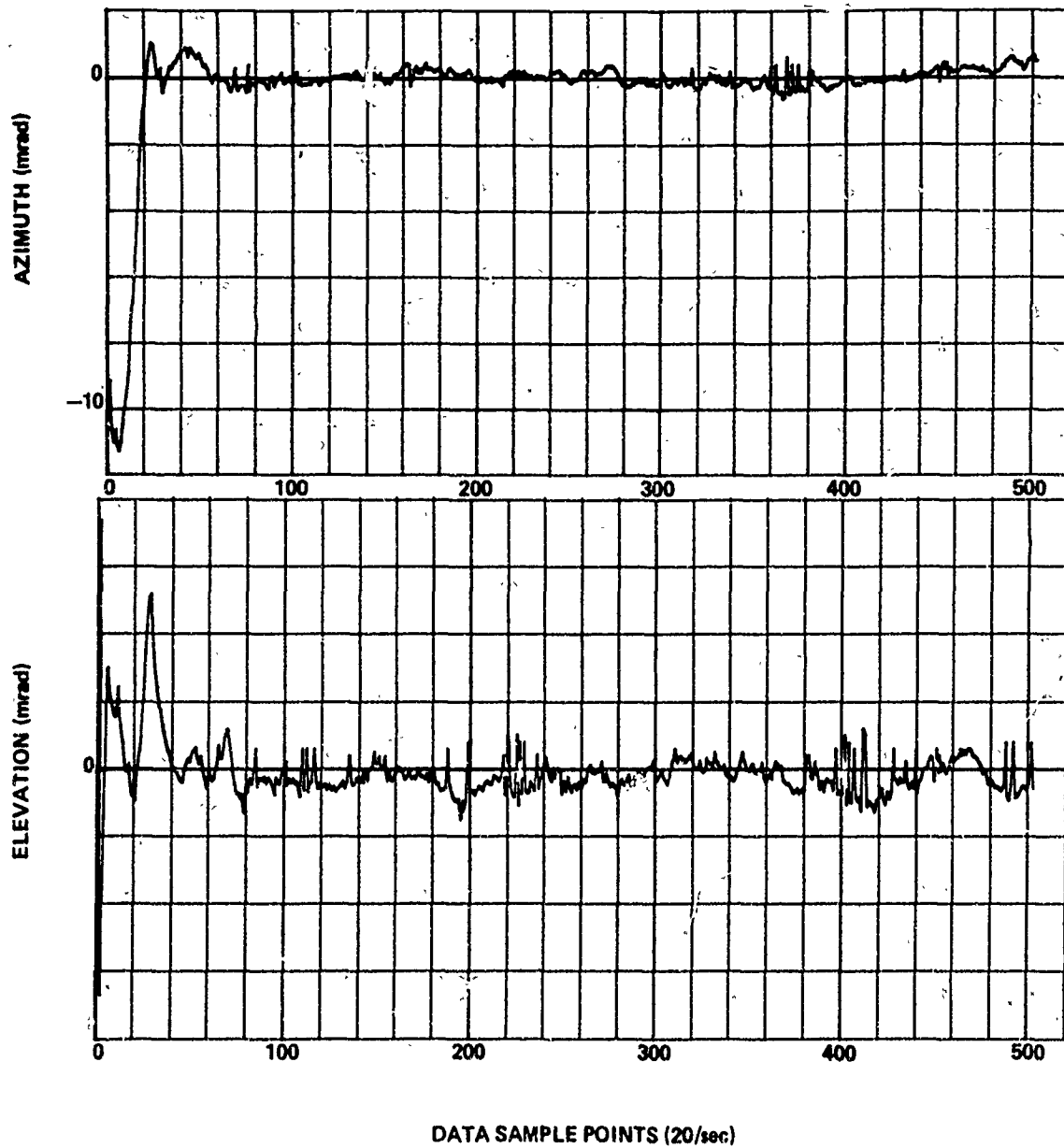




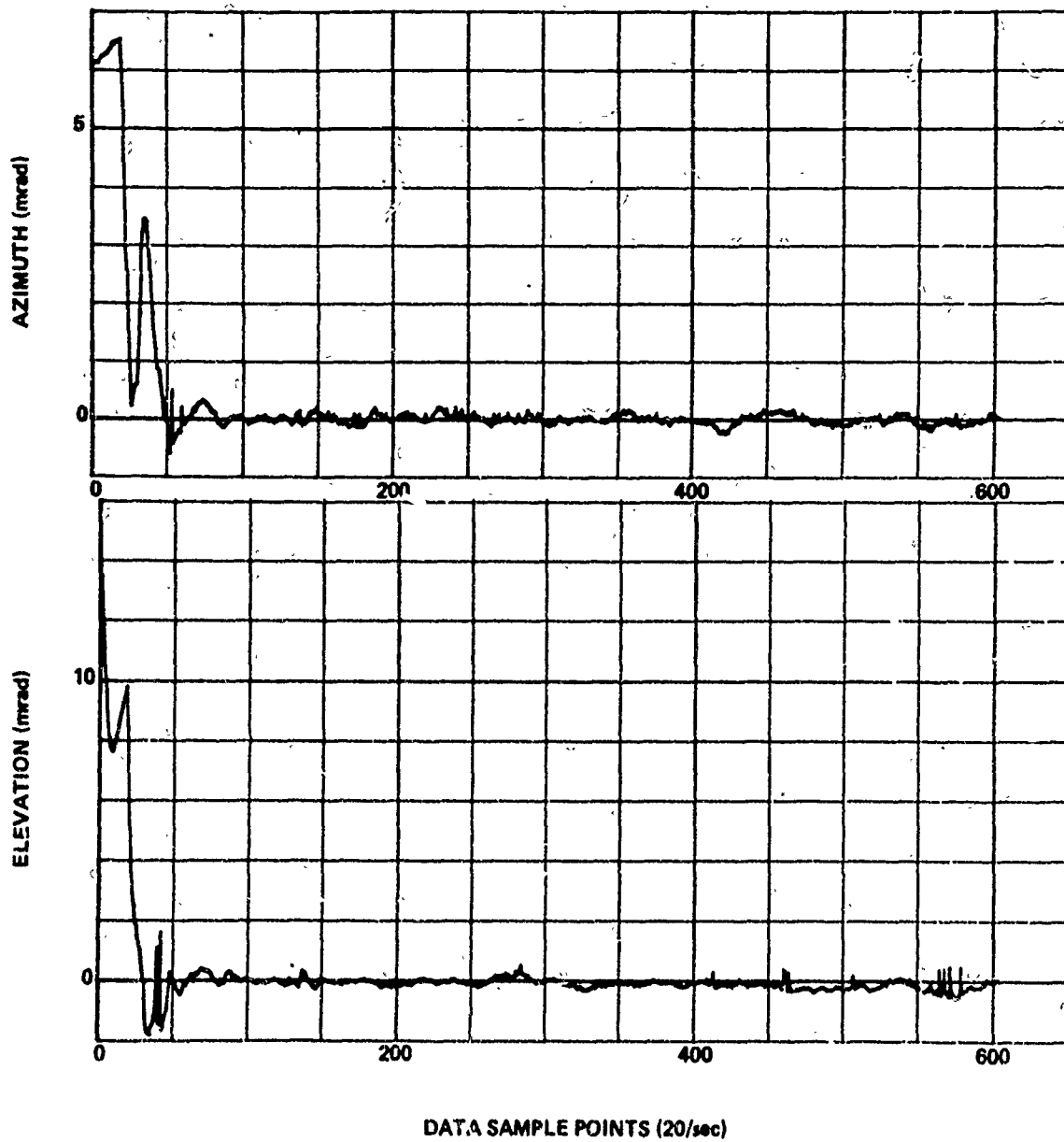
RUN 217



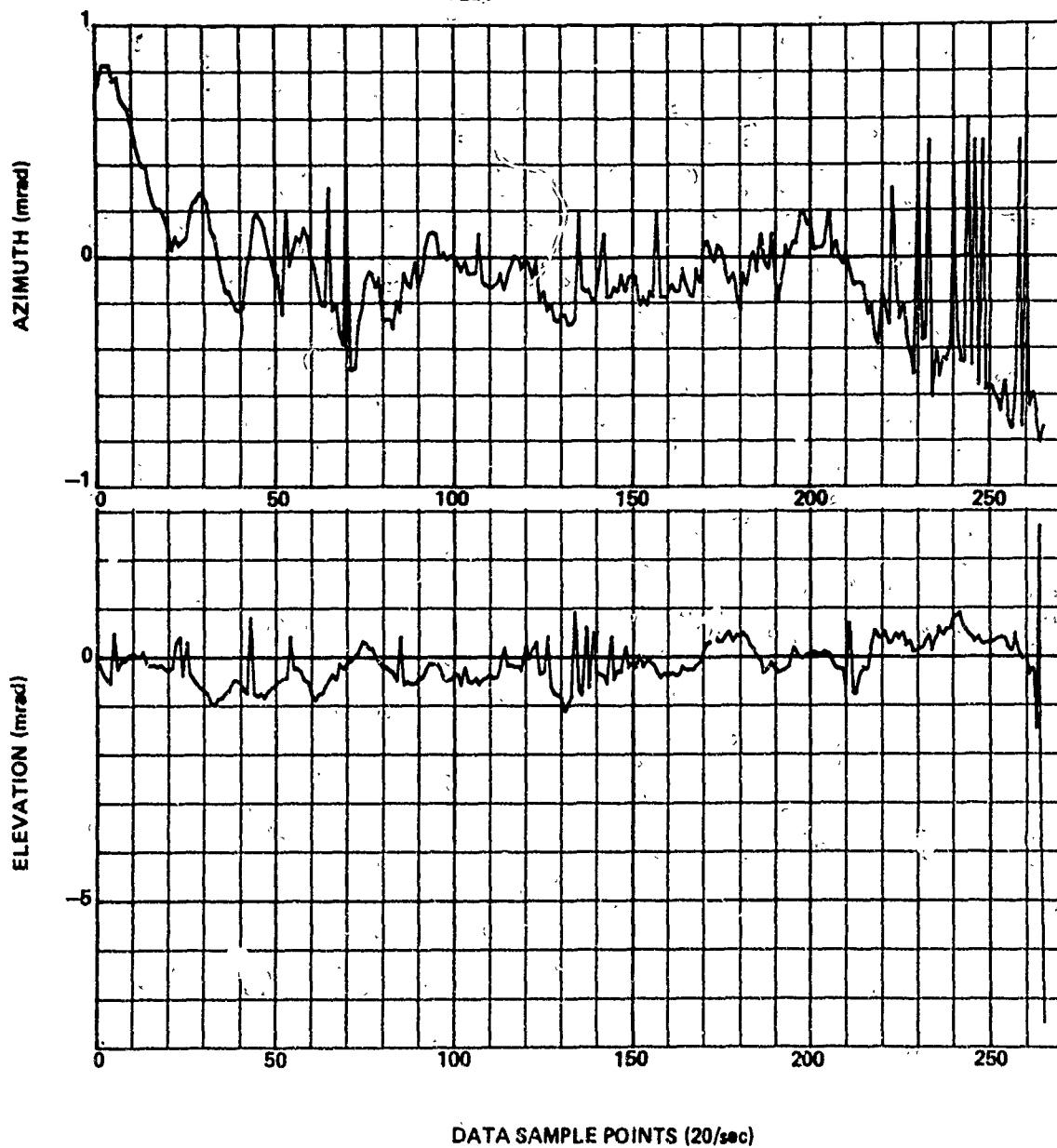
RUN 218



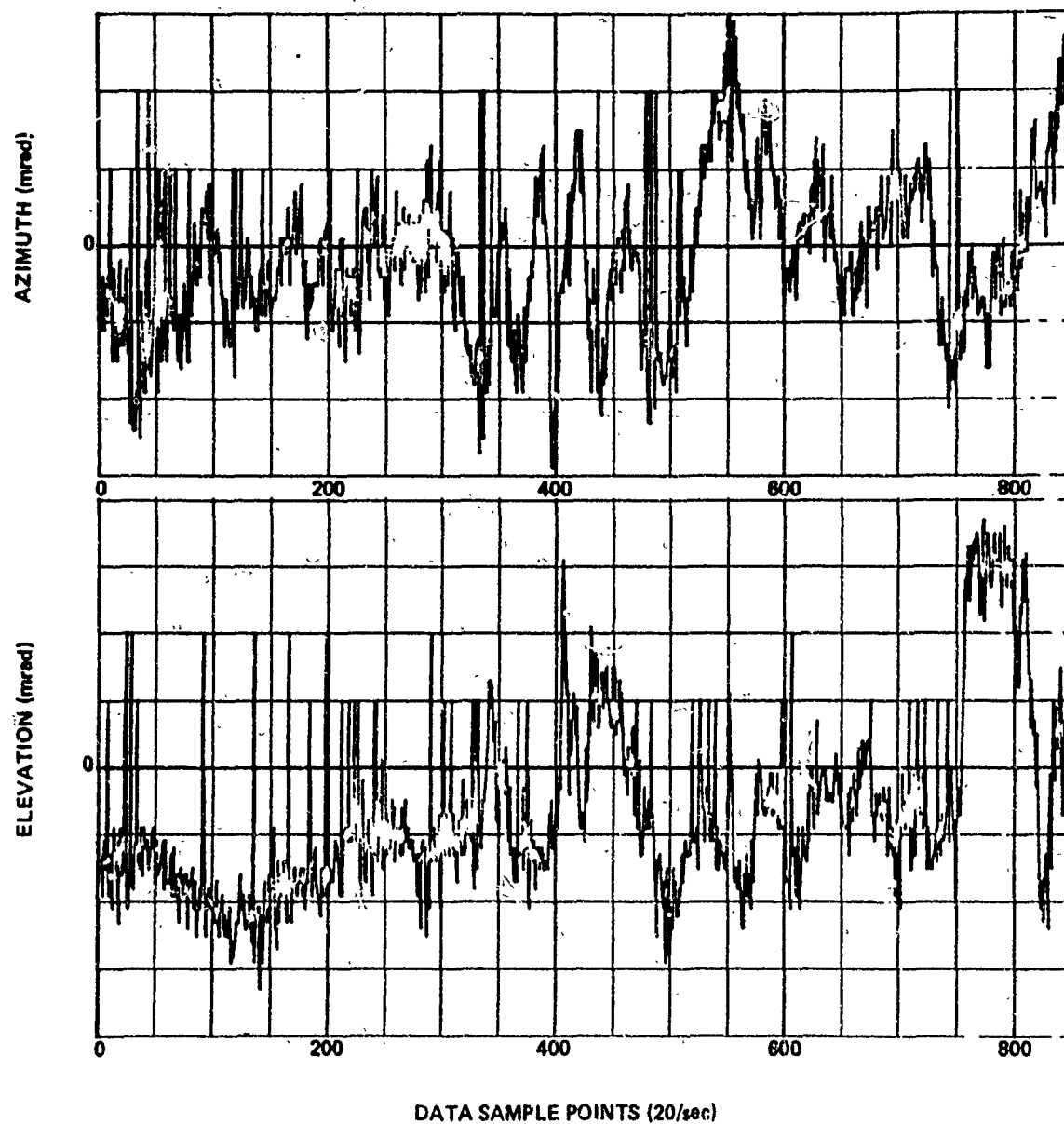
RUN 219



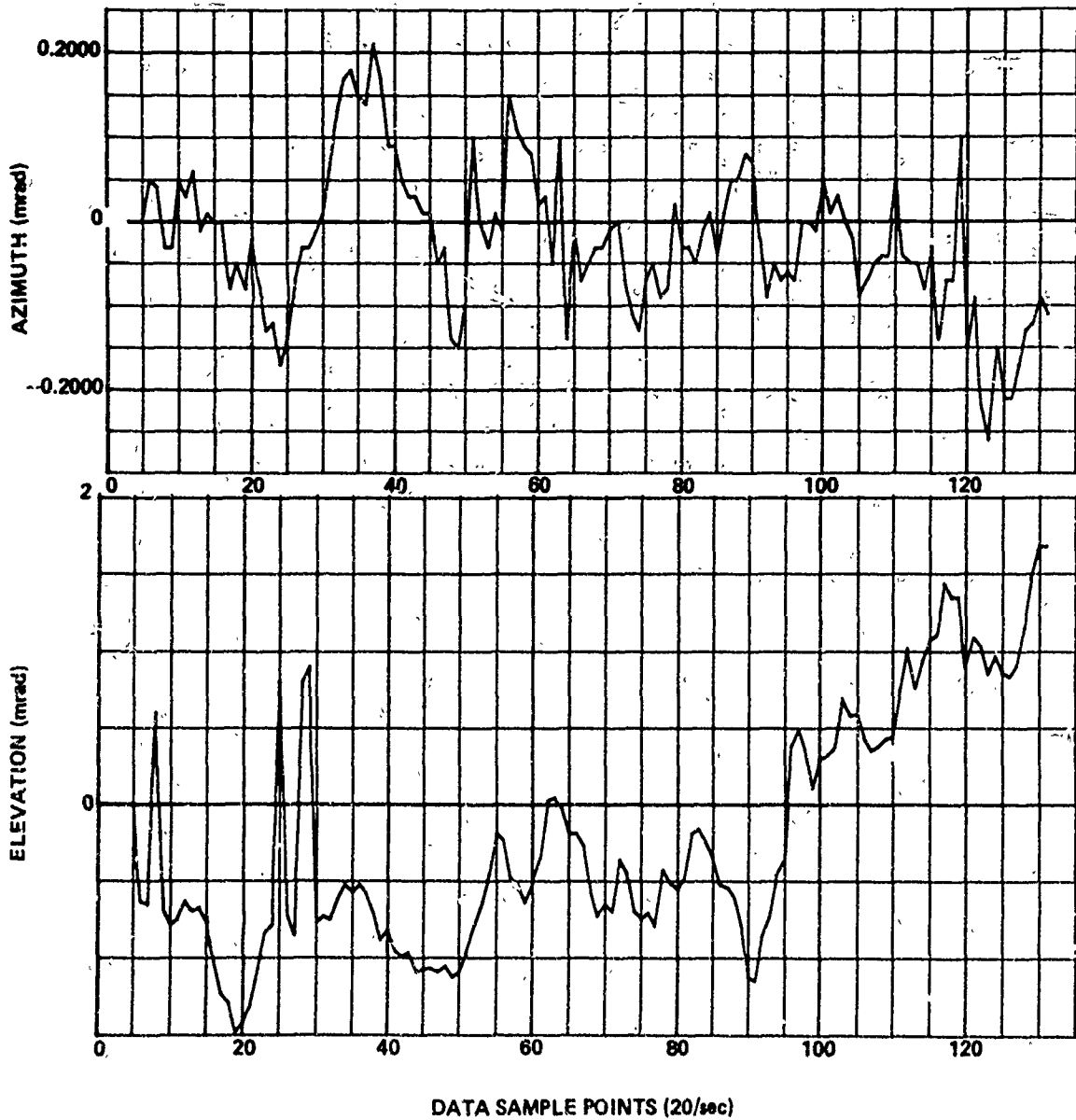
RUN 220



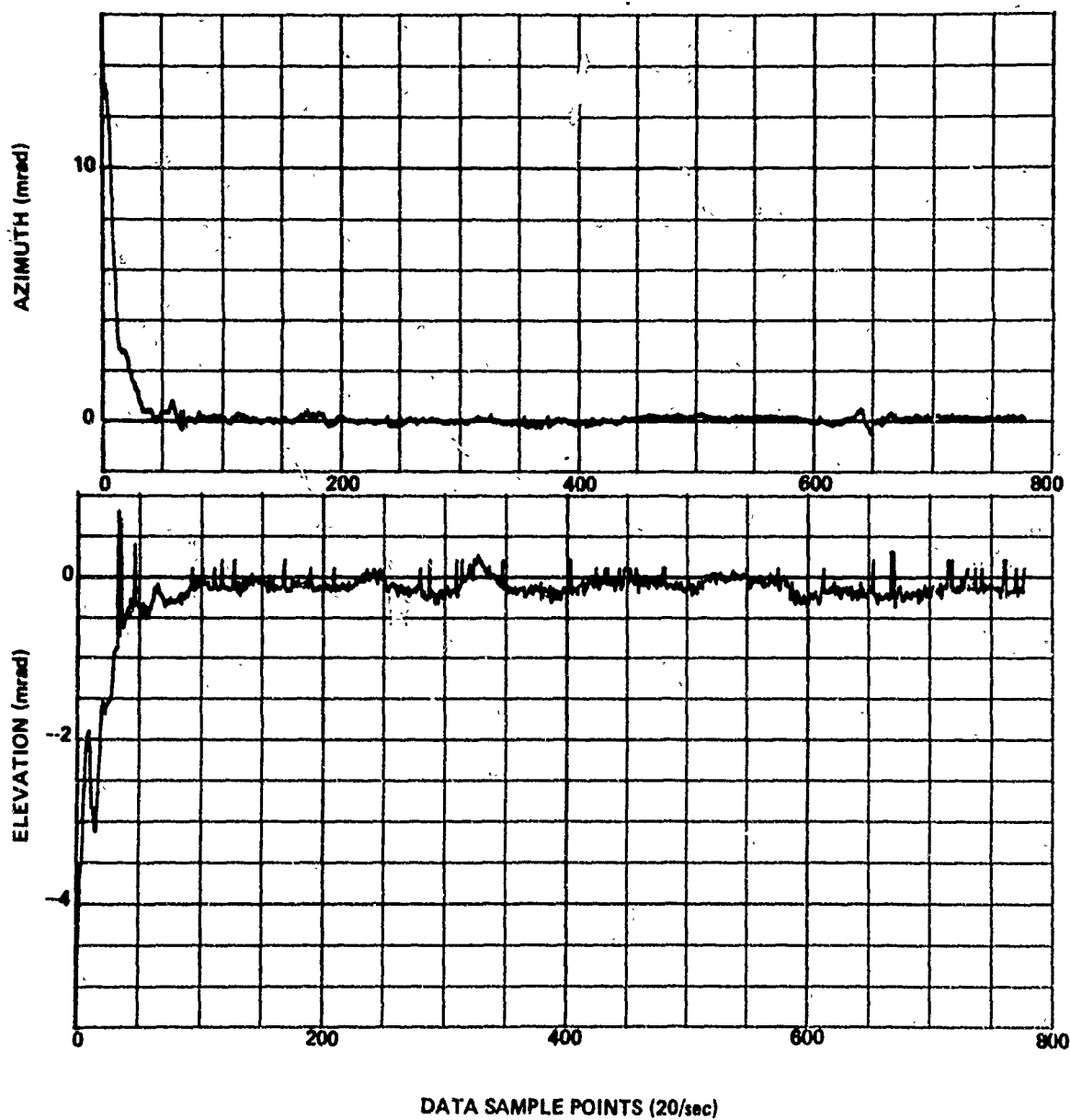
RUN 221



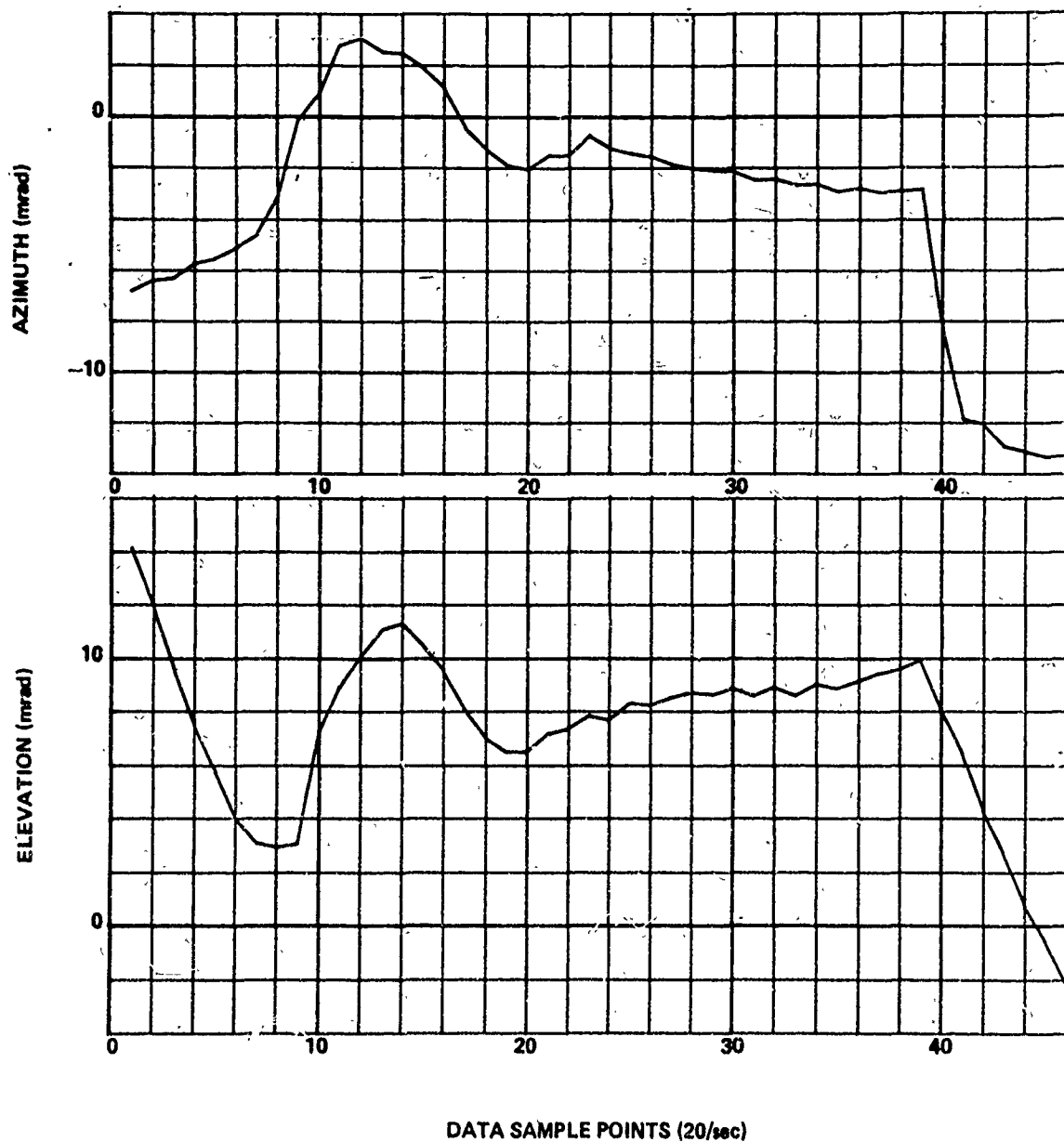
RUN 222



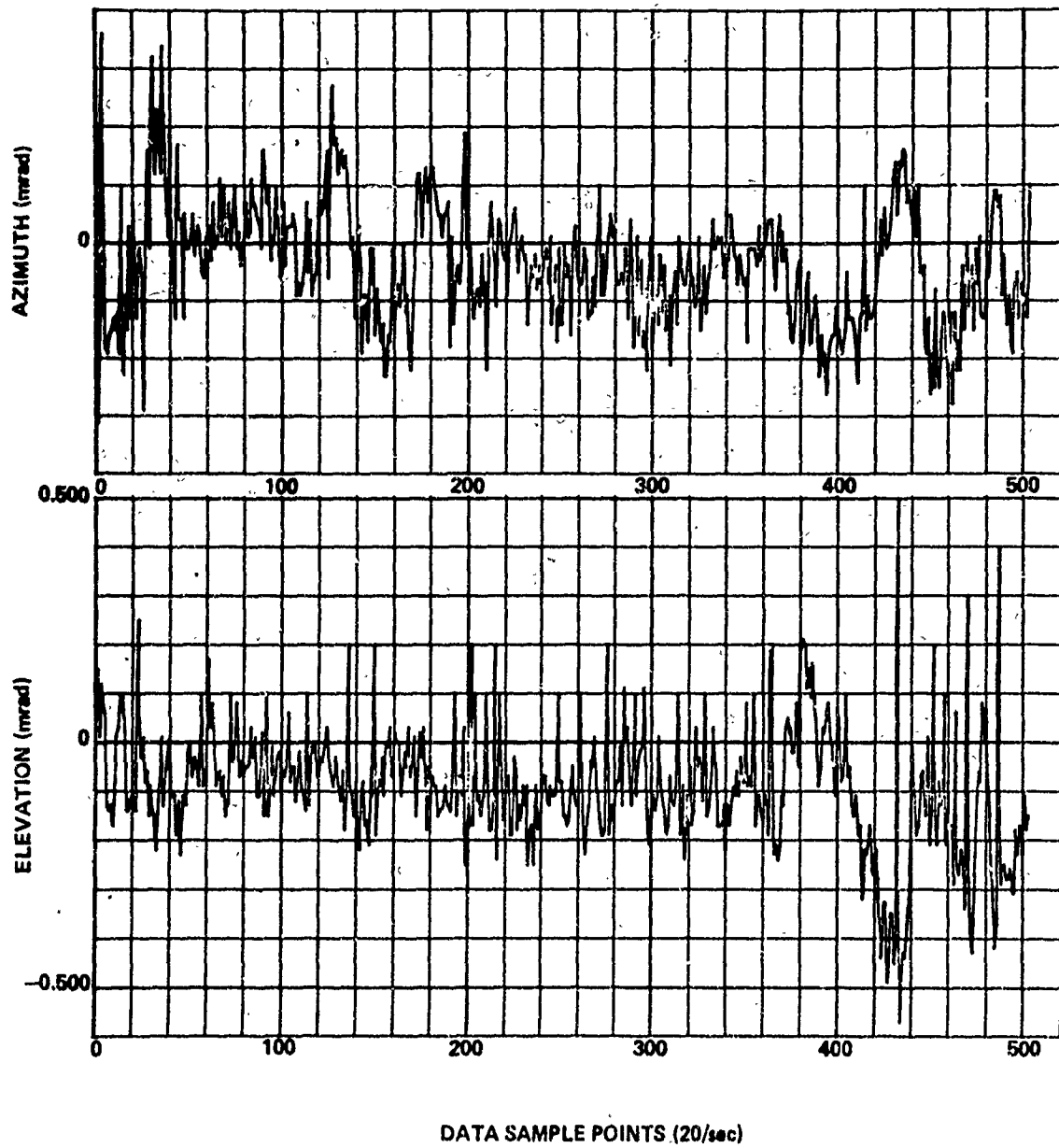
RUN 223



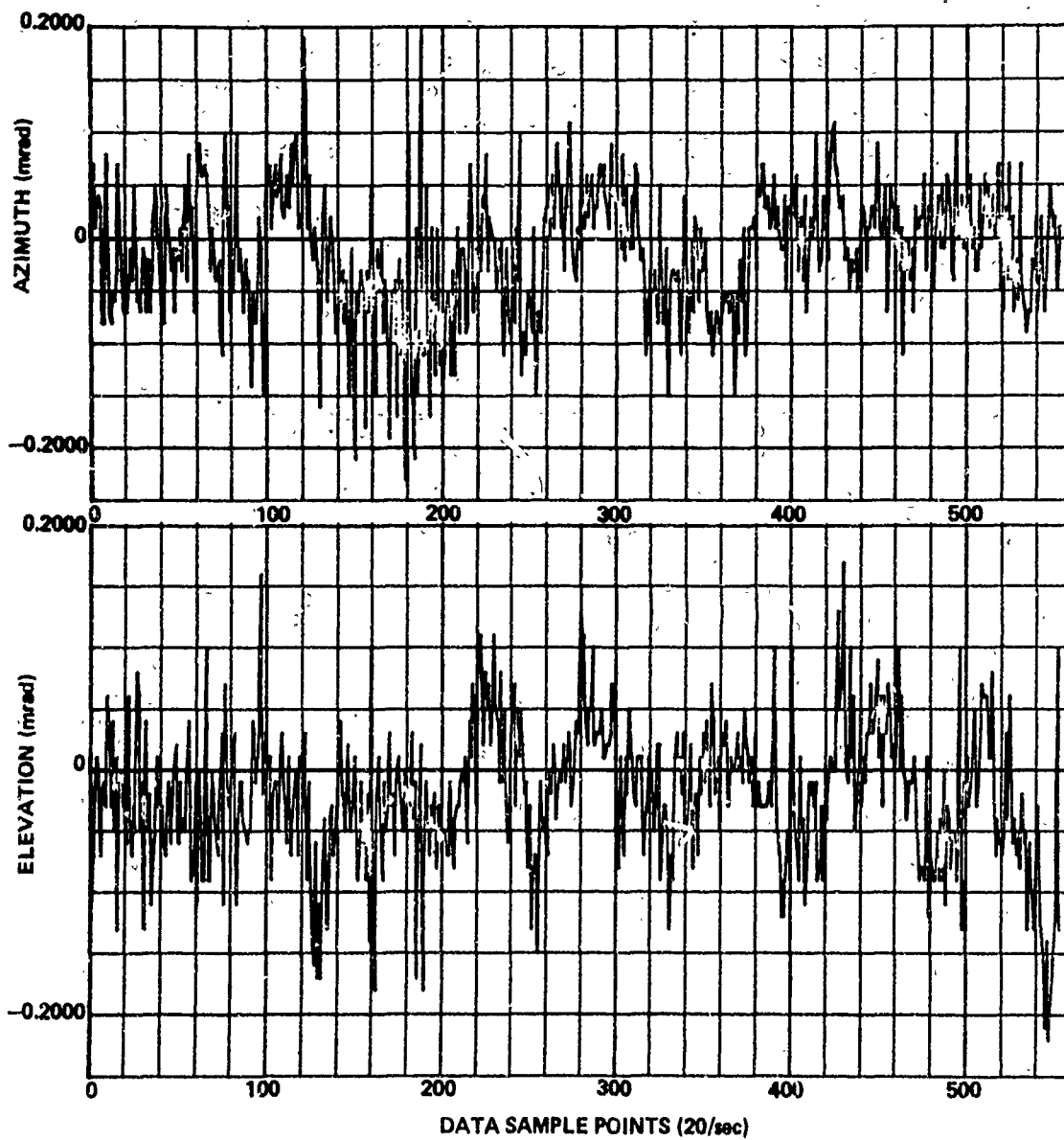
RUN 227



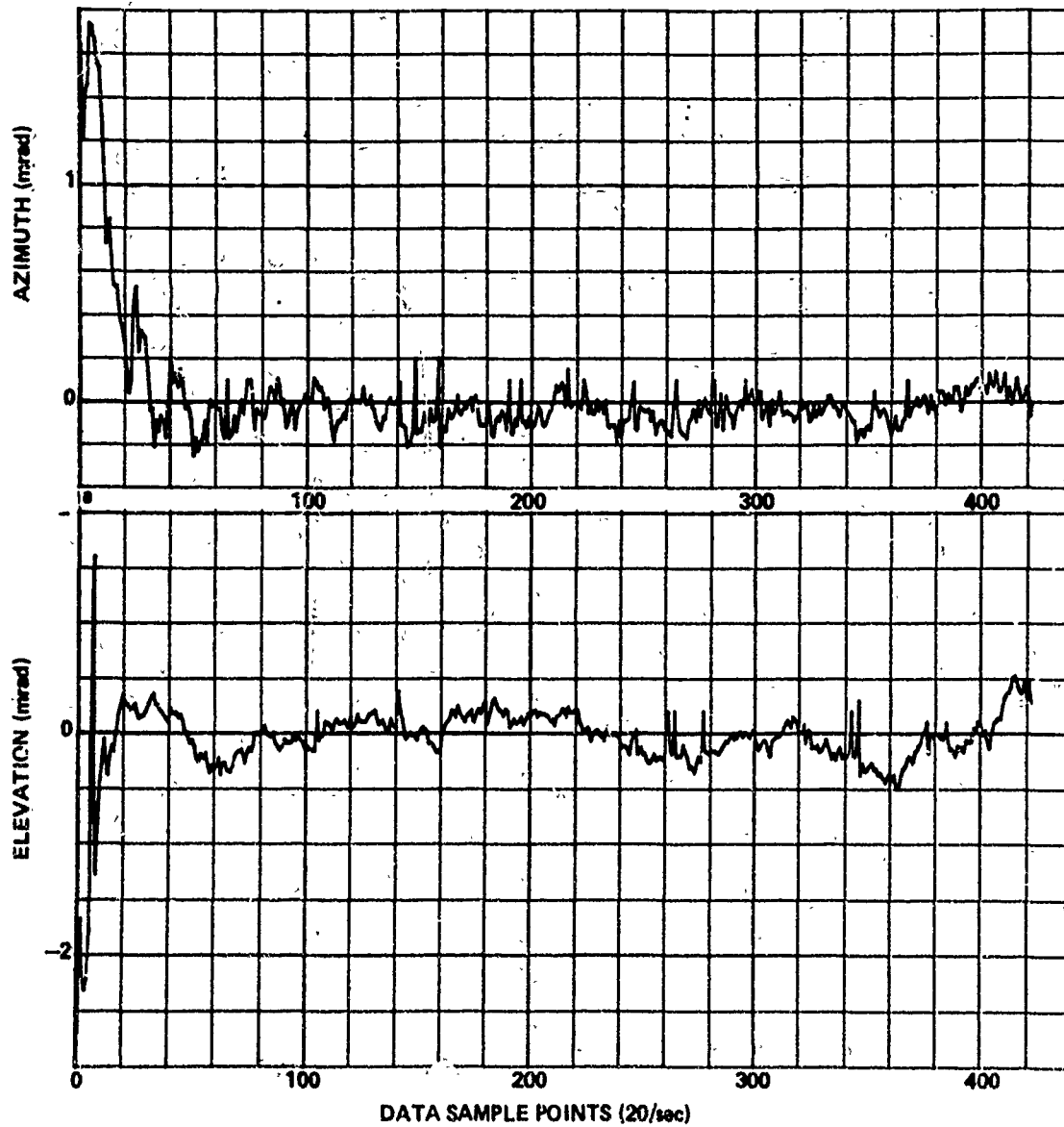
RUN 230



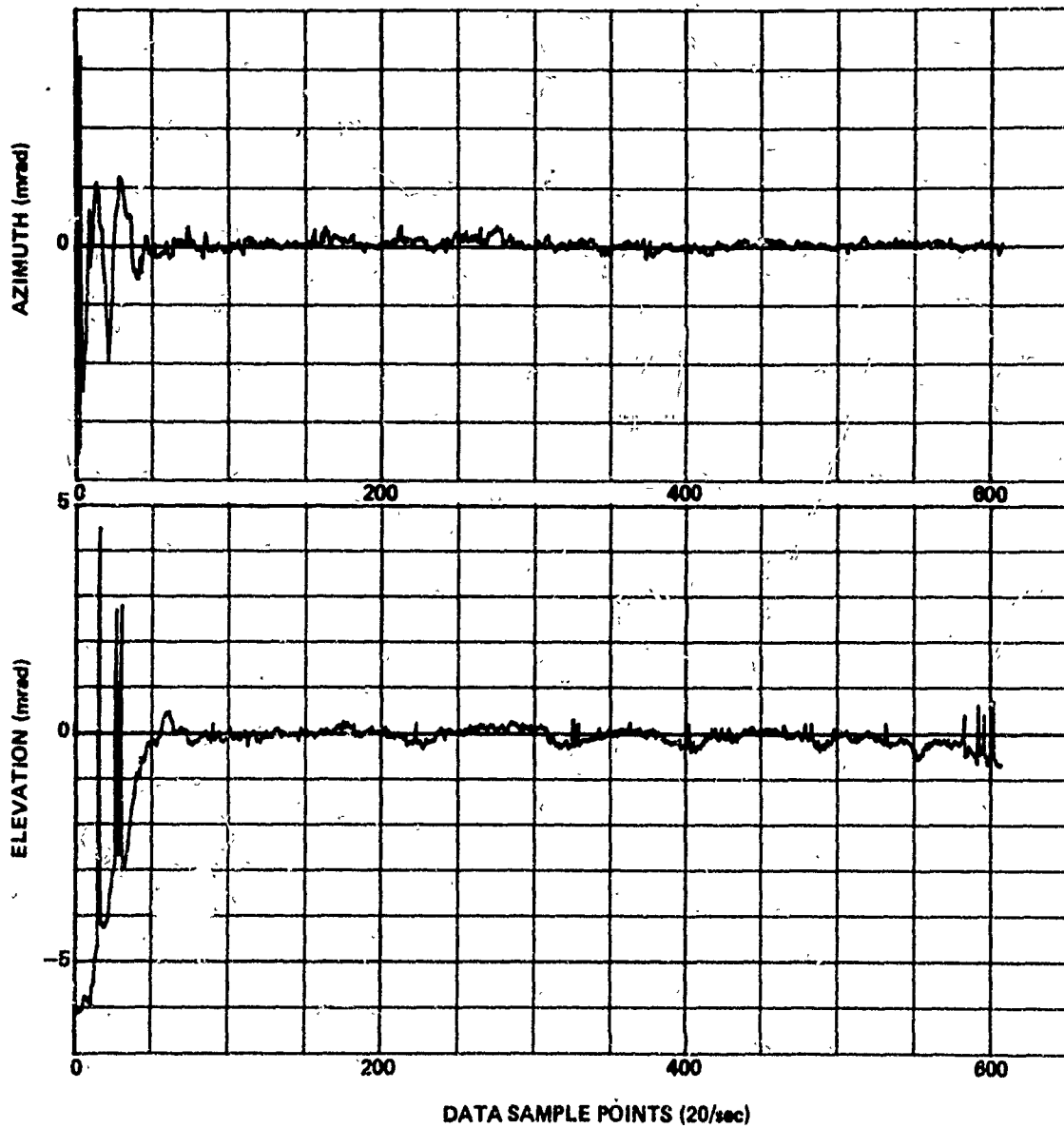
RUN 231



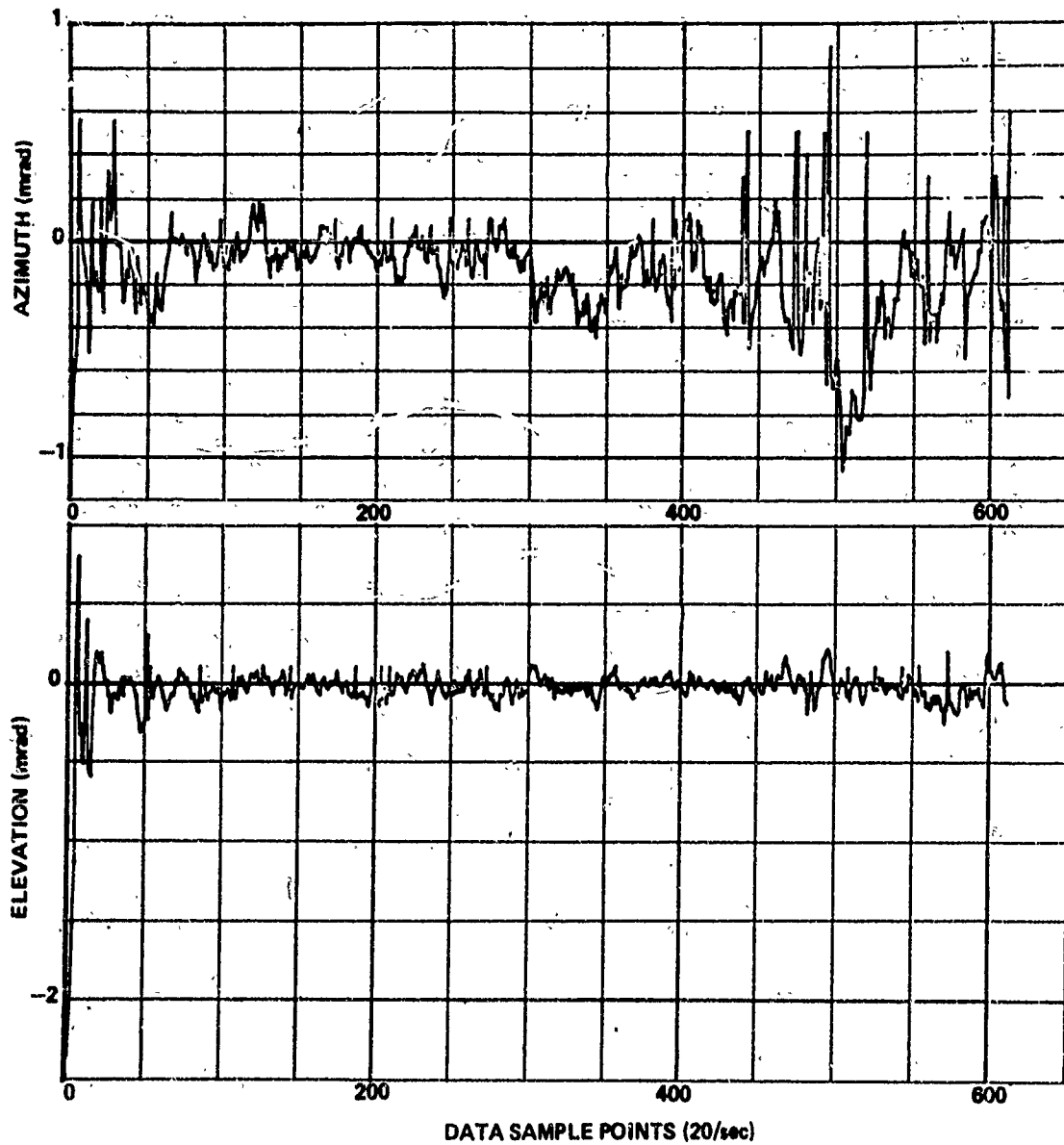
RUN 235



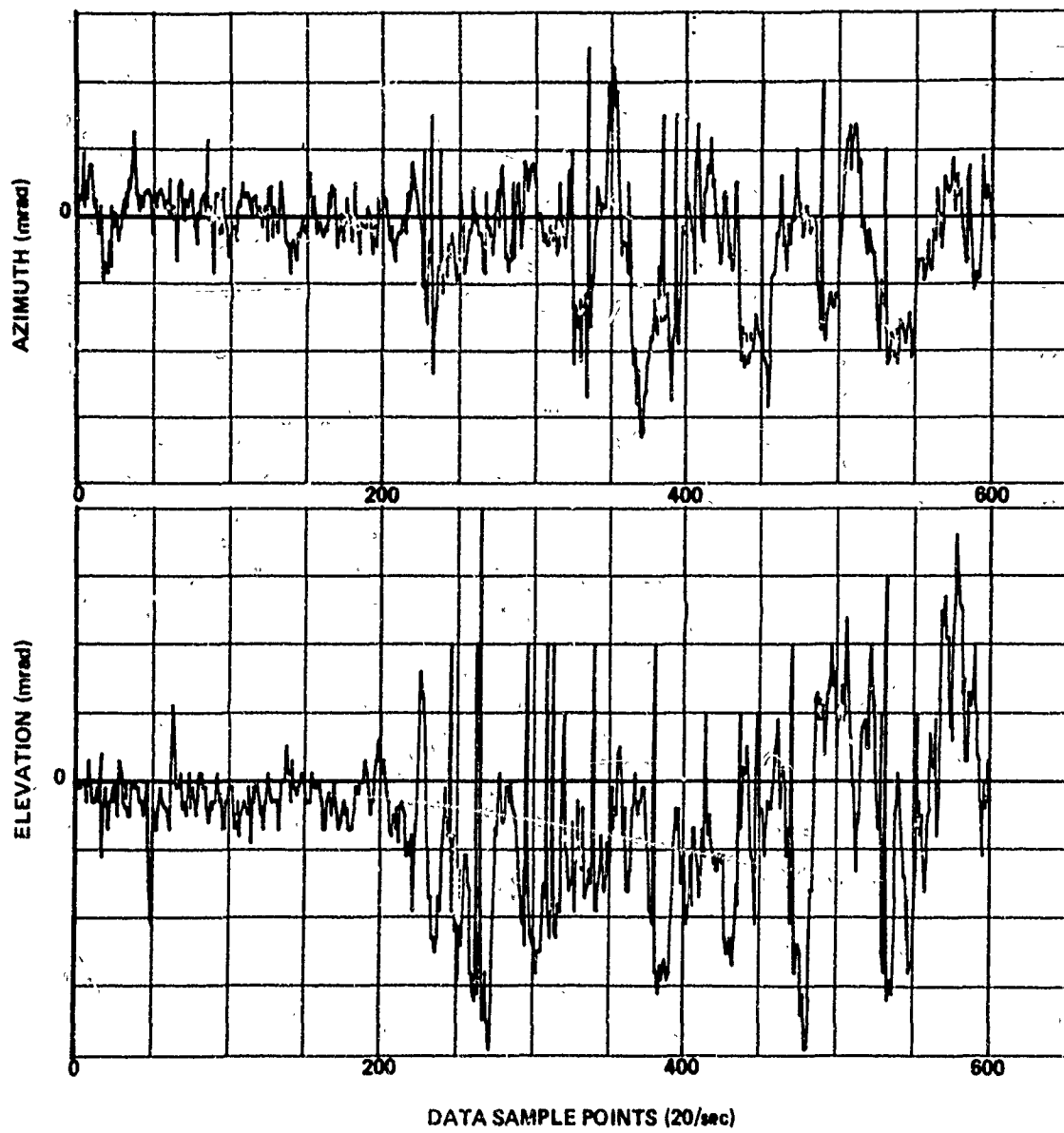
RUN 236

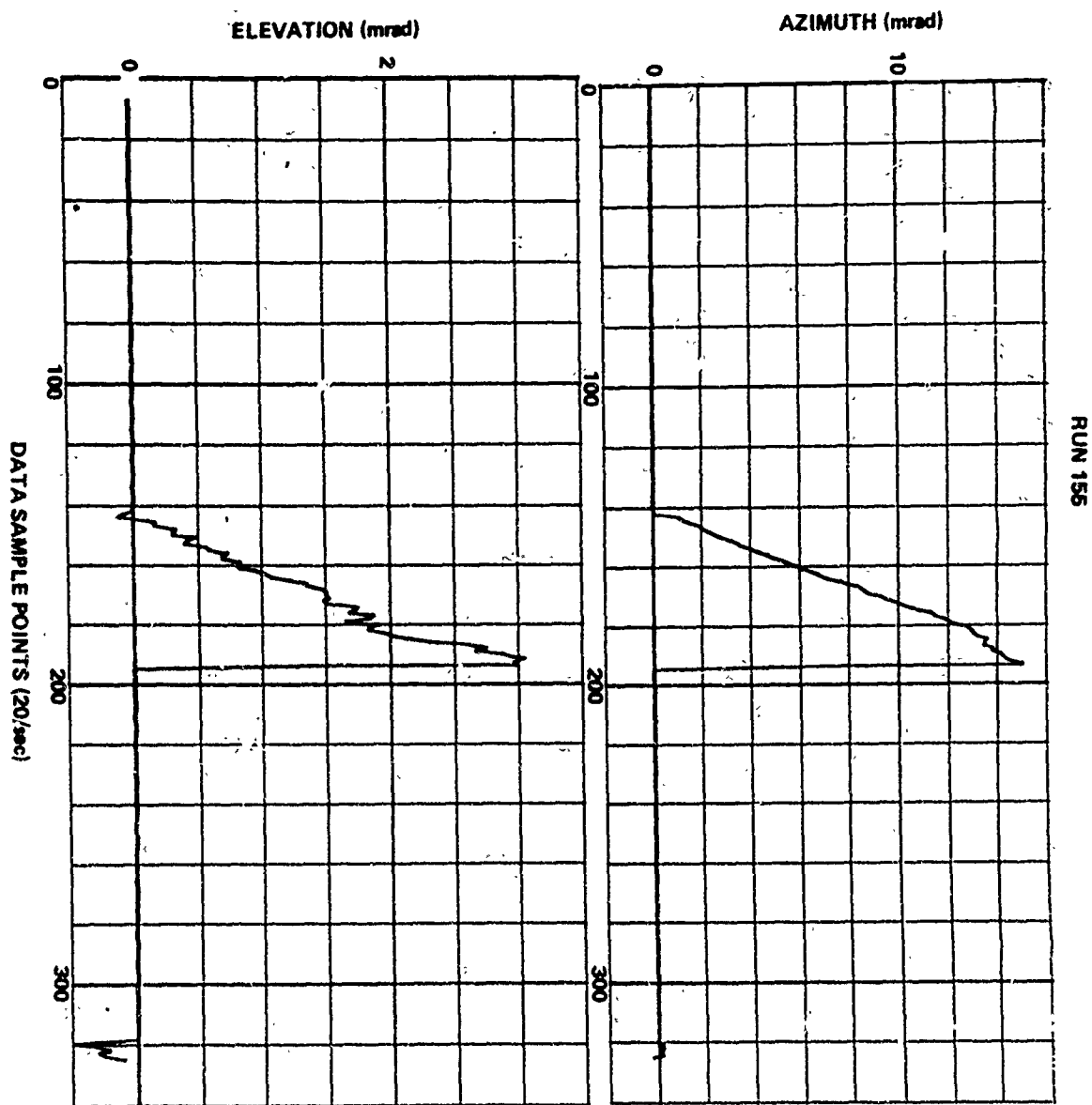


RUN 3

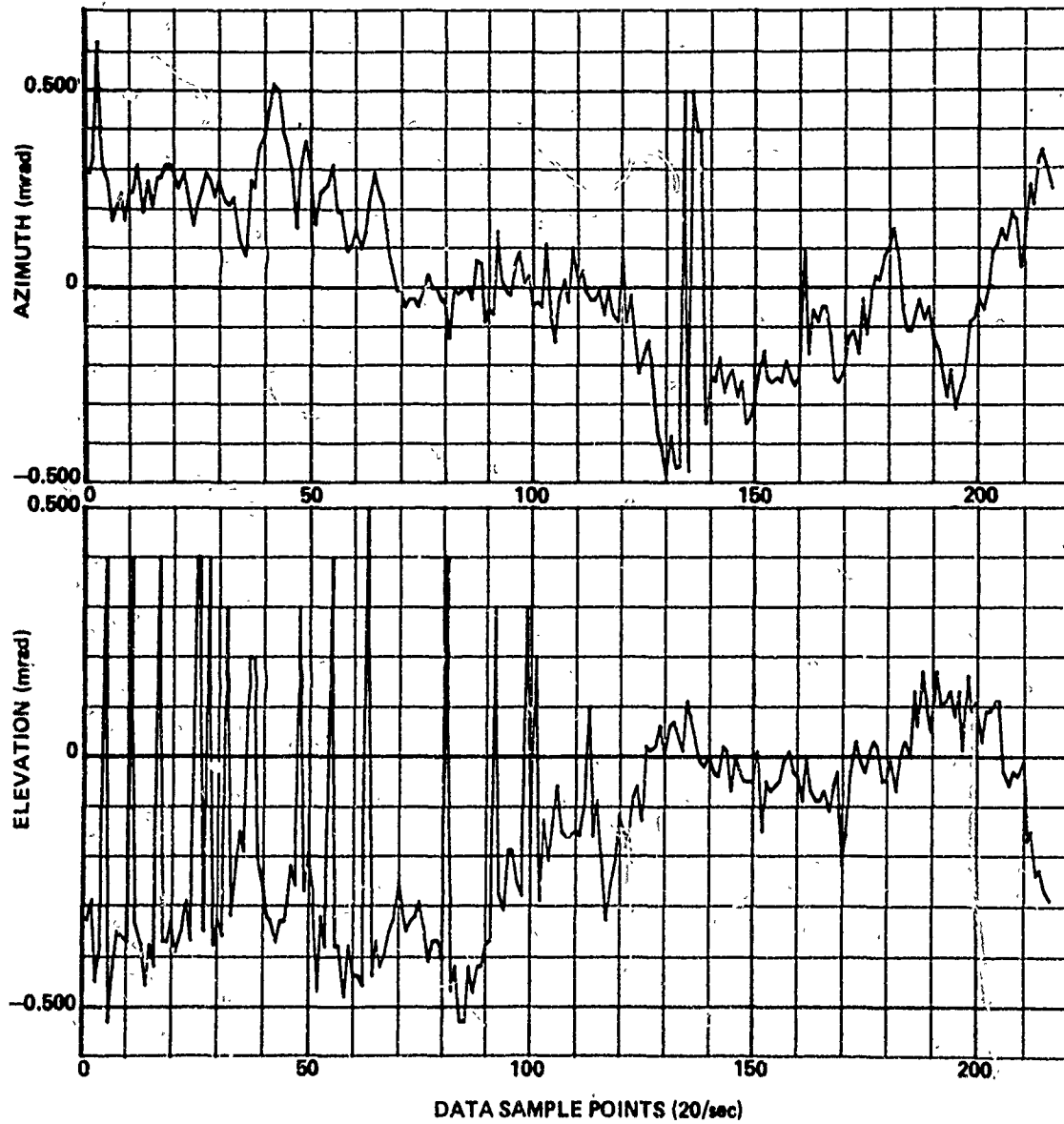


RUN 4.

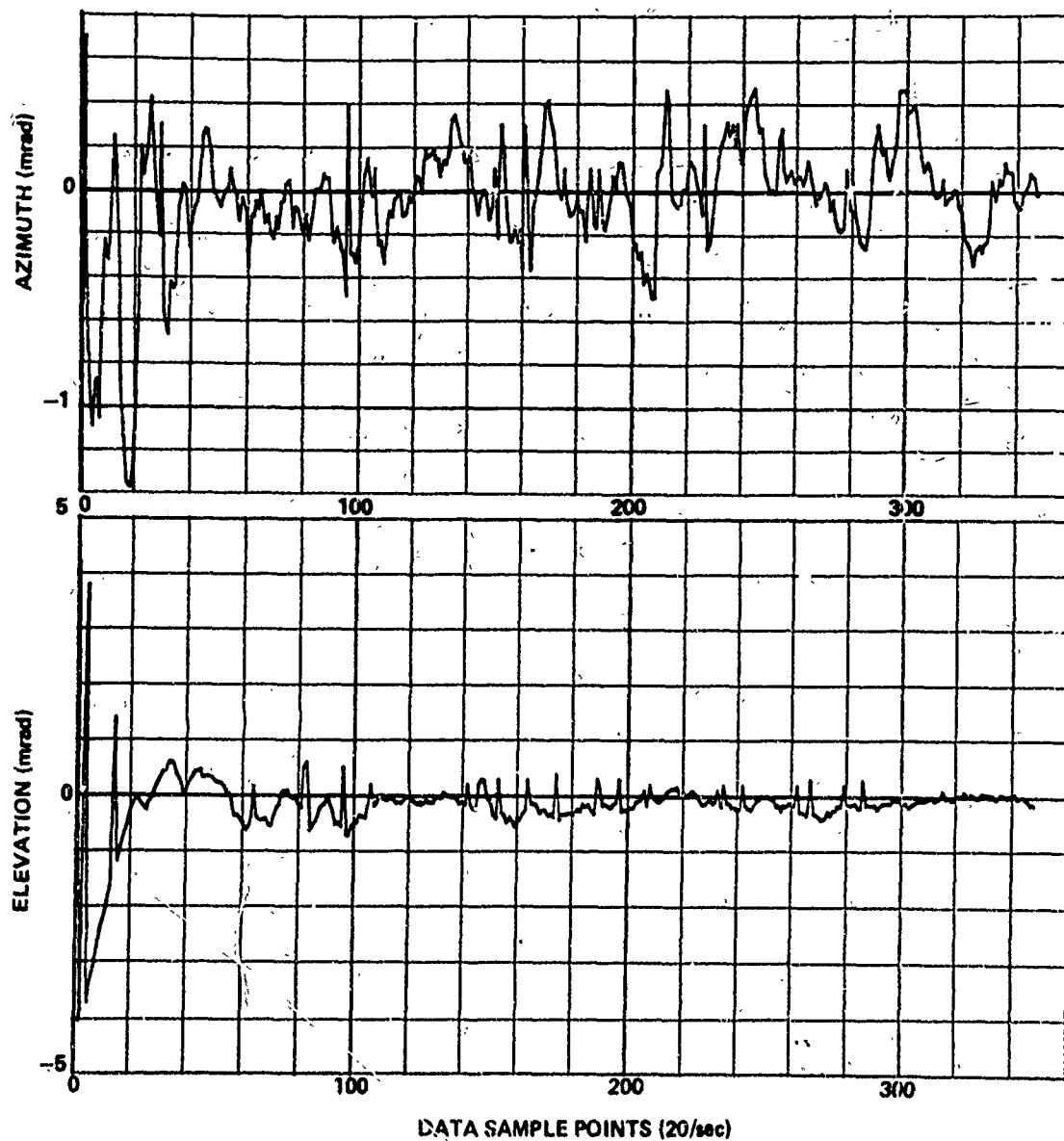




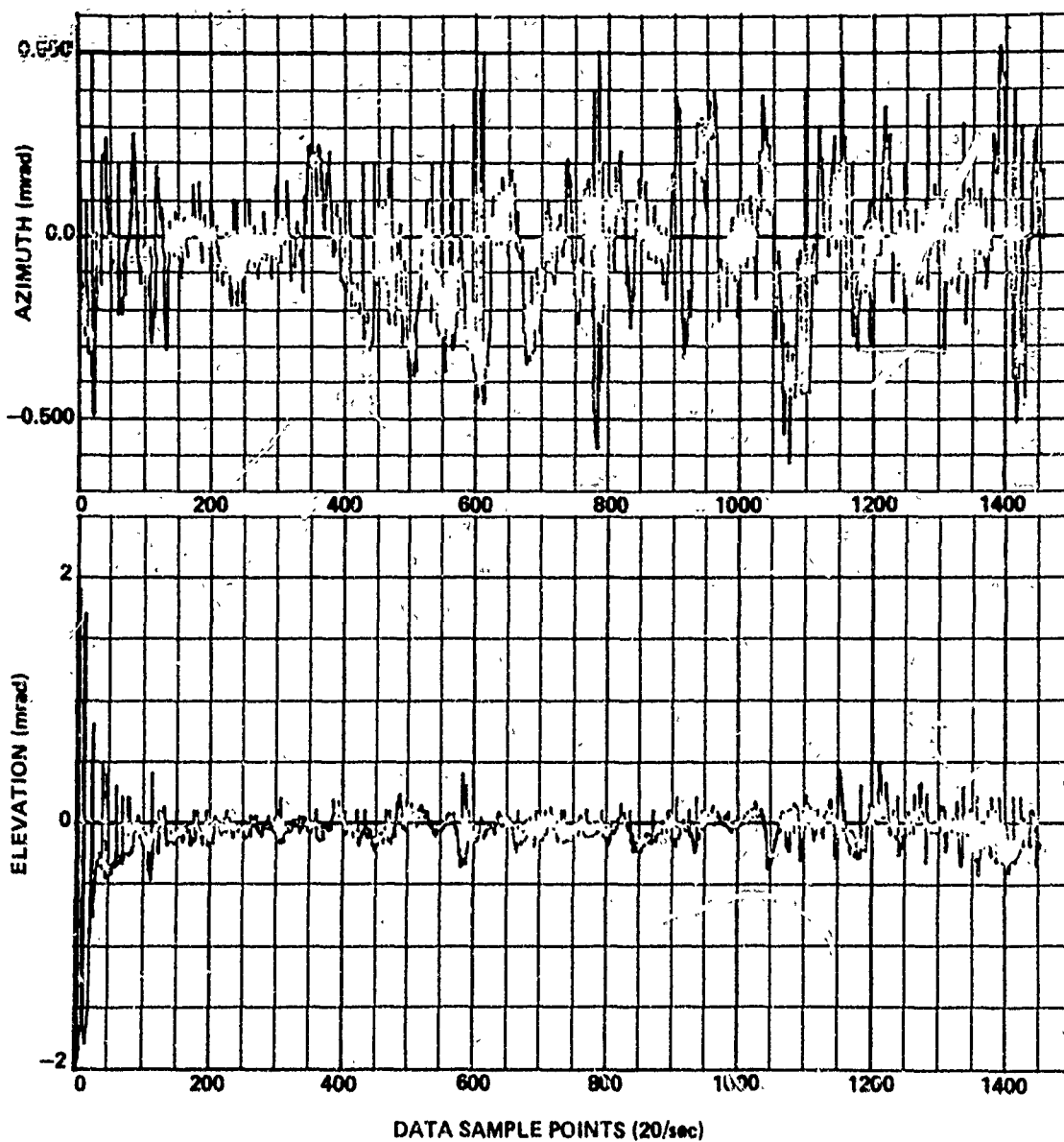
RUN 156



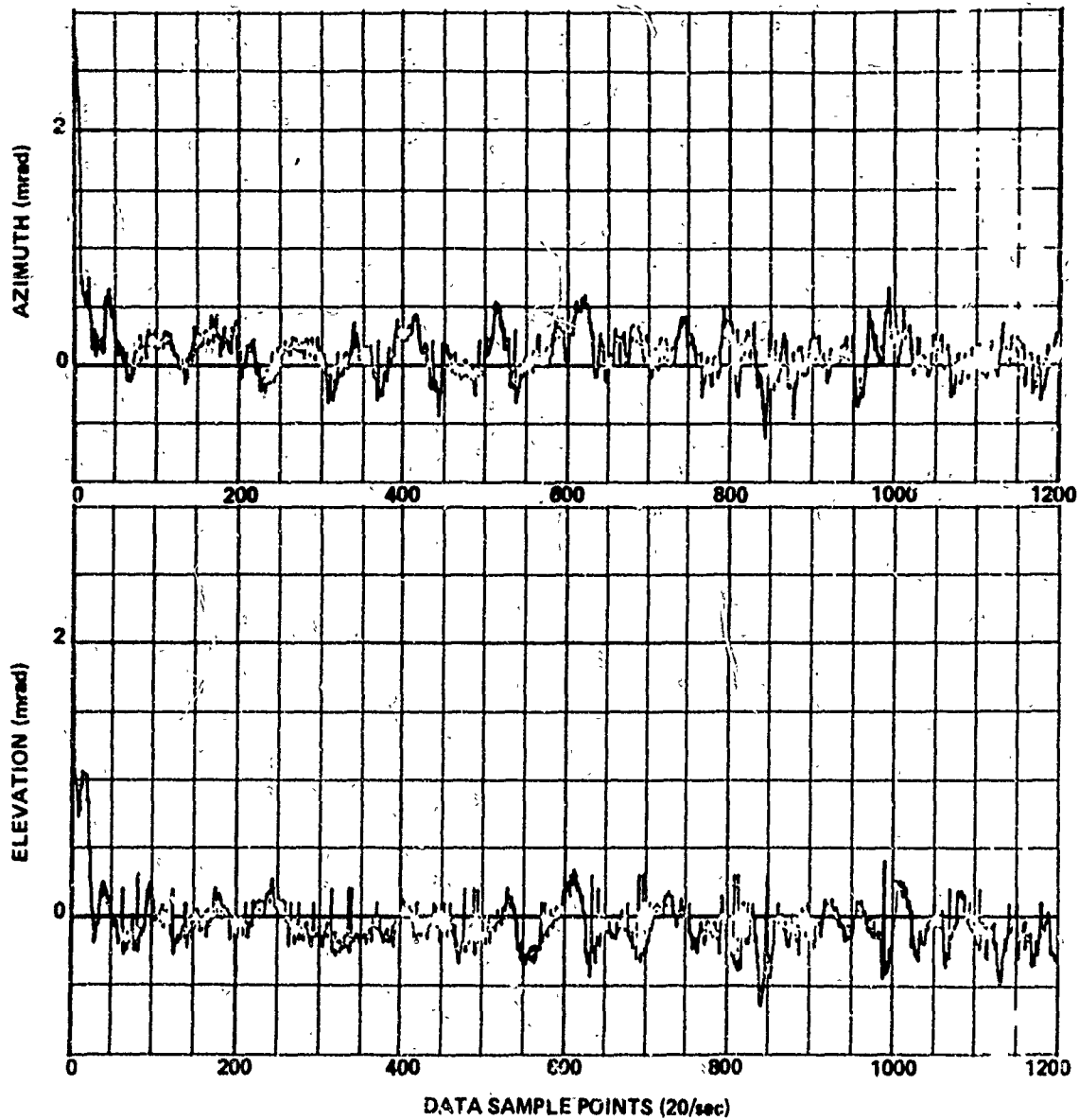
RUN 158



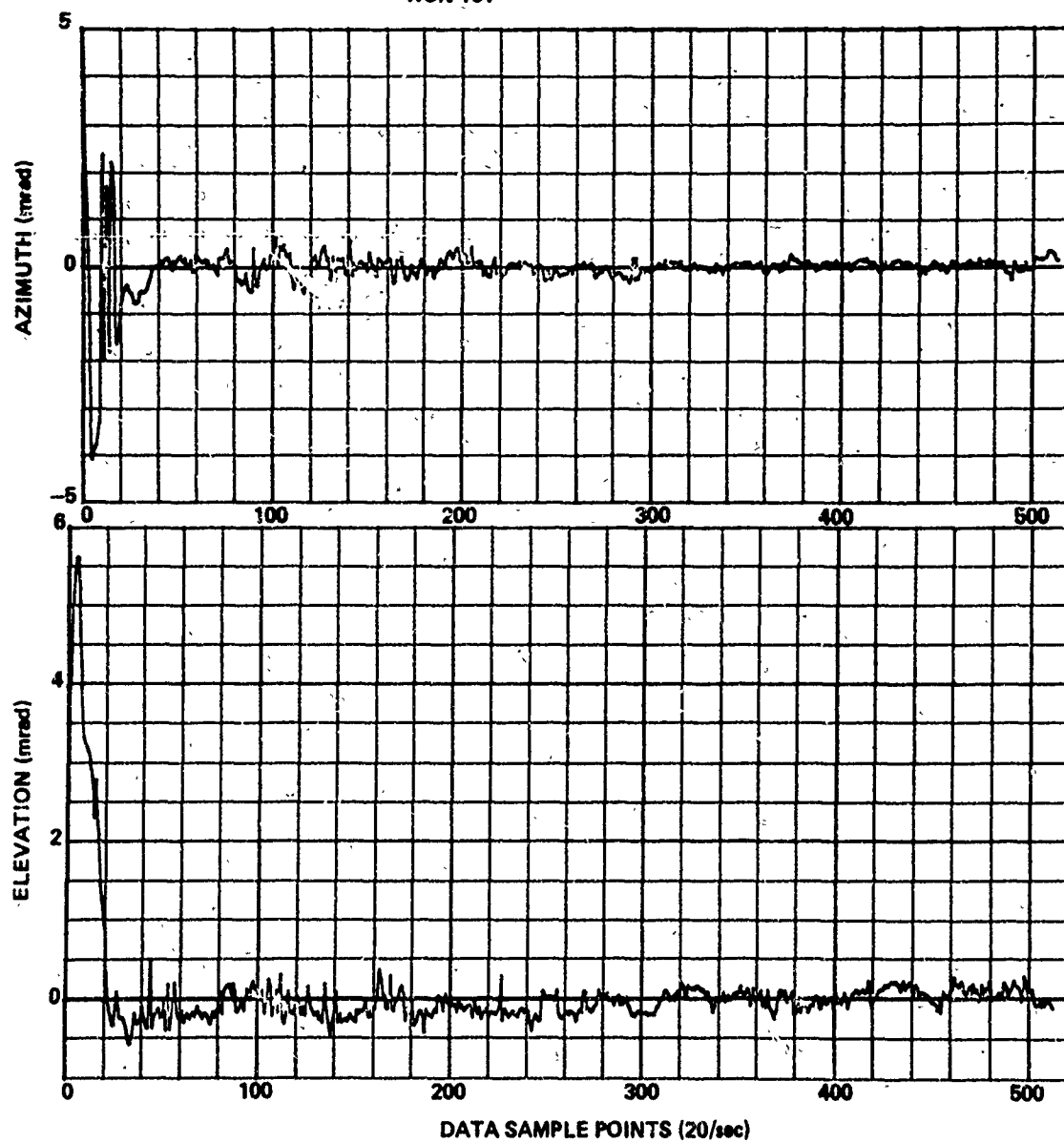
RUN 159



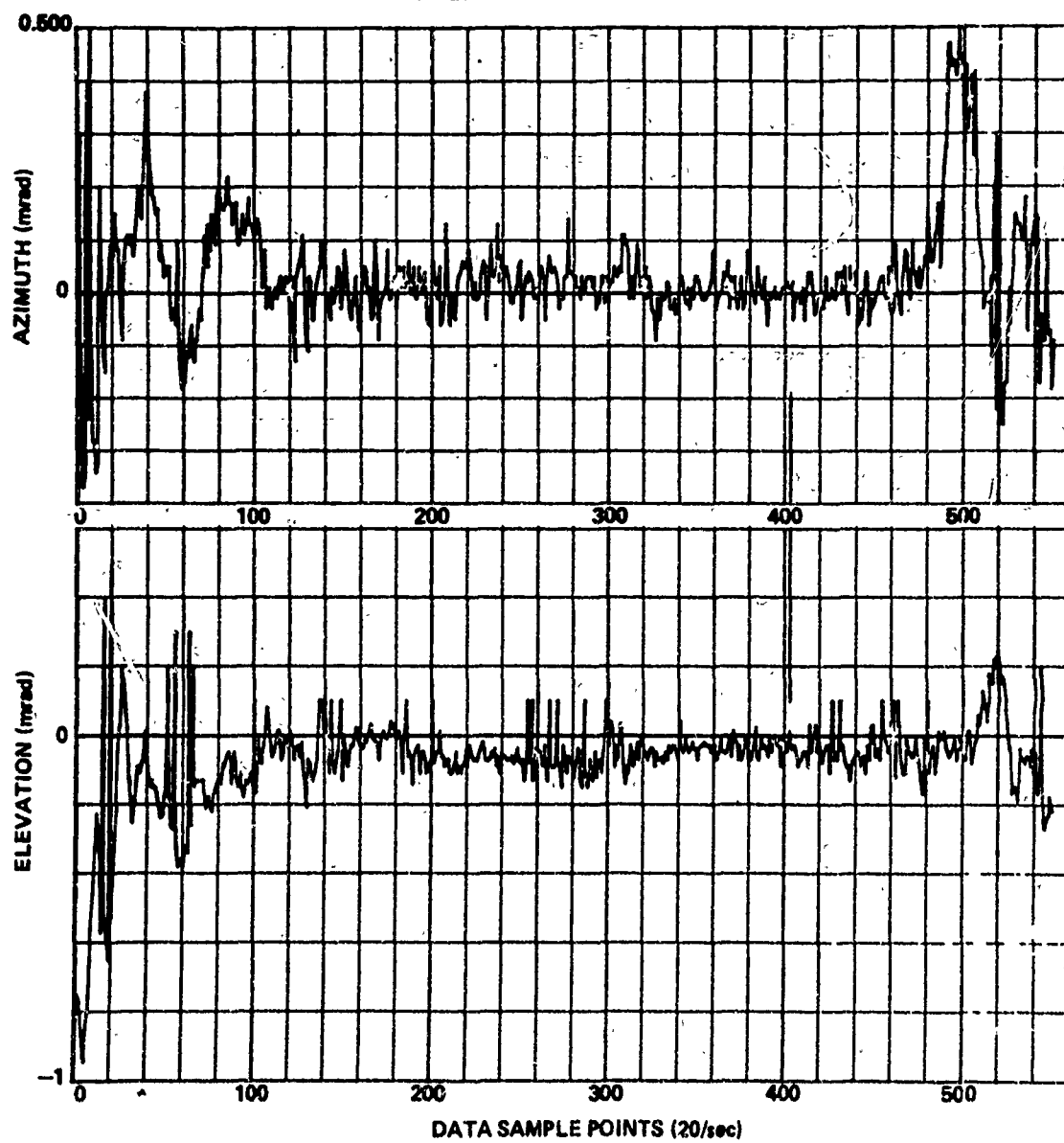
RUN 100



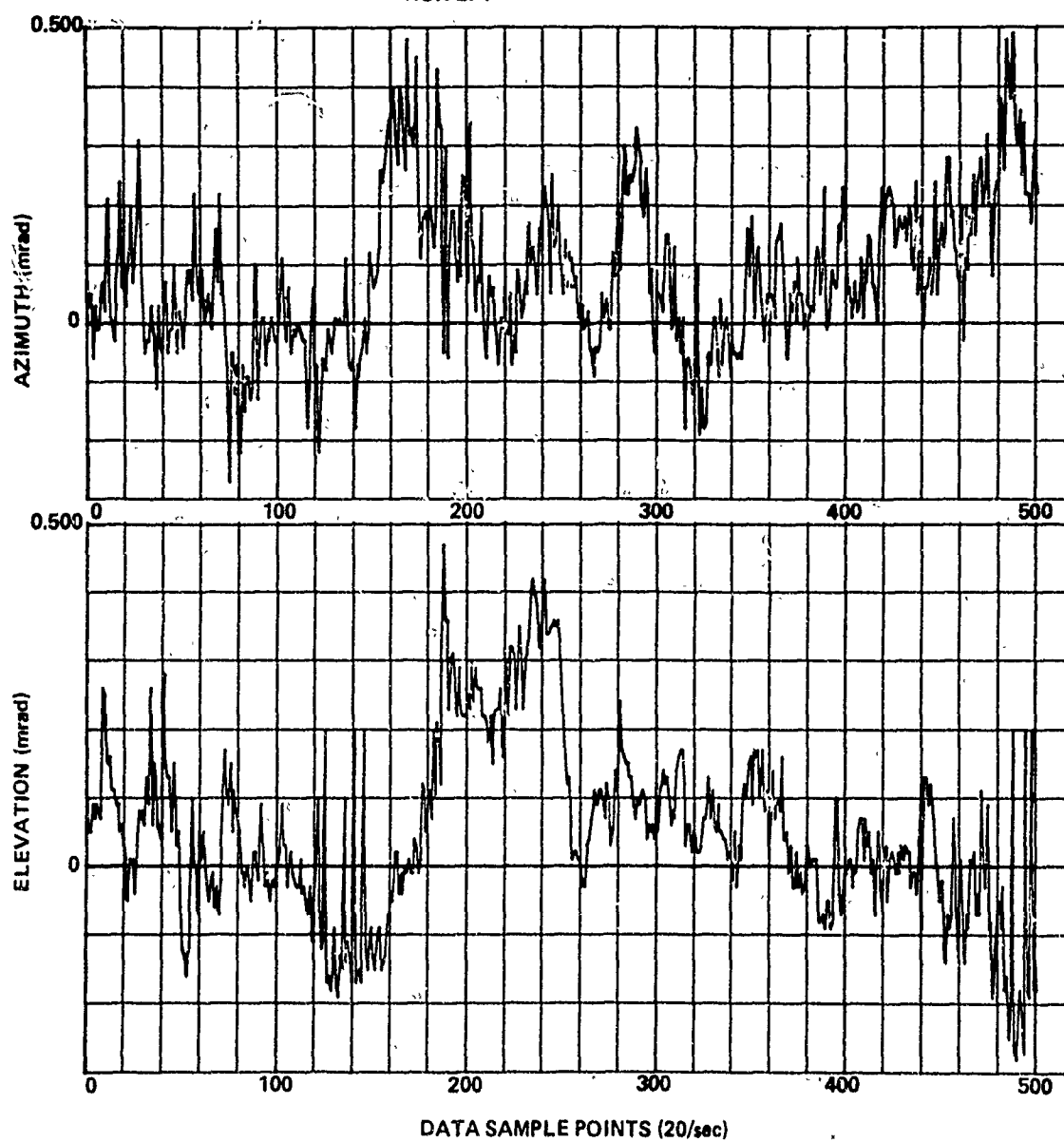
RUN 161



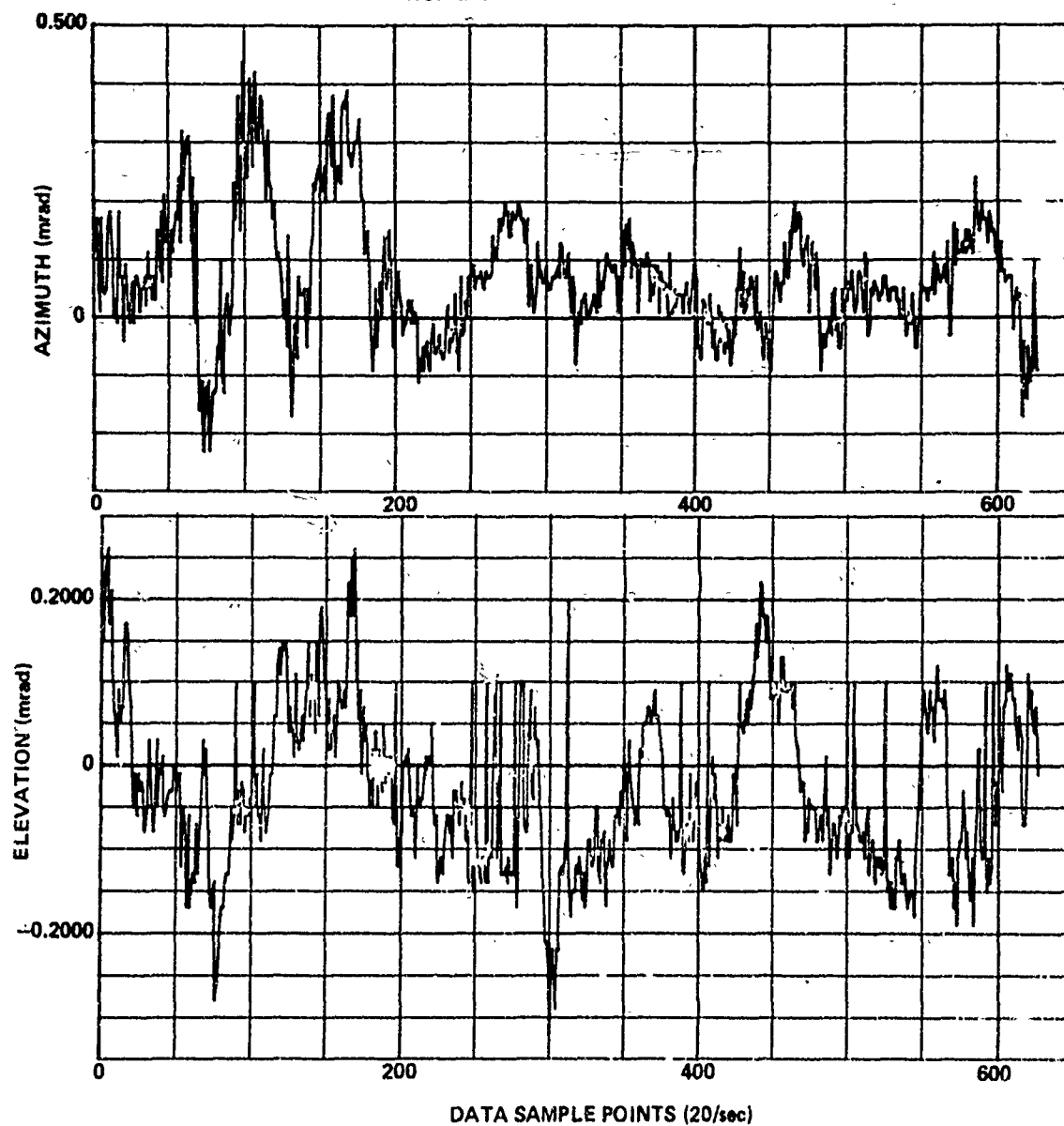
RUN 273



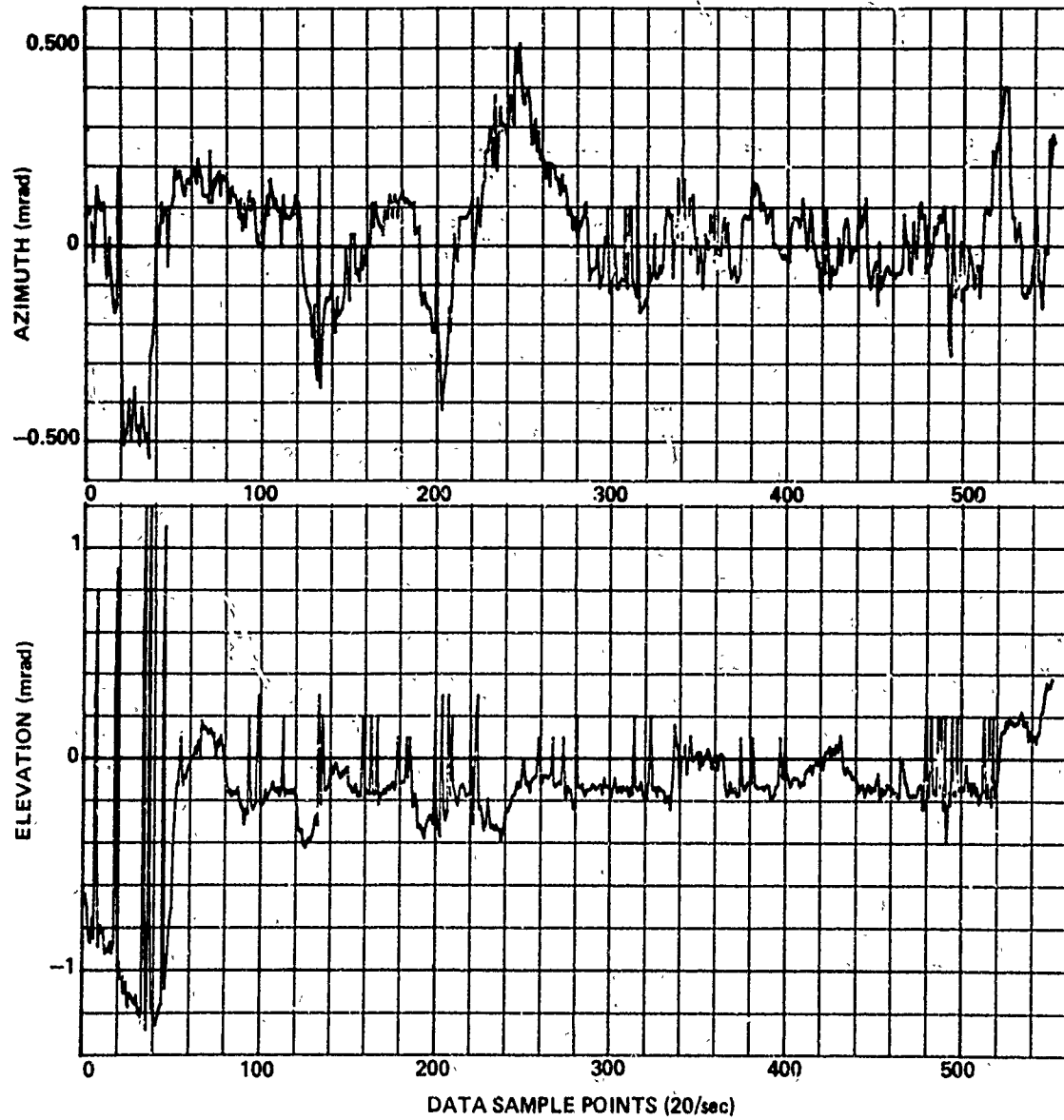
RUN 274



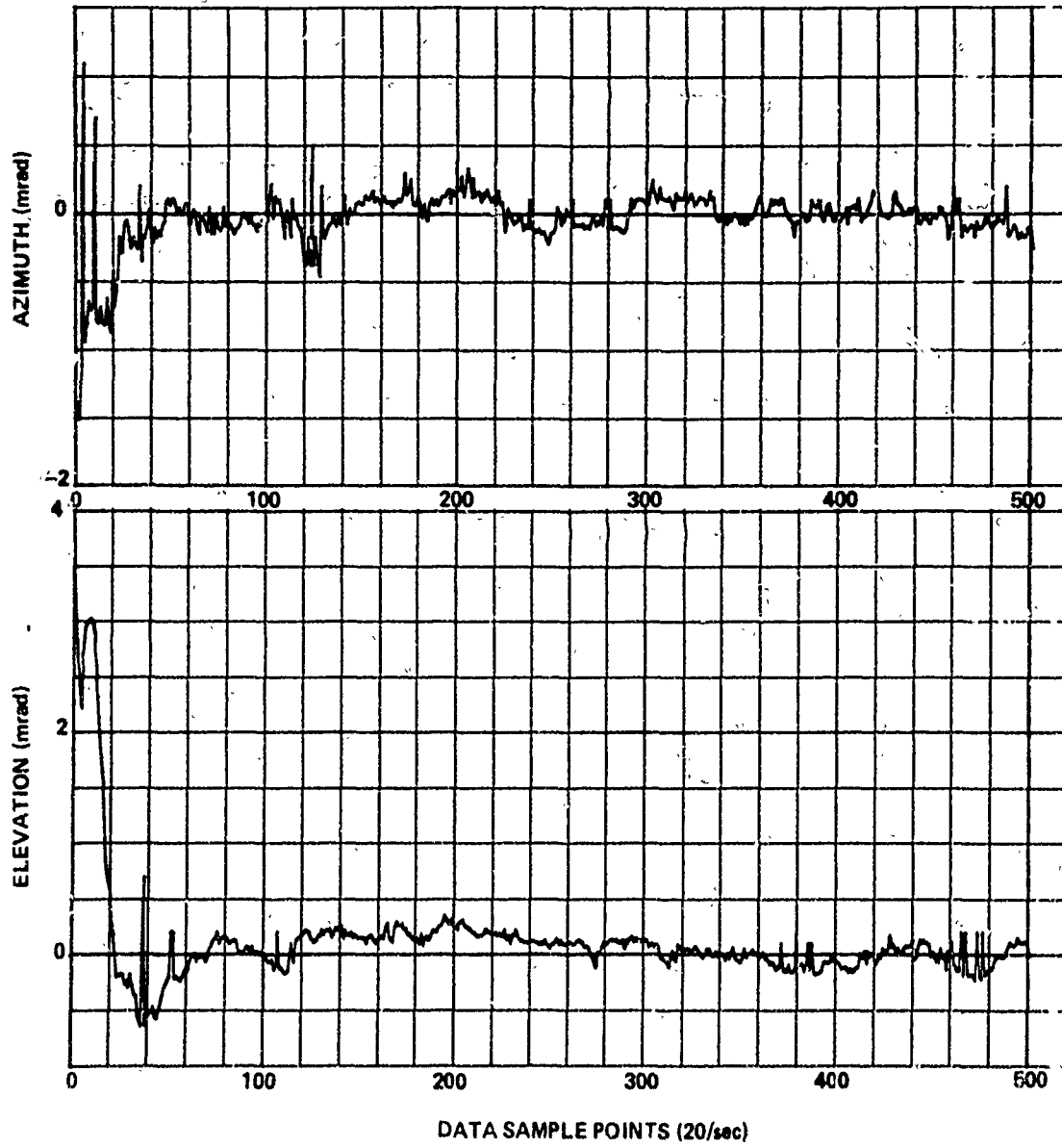
RUN 275



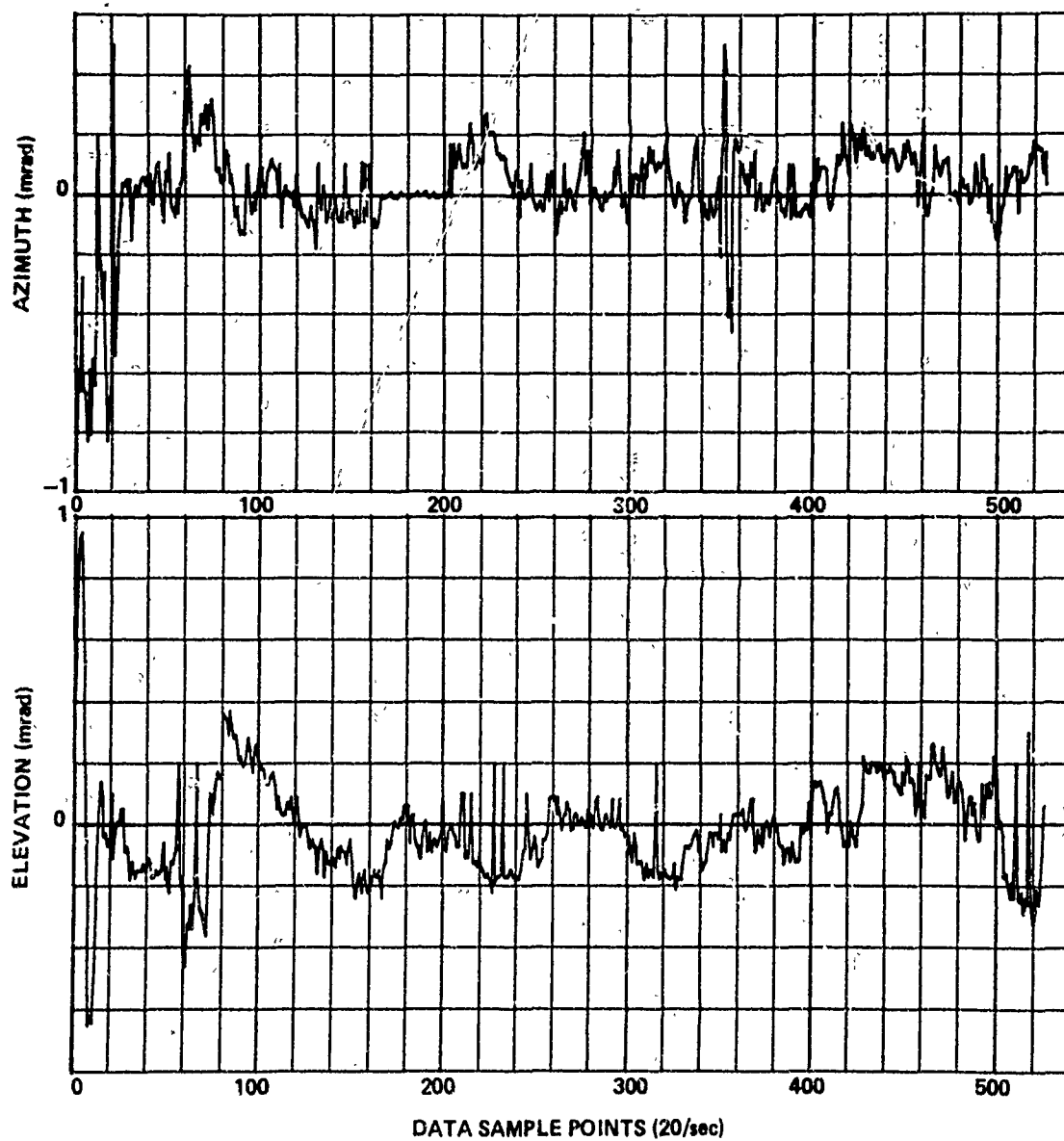
RUN 276



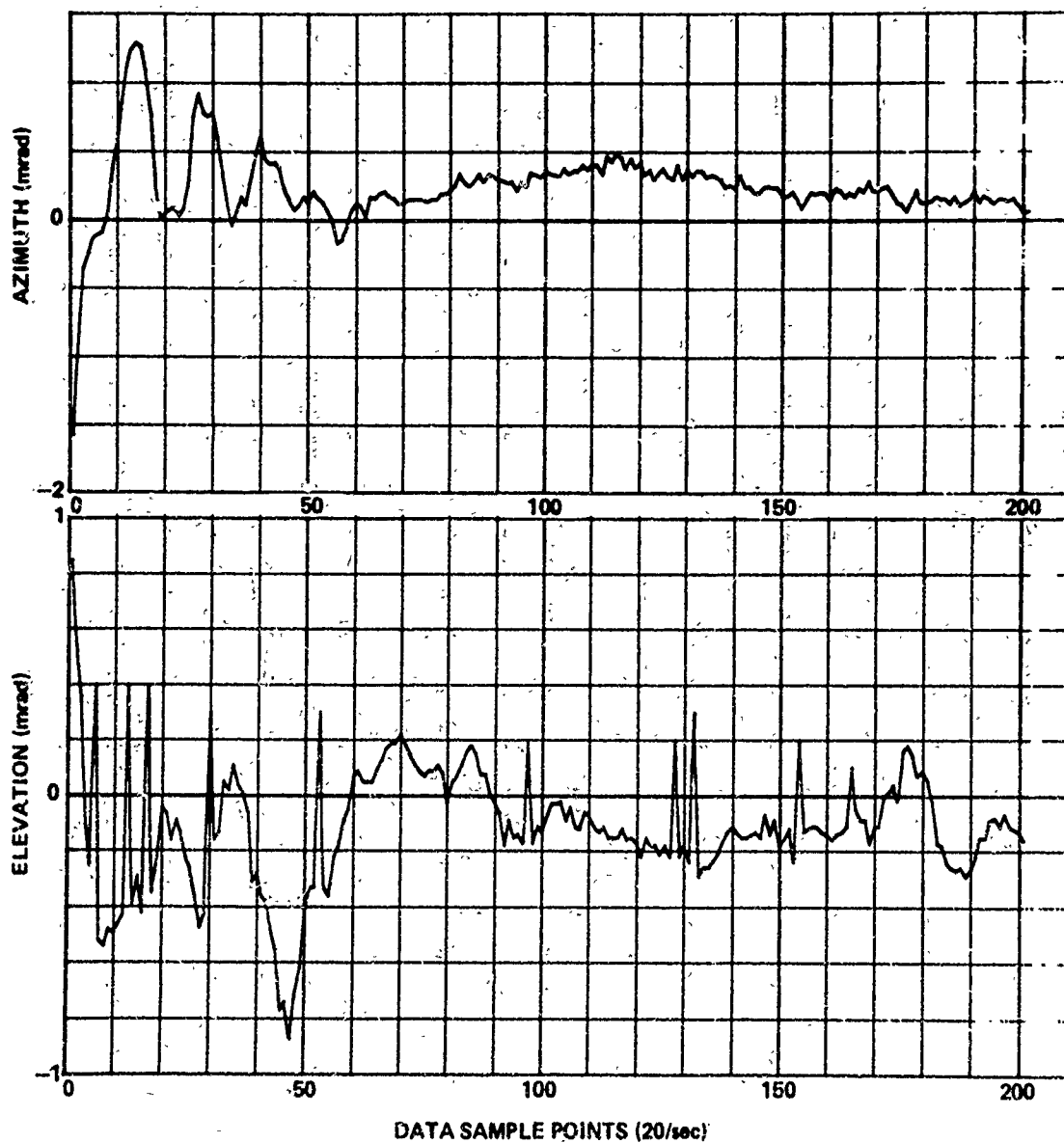
RUN 278



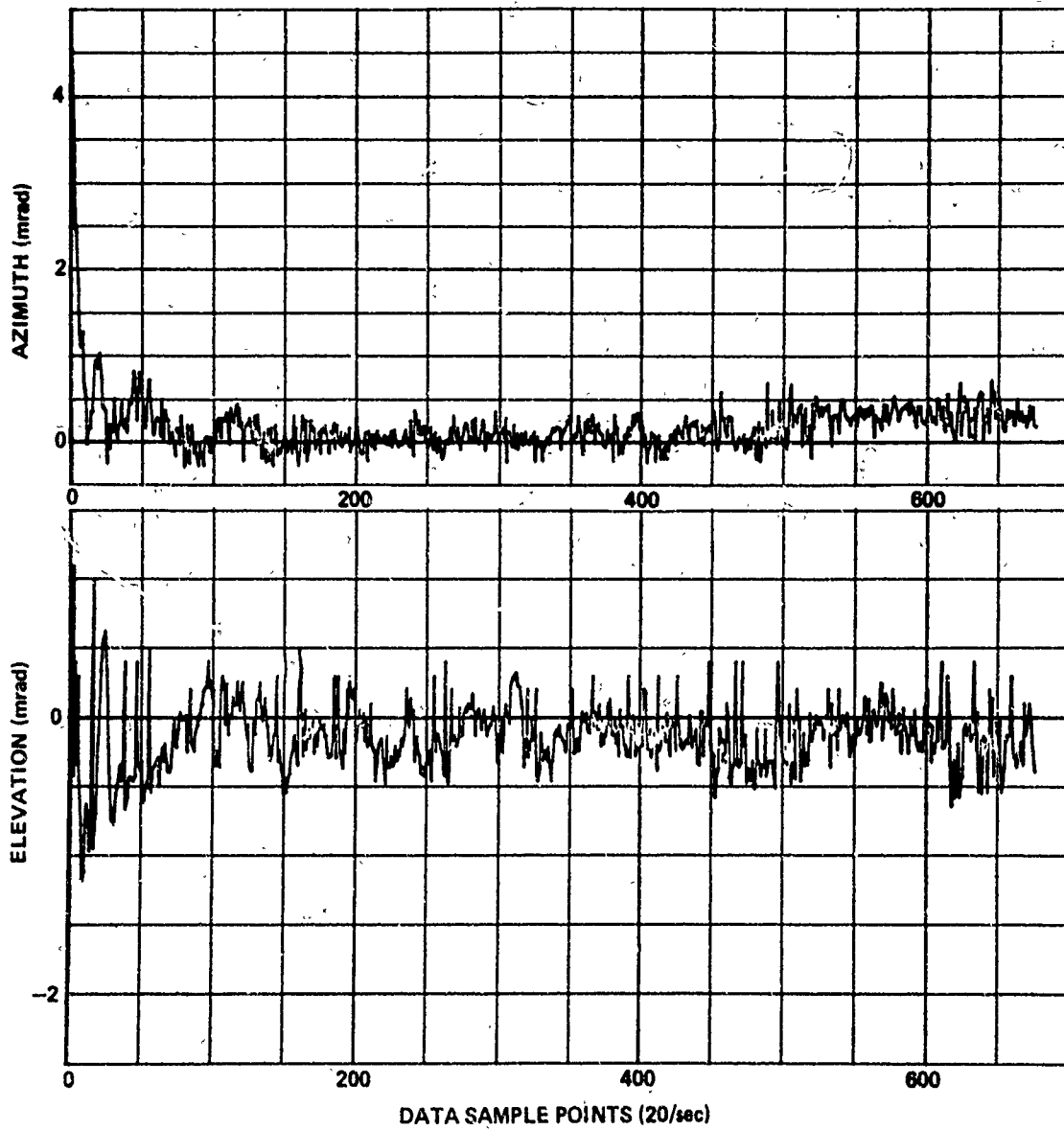
RUN 279



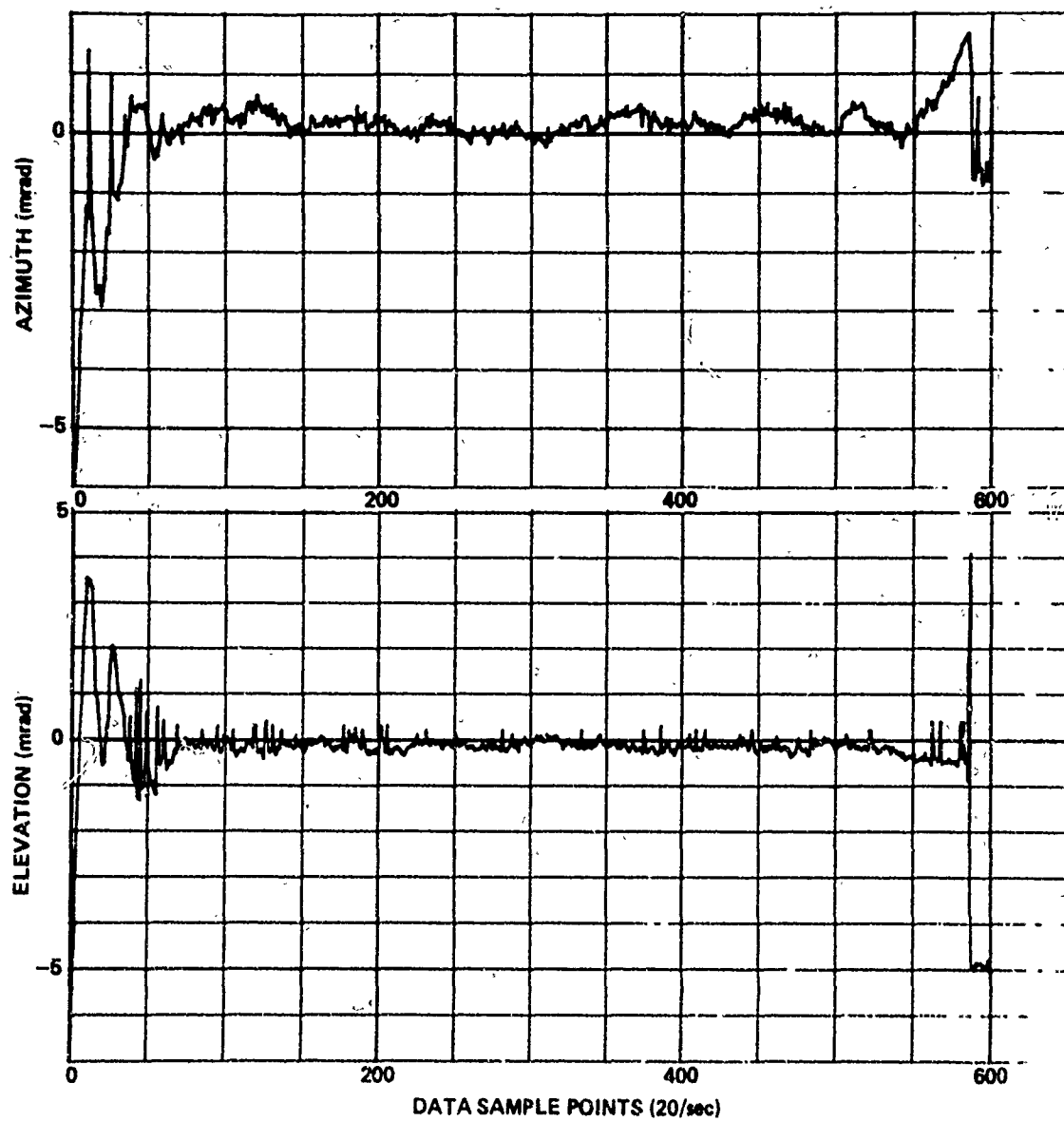
RUN 280



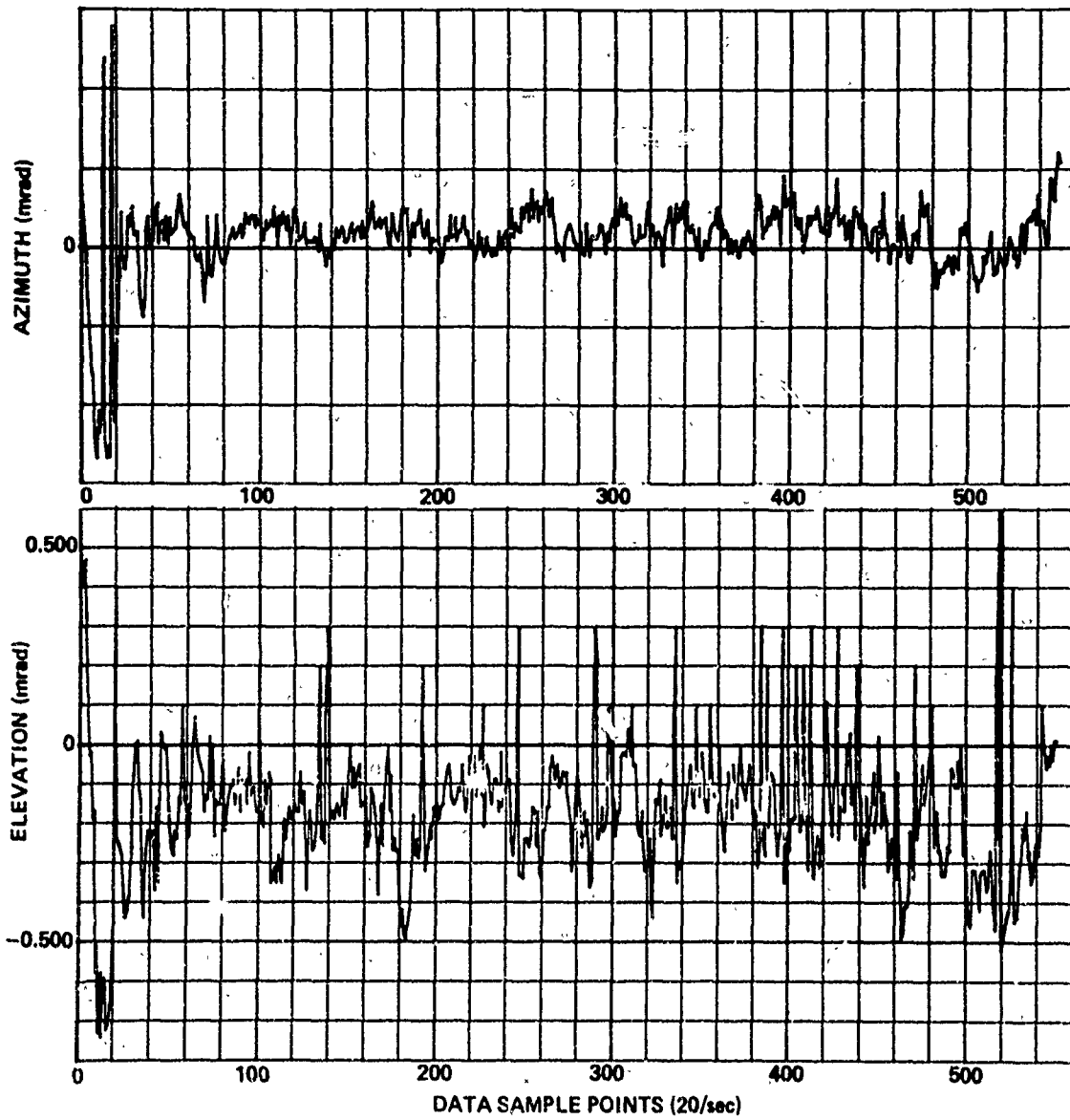
RUN 294



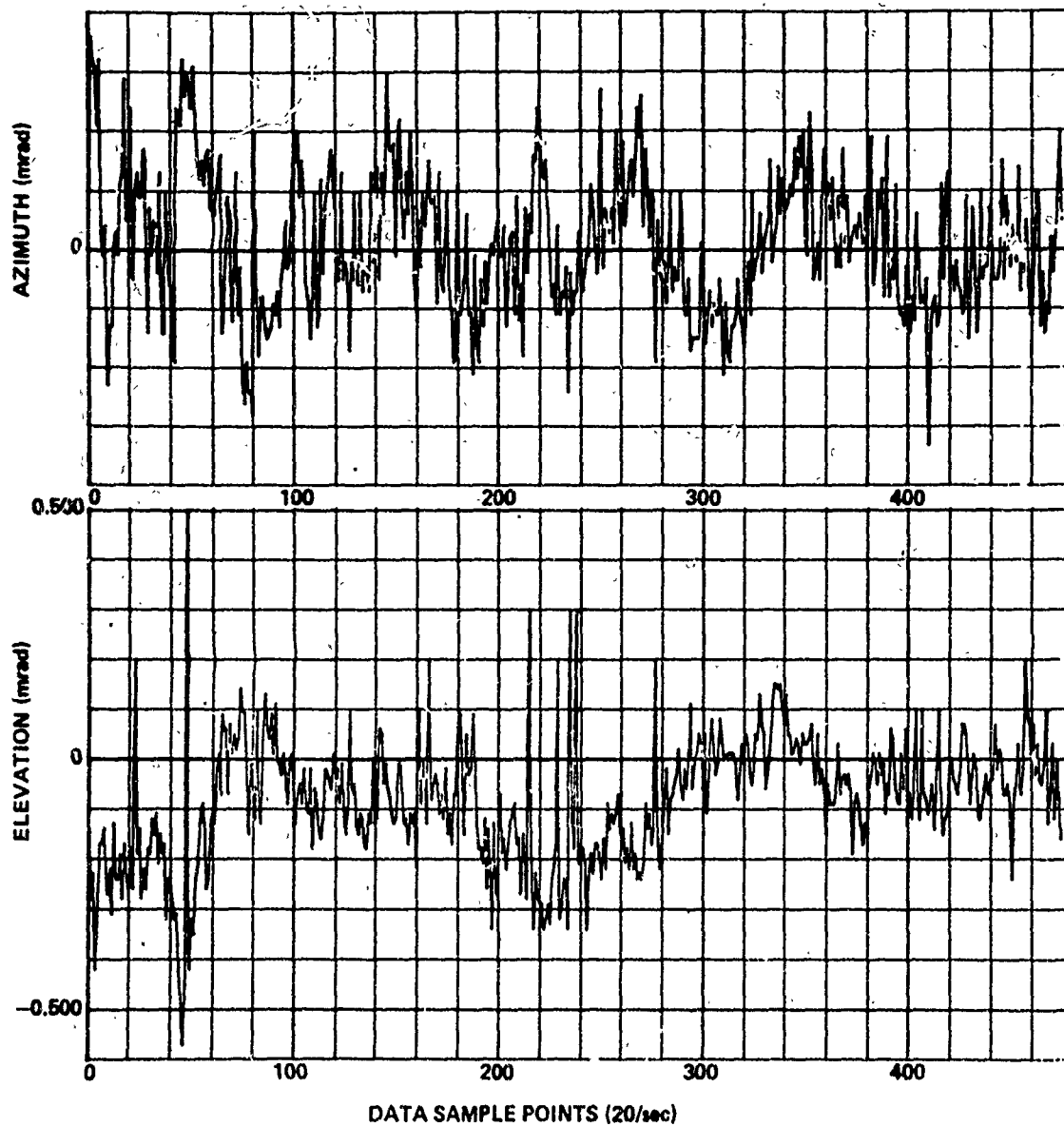
RUN 295



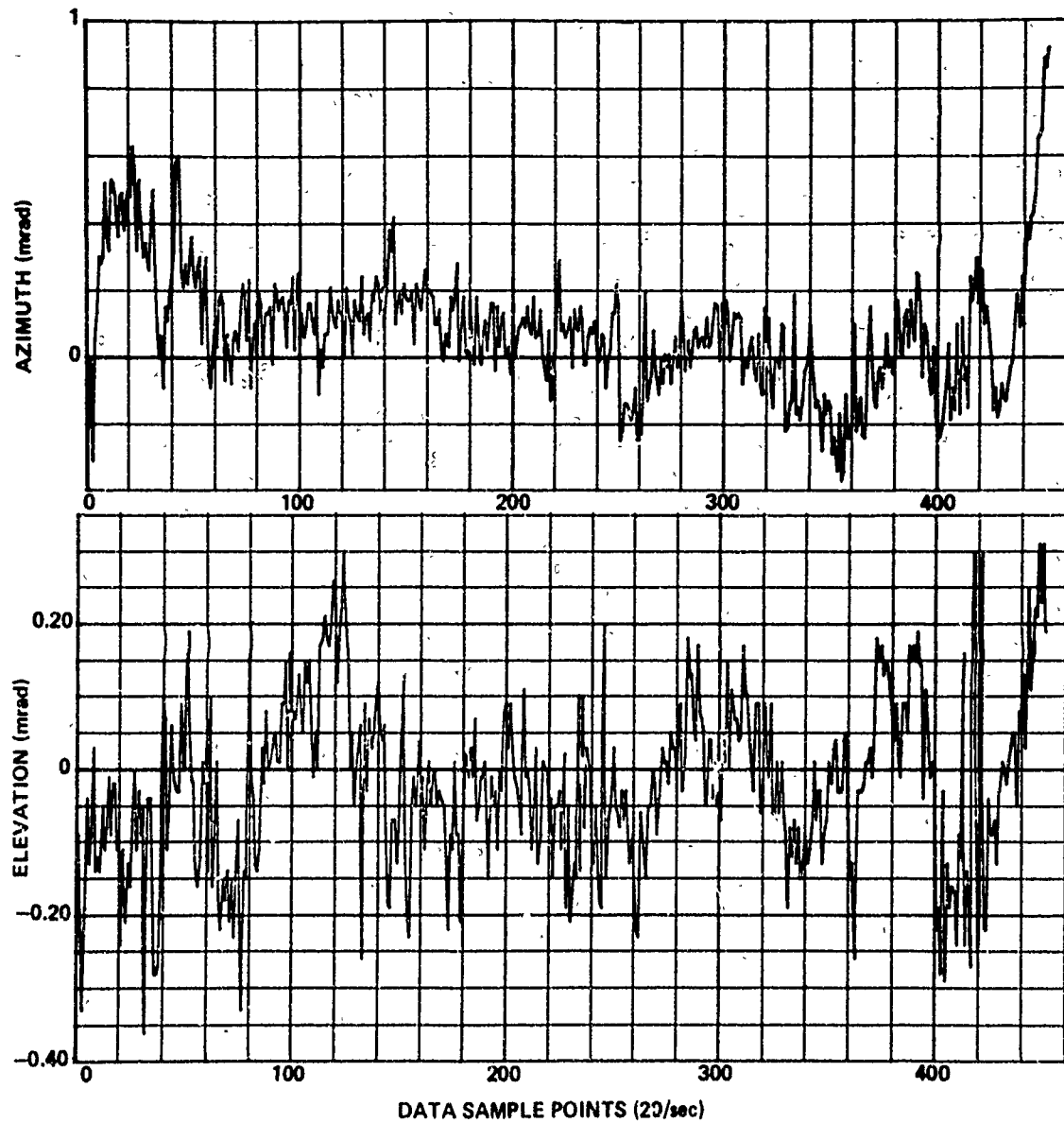
RUN 296



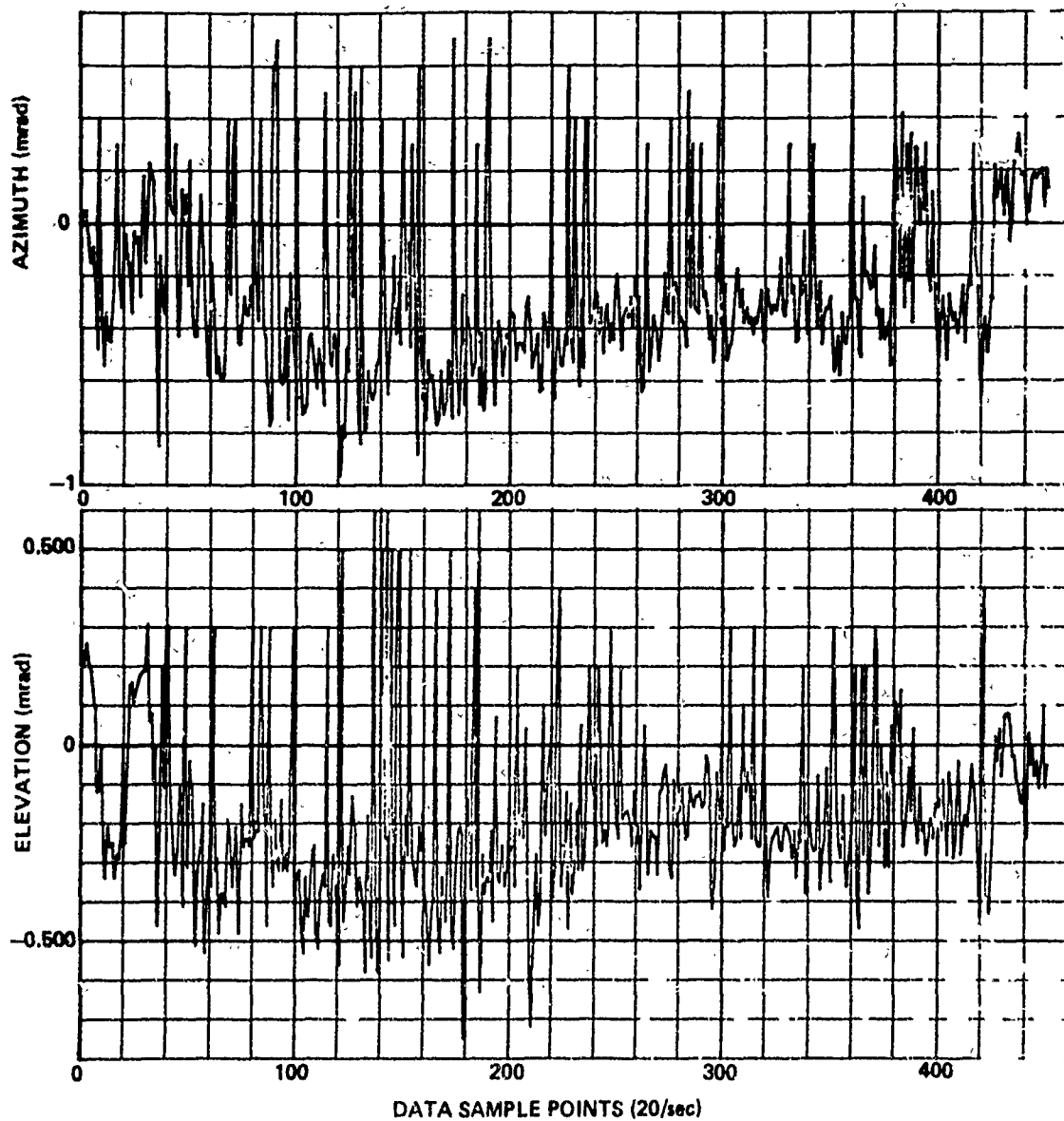
RUN 297



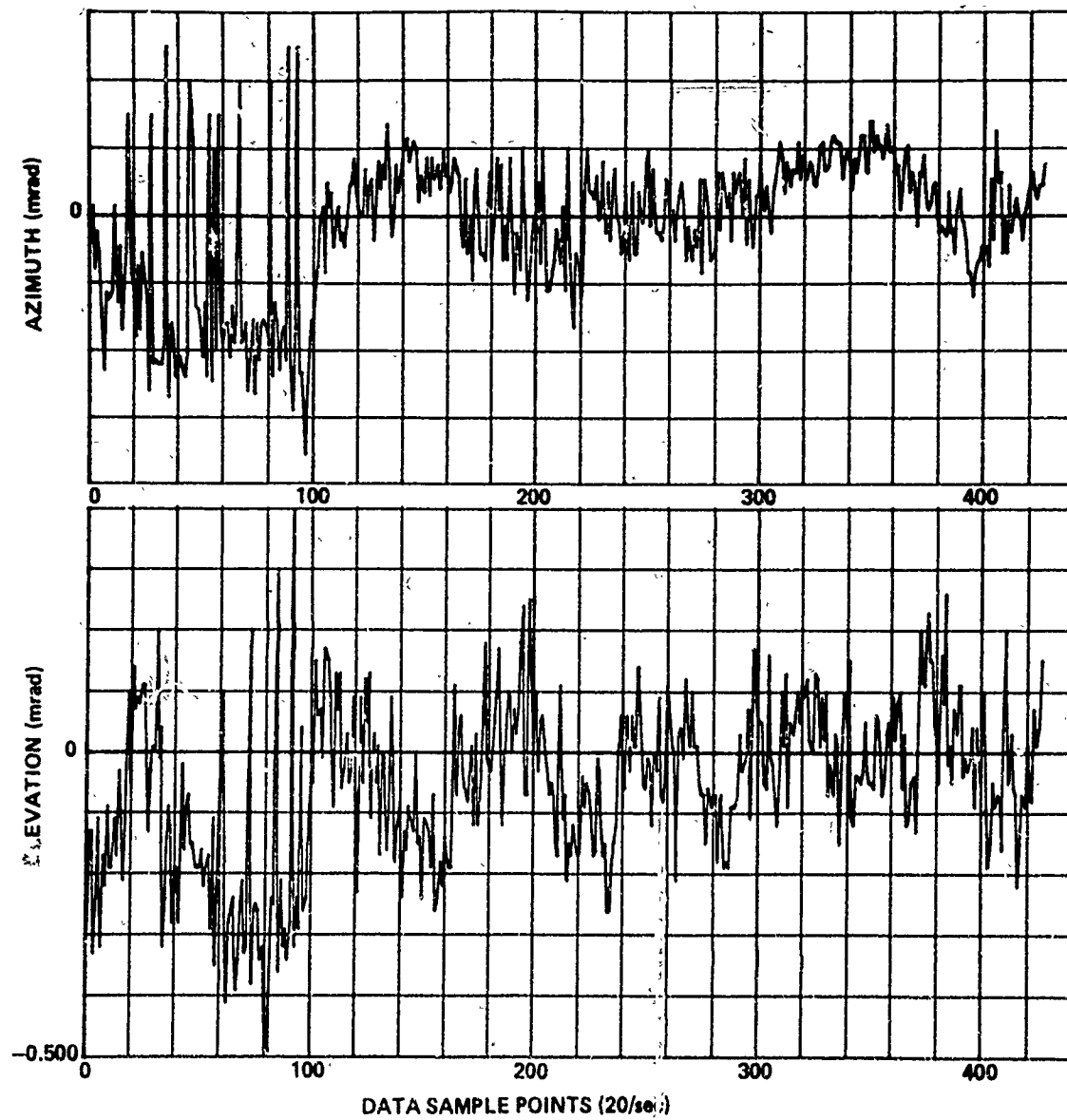
RUN 298



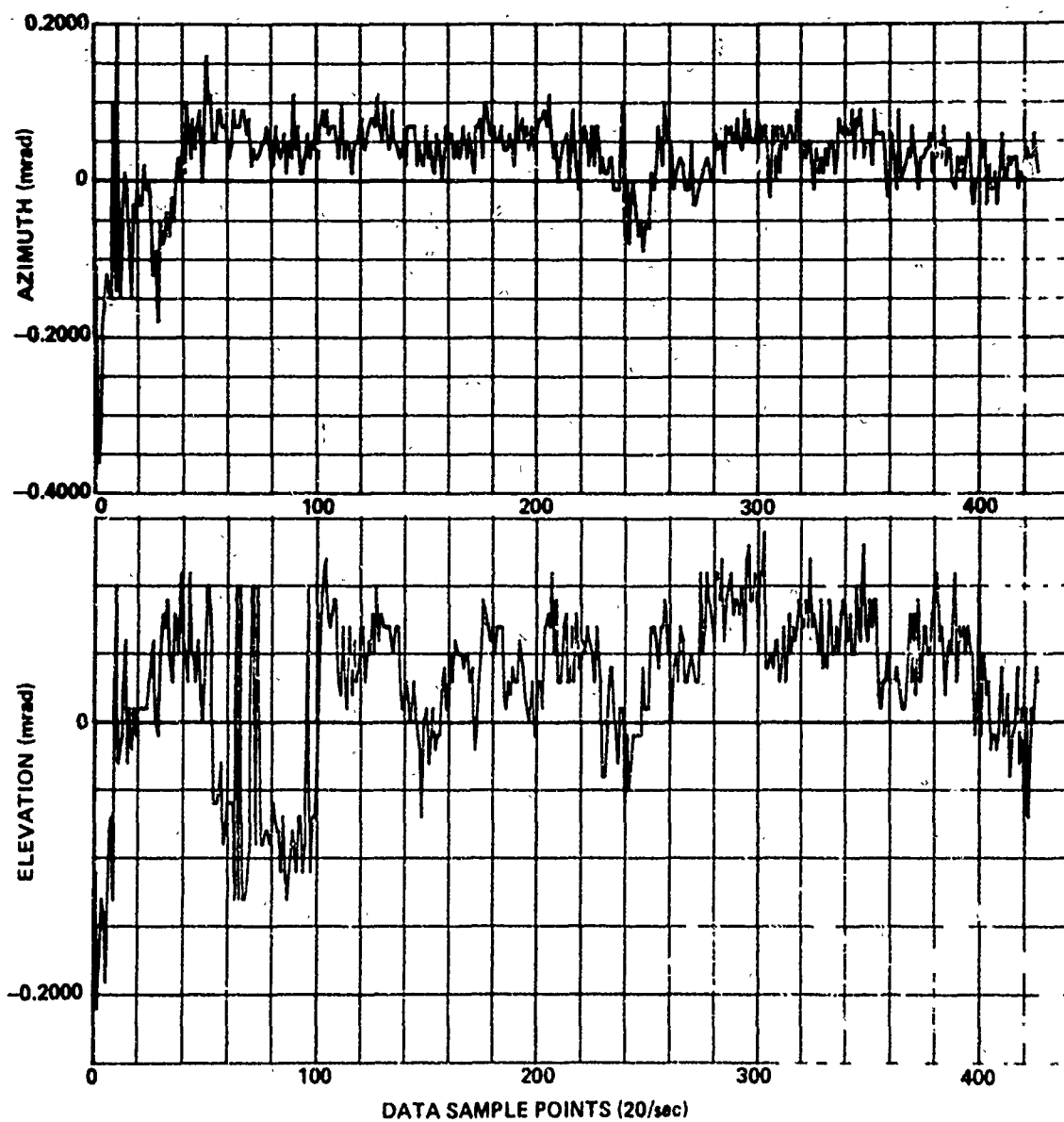
RUN 300



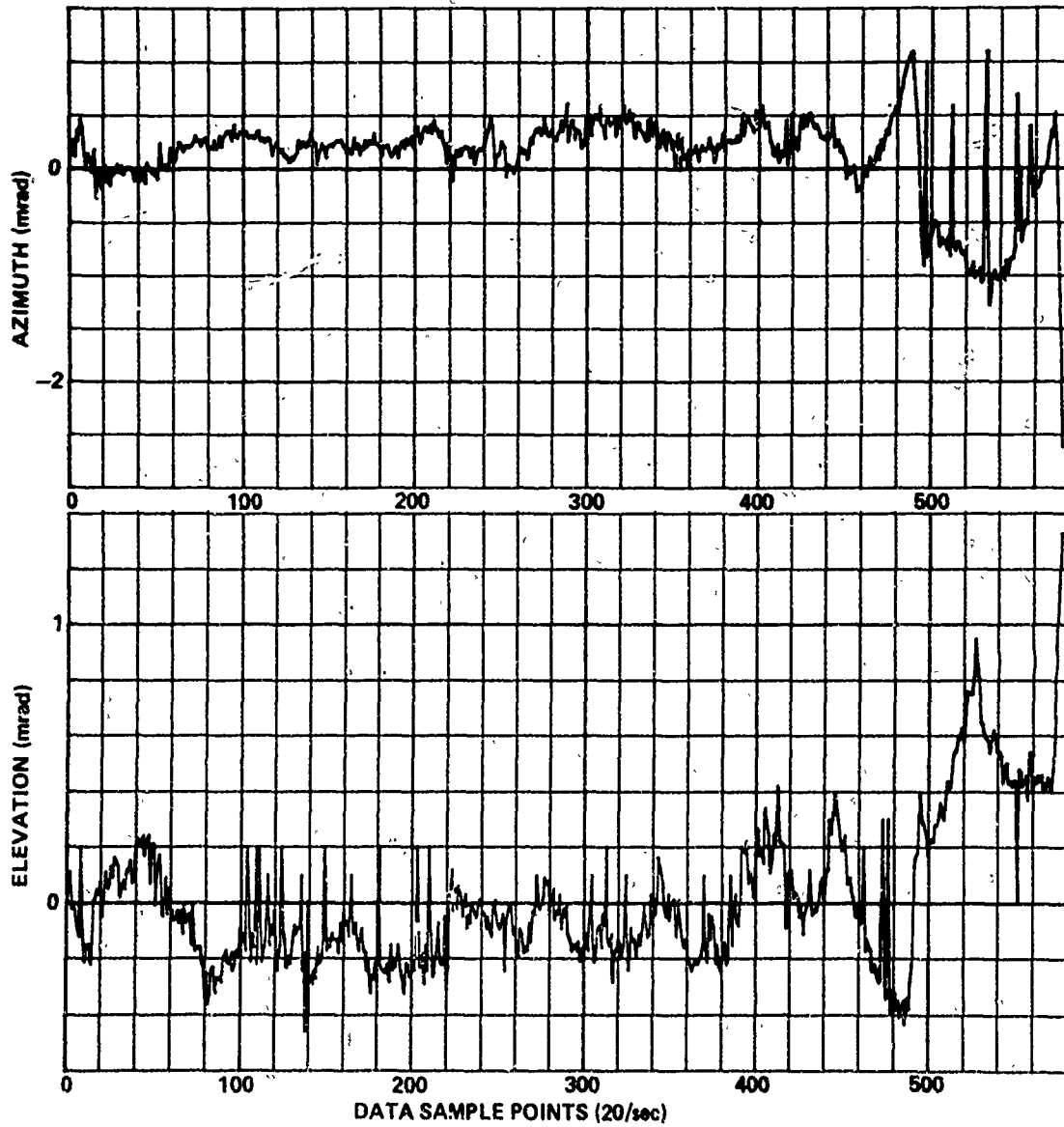
RUN 301



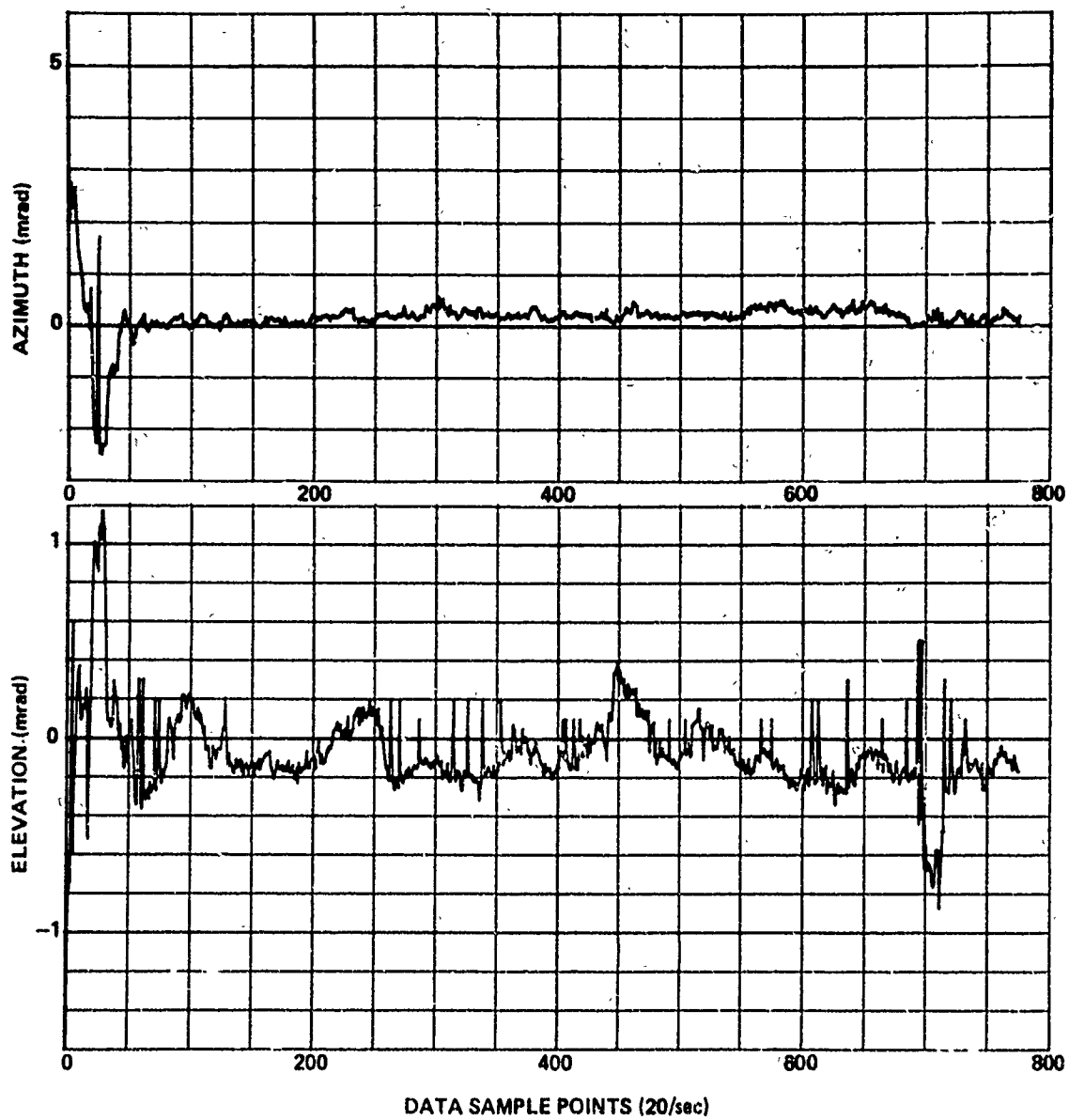
RUN 302



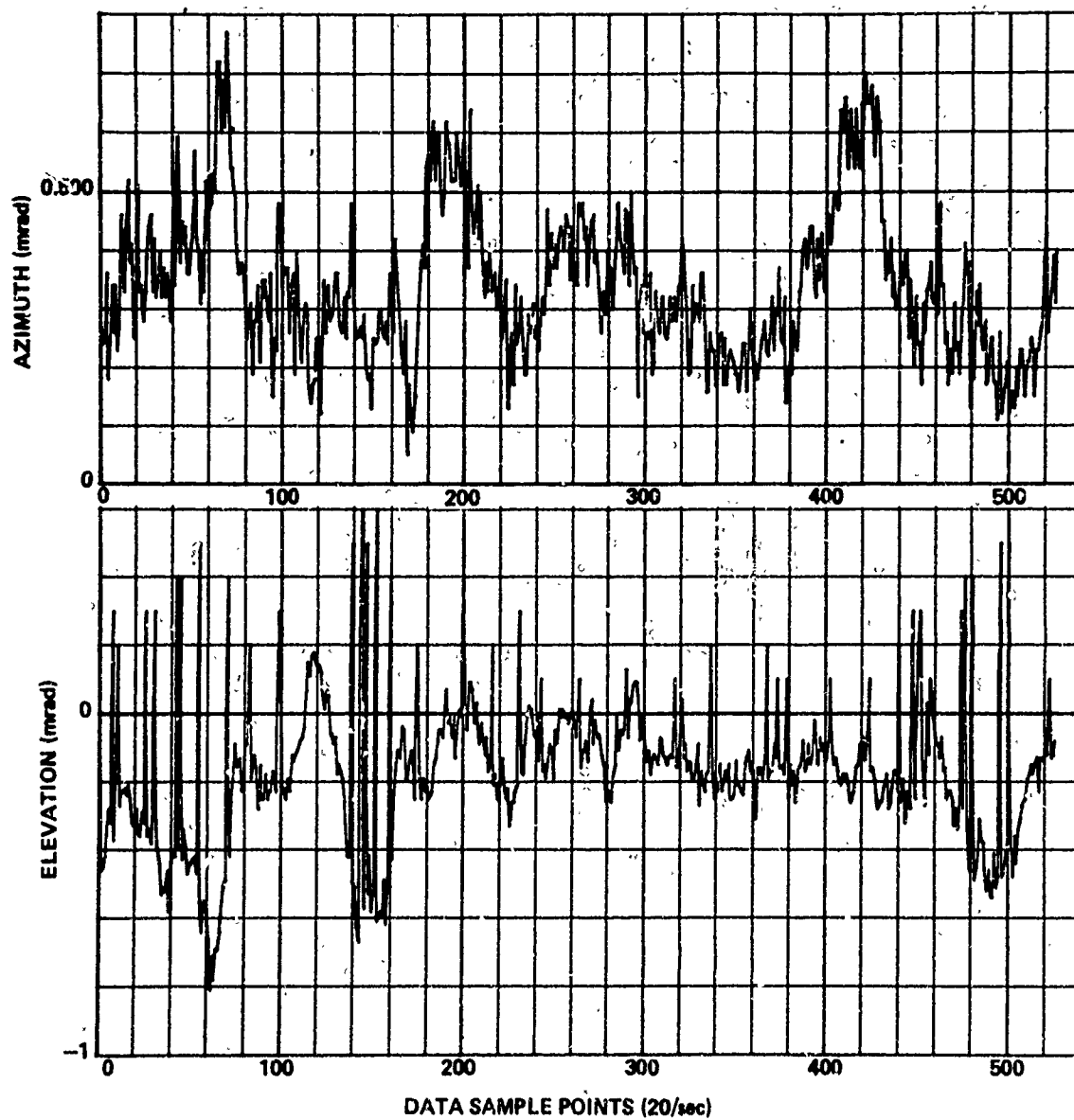
RUN 303



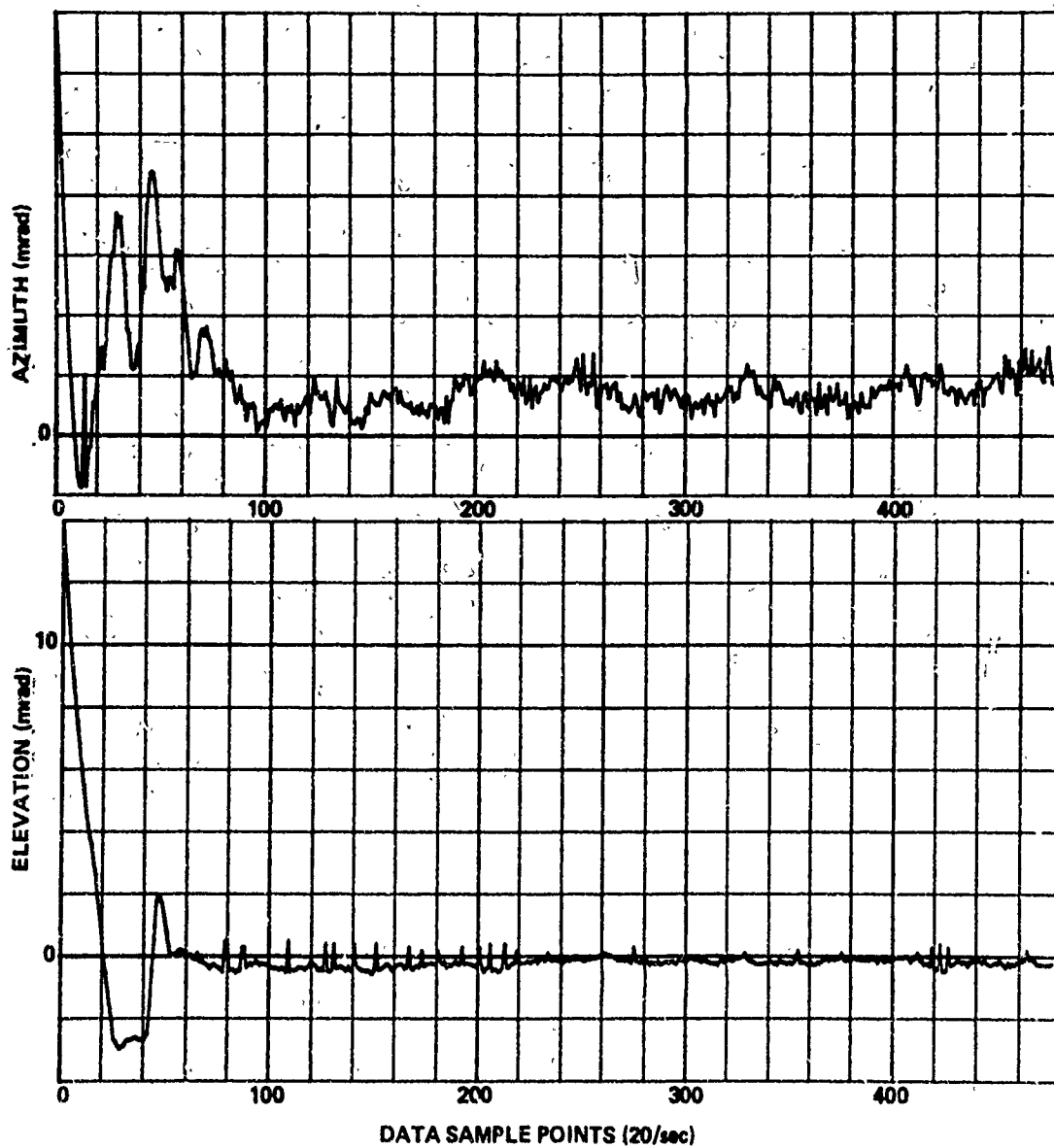
RUN 305



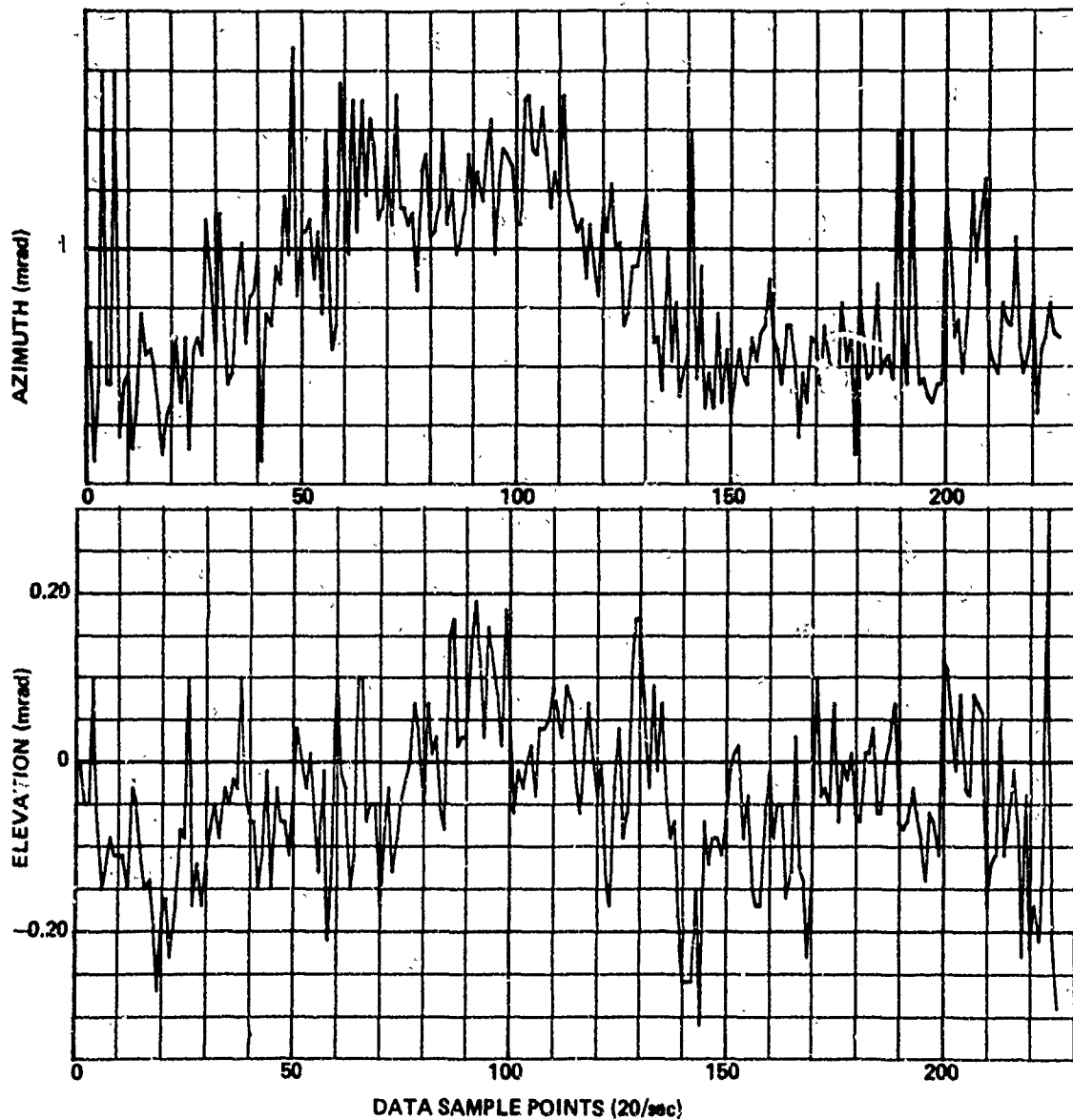
RUN 306



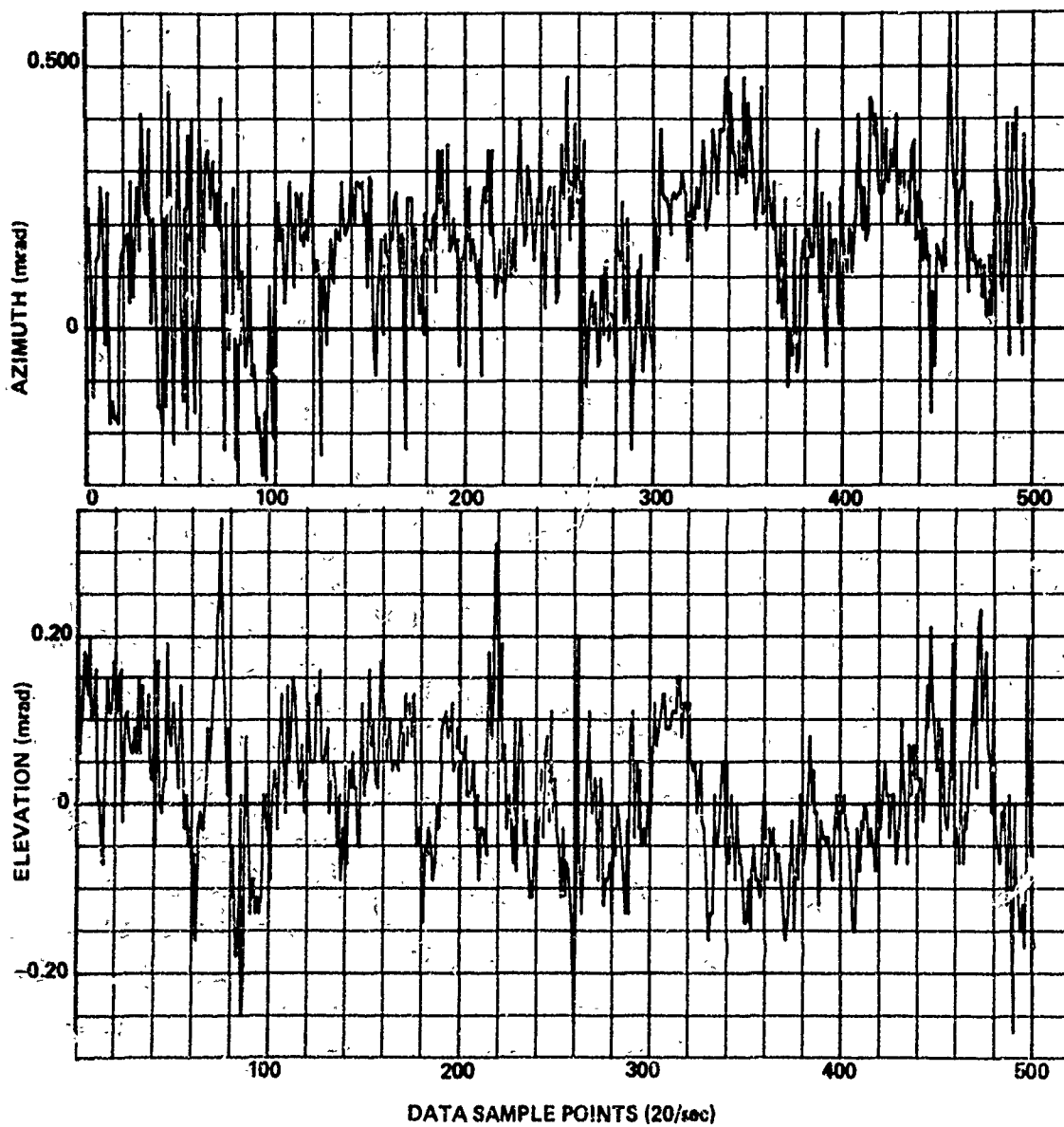
RUN 307



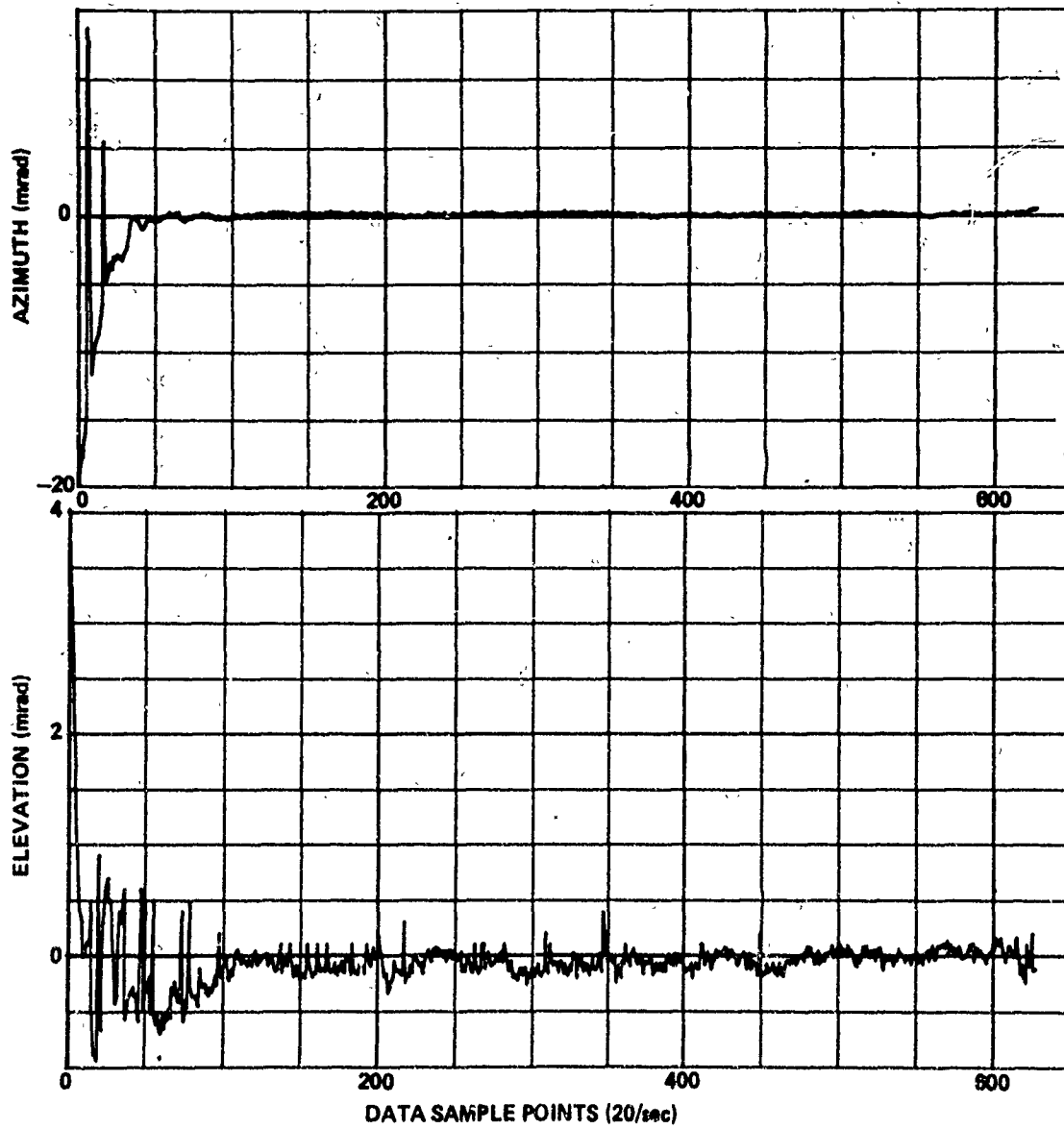
RUN 308



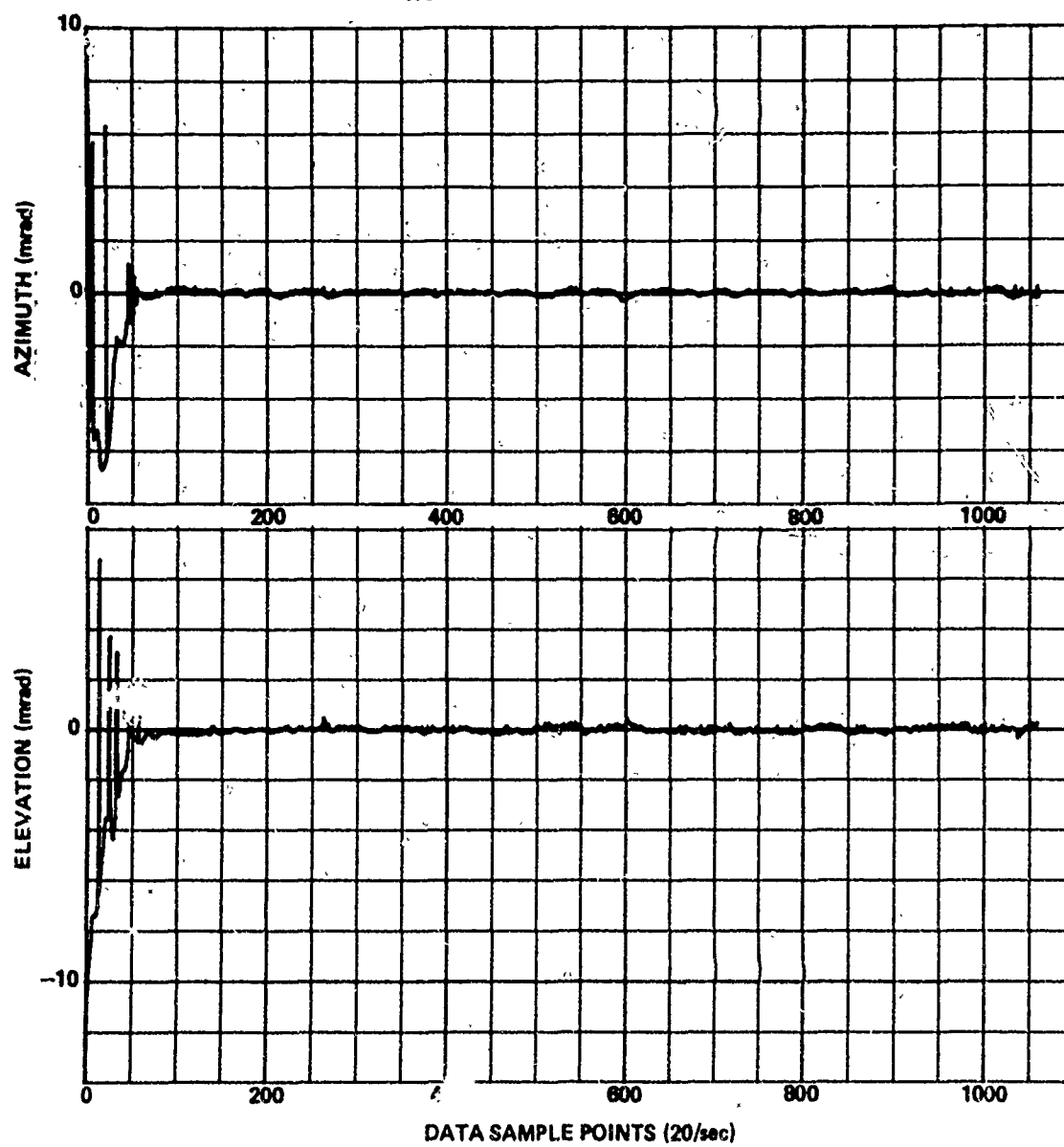
RUN 309



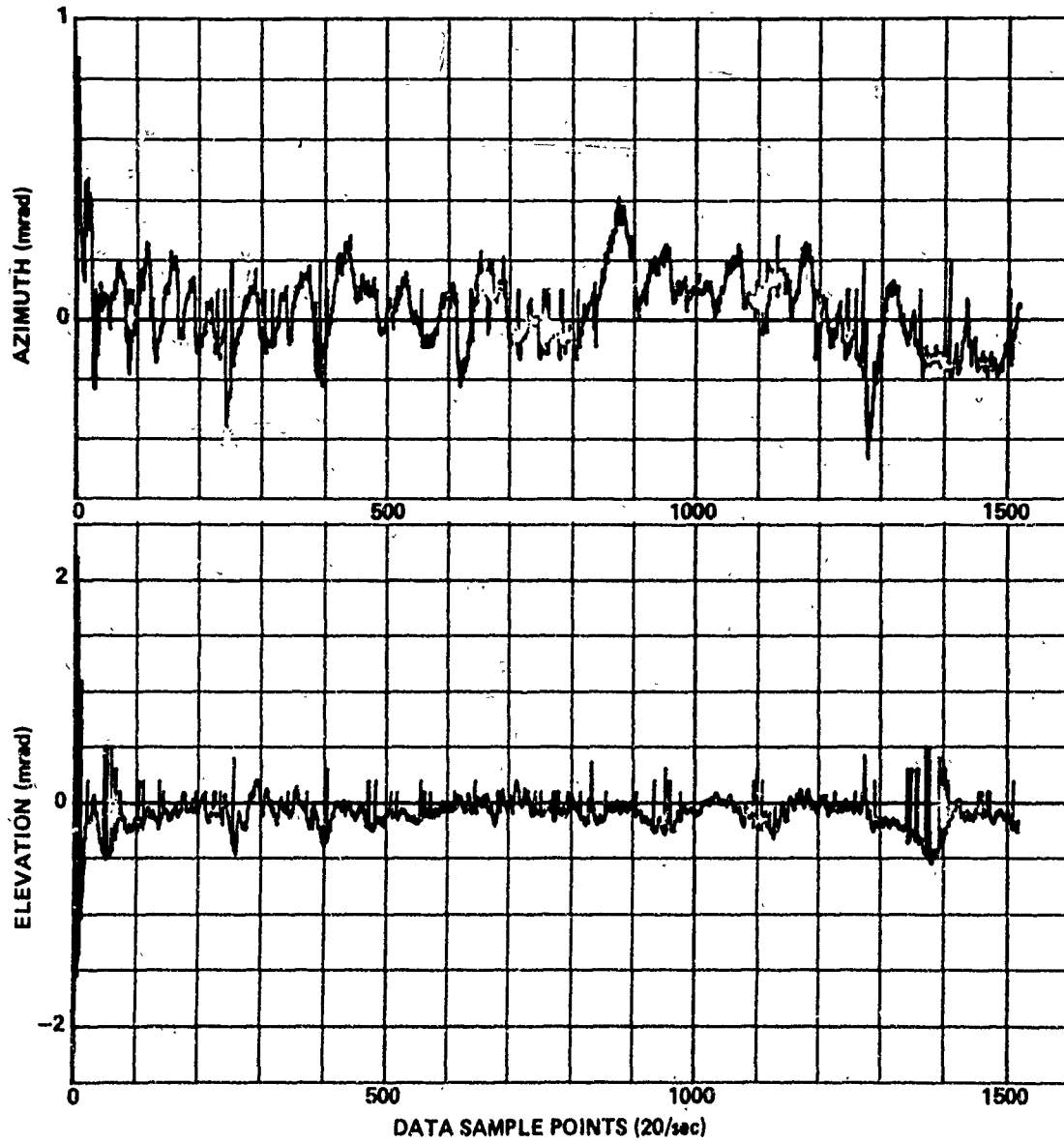
RUN 311.



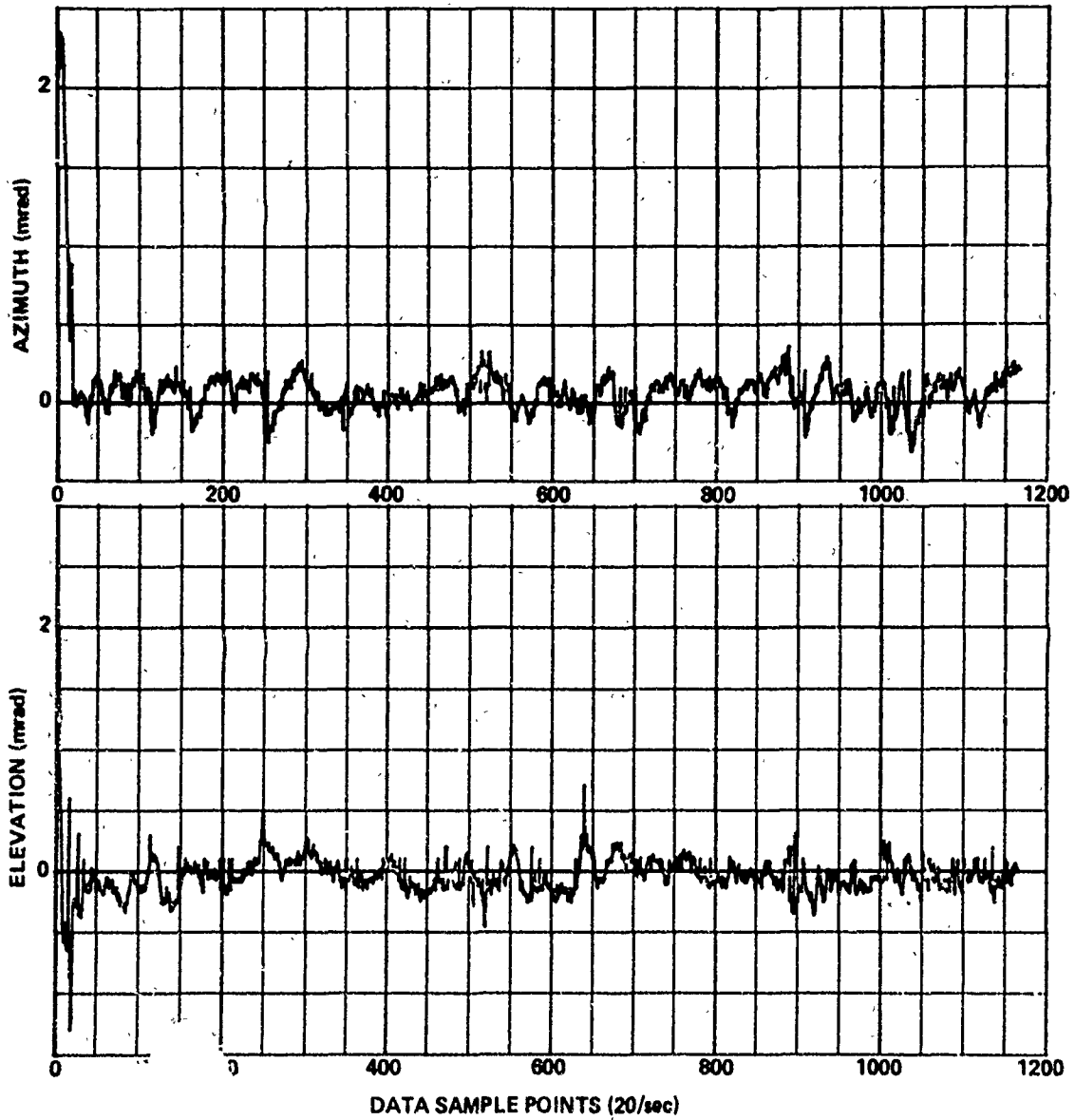
RUN 312



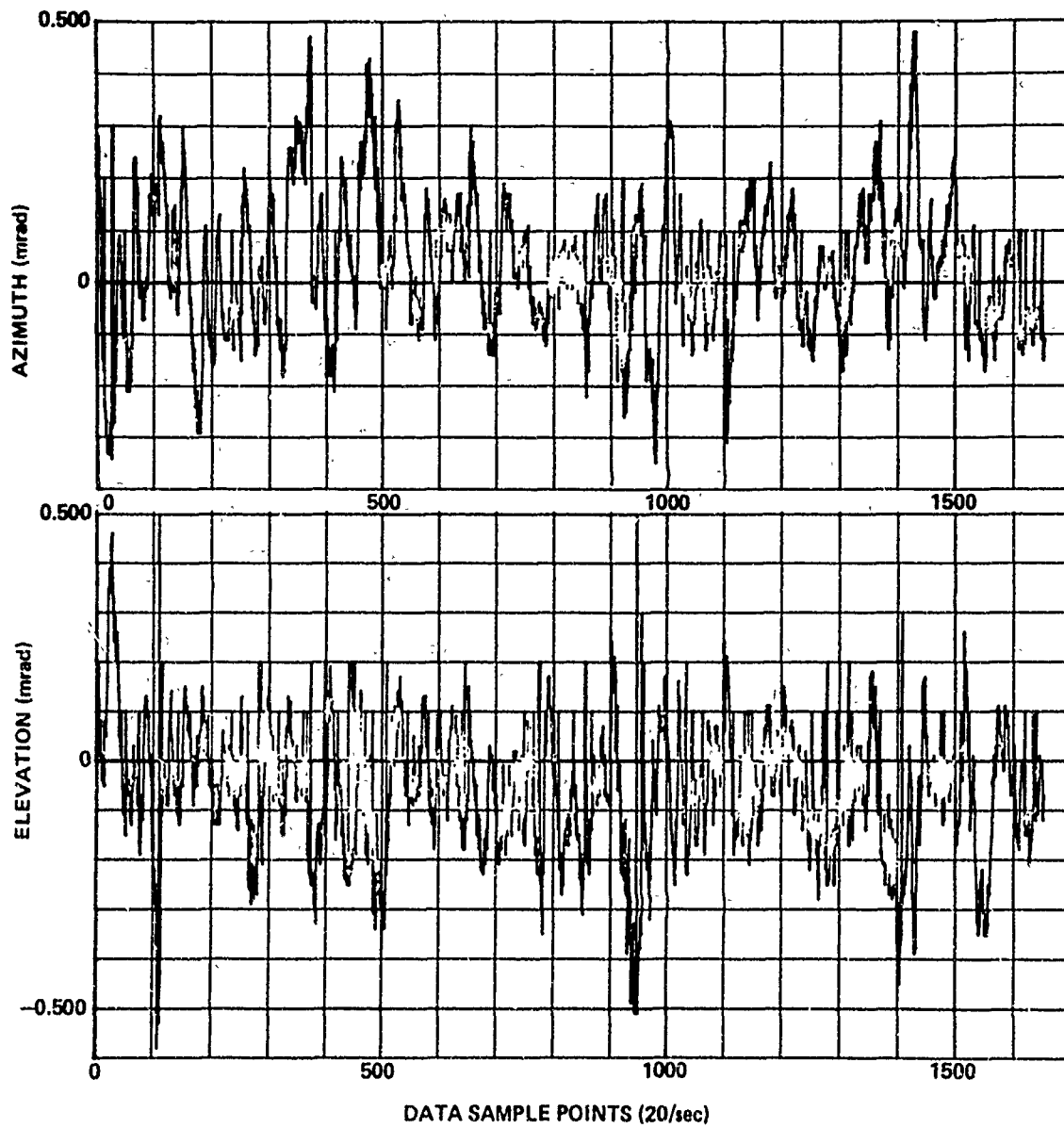
RUN 313



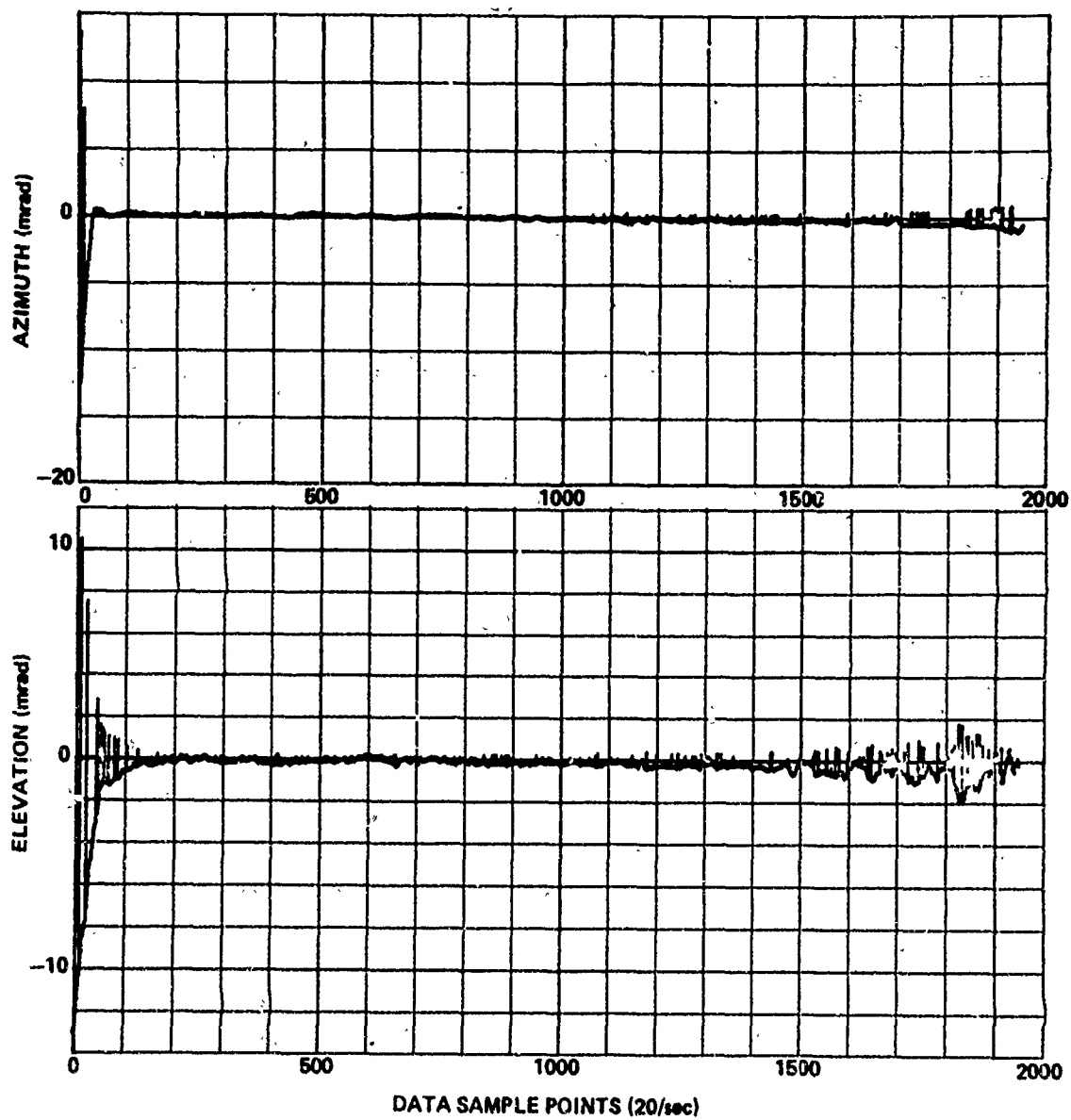
RUN 314



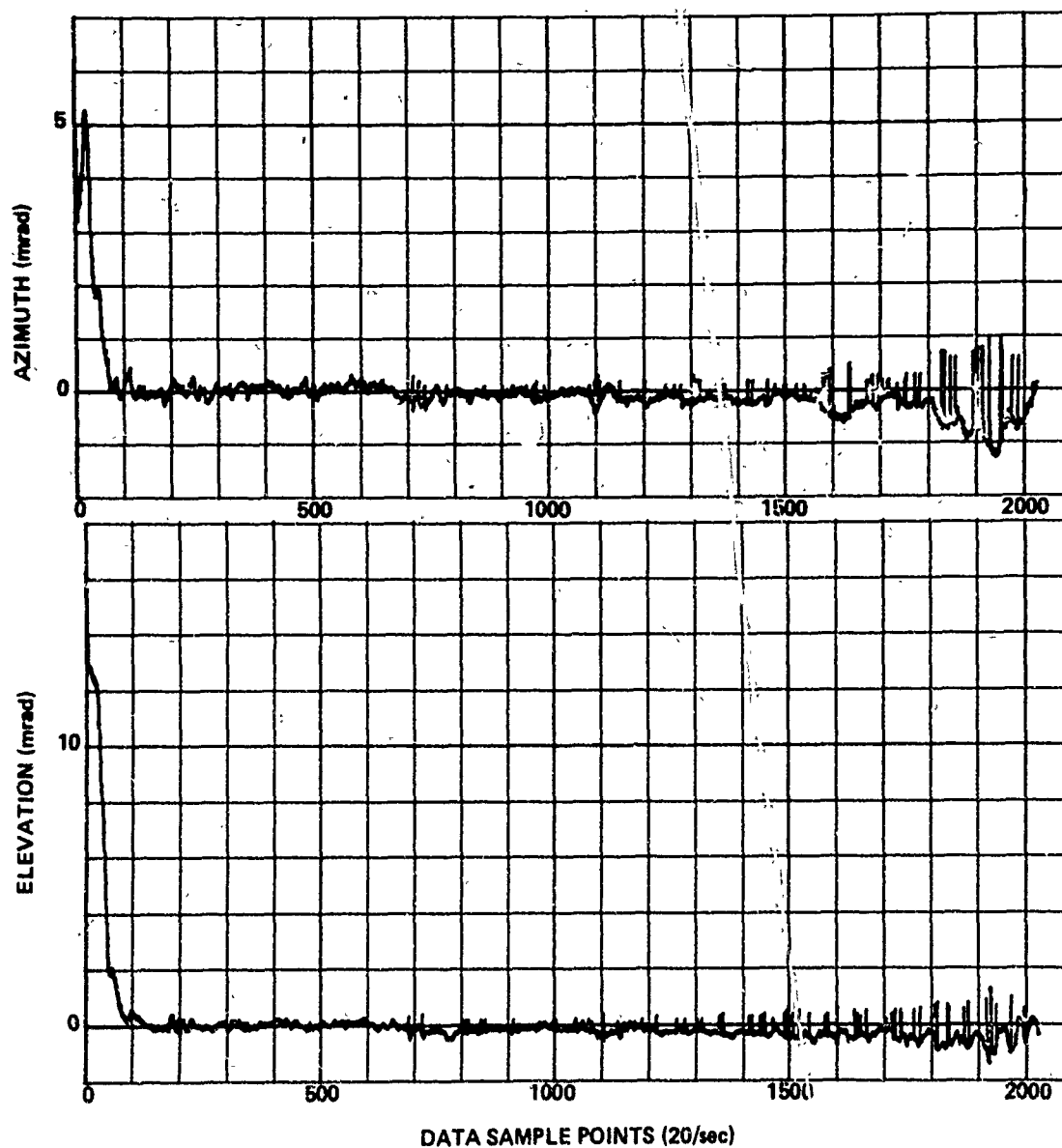
RUN 315



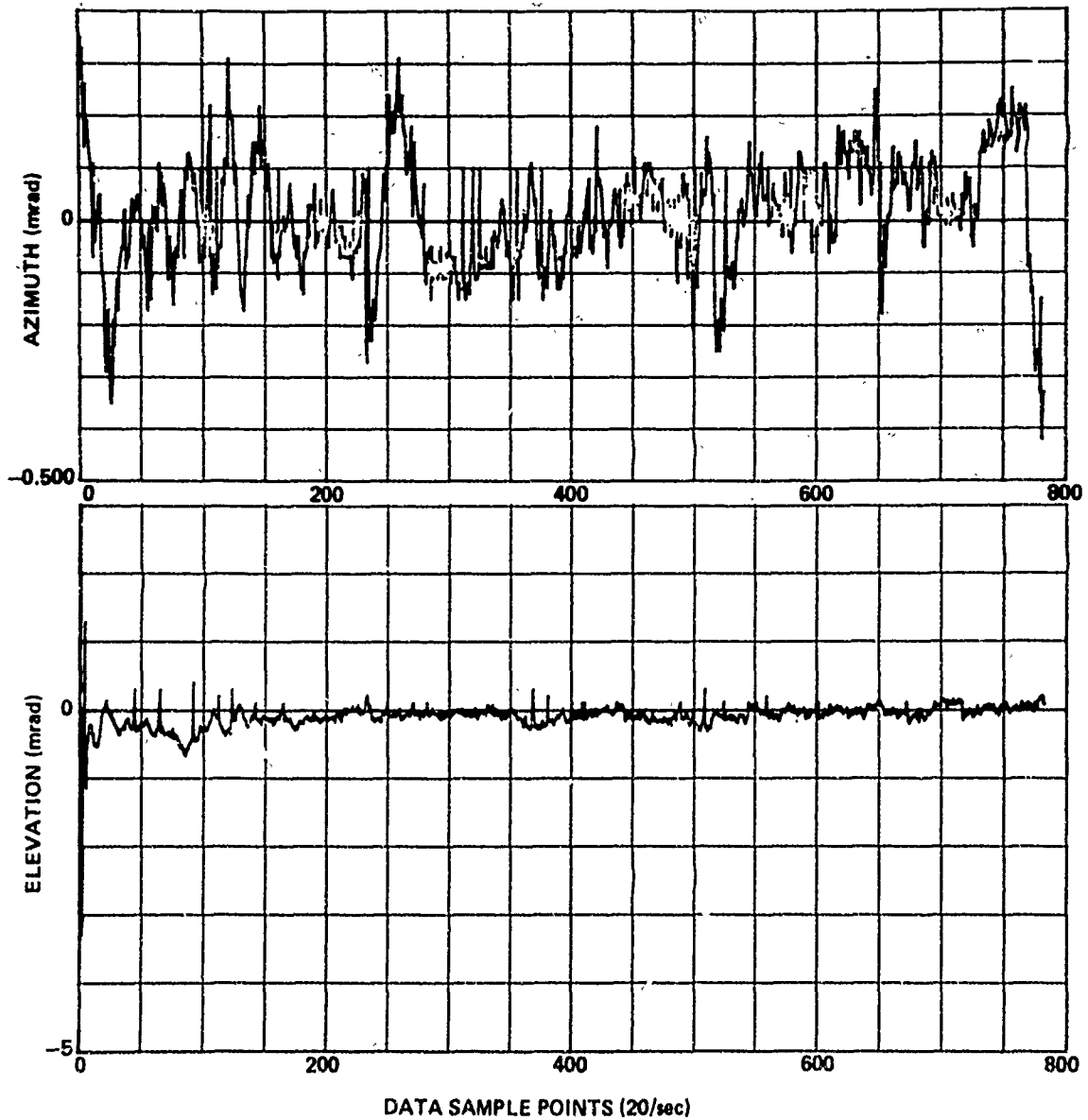
RUN 316



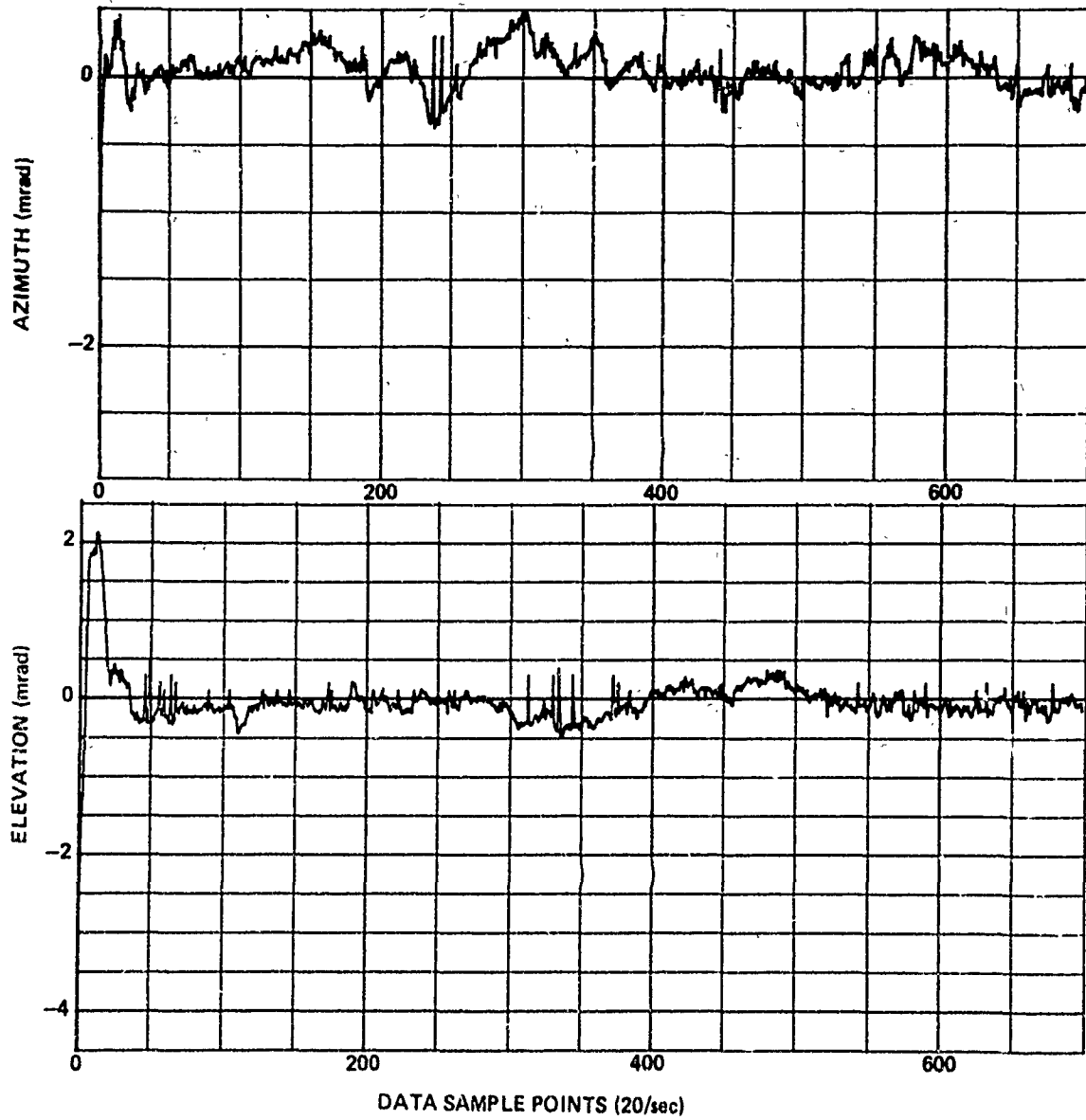
RUN 317



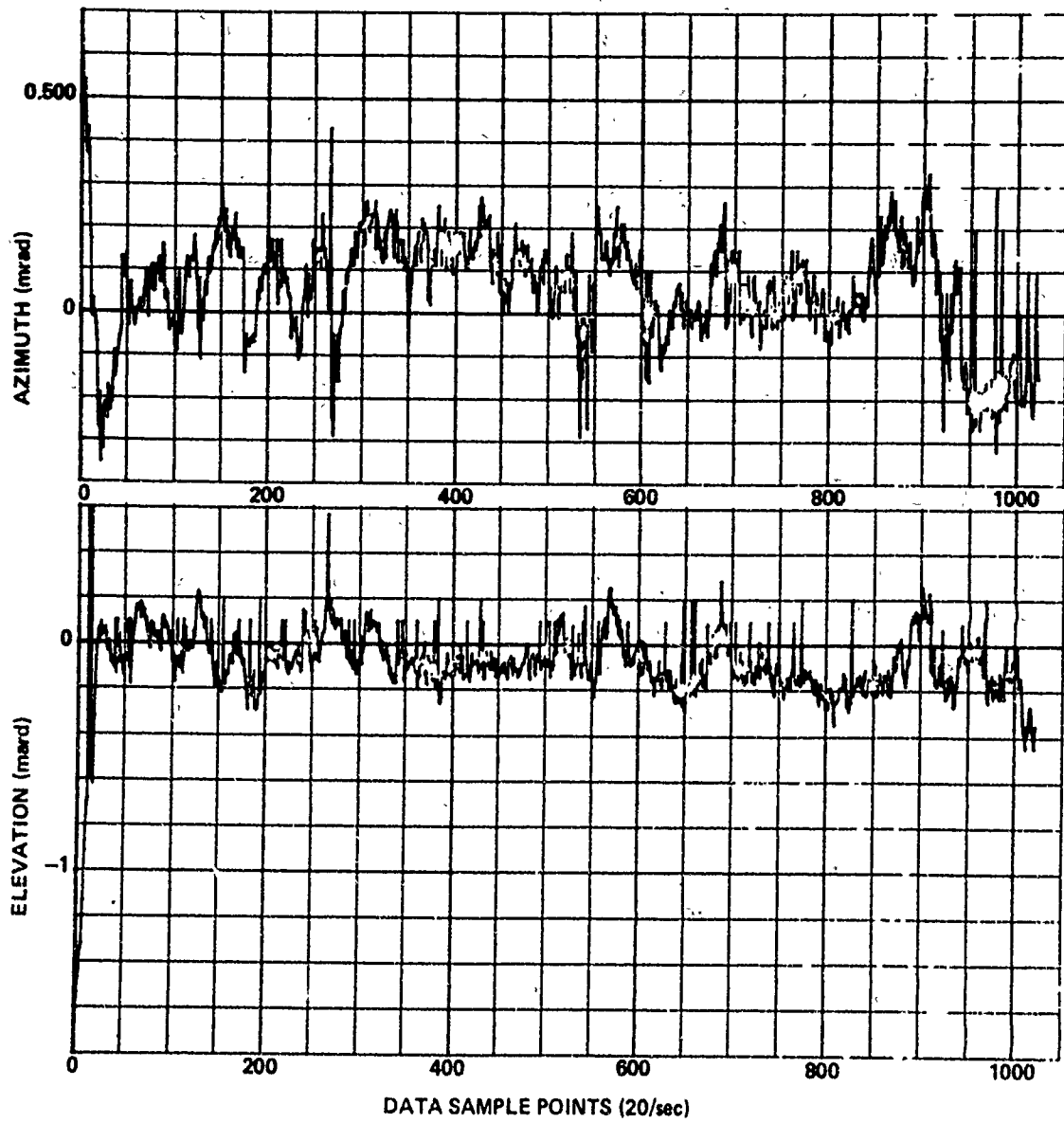
RUN 318



RUN 319



RUN 320



REFERENCES

1. Box, G. E. P. and Jenkins, G. M., Time Series Analysis, Forecasting and Control, Holden-Day, San Francisco, 1970.
2. Fuller, F. C., Jr. and Tsokos, C. P., "Time Series Analysis of Water Pollution Data," Biometrics, 1971, pp. 1017-1034.
3. Cleveland, W. S., "Fitting Time Series Models for Prediction," Technometrics, 1971, pp. 713-723.
4. Cleveland, W. S., "The Inverse Autocorrelations of a Time Series and Their Applications," (with discussion by Parzen), Technometrics, 1972, pp. 277-298.
5. Box, G. E. P., Jenkins, G. M., and Bacon, D. W., "Models for Forecasting, Seasonal and Nonseasonal Time Series," Spectral Analysis of Time Series, ed by B. Harris, Wiley, N. Y., 1967.
6. Clevenson, M. L., "Asymptotically Efficient Estimates of the Parameters of a Moving Average Time Series," Stanford University Tech. Rep. #15, 1970.
7. Parzen E., "Efficient Estimation of Stationary Time Series Mixed Schemes," SUNY/Buffalo Tech. Rep., 1972.

Appendix A.
SIMULATION PROGRAM LISTING

```

PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
  DIMENSION ALIMIT(10),ELIMIT(10),XUA(11),XUE(11),XLA(11),XLE(11),
  PH(11),PHE(11),SP(11),SPE(11),A(500),AE(500),AZ(500),EL(500)
  DIMENSION SPI(11),SPEI(11),PHI(11),PHE(11)
  DIMENSION B(11),RR(11),RI(11),R(11)
  DIMENSION IK(500)
  DATA B/11*0.0/
  DATA ALIMIT/0.,.3291,.8065,.8549,.9114,.9436,.9517,.9759,.9920,1./
  DATA ELIMIT/0.,.6649,.7501,.8460,.9193,.9677,.9750,.9839,.9920,1./
  READ 1,1,(PH(I),I=1,11)
  READ 1,1,(SP(I),I=1,11)
  READ 1,1,(PHE(I),I=1,11)
  READ 1,1,(SPE(I),I=1,11)
  READ 1,1,AMEAN,ANV,EMEAN,ENV,VARA,VVARA,VARE,VVARE
  NPTS = 300
  JUMPA = 0
  JUMPE = 0
  C DETERMINE ORDER OF TIME SERIES
  START = 0.
  STERT = 0.
  CALL RANNUH(1,START,RNA)
  CALL RANNUH(1,STERT,RNE)
  DO 10 I = 2,9
    IF((RNA.GE.ALIMIT(I)).AND.(RNA.LT.ALIMIT(I+1))) JUMPA=I+2
    IF((RNE.GE.ELIMIT(I)).AND.(RNE.LT.ELIMIT(I+1))) JUMPE=I+2
  10 CONTINUE
  G GENERATE MU,PHI-S,VAR(A)
  DO 302 I = 1,11
    SP1(I) = -SQRT(SP(I))
    SPE1(I) = SRT(SPE(I))
  302 DO 20 I = 1,11
    XUA(I) = PH(I) + 5.*SP1(I)
    XLA(I) = PH(I) - 5.*SP1(I)
    XUE(I) = PHE(I) + 5.*SPE1(I)
    XLE(I) = PHE(I) - 5.*SPE1(I)
  20 DO 54 I = 1,11
    PHI(I) = 0.0
    DO 40 I = 1,3
      CALL NORMAL(PHI(I),XLA(I),XUA(I),PH(I),SP1(I))
      IF(JUMPA.EQ.0) GO TO 50
      I = JUMPA
      CALL NORMAL(PHI(I),XLA(I),XUA(I),PH(I),SP1(I))
    NN = JUMPA
    GO TO 55
  50 NN = 3
  55 R(1) = 1.0
  DO 57 I = 1,NN
    57 R(I+1) = -PHI(I)
    CALL ROOTS(R,B,NN,RR,RI)
    INOSA = 0
    DO 56 I = 1,NN
      IF(ABS(RR(I)).GE.1.) INOSA=1
  56 CONTINUE
  IF(INOSA.NE.1) GO TO 61
  PRINT 1,2
  GO TO 62
  61 DO 63 I = 1,11

```

PROGRAM MAIN 7/4/74 OPT=1 FTN 4.0+P353 07/10/73

```

63 PHE(I) = 0.
DO 65 I = 1,3
65 CALL NORMAL(PHE(I),XLE(I),XUE(I),PHE(I),SPE1(I))
IF(JUMPE.EQ.0) GO TO 66
I = JUMPE
CALL NORMAL(PHE(I),XLE(I),XUE(I),PHE(I),SPE1(I))
NN = JUMPE
GO TO 67
66 NN = 3
67 R(1) = 1.0
90-82 I = 1,NN
92 R(I+1) = -PHE(I)
CALL ROOTS(R,0,NN,RR,R1)
INDS = 1
80-58 I = 1,NN
IF(ABS(RR(I)).GE.1.) INDSE=1
68 CONTINUE
IF(INDSE.NE.1) GO TO 69
PRINT 103
GO TO 61
69 AMV1 = SQRT(AMV)
EMV1 = SQRT(EMV)
VVARA1 = SQRT(VVARA)
VVARE1 = SQRT(VVARE)
XLMA = AMEAN-3.*AMV1
XLME = EMEAN-3.*EMV1
XUMA = AMEAN+3.*AMV1
XUME = EMEAN+3.*EMV1
CALL NORMAL(AMN,XLMA,XUMA,AMEAN,AMV1)
CALL NORMAL(EMN,XLME,XUME,EMEAN,EMV1)
XLVA = VARA - 5.*VVARA1
XLVE = VARA - 5.*VVARE1
XUVA = VARA + 5.*VVARA1
XUVE = VARA + 5.*VVARE1
CALL NORMAL(AVAR,XLVA,XUVA,VARA,VVARA1)
CALL NORMAL(EVAR,XLVE,XUVE,VARE,VVARE1)
C GENERATE A(1)
AVAR1 = SQRT(AVAR)
EVAR1 = SQRT(EVAR)
XLAA = -5.*AVAR1
XLAE = -5.*EVAR1
XUAA = 5.*AVAR1
XUAE = 5.*EVAR1
DO 81 I = 1,NPTS
CALL NORMAL(A(I),XLAA,XUAA,0.,AVAR1)
81 CALL NORMAL(AE(I),XLAE,XUAE,0.,EVAR1)
C PRINT INITIALLY SELECTED VALUES
PRINT 1
IF(JUMPA.EQ.0) GO TO 90
PRINT 2,AMN,AVAR,(PHI(I),I=1,3),JUMPA,PHI(JUMPA)
GO TO 100
90 PRINT 3,AMN,AVAR,(PHI(I),I=1,3)
100 IF(JUMPE.EQ.0) GO TO 110
PRINT 4,EMN,EVAR,(PHE(I),I=1,3),JUMPE,PHI(JUMPE)
GO TO 120
110 PRINT 5,EMN,EVAR,(PHE(I),I=1,3)
5 FORMAT(3X,'LEVATION'F6.4,4F6.4)

```

```

120 PRINT 6
C   COMPUTE AZ AND EL VALUES
AZ(1) = AMN + A(1)
AZ(2) = AMN + PHI(1) * (AZ(1) - AMN) + A(2)
AZ(3) = AMN + PHI(1) * (AZ(2) - AMN) + PHI(2) * (AZ(1) - AMN) + A(3)
IF(JUMPA, EQ, 0) GO TO 300
DO 310 I = 4, JUMPA
310 AZ(I) = AMN + PHI(1) * (AZ(I-1) - AMN) + PHI(2) * (AZ(I-2) - AMN) + PHI(3) *
      A(I - (AZ(I-3) - AMN) + A(I))
J = JUMPA + 1
DO 330 I = J, NPTS
330 AZ(I) = AMN + PHI(1) * (AZ(I-1) - AMN) + PHI(2) * (AZ(I-2) - AMN) + PHI(3) *
      A(I - (AZ(I-3) - AMN) + PHI(JUMPA) * (AZ(I-JUMPA) - AMN) + A(I))
GO TO 340
340 DO 320 I = 4, NPTS
320 AZ(I) = AMN + PHI(1) * (AZ(I-1) - AMN) + PHI(2) * (AZ(I-2) - AMN) + PHI(3) *
      A(I - (AZ(I-3) - AMN) + A(I))
C   EL
340 EL(1) = EMN + AE(1)
EL(2) = EMN + PHE(1) * (EL(1) - EMN) + AE(2)
EL(3) = EMN + PHE(1) * (EL(2) - EMN) + PHE(2) * (EL(1) - EMN) + AE(3)
IF(JUMPE, EQ, 0) GO TO 400
DO 410 I = 4, JUMPE
410 EL(I) = EMN + PHE(1) * (EL(I-1) - EMN) + PHE(2) * (EL(I-2) - EMN) + PHE(3) *
      A(I - (EL(I-3) - EMN) + AE(I))
J = JUMPE + 1
DO 440 I = J, NPTS
440 EL(I) = EMN + PHE(1) * (EL(I-1) - EMN) + PHE(2) * (EL(I-2) - EMN) + PHE(3) *
      A(I - (EL(I-3) - EMN) + PHE(JUMPE) * (EL(I-JUMPE) - EMN) + AE(I))
GO TO 450
450 DO 420 I = 4, NPTS
420 EL(I) = EMN + PHE(1) * (EL(I-1) - EMN) + PHE(2) * (EL(I-2) - EMN) + PHE(3) *
      A(I - (EL(I-3) - EMN) + AE(I))
C   PRINT VALUES
450 DO 430 I = 1, NPTS
430 IK(I) = I
IB = 0
IE = 0
IF(NPTS, LT, 220) GO TO 451
IS = IE + 1
IE = IB + 54
454 DO 452 I = IB, IE
452 PRINT 8, IK(I), AZ(I), EL(I), IK(I+55), AZ(I+55), EL(I+55), IK(I+110),
      AZ(I+110), EL(I+110), IK(I+165), AZ(I+165), EL(I+165)
PRINT 104
PRINT 6
IF((NPTS-4*IE), LT, 220) GO TO 451
IB = 4*IE + 1
IE = IB + 54
GO TO 454
451 NLEFT = NPTS - 4*IE
NCOL = NLEFT / 55
NEX = NLEFT - NCOL * 55
IB = 4*IE + 1
IE = IB + 54
GO TO (455, 456, 457), NCOL
455 IF(NEX, EQ, 0) GO TO 461

```

OSRAM MAIN

7477+

OPT=1

FTN 4.0+2353

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```

NEX = I3 - NEX - 1
DO 458 I = I3, NEX
+50 PRINT 8, IK(I), AZ(I), EL(I), I<(I+55), AZ(I+55), EL(I+55)
NX1 = NEX + 1
DO 459 I = NX1, IE
+53 PRINT 3, IK(I), AZ(I), EL(I)
GO TO 460
+61 DO 462 I = I3, IE
+62 PRINT 8, IK(I), AZ(I), EL(I)
GO TO 460
+55 IF (NEX.EQ.0) GO TO +63
NX = I3 + NEX + 1
DO 464 I = I3, NX
+64 PRINT 8, IK(I), AZ(I), EL(I), I<(I+55), AZ(I+55), EL(I+55), I<(I+110),
1 AZ(I+110), EL(I+110)
NX1 = NEX + 1
DO 465 I = NX1, IE
+65 PRINT 8, IK(I), AZ(I), EL(I), I<(I+55), AZ(I+55), EL(I+55)
GO TO 460
+63 DO 466 I = I3, IE
+66 PRINT 8, IK(I), AZ(I), EL(I), I<(I+55), AZ(I+55), EL(I+55)
GO TO 460
+57 IF (NEX.EQ.0) GO TO +73
NEX = I3 + NEX - 1
DO 474 I = I3, NEX
+74 PRINT 3, IK(I), AZ(I), EL(I), I<(I+55), AZ(I+55), EL(I+55), I<(I+110),
1 AZ(I+110), EL(I+110), IK(I+165), AZ(I+165), EL(I+165)
NX1 = NEX + 1
DO 475 I = NX1, IE
+75 PRINT 8, IK(I), AZ(I), EL(I), I<(I+55), AZ(I+55), EL(I+55), I<(I+110),
1 AZ(I+110), EL(I+110)
GO TO 460
+73 DO 476 I = I3, IE
+76 PRINT 3, IK(I), AZ(I), EL(I), I<(I+55), AZ(I+55), EL(I+55), I<(I+110),
1 AZ(I+110), EL(I+110)
1 FORMAT(1H1.2X*INITIALLY SELECTED VALUES*/13X*MEAN*2X*AVAR*2X
4*PHI1*2X*PHI2*2X*PHI3*2X*JUMP*2X*PHI4JUMP*)..
2 FORMAT(3X*AZIMUTH *F6.4,4F6.4,3X12,4XF6.4)
3 FORMAT(3X*AZIMUTH *F6.4,4F5.4)
4 FORMAT(3X*ELEVATION*F6.4,4F5.4,3X12,4XF6.4)
5 FORMAT(//,3X*TIME*3X*AZIMUT*3X*ELEVATION*,3(4X*TIME*3X*AZIMUTH*3X
1 *ELEVATION*))
7 FORMAT(3X13,5XF6.4,5XF6.4)
8 FORMAT(4X13,1XF8.4,5XF8.4,3(5X13,1XF8.4,5XF8.4))
101 FORMAT(5X*1F6.6)
102 FORMAT(///,1X*INOSA = 1, REITERATED*)
103 FORMAT(///,10X*INOS=1, REITERATED*)
104 FORMAT(141)
10000 STOP
END

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LINE NORMAL 7-7- OPT=1 FTM 4.0-P353 07/10/73

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SUBROUTINE NORMAL (RX, XL, XU, MU, SIGMA)
C SUBROUTINE NORMAL (RX, XL, XU, MU, SIGMA)
C DESCRIPTION
C THIS ROUTINE PRODUCES NORMALIZED RANDOM NUMBERS WITHIN
C A RANGE SPECIFIED BY THE USER.
C INPUT
C 1 XL LOWER LIMIT OF NORMAL CURVE
C 2 XU UPPER LIMIT OF NORMAL CURVE
C 3 MU MEAN OF NORMAL CURVE (TYPE REAL)
C 4 SIG STANDARD DEVIATION OF NORMAL CURVE
C OUTPUT
C 1 RX THE NORMALIZED RANDOM NUMBER
C
C DIMENSION FZ(126)
C REAL MU
C DATA DT,DT1,NTP,NPT,SQ2PI/.01,.04,126,C,.398942283/
C SL5 = MU - 5.0 * SIGMA
C SUB = MU + 5.0 * SIGMA
C IF (XL .LT. SUB .AND. XU .GT. SL5) GO TO 10
C PRINT *,SL5, SUB, XL, XU, MU, SIGMA
C 361 FORMAT(11X,'LIMITS FOR NORMAL DISTRIBUTION SHOULD BE BETWEEN',F10.2,
C 1 * AND',F10.2, ' --- PROGRAM TERMINATED.////' * XL =',F10.2,5X
C 2 * XU =',F10.2,5X * MU =',F10.2,5X * SIGMA =',F10.2)
C STOP 123
C 10 IF (NPT .NE. 1) GO TO 2
C T2=DT1
C FZ(1)=.5
C FC=FZ(1)
C T=.5
C FP=SQ2PI*EXP(-.5*T*T)
C DT2=DT*.5
C NPT=1
C 1 CONTINUE
C T = T+DT
C F = SQ2PI*EXP(-.5*T*T)
C FC=FC + DT2*(F+FP)
C FP=F
C IF (ABS(T-T2).GT..0001) GO TO 1
C NPT=NPT + 1
C FZ(NPT)=FC
C T2=T+DT1
C IF (NPT.LT.NTP) GO TO 1
C 2 CONTINUE
C RH = RANF(R)
C R=RN
C IF (R.LT..5) R=1.-R
C IF (R.GT.FZ(NPT)) GO TO 2
C DO 3 I=1,NPT
C IF (R.GT.FZ(I)) GO TO 3
C IF (I.EQ.1) GO TO 4
C X=I-1
C X=X*DT1
C X1=X-DT1
C RX = X1 + (R-FZ(I-1))*DT1/(FZ(I)-FZ(I-1))
C GO TO 5
C 3 CONTINUE

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LINE NORMAL 7-7- OPT=1 FTM 4.1-P353 07/10/73

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PRINT *,RX
100 FORMAT(13H, 'ERROR DISRN')
STOP
C 4 CONTINUE
C RX=6.
C 5 CONTINUE
C IF (R.LT..5) RX=1.-RX
C RX= SIGMA * RX + MU
C IF (RX.GT.XU) GO TO 2
C IF (RX.LT.XL) GO TO 2
C RETURN
C END

```