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RANGE RESIDUALS IN VHF RADAR TRACKING

by B. Rosenbaum

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Greenbelt, Md.

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ABSTRACT

The ionosphere imposes a large bias on the accuracy of tracking at VHF, while the irregularities in the ionospheric density add a fluctuating component to range tracking residuals which is about one percent of the principal range bias. The overall variation of these ionospheric effects is about two orders of magnitude during the diurnal cycle and the eleven-year solar cycle. Near peak ionospheric activity, it is estimated that the irregularities introduce a noise level of 20 meters in radar tracking at VHF, compared to an instrumental precision of 15 meters rms for the GSFC range and range-rate system.

In this preliminary study, the range residuals of samples of IMP-I tracking data are examined to detect tracking noise having an ionospheric origin. The data show fluctuating residuals of about 15 meters rms and an anomalous, systematic variation on the order of 100 meters, which could be attributed to the tracking system.

The negligible role of ionospheric irregularities observed in range residuals is consistent with the current epoch of the quiet sun. In the next few years, which is a period of ascending solar activity, the ionospheric irregularities could introduce a tracking noise factor comparable with VHF tracking system precision.

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INTRODUCTION

A substantial bias in radar range tracking at VHF is introduced by ionospheric propagation delay. Correction for this effect is made difficult by the wide diurnal excursion of the ionospheric electron content and its irregular behavior, especially during periods of high solar activity. There are systematics in ionospheric behavior, such as the monthly mean ionospheric parameters (Reference 1). However, the day-to-day variability is large. While the bias is the paramount problem posed by the ionosphere for VHF range tracking accuracy, this note will be mainly concerned with range tracking effects due to small-scale irregularities in ionospheric electron content, which generate a fluctuating component for radar range measurements in the presence of the large bias, and are thus a possible source of precision-reducing noise in tracking.

In the first section of this report, the ionospheric bias is compared to the instrumental precision of the GSFC range and range-rate tracking system. Estimates are then made of the contribution of the irregularities to tracking noise. Finally, the residuals of IMP-I range and range-rate data are analyzed for tracking noise characteristics, and some preliminary comments are given on correlations in the residuals.

IONOSPHERIC RANGE BIAS

The GSFC range and range-rate system is designed for operation at two frequencies, S-band and VHF (Reference 2). The range measurements employ side-tones which modulate the carrier frequency, and the range-rate measurements use the coherent Doppler technique. The design goal of the instrumental precision of the system is given in Table 1.

Table 1

Instrumental Design Precision of the GSFC Range and Range-Rate System (from Reference 3).

Type of Measurement	VHF	S-Band
Range (meters)		
100 kc Range Tone	±15 rms	±15 rms
20 kc Range Tone	±75 rms	±75 rms
Range Rate (meters/sec)	±1 rms	±0.1 rms

The design precision of range measurements is relatively high for both S-band and

VHF, being 15 meters for the VHF 100 kc range tone. The principal difference for range tracking accuracy between S-band and VHF arises from the frequency dependence of ionospheric propagation. The ionospheric radar range bias, ΔR_I, is determined from the subsatellite columnar electron content, n_t (electrons/meter^2), along the radar line-of-propagation between the satellite and ground station. This is given by (Reference 4)

$$\Delta R_I = \frac{40.3\, n_t}{f^2} \text{ (meters)},$$

where f (cy/sec) is the radar frequency. For a satellite at the zenith and at an altitude of 1000 km, n_t includes effectively the total ionospheric integrated electron content. The content varies widely during the phases of the diurnal cycle and epoch of the eleven-year solar cycle. The estimated magnitudes of ΔR_I, corresponding to the extreme variation of the ionospheric electron content under these cyclic parameters, are given in Table 2.

Table 2

Estimated Range Bias for Extremes of Ionospheric Variation, ΔR_I (meters).

Frequency Band	Solar Epoch	Diurnal Maximum	Diurnal Minimum
VHF (148-136 Mc)	Solar Maximum	2000	200
	Solar Maximum	200	20
S-band (2271-1705 Mc)	Solar Maximum	10	1
	Solar Minimum	1	0.1

Except, then, for the diurnal minimum at the quiet phase of the solar cycle, the range defect for VHF due to ionospheric propagation will be very large, even larger than the bias error associated with tracking site locations, such as the 50 meter uncertainty for Rosman and 107 meters for Carnarvon (Reference 5). S-band ionospheric range bias, on the other hand, is generally small compared to instrument error.

IRREGULARITIES IN THE IONOSPHERIC MEDIUM

Irregularities in the ionospheric medium have been investigated by various radio techniques (Reference 6), including (1) radio sounding from ground-based stations, (2) observation of stellar radio sources, and (3) observation of satellite signal sources in the ionosphere. From these observations, estimates have been made of the spatial dimensions of the regions of irregularity, their apparent drift velocity, and their electron content.

Titheridge (Reference 7) has investigated irregularities in the ionosphere, utilizing subsatellite electron content data from Explorer VIII (1958 ι1), and deduced deviations of electron density from the mean background of about one to ten percent. The regions of irregularity, according to

Titheridge, are slab-shaped, having thickness of about one-fifth their horizontal extension. The large slabs extend over hundreds of kilometers, while the smallest forms observed are a half-kilometer. The small ones generally appear as patches superimposed on large slabs.

An early determination in the fluctuation of the ionospheric subsatellite electron content (Little and Lawrence, Reference 8) from the signals of Sputnik III (1958 δ2) revealed variations (from the mean background) one of to two percent, with a spatial extension of the irregular region of several hundred kilometers (Figure 1).

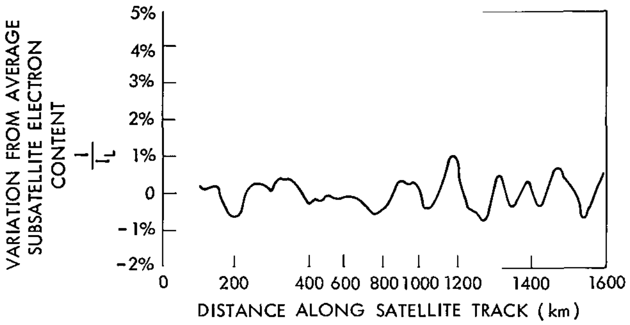

Figure 1—Irregularities in subsatellite ionospheric electron content 0830 MST, September 4, 1958 (from Reference 8).

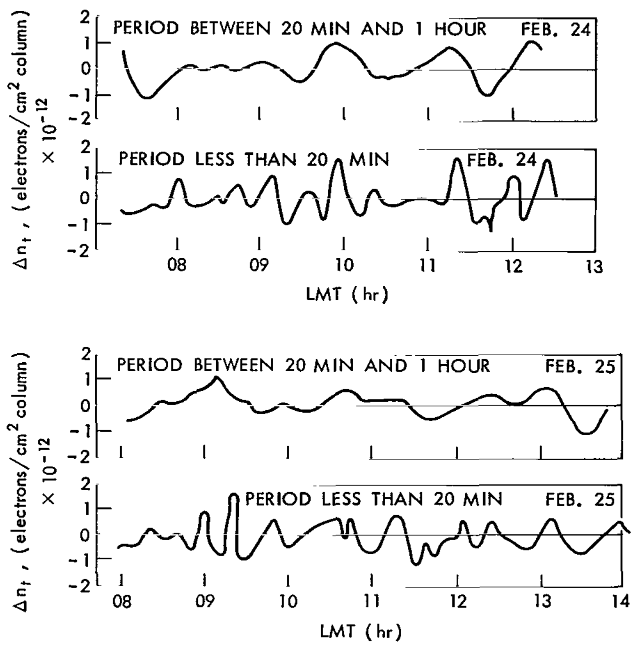

Figure 2—Irregular variations of n_t observed on two consecutive days in February 1960, by the moon radar technique (from Reference 9).

Evans et al. (Reference 9), using lunar-radar techniques, found columnar electron content variations of about one percent, and less frequently, two percent near midday in the winter. Examples are shown in Figure 2. The data were smoothed for periods from 5 to 20 minutes and from 20 minutes to one hour. The time scale of the variations is a manifestation of the size of ionospheric irregularities and of the component of their drift velocity across the radar line-of-propagation.

Studies of the ionosphere using ground-based radio sounding (References 6 and 7) indicate typical drift velocities of about 100 meters/sec, with higher velocities of several hundred meters/sec observed under magnetically disturbed conditions. The data in Figure 2 suggest that the irregularities extend from about 30 to 300 km, assuming a drift velocity across the radar beam of 100 meters/sec. No information on irregularities less than a kilometer can be inferred from Figure 2 because of the smoothing of the data.

As a consequence of the ionospheric irregularities and the fluctuations of the subsatellite electron content, there is a corresponding variation in ΔR_I. This variable component added to the tracking noise follows the pattern characteristics of the irregular regions crossing the radar beam. The time scale of this effect is therefore related to angular tracking rate, and is estimated to vary from a second to minutes. For near-earth satellites having a high angular tracking rate, the fluctuation in ΔR_I can be rapid, while for the more distant satellites, such as IMP-1 (1963 46A), the fluctuation in ΔR_I will depend on the relatively slow drift rate of the ionospheric irregularities across the nearly stationary radar beam direction.

The ionosphere, then, displays two levels of effects on radar range: a main bias, generally amounting at VHF to hundreds of meters, which varies by a major fraction of its magnitude over a period of hours, and superimposed fluctuations amounting to about one percent of the main bias, with a short-term time scale related to ionospheric drift velocity or satellite motion and the spatial extension of the irregularities.

RANGE RESIDUALS

This section considers the detectability of the effect of fluctuating subsatellite electron content on range residuals of VHF tracking data. The measure of the range tracking fluctuation is taken to be, consistent with the ionospheric observations described above, one percent of the ionospheric bias. Applying this measure to the entries of Table 2, an estimate is then obtained for the fluctuation magnitude under the extremes of ionospheric variation in the diurnal and eleven-year solar cycle (Table 3).

Table 3

Ionospheric Range Fluctuations for Extreme Ionospheric Conditions (meters).

Frequency Band	Solar Epoch	Diurnal Maximum	Diurnal Minimum
VHF (148-136 Mc)	Solar Maximum	20	2
	Solar Minimum	2	0.2
S-band (2271-1705 Mc)	Solar Maximum	10^{-1}	10^{-2}
	Solar Minimum	10^{-2}	10^{-3}

On the basis of the estimated values in Table 3, ionospheric range residuals are well below instrument error for S-band, but can be significant for VHF tracking at peak solar activity, exceeding instrument error near the period of the diurnal maximum and during the epoch of maximum solar activity. The last period of peak solar activity was in 1957-58 and the next will appear about 1968-69. The ionospheric range residuals are negligible for 1963-65, a period of minimum solar activity.

The latter statement is supported by an analysis of calculated tracking residuals and their rms deviations from IMP-I tracking data obtained at Scottsdale, Arizona, from 26 December 1963 to 8 February 1964 (summarized in Table 4). The tracking data points, printed at the rate of one per second, are an average of eight measurements per second. For calculating the residuals, the data were divided into intervals, each time-continuous and not exceeding 150 points. A cubic polynomial was fitted to each interval by the least squares method, and the rms deviation of the residuals determined. The median and the average of the rms residuals for the fifty sample

Table 4

RMS Residuals of VHF Range and Range Rate Tracking Data, 20 kc Range Tone, Scottsdale, Arizona.

Sample No.	Date	Time (GMT)	Data Points	Range (10^3 km)	Range Rate (m/sec)	K_p*	RMS Residual Range (m)	RMS Residual Range Rate (cm/sec)
1	Dec. 26, 1963	14:45	96	194	- 394	1-	23.4	19.3
2	Dec. 26, 1963	16:36	128	191	- 291	1-	20.7	24.7
3	Jan. 3, 1964	16:49	96	181	- 455	3+	96.1	20.3
4	Jan. 4, 1964	15:37	98	85	-2200	3+	30.1	55.6
5	Jan. 4, 1964	15:38	61	85	-2200	3+	14.6	55.9
6	Jan. 4, 1964	19:51	150	48	-2940	3+	46.6	14.5
7	Jan. 4, 1964	19:53	74	48	-2950	3+	14.1	13.5
8	Jan. 4, 1964	20:37	64	39	-3300	3+	14.4	16.7
9	Jan. 4, 1964	20:38	32	39	-3320	3+	13.9	14.9
10	Jan. 4, 1964	22:36	101	8.5	-6020	3_o	16.3	24.8
11	Jan. 4, 1964	22:37	59	8.0	-6070	3_o	14.3	25.0
12	Jan. 10, 1964	14:32	32	196	+ 140	3_o	15.6	19.4
13	Jan. 10, 1964	14:34	128	196	+ 141	3_o	23.3	19.9
14	Jan. 11, 1964	16:42	96	168	- 651	2_o	14.9	49.6
15	Jan. 11, 1964	18:51	96	164	- 596	2_o	14.9	27.7
16	Jan. 12, 1964	14:32	150	48	-3260	1_o	13.2	22.8
17	Jan. 12, 1964	14:34	40	47	-3270	1_o	12.1	23.0
18	Jan. 12, 1964	15:31	150	35	-3660	1+	11.0	10.7
19	Jan. 12, 1964	15:33	74	35	-3680	1+	6.0	11.3
20	Jan. 17, 1964	13:38	128	162	+ 890	3_o	19.5	23.9
21	Jan. 17, 1964	14:32	104	164	+ 925	3_o	21.7	30.2
22	Jan. 17, 1964	14:34	120	165	+ 926	3_o	18.0	27.4
23	Jan. 18, 1964	12:25	102	197	- 118	1+	14.0	33.0
24	Jan. 18, 1964	12:37	90	197	- 117	1+	13.9	29.3
25	Jan. 18, 1964	13:31	98	197	- 68	1+	25.0	26.0
26	Jan. 18, 1964	13:33	125	197	- 66	1+	18.5	28.8
27	Jan. 18, 1964	14:35	101	197	- 8	1+	20.4	53.0
28	Jan. 18, 1964	14:36	90	197	- 7	1+	18.4	49.9
29	Jan. 18, 1964	15:43	96	197	+ 54	1+	17.2	40.8
30	Feb. 6, 1964	14:33	110	193	+ 452	4_o	19.8	21.7
31	Feb. 6, 1964	14:35	85	193	+ 453	4_o	19.0	20.2
32	Feb. 7, 1964	14:36	150	183	- 405	2-	17.7	18.1
33	Feb. 7, 1964	14:38	100	183	- 403	2-	15.0	18.6
34	Feb. 8, 1964	12:42	96	98	-1990	1+	15.5	80.3
35	Feb. 8, 1964	13:35	30	92	-2030	1+	10.7	69.6
36	Feb. 8, 1964	13:36	32	92	-2030	1+	11.1	72.1
37	Feb. 8, 1964	13:37	64	92	-2030	1+	13.1	72.1
38	Feb. 8, 1964	13:38	64	92	-2030	1+	12.2	70.0
39	Feb. 8, 1964	14:44	64	83	-2090	1+	14.4	21.3
40	Feb. 8, 1964	14:46	88	83	-2100	1+	10.3	22.1
41	Feb. 8, 1964	14:47	72	83	-2100	1+	12.0	19.1
42	Feb. 8, 1964	15:31	150	77	-2160	3+	53.6	33.2
43	Feb. 8, 1964	15:34	106	77	-2160	3+	12.4	37.2
44	Feb. 8, 1964	16:31	150	70	-2290	3+	19.7	64.2
45	Feb. 8, 1964	16:34	100	69	-2290	3+	12.5	68.7
46	Feb. 8, 1964	17:33	32	61	-2480	3+	9.9	35.7
47	Feb. 8, 1964	17:34	150	60	-2480	3+	10.7	33.4
48	Feb. 8, 1964	17:36	106	60	-2490	3+	10.9	30.3
49	Feb. 8, 1964	18:31	150	51	-2760	4-	35.5	14.4
50	Feb. 8, 1964	18:33	73	51	-2780	4-	13.5	15.1
						Average	19.0	33.0
						Median	15.0	25.5

*Mean 3-hour interplanetary magnetic index.

intervals are 15.0 and 19.0 meters, respectively. The 15 meter median residual closely approximates the rms errors attributed to the instrument effects (for tracking intervals less than 150 seconds).

Some entries in Table 4 merit special attention. Five out of the 50 sample intervals (nos. 3, 4, 6, 42, and 49) have rms range residuals greater than 30 meters, double the median. These samples and other typical samples are shown in Figures 3 through 17. Both the range and range-rate data show evidence that residuals are correlated. The range residuals in addition to the approximate 15 meter noise level, exhibit a large residual component on the order of 100 meters. One recognizes that the anomalously large residuals stem from a systematic, periodic effect which could originate in the tracking system. The source of the disturbance has yet to be determined.

Certain pairs of time-continuous range data samples (nos. 4 and 5, Figures 4 and 5; 6 and 7, Figures 6 and 7; 42 and 43, Figures 8 and 9; 49 and 50, Figures 11 and 12), which are expected to have similar residual characteristics, show marked variations in the pattern of the residuals. The large rms residual and pronounced periodic trend are common to only one member of the pairs. This difference is not a real effect, but rather a consequence of the method of treating the data. In the

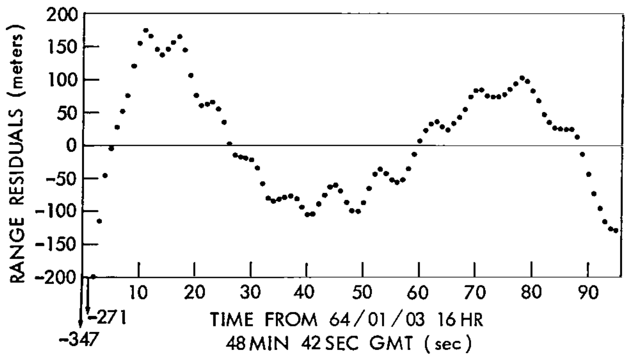

Figure 3—Range residuals - IMP-I tracking data, sample no. 3 (range 181,000 km).

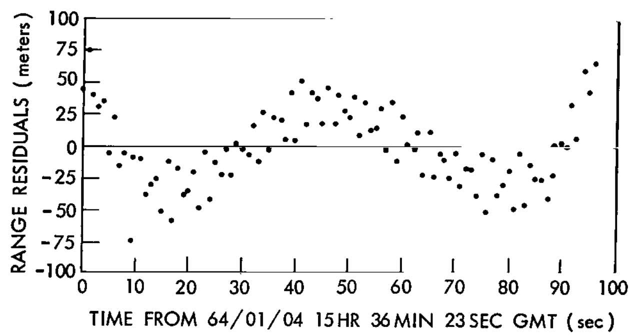

Figure 4—Range residuals - IMP-I tracking data, sample no. 4 (range 85,000 km).

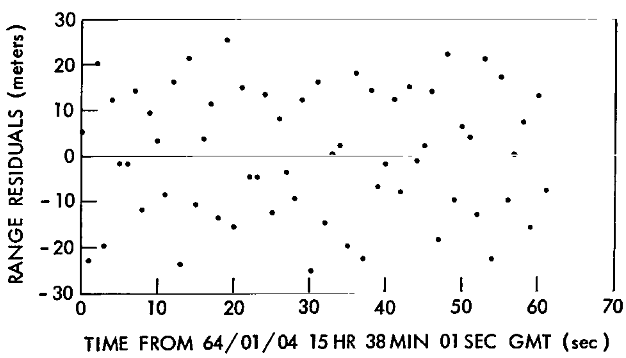

Figure 5—Range residuals - IMP-I tracking data, sample no. 5 (range 85,000 km).

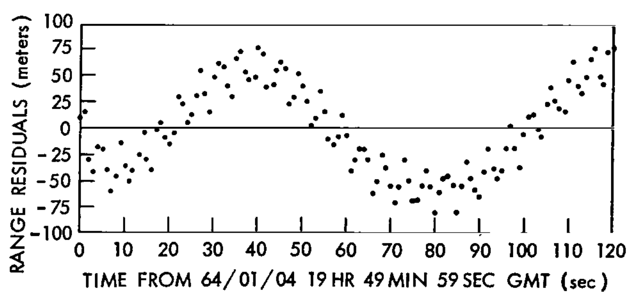

Figure 6—Range residuals - IMP-I tracking data, sample no. 6 (range 48,000 km).

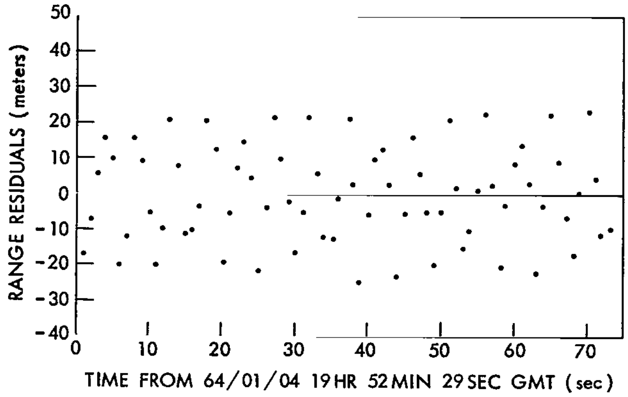

Figure 7—Range residuals - IMP-I tracking data, sample no. 7 (range 48,000 km).

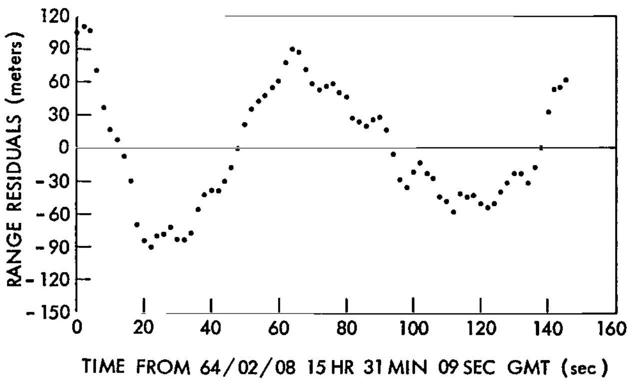

Figure 8—Range residuals - IMP-I tracking data, sample no. 42 (range 77,000 km).

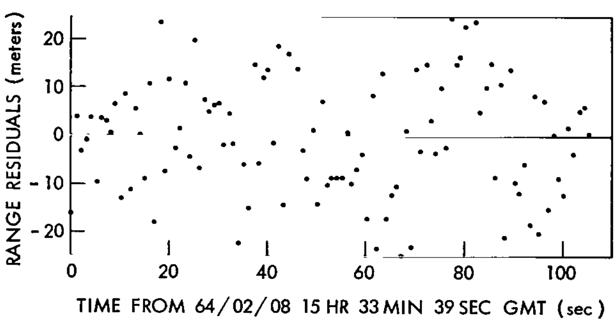

Figure 9—Range residuals - IMP-I tracking data, sample no. 43 (range 77,000 km).

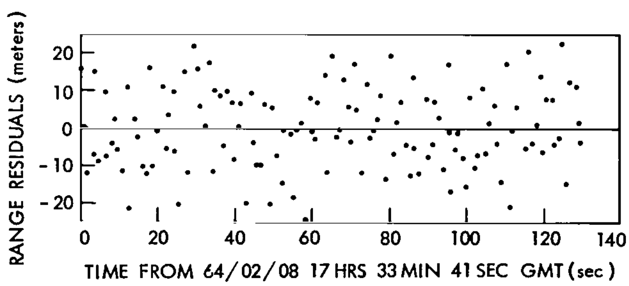

Figure 10—Range residuals - IMP-I tracking data, sample no. 47 (range 61,000 km).

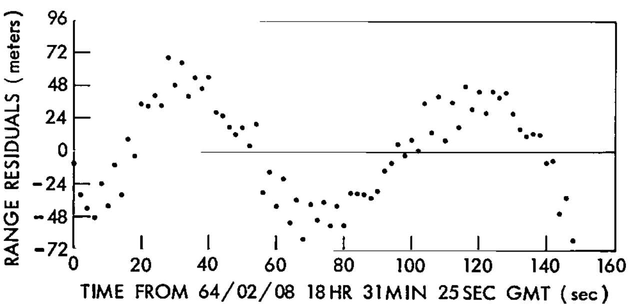

Figure 11—Range residuals - IMP-I tracking data, sample no. 49 (range 61,000 km).

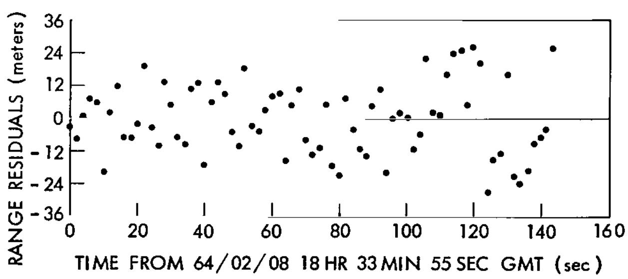

Figure 12—Range residuals - IMP-I tracking data, sample no. 50 (range 51,000 km).

samples having fewer data points, the cubic polynomial could fit the data so as to eliminate the major periodic disturbances from the residuals.

The freedom of the range residuals from the influence of ionospheric irregularities could be attributable to unusually quiet ionospheric conditions prevailing during the intervals of tracking.

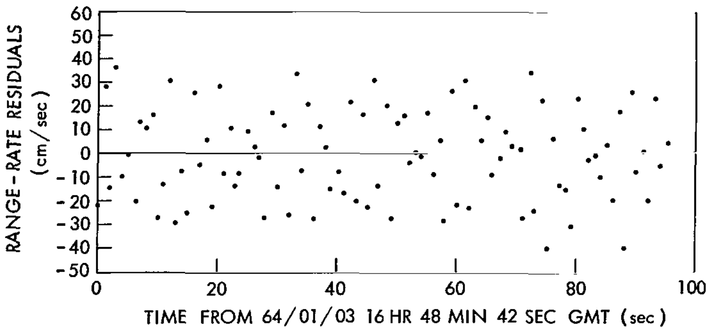

Figure 13—Range-rate residuals - IMP-I tracking data, sample no. 3 (range 181,000 km).

Consequently, for each tracking interval in Table 4, the mean three-hour planetary magnetic index, K_p (Reference 10) is entered. From the eleven tracking days represented in Table 4, there were six with disturbed conditions ($K \geq 3$) and five with quiet magnetic conditions. Of the total of 50 sample intervals, half were during disturbed and the other half were during undisturbed magnetic conditions. There is no severe magnetic disturbance ($K \geq 5$) in the data. The samples of tracking data suggest ionospheric irregularities to be a generally negligible factor in the range residuals for the epoch of the quiet sun.

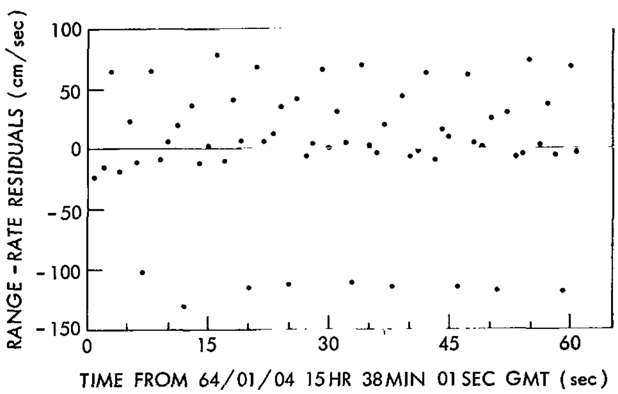

Figure 14—Range-rate residuals - IMP-I tracking data, sample no. 5 (range 85,000 km).

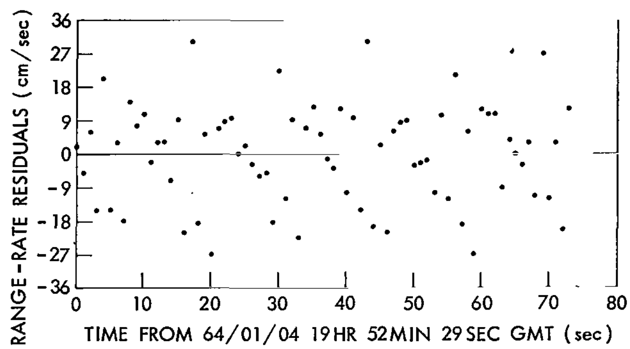

Figure 15—Range-rate residuals - IMP-I tracking data, sample no. 7 (range 48,000 km).

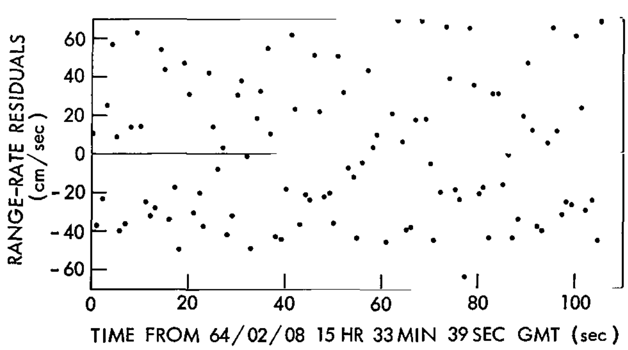

Figure 16—Range-rate residuals - IMP-I tracking data, sample no. 43 (range 77,000 km).

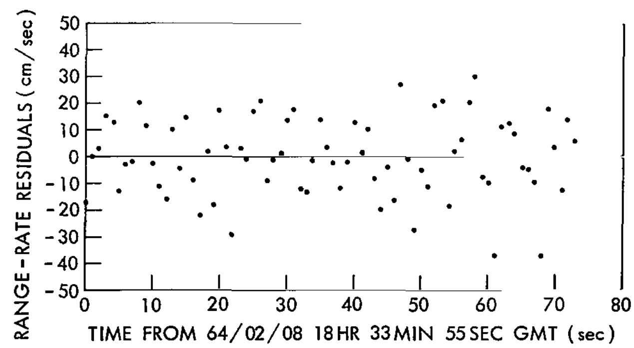

Figure 17—Range-rate residuals - IMP-I tracking data, sample no. 50 (range 51,000 km).

The effect of signal level on the rms residual and bias errors has previously been analyzed in detail in the Test Evaluation Report (Reference 3). In that study, the residuals of operational IMP-I range, and range-rate data points are also compared closely with the design goal of the GSFC VHF system and with test results. The report (Reference 3) finds a generally favorable agreement between IMP-1 tracking data and the design goal.

(Manuscript received January 7,1966)

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Appendix A

Computation of VHF Range and Range-Rate Residuals of Tracking Data from Scottsdale, Arizona

Cubic polynomials,

$$R = a_0 + a_1 t + a_2 t^2 + a_3 t^3$$

and

$$\dot{R} = b_0 + b_1 t + b_2 t^2 + b_3 t^3 ,$$

were fitted, respectively, to range and range-rate data by the conventional least squares method, where R = range, $\dot{R}$ = range rate, and t = time of observation. The square root matrix function was used to solve the system of normal equations, as outlined in "Spacecraft Observations Input Routine," GSFC Document X-542-64-11, October, 1963.

Table A1 summarizes the calculation of the polynomial coefficients. Vanguard units were used in the computation routine. The conversion factors are:

Vanguard unit of length = 6,378,388 meters, and

Vanguard unit of time = 790,547 seconds.

Table A1
Polynomial Coefficients.

	Range (Vanguard units)					Range Rate (Vanguard units)			
No.	$a_0 \times 10^{-p}$ P	$a_1 \times 10^{-p}$ P	$a_2 \times 10^{-p}$ P	$a_3 \times 10^{-p}$ P	No.	$b_0 \times 10^{-p}$ P	$b_1 \times 10^{-p}$ P	$b_2 \times 10^{-p}$ P	$b_3 \times 10^{-p}$ P
1	+.30350153(+2)	-.62406637(-4)	+.13349359(-7)	-.78732229(-10)	1	-.49937663(-1)	+.23816611(-5)	-.12943690(-8)	-.36669703(-10)
2	+.29990930(+2)	-.45367143(-4)	-.20888045(-8)	+.18626636(-10)	2	-.36754107(-1)	+.16831194(-5)	+.26368782(-8)	-.68248878(-11)
3	+.28418004(+2)	-.93722089(-4)	+.27168338(-6)	-.84051656(-9)	3	-.57593169(-1)	+.29469085(-5)	-.28615150(-7)	+.18704683(-9)
4	+.13420519(+2)	-.34581037(-3)	+.77384614(-7)	-.56557200(-9)	4	-.27753728(0)	-.23485217(-5)	+.21468375(-8)	-.46782524(-10)
5	+.13386854(+2)	-.34478324(-3)	+.37244425(-8)	+.77427155(-11)	5	-.27775320(0)	-.53750413(-5)	+.88470268(-7)	-.78685500(-9)
6	+.75468770(+1)	-.45338060(-3)	-.93027280(-7)	+.32109907(-9)	6	-.37100715(0)	-.13133671(-4)	-.54181784(-8)	+.19016544(-10)
7	+.74778391(+1)	-.46224177(-3)	-.11514578(-7)	+.26221884(-10)	7	-.37303929(0)	-.13720821(-4)	+.96305758(-9)	-.21398579(-10)
8	+.61867580(+1)	-.51724700(-3)	-.13632623(-7)	+.23930989(-10)	8	-.41729098(0)	-.19788209(-4)	-.22374401(-7)	+.21435979(-9)
9	+.61453002(+1)	-.51951400(-3)	+.23816546(-7)	-.91537321(-9)	9	-.41892798(0)	-.20093543(-4)	-.59432424(-7)	+.17681750(-8)
10	+.13915853(+1)	-.94481852(-3)	-.13940914(-7)	-.18091743(-9)	10	-.76123355(0)	-.75814187(-4)	+.47266516(-7)	+.13001681(-9)
11	+.12958360(+1)	-.95242350(-3)	-.35088131(-7)	+.21008098(-10)	11	-.76827779(0)	-.61575224(-4)	+.52351460(-7)	+.59193645(-9)
12	+.30767173(+2)	+.18008253(-4)	+.20064471(-6)	-.12615717(-8)	12	+.17701539(-1)	+.19971884(-5)	-.27393046(-7)	+.12214216(-8)
13	+.30768227(+2)	+.26193681(-4)	-.64368550(-7)	+.28551249(-9)	13	+.17783758(-1)	+.23681056(-5)	-.40511425(-8)	+.14510740(-10)
14	+.26415921(+2)	-.98220201(-4)	-.23362989(-7)	-.87221613(-10)	14	-.75420289(-1)	-.79172453(-6)	+.22598056(-7)	-.13186247(-9)
15	+.25670646(+2)	-.94759396(-4)	+.26279570(-7)	-.13658919(-9)	15	-.82357747(-1)	+.10754949(-5)	+.82547719(-8)	-.46325941(-10)
16	+.75082860(+1)	-.51069298(-3)	-.73127774(-8)	-.41468287(-13)	16	-.41201967(0)	-.11271415(-4)	-.42776788(-8)	+.18941765(-10)
17	+.74315182(+1)	-.51283886(-3)	-.12200115(-7)	+.90100111(-10)	17	-.41377609(0)	-.77506458(-5)	-.14916060(-6)	+.17734856(-8)
18	+.55901156(+1)	-.57300192(-3)	-.10592307(-7)	-.25143093(-11)	18	-.46235079(0)	-.17449367(-4)	-.70517248(-9)	-.14168307(-11)
19	+.55039229(+1)	-.57655618(-3)	-.95842321(-8)	+.25384103(-10)	19	-.46499316(0)	-.17232065(-4)	-.14344205(-7)	+.90221456(-10)
	. . .	. .	. . .	. . .	.	. .	. . .	. .	. . .
	. . .	. .	. . .	. . .	.	. .	. . .	. .	. . .
30	+.30263725(+2)	+.68930904(-4)	+.32349677(-7)	-.14532638(-9)	30	+.57114919(-1)	+.16604645(-5)	-.17388188(-8)	+.74220203(-11)
31	+.30269446(+2)	+.70288078(-4)	+.17994002(-7)	-.11850104(-9)	31	+.57352703(-1)	+.12096766(-5)	+.17931731(-7)	-.18771967(-9)
32	+.28682169(+2)	-.63812830(-4)	+.32825595(-8)	+.83956771(-11)	32	-.51351653(-1)	+.18546105(-5)	-.28983063(-8)	+.14380145(-10)
33	+.28676334(+2)	-.64360155(-4)	+.23640542(-7)	-.14321921(-9)	33	-.51091565(-1)	+.10755600(-5)	+.67070006(-7)	-.15557374(-8)
34	+.15442653(+2)	-.31187293(-3)	+.12780052(-8)	+.12497974(-11)	34	-.25150956(0)	-.39997373(-5)	+.81431335(-7)	-.71222300(-9)
35	+.14422896(+2)	-.31811009(-3)	+.17081892(-6)	-.35239842(-8)	35	-.25630664(0)	-.18828136(-4)	+.14801905(-5)	-.32969512(-7)
36	+.14409604(+2)	-.31779046(-3)	+.52088028(-8)	-.27295457(-9)	36	-.25642253(0)	-.12313464(-5)	+.12596864(-7)	-.15781052(-8)
37	+.14390531(+2)	-.31761783(-3)	-.30439511(-8)	+.29900907(-11)	37	-.25654837(0)	+.27105446(-5)	-.12025651(-6)	+.93450813(-9)
38	+.14368920(+2)	-.31781555(-3)	-.61516585(-8)	+.36748717(-10)	38	-.25663653(0)	+.11514751(-5)	-.10826405(-6)	+.95627670(-9)
39	+.13084527(+2)	-.32709813(-3)	-.21458067(-7)	+.81707790(-10)	39	-.26477237(0)	-.41095416(-5)	+.43270932(-7)	-.34221441(-9)
40	+.13058276(+2)	-.32848040(-3)	-.37317889(-10)	-.11716509(-10)	40	-.26499233(0)	-.22437503(-5)	-.13866056(-7)	+.12532841(-9)
41	+.13029363(+2)	-.32894132(-3)	+.62777782(-8)	-.72666058(-10)	41	-.26522916(0)	-.13827124(-5)	-.36712483(-7)	+.32181752(-9)
42	+.12146580(+2)	-.34284170(-3)	+.51170618(-7)	-.20048408(-9)	42	-.27322483(0)	-.32895543(-5)	-.31290054(-8)	+.11762513(-10)
43	+.12095646(+2)	-.33937027(-3)	+.21153677(-8)	-.34893760(-10)	43	-.27376060(0)	-.26996596(-5)	-.18405706(-7)	+.10273708(-9)
44	+.10897087(+2)	-.35856224(-3)	+.50337277(-8)	-.33253875(-10)	44	-.28889167(0)	-.45844859(-5)	-.15333881(-8)	-.10377672(-10)
45	+.10843310(+2)	-.35914854(-3)	-.95748924(-9)	-.80595608(-11)	45	-.28965362(0)	-.47476818(-5)	-.13778891(-7)	+.80995724(-10)
46	+.95120670(+1)	-.38916101(-3)	-.21229949(-7)	+.80894619(-9)	46	-.31343783(0)	-.15556716(-5)	-.48951702(-6)	+.10288838(-7)
47	+.94980592(+1)	-.38865698(-3)	-.69634777(-8)	+.70523995(-11)	47	-.31369750(0)	-.86426622(-5)	+.67131009(-8)	-.29932092(-10)
48	+.94396289(+1)	-.39036387(-3)	-.35808217(-8)	-.14560758(-10)	48	-.31493682(0)	-.83189843(-5)	-.16061945(-8)	+.10481713(-10)
49	+.80813882(+1)	-.42858391(-3)	-.50470767(-7)	+.15882151(-9)	49	-.34861274(0)	-.12192753(-4)	-.27363401(-8)	+.73282356(-11)
50	+.80164890(+1)	-.43467585(-3)	+.76557044(-8)	-.19284790(-9)	50	-.35048435(0)	-.11975400(-4)	-.16172416(-7)	+.84694810(-10)

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